FILOZOFSKI
vestnik

XXV • 2/2004

Izdaja
Filozofski inštitut ZRC SAZU
Published by
the Institute of Philosophy at ZRC SAZU

Ljubljana 2004

Programska zasnova

FILOZOFSKI VESTNIK je glasilo Filozofskega inštituta Znanstvenoraziskovalnega centra Slovenske akademije znanosti in umetnosti. Filozofski vestnik je znanstveni časopis za filozofijo z interdisciplinarno in mednarodno usmeritvijo in je forum za diskusijo o širokem spektru vprašanj s področja sodobne filozofije, etike, estetike, politične, pravne filozofije, filozofije jezika, filozofije zgodovine in zgodovine politične misli, epistemologije in filozofije znanosti, zgodovine filozofije in teoretske psihoanalize. Odprt je za različne filozofske usmeritve, stile in šole ter spodbuja teoretski dialog med njimi.

Letno izidejo tri številke. V prvi in tretji so objavljeni prispevki domačih in tujih avtorjev v slovenskem jeziku s povzetki v slovenskem in angleškem jeziku. Druga številka je mednarodna in posvečena temi, ki jo določi uredniški odbor. Prispevki so objavljeni v angleškem, francoskem in nemškem jeziku z izvlečki v angleškem in slovenskem jeziku.

Filozofski vestnik je ustanovila Slovenska akademija znanosti in umetnosti.

Aims and Scope

FILOZOFSKI VESTNIK is edited and published by the Institute of Philosophy at the Scientific Research Centre of the Slovenian Academy of Sciences and Arts. Filozofski vestnik is a journal of philosophy with an interdisciplinary character. It provides a forum for discussion on a wide range of issues in contemporary political philosophy, history of philosophy, history of political thought, philosophy of law, social philosophy, epistemology, philosophy of science, cultural critique, ethics and aesthetics. The journal is open to different philosophical orientations, styles and schools, and welcomes theoretical dialogue among them.

The journal is published three times annually. Two issues are published in Slovenian, with abstracts in Slovenian and English. One issue a year is a special international issue that brings together articles in English, French or German by experts on a topic chosen by the editorial board.

Filozofski vestnik was founded by the Slovenian Academy of Sciences and Arts.

FILOZOFSKI VESTNIK je vključen v / is included in: Arts & Humanities Cit. Index, Current Contents / Arts & Humanities, Internationale Bibliographie der Zeitschriften, The Philo-sopher's Index, Répertoire bibliographique de philosophie, Sociological Abstracts.

FILOZOFSKI VESTNIK izhaja s podporo Ministrstva za šolstvo, znanost in šport in Ministrstva za kulturo Republike Slovenije.

FILOZOFSKI VESTNIK is published with the support of the Ministry of Education, Science and Sport and the Ministry of Culture of the Republic of Slovenia.

FILOZOFSKI VESTNIK • Volume XXV • Number 2 • 2004

Edited by Matjaž Vesel

CONTENTS

Copernicus and the Philosophy of Copernican Revolutions

Matjaž Vesel, *Editorial* 5

Richard DeWitt, *The Beginnings of a Modern Copernican Revolution* 9
Hilary Gatti, *Giordano Bruno's Copernican Diagrams* 25
Myriam Gerhard, *"Certe rationem ordinis non esse"?: Zur Konstituierbarkeit einer vernünftigen Ordnung der Natur bei Copernicus, Bruno und Schelling* 51
Fernand Hallyn, *Gemma Frisius: A Convinced Copernican in 1555* 69
Karsten Harries, *Truth and Value Today: Galileo contra Bellarmine* 85
Peter Klepec, *Lyotard and the "Second Copernican Turn"* 107
F. Jamil Ragep, *Copernicus and his Islamic Predecessors: Some Historical Remarks* 125
Katherine A. Tredwell and Peter Barker, *Copernicus' First Friends: Physical Copernicanism from 1543 to 1610* 143
Matjaž Vesel, *What is Revolutionary in the Copernicus'* Revolutions 167

Notes on Contributors 187

Abstracts 189

FILOZOFSKI VESTNIK • Letnik XXV • Številka 2 • 2004

Uredil Matjaž Vesel

VSEBINA

Kopernik in filozofija kopernikanskih revolucij

Matjaž Vesel, *Uvodnik* 5

Richard DeWitt, *Začetki moderne kopernikanske revolucije* 9
Hilary Gatti, *Kopernikanski diagrami Giordana Bruna* 25
Myriam Gerhard, *»Certe rationem ordinis non esse«?: k zmožnosti vzpostavitve razumnega reda narave pri Koperniku, Brunu in Schellingu* 51
Fernand Hallyn, *Gemma Frisius: prepričan kopernikanec leta 1555* 69
Karsten Harries, *Resnica in vrednota danes: Galilej proti Bellarminu* 85
Peter Klepec, *Lyotard in »drugi kopernikanski obrat«* 107
F. Jamil Ragep, *Kopernik in njegovi islamski predhodniki: nekatere zgodovinske opazke* 125
Katherine A. Tredwell in Peter Barker, *Prvi Kopernikovi prijatelji: fizikalni kopernikanizem od leta 1543 do 1610* 143
Matjaž Vesel, *Kaj je revolucionarno v Kopernikovih* Revolucijah 167

Podatki o avtorjih 187

Izvlečki 189

EDITORIAL

The book De revolutionibus orbium coelestium*, in which Copernicus presents the thesis that "the Earth moves, whereas the Sun is at rest in the center of the Universe", belongs to that small group of scientific works which, despite addressing a particular scientific field, had universal reach.*

Copernicus' work is still much debated. For a long time he was considered the person who had not only radically changed astronomy, but who also initiated the transformation of science in general. More detailed analyses of his work revealed that, epistemologically speaking, his "conceptual universe" is still predominantly traditional and that, aside from decentering the Earth and setting it in motion, it does not present anything radically new. Is Copernicus then a conservative or a revolutionary? This is only one of the "disputed questions" that concern Copernicus' work and his role in the scientific revolution (provided, of course, that we accept the presumption that the scientific revolution did indeed take place). There are, however, numerous other issues at stake here, such as: what is his relation to traditional astronomy, in particular to Islamic astronomy; what was the effect or influence of his work on the first "Copernicans", to mention just two such questions. But Copernicus left his trace on other areas of human thought too. In philosophy, one can follow the metaphor of "the Copernican turn" from Kant and Nietzsche all the way to postmodern philosophers. At issue here is the relation of various modern "returns to Kant" and of demands for "the second Copernican turn" in philosophy to Copernicus and his heritage. Last but not least, we can ask ourselves if perhaps modern science is on the threshold of a new "Copernican revolution".

I would like to express my warm thanks to all those who shed some light on these issues with their excellent and insightful contributions.

Ljubljana, October 2004 *Matjaž Vesel*

COPERNICUS
AND THE PHILOSOPHY OF COPERNICAN REVOLUTIONS

Filozofski vestnik Volume/Letnik XXV • Number/Številka 2 • 2004 • 9–24

THE BEGINNINGS OF A MODERN COPERNICAN REVOLUTION

Richard DeWitt

The 100 years between the mid 1500s and mid 1600s produced a number of important new theories and surprising discoveries. Copernicus' sun-centered system, Tycho's astronomical observations, including the discovery that supernovae and comets are superlunar phenomena, Galileo's investigations with the telescope, Kepler's discovery that planetary motion could be accounted for vastly better by abandoning the old view of planetary motion as perfectly circular and uniform – these theories and discoveries, and others, would eventually lead us to a substantially different view as to the sort of universe we inhabit.

The set of changes that eventually resulted from such discoveries is often referred to as the "Copernican revolution." Although this phrase is rather imprecisely defined, there is not much doubt that the changes involved went far beyond the mere issue of whether the earth moves about the sun, or vice versa. Instead, discoveries such as those noted above led to a wide range of dramatic changes – scientific changes, conceptual changes, and technological changes, and arguably political, social, and religious changes as well, to name just a few – that could not even be imagined in the early years of the 1600s.

One of my central questions in this paper is whether we, in the early years of the 21st century, are in a similar situation to that of our predecessors in the early years of the 1600s. Roughly, are we in the beginning stages of a modern Copernican revolution?

Generally, as will emerge below, I think it likely that the answer to this question will turn out to be "yes." In the 1600s, new discoveries eventually led us to understand that we did not inhabit the sort of universe we thought we inhabited. We came to realize that the old view of the universe – the teleological, essentialistic, more or less Aristotelian sort of universe that had been accepted for 2,000 years – was the wrong *sort* of view. The universe, we realized, was nothing like the way it had been conceived to be for the past two millennia.

Instead, we eventually came to believe, we live not in a teleological universe in which natural objects behave as they do largely because of internal, goal-directed essential natures, but rather we live in a mechanistic universe, in which objects behave as they do largely because of the influence of external objects and forces. And these objects and forces could be described by precise, deterministic mathematical laws within a more or less Newtonian framework. Generally speaking, we came to believe that the universe is like a machine. Much as parts of a machine interact with one another in a push-pull sort of way, so too do objects in the universe interact with one another in this sort of machine-like, mechanistic way. We knew, or thought we knew, what sort of universe we inhabit.

In recent years, however, new discoveries have arisen that call into question this machine-like view of the universe. These discoveries are, at bottom, a combination of a relatively-recent mathematical proof, together with the outcome of a series of carefully conducted experiments. For reasons that will emerge below, these new discoveries are, I think, every bit as dramatic as, say, Galileo's discoveries with the telescope, or Kepler's discoveries about planetary orbits.

Unfortunately, these new discoveries are not nearly as widely known as the discoveries of Galileo and Kepler just mentioned (or of most of the discoveries and new theories in play in the early 1600s). Partly this is because these new discoveries involve a mathematical theorem (namely, Bell's theorem), and also because they involve one of the more difficult of modern theories (namely, quantum theory). This, too, provides part of the motivation for this paper. I think these new discoveries are fascinating and important, and deserve to be more widely known. And so, generally speaking, the goals of this paper are to present the new discoveries alluded to above in a way that is accessible to a non-technical audience, and to explore the question of whether, as with the situation in the early 1600s, these discoveries call into question the overall machine-like view of the universe we have had since the first Copernican revolution.

The structure of the paper is straightforward. My first general goal will be to explain, in a manner as accessible as possible, the new discoveries alluded to above. These discoveries are best approached by first discussing what has come to be called the *locality assumption.* This will lead to a discussion of the mathematical theorem mentioned above, generally referred to as *Bell's theorem* or *Bell's inequality,* which in turn will be followed by a discussion of the ties between the locality assumption, Bell's theorem, and quantum theory. Finally, we will turn to an explanation of certain new experimental results (which I will refer to collectively as the Aspect experiments), followed by a discussion of the implications of these discoveries. In particular, the concern of this final section will be to assess what these newly discovered facts tell us about the sort of universe we inhabit.

In outline, then, the major sections of the paper are as follows:

1. The Locality Assumption
2. Bell's Theorem
3. The Ties Between the Locality Assumption, Bell's Theorem, and Quantum Theory
4. The Aspect Experiments
5. Implications of Bell's Theorem and the Aspect Experiments
6. Concluding Thoughts

The Locality Assumption

Roughly speaking, the locality assumption is a somewhat updated version of the old "no action at a distance" idea, that is, that an event at one location cannot influence an event at another location unless there is some sort of connection, or contact, or communication, between the two events. For example, if there is a coin balanced on the table in front of us, we tend to think that we cannot influence the coin (say, cause it to fall over) unless there is some sort of contact or connection between us and the coin (we reach out and push it over, throw a book at it, shake the table, or ask someone else to push the coin over for us, and so on). The idea that what happens at one location cannot influence what happens at another location, unless there is some sort of connection or communication between the two locations, is a deeply-rooted belief dating at least back to the ancient Greeks. Notably, given the centrality of push-pull sorts of interactions inherent in the universe-as-machine metaphor, this belief became even more entrenched with the advent of the mechanistic, machine-like view of the universe that developed following the events of the 1600s. The phrase used above – that what happens at one location cannot influence what happens at another location unless there is some sort of connection or communication between the two locations – is one common, though somewhat rough, way of phrasing the locality assumption.

In this rough phrasing, the notion of "some sort of communication or connection" is rather imprecise. The locality assumption is typically made more precise by employing an implication of Einstein's relativity theory. From relativity, there is good reason to think that the speed of light is a sort of universal speed limit. That is, no influence can propagate faster than the speed of light.[1] Given this, if two events take place within a space of time too short for light to cover the distance between the two events, then there can be no possibility of any sort of signaling or communication or contact or connection between two events. Such events – that is, events that occur within a length of time too short for light to cover the distance between them – are said to have occurred *at a distance* or, equivalently, at *distant locations.*

This consideration leads to a more precise formulation of the locality assumption, sometimes termed *Einstein locality* (partly because of the emphasis on the speed of light stemming from Einstein's relativity, and partly because this sort of influence seemed to be the most worrisome for Einstein – this is the sort of influence he once famously referred to as "spooky action at a distance").

> *The Locality Assumption (Einstein Locality):* An event at one location cannot influence an event at a distant location.

At bottom, that is all there is to the locality assumption. As I am construing it here (that is, in terms of Einstein locality), the locality assumption is essentially the dictum "no action at a distance," somewhat modified and made more precise by employing the speed of light restrictions from relativity. With this brief description of the locality assumption finished, the next task is to consider Bell's theorem.

Bell's Theorem (An Informal Account)

As the name suggests, Bell's theorem is a mathematical theorem, first produced by John Bell in 1964.[2] As will emerge, Bell's theorem has interesting ties to both the locality assumption and to quantum theory. In what follows, I will present a quite informal, non-mathematical account of Bell's theorem. I should note that my approach owes much to what I take to be some very good informal accounts provided by Bell himself, as well as by David Mermin and Nick Herbert.[3]

Suppose we have two devices that we will simply call "A" and "B," each

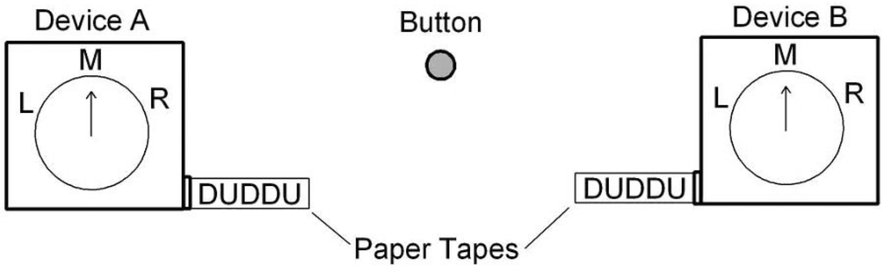
---

[1] See Maudlin (1994) for a careful analysis of what sorts of influences are and are not ruled out by relativity.

[2] Most of Bell's writings on the foundations of quantum theory can be found in Bell (1988).

[3] Most notably, Bell (1988), Mermin (1981) and (1985), and Herbert (1985).

having a dial with three settings, labeled "L" (left), "M" (middle), and "R" (right), and each equipped with a paper tape on which the device can print. Suppose also that we have a button, and that each time we press the button, each device records either a "D" or a "U" on its paper tape. Pictorially, this setup would look as follows:



We will use "A:M" to abbreviate that the dial on device A is set to the middle position, and likewise use "B:M" to abbreviate that the dial on device B is set to its middle position (we will likewise use "A:L" to abbreviate that A is set to its left position, and so on). Using this notation, we can compactly summarize the results of various button presses with the dials set to various positions. For example, "A:M DUDDUDUUUD" will represent the output of 10 button presses for device A when that device is set to its middle position.

Now let's consider four scenarios involving these devices.

Scenario 1: For scenario 1, we set the dial on device A to its middle position, and we likewise set the dial on B to its middle position. We push the button hundreds of times, and we notice that every time we push the button, each device records an identical output. That is, each time device A records a D on its tape, device B likewise records a D on its tape, and each time device A records a U, device B likewise records a U. Moreover, we notice that the devices produce a random mixture of D's and U's. That is, although for each button press the devices record identical outputs, 50% of the time the outputs are D's and 50% of the time the outputs are U's.

Using the notation mentioned above, we can summarize scenario 1 as follows.

Scenario 1:
A:M DUDDUDUUUDUDDUUDUDDUDUUUDUDD...
B:M DUDDUDUUUDUDDUUDUDDUDUUUDUDD...
Summary: Identical Outputs

Scenario 2: For scenario 2, we move the dial on A to its left position, and leave the dial on B in its middle position. Now when we press the button a number of times, we notice that although the devices usually record identical outputs, occasionally the outputs do not match. In particular, we notice that there is a roughly 25% difference in the output of the two devices when the dials are set in this way. To summarize:

Scenario 2:
A:L DDUDUUDUDDUUDUDUUDUDDDUDUUDU...
B:M DUUDUDDUDDUUDUUDUDUDUDUDDUUU...
Summary: 25% Difference

Scenario 3: For scenario 3, we return the dial on A to its middle position, and move the dial on B to its right position. We again push the button a number of times, and again notice that, although the outputs usually match, roughly 25% of the time they do not. In summary:

Scenario 3:
A:M UUDUDDUDUUDDDUDUUUDUDUUDDUDD...
B:R UDDUDUUDDUDUDUDDUUUUDUDDDUDD...
Summary: 25% Difference

Scenario 4: For scenario 4, we put the dial on machine A in its left position (as in scenario 2), and put the dial on machine B in its right position (as in scenario 3). But before going further, we will assume the following hold:

(i) The locality assumption (that is, Einstein locality) is correct,

and

(ii) The recording of the outputs of the two devices (A and B) occur at a distance. (In other words, each time we push the button, the event of device A recording a D or U on its tape, and the event of device B recording a D or U on its tape, are events that occur at a distance.)

If (i) and (ii) are correct, it follows that the 25% difference in scenario 2 has to be a result only from changes to device A resulting from moving its dial. And likewise, the 25% difference in scenario 3 must be the result only of changes made to B resulting from moving B's dial. These two 25% differences, then, can combine in scenario 4 to result in a maximum 50% difference between the two outputs. In short, if (i) and (ii) are correct, then in scenario 4 the maximum difference between the output of device A and the output of device B will be 50%.

This latter statement, that in scenarios such as that described above, the maximum difference in outcomes in scenario 4 is 50%, is essentially Bell's theorem (or more precisely, a somewhat restricted version of Bell's theorem). So if the 50% figure makes sense, then you understand, for our purposes, Bell's theorem.

The next task is to explain the ties between the locality assumption, Bell's theorem, and quantum theory.

The Ties Between the Locality Assumption, Bell's Theorem, and Quantum Theory

Polarization is an attribute of photons, and an attribute that is not particularly difficult to measure. Moreover, quantum theory is the theory used to make predictions involving the polarization of photons. Given this, polarization will provide a convenient way to illustrate the ties between the locality assumption, Bell's theorem, and quantum theory.

For the sake of making the discussion easier, we will make the following simplifying assumptions:

(a) When the polarization of a photon is measured, it will be measured as having either "Up" polarization or "Down" polarization,

and

(b) there is a 50/50 chance of a photon being measured as having Up polarization and a 50/50 chance of it being measured as having Down polarization.

The actual situation regarding polarization is slightly more complex than summarized in (a) and (b), but making the simplifying assumptions (a) and (b) will make the following discussion much more straightforward, and these simplifying assumptions will not change any important facts about what is to follow.

Recall the two devices A and B in the discussion of Bell's theorem above. We will now take these devices to be polarization detectors, with the U and D recorded on the tape representing Up and Down polarization. As in the discussion above, the detectors will have L, M, and R settings. (The details need not concern us, but polarization detectors can indeed have the equivalent of L, M, and R settings.)

It is not difficult to generate pairs of photons in what are called the "twin state," and it is possible to separate such photons and send one to polarization detector A and one to polarization detector B. So now, in the setup described in the section above, suppose each time we push the button, it generates a pair of photons in the twin state, separates the photons, and sends one to detector A and one to detector B. Each detector subsequently measures the polarization of its respective photon, and records either a D or a U on its respective paper tape.

Photons that are in the twin state are such that, if polarization detectors A and B are set to the same position (that is, both are set to the L position, or both set to the M position, or both to the R position), then when the two detectors are used to measure the polarization of the two photons, the photons will be measured to have the same polarization. For example, suppose both detectors are set to their M position. We push the button many times, and each time we push the button, a pair of photons in the twin state are generated, separated, and sent to their respective detectors. In this situation, every time we push the button, whenever detector A measures its photon as having Up polarization, detector B will likewise measure its photon as having Up polarization. And likewise, if one of a pair of such photons is measured as having Down polarization, then the other will be Down as well.

Now consider four experimental setups, exactly analogous to the four scenarios described above in the discussion of Bell's theorem. In the first scenario, exactly as described above, we set both detectors to their M positions, and we push the button hundreds of times. The result will be exactly the pattern described in scenario 1 above, that is, whenever detector A measures a photon as having Up polarization, detector B will register its photon as also having Up polarization.

Importantly, note that this is simply an empirical fact about photons, polarization detectors, and certain experimental setups. This is not a conjecture, or theory, or thought experiment, or whatever. Rather, what is described above is simply a fact about the universe we live in. When polarization detectors are set so that both are in their M positions, and photons in the twin state are generated and separated, with one being sent to each detector, then the photons will always be measured as having the same polarization.

Now we set the detectors up as in scenario 2, that is, we move the dial on A to its L position and leave the dial on B in its M position. Again we push the button hundreds of times. Again the result will be exactly as summarized above in the discussion of Bell's theorem, that is, most of the time the two photons will be measured as having the same polarization, but about 25% of the time the polarization will differ.

Again it is important to note that this is simply an experimental fact. Set the dials on the detectors as described, and the experimental outcome will be as described.

Likewise for scenario 3. Move the dial on A back to its M position, and turn the dial on B to its R position. Push the button hundreds of times, and again the experimental outcome will be as described, that is, about 25% of the time the two polarization detectors will record different polarizations for the two photons. And again, this is simply a fact about the universe we inhabit.

Finally, scenario 4 will likewise be exactly as described in the section above on Bell's theorem. That is, set A to its L position and B to its R position. Once again we will push the button hundreds of times.

Before going further, suppose we can assure that, each time detector A and B measure the polarization of a pair of photons in the twin state, that these measurements occur at a distance. That is, the event of polarization detector A measuring the polarization of the photon sent to it, and the event of polarization detector B measuring the polarization of the photon sent to it, take place within a period of time too short for any sort of signal or communication to be sent between them. Then, exactly as in the discussion in the section above, if the locality assumption is correct, it follows from Bell's theorem that in this scenario there can be at most a 50% difference between the pattern of D's and U's on the tapes of detectors A and B.

This is where the tie to quantum theory comes in. As noted, quantum theory is the appropriate theory for making predictions about the readings of polarization detectors such as those described above. When quantum theory is used to make predictions about what will be observed in scenario 4, the prediction is that there should be an almost 75% difference between the recordings of detector A and B.

In short, Bell's theorem amounts to a discovery that predictions based on the locality assumption, on the one hand, and predictions based on quantum theory, on the other hand, conflict. So although Bell's theorem is essentially a mathematical theorem, the main importance of it (and this is what Bell was primarily interested in) is that it shows that quantum theory and the locality assumption cannot both be correct.

The Aspect Experiments

Although Bell's theorem, and the ties to quantum theory, are reasonably straightforward, it is not so straightforward to carry out actual experiments to test the conflict between the locality assumption and quantum theory. There is no difficulty in generating photons in the twin state, or in generating other particles whose states are tied to one another in a way similar to the way the polarization of photons in the twin state are tied to one another. (Such particles are said to be *correlated*, and correlated particles are not at all uncommon.) Rather, the main difficulty is in assuring that the measurements on the photons (or other correlated particles) are such that they take place at a distance (that is, such that there is no possibility of any sort of signal or communication between the two detectors).

Following the publication of Bell's theorem, a number of labs worked on designing such experiments. Some of the most important of these experiments were carried out by Alain Aspect and his colleagues at the University of Paris in the early 1980s.[4] The design of these experiments was analogous to what was described above (though not surprisingly, the details are a bit more complicated than the setup described above). The experiments used pairs of photons whose polarization was correlated, and the photons were separated and sent to respective detectors that had settings analogous to the L, M, and R settings described above. And the measurements of the polarization of the respective photons took place at a distance, that is, the experimental setup was such that there could be no communication or connection between the detectors.[5]

The results of the Aspect experiments were very much in line with the predictions of quantum theory. Such results have been replicated numerous times by different labs, using different sorts of correlated particles, and the results are quite robust. That is, in the conflict Bell discovered between predictions based on quantum theory and predictions based on the locality assumption, the locality assumption loses.

Of course, new discoveries are not uncommon. After all, new facts are discovered often. So why are the new facts revealed by the Aspect experiments (and similar experiments) of particular interest? For this question, we turn to the next section.

---

[4] See Aspect (1982).

[5] Assuring that the measurements of the photons occurred at a distance was one of the most difficult tasks to accomplish. It is not crucial for this paper, but in essence, and speaking a bit roughly, this was accomplished in Aspect's lab by waiting until the photons were separated and each heading toward their respective detectors before (quasi) randomly setting each detector to its L, M, or R setting. Baggott (1992) and Cushing (1998) contain nice discussions, thorough and accurate but still accessible to a general audience, of the Aspect experiments.

Implications of Bell's Theorem and the Aspect Experiments

In this final section, I want to consider the general question of whether we find ourselves, in the late 20th and early 21st century, in a situation similar to that of the early 1600s. As noted earlier, in the early 1600s new discoveries led to the realization that the existing general conception of the universe was mistaken. The cumulative effect of Copernicus' sun-centered theory, discoveries such as those Galileo reported from his observations with the telescope, Kepler's discovery that a sun-centered system employing elliptical orbits and varying speeds would account for the astronomical data far better than any of the alternatives, Kepler's publication of substantially superior astronomical tables based on his sun-centered system, and other new discoveries and theories, eventually led to the acceptance of the sun-centered view. And with the acceptance of a sun-centered view came the rejection of the general, roughly Aristotelian, conception of the universe. Importantly, it was not merely that this or that particular theory proved to be mistaken. Rather, it was the general Aristotelian, teleological, essentialistic conception of the universe that was wrong. That is, we turned out to be mistaken about the *sort* or universe we inhabit.

For the sake of having a convenient term, I will refer to the sort of instantaneous influences between distant events, of the sort demonstrated by the Aspect experiments, as Bell-like influences. The discovery, in recent years, that we live in a universe that allows for Bell-like influences is certainly an interesting discovery, and one that most people find quite surprising. But how similar is our situation today to that of the early 1600s? Do Bell's theorem and the Aspect experiments suggest, as was the case with the situation in the early 1600s, that we are mistaken about the sort of universe we have thought we inhabited for some time?

There is no doubt that there are differences between the situation today and that of the early 1600s. One difference is that the existence of Bell-like influences is not as widely known as were the theories and discoveries that were central in the early 1600s. For example, Galileo communicated his discoveries with the telescope in a popular and accessible manner, and as a result, his discoveries quickly became widely known. Other key works, such as that of Copernicus and Kepler, were directed more toward a narrower audience, but still, it seems safe to say that the theories and discoveries that were key in the early 1600s were more widely known than are Bell's theorem and the Aspect experiments today.

Interestingly, it is not clear that Bell's theorem and the Aspect experiments are widely appreciated even within the physics community. Consider, for example, the physicist Jim Baggott's reaction to his first coming to appreciate these results:

> Here I was, proud of my scientific qualifications and with almost 10 years' experience in chemical physics research at various prestigious institutions around the world, and I had been going around with a conception of physical reality that was completely wrong! *Why hadn't somebody told me about this before?*[6]

Such reactions seem not to be particularly unusual.[7] In short, even within the relevant scientific community, these results are not as widely known as were the relevant similar results in the 1600s.

Outside the physics community, no doubt part of the reason results such as those described above are not more widely known is that we tend to work in quite specialized fields, certainly much more specialized than was the situation in the early 1600s. We each have our narrow areas of specialization, and mainly talk (and read the papers of, and so on) to others in that same narrow area. Note that this is not a difference that is relevant to how important the existence of Bell-like influences are, but it is certainly a factor in how well known are those influences. (And to repeat a point made in the introduction, this is one of my motivations for focusing on these results in this paper. That is, such results are not so technical as to be beyond the understanding of almost anyone who is interested, yet these results are not widely known. Anyone interested in what is perhaps the most basic question we have had since the time of the ancient Greeks – what sort of universe do we live in? – will be well served by becoming familiar with these results.)

Although there are certainly differences between the early 1600s and our time, there are, I think, striking similarities. Prior to the Copernican revolution of the 1600s, we were convinced we understood the sort of universe we inhabited. The universe, we believed, was a universe in which things behaved as they did because of internal, teleological, essential natures. In much the same way that an organism consists of parts that function to achieve natural goals, so too does nature consist of parts that function to achieve natural goals. The heavenly bodies move in continual perfect circles at uniform speeds because that is the internal, teleological, essential nature of the superlunar element. Natural objects in the sublunar region naturally move with straight line mo-

---

[6] See Baggott (1992; p. ix). Emphasis his.

[7] An interesting discussion of this can be found in Mermin (1985), especially around page 41.

tion, with heavy objects moving out of a natural, internal "desire" to move toward the center of the universe, with light elements such as fire having a natural desire to move away from the center. In general, we thought we had a good understanding of the sort of universe we inhabit – we live in a universe in which objects behave as they do out of internal, natural, essential, goal oriented desires.

The situation in the early 1600s would eventually lead to a change in this conception of the sort of universe we inhabit. And eventually, a new general view emerged as to the sort of universe we find ourselves in. The universe, we came to believe, is a mechanistic universe, one that is like a machine. We came to view the universe as proceeding as a machine-like series of events. Objects behave as they do because of interactions with other objects and because of the influence of external forces. Central to this mechanistic concept is that interactions and influences are local interactions and influences. In a machine, gears influence only other gears in their local area, pulleys influence only other parts of the machine with which they are connected, and in general, parts influence only other parts of the machine with which they have some sort of contact or connection.

In short, the idea of local interactions is a central, core part of the mechanistic conception of the universe that has been dominant since the Copernican revolution. But Bell's theorem and the Aspect experiments show that we are simply mistaken about this core part of our general conception of the universe. The existence of Bell-like influences, demonstrated by the Aspect experiments (and other experiments of a similar sort), shows that we live in a universe with instantaneous, non-local influences between events, even events separated by substantial distances and for which there is apparently no possibility of any sort of communication or connection between them. No one knows *how* the universe can be like this, only that the universe *is* like this.[8]

In this, we are in a similar situation to that of the early 1600s. They knew that the earth moved about the sun, and eventually (from Kepler's work) that planets moved in elliptical orbits and at varying speeds at different places in their orbits. But they, like us, knew only *that* the universe was like this, with no conception of *how* it could be this way. That is, there was no broader framework, metaphorical or mathematical, into which to put these discover-

---

[8] Richard Feynman (1965, p. 129), one of the top physicists of the 20th century, puts the oddness of non-local influences this way: "Do not keep saying to yourself, if you can possibly avoid it, 'But how can it be like that?' because you will get 'down the drain,' into a blind alley from which nobody has yet escaped. Nobody knows how it can be like that."

ies. There were specific, mathematically-based approaches that allowed for increasingly-accurate predictions (for example, Kepler's account of planetary motion, Galileo's work with the mechanics of falling bodies, and others), but no broader framework into which to place these findings. (Such a broader framework would eventually be discovered, culminating in Newton's physics, but not until some decades later.)

Likewise for us. We know that the universe allows for Bell-like influences, and we have quite good mathematically-based theories (mainly the mathematics of quantum theory) that result in very good predictions. But we have no broader framework, again neither metaphorical nor mathematical, into which to place these findings.

I need to be careful here so as not to be misunderstood. The mathematics of quantum theory is a type of mathematics with which physicists have been well acquainted for a long time.[9] It is a widely used, well understood type of mathematics. So in this sense, the mathematics of quantum theory is not at all unique or unusual.

The sense I have in mind is that the mathematics of quantum theory does not fit well with what is generally taken as the other most important branch of modern physics, namely, relativity. Unifying relativity and quantum theory into a broader mathematical framework has been a goal for some time now, but one that thus far has eluded researchers. It is probably safe to say that most physicists are optimistic that the two will eventually be placed within a broader, unifying theory. But at this point, we are in the same situation as the early 1600s, in that we have no such broader framework.[10]

Likewise with respect to a broader, more metaphorical framework. As noted earlier, the discoveries of the early 1600s were eventually subsumed under an overall mechanistic view of the universe. But also as described above, Bell's theorem and the Aspect experiments demonstrate clearly that, whatever sort of universe we inhabit, it is at bottom not a universe for which a machine metaphor is appropriate.

In fact, no metaphor seems to fit comfortably with the existence of Bell-like influences. The sort of Bell-like influences demonstrated by the Aspect

---

[9] See Gasiorowicz (2003) for a typical presentation of the mathematics of quantum theory.

[10] The prospects for reconciling the usual approach to quantum theory (for example, the way the mathematics of quantum theory is typically taught and used, where the mathematics includes a projection postulate governing the collapse or reduction of the wave function) with special relativity may be particularly problematic. See Maudlin (1994) for an analysis of some of the difficulties with reconciling the usual mathematical approach to quantum theory with the Lorentz invariance required by special relativity.

experiments are not like anything we have ever experienced. It is worth taking a moment to appreciate this. The Bell-like influences demonstrated by the Aspect experiments are influences that occur instantaneously, between objects that are separated in space and for which there is no connection of any sort between them. In the experiments carried out in Aspect's lab in the 1980s, the devices were separated by a distance of about 13 meters. But similar instantaneous influences would be expected regardless of the distance involved. That is, we live in a universe that allows for instantaneous influences even between objects and events that may be separated by any distance, even light-years.[11]

And a universe that allows for such influences is certainly not the sort of mechanistic, machine-like universe we have been comfortable with for some centuries. Nor does it seem to be a universe that is like anything we have ever experienced. In short, the fact that we inhabit a universe that allows for Bell-like influences may mean that we live in a universe that can no longer be neatly and concisely summarized by appeal to any sort of familiar metaphor.

In short, we are in a situation which in important ways is like the situation of the early 1600s, of the original Copernican revolution. The view of the universe that we have become comfortable with over the past several hundred years, the mechanistic, machine-like view, cannot be maintained in light of the discoveries discussed above. Whatever the universe is like, it is, at bottom, not like a machine.

Concluding Thoughts

As noted earlier, the discoveries of the late 1500s and early 1600s led to dramatic changes – scientific changes, conceptual changes, and technological changes, to name just a few, that could not even be imagined in the early years of the 1600s. What was clear in the early 1600s, upon the recognition that the earth did move about the sun, was that the old teleological, essentialistic view of the universe could not be maintained.

It is too early to tell where the discoveries discussed in this paper will eventually lead. But it is clear, as it was clear in the early 1600s, that the view

---

[11] It is worth noting that, since the Aspect experiments of the 1980s, physicists have demonstrated Bell-like instantaneous influences between ever larger and further separated entities (including golf -ball sized collections of atoms). So it is not at all clear that this sort of oddness of quantum theory is confined only to microscopic entities, such that it cannot be brought into the macroscopic level. See DeWitt (2004), especially chapter 25, for a more thorough discussion of this.

of the universe that has been in place for some time – for us, the mechanistic, machine-like view – is no longer a viable view.

In closing, it is worth noting one final difference between our situation and the situation of the early 1600s. Because of what happened then, and because we have had the luxury of studying those developments, we are in a vastly better position to observe and chronicle the developments taking place in our time. Although the increasing specialization mentioned at the beginning of this section has some unfortunate consequences, one good consequence is that we have specialists who are experts in studying not only the changes that took place in the past, but the changes we find ourselves in the midst of. As with the early 1600s, ours is an exciting time.

Bibliography

Aspect, A., Dalibard, J. and Roger, G. (1982) "Experimental Tests of Bell's Inequalities Using Time-Varying Analyzers", *Physical Review Letters* 491 1804–1807,

Baggott, J. (1992) *The Meaning of Quantum Theory*, Oxford University Press, Oxford.

Bell, J. (1988) *Speakable and Unspeakable in Quantum Mechanics: Collected Papers on Quantum Philosophy*, Cambridge University Press, Cambridge.

Cushing, J. (1998) *Philosophical Concepts in Physics: The Historical Relationship between Philosophy and Scientific Theories*, Cambridge University Press, Cambridge.

DeWitt, R. (2004) *Worldviews: An Introduction to the History and Philosophy of Science*, Blackwell Publishing, Oxford.

Feynman, R. (1965) *The Character of Physical Law*, MIT Press, Cambridge, Mass.

Gasiorowicz, S. (2003) *Quantum Physics*, Third edition, John Wiley and Sons, Inc.

Herbert, N. (1985) *Quantum Reality: Beyond the New Physics*, Doubleday, New York.

Maudlin, T. (1994) *Quantum Non-Locality and Relativity*, Blackwell Publishers, Oxford.

Mermin, D. (1981) "Quantum Mysteries for Anyone," *Journal of Philosophy* 78; 397–408.

Mermin, D. (1985) "Is the Moon There When Nobody Looks? Reality and the Quantum Theory," *Physics Today* 38; 38–47.

Filozofski vestnik Volume/Letnik XXV • Number/Številka 2 • 2004 • 25–50

GIORDANO BRUNO'S COPERNICAN DIAGRAMS

Hilary Gatti

The study of Giordano Bruno's Copernicanism has a long and distinguished history, going back to the nineteenth century and continuing until the present day. It has involved a number of prestigious scholars, both historians of science and historians of philosophy, such as Paul-Henri Michel, Alexandre Koyré, Hélène Vedrine, Thomas Kuhn and Robert Westman, among many others[1]. This notable body of comment on Bruno as one of the major Copernican philosophers of the sixteenth century will be taken as given, and mention will be made of the details of his reading of the *De revolutionibus* only when necessary to the development of our subject. This intends to be a comment on the way in which Bruno attempted to pilot a recalcitrant sixteenth-century public, convinced of the falsity of the Copernican hypothesis except within a strictly mathematical formulation of it, towards a realist acceptance of the heliocentric principle, together with much else that Copernicus himself would not have been prepared to accept. It was precisely this realist helio-

---

[1] Serious consideration of Bruno's Copernicanism starts with Domenico Berti's pages in *Copernico e le vicende del sistema copernicano in Italia,* Paravia, Rome 1876, pp. 76–92. For the twentieth century comments listed above, see Alexander Koyré, *From the Closed World to the Infinite Universe,* Johns Hopkins University Press, Baltimore 1957; Thomas Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought,* University of Harvard Press, Cambridge (Mass) 1957; Paul-Henri Michel, *The Cosmology of Giordano Bruno,* Cornell University Press, Ithaca (NY) [1962] 1973; Hélène Vedrine, *La conception de la nature chez Giordano Bruno,* J. Vrin, Paris 1967; Robert Westman, "Magical Reform and Astronomical Reform: the Yates Thesis Reconsidered", in *Hermeticism and the Scientific Revolution,* University of California Press, Los Angeles 1977. More recently, Bruno's Copernicanism has been reconsidered by, among others, E. McMullin, "Bruno and Copernicus", in *Isis,* (78/1987); J. Seidengart, "La cosmolgie infinitiste de Giordano Bruno" in *Infini des mathématiciens, Infini des philosophes,* F. Monnayeur (Ed.), Belin, Paris 1992, and R.G. Mendoza, *The Acentric Labyrinth: Giordano Bruno's Prelude to Contemporary Cosmology,* Element Books, Shaftesbury 1995. See also the relevant chapters in Hilary Gatti, *Giordano Bruno and Renaissance Science,* Cornell University Press, Ithaca (NY) 1999.

centric stand, however, shared by only a small handful of his contemporaries, which involved Bruno in the attempt to visualise a new world picture; for he left to others the task of calculating more precisely the movements of the heavenly bodies. At the same time as he praised Copernicus publicly as one of the most audacious and innovative minds of all times, he also chided him for being "too much of a mathematician, and not enough of a natural philosopher"[2].

Bruno did not make the mistake of identifying Copernicus himself with the famous anonymous preface to the *De revolutionibus* written by Andreas Osiander, which advised use of the astronomical system proposed in the volume only in terms of a mathematical hypothesis. Indeed he was the first to declare publicly that Copernicus himself could not possibly have written that preface, although he seems not to have known who the true author was. But Bruno did think that Copernicus himself had not stood out strongly enough in defence of the realist nature of his own proposal. Bruno saw himself as assuming Copernicus's mantle in so far as he accepted the difficult challenge of making people see the world in its new shape, not just mathematically but physically. For Bruno, who was a philosopher not an astronomer, the new universe was the place we have to live in, and he hoped that it would be possible to live better there than in the world people had thought they were living in before. This was made all the more difficult by the fact that Bruno also extended the Copernican hypothesis to infinite dimensions, proposing not a unique universe with a single sun at its centre but an infinite world inhabited by an infinite number of solar systems. For, as Michel-Pierre Lerner has recently once again underlined, Bruno was among the first to develop a radical criticism of the finite cosmology delimited by the so-called planetary spheres. These were supposed to carry the planets round in their harmonious circles in a crystalline quintessence of Aristotelian origin: for Bruno, they were pure fictions with no physical basis at all[3]. Bruno's own cosmology derives from Epicurus and Lucretius rather than Aristotle. Space becomes an infinite envelope filled by a tenuous ether which pervades it in all its parts. Visualising our own solar system in Copernican terms thus meant for Bruno not visualising the universe as such, but visualising only a small speck of it floating within an im-

---

[2] The quotation is from Dialogue 1 of *La cena de le ceneri (The Ash Wednesday Supper)*. All references to Bruno's Italian dialogues are to the texts prepared by Giovanni Aquilecchia in *Opere italiane di Giordano Bruno,* 2 vols., Nuccio Ordine (Ed.), UTET, Turin 2002. For the above quotation, see vol. 1, p. 449. All translations from Bruno's works in this paper are mine.

[3] See Michel-Pierre Lerner, *Le monde des sphères,* 2 vols., Les belles Lettres, Paris 1996–97, vol. 2 : *La fin du cosmos classique,* pp. 157–166.

mense and infinitely populated whole. Although to-day we have become used to seeing the earth as a minute, hardly visible point within immense vistas of space and time, such an idea at the end of the sixteenth and beginning of the seventeenth centuries appeared overwhelmingly unfamiliar and strange. Even those who had made the effort to accomodate their minds to the new Copernican system, such as Johannes Kepler, found Bruno's overall cosmological picture totally unacceptable. Kepler referred to it as Bruno's "innumerabilities", expressing concern for his friend Johann Matthaüs Wacker von Wackenfels's "deep admiration for that dreadful philosophy"[4]. On the other hand, it was precisely Bruno's conceptual leap towards the idea of an infinite universe which lead Alexandre Koyré to exclaim, four hundred years later:

> On reste confondu devant la hardiesse, et le radicalisme de la pensée de Bruno, qui opère une transformation – révolution véritable – de l'image traditionelle du monde et de la réalité physique.[5]

The Physically Real

To be sure, the criterion of scientific realism which inspired Koyré's outburst of praise for Bruno's conceptual leap into infinite space appears now as part of the "traditional" view of the so-called "scientific revolution". Proponents of the more recent historiographical criteria of contingency and scientific sociology, or social constructivism, would be quick to brand it as suspect "for want of a right reason constituted by nature"[6]. It would overrun the bounds of this paper to enter into our contemporary debate concerning the respective claims of a logical system of reasoning based on a coherent concept of scientific objectivity, and the idea of science as "a form of intellectual

---

[4] Johannes Kepler, *Conversation with the Sidereal Messenger recently sent to Mankind by Galileo Galilei* [Daniel Sedesanus, Prague 1610]. Translated with an Introduction and Notes by Edward Rosen, Johnson Reprint Corp., New York 1965, p. 37.

[5] Alexandre Koyré, *Etudes galiléennes,* 2 vols., Hermann, Paris 1939–40, vol. 1, p.141.

[6] The quotation, which is from Hobbes, is used by S. Shapin and S. Schaffer to question the whole concept of scientific realism. See their much discussed volume, *Leviathan and the Air-Pump,* Princeton University Press, Princeton 1985. Previous philosophical discussion concerning the problem of scientific realism had included, B.C. Van Fraasen, *The Scientific Image,* Oxford University Press, Oxford 1980, and Ian Hacking, *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science,* Cambridge University Press, Cambridge 1983. For a synthesis of this discussion, see W.H. Newton-Smith, "Realism", in *The Routledge Companion to the History of Modern Science,* R.C. Olby et al. (Eds.), Routledge, London and New York 1990, pp. 181–195.

ecology rather than of inductive logic"[7]. It is worth pointing out, however, that Bruno himself, placed at the very beginning of what still continues to be called "the scientific revolution", was aware of precisely this problem, and discussed it openly in his cosmological dialogues. In the remarkable second dialogue of his major cosmological work in Italian, *La cena de le ceneri* or *The Ash Wednesday Supper,* written and published in London in 1584, Bruno pictures himself as "the Nolan philosopher" (he was born in Nola, near Naples) and sees himself as undertaking a night-time journey which will eventually lead him to the rooms of Sir Fulke Greville where the supper and the cosmological discussion were held. Travelling in an ancient creaking boat down the Thames, followed by an adventurous walk through the muddy streets of the still crowded city – metaphors of a world still enclosed within the gradually disintegrating structure of the traditional Aristotelian-Ptolomaic universe – Bruno notes how on the way he cannot avoid meeting with "a princely palace here, there a wooded plain with a glimpse of the sky lit by the morning sun"[8]. The dialogue continues by offering a wealth of further information about the London of the day: how the unfriendly English servants dress and behave, the affectations and at times the arrogant behaviour of Bruno's aristocratic hosts, how wine at table was drunk out of a communal cup (complete with only half-hidden references to the Protestant transformations of the rituals of the Catholic mass). Such was the social context in which a cosmological discussion based on Bruno's reading of Copernicus's *De revolutionibus* was held on the evening of Ash Wednesday, 1584, in the rooms of Sir Fulke Greville, friend and future biographer of Sir Philip Sidney whom Bruno praises in his work as one of the most brilliant minds of his time. Bruno is aware that all this cannot but affect the way in which Copernicus's book was being read and discussed in London on that momentous evening.

Nevertheless, having dealt with such "preliminaries" in the first two dialogues of the *Supper,* in the third dialogue, where the cosmological discussion properly begins, Bruno does call upon a criterion of physical objectivity in his defence of the Copernican astronomy. He does this in the first place by mounting a bitterly ironic attack on the writer of the anonymous preface, whom he brands as an unfaithful doorkeeper of Copernicus's new edifice. This in itself is clearly a metaphor pregnant with important meanings; for an

---

[7] See Stephen Toulmin, "From Logical Systems to Conceptual Populations", in *Boston Studies in the Philosophy of Science,* (8/1971), R.C. Buck and R.S. Cohen (Eds.), pp. 552–64. For a balanced discussion of the recent debate concerning scientific realism, see H. Floris Cohen, *The Scientific Revolution: a Historiographical Enquiry,* Chicago University Press, Chicago and London 1994, pp. 230–36.

[8] See the *Argomento del secondo dialogo,* in *La cena de le ceneri,* op. cit., p. 434.

edifice must have its mathematical co-ordinates, but it is evidently in the first place a physical construction. Although "set" within a definable social, geographical and historical landscape, nevertheless an edifice constitutes an autonomous architectonic structure within which its inhabitants live, move and create their world. There is clearly a sense in which a physical edifice is more "real" than the mathematical calculations which have served to create it or than the social and historical context within which it has been built. Bruno's choice of metaphor, at the very beginning of the discussion of Copernicus's book which the final three dialogues of *The Ash Wednesday Supper* narrate, is thus a conceptually appropriate one with which to define the complex but nevertheless "realist" terms in which, as the Nolan philosopher, he intends to conduct the debate.

Robert Westman, in what he has called the "Wittenberg interpretation" of Copernicanism in the sixteenth century, has demonstrated how rare were the early attempts to read the new astronomy in realist terms, in the Protestant parts of Europe as well as in the Catholic ones. He includes Bruno among the very few Copernican realists active in sixteenth century Europe[9]. Undoubtedly, given the fact that the discussion narrated by Bruno in the *Supper* took place in London, and that he wrote about it and published his work in that city, the most important precedent to Bruno's realist stand was that of Thomas Digges. First published in 1576, and presented somewhat slyly as a mere addition to his father's completely traditional work on astrology, in particular in its practical application to weather forecasting, *A Prognostication Everlastinge,* Digges's few Copernican pages are partly direct translation from book I of *De revolutionibus,* and partly stringent comment on their implications. Unlike Bruno, Digges does all he can to avoid underlining the "revolutionary" nature of the Copernican proposal. In so far as he also sees it as opening out the universe to possibly infinite dimensions, he proclaims his entirely traditional acceptance of the four elemental spheres reaching as far as the moon, surrounded by a crystalline semi-divine substance identifiable as Aristotle's quintessence. Thus, for Digges there is only one solar system, not an infinite number as Bruno would proclaim. So Digges saw no need for his readers to be alarmed by the new astronomy, and he precedes his Copernican pages with the picture of a ship sailing in calm waters: presumably a tranquilizing message to Sir Edward Fines, the Lord High Admiral, to whom the book, in his father's name, is dedicated. Within this overall strategy of underplaying the innovative aspects of his own pages, it is entirely character-

---

[9] See Robert Westman, "The Melancthon Circle, Rheticus, and the Wittenberg Interpretation of the CopernicanTheory", in *Isis,* (66/1975).

istic of Digges that he should give his key punch for a realist reading of the heliocentric proposal almost in a throw-away aside. It is not clear how many of his English readers (for Digges was writing in English rather than in Latin, as his father had done before him) understood the literally world-shattering implications of his claim:

> Copernicus mente not as some have fondly excused him to deliver these grounds of the Earthes mobility onely as Mathematicall principles, fayned and not as Philosophicall truly averred.[10]

Bruno himself, on the other hand, had already discovered that even in England the waters of Copernican discussion tended to be remarkably agitated, and not tranquil at all. By the time Sir Fulke Greville invited him to supper to discuss his reading of Copernicus as well as other "paradoxes" of his new philosophy, Bruno had already been publicly derided by the Oxford dons after his attempts to explain the Copernican astronomy in lectures at the university given during the summer of 1583[11]. His own ship diagram in *The Ash Wednesday Supper* depicts stormy waters, in the course of being stirred up to further tempests by a chubby-cheeked north wind. Nevertheless, Bruno's ship image may be, and frequently has been, compared with Digges's ship in so far as both authors are concerned to argue that the impetus of a ship's movement would be "impressed" on a weight dropped from the mast, which would therefore fall vertically to the foot of the mast and not be left behind by the moving ship. This argument was already known and discussed in the middle-ages, although in an Aristotelian-Ptolemaic context. It was repeatedly used in early Copernican discussion, up to and including Galileo, to contradict the anti-Copernican objection that a moving earth would leave all the clouds and the birds behind[12]. Bruno never mentions Digges in his work (an example followed by Galileo, who never mentions Bruno, to Kepler's surprise and concern); but it seems more than likely that Bruno at least knew of Digges's work. For Digges was a pupil of John Dee, who also taught math-

---

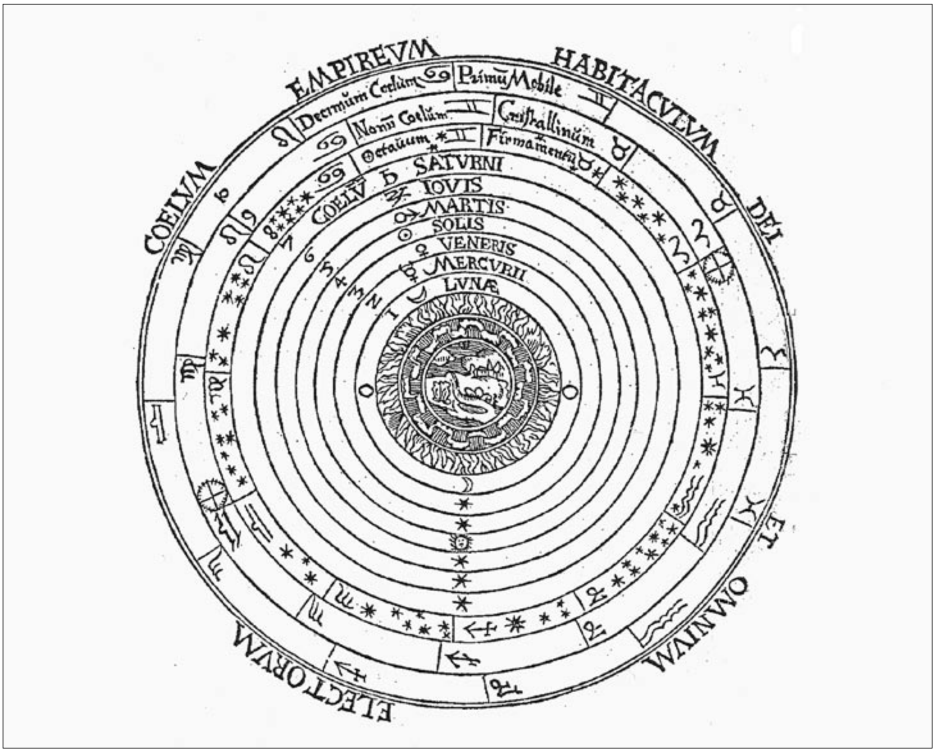
[10] Leonard Digges, *A Prognostication everlastinge … lately corrected and augmented byThomas Digges, his sonne,* Thomas Marsh, London 1576, fol. Mi, r and v.

[11] This episode, although much discussed and the subject of many conjectures, remains obscure in so far as the texts of Bruno's lectures have not survived. For the known documents, see Giovanni Aquilecchia, "Giordano Bruno at Oxford", in *Giordano Bruno, 1583–1585: The English Experience,* M. Ciliberto and N. Mann (Eds.), Olschki, Florence 1997.

[12] See D. Massa, "Giordano Bruno and the Top-Sail experiment" in *Annals of Science,* (30/1973); Robert Westman, "Magical Reform and Astronomical Reform", op. cit., and G. Aquilecchia, "I 'Massimi sistemi' di Galileo e la 'Cena' di Bruno", in *Nuncius: Annali di Storia della Scienza,* (X/1995), pp. 485–496.

ematics to Sir Philip Sidney and whose remarkable library, which contained Copernicus's *De revolutionibus,* was the occasion of a meeting with Sidney and his entourage after a state visit to Oxford in which Bruno is known to have participated[13]. Although Bruno, unless unaided by a friend, would not have been able to read Digges's English text, he could certainly have contemplated his well-known Copernican picture of the universe, and may have had it in mind when preparing his own rather different Copernican picture to illustrate the text of the fourth dialogue of *The Ash Wednesday Supper.*

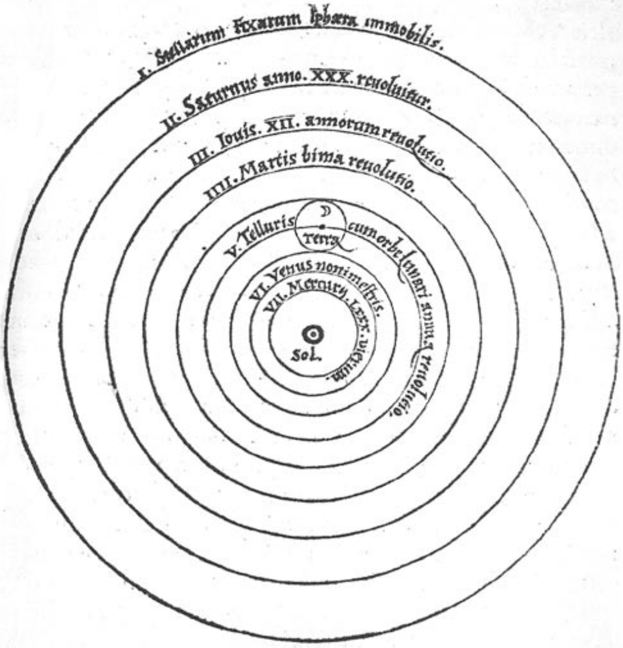
Copernican realism, already a characteristic (if constantly underplayed) of Copernicus himself and of Digges, and a defining one of Bruno's readings of his astronomy, caused problems of visualisation from the very beginning. It decreed the sudden superfluity of a centuries-long tradition of illustrations of the Aristotelian-Ptolemaic universe, which had assumed a notable aesthetic as well as scientific dimension (see fig. 1 from the cosmological work of Peter Apian, 1524).



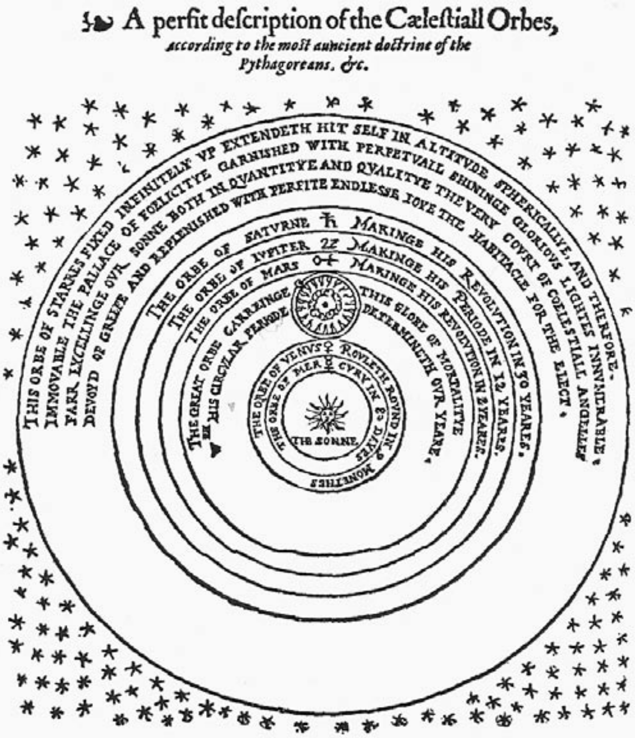
[Fig. 1]

---

[13] See *John Dee's Library Catalogue,* J. Roberts and A.G. Watson (Eds.), Bibliographical Society, London 1990, n. 220.


I. Stellarum fixarum sphaera immobilis.
II. Saturnus anno. XXX. reuoluitur.
III. Iouis. XII. annorum reuolutio.
IIII. Martis bima reuolutio.
V. Telluris cum orbe lunari annua reuolutio.
Terra
VI. Venus nonimestris.
VII. Mercurii. LXXX. dierum.
Sol.

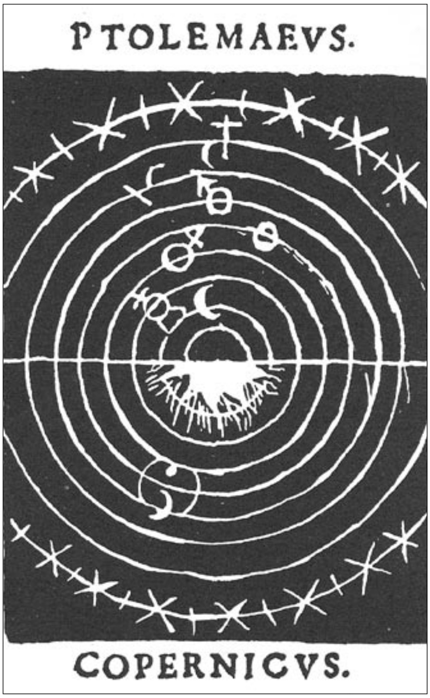
[Fig. 2]


A perfit deſcription of the Cæleſtiall Orbes,
according to the moſt auncient doctrine of the Pythagoreans, &c.
THIS ORBE OF STARRES FIXED INFINITELY VP EXTENDETH HIT SELF IN ALTITVDE SPHERICALLYE, AND THEREFORE
IMMOVABLE THE PALLACE OF FOELICITYE GARNISHED WITH PERPETVALL SHININGE GLORIOUS LIGHTES INNUMERABLE,
FARR EXCELLINGE OVR SONNE BOTH IN QVANTITYE AND QVALITYE THE VERY COVRT OF COELESTIALL ANGELLES
DEVOYD OF GREEFE AND REPLENISHED WITH PERFITE ENDLESSE IOYE THE HABITACLE FOR THE ELECT.
THE ORBE OF SATVRNE ♄ MAKINGE HIS REVOLUTION IN 30 YEARES.
THE ORBE OF IVPITER ♃ MAKINGE HIS PERIODE IN 12 YEARES.
THE ORBE OF MARS ♂ MAKINGE HIS REVOLVTION IN 2 YEARES.
THE GREAT ORBE CARRYINGE THIS GLOBE OF MORTALITYE
HIS CIRCULAR PERIODE DETERMINETH OVR YEARE.
THE ORBE OF VENVS ♀ ROVLETH ROVND IN 9 MONETHES
THE ORBE OF MERC ☿ CURU IN 80 DAYES
THE SONNE

[Fig. 3]

The task of drawing a new and unfamiliar image of a now heliocentric cosmology was by no means simple; and Edward Rosen has drawn attention to the fact that difficulties arose at once, with relation to the illustration to be included in first editions of the *De revolutionibus.* Copernicus's own diagram was rejected and one (possibly by Rheticus) included which was to be the cause of perplexities and misunderstandings throughout the sixteenth century (see fig. 2)[14]. Digges's Copernican diagram is virtually the same as that in the *De revolutionibus,* except for the suggestion of an infinite number of stars stretching out beyond a unique astronomical system of a heliocentric kind (see fig. 3).

In Dialogue 4 of *The Ash Wednesday Supper,* the published diagram in *De revolutionibus* appears at the centre of the heated Copernican discussion between Theophilus, the mouthpiece of Bruno himself, and Torquato, one of the two bejewelled and conservative Oxford dons called in by Sir Fulke Greville to defend the traditional cosmology at his supper party. The problem raised by Bruno has been often considered both puerile and mistaken by commentators, especially by those anxious to further Frances Yates's Hermetical and magical reading of Bruno's works, which denies any scientific value to his Copernicanism at all[15]. In fact, Bruno's argument is both justified and not altogether incorrect. Torquato, as Bruno points out, bases his anti-Copernican comments on Rheticus's diagram rather than on a serious reading of Copernicus's text, thus failing to understand that if the orbit of the earth around the sun is seen as perfectly circular, then the sun has to be slightly off-centre for the system to be valid. Otherwise, as Bruno puts it, the diameter of the sun would appear constant throughout the year. Another solution to this problem, put



[Fig. 4]

---

[14] See Copernicus, *De revolutionibus (On the Revolutions),* Jerzy Dobrsycki (Ed.), comment by Edward Rosen, Macmillan, London 1978, p. 359, note 21.

[15] See Frances Yates, *Giordano Bruno and the Hermetic Tradition,* Routledge and Kegan Paul, London 1964.

forward by Copernicus himself only in book III of *De revolutionibus,* is to keep the sun at the geometrical centre of the system and put the earth on an epicycle, which is the solution adopted by Bruno in his own Copernican diagram in *The Ash Wednesday Supper* (see fig. 4).

Bruno's visualisation of the new sun-earth relationship, although very schematic, is thus quite correct: more correct than that suggested by the *De revolutionibus* diagram, and indeed by that of Digges[16]. It is interesting to note, however, that Digges, in a previous Latin work of 1573, *Alae seu scalae mathematicae,* written together with John Dee, had already made a number of references to Copernicanism in Latin. This work could well have been read by Bruno, as in it Digges raises the same questions that Bruno is discussing here: that is, the necessity of introducing either epicycles or eccentrics to guarantee the apparent changes in the sun's diameter[17]. Bruno, furthermore, goes on to make a mistake himself, by putting the moon on the same epicycle as the earth, whereas Copernicus (in bk. III) puts it on a second epicycle centred on the revolving earth. These were still early Copernican times, and mistakes in reading the new cosmology were many. Both Kepler and Galileo made their own seriously mistaken conjectures, raising the whole question of "Copernican mistakes" which are themselves an interesting, and ultimately not unfruitful, aspect of his reception. Where Bruno leaves Digges far behind, although in written text rather than in illustration, is in his attempt to visualise an entirely homogeneous and infinite universe, no longer characterised by those elemental spheres which are still so clearly depicted by Digges in his diagram (see fig. 3) as still dominant in the earth-moon orbit of his newly Copernican world.

Waiting for the Telescope

> Advances in engraving techniques, and in particular the detail made possible by copper-plate, meant that illustrations could match the most disparate subjects. Maps, plans, structural and logical diagrams, mathematical figures, drawings of machines and cog wheels, reproductions of animal or plant species, and synoptic tables invaded the printed page, clarifying, qualifying and completing it… The image acquired a philosophical role, and the ensuing redefinition in figures and signs of the totality of knowledge would play its part in the development of a new conception of man and the cosmos.

---

[16] For Bruno's use of bk. III of *De revolutionibus* in this context, see my chapter on "Reading Copernicus" in *Giordano Bruno and Renaissance Science,* op. cit., pp. 43–77.

[17] See Thomas Digges, *Alae seu scalae mathematicae, quibus visibilium remotissima Caelorum Theatra conoscendi,* Thomas Marsh, London 1573, fols. Aiir-Aiiiv.

This eloquent passage written by Luce Giard on illustrations in texts of the early modern period defines the context in which discussion of Bruno's illustrations, cosmological and otherwise, should be examined[18]. Much recent discussion of the problem of visualisation of astronomical objects, however, has concentrated on the hiatus between the pre- and the post-telescopic age. The advent of telescopic observation with Galileo, it is argued, raised a whole series of new optical issues, including those relating to the degree of accuracy of scientific instruments themselves. A systematic programme of observations of the moon, for example, was not carried out until well after Galileo's death, and even then not without numerous problems interfering relating to sightings of discs created by the telescope itself[19].

It is known that telescopes were already being made and discussed in Bruno's time. Bruno himself would undoubtedly have known about them from the work on natural magic of his fellow Neapolitan, Giovan Battista della Porta, which was also known to Kepler, and possibly also from the works of Leonard and Thomas Digges[20]. Both Della Porta and the Digges, however, only discuss in their works the use of telescopes for terrestial observation, particularly in the field of navigation. Modern comentators have tended to deduce from this that visualisation of the new astronomy only started with Galileo. The pre-telescopic age appears relegated by this discussion to a kind of meaningless limbo, as if from Copernicus himself the reception of his theory had jumped to the momentous event expressed by Galileo's succinct comment of 1610: "But forsaking terrestial observations, I turned to celestial ones"[21].

---

[18] See Luce Giard, "Remapping knowledge, reshaping institutions", in *Science, Culture and Popular Belief in Renaissance Europe,* Stephen Pumphrey, Paolo L. Rossi, Maurice Slawinski (Eds.), Manchester University Press, Manchester 1991, pp. 19–47: 29–31.

[19] See Mary G. Winkler and Albert Van Helden, "Representing the Heavens: Galileo and Visual Astronomy", in *Isis,* (83/1992), pp. 195–217; Mary G. Winkler and Albert Van Helden, "Johannes Hevelius and the Visual Language of Astronomy", in *Renaissance and Revolution: Humanists, Scholars, Craftsmen and Natural Philosophers in Early Modern Europe,* J.V. Field and Frank A.J.L. James (Eds.), Cambridge University Press, Cambridge 1993, pp. 97–116, and Isabelle Pantin, "L'illustration des livres d'astronomie à la renaissance : l'evolution d'une discipline à travers ses images", in *Immagini per conoscere: dal Rinascimento alla Rivoluzione Scientifica,* Fabrizio Meroi and Claudio Pogliano (Eds.), Olschki, Florence 2001.

[20] See Albert Van Helden, "The Invention of the Telescope", in *Transactions of the American Philosophical Society,* (67, pt. 4/1977), and for a claim that the telescope was invented in England by Leonard Digges, see C.A. Ronan, "The Origins of the Reflecting Telescope", in the *Journal of the British Astronomical Association,* (101/1991), pp. 335–342.

[21] Galileo Galilei, *The Starry Messenger* [1610], translated with an Introduction and Notes by Stillman Drake, Doubleday, New York 1957, p. 28.

Nobody was more critical of such an approach to the new astronomy than Kepler himself. For Kepler formulated his theory of the elliptical orbit of Mars on the basis of observations made with the naked eye. Furthermore he wrote his famous *Dissertatio* on Galileo's discovery of the moons of Jupiter, shortly after it had been published in the *Sidereus nuncius,* before having obtained a telescope with which to observe them for himself. There is a curious note of disdain in Kepler's disparagement of Galileo's ability to make his own telescope. Kepler himself is not able, he assures his public, to work with his hands; but soon someone will lend him a telescope and then he will see Galileo's new moons himself[22]. To his credit, Kepler never doubts the authenticity of Galileo's discovery, as Galileo's ecclesiastical enemies went on doing until well after his trial and house imprisonment at Velletri. Kepler's instinctive trust in Galileo's observational skill throws a deep shadow over Galileo's own mistrust, indeed total silence, with respect to Kepler's momentous discovery of elliptical orbits. It was Galileo himself who was largely responsable for the assumption, made by so many scholars to-day, that serious visualisation of the Copernican theory began only with telescopic observation of the new pattern in the skies.

A major claim made by Kepler in his *Dissertatio* is that a number of post-Copernican theories and discoveries formulated before Galileo's observations of the moons of Jupiter made that discovery conceptually possible. He thinks that Galileo should have recognised their importance in his text. And if Kepler's main concern is to insist on the importance of his own theories and discoveries, he also includes Bruno in this context. For Bruno had formulated a clear distinction between bodies such as suns and stars which generate their light from within, and moons or earths which are illuminated from without. Kepler agrees with Bruno that it is necessary to move beyond the purely visual outlook of the new system provided by Copernicus himself, and to pass from the facts to the causes[23]. This had become imperative to the natural philosopher of the time, as the new system virtually banished from the cosmological picture the traditional Aristotelian "prime mover", which had set the Ptolemaic celestial system in motion in the first place (see fig. 1). Copernicus himself, as well as an early Copernican such as Thomas Digges, had fleetingly referred to the neo-Platonic concept of elemental motion put forward, in an Aristotelian cosmological context, by Marsilio Ficino. Recently studied by Dilwyn Knox, this doctrine sees gravity and levity as causes of ce-

---

[22] See Kepler, *Conversation with the Sidereal Messenger,* op. cit.

[23] For a comment on Kepler's multiple references to Bruno in this text, see L. Simoni Varanini, "La *Dissertatio cum Nuncio Sidereo* fra Galileo e Bruno", in *Bruniana e campanelliana,* (IX-1/2003), pp. 207–215.

lestial motion, within a conceptual context still founded on the theory of the four elemental spheres as the primary constituents of matter up to the planetary sphere of the moon[24]. However, Bruno repudiated the elemental spheres just as he repudiated the planetary spheres of Aristotelian fame. Serious speculation about the universal causes of the heavenly motions within the new cosmology thus may be seen as starting with Bruno; even if Kepler prefers his own unique world based on his more mathematical idea of a universe divided among the five Platonic solids. Galileo, for his part, had little time to spare for Kepler's mystical neo-Platonism, and in his later *Dialogue concerning the two chief world systems* preferred to refer to William Gilbert's magnetical explanation of the causes of celestial motions[25]. Kepler himself also knew and admired Gilbert's *De magnete,* which had been published in 1600, the year of Bruno's death. Nevertheless, in his *Conversation* with Galileo, it is through multiple references to Bruno's natural philosophy that Kepler establishes the principle that a new, universally valid cause of the celestial motions was necessary to make sense of Copernicus's theory at all.

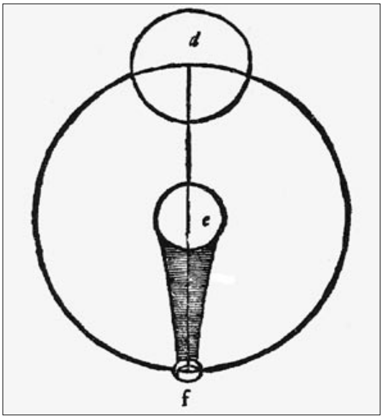
Bruno's own solution, already put forward in *The Ash Wednesday Supper* and never abandoned, was based on a thermodynamic concept of the play between the contrary forces of cold and heat. Its root lay in the anti-Aristotelian natural philosophy of Bernardino Telesio, whom Bruno greatly admired[26]. Telesio saw the whole universe as moved throughout by the active principles of heat and cold, even if he himself never abandoned the Aristotelian, finite cosmology. Telesio's thermodynamic doctrine of planetary movement, however, did defy the traditional idea of elemental spheres, for the contrary forces of heat and cold were seen as dominant throughout his still finite and geocentric universe. Kepler was probably thinking of Bruno's enthusiastic adoption of this concept when he criticised Bruno for "talking in generalities". However, a careful reading of Bruno's *De immenso et innumerabilibus* of 1591 shows that he did attempt to specify his thermodynamic theory of planetary motion by supplying it with a mathematical formulation. He does this through the use of a diagram whose importance seems to have escaped the notice of his commentators (see fig. 5).

---

[24] See Dilwyn Knox, "Ficino, Copernicus and Bruno on the Motion of the Earth", in *Bruniana e campanelliana,* (V- 2/1999), pp. 333–66, and *Physis,* (38/2001), pp. 171–209.

[25] Galileo Galilei, *Dialogue Concerning the Two Chief World Systems,* Stillman Drake (Ed.), California University Press, Berkeley and Los Angeles 1953, pp. 400–411.

[26] On Bruno and Telesius, see Giovanni Aquilecchia, "Ramo, Patrizi, e Telesio nella prospettiva di Giordano Bruno" and "Ancora su Bruno e Telesio", in *Schede bruniane,* Vecchiarelli, Manziana 1993, and Hilary Gatti, "Telesio, Giordano Bruno e Thomas Harriot", in *Accademia cosentina: Atti 1991–2,* Accademia Cosentina, Cosenza 1994.



[Fig. 5]

Bruno's text claims that in the infinite universe, if considered infinitely, nothing can be said either to act or to be acted upon. But if considered in terms of the finite bodies within it, then they do act and are acted upon. He goes on to consider how, in a general sense, action of one body on another decreases with respect to increase in the distance between them. For example, the fire e heats point f according to the distance e–f. If the fire d is four times as hot as e, it will heat e according to the distance d-e four times as much as e heats f, but it will heat f only twice as much because it needs to travel twice the distance to reach it. Thus Bruno is introducing a mathematical idea of the ratio of distance to intensity to measure the amounts of heat by which the hot bodies (stars or suns) attract the cold ones (earths or moons) into their orbit. The argument goes on to consider Aristotle's (puerile) claim that if the universe were infinite and the heat of an ethereal fire were of infinite intensity, then there would be no chance of the earth withstanding such heat: therefore all bodies must be contained within a finite world. Bruno's final claim is that Aristotle would have been right if the elements were confined, as Aristotle thought, to separate spheres, and therefore fire, in its own sphere, were pure. As we have seen, however, for Bruno there are no elemental spheres, just as there are no planetary spheres, but only an infinite universe filled with a universal ether. In this universe, in all its parts, Bruno claimed that fire is always united in some degree to humidity, creating an atmosphere in which all the celestial bodies, including the so-called "fixed stars", can move and survive[27]. As we shall see later on, Bruno's thermodynamic theory of celestial motion got him into difficulties when he had to consider the movements of moons about cold planets. For the moment, however, it is enough to notice that he is already thinking in terms of a universally valid cause of the movements of stars and planets within heliocentric systems, which can be expressed by a mathematical formulation. Kepler was surely right to note that Bruno's published discussions of

---

[27] An anastatic reprint of the first edition of Bruno's *De immenso* [1591] may be consulted in Giordano Bruno, *Poemi filosofici latini,* ed. Eugenio Canone, Agora, La Spezia 2000, pp. 399–907. For this diagram and its textual explication, see pp. 490–92. There is no English translation of this text, but an Italian translation is in Giordano Bruno, *Opere latine,* translated and edited by Carlo Monti, UTET, Turin 1980. For this diagram and its textual explication, see pp. 493–94.

the heliocentric astronomy constitute a development in the reception of the Copernican revolution which Galileo should not have ignored[28].

Bruno's diagram also shows that the visualisation of the new celestial problems was an important moment of pre-telescopic thought about the new astronomy. Two more of his Copernican diagrams may be mentioned here, although these have already attracted the attention of commentators. Both come from the Copernican discussion in the earlier *Ash Wednesday Supper.* In that work Bruno makes a considerable use of optics to justify the new astronomy. He makes no mention of his sources; but it has been supposed by his commentators that he had been reading the work of Jean Pena. Before arriving in London, Bruno had been living and lecturing in Paris, where Pena's optical writings, which already apply optics to a discussion of the Copernican theory, were well known[29]. Bruno's reasoning in *The Ash Wednesday Supper* may also have been influenced by the *Optics* of Ibn Al-Haytham (Alhazen), an Arabic mathematician and astronomer who originated from Iraq and was active in Cairo in the first half of the eleventh century. A Latin translation of his work, known as the *Perspectiva,* was published in 1572 by Freidrich Risner in Basle, and widely used by the natural philosophers of the period. The Ninth Earl of Northumberland, who owned one of the most important contemporary collections of Bruno's texts, attributed the change of his life from a frivolous courtier to a dedicated natural philosopher to a reading of this work of Alhazen[30]. In bk. III, chap. 7, Alhazen considers "The Ways in which Sight Errs in Inference", and writes that "by looking at a fixed star and a planet at the same time sight will not perceive the difference between their distances, but rather perceive them both in the same plane despite the great difference between their distances". These, and similar optical arguments, were used by Bruno to justify not only the astronomy of heliocentric systems but also his

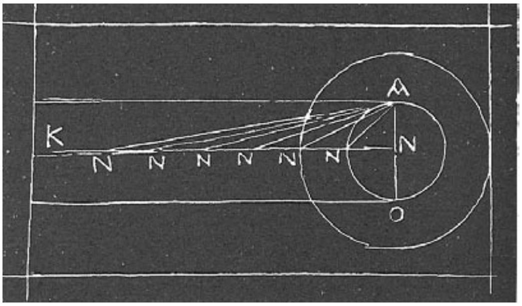
---

[28] For a recent, detailed comparison of Bruno's cosmology with that of Galileo, see Arcangelo Rossi, "Bruno, Copernico e Galilei", in *Physis* (XXXVIII/2001), pp. 283–303.

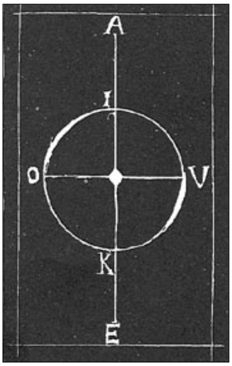
[29] For the importance of Pena's application of optics to the new Copernican astronomy, see W.G.L. Randles, *The Unmaking of the Medieval Christian Cosmos,* Ashgate, Aldershot 1999, chap. 3: "The Challenge of Applied Optics", pp. 58–79. Bruno's possible use of Pena's optical theories has been considered by M. R. Sturlese Pagnoni, "Su Bruno e Tycho Brahe", in *Rinascimento* (25/1994).

[30] For an English translation of this text, see Alhazen [Ibn Al-Haytham], *Optics,* ed. I. Sabra, The Warburg Institute, London 1989. For Northumberland's claim, see his essay on "Love", first published by Frances Yates in *A Study of 'Love's Labour's Lost',* Cambridge University Press, Cambridge 1936, pp. 206–11. On the importance of Alhazen's optics in renaissance thought, see J.V. Field, *The Invention of Infinity,* Blackwell, Oxford 1997. For Northumberland as a reader of Bruno, see Hilary Gatti, "Giordano Bruno: the Texts in the Library of the Ninth Earl of Northumberland", in *The Journal of the Warburg and Courtauld Institutes* (46/1983).

theory of an infinite universe. Two of his best known Copernican diagrams in *The Ash Wednesday Supper* (see figs. 6 and 7) are of some importance in his discussion of his new picture of the universe.



[Fig. 6]



[Fig. 7]

In fig. 6, Bruno is concerned to show that a smaller opaque body placed between the eye and a larger luminous body becomes invisible to the eye at great distances. This simple diagram thus supplies him with a conceptual instrument for challenging the Aristotelian doctrine that the sky contains only those bodies which are visible to the eye. Bruno's frequently expresssed conviction that the sky could and undoubtedly did contain numerous bodies which had so far never been seen was probably what Kepler was thinking about when he told Galileo that Bruno was one of those who had helped to prepare the conceptual grounds for his discovery of the moons of Jupiter[31].

In fig. 7, the last of the diagrams in *The Ash Wednesday Supper,* Bruno attempts to visualise the multiple movements of an earth in motion according to the Copernican hypothesis by using the example of a ball thrown into the air. Bruno thinks of the ball as having four different motions, all of them part of one single complex motion. The first and principal one is along the trajectory A-E, the second around its own axis I-K. The third movement consists of an oscillation in the revolution of the moving ball along parts of the circumference which Bruno visualises in his text by dividing it into eight segments. These segments are not indicated in the diagram; and it is not altogether clear what circumference he is referring to. In a recent edition of this text, it has been assumed to refer to a slipping back of the travelling ball along the circumference of the orbit A-E; which would make it correspond to Copernicus's account of the movement known as the precession of the equinoxes. This, however, presupposed an earth still fixed onto precisely those celestial spheres which Bruno, earlier on in this work, had already denied. Alterna-

---

[31] For Bruno's discussion of this diagram, see *La cena de le ceneri,* op. cit., p. 504.

tively, Bruno's third movement may have corresponded to what was known as axial precession, composed of an oscillation which traced a figure of eight around the two poles of the earth itself. This movement of axial precession, however, could be considered as integrated into Bruno's fourth movement of the ball, visualised as an oblique spin which eventually inverts the positions of O-V. Undoubtedly some obscurity remains in Bruno's account of the third and fourth movements of the ball in the air, largely due to the incomplete nature of his diagram. The important point to be made, however, is that Bruno has understood the principal novelty constituted by the Copernican account of precession of the equinoxes and its accompanying anomalies: that is, that it should be seen as a complex of very slight, long-term variations in the movements of the earth itself, and not of the zodiac or sphere of fixed stars as was the case in the traditional astronomy. Bruno thinks of the four movements of the ball in his figure as roughly corresponding to the Copernican annual movement of the earth around the sun, its daily revolutions around its own axis, added to two of the complex set of long-term anomalies associated in Copernicus's still circular astronomy with the precession of the equinoxes, although Bruno never uses that term. Precession remained extremely complicated in Copernicus's system, as it had been in Ptolemy's, and it was giving rise to heated discussion among more technical experts than Bruno. In any case, Bruno thought that the astronomers were not capable of offering more than mathematical approximations of the movements of the earth and the other planets. His main purpose with the ball image and its accompanying diagram was to catapult his readers into a new adventure in outer space, for ever ousting them from their once comfortably central and immobile earth. In *The Ash Wednesday Supper,* Bruno insists that the multiple motions of the now moving earth are regular and constant, and must be respected as such. If he thought that astronomical calculations were inevitably approximate, that was because of his mistrust of mathematics as the perfect instrument of human prediction, rather than lack of faith in the ordered regularity of the natural world[32].

Work in Progress

Owen Gingerich's *Annotated Census of Copernicus's "De revolutionibus" (Nuremberg, 1543 and Basel, 1566)* contains a description of a copy in the Biblioteca Casanatense in Rome of the 1566 edition with a signature "Brunus

---

[32] For Bruno's discussion of the earth as a moving ball, see *La cena de le ceneri,* op. cit., pp. 566–68.

Fr[ater] D[ominicanus]", but no annotations by Bruno[33]. This is claimed by Gingerich as "the bold Giordano Bruno signature from the fly-leaf", although Bruno scholars tend to be more cautious. There are, however, some interesting points to be made about this volume. Firstly, it is almost impossible either to attribute it to Bruno, or not to do so, on the basis of the hand-writing of what is not strictly speaking a signature but rather a florid and highly stylized design. Secondly, the book reached Rome from Naples, where it was in the original nucleus of the library belonging to the Spaniard Matias de Casanate (c. 1580–1651), father of the Cardinal Casanatense who brought the collection to Rome. Matias was a high-ranking judicial official, and might have obtained it during the agitation caused by Bruno's trial and execution in Rome in 1600, when the official investigations into Bruno's heresies by the Dominican monastery in Naples became a subject of attention by the inquisition. Thirdly, it has been convincingly shown by Miguel Granada that Bruno must have been reading the 1566 edition, which also contained the *Narratio prima* of Rheticus, passages of which Bruno often transcribes[34]. Fourthly, if this really is Bruno's copy of the *De revolutionibus,* which would not be put on the Index of forbidden books until much later, in 1616, then he was presumably reading Copernicus at a considerably earlier age than commentators have usually supposed. Bruno entered the Dominican monastery in Naples in 1565 at the age of seventeen, and fled north in 1576, at the age of twenty-eight.

Gingerich's *Census* also contains a description of Kepler's annotations to his 1543 copy of the *De revolutionibus,* at present held by the Universitätsbibliothek at Leipzig[35]. These clearly show how sixteenth century and early seventeenth century readings of the Copernican astronomy were in the form of "work in progress" rather than constituting a definitely acquired body of new astronomical knowledge. They also emphasize how a major problem in the ongoing understanding of Copernicus's system concerned the question of where to situate the centre of the new universe. This is the problem raised by Bruno in *The Ash Wednesday Supper.* Also in his case it is correct to speak of "work in progress": in fact it is Bruno himself who, in the fourth dialogue of that work, gives his readers an account of his progressive reactions to the Copernican astronomy. Bruno claims that he had passed through the following

---

[33] Owen Gingerich, *An Annotated Census of Copernicus's 'De revolutionibus' (Nuremberg, 1543 and Basel, 1566),* Brill, Leiden 2002, p. 115.

[34] For the history of the Casanatense collection, see Marina Panetta, *La 'Libraria' di Mattia Casanate,* Bulzoni, Rome 1988, where *De revolutionibus* is listed as no. 1263. For Bruno and Rheticus, see Miguel Granada, "L'interpretazione bruniana di Copernico e la *Narratio prima* di Rheticus", in *Rinascimento* (30/1990).

[35] For Kepler's annotations, see Gingerich, *An Annotated Census,* op. cit., pp. 76–80.

stages of growing Copernican conviction: firstly, he considered the new cosmology a mere joke put forward in debate by those who amuse themselves by trying to demonstrate that black is white; secondly, he began wondering why Aristotle had spent so much time in his *De caelo,* bk. II, criticising the heliocentric theory of Pythagoras and his followers; thirdly, in a more mature period of his youth, he began to think of Copernicus's theory as a possibility. Later on (at an unspecified date) came the growing conviction of its certain truth[36].

In a page of bk. III, chap. 5, of his later *De immenso,* Bruno harks back to what seems to be the third stage of this story: that is, his growing conviction of the truth of the new theory (see figs. 8 and 9)[37]. Referring to a time "when he was younger", he describes a picture he had formulated in his mind of the following cosmological hypothesis: the sun together with the fixed stars orbits annually around the earth through AF; the earth revolves around its centre at C along the axis HI in its diurnal rotation; the earth does, however, move from the geometrical centre, travelling annually away from the equator of the universe, at times towards the tropical pole E, at times towards the antarctic pole G. The traditional long-term movements of trepidation and oscillation are assured by additional spiralling movements of the earth which expose its surface to the heat or the cold of the poles according to the long-term necessities of its evolution. Bruno illustrates this very schematic cosmological picture with a diagram which he insists represents "the philosophy of the masses", and not his own mature convictions. The question it poses is whether it was possible to maintain a central earth within a compromise solution which took at least some minimal account of the Copernican theory. By 1591, when the *De immenso* was published, such a system had been worked out in much finer technical detail by Tycho Brahe, who had published an account of his own partly-Copernican cosmology in 1588[38]. Brahe, although not explicitly mentioned, is probably being criticised here as over-prudent and "immature" in so far as he failed to step into a fully heliocentric world. Interestingly William Gilbert was aware of this cosmological model of Bruno's "when he was younger" (*cum esset junior).* He commented on it in his posthumously published *De mundo,* adding a diagram of his own. Gilbert criticises the hypothesis for making the earth move in a straight line, "which is not normally attributed to celestial bodies"; although it is probable that Bruno's diagram was not intended to indicate movement in a straight line but rather a small orbit of the

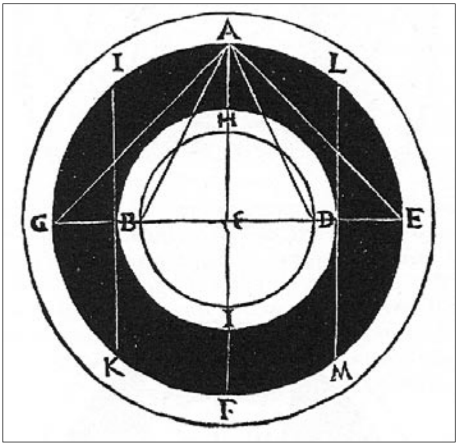
---

[36] See *La cena de le ceneri,* op. cit., pp. 535–36.

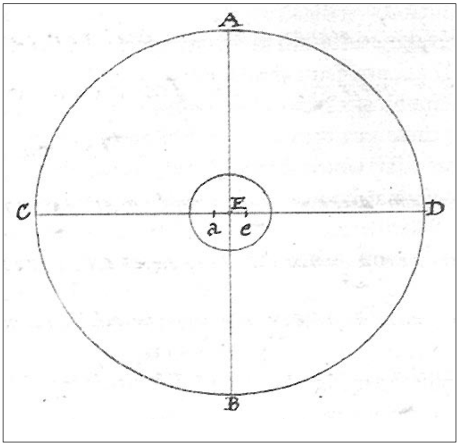
[37] See, *De immenso,* in *Poemi filosofici latini,* op. cit., p. 559. The diagram is at p. 553.

[38] For the importance of 1588 in the development of the new cosmology, see Miguel Granada, *El debate cosmológico en 1588: Bruno, Brahe, Rothmann, Ursus, Röslin,* Bibliopolis, Naples 1996.

earth around the geometrical centre, through BD in Bruno's diagram and ae in Gilbert's [39]. It is not clear whether Gilbert was aware of the ironic stance assumed by Bruno in these pages. Although Gilbert himself was sympathetic to Bruno's cosmological theses, his circle of magnetic philosophers either remained stubbornly Aristotelian in their cosmology, or referred to Tycho Brahe's compromise solution which Bruno could not accept.[40]



[Fig. 8]



[Fig. 9]

Gilbert's interest in Bruno's cosmological theories did not stop with this diagram. On the very next page, he presents another (by now more fully Copernican) way of visualising the cosmos in terms of Bruno's ideas (*Alius modus iuxta Nol.,* see fig.10)[41]. Gilbert found this new theory in the *De immenso,* bk. III, chap. X[42]. In the pages which interested Gilbert, Bruno appears to be referring to *De revolutionibus,* III, 25, where Copernicus supposes an anomolous heliocentric model in which "the center of the annual revolution be fixed, as though it were the centre of the world, but the sun be moveable by two motions similer and equal to those which we have demonstrated for the center of the eccentric, everything will appear just as before... For then the motion of the centre of the earth would be a perfect and simple motion about the centre of the world, since the two other motions have been granted to the sun". Bruno begins by criticising Copernicus because he does not normally

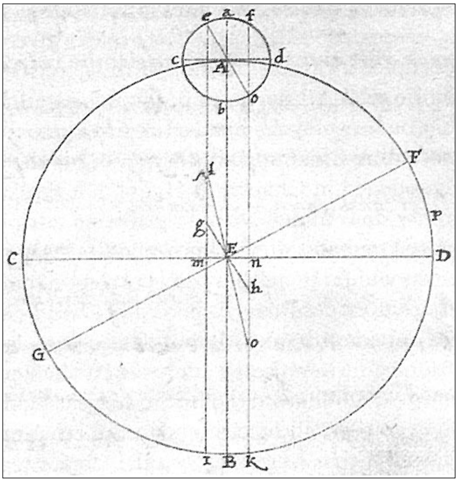
---

[39] William Gilbert, *De mundo nostro sublunari philosophia nova,* Ludovicum Elzevirium, Amsterdam 1651, p. 199–200.

[40] See my chapter on "Bruno and the Gilbert Circle", in *Giordano Bruno and Renaissance Science,* op. cit., pp. 86–98.

[41] See Gilbert, *De mundo,* op. cit., pp. 200–01.

[42] See Bruno, *De immenso,* op. cit., pp. 592–93.



[Fig. 10]

make the sun orbit at the centre of the solar system. Further criticism addresses Copernicus's account of precession of the equinoxes, which posited a third movement of the earth as if it was carried around on its planetary sphere and therefore had to slip back gradually on its orbit in order to remain constant[43]. Bruno himself had long maintained that there are no planetary spheres, and that the earth and other planets hang freely in the universal ether. He now sees it as a principle of rotatory planetary motion that the axis remains parallel to itself and in equilibrium, thus rendering superfluous Copernicus's third motion of the earth: a principle which will later on be confirmed both by Gilbert himself and by Galileo. As for the sun, Bruno in these pages, like Copernicus in the passage above, visualises it as moving in an oblique orbit with respect to an earth which travels around the centre of the system on an axis parallel to the equator of the world. The sun must also rotate around itself with a spiralling motion, according to Bruno, as otherwise it would always seem to rise in the same place. Further oscillations of the earth's poles with respect to the zodiac, Bruno notes with admiration, had been introduced by Copernicus to compensate for the traditional slipping back of the zodiac itself which explained, in the Ptolemaic system, the precession of the equinoxes. The lack of any diagram in these pages of the *De immenso* makes Bruno's text arduous reading. Such must have been the impression of Gilbert, whose second Bruno diagram in his *De mundo* illustrates this anomolous heliocentric system described in words by Bruno himself.

In Gilbert's diagram, which correctly illustrates this page of Bruno's, DFCG represents the colure of the solstitial points, and C and D the poles of the universe. AB is the equator of the universe around which the earth moves annually from west to east. The earth's equator, ab, moves daily around its own axis, also from west to east. The sun describes a small circle limited by the

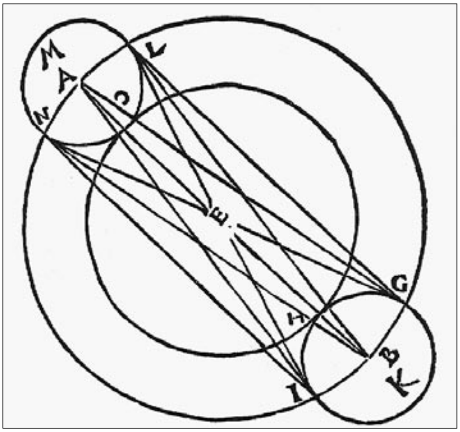
---

[43] For what they consider Copernicus's "interesting" alternative model to his usual solar theory, see N.M. Swerdlow and O. Neugebauer, *Mathematical Astronomy in Copernicus's 'De revolutionibus'*, 2 vols., Springer-Verlag, New York-Berlin 1984, p. 159. For Copernicus's account of precession, see N.M. Swerdlow, "On Copernicus' Theory of Precession", in *The Copernican Achievement,* ed. Robert Westman, California University Press, Los Angeles 1975.

equinoctial parallels egi and fhk. If its poles are G and F, the orbit of the sun will pass through g and h, or its two tropical limiting points, although other angulations of the orbit of what seems also here to be a spiralling sun are posited by Gilbert as possible. Bruno himself had further justified this principle as necessary to guarantee the evolution of the planets by supplying them with ever varying quantities of heat and cold. Later on, in Galileo, the idea of a sun which revolves around its own axis would become important to explain the sighting of sun-spots. Surely Bruno was right to consider early Copernicanism as a slow acquisition of new astronomical concepts according to various approaches and reached by travelling along many different paths of thought.

What is right and what is wrong?

Let us now come back to Kepler's mistaken distrust of Bruno's "innumerabilities", expressed to Galileo in his replies to the *Sidereus nuncius*. Kepler points out that Galileo's discovery does not support it because Bruno thought of earths as circling around suns, while Jupiter is a planet, and yet the new moons circle around it[44]. For Kepler this suggested that our own solar system constitutes a unique universe: thus saving him from Bruno's "horrible" idea of a plurality of suns. Kepler's observation, however, carries other implications. It highlights the terms of Bruno's "lunar" mistake in *The Ash Wednesday Supper* (see fig. 3), although Kepler does not mention this specifically. Yet Bruno himself had already realised that his thermodynamic theory of planetary motion did not permit him to put the moon on a further epicycle centred on earth (or an epicycle), as Copernicus had done to save the phenomena; because this would have meant visualising a cold moon as circling around the centre of a cold earth. Why should it do that? For Bruno the moon too must circle around the sun as its centre: the sun becoming thus the fountain of heat and light for the moon in the same degree as for the earth. This precedent in the *Ash Wednesday Supper* should be remembered when considering Bruno's final cosmological diagram in the *De immenso,* bk. 3, chap. X (see fig. 11).



[Fig. 11]

---

[44] Kepler, *Conversation with the Sidereal Messenger,* op. cit., pp. 11 and 34.

Bruno says of this diagram that it derives from his conviction that the orbits of Mercury and Venus around the sun cannot really be smaller than those of the earth and the moon, as the astronomers claim[45]. He proposes a system in which the earth A, with the moon now on its epicycle NMLO, revolves around the sun E in direct opposition to Mercury B, which carries Venus on its epicycle IHGK. Although in flagrant disregard of astronomical observation as well as of Copernicus's mathematics, this diagram occurs in a part of Bruno's text devoted to praise of Copernicus as the true hero of the modern world. It reflects Copernicus's conviction, eloquently expressed in his own dedicatory letter of the *De revolutionibus* to Pope Paul III, that a well ordered universe implies uniformity and harmony of the spheres. Undoubtedly the Pythagorean bases of both Copernicus's and Bruno's cosmologies need to be underlined here, as much recent commentary has been doing[46]. Bruno himself refers to both Pythagoras and Plato just before describing this diagram in his text. Nevertheless it was Kepler who understood most clearly the specific technical difficulty which Bruno's thermodynamic theory of planetary movement had led to: if cold planets like the earth fulfill their purpose in the universe by varying on their surface the intensity of heat and light, cold and shadow, through which life evolves on their surface, why should cold moons circle around them at all? Bruno recalls his thermodynamic theory of planetary motion in the opening pages of *De immenso,* bk. 3, chap. X. His attempt to visualise a rudimentary planetary system in this diagram tries to solve the problem which would later be raised by Kepler. It shows how cold planets and the cold moons which revolve around them, by clinging together in epicycles all orbit at harmonious distances around the sun, from which their life-giving energies arise.

Two considerations are in order here. Firstly, Bruno is not addressing in these pages the Hermetic magicians or the neo-Platonic magi (although

---

[45] Bruno, *De immenso,* op. cit., pp. 596–98.

[46] For an extended comment on Copernicus's own dedicatory letter, see Robert Westman, "Proof, Poetics and Patronage: Copernicus's Preface to *De revolutionibus*", in *Reappraisals of the Scientific Revolution,* D.C. Lindberg and R.S. Westman (Eds.), Cambridge University Press, Cambridge 1990. See also P.L. Rose, "Universal Harmony in Regiomontanus and Copernicus", in *Avant, avec, après Copernic,* Centre national de la recherche scientifique (Ed.), Blanchard, Paris 1975, pp. 153–163. The Pythagorean and neo-Platonic sources of the new sun-centred cosmology have been discussed by Eugenio Garin, "La rivoluzione copernicana e il mito solare" in *Rinascite e rivoluzioni: movimenti culturali dal XIV al XVIII secolo",* Laterza, Bari 1975, pp. 257–295, and Paolo Casini, "Il mito pitagorico e la rivoluzione astronomica", in *Rivista di filosofia* (85,1/1994). On Bruno's Pythagoreanism, see Dario Tessicini, "'Pianeti consorti': la Terra e la Luna nel diagramma eliocentrico di Giordano Bruno", in *Cosmología, teologia y religión en la obra y en el proceso di Giordano Bruno,* Miguel Granada (Ed.), Universitat de Barcelona, Barcellona 2001, pp. 159–188.

he does do that in other parts of his work). Here, he is explicitly addressing the astronomers. Translated into modern vocabulary, with respect to this rudimentary planetary diagram, Bruno himself admits defeat. He is quite aware that his picture fails to save the phenomena, and therefore that some kind of extension is required to his thermodynamic theory of planetary motion. He tries to turn this into a qualified defeat by pointing out that he at least has a physical theory of planetary motion which postulates a universally valid cause. The empirical problem of saving the phenomena is something which Bruno thinks cannot be solved by simply calculating quantities from the basic observables of time and position. It must be solved within a theoretically acceptable physical framework: a necessity which, in his opinion, Copernicus himself and most of the early post-Copernicans continued to ignore. His own comment on his planetary diagram ends with an appeal to the astronomers to integrate their mathematical skills into a theoretical physics: that, he claims, is all he asks of them in order to be satisfied. Secondly, the frequent use of this diagram by those commentators who are concerned to enclose Bruno's thought entirely within a magical and Hermetic tradition which has nothing to do with a scientific logic is questionable, particularly if it implies (as it frequently does) that serious mistakes in reading Copernicus oust the culprit from any valid tradition of properly scientific thought. Such a premise would clearly present problems with Kepler, given his mistaken attempt to construct a new heliocentric cosmology on the basis of the five Platonic solids, with Galileo who thought he had "proved" the Copernican hypothesis with a mistaken theory of the movements of the tides, as well as with Tycho Brahe who constructed a short-lived compromise cosmology whose conceptual basis was clearly religious and not scientific at all. Furthermore, it is worth reflecting on the fact that one of the earliest formulations of an entirely negative judgement on Bruno's Copernicanism derives from the nineteenth century astronomer Giovanni Virginio Schiaparelli. Appealed to by Felice Tocco, a prestigious nineteenth-century Italian philosopher who was presenting a positive reading of Bruno's Copernicanism as a prelude to Galileo's in a volume which remains essential reading to-day, Tocco found himself in difficulty when the internationally renowned Schiaparelli replied that Bruno's cosmological arguments were obscure, puerile and of no validity at all. Tocco found a clever solution to his problem by continuing to develop in his text a fundamentally positive appreciation of Bruno's cosmological speculation, while relegating to a series of much discussed notes the impatient criticisms of Schiaparelli[47].

---

[47] See Felice Tocco, *Le opere latine di Giordano Bruno esposte e confrontate con le italiane,* Le Monnier, Florence 1889. For the letter from Schiaparelli, see the notes at pp. 313–17.

Those commentators who are still to-day using Schiaparelli to eliminate Bruno from the scientific scene may, however, wish to reflect on the fact that Schiaparelli himself perpertrated one of the most colossal and colourful of scientific "mistakes" when he claimed that his telescopic sightings had revealed a regular network of canals on the surface of Mars, which it was "not impossible" to conceive of as constructed by intelligent beings. Schiaparelli's sightings gave rise to more than half a century of fervid Martian speculation. This included the life-long work of Percival Lowell, who built an observatory in California and dedicated his life to what became ultimately a desperate attempt to prove Schiaparelli right. Of course, he may have been; but the Martian probes at present are not pointing in Schiaparelli's direction[48]. Ironically, Schiaparelli may have been thinking about life on Mars because he had been reading the work of the "confused and imprecise" Bruno, whose concept of an infinite universe was based on the postulate that it was a "living" universe in all its parts. It is, in any case, unfortunate that the most recent enthusiast of Schiaparelli's criticisms of Bruno's cosmological speculation is the editor of the important volume recently dedicated to a comment on all Bruno's illustrations and diagrams. Following in Schiaparelli's footsteps has led their editor to take into little or no serious consideration the many diagrams which Bruno uses to illustrate both his atomism and his Copernicanism: two of the most advanced scientific speculations of his day[49].

What is "right" and what is "wrong" is surely not the point which needs to be laboured in studying the early readings of the Copernican astronomy. The historian's task is to address those original minds which responded positively to the overwhelmingly unfamiliar implications of a new theory destined to become the foundation stone of modern cosmological thought. Bruno was among the first to understand that this would be the case: that the centuries-old Aristotelian-Ptolemaic cosmos had suddenly become a thing of the past, and that a new world picture had to be formulated of a radically different kind. His limited grasp of the mathematics of Copernicus's *De revolutionibus* is more than compensated for by his remarkably subtle and daring speculation into its physical and philosophical implications. His extension of the much-enlarged but still finite Copernican universe to infinite dimensions, conceived of as a new infinitistic physics and not only (or even primarily) as

---

For a discussion of Bruno's Copernicanism based on a critique of Schiaparelli's remarks, see Alfonso Ingegno, "Bruno, Copernico e i moti della terra" in *Cosmologia e filosofia nel pensiero di Giordano Bruno,* Nuova Italia, Florence 1978, pp. 63–70.

[48] This story is told by F.I. Ordway, "The Legacy of Schiaparelli and Lowell", in *Journal of the British Interplanetary Society* (39/1986), pp. 19–27.

[49] See Giordano Bruno, *Corpus iconographicum,* Mino Gabriele (Ed.), Adelphi, Milan 2001.

a religious intuition, added, less than half a century after the publication of the *De revolutionibus,* another stone to the foundation of the modern world. Furthermore, Bruno's infinite universe incorporated a Copernican heliocentric principle in a "realist" sense: he thought of his infinite number of finite astronomical systems as all centred on suns, seen as the source both of their revolutions and of their life. Bruno knew that his philosophical achievement in his cosmological works depended on the original "revolution" proposed by Copernicus himself. More than once he attributed generous public recognition to Copernicus as the genius whose "light" had ushered in a new era:

> For he had a profound, subtle, keen and mature mind. He was a man not inferior to any of the astronomers who preceded him, unless they are considered in their own time and place. His natural judgement was far superior to that of Ptolemy, Hipparchus, Eudoxus, and all the others who followed them; and this allowed him to free himself from many false axioms of the common philosophy, which – although I hesitate to say so – had made us blind.[50]

---

[50] See Dialogue 1 of *La cena de le ceneri,* op. cit., pp. 448–49.

Filozofski vestnik Volume/Letnik XXV • Number/Številka 2 • 2004 • 51–67

“CERTE RATIONEM ORDINIS NON ESSE”[1]?: ZUR KONSTITUIERBARKEIT EINER VERNÜNFTIGEN ORDNUNG DER NATUR BEI COPERNICUS, BRUNO UND SCHELLING

Myriam Gerhard

I. Copernicus

Die augenscheinlichen Ungleichmäßigkeiten der Planetenbewegungen auf eine rationale Grundlage, ein mathematisch beschreibbares Bewegungsmuster zurückzuführen, gehört seit jeher zu den von der Astronomie zu lösenden Problemen. Der durchgängig systematischen Einheit der Astronomie schien über Jahrhunderte hinweg die Existenz der sogenannten irrenden Sterne zu widersprechen. Die wechselnden Abstände der Planeten von der Erde, sowie ihre retrograde Bewegung einer einheitlichen mathematischen Berechnung zugänglich zu machen, war die von Copernicus zu lösende Aufgabe. Für Osiander gab es keinen Zweifel daran, daß es der Astronomie allein um die mathematische Berechenbarkeit der Sternenörter ginge und nicht um eine physikalische oder naturphilosophische Erklärung der Bewegungserscheinungen. In seinem Vorwort zu Copernicus’ *De revolutionibus orbium coelestium* betont Osiander, daß die Astronomie “die Ursachen der erscheinenden ungleichmäßigen Bewegungen schlicht überhaupt nicht kennt.”[2] Mit dieser Aussage steht Osiander in einer langen Tradition. So schreibt auch schon Simplikios, daß es nicht die Aufgabe des Astronomen sei, “zu erkennen, warum etwas von Natur ruht und welcher Art das Bewegliche ist, sondern er untersucht nur, indem er als Hypothesen einführt, daß das eine ruht und

---

[1] N. Copernicus, *De revolutionibus orbium coelestium*, in: ders., *Das neue Weltbild* hrsg. u. übers. v. H. G. Zekl, Hamburg 1990, Liber *I/10*, p. 130

[2] Osiander, »An den Leser«, in: op. cit., p. 63.

das andere sich bewegt, welchen Hypothesen die Himmelserscheinungen folgen werden."[3] Copernicus sieht sich dieser traditionsreichen Aufgabe der Astronomie, der Berechnung der Himmelsbewegungen, verpflichtet, geht aber über den ausschließlichen Zweck der bloßen Berechenbarkeit hinaus. Um die augenscheinlich ungleichmäßigen Planetenbewegungen einer mathematischen Berechnung zugänglich zu machen, stellt Copernicus die von den Mathematikern postulierten Voraussetzungen in Frage. Copernicus fragt sich, "ob nicht einmal einer vermutet hätte, die Bewegungen der Weltkugeln seien anders, als die Leute sie ansetzten, die an den Schulen Mathematik lehren."[4] Den mathematischen Modellen zur Berechnung der Planetenbewegungen wurde seinerzeit die geozentrische Vorstellung kreisförmiger Bewegungen um die Erde zugrundegelegt. Die Astronomen beanspruchten auf der Grundlage des geozentrischen Modells jede einzelne Himmelsbewegung auf zusammengesetzte oder sich überlagernde Kreisbewegungen zurückführen zu können. Für Copernicus beruht die Möglichkeit einer einheitlichen Berechnung aller Planetenbewegungen weder allein auf mathematische Hypothesen noch hält er die überlieferte Anordnung von Kreisen für unumstößlich. Vielmehr kommt Copernicus zu dem Schluß, ob nicht eine andere, eine "vernünftigere Anordnung von Kreisen"[5] die augenscheinlich ungleichmäßigen Planetenbewegungen überhaupt erst einer einheitlichen mathematischen Berechnung zugänglich machen würde. Die Frage, "ob nicht etwa eine vernünftigere Anordnung von Kreisen zu finden sei, von welchen alle erscheinende Ungleichmäßigkeit abhinge"[6], ist das leitende Motiv der Untersuchung Copernicus'. Die Anordnung von Kreisen gemäß der geozentrischen Vorstellung entspricht dieser Forderung nicht, denn weder hängt die erscheinende Ungleichmäßigkeit von der geozentrischen Anordnung ab, noch läßt sich die erscheinende Ungleichmäßigkeit durch sie erklären und hinreichend mathematisch beschreiben. Gegen das geozentrische Modell konzentrischer Kreise, das die Erde als Mittelpunkt aller Himmelsbewegungen behauptet, spricht "die erscheinende ungleichförmige Bewegung der Wandersterne und ihre wechselnden Abstände von der Erde, was mithilfe eines Kreises um die Erde mit einem und demselben Mittelpunkt nicht ver-

---

[3] Simplikios, zit. n.: F. Krafft, *Physikalische Realität oder mathematische Hypothese? Andreas Osiander und die physikalische Erneuerung der antiken Astronomie durch Nicolaus Copernicus*, Philosophia Naturalis 14, 1973, p. 255 [243–275].

[4] N. Copernius, *op. cit.*, p. 73.

[5] N. Copernicus, *De Hypothesibus motuum coelestium a se constitis Commentariolos*, in: ders., *Das neue Weltbild*, Hamburg 1990, p. 5.

[6] Ibid: »(...) si forte rationabilior modus circulorum inveniri possit, e quibus omnis apparens diversitas dependeret (...).«

standen werden kann."[7] Mit anderen Worten ist es die Erscheinung ungleichförmiger Bewegungen, die dazu nötigt, vom geozentrischen Modell Abstand zu nehmen. Wie seine Vorgänger, so zweifelt auch Copernicus nicht an der "Tatsache" der ungleichmäßig erscheinenden Planetenbewegungen. Im Anliegen, die augenscheinlichen Ungleichmäßigkeiten auf eine Gesetzmäßigkeit zurückzuführen, sind Ptolemaeus und Copernicus sich einig. Ptolemaeus sieht sich vor die Aufgabe gestellt, "für die fünf Wandelsterne, wie für die Sonne und für den Mond, den Nachweis zu führen, daß ihre scheinbaren Anomalien alle vermöge gleichförmiger Bewegungen auf Kreisen zum Ausdruck gelangen, weil nur diese Bewegungen der Natur der göttlichen Wesen entsprechen, während Regellosigkeit und Ungleichförmigkeit ihnen fremd sind."[8] Einen weiterführenden Erklärungsgrund für diese Ungleichmäßigkeit sucht Ptolemaeus jedoch nicht. Daß die Gründe für diese Ungleichmäßigkeit nicht nur einer Untersuchung wert wären, sondern ihre Erkenntnis gar zur Aufklärung der scheinbaren Ungleichmäßigkeiten führen könnte, wird erst Copernicus deutlich. Um zu dieser Einsicht zu gelangen, muß jedoch die Annahme, daß die Erde der Weltmittelpunkt sei, als irreführende Hypothese aufgegeben werden.[9]

> Wenn man nämlich bestritte, daß die Erde die Weltmitte, ihren Mittelpunkt, einnehme und dabei andrerseits nicht einräumte, daß die Entfernung so groß wäre, daß sie im Verhältnis zur Kugel der feststehenden Sterne meßbar würde, dagegen sehr wohl augenfällig und sichtbar im Vergleich zum Sonnen- und anderen Gestirnskreisen, und wenn man weiter annähme, daß aus dem Grund deren Bewegung als ungleichmäßig erscheint, als ob sie auf einen anderen Mittelpunkt hingeordnet wären, als der der Erde ist: der wird vielleicht keine törichte Begründung für die erscheinende ungleichmäßige Bewegung beibringen können.[10]

Copernicus hebt die Bedeutung des Bezugssystems für die Erklärung der ungleichmäßigen Bewegungserscheinungen hervor. Entscheidend sei, ob die Bewegungen der Wandersterne auf die Erde als ruhenden Weltmittelpunkt oder auf eine Kreisbewegung der Erde bezogen werden. "Wenn man die Bewegungen der übrigen Wandersterne auf eine Kreisbewegung der Erde bezieht und entsprechend dem Umlauf jedes Sterns die Rechnung

---

[7] N. Copernicus, *De revolutionibus I/9*, p. 123.

[8] C. Ptolemaeus, *Handbuch der Astronomie I–II (Almagest)*, übers. v. K. Manitius, Leipzig 1963, IX.2, Bd. II, p. 94.

[9] Cf. H. Blumenberg, *Die kopernikanische Wende,* Frankfurt/M. 1965, p. 15.

[10] N. Copernicus, *De revolutionibus I/5*, p. 101.

macht, so folgen daraus nicht nur deren Erscheinungsbilder, sondern auch bei allen Sternen und Kreisläufen sind Anordnung und Größe, und überhaupt das ganze Himmelsgeschehen selbst, so verknüpft, daß in keinem Teil von ihm etwas umgestellt werden kann, ohne bei den übrigen Teilen und überhaupt im ganzen All Verwirrung (anzurichten)."[11] Die Beziehung der Planetenbewegungen auf die Kreisbewegung der Erde hätte demnach nicht nur eine Aufklärung der augenscheinlichen Ungleichmäßigkeiten der Bewegungen zur Folge, sondern würde zudem eine einheitliche, systematische Erklärung aller Himmelsbewegungen erlauben. Die einheitliche Bestimmung der Weltgestalt und des festen Ebenmaßes ihrer Teile zählt Copernicus zu den Hauptaufgaben der Astromomen. Mit der überlieferten Theorie sei diese Aufgabe nicht zu erfüllen; aus ihren Voraussetzungen ließe sich weder die Weltgestalt noch das feste Ebenmaß ihrer Teile erschließen. Den von Copernicus kritisierten Astronomen ginge es so, "wie wenn einer von verschiedenen Stellen aus Hände, Füße, Haupt und andere Glieder, zwar in schönster Ausführung, aber nicht nach dem Vergleichsmaßstab *eines* Körpers gemalt, hernähme, die wechselseitig überhaupt nicht sich entsprächen, sodaß ein Ungeheuer eher als ein Mensch sich daraus zusammensetzte."[12] Die Erkenntnis der einheitlichen Weltgestalt und des festen Ebenmaßes ihrer Teile hat die Annahme eines die systematische Einheit konstituierenden Prinzips zur Voraussetzung. Eine naturphilosophische oder gar eine metaphysische Bestimmung dieses Prinzips liegt Copernicus jedoch fern. Bestenfalls erkenntnistheoretische Überlegungen zur Bestimmung des Prinzips lassen sich bei Copernicus finden. In seinem *Brief gegen Werner* hebt Copernicus hervor, "daß die Wissenschaft von den Sternen zu denen gehört, die von uns genau umgekehrt, bezogen auf die natürlichen Verhältnisse, erkannt werden."[13] Das der Sache nach Frühere, die Ursache oder das Prinzip, erscheint im Erkenntnisprozeß als das Spätere, als das Erschlossene. In der Astronomie wird demgemäß von der Erscheinung auf die Ursache dieser Erscheinung geschlossen. So nennt Copernicus als ein Beispiel den Schluß von der ungleichmäßigen Erscheinung der Planetenbewegung auf die Erklärung dieser Bewegungserscheinungen durch die Annahme von Deferenten und Epizykel. Das Problem dieses Schlusses von der Erscheinung auf die mögliche Ursache ist seine Mehrdeutigkeit. Der Schluß von der Erscheinung auf die Ursache ist nicht eineindeutig, sondern ergibt mehrere mögliche Ursachen und damit mehrere, gleichwertige Erklärungsmodelle für die Planetenbewe-

---

[11] N. Copernicus, *De revolutionibus I/Praefatio*, p. 75.

[12] N. Copernicus, *De revolutionibus I/Praefatio*, p. 72f.

[13] N. Copernicus, *Brief gegen Werner*, in: op. cit., p. 45.

gungen. Diese Gleichgültigkeit von Erklärungsmodellen läßt sich auch auf das Verhältnis von Geozentrismus und Heliozentrismus übertragen. Solange es nur um eine rein phoronomische Beschreibung der Himmelsbewegungen geht, ist weder das geozentrische noch das heliozentrische Weltbild ausgezeichnet; beide sind für eine phoronomische Bewegungsbeschreibung gleichwertig. Das heliozentrische Modell hat lediglich den Vorteil, in seinen Berechnungen weniger kompliziert zu sein als das geozentrische. Eine solche Gleichgültigkeit des geozentrischen und heliozentrischen Erklärungsmodells liegt Copernicus jedoch in jeder Hinsicht fern. Den Schluß von den Bewegungserscheinungen der Planeten auf den die Einheit der Bewegungen stiftenden Grund hält Copernicus, allen Schwierigkeiten zum trotz, für notwendig; vorausgesetzt jedoch, daß sich aus dem Erschlossenen die systematische Einheit aller Bewegungen darlegen läßt. Für uns sind zunächst die ungleichmäßig erscheinenden Sternenbewegungen. Erst später kann ein möglicher Erklärungsgrund, wie z.B. die Bewegung der Sterne auf Epizykeln und Deferenten, erschlossen werden.

> Und ich möchte das so ausgesprochen wissen: Daß Notwendigkeit bestand, daß jene alten Wissenschaftler erst die Sternörter mithilfe kunstvoller Instrumente festhielten in Verbindung mit den Zeitabständen und daß sie, durch diese “Handführung” gewissermaßen geleitet, damit die Frage nach der Himmelsbewegung nicht völlig begriffslos bleibe, nach irgendeiner sicheren Berechnung davon getastet haben, und die scheinen sie zu dem Zeitpunkt gefunden zu haben, als nach gründlicher Beobachtung aller Sternörter eine gewisse Übereinstimmung bei ihnen allen eintrat.[14]

Die genaue Beschreibung der erscheinenden Sternenbewegung ist somit eine Bedingung für den Schluß auf die Ursache der Bewegungserscheinungen. Damit die Frage nach der Himmelsbewegung aber nicht *begriffslos* bleibe, müsse *ein* vernünftiger Grund für die Erklärung aller Bewegungserscheinungen angeben werden. Die Erdbewegung hat für Copernicus die Funktion einer vorauszusetzenden Annahme, mit Hilfe derer die Bewegungserscheinungen, die einheitliche Weltgestalt und das feste Ebenmaß ihrer Teile dargestellt werden können.[15] Die Erdbewegung setzt Copernicus ein “wie einen Anfangssatz und eine Grundannahme (…) beim Aufzeigen der übrigen Erscheinungen.”[16] Die Erdbewegung bestimmt Copernicus hier als

---

[14] Ibid.

[15] Cf. N. Copernicus, *De revolutionibus I/11,* p. 139.

Prinzip und Hypothese. Eine Hypothese ist die Annahme der Erdbewegung, sofern es auch Copernicus darum geht, zu erkennen, "welchen Hypothesen die Himmelserscheinungen folgen werden."[17] Die Annahme der Erdbewegung ist für Copernicus aber nicht bloß eine mathematische Hypothese, sofern durch sie die Erklärung des Kosmos aus einem Prinzip möglich wird. Die Annahme, daß die Erde nicht der ruhende Mittelpunkt aller Planetenbewegungen ist, ist, wie Copernicus betont, die notwendige Bedingung einer systematischen und vernünftigen Erklärung der Himmelserscheinungen. Oder, anders formuliert: entweder die Erde ruht oder die Himmelsbewegungen sind einer rationalen Erklärung zugänglich.

> Notwendig wird also die Annahme sein, entweder daß die Erde der Mittelpunkt nicht ist, auf welchem die Reihe der Sterne und Kreise bezogen würde, oder daß es eine vernünftige Begründung ihrer Anordnung so sicher nicht gibt und daß sich kein Grund zeigt, warum eher dem Saturn als dem Jupiter oder einem anderen beliebigen Stern ein oberer Platz gebührte.[18]

II. Bruno

Der Einfluß der Kopernikanischen Theorie auf Brunos Philosophie wird vor allem in den drei italienischen Dialogen *La cena de le ceneri*, *De causa, principio et uno* und *De l'infinito, universo et mundi* (1584/85) deutlich. Die Begründung der Anordnung der Planeten ist für Bruno kein ausschließlich mathematisches, sondern ein naturphilosophisches Problem. In diesem Sinne weist er auch Osianders Interpretation der Kopernikanischen Lehre zurück. Wider Osiander und die Unterstellung, daß die Annahme astronomischer Hypothesen nur Kalkulationszwecken dienen könne, betont Bruno, daß Copernicus "sich nicht damit begnügt, als bloßer Mathematiker zu supponieren, sondern auch als Physiker die Bewegung der Erde nachweist."[19] Die Annahme der Erdbewegung versteht Bruno nicht bloß als eine mathe-

---

[16] N. Copernicus, *De revolutionibus I/11*, p. 149. »(…) quo tamquam principio et hypothesi vtemur in demonstrationibus aliorum.« Ibid, p. 148.

[17] Simplikios, zit. n. F. Krafft, *Physikalische Realität oder mathematische Hypothese? Andreas Osiander und die physikalische Erneuerung der antiken Astronomie durch Nicolaus Copernicus*, Philosophia Naturalis 14, 1973, S. 255 [243–275].

[18] »Oportebit igitur vel terram non esse centrum, ad quod ordo syderum orbiumque referatur, aut *certe rationem ordinis non esse* (Hervorhebung M.G.), nec apparere, cur magis Saturno quam Ioui seu alij cuiuis superior debeatur locus.« N. Copernicus, *De revolutionibus I/10*, p. 130/131.

[19] G. Bruno, *Das Aschermittwochsmahl*, in: Giordano Bruno Gesammelte Werke, Bd. 1, hrsg. u. übers. v. L. Kuhlenbeck, Leipzig 1904, p. 89.

matische Hypothese, sondern als ein Prinzip der Naturerklärung. Bruno wendet sich aber nicht generell gegen den Anspruch der mathematischen Beschreibung und der Berechenbarkeit der Planetenbewegungen auf der Grundlage mathematischer Hypothesen. Seine Kritik richtet sich eher gegen die Beschränktheit der mathematischen Herangehensweise, die die wahre Natur der Bewegungsursache nicht erfasse.[20] So sind zwar "(…) die Voraussetzungen (…) das Prinzip der Beweisführung, aber nicht ihre Ursache (…)."[21] Die Annahme von Deferenten und Epizykeln sei zwar als ein Prinzip der mathematischen Beschreibung der Planetenbewegungen zweckmäßig, ermögliche aber keinen Einblick in die Natur und die Ursache der Bewegungserscheinungen. Bruno läßt keinen Zweifel daran, "daß die allgemeine Bewegung, die der sogenannten Exzenter und was immer sich an Bewegungen auf das sogenannte Firmament beziehen mag, daß diese alle Ausgeburten der Phantasie sind und in Wirklichkeit von der Bewegung abhängen, welche die Erde mit ihrem Mittelpunkt durch die Ekliptik vollführt (…)."[22] Die Vorstellung, daß die Erde der ruhende Mittelpunkt aller Planetenbewegungen sei, sei die Ursache für "jenes Phantasieren von Sternträgern und Flammenträgern, von Achsen und Deferenten, vom Hilfsdienst der Epizykeln und von einer großen Menge anderer Chimären (…)."[23] Mit der Einsicht in die wahre Ursache der erscheinenden Ungleichmäßigkeit der Planetenbewegungen würde dieses Phantasieren überflüssig werden. Es sei das Verdienst Copernicus' über den Tellerrand des rein mathematisch vorgehenden Astronomen hinausgewiesen zu haben. Copernicus habe sich von einigen falschen Voraussetzungen befreit, doch sei er zu sehr Mathematiker gewesen, als daß er die naturphilosophischen Konsequenzen hätte umsetzen können.[24] Als eine wichtige Konsequenz der kopernikanischen Theorie hebt Bruno die Unendlichkeit des Weltalls hervor. Mit der Aufgabe der Vorstellung einer im Zentrum des Universums ruhenden Erde fiele die Notwendigkeit weg, die Entfernung der sogenannten Fixsterne als durchgängig einheitlich aufzufassen. Mit dem Geozentrismus fällt für Bruno auch die Zentralsymmetrie des Universums.[25]

---

[20] Cf. ibid, p. 117.

[21] G. Bruno, *Über die Ursache, das Prinzip und das Eine*, übers. u. hrsg. v. Ph. Rippel, Stuttgart 1986, p. 55.

[22] G. Bruno, *Über das Unendliche, das Universum und die Welten*, übers. u. hrsg. v. Ch. Schultz, Stuttgart 1994, p. 16.

[23] Ibid, p. 94.

[24] Cf. G. Bruno, *Das Aschermittwochsmahl*, p. 50f.

[25] Cf. G. Bruno, *Das Aschermittwochsmahl*, p 98.

> Ist einmal erkannt, daß der Anschein der täglichen Weltbewegung von der wahren Tagesbewegung der Erde herrührt, dann besteht kein Grund, der uns zwingen könnte, die gleiche Entfernung der Gestirne anzunehmen, welche der große Haufen als an einer achten Sphäre angenagelt ansieht (...).[26]

Hatte Copernicus die Frage, ob die Welt begrenzt oder unbegrenzt sei, dem Streit der Naturphilosophen überlassen,[27] so macht Bruno die Beantwortung dieser Frage zur Hauptaufgabe des Dialogs *De l'infinito, universo et mondi.* Die Argumentation für die Unendlichkeit des Universums scheint zunächst apagogisch zu sein, wenn Bruno zu Beginn des ersten Dialogs die Beweisbarkeit der Endlichkeit in Frage stellt. "Wenn die Welt endlich ist und außerhalb ihrer nichts ist, dann frage ich Euch: Wo ist die Welt? Wo ist das Universum?"[28] Philotheo läßt Aristoteles auf diese Frage antworten und sich in einen Widerspruch verwickeln: Das Universum sei in sich selbst. "Die Außenwölbung der ersten Himmelssphäre ist der universelle Ort, und als erstes Enthaltendes ist sie in keinem weiteren Enthaltenden (...)."[29] Weil das erste Enthaltende selbst nicht wieder in etwas anderem enthalten sein könne, müsse, so das aristotelische Argument, das Enthaltende alles und sich selbst enthalten. Diese Indifferenz der Grenze, des Enthaltenden und des Enthaltenen[30], läßt sich, Bruno zur Folge, nur um den Preis der Bestimmungslosigkeit des Universums begründen. Läßt der Ort eines Dinges sich nur angeben, sofern dieses in etwas enthalten ist, so hat das Universum, das alles enthält ohne selbst in etwas anderem enthalten zu sein, keinen Ort und existiert demnach nirgends. Die Bestimmung des Universums habe somit etwas zur Voraussetzung, was weder ein Teil des Universums noch mit diesem identisch sei. Die intellektuelle Bestimmung des Universums selbst fordert demnach ein Außerhalb des Universums. Mit dieser erkenntnistheoretisch motivierten Forderung geraten die physischen Grenzen der Welt ins Wanken. Mit "der Frage nach dem Außerhalb"[31] und dem, "was sich jenseits und außerhalb des Universums befindet"[32], überschreitet Bruno die Grenzen, die

---

[26] G. Bruno, *Über das Unendliche, das Universum und die Welten,* p. 124.

[27] N. Copernicus, *De revolutionibus I/8,* p. 115.

[28] G. Bruno, *Über das Unendliche, das Universum und die Welten,* p. 35.

[29] Ibid.

[30] Cf. ibid, p. 36: »Aristoteles hat den Ort nicht als enthaltenden Körper definiert, nicht als einen bestimmten Raum, sondern als Oberfläche eines enthaltenden Körpers; und dann ist der erste, grundlegende und erhabenste Ort derjenige, auf den diese Definition am wenigsten und in keiner Weise zutrifft.«

[31] Ibid, p. 35.

[32] Ibid.

mit der Annahme der Fixsternsphäre gesetzt waren. Läßt sich das Universum nur unter der Voraussetzung eines ihm Äußerlichen bestimmen, so ist das Universum entweder nicht länger als Inbegriff aller Realität zu begreifen oder aber bestimmungslos. Der Versuch, das Universum als Totalität zu bewahren, indem das Nichts oder das Leere als äußerlicher Bestimmungsgrund angesetzt wird, führt selbst zur Bestimmungslosigkeit des Universums. Als äußerlicher Bestimmungsgrund des Universums kann weder das Nichts noch das Leere behauptet werden, da beide selbst bestimmungslos sind und somit nicht als Bestimmungsgrund fungieren können. Die Bestimmtheit des Universums läßt sich, so Brunos Argumentation, nur retten, indem die Einheit der einen endlichen Welt überführt wird in die Einheit unendlich vieler endlicher Welten.

Am Begriff der Unendlichkeit zeigt sich Brunos Gedanke der durchgängigen Übereinstimmung von Natur und Vernunft. Die Einsicht in die Unendlichkeit des Universums beruht auf der Uneingeschränktheit der Einbildungskraft, der "Fähigkeit des Intellekts, die immer Raum an Raum, Ausdehnung an Ausdehnung, Einheit an Einheit, Zahl an Zahl fügen will und kann (…)."[33] Aufgrund dieser Fähigkeit des Intellekts gelingt es der Wissenschaft "uns von den Ketten des allerengsten Reiches" zu lösen "und in die Freiheit des allerherrlichsten Reiches (…), aus der vermeintlichen Armut und Enge in die unzähligen Reichtümer eines so großen Raumes, eines so würdigen Feldes, so vieler bestbestellter Welten [zu führen; M.G.]; und sie läßt nicht den Kreis des Horizontes, vom Auge lügnerisch auf der Erde und von der Phantasie fälschlich im Ätherraum vorgegaukelt, unserem Geist Fesseln anlegen (…)."[34] Daß die Fesseln des Geistes abgelegt werden können, sei dem Vermögen des Geistes selbst zu verdanken. Weder die Sinneswahrnehmung, noch die sachlich, bzw. physikalisch unbegründeten mathematischen Hypothesen seien in der Lage den Gegenstand der Erkenntnis so zu bestimmen, daß er für den erkennenden Geist als einzig wahrer erscheinen müsse. Das Kriterium einer sicheren, einer gewissen Erkenntnis liegt somit im Vermögen des erkennenden Subjektes selbst. Ist das erkennende Subjekt fähig, sich über die Beschränktheit und die Relativität seines Standortes hinwegzusetzen, um die wahre Ordnung des Alls zu erfassen, die der augenscheinlichen Erscheinung zu widersprechen scheint, so offenbart sich in dieser Fähigkeit, wie Hegel in seiner *Geschichte der Philosophie* schreibt, "die Gegenwart der Vernunft in der Natur (…)."[35]

---

[33] Ibid, p. 26.

[34] Ibid.

[35] G.W.F. Hegel, *Vorlesungen über die Geschichte der Philosophie*, Werke Bd. 20, Frankfurt/M. 1986, p. 25.

In seinem 1591 erschienenem Werk *De innumerabilibus, immenso et infigurabili* schreibt Bruno, daß die Natur nichts anderes sei "als die Kraft, die den Dingen eingepflanzt ist und das Gesetz, nach dem sie ihren eigenen Lauf vollenden."[36] Der Gegenstand der Naturerkenntnis ist demnach kein Naturding, sondern die Natur als die systematische Einheit und das allgemeine Gesetz, das allen besonderen Erscheinungen zu Grunde liegt.[37] Schon in *De uno* verweist Bruno auf die Strukturgleichheit von Natur und Vernunft, vom Entstehungsprozeß in der Natur und dem Erkenntnisprozeß. Es sei "ein und dieselbe Stufenleiter (…), auf der die Natur bis zur Hervorbringung des Seienden herabsteigt und auf der die Vernunft zu dessen Erkenntnis emporsteigt (…)."[38] Keine Ordnung sei ohne eine gewisse Teilhabe möglich, keine Teilhabe sei ohne eine gewisse Verknüpfung denkbar, wie auch jede Teilhabe auf eine Verknüpfung angewiesen sei. Eine Ordnung sei deshalb nur unter der Voraussetzung möglich, daß das Subjekt wie das Objekt der Ordnung sich auf ein Prinzip zurückführen ließen.[39]

> Und gewiß läßt es sich nicht leugnen, daß wie alles sinnlich Wahrnehmbare ein Substrat der sinnlichen Wahrnehmung, so alles Intelligible ein Substrat der Intelligibilität voraussetzt.[40]

Die Natur, der Gegenstand der Erkenntnis, offenbart sich nicht bloß als vernunftgemäß, sondern als durchaus intelligibel.

III. Schelling

Anders als Bruno bezieht Schelling sich nicht unmittelbar auf Copernicus' Werk und auch dessen zur Metapher gewordenen Wende widmet Schelling nur wenige Zeilen.[41] Im folgenden soll auch weniger der Einfluß Copernicus', als vielmehr der Weiterentwicklung der Idee einer intelligiblen Natur nachgegangen werden. In seinem 1802 erschienenen Dialog *Bruno oder über das göttliche und natürliche Prinzip* bezieht sich Schelling auf die von

---

[36] G. Bruno, *De immenso et innumerabilibus seu de universo et mundis*, Opera lat. I.2, Lib. VIII, Cap. IX, p. 310: »Natura estque nihil, nisi virtus insita rebus. Et Lex, qua peragunt proprium cuncta entia cursum.«

[37] Cf. E. Cassirer, *Das Erkenntnisproblem in der Philosophie der neueren Zeit*, Bd. I, Darmstadt 1994, p. 298.

[38] G. Bruno, *Über die Ursache, das Prinzip und das Eine*, p. 139.

[39] Cf. ibid, p. 112.

[40] Ibid.

[41] Cf. FN 73.

Jacobi besorgte Teilübersetzung von *De uno*. Dem Gespräch zwischen Bruno, Alexander, Anselmo und Lucian legt Schelling die Idee dessen zugrunde, "worin alle Gegensätze, nicht sowohl vereinigt, als vielmehr eins, und nicht sowohl aufgehoben, als vielmehr gar nicht getrennt sind (…)."[42] Es ist die Idee der absoluten Identität, die Schelling in Brunos Werk angelegt sieht, und um deren Explikation er sich in diesem Dialog bemüht. Die Idee der *coincidentia oppositorum*[43] hat Bruno im 5. Dialog von *De uno* dargelegt. Das Universum sei "Eins, unendlich und unbeweglich"[44] und verbinde "überdies alle Gegensätze in seinem Sein zu Einheit und Harmonie (…)."[45] Die Gegensätze in der Natur, die eine durchgängige Einheit der Natur schon im Ansatz zu sprengen drohen, seien in einem Dritten zur Einheit verbunden. Der Idee der *coincidentia oppositorum*, die sich schon bei Cusanus findet, liegt die Überlegung zugrunde, daß jede Entgegensetzung selbst eine Einheit der Entgegengesetzten zur Voraussetzung hat. Diese Einheit der Entgegengesetzten ist zunächst nichts anderes als ihr gemeinsamer Beziehungsgrund, das *tertium comparationis* der als einander entgegengesetzt aufeinander Bezogenen. Die Entgegengesetzten bestimmen sich im Verhältnis zueinander. Weil die Relation der Entgegengesetzten notwendig auf einen gemeinsamen Beziehungsgrund verweist, erscheint dieser Beziehungsgrund als der einheitliche Bestimmungsgrund beider: "Kälte und Wärme, jedes im niedrigsten Grade, verlieren sich in Eine und dieselbe Eigenschaft, und beweisen die Identität ihres Prinzips (…)."[46] Die Entgegengesetzten treten zur Bildung des Einen zusammen; sie gehören zu einer Ordnung und sind in dieser Ordnung Eines.[47] Für Schelling sind die Entgegengesetzten jedoch "nicht bloß in einem Dritten, sondern an sich und vor der Trennung eins (…)."[48] Hat Schelling vor allem in den Jahren 1797–1800 seine Philosophie von zwei Seiten, als Natur- und Transzendentalphilosophie, darzustellen versucht, so bemüht er sich ab 1801, sein System der Philosophie ausgehend vom Indifferenzpunkt dieser beiden Seiten zu entwickeln. Das absolute Identitätssystem beginnt

---

[42] F.W.J. Schelling, *Bruno oder über das göttliche und natürliche Princip der Dinge* (1801), Ausgewählte Werke, reprogr. Nachdruck v. Friedrich Wilhelm Joseph von Schellings sämmtliche Werke Bd. IV (SW IV), hrsg. v. K. F. A. Schelling, Stuttgart/Augsburg 1859, Darmstadt 1988, p. 131 (SW IV, p. 235).

[43] Cf. G. Bruno, *Über die Ursache, das Prinzip und das Eine*, p. 130ff.

[44] Ibid, p. 130.

[45] Ibid.

[46] G. Bruno, *Über die Ursache, das Prinzip und das Eine*, übers. v. F. H. Jacobi, in: Friedrich Heinrich Jacobi Werke, Bd. 1 Schriften zum Spinozastreit, Hamburg 1998, p. 204.

[47] Cf. *De l'infinito*, p. 77.

[48] F.W.J. Schelling, *Bruno oder über das göttliche und natürliche Princip der Dinge*, p. 137 (SW IV, p. 241).

mit der absoluten Vernunft, der Vernunft, "insofern sie als totale Indifferenz des Subjektiven und Objektiven gedacht wird."[49] In der Identitätsphilosophie wird die "Einheit aller Gegensätze"[50] zum Ersten, von dem die wahre Philosophie ihren Ausgang zu nehmen habe. Schelling fordert die absolute Erkenntnisart, die ein Unbedingtes zum Fundament ihrer Gewißheit hat, denn "wie kann eine Reihe von Kenntnissen ein Wissen seyn, welche in keinem Punkt etwas Unbedingtes hat (...)."[51] Im Fokus der Kritik steht der Schluß von der Wirkung auf die Ursache. Diese Erkenntnisart, die "das Princip durch dasjenige, wovon es das Princip ist, das Ursprüngliche im Abgeleiteten erkennen will"[52] könne niemals auf etwas führen, "das an sich selbst wäre und durch sich selbst bestände (...)."[53] Das Einzige, was diese Erkenntnisart auszeichne, sei "die Willkür in der Erdichtung der Ursachen aus den Wirkungen (...)."[54] Unter diesen Vorwurf des willkürlich Erdichteten fallen auch Epizykel, Deferenten und Exzenter. Schelling möchte die kausale Erkenntnisart, die eine Erscheinung durch eine andere zu erklären versuche, durch die absolute Erkenntnisart ersetzt wissen. Mit dem Vernunftgesetz der Identität sei diese geforderte absolute Einheit des Endlichen und Unendlichen, des Besonderen und Allgemeinen gesetzt.[55]

> Denn was kann wohl Herrlicheres und Vortrefflicheres gedacht werden als die Natur desjenigen, in welchem durch das Allgemeine auch das Besondere, durch den Begriff auch die Gegenstände gesetzt und bestimmt werden, so, daß in ihm selbst beides ungetrennt ist, und wie sehr hast du dich mit dieser Idee über die endliche Erkenntnis erschwungen, in welcher dies alles getrennt ist, und wie viel mehr über die eingebildete Erkenntnis der Philosophen, welche erst die Einheit und dann die Mannichfaltigkeit, beide aber einander schlechthin entgegensetzen.[56]

---

[49] F.W.J. Schelling, *Darstellung meines Systems der Philosophie*, Schellings Werke Bd. III, hrsg. v. M. Schröter, München 1927, p. 10 (SW IV, p. 114).

[50] F.W.J. Schelling, *Bruno oder über das göttliche und natürliche Princip der Dinge*, p. 132 (SW IV, p. 236).

[51] F.W.J. Schelling, *Fernere Darstellungen aus dem System der Philosophie*, Ausgewählte Werke, reprogr. Nachdruck v. Friedrich Wilhelm Joseph von Schellings sämmtliche Werke Bd. IV (SW IV), hrsg. v. K. F. A. Schelling, Stuttgart/Augsburg 1859, Darmstadt 1988, p. 239 (SW IV, p. 343).

[52] Ibid, p. 238 (SW IV, p. 342).

[53] Ibid.

[54] Ibid.

[55] Cf. ibid, p. 242 (SW IV, p.346).

[56] F.W.J. Schelling, *Bruno oder über das göttliche und natürliche Princip der Dinge*, p. 137 (SW IV, p. 241).

Die Einheit der Erkenntnis und die Mannigfaltigkeit der Gegenstände der Erkenntnis seien nicht einander entgegenzusetzen, sondern absolut aufeinander zu beziehen. Schellings Kritik richtet sich gegen Kants Forderung, daß zu der formalen Bedingung der Möglichkeit von Erkenntnis Erfahrung hinzu kommen müsse. In der *Kritik der reinen Vernunft* bestimmt Kant die Form der Anschauung und die reinen Verstandesbegriffe als die formalen Bedingungen der Möglichkeit der Erfahrung. So "müssen alle möglichen Wahrnehmungen, mithin auch alles, was zum empirischen Bewußtsein immer gelangen kann, d.i. alle Erscheinungen der Natur, ihrer Verbindung nach, unter den Kategorien stehen, von welchen die Natur (bloß als Natur überhaupt betrachtet), als dem ursprünglichen Grunde ihrer notwendigen Gesetzmäßigkeit (als *natura formaliter spectata*), abhängt. Auf mehrere Gesetze aber, als die, auf denen eine Natur überhaupt, als Gesetzmäßigkeit der Erscheinungen in Raum und Zeit, beruht, reicht auch das reine Verstandesvermögen nicht zu, durch bloße Kategorien den Erscheinungen a priori Gesetze vorzuschreiben. Besondere Gesetze, weil sie empirisch bestimmte Erscheinungen betreffen, können davon nicht vollständig abgeleitet werden, ob sie gleich alle insgesamt unter jenen stehen. Es muß Erfahrung dazu kommen, um die letzteren überhaupt kennen zu lernen; von Erfahrung aber überhaupt, und dem, was als ein Gegenstand erkannt werden kann, geben allein jene Gesetze *a priori* Belehrung."[57] Die reinen Verstandesbegriffe bestimmen die Form der Erscheinungen, sind aber nicht der Grund der Existenz dieser Erscheinungen. Die Bestimmung der Form der Gesetzmäßigkeit der Erscheinungen durch die Kategorien hat keine durchgängige Determination der Erscheinungen zur Folge. Die spezifischen Gesetze der Natur werden, anders als die Form der Gesetzmäßigkeit der Erscheinungen der Natur, nicht durch die Kategorien bestimmt. Physik als die Wissenschaft der Gesetze der körperlichen Natur ist rein erkenntnistheoretisch nicht zu begründen, sondern bedarf der Erfahrung. Die Erfahrung ist somit die materiale Voraussetzung jeder Einzelwissenschaft, obwohl jede Erfahrung als Erfahrung notwendig unter der Form der Gesetzmäßigkeit der Erscheinungen stehen muß. Die Forderung nach einer hinzukommenden Erfahrung, um aus der formalen Möglichkeit der Erkenntnis zu einer wirklichen Erkenntnis zu gelangen, kann jedoch allein für diejenigen Erkenntnisse zwingend sein, die eine Beziehung der Kategorien auf Erscheinungen erfordern. Sofern rein mathematische Erkenntnisse durchgängig synthetische Urteile a priori sind, ist für diese Form der Erkenntnis eine hinzukommende Erfahrung nicht von konstitutiver Bedeutung. An diesem Punkt setzt Schelling an. Die Vereinigung

---

[57] I. Kant, *Kritik der reinen Vernunft*, B 164 f.

von Endlichem und Unendlichem, von Besonderem und Allgemeinem sieht Schelling mit der mathematischen Konstruktion gegeben. Jede Konstruktion unterstellt die Indifferenz von Konstruktionsanweisung und Konstruiertem. So ist jedes einzelne konstruierte Dreieck Repräsentant einer allgemeinen Konstruktionsregel. Besonderes und Allgemeines erscheinen in dem einzelnen konstruierten Dreieck als indifferent. "Diese Einheit, die in jeder ihrer Construktionen ausgedrückt ist, ist der Grund ihrer absoluten Gewißheit (…)."[58] Die Apodiktizität der synthetischen Urteile *a priori* läßt sich jedoch nicht aus der Tätigkeit des urteilenden Subjektes deduzieren. Das bloße Befolgen einer Handlungsforderung, einer Konstruktionsanweisung hat keine apodiktisch gültigen Urteile über die Gegenstände der konstruierten Begriffe zum Resultat. Daß "dasjenige, was aus den allgemeinen Bedingungen der Konstruktion folgt, auch von dem Objekte des konstruierten Begriffs allgemein gelten muß (…)"[59], läßt nicht den umgekehrten Schluß zu, daß mit der Konstruktion synthetische Urteile *a priori* hervorzubringen seien, die allein in dieser Tätigkeit den Grund ihrer Apodiktizität hätten.

Die Übereinstimmung von Subjekt und Objekt, von Endlichem und Unendlichem, Besonderem und Allgemeinem, Natur und Vernunft in der absoluten Vernunft ist für Schelling der Grund der objektiven Realität des Wissens.[60] Damit wird die für eine objektive Erkenntnis notwendige Vernunftgemäßheit der Natur in die Vernünftigkeit der Natur überführt. Der Vernunft des Geistes scheint damit eine Grenze gesetzt zu sein. "In Schellings Naturphilosophie ist ein Versuch überliefert, wissenschaftlich-technische Rationalität nicht etwa preiszugeben, sondern durch ihre Rückbindung an eine sie fundierende absolute Vernunft kritisch zu beschränken und damit ihrer Anmaßung, die ganze Vernunft sein zu wollen, zurückzuweisen."[61] Mit dieser Interpretation wird unterstellt, daß die Übereinstimmung von Natur und Geist, erkennendem Subjekt und erkannter Natur in ein Drittes falle, das in seiner Funktion der Vermittlung sowohl das erkennende Subjekt als auch die erkannte Natur gleichermaßen unter sich subsumiere. Der Grund der objektiven Realität der Erkenntnis eines endlichen Geistes fiele damit

---

[58] F.W.J. Schelling, *Fernere Darstellungen aus dem System der Philosophie*, p. 242 (SW IV, p. 346).

[59] I. Kant, *Kritik der reinen Vernunft*, B 744.

[60] Cf. F. W. J. Schelling, *Darstellung meines Systems der Philosophie*, p. 10, (SW IV, p. 114): »Ich nenne Vernunft die absolute Vernunft, oder die Vernunft, insofern sie als totale Indifferenz des Subjektiven und Objektiven gedacht wird.«

[61] R. Heckmann, "Vorwort. Die Naturphilosophie Schellings", in: R. Heckmann, H. Krings und R. W. Meyer (Hg.), *Natur und Subjektivität. Zur Auseinandersetzung mit der Naturphilosophie des jungen Schelling*, Stuttgart-Bad Cannstatt 1985, p. 9.

in eine absolute Vernunft, an der sowohl der beschränkte Geist als auch die Natur als Attribute teilhätten. Natur und Geist wären, wie Schelling in seiner Identitätsphilosophie ausführt, als Attribute des Absoluten zu begreifen.[62] Schon im *Timaeus* versucht Schelling die Vermittlung von erkennendem Subjekt und erkannter Natur, die Form des Verstandes mit der Materie durch ein Drittes darzustellen: "diß war Werk des Weltbaumeisters, der die FORM des Verstandes mit der Materie vereinigte, u. dad*urc*h nicht nur die allgemeine Gesetzmäßigkeit der Natur, sondern auch die Gesetzmäßigkeit einzelner Produkte derselben zu Stande brachte (...). Jedes einzelne Weltwesen war also nicht Werk der Materie, sondern eigentlich Zusammenstimmung einzelner reiner Gesetze zu Einem Ganzen, d.h. es war Werk einer Idee, einer Vorstellung von der Zusammenstimmung einzelner reiner Gesetze zu Einem Ganzen. Überdiß war diese Zusammenstimmung reiner Gesetze zur Hervorbringung Eines Ganzen wieder nach Regeln geschehen, die Zusammenstimmung dieser Gesetze selbst also wieder Werk (nicht der Materie), sondern einer reinen Form der Einheit, Werk einer Intelligenz."[63] Diese Intelligenz, das Absolute als die Einheit in der Entgegensetzung bestimmt Schelling in der *Fernere(n) Darstellung aus dem System der Philosophie* (1802) als die "allgemeine Form des Universums"[64], als "die Quelle aller Gesetze."[65] Alle Gesetzmäßigkeit sei nichts anderes als ein Spiegel der ewigen Einheit und Harmonie. In diesem Sinne versteht Schelling den Umlauf der Planeten als "die Vertilgung alles Gegensatzes und die reine Einheit (...)."[66] Das Universum selbst bestimmt Schelling als die absolute Totalität, die selbst wiederum nichts anderes als die absolute Identität sei.[67] Außer, oder unabhängig von

---

[62] K.-J. Grün unterscheidet bei Schelling zwei Phasen der Spinoza-Rezeption: »Die erste reicht bis zum *System des transzendentalen Idealismus* und beruht auf einer gewissen Orientierung *an* Spinoza, die allerdings nicht die Einflüsse anderer Denker verdunkelt. Diese Schriften lassen sich (...) spinozistisch auslegen, werden vom Verfasser jedoch noch nicht als solche deutlich ausgewiesen. Die zweite Phase aber stellt drastisch – sowohl rückwirkend als auch vorausweisend – die eigene Philosophie als einen Entwurf nach dem Muster des Spinozismus heraus.« [K.-J. Grün, *Das Erwachen der Materie. Studie über die spinozistischen Gehalte der Naturphilosophie Schellings*, Hildesheim/ Zürich/ New York 1993, p. 173].

[63] F.W.J. Schelling, *Timaeus* (1794), Schellingiana Bd. 4, hrsg. v. H. Buchner, Stuttgart-Bad Cannstatt 1994, p. 32f.

[64] F.W.J. Schelling, *Fernere Darstellungen aus dem System der Philosophie*, p. 297 (SW IV, p. 401).

[65] Ibid., p. 346 (SW IV, p. 450).

[66] F.W.J. Schelling, *Bruno oder über das göttliche und natürliche Princip der Dinge*, p. 165 f. (SW IV, p. 269f).

[67] Cf. F.W.J. Schelling, *Darstellung meines Systems der Philosophie*, p. 11 (SW IV, p. 115).

dieser absoluten Identität sei nichts[68], alles sei in der absoluten Identität, der Vernunft.[69]

> Nur für die Vernunft ist ein Universum, und etwas vernünftig begreifen heißt: es zunächst als organisches Glied des absoluten Ganzen, im nothwendigen Zusammenhang mit demselben, und dadurch als einen Reflex der absoluten Einheit begreifen.[70]

Auch wenn so manche Erscheinung ob ihrer Unregelmäßigkeit, ihrer chaotischen Mannigfaltigkeit unvernünftig scheine, so unterstelle das erkennende Subjekt jedoch notwendig, daß alles, “was ist oder was geschieht, vernünftig, und die Vernunft mit Einem Worte der Urstoff und das Reale alles Seyns sey.”[71] Die Vernunft ist somit der “ewige Vater aller Dinge”[72], der Grund aller möglichen Erkenntnis sowohl als auch der Grund aller möglichen Gegenstände der Erkenntnis. Das die Erde sich bewegt, hätte somit seinen Grund in der absoluten Vernunft. Es ist dieser Idealismus, dem Schelling den Rang der Kopernikanischen Wende einräumt:

> Johannes Kepler rühmt von der Copernicanischen Lehre, daß sie die Welt von der *insana et ineffabilis celeritas* der Ptolemäischen Bewegung befreie. Kant vergleicht den Idealismus mit dem Gedanken des Copernicus. Dieser habe, da die Erklärung der Himmelsbewegungen nicht gut von Statten ging, wenn man annahm, das Sternenheer drehe sich um den Zuschauer, den Versuch gemacht, ob es nicht besser gelinge, wenn man den Zuschauer sich drehen und dagegen die Sterne in Ruhe ließ. Der Idealismus sey eine gleiche Umkehrung des Standpunktes, von der man sich ähnlichen Erfolg versprechen dürfe. Wirklich scheint der Idealismus – nicht jeder freilich; denn auch Berkeleys Meinung ist so genannt worden, selbst nicht der kantische, der es zu keiner Ausführung gebracht, noch weniger freilich, was man in neuester Zeit durch diese Benennung zu empfehlen gesucht, aber – der Idealismus in dem Sinn, den ich durch die letzten Vorträge hinlänglich erklärt annehmen kann: dieser also scheint allerdings das Mittel, das viele Grenzenlose, das bis jetzt in den Naturwissenschaften sich findet, hinwegzuschaffen,

---

[68] Cf. F.W.J. Schelling, *Darstellung meines Systems der Philosophie*, p. 15 (SW IV, p. 119).

[69] Ibid., p. 11 (SW IV, p. 115).

[70] F.W.J. Schelling, *Fernere Darstellungen aus dem System der Philosophie*, p. 286 (SW IV, p. 390).

[71] Ibid.

[72] Cf. F.W.J. Schelling, *Bruno oder über das göttliche und natürliche Princip der Dinge*, p. 148 (SW IV, p. 252).

> und die ausschweifenden Gedanken (…) in die dem Philosophen erwünschte Enge zu bringen. Denn je weiter von aller Schranke, desto weiter ist jedes vom Denken, und darum der Gedankenlosigkeit willkommen, dem Philosophen aber zuwider.[73]

Der von Schelling hier hervorgehobene Idealismus ist der eine rein rationale Wissenschaft ermöglichende Idealismus. In dieser rein rationalen Wissenschaft habe "nichts der Vernunft Fremdes Zutritt (…)."[74] Die Gewißheit einer vernünftigen Anordnung der Planeten hätte somit ihren Grund ausschließlich in der Vernunft.

Für Schelling ist die zur Metapher gewordene Kopernikanische Wende nichts anderes als der absolute Idealismus. Copernicus ging es um die Erklärung der wahren Ursache für die erscheinende Ungleichmäßigkeit der Planetenbewegung. Dieses Ziel wurde für ihn durch die Aufgabe der überlieferten Hypothese der ruhenden Erde greifbar. Mit der Umkehrung der Bewegungshypothesen wurde der Schein der irrenden Sterne entlarvt und der wahre Grund der erscheinenden Bewegungsungleichmäßigkeiten erkennbar. Copernicus' Standortwechsel ist durch seinen Realismus motiviert. Bei Schelling wird jeder mögliche Realismus zum bloßen Moment seines absoluten Idealismus. So stellt die Kopernikanische Wende Copernicus selbst auf den Kopf.

---

[73] F.W.J. Schelling, *Philosophische Einleitung in die Philosophie der Mythologie oder Darstellung der reinrationalen Philosophie*, Schellings Werke, Bd. V, hrsg. v. M. Schröter, München 1928, p. 672 (SW XI, p. 491).

[74] Ibid, p. 557 (SW XI, p. 375.)

Filozofski vestnik Volume/Letnik XXV • Number/Številka 2 • 2004 • 69–83

GEMMA FRISIUS: A CONVINCED COPERNICAN IN 1555

Fernand Hallyn

Gemma Frisius (1508–1555), cosmographer from Louvain, editor and continuator of Peter Apian's *Cosmography*, author of the 16th century's best-selling manual of *Arithmetics*, maker of globes, maps of the world and various instruments, inventor of new methods of topographical triangulation and maritime orientation, consistently demonstrated great interest in the Copernican system, from the hopes he expressed after reading the *Narratio prima*[1] of Rheticus, via the favourable judgements of the *De Revolutionibus* pronounced in the *De Radio* and the *De Astrolabo*[2], through to the preface to the *Ephemerides* of his pupil Stadius[3]. It is this latter text that I would like to examine in more detail here. As one of Gemma's very last writings, it has every chance of reflecting his decided opinion. It is also the only text by Gemma to consider the question of heliocentrism in full. And in this regard, it is arguable that its real profundity has not hitherto been recognised[4].

---

[1] See especially the letter to Dantiscus of 1541, published by F. Van Ortroy, *Bio-bibliographie de Gemma Frisius, fondateur de l'école belge de géographie, de son fils Corneille et de ses neveux les Arsenius*, Brussels, Hayez, 1920 (repr. Amsterdam, 1966), pp. 409–410, as well as the French translation and detailed commentary in: G.J. Rhéticus, *Narratio prima*, ed. and trans. by H. Hugonnard-Roche & J.-P. Verdet, with the collaboration of M.-P. Lerner & A. Segonds, Wroclaw, Ossolineum, 1982, pp. 248–249.

[2] *De Radio astronomico et geometrico…*, Antwerp-Leuven, 1545, 29 v°, 34 v° 35 v°, etc.; *De Astrolabo catholico…*, Antwerp, 1556, 13 r°, 31 v°, 34 r°-v°, etc.

[3] Johan van Staeyen (Stadius) van Loenhout (1527–1579) was Gemma Frisius' pupil before becoming mathematician and astronomer to the duke of Savoy and to the prince-bishop of Liège, Robert de Bergen; he was subsequently appointed professor at the Collège Royal in Paris. The *Ephemerides* of 1556 (*Ephemerides novae et exactae… ab anno 1554 ad annum 1570*, Cologne, 1556) were followed in 1560 by the *Tabulae Bergenses*, named after the prince-bishop of Liège and intended to provide an instrument that was easier to consult than Rheinhold's *Prutenic Tables.*

[4] On Gemma Frisius and Copernicus, see especially: G. McColley, "An Early Friend of the Copernican Theory: Gemma Frisius", *Isis*, 1937, pp. 322–325; A. de Smet, "Copernic

Stadius' *Ephemerides* were published in 1556, after Gemma's death. The latter's preface is dated March 1555. These *Ephemerides* are, with those by the Englishman John Feild, which appeared in the same year, the first to be based on the *Prutenic Tables*, devised by Erasmus Reinhold on the basis of the *De Revolutionibus.* It is worth noting that they borrow from Gemma a "*Tabula stellarum fixarum*" and a "*Tabella civitatum aliquot insigniorum*", which had first appeared in the 1548 edition of another of his works *De Principiis astronomiae et geometriae.*

The tone of Gemma's preface is unusual: vehement, polemical and marked by great rhetorical power. The author offers a quite solemn treatment of *truth,* which is presented as "the queen and just overseer of all the arts" ("*omnium artium Regina & iusta gubernatrix*"). His adversaries are presented as a pack of dogs ("*oblatrantium turba*") and as croaking jackdaws ("*garriant graculi*"). The only other passage which is comparable with this preface from the point of view of vehemence of tone is the digression against homocentric systems in the *De Radio*[5]. This similarity in itself indicates that, regardless of the tone of other passages, which merely discuss the precision of observations and the correctness of calculations, Gemma was by no means indifferent to the question of the choice of a world system. The nature of the works he published – most of which were manuals on the use of instruments – probably explains in large measure the sparing nature of his explicit contributions to the cosmological debate. But it must not be allowed to conceal the real interest he took in the matter. It can only be regretted that he did not have the time to write the *Theoricae planetarum* announced in 1545 in the *De Radio*[6]. What is more, the very importance that he attributed to observation and to instruments was probably not just due to a cosmographer's concern for mainly practical matters. His taste for exactitude and precision, which prefigures

---

et les Pays-Bas", *Janus,* LX (1973), pp. 13–23; id., "Gemma Frisius et Nicolas Copernic", *Der Globusfreund,* XXI–XXIII (1972–74), pp. 72–78; E.H. Waterbolk, "The 'Reception'of Copernicus's Teachings by Gemma Frisius (1508–1555)", *Lias,* I (1974), pp. 225–241; G. Vanpaemel, "Het copernicanisme aan de oude Leuvense universiteit", in C. Opsomer (ed.), *Copernicus en Galilei in de wetenschapsgeschiedenis van België,* Brussels, Palais des Académies, 1995, pp. 101–122; F. Hallyn, "La Cosmologie de Gemma Frisius à Wendelen", in R. Halleux *e.a., Histoire des sciences en Belgique des origines à 1815,* Brussels, Crédit Communal, 1998, pp. 145–167.

[5] *De Radio…,* 29b: "Hic autem lubet ridere quorundam audaciam, qui ut suis inventis fidem faciant, autoritatemque concilient, negant plane Solis aut Lunae magnitudinem secundum visum variari, nempe illos in homocentricis moveri cum asserere studeant, haec experimenta, quae facile illorum fundamenta subvertunt, ridendo contemnunt."

[6] *De Radio…,* A ii r°: among the works he wants to undertake ("alia partim animo iam concepta, partim adhuc per tempus invenienda vel facienda"), Gemma mentions *Novae Planetarum theoricae multo quam antea verisimiliores et motui apparenti accommodatiores.*

that of Tycho Brahé, can also be linked with the need to bring clarity to the cosmological debate in the years immediately following the appearance of the *De Revolutionibus*. This in any case is the way in which Gemma's efforts are depicted by Rheticus in 1550 in the preface to his *Ephemerides novae*. Written eleven years after the appearance of the *Narratio prima*, and eight years after that of the *De Revolutionibus*, this preface returns to the conversations in which Copernicus had explained to Rheticus the main difficulties that contemporary astronomy was running up against. Relating these reflections to the present day, Rheticus adds:

> He [Copernicus] gave me much advice and many suggestions, and especially urged me to concentrate on observing the fixed stars. When the highly learned Gemma Frisius holds the view that this is what needs to be done, I believe that, like a new Copernicus for our age, he is laying solid foundations for this science and, as is right, I admire him with all my heart.[7]

A look in detail at the preface to Stadius' work makes clear that it consists of two parts. The first part is devoted to a critique of astronomical tables prior to those of Reinhold. It is presented as an exhortation addressed to Stadius, encouraging him to publish new ephemerides, despite his fears. Stadius should not feel compelled to publish by Gemma, but by a concern for truth, which, in this field, cannot be oppressed, as it is a matter not of authority, but of observation and demonstration. To be sure, Stadius will immediately come under attack. He will be charged with seeking to supplant the *Alphonsine Tables*, which have been in use for generations. He will be accused of deliberately espousing paradox, for who will believe that the earth is in motion and the sun is at rest? The differences between the new tables and the old ones will be adduced as evidence: for Mercury, a difference of 10 to 11°, for Mars, of 4°, and for the Sun, of 50'. But these differences do not in the least diminish the worth of Stadius' work. On the contrary, they merely serve to show up the errors in the old tables. Gemma cites his own personal observations, which have proven the superiority of the *Prutenic Tables* over the others for him. One day, the star Regulus, forecast at 5° 22' 8" in Leo by the *Alphonsine Tables*, was observed by him at 5° 23' 20" in that constellation – an observation which only the *Prutenic Tables* predicted correctly. Likewise, he noticed a conjunction between Saturn and Mars which preceded the forecasts in Stöffler's ephemerides by more than six days. One can only laugh at

---

[7] Rheticus, *Narratio prima*, op. cit., p. 223.

those who predict the equinox up to twelve hours early. In short, one must follow Stadius in taking as one's starting-point Reinhold's tables, which are themselves founded on Copernicus[8]: "Concerning these, therefore, no-one may tender any criticism unless he has employed the same principles himself, in other words *observations and demonstration* [...] Here, in truth, lies the task, here the labour, and thus is opened the way to the stars."

After this very long but ultimately predictable attack on the usefulness of the traditional tables, Gemma finally comes to the question of the world systems on which the different tables are founded: "So much for the diversity of tables and the authority of their authors. There now remains the final problem concerning the earth's motion and the paradox of the sun at rest at the centre of the world."[9] I shall examine this section step by step, seeking to tease out its implications. I shall proceed in five steps, following the text and quoting the most important sentences in bold.

1. Gemma starts by introducing the question of the exact nature of hypotheses:

"As they [the expected adversaries and critics of Stadius] have no idea about philosophy or the method of demonstration, they understand neither the causes of hypotheses nor how they should use them. For hypotheses are not put forward by their authors as if they had to be expressed in this way and could not be constructed otherwise."[10]

These lines, which reject the presentation of hypotheses as necessary truths, may be compared with theses put forward by Aristotle, and in particular with what he says about comets in the *Meteorologica*[11]: "We consider a satisfactory explanation of phenomena inaccessible to observation to have been given when our account of them is free from impossibilities."

In 1567, Christian Wursteisen directly echoed this passage, when he

---

[8] "De his igitur nemo censuram ferre poterit, nisi qui eisdem principijs usus, hoc est, τοῖς φαινομένοις καί ἀποδείξεσι [...] Verum hoc opus, hic labor est, sic patet iter ad astra." Here and elsewhere, the use of italics in the translation marks the use of Greek terms in Gemma's Latin text.

[9] "Ac tantum de diversitate tabularum & de authorum authoritate. Restat iam ultimus nodus de terrae motu, solisque in mundi centro quiescentis τὸ παράδοξον."

[10] "Verum quum & philosophia, & demonstrationis methodo careant, non intelligunt hypothesium causas & usum. Non enim illa statuuntur ab authoribus, tanquam necessario ita se habere debeant, neque aliter constitui possent."

[11] Aristotle, *Meteorologica*, I, 7 (344 a 5–8), in *Complete Works*, Princeton, Princeton University Press, 1984, vol. II, p. 562.

wrote in his commentary on Peurbach's *Theoricae novae*[12]: "Thus, regarding those objects which do not fall within the scope of our senses, we believe we have taken our demonstrations sufficiently far when we have brought them back to possible causes, in other words those from which no absurdity results." Pierre Duhem, who cites this passage and compares it with Aristotle, draws attention to the injunction to avoid the "absurd", which, he says, will soon be the principal objection to the adoption of the Copernican system.

Copernicus himself had foreseen the objection[13]: "This is why, when I realised how *absurd* this *akroama* will be deemed by those who know that the view that the earth is motionless at the middle of the sky and forms its centre is confirmed by the judgement of the centuries, if I by contrast assert that the earth moves: for a long time I wondered whether I should publish my commentaries, which were written to demonstrate its motion …" The "absurdity" lies, according to these lines, in the failure to conform with "the judgement of the centuries", it characterizes a hypothesis whose implications seem irreconcilable with a commonly adopted theory or viewpoint[14]. And sure enough, it was along such lines that Clavius, for example, would denounce the absurdity of heliocentrism:

> If Copernicus' position did not encompass any falsehood or absurdity, it is clear that there would be some doubt regarding which of the two opinions, that of Ptolemy or that of Copernicus, one should follow (on the question of what view should be taken of these phenomena). But as Copernicus' position contains numerous absurdities and errors, such as claiming that the earth does not lie at the middle of the firmament, that it moves with three motions (by what process this can occur, I can scarcely understand, as according to the philosophers a single motion is appropriate for a single body), and that the Sun has been placed at the centre of the world and is devoid of all motion. Now, all this is against

---

[12] P. Duhem, *"Sozein ta fainomena." Essai sur la notion de théorie physique de Platon à Galilée*, reissued Paris, Vrin, 1994 (first ed. 1908), p. 95.

[13] Copernicus, *De Revolutionibus*, letter to Paul III, my translation. On the signification of the Greek term ἀκροάμα, see my article "L'*absurdum* ἀκροάμα de Copernic", *Bibliothèque d'Humanisme et Renaissance*, LXII (2000), pp. 7–24.

[14] Cf. P. Machamer, "Fictionalism and Realism in Sixteenth Century Astronomy", in R. Westman (ed.), *The Copernican Achievement*, Berkeley-Los Angeles-London, University of California Press, 1975, p. 348: "In the 16th century, one important form of argument is that which involves attributing an absurdity to an opponent's position. Roughly characterized, this seems to involve showing that the opponent's theory or point of view leads to a conclusion which contradicts (or at least, seems incompatible with) an accepted basis, i.e. a substantive or philosophical claim accepted as true by the proponent (and his friends)."

> the common teaching of the philosophers and astronomers, and plainly contradicts what Holy Scripture teaches us in several places …[15]

For Clavius, therefore, those things are "absurd", "quae cum communi doctrina philosophorum et astronomorum pugnant", in other words anything opposed to a paradigmatic treatment of questions concerning the earth or the sky. However, the next part of Gemma's text contains a shift of meaning which leads to a different assessment of the absurdity of a hypothesis.

2. **"But [hypotheses are formed] so that, once we have accepted that they are not entirely absurd, but are in keeping with the principles of nature, we may have a precise explanation for the motions, corresponding to the visible positions of the stars in the sky, for future, past and present alike."**[16]

Here then, two conditions are defined by Gemma that a hypothesis must satisfy.

Firstly, it may not be "absurd". By opposition, "absurdity" is implicitly defined as whatever is contrary to the "principles of nature". But what are those "principles"? Should they be sought in authoritative texts, in the "communis doctrina" to which Clavius refers? Or must one compare those texts with observed data in order to arrive at them? The next part of the argument will clear up this point.

A second requirement is set to do with correspondence to reality and with effectiveness for the purposes of calculation: a hypothesis must provide a precise method for calculating the positions actually occupied by the heavenly bodies in the past, present and future. This is, of course, the most commonly accepted requirement. The entire first part of the preface, with its

---

[15] C. Clavius, *In Sphaeram Ioannis de Sacro Bosco commentarius…*, Rome, 1581, p. 437: "Quod si positio Copernici nihil falsi et absurdi involueret, dubium sane esset, utri opinioni, Ptolemaeine, an Copernici potius (quod attinet ad huiusmodi phainomena tuenda) adhaerendum esset. Sed quoniam multa absurda et erronea in Copernici positione continentur, ut quod terra non sit in medio firmamenti, moveaturque triplici motu, quod qua ratione fieri possit, vix intelligo, cum secundum philosophos uni corpori simplici unus debeatur motus: et quod Sol in centro mundi statuatur, sitque omnis motus expers. Quae omnia cum communi doctrina philosophorum et astronomorum pugnant, et videntur iis, quae sacrae litterae plerisque locis docent, contradicere…" On Clavius, see J.M. Lattis, *Between Copernicus and Galileo. Christoph Clavius and the Collapse of Ptolemaic Cosmology*, Chicago, Univ. of Chicago Press, 1994.

[16] "Sed ut assumptis non prorsus absurdis, sed naturae congruis exordiis, habeamus certam rationem, motuum correspondentem, in coelo conspicuis stellarum locis, tam pro tempore futuro vel elapso, quam pro praesenti."

references to the errors in the various astronomic tables, has already emphasised that only the *Prutenic Tables*, based on Copernicus, satisfy it. The next part of the argument therefore focuses, highly logically, on the requirement to avoid the "absurd".

3. **"Although, in fact, Ptolemy's hypotheses are at first sight more plausible than those of Copernicus, they commit a not inconsiderable number of absurdities; when the stars are understood to be moving irregularly in their circles, they lack explanations of the phenomena as clear as those of Copernicus. For Ptolemy states that the three upper planets (to give an example), when they are "akronic", or diametrically opposite the Sun, are always at the perigee of their epicycle, and this is a fact. But Copernicus' hypotheses take account of this fact as a necessity, and demonstrate why."**[17]

The passage offers an example of an "absurdity" in Ptolemy's system, concerning the motions of the upper planets in their epicycle. But it is clear from the start that Gemma will not refer to an incompatibility with a "*communis doctrina*", since he states his wish to compare the power of causal explanation of the two systems and introduces Aristotle's technical vocabulary in this connection.

That the upper planets are the closest to the earth when they areor diametrically opposite the sun, results from the earth's motion in the Copernican system: the shortest distance implies that the earth lies on the radius which links the upper planet to the sun; and if this is true, the sun and the planet really are diametrically opposed compared with the earth, because they correspond to the centre and a point on the circumference intersected by the radius of the circle of the upper planet which passes through the earth. If, on the contrary, it is supposed that the earth lies motionless at the centre of the world, all one can do is point to the coincidence of the two phenomena (the planet's proximity and the interposition of the earth between the planet and the sun), without providing any explanation.

The example had already been given by Copernicus himself (*De Revolutionibus*, I, 10). What is interesting here is that Gemma refers to the Ar-

---

[17] "Quamvis vero hypotheses Ptolemaei prima facie sint plausibiliores, quam Copernici, non pauca tamen illae absurda committunt, dum stellae in suis circulis inaequaliter moveri intelliguntur, tum non habent tam evidentes τῶν φαινομένων causas, atque illae Copernici. Nam quod tres superiores planetae (ut demus exemplum) ἀκρόνυχοι, sive e diametro Solis positi semper sint in perigeo sui epicycli, assumit Ptolomaeus atque hoc est τὸ ὅτι. Verum Copernici hypotheses idem illud necessario inserunt, ac demonstrant δί ὅτι."

istotelian distinction between two types of demonstration: ἀποδείξις τὸυὅτι (*demonstratio quia*) and τὸυ δί ὅτι (*demonstratio propter quid*). In the *Posterior Analytics* (I, 13), this distinction is illustrated by an astronomical example, concerning the observation that, unlike the stars, the planets do not twinkle[18]. Hence the following two syllogisms:

I. The planets do not twinkle.
That which does not twinkle is close to the earth.
Therefore the planets are close to the earth.

II. That which is close to the earth does not twinkle.
The planets are close to the earth.
Therefore the planets do not twinkle.

The two arguments lead to a correct conclusion. But the first merely brings together two facts, without linking them in a causal order; it remains at the level of τὸ ὅτι. The argument τὸυ ὅτι is merely founded on the concomitance of two phenomena; it does not describe the necessary relationship which links them, nor, of course, the meaning of that relationship. By means of an argumentation τὸυ ὅτι, one may even draw a true conclusion from false premises[19]. The second syllogism, by contrast, proceeds from a cause to its effect, supplying the explanation, the δί ὅτι or *propter quid* for the absence of twinkling in the planets. It establishes a necessary relationship between the statements. A demonstration δί ὅτι supposes that the middle term of the syllogism ("being close to the earth") is the immediate cause of an effect, i.e. that it is always present when the effect occurs, and only when it occurs.

The distinction between the two forms of demonstration constitutes an important theme in Renaissance works on astronomy and physics[20]. Useful light can be thrown on Gemma's position by a comparison with some of these texts.

In the preface to Reinhold's commentaries on Peurbach's *Theoricae novae* (Wittenberg, 1542), Melanchthon states that Ptolemy offers a systematic,

---

[18] The example is repeated by Copernicus in his *Letter against Werner* and in the *De Revolutionibus* (I, 10).

[19] Cf. *Prior Analytics*, II 2 53 b 5 ss., and II 4 57 a 38 ss. In his discussion of heliocentrism, Clavius supplies several examples: "Omnis planta est sensitiva. Omne animal est planta. Igitur omne animal est sensitivum. […] Omnis lapis est rotundus. Omnis stella est lapis. Igitur omnis stella est rotunda." (*In Sphaeram…*, ed. cit., p. 435.)

[20] Cf. N. Jardine, "The Forging of Modern Realism: Clavius and Kepler against the Sceptics", *Studies in History and Philosophy of Science*, X (1979), pp. 141–173, and id., "Epistemology of the Sciences", in C. Schmitt & Q. Skinner (eds.), *The Cambridge History of Renaissance Philosophy*, Cambridge, Cambridge University Press, 1988, pp. 685–711.

geometric explanation of phenomena, whereas Peurbach only proceeds according to τo ὅτι. In his commentary, Reinhold takes up the distinction and attributes a discourse τοῦ δί ὅτι to Ptolemy alone. Regarding the moon, he writes[21]: "You see the δί ὅτι of this part of astronomy, and the subtlety and skill with which Ptolemy investigates the causes of these phenomena by means of observation."

A similar distinction is drawn by Erasmus Oswald Schreckenfuchs in another commentary on Peurbach, published in 1556. He writes that Peurbach "treated everything according to τὸ ὅτι, because this is the easiest method for beginners. He described phenomena without adding any demonstrations or looking for their causes. For example, he stated that Mercury attains its perigee and its apogee twice during a single revolution, without showing why this is so. By contrast, Ptolemy, as the "*artifex summus*", "proceeds according to the δί ὅτι"; he looks for and discovers causes, showing that the centre of Mercury's deferent does not coincide at all with the centre of the world, but is mobile – as is the case with the Moon[22].

Schreckenfuchs knew Copernicus, and praised him, as had Reinhold after reading the *De Revolutionibus*, from which he borrowed calculatory estimates for his *Prutenic Tables*, but without departing from the geocentric paradigm. For both of them, the world *system,* in which *causes* must be located, the δί ὅτι of phenomena, remains the Ptolemaic system. Copernicus merely made the task of calculation easier, and heliocentrism did not offer the causal explanation, the *propter quid* for phenomena. Gemma's position is radically different: for him, it is Ptolemy who simply provides τὸ ὅτι (similar in this respect to what Peurbach provides according to Reinhold and Schreckenfuchs), whereas the δί ὅτι must be sought in Copernicus' system.

---

[21] Reinhold, *Theoricae novae planetarum Georgii Purbachii* [...] *pluribus figuris auctis, et illustratae scholiis...*, pref. by Melanchthon, Wittenberg, 1543. Quoted by Duhem, *op. cit.*, p. 83. In 1542, Reinhold was already familiar with Copernicus via the *Narratio prima,* as is shown by other passages cited by Duhem, *op. cit.*, p. 72. Moreover, Gemma was familiar with the commentary on the *Theoricae novae,* as he refers to it in connection with the *camera obscura* in his *De Radio,* chap. 18.

[22] E.O. Schreckenfuchs, *Commentaria in novas theoricas planetarum Georgii Purbachii,* Basel, H. Petrus, 1556, a 3 i r°: "Tradidit omnia secundum τὸ ὅτι, si quidem incipientibus haec ratio tradendi est, ob suam facilitatem, commodissima. Proponit enim res ut sunt, absque ullis demonstrationibus. Ptolemaeus vero tanquam artifex summus, arripuit viam tradendi secundum δί ὅτι. Quid multis? author iste proposuit diligentissime in hoc libello nuda ac brevia praecepta & regulas absque ullis causis & demonstrationibus, ut dictum est paulo ante. Ponit enim Mercurium verbi gratia, bis in una revolutione terrae proximum fore, ac bis ab ea maxime removeri quare hoc fiat non ostendit. Sed Ptolemaeus, qui secundum δί ὅτι incedit, quaerit causas, quibus inventis, demonstrat centrum deferentis epicyclum esse mobile, sicuti in Luna, & esse prorsus extra mundi centrum."

In the preface to Stadius' *Ephemerides*, Gemma thus reveals himself to be markedly more Copernican than his German contemporaries. In referring to the upper planets, he even puts forward an argument whose importance was later also noticed by Kepler, who went so far as to state it on several occasions. Thus he writes in the *Mysterium cosmographicum*:

> Similarly the ancients rightly wondered why the three superior planets ar always in opposition to the Sun when they are at the bottom of their epicycles, but in conjunction when they are at the top [...] In Copernicus's theory the reason is easily supplied. For it is not Mars on an epicycle but the Earth on its own circle which causes this variation.[23]

And in his *Apologia pro Tychone*, he likewise remarks:

> Copernicus wanted to simultaneously demonstrate the cause and the necessity of the three upper planets always being at the bottom of their epicycle when they are in opposition with the sun, [and] at the top when they are in conjunction. [...] In Copernicus, the cause is easily found. For it is not Mars in its epicycle, but the earth in its orbit which causes this variation.[24]

The closeness of Gemma's and Kepler's views on this point did not escape Riccioli, who, in his *Almagestum novum*, brought together the passages from the preface for Stadius and the quotation from the *Mysterium cosmographicum*[25]. We may in any case note that the preference given to Copernicus here is not based purely on calculatory and instrumental superiority, but concerns the system's intrinsic logic.

4. "And [Copernicus' hypotheses] attribute practically no absurdity to natural motions, as a result of which a more complete knowledge of the distances between the planets is drawn hence than from other hypotheses."[26]

Gemma remains very discreet about Copernican physics, contenting himself with the comment that they attribute "practically no absurdity to nat-

---

[23] Kepler, *Mysterium cosmographicum. The Secret of the Universe*, I, transl. A.M. Duncan, New York, Abaris Books, 1981, p. 81.

[24] Kepler, *Apologia pro Tychone contra Ursum*, I, ed. and transl. in N. Jardine, *The Birth of History and Philosophy of Science ...*, Cambridge, Cambridge University Press, 1984, p. 90.

[25] Riccioli, *Almagestum novum*, Bologna, 1656, VII, III, xi.

[26] "Neque quicquam fere absurdum naturalibus motibus committunt, unde hic amplior cognitio de planetarum distantiis colligitur, quam ex illis."

ural motions". Yet the recognition of multiple "natural" motions in the earth, like the attribution of its own centre of gravity to each planet, was in flagrant contradiction with Aristotelian physics. Copernican physics could not be reconciled with the "*doctrina communis*", and therefore contained significant "absurdities" in the sense in which the term was used at that time. Moreover, such "absurdities" would be severely criticised subsequently, as we learned from the example of Clavius, who sees this as one of the main arguments for rejecting the Copernican system[27]. For Gemma, however, this physical "absurdity" seems far less important than the mathematical coherence introduced by Copernicus in the planetary system. This eliminates another type of "absurdity", concerning logical inconsistency. The soundness of heliocentrism's internal logic is reflected in the better knowledge ("*amplior cognitio*") it affords of the distances between the planets. Gemma obviously has in mind the famous "symmetry" of the Copernican world, i.e. the proportionality of the planets' revolution times and their distances from the centre[28]. Ptolemy arranged the planets in a concentric order in which, in principle, revolution time increased with distance from the earth; in fact, however, the times taken by the Sun, Venus and Mercury to go round the Earth were the same, although they were located in different orbs. This inconsistency between principle and fact disappears in Copernicus' system, in which all the planets have different revolution times, the length of which increases with their distance from the centre. A logical "absurdity" is thus eliminated, the facts fit with the principle, and knowledge of the planets' distances has been improved on, as one can now precisely define the order of succession of all the planets.

5. **"Better still, if someone wishes, he can assign to the sky those motions of the earth that [Copernicus] adds to the first two, and use the same calculation procedures. But that highly learned and intelligent man considered it inadvisable, on account of these undisciplined minds, to invert the entire system of his hypotheses, and he contented himself with having established that which was sufficient for the true discovery of phenomena."**[29]

---

[27] For details, cf. J.M. Lattis, *op. cit.*, chap. V.

[28] Copernicus, *op. cit.*, p. 41: "Finally, concerning the main thing, i.e. the form of the world and the exact symmetry of its parts, they were unable either to find it or to recreate it." For a more detailed discussion of this "symmetry", cf. my *The Poetic Structure of the World,* New York, Zone Books, 1990, chap. 3.

[29] "Quin si quoque quispiam velit, poterit illos motus terrae, quos praeter duos primos ponit, ad coelum referre ac uti ijsdem Canonibus calculorum. Sed non placuit viro doctissimo & prudentissimo, ob ingenia haec indomita, totam Hypothesium suarum ordinem invertere, contentus statuisse, quae ad veram τῶν φαινωμένων inventionem sufficerent."

The text is extremely clear. Gemma passes in silence over the earth's diurnal and annual motions, as though these simply have to be accepted. But he speaks out in a more nuanced manner regarding the third motion. Copernicus assigned the third motion to the earth in order to uphold the consistency of his system, but its effects (the seasons, the precession of the equinoxes, the obliquity of the ecliptic) can also be attributed to celestial motions. Light can be shed on this reservation, regarding the third motion alone, by reading a number of passages of *De Astrolabo.* In the following extract, Gemma describes the equivalence between the two mechanisms:

> Since the opportunity arises, we shall now say a few words regarding the motion of the fixed stars, but I shall now follow the tables or canons of Copernicus to discover the position of the tail of Ursa Major in Roman times, because these alone correspond to the experience of the foregoing observations. And so that this may be understood by all those who are interested, we shall change the names and titles he uses into terms which are more easily grasped by everyone. Thus, let the motion that he calls the precession of the equinoxes be the motion of the ninth sphere, whose period is 25,816 years. And let the motion of the anomaly be the motion of the eighth sphere, one revolution of which is completed in 1,717 years. It follows that since, according to Copernicus, the point of the mean equinox was remote from the first star of Aries in the time of Christ – or [in other words] the first star of Aries was itself remote, by its mean motion (which we place in the ninth sphere) from the equinox or from the intersection of the ecliptic of the eighth sphere and of the equator – by 5°32' [...] The root of the anomaly or the motion of the eighth sphere at the time of Christ was, according to the same Copernicus, 6°45'.[30]

The precession of the equinoxes contains two aspects: a continuous motion and a *trepidation* or variation in the speed of this motion. Copernicus dis-

---

[30] "Dicemus autem per oportunitatem de fixarum motu aliqua, verum nunc sequar Copernici tabulas seu Canones ad inveniendum locum caudae Ursae Maioris ad tempus urbis Romae. Quoniam hae solae experientiae praecedentium observationum respondent. Atque haec ut et studiosis omnibus intelligantur permutabimus nomina appellationesque quibus ille utitur in eas quae ab omnibus facilius percipiuntur. Motus igitur praecessionis aequinoctiorum ab illo appellatus sit motus nonae sphaerae, cuius periodus est 25816 annorum. Motus vero anomaliae sit motus octavae sphaerae cuius integra rotatio una perficitur annis 1717. Quoniam ergo secundum Copernicum tempore Christi punctum aequinoctij mediocris erat remotum a prima stella Arietis, vel ipsa prima stella Arietis mediocri motu (quem nonae sphaerae ponimus) abscesserat ab aequinoctio seu intersectione eclipticae octavi orbis et aequatoris per 5 partes et 32 scrupula. [...] Iam vero radix anamoliae [sic] seu octavi orbis motus tempore Christi secundum eundem Copernicum erat 6 partibus 45 scrupulis." (*De Astrolabo,* 44 a–b).

tinguishes two components in his third motion, producing a conical motion of the earth's axis. One complete period of continuous motion takes 25,816 years, whereas one cycle of trepidation lasts 1,716 ans[31]. Gemma describes how the two components of the earth's third motion may be related to motions of the celestial spheres, according to traditional conceptions: in Peurbach, for example, who adopts the Alphonsine model, the continuous motion becomes dependent on the ninth sphere, which turns in the opposite direction to the tenth or first mobile (in 49,000 years according to the *Alphonsine Tables*), and the trepidation depends on the eighth, which turns about the ecliptic of the ninth and thus causes the irregularities identified (with a periodicity of 7,000 years according to the same tables). As can be seen, Gemma transposes the Copernican periodicities in the traditional framework.

Another passage of the *De Astrolabo* is important for a proper understanding of Gemma's attitude:

> Regarding the stars' longitudes, let others extract them from whatever tables or canons they like; I for my part prefer to follow those which I find correspond more precisely to both the Ancients' and our own observations, in other words the canons of Copernicus which Erasmus Reinhold has also followed in the *Prutenic Tables.* For the data found in the *Alphonsine Tables* depart by more than one degree from the apparent positions in the sky, as we have often experienced. Nor do they agree with the observations of others. I will not discuss here the theses regarding such motions or the motion of the eighth sphere or of the earth, because I know that when motions are invented orbits can easily be imagined along which such motions can be effected, either in the sky or sometimes on earth, according to one's fancy. But this debate must not be allowed to hold back those who are more skilled, since they know that orbits, epicycles and other such things have been formed to enable calculations to be made rather than that we might believe that such things really exist in nature. Even Ptolemy, who teaches that the same motion may be explained by an epicycle or by an eccentric, says this. But this lies outside my subject.[32]

In these lines, once again, Gemma does not take up a position regarding

---

[31] The obliquity of the ecliptic, which Gemma does not refer to here, follows a periodicity which is double that of the trepidation (3,436 years) whose cycle commences at the same moment.

[32] "Quod ad longitudines stellarum attinet, colligat alius ex quibuslibet tabulis seu canonibus, ego malo sequi illos quos experientiae cum veterum tum nostrae exactius respondere deprehendo, hoc est Copernici canones quos & Erasmus Reinheldus in tabulis

the choice between a third motion of the earth or the addition of new spheres. However, he does add that the epicycles and eccentrics have been introduced as calculation aids, rather than as celestial realities. Here he introduces an argument often expressed in the 16th century[33]. Should it be concluded from this that the entire representation of the planetary motions, and hence also that of the earth, is no more than a matter of astronomic fiction? Such an interpretation would be in contradiction with the lines of the preface to Stadius, where it is clearly stated that only the third motion can be called into question. How can these two texts be reconciled? The thesis regarding the earth's annual motion should doubtless be dissociated from the representation of that motion. Whether this latter is conceived of as including an epicycle or not is a matter of practical convenience, of effectiveness for calculation purposes. But the fact that an annual motion has every chance of being real and that it may be adopted as a truth, in whatever form it occurs, is another matter on which the preface to Stadius seems to leave no doubt.

The comparison between the preface to Stadius and the *De Astrolabo* shows that Gemma Frisius' position is carefully thought out, complex and nuanced. He takes as his basis a profound knowledge of questions of observation and of mathematical representation, together with an epistemological thinking which has its roots in the Aristotelian theory of knowledge. The combination of these factors brings him to the recognition of the mathematical truth of the earth's first two motions: "veram τῶν φαινωμένων inventionem". But he makes no pronouncement regarding the third motion, or the way in which the second is effected.

All of this demonstrates both conviction and prudence. The world's best mathematical system is heliocentric, to be sure. But uncertainties remain, regarding the number of the earth's motions and the exact way in which the planets in general perform their revolution around the Sun. We may also note that Gemma strongly emphasises the demonstrative superiority of heliocentrism when it comes to explaining phenomena mathematically, but that he scarcely touches on the physical implications of the matter.

Prutenicis observavit. Nam Alphonsinorum inventa plus integra parte aberrant ab apparentibus in coelo locis, ut saepius experti sumus. Neque cum aliorum observatis congruunt. Hic vero de thesibus talium motuum et de motu octavi orbis aut terrae nihil agam, quod sciam inventis motibus facile confingi orbes posse, per quos tales motus absolvantur, seu in coelo seu interdum in terra si quis velit. Sed haec disputatio non admodum distinere debet eruditiores, qui norunt orbes, Epicyclos, aliaque talia ad calculi inventionem constituti potius, quam ut revera credamus tales extare in rerum natura. Quod et Ptolomaeus fatetur, qui eundem motum et per Epicyclum et per Eccentrum exhibere posse docet. At haec praeter propositum…" (*De Astrolabo*, 31b–32a.)

[33] Cf. N. Jardine, *The Birth of History and Philosophy of Science…*, (*op. cit.*) pp. 225–258, *passim.*

It should doubtless be concluded that "truth" does not necessarily mean "reality". We should remember that at the start of the passage we have analysed, Gemma acknowledged that "hypotheses are not put forward by their authors as if they had to be expressed in this way and could not be constructed otherwise." This seems to mean that, for him, scientific truth is not necessarily ontological truth. At the very least, it seems justified to attribute to Gemma an attitude which could be described as "prudent realism", distinct from both radical realism and the various forms of scepticism. In Gemma's view, positing the double motion of the earth means more than employing an alternative calculation strategy: it is the best approximation of reality, the best "truth" we possess, because it offers greater effectiveness and above all the best consistency and the strongest mathematical explanatory power.

In all of this, Gemma's attitude is not fundamentally different from that of Copernicus, who also refers to uncertainties and expresses reservations about some of his propositions – and in fact on precisely those points on which Gemma is also hesitant. In his explanation of the obliquity of the ecliptic, he acknowledges that he is employing hypotheses which are merely probable, using expressions such as "*simplici coniectura*" or "*coniectura satis probabili*"[34]. Elsewhere (III, 20), the *De Revolutionibus* proposes three equivalent models for the Sun's motion: the double epicycle, the eccentric epicycle, and the double eccentric, all of which are accompanied by the following comment: "And since all ways lead to the same number, I could not easily say which is correct, but only that, that perpetual consonance of numbers and appearances obliges us to believe that it is one of them."[35] When a fourth possibility is then added (III, 25), Copernicus comments: "But we shall say more about this question in our explanation of the five wandering planets and we shall decide as far as we can, regarding it enough to apply calculations which are certain and not erroneous to the Sun's apparent motion."[36]

If Gemma had accepted the truth of all the particular constructions of the heliocentric system, he would in short have been more Copernican than Copernicus himself.

---

[34] Cf. N. Swerdlow, "On Copernicus' Theory of Precession", in R. Westman (ed.), *The Copernican Achievement* (o.c.), pp. 73 and 75. Swerdlow also notes that between the manuscript and the printed text, Copernicus adapts certain data to the theory.

[35] "Cumque tot modi ad eundem numerum sese conferant, quis locum habeat haud facile dixerim, nisi quod illa numerorum ac apparentium perpetua consonantia credere cogit eorum esse aliquem."

[36] "Sed de haec quaestione plura dicemus, in quinque stellarum errantium explanatione, quae pro posse nostro etiam decidemus, satis esse putantes, si iam certos numeros minimeque fallaces adsciverimus apparentiae Solari."

TRUTH AND VALUE TODAY: GALILEO CONTRA BELLARMINE

Karsten Harries

1.

Whenever science and religion collide, the condemnation of Galileo is almost inevitably mentioned as the most obvious example of the Church abusing its authority by trying to subject science to its will, denying the freedom that is demanded by the pursuit of truth: that philosophical freedom on which Giordano Bruno had so courageously and for him disastrously insisted.[1] With his precursor's fate in mind, Galileo was less courageous, but more prudent. Such prudence may have been strengthened by a conviction that, no matter what victories those who would silence those who speak the truth can claim, in the end truth will win out. And indeed: was the Church not forced to accept the truth defended by Galileo? In 1820 the Catholic astronomer Joseph Settele was allowed to teach the earth's motion as an established fact; in1822 the Church allowed books teaching it to be published; in 1835 Galileo's *Dialogue Concerning the Two Chief World Systems*, condemned in 1633, was omitted from the list of forbidden books; in 1893, in the encyclical *Providentissimus Deus*, Pope Leo XIII endorsed a view of the relationship of science and Biblical interpretation rather like that insisted on by Galileo in his "Letter to the Grandduchess Christina"; and finally, on November 10, 1979, Pope John Paul II, in a speech celebrating the centenary of Einstein's birth, admitted that Galileo had been treated unjustly by the Church, praised his religiousness, and singled out for special praise his understanding of the relationship of sci-

---

[1] Bruno pleaded for *philosophica libertas* in his valedictory oration to the professors at Wittenberg (1588). Campanella and Galileo were to reiterate that plea. See John M. Headley, *Tommaso Campanella and the Transformation of the World* (Princeton: Princeton University Press, 1997), pp. 172–173, fn 109.

ence and religion.[2] Here then we would seem to have the most famous example of the futility of all attempts to stifle free and independent inquiry in the name of orthodoxy. And is this not in accord with what St. Thomas already taught: that there is only one truth and that when science really establishes a truth, such truth cannot contradict Scripture. So let us not repeat the errors of the past.

But was the Church really so blind? Is Pope John Paul II's praise of Galileo's understanding of the relationship of science and religion deserved? Just how did Galileo understand that relationship? At issue here is not so much the truth of the Copernican position embraced by Galileo, as the meaning of truth and, bound up with this and more importantly, the problem of the value of truth, raised so insistently by Nietzsche, especially in *Beyond Good and Evil* and *On the Genealogy of Morals*.[3] Nietzsche thought that there was a deep connection between the commitment to truth presupposed by modern science and nihilism. How then can religion make its peace with science?

Nietzsche placed Copernicus at the origin of our nihilism: "Since Copernicus, man seems to have got himself on an inclined plane – now he is slipping faster and faster away from the center into – what? into nothingness? into a *penetrating* sense of his own nothingness?" "Has the self-belittlement of man, his will to self-belittlement not progressed irresistibly since Copernicus? Alas, the faith in the dignity and uniqueness of man, in his irreplaceability in the great chain of being, is a thing of the past – he has become an animal, literally and without reservation and qualification, he who was, according to the old faith, almost God ('child of God', 'Godman')."[4]

Already Schopenhauer had recognized the nihilistic implications of our post-Copernican cosmology. Here the beginning of Volume Two of *The World as Will and Representation*: "In endless space countless luminous spheres, round each of which some dozen smaller illuminated ones revolve, hot at the core and covered with a hard cold crust; on this crust a mouldy film has produced

---

[2] Maurice A. Finocchiaro, *The Galileo Affair. A Documentary History* (Berkeley, Los Angeles, London: University of California Press, 1989), pp. 306–308. Pope John Paul II's "Mémoration de la Naissance d'Albert Einstein," November 10, 1979, is now readily available on the internet: http://www.vatican.va/holy_father/john_paul_ii/speeches/1979.

[3] Friedrich Nietzsche, *Jenseits von Gut und Böse*, I, 1, *Sämtliche Werke, Kritische Studienausgabe*, ed. Giorgio Colli and Mazzino Montinari (Munich, Berlin, and New York: Deutscher Taschenbuch Verlag and de Gruyter, 1980), vol. 5, p. 15 and *Zur Genealogie der Moral*, III, 24, *Kritische Studienausgabe*, vol. 5, pp. 398–401.

[4] Nietzsche, *Zur Genealogie der Moral*, III, 25, *Kritische Studienausgabe*, vol. 5, p. 404. Trans. Walter Kaufmann and R. J. Hollingdale, *On the Genealogy of Morals and Ecce Homo* (New York: Vintage, 1989), p. 155.

living and knowing beings; this is empirical truth, the real, the world."[5] Our science knows nothing of privileged places, of absolute values, of home. And if what that science teaches us to accept as truth is identified with *the* truth, then, if we are to escape from nihilism, will we not have to cover up the truth or abandon it altogether? Could the insistence on *the* truth be an obstacle to living the good life? An obstacle to salvation or whatever might take the place of salvation given that death of God proclaimed by Nietzsche?

Nietzsche appropriated Schopenhauer's dismal if sublime vision in the very beginning of his youthful fragment *On Truth and Lie in an Extra-Moral Sense,* now so popular with post-modern critics weary of all centers: "Once upon a time, in some out of the way corner of that universe which is dispersed into numberless twinkling solar systems, there was a star upon which clever beasts invented knowing. That was the most arrogant and mendacious minute of 'world history,' but nevertheless, it was only a minute. After nature had drawn a few breaths, the star cooled and congealed, and the clever beasts had to die."[6] Nietzsche here emphasizes the immense disproportion between our life-time and the time of the world: does our post-Copernican universe, which threatens to reduce the time and space allotted to us to insignificance, care for us?[7] Was Nietzsche not right to insist that the progress that celebrates its triumphs in modern science and technology is necessarily attended by the specter of nihilism? The price of the rigorous pursuit of the facts of nature appears to be the progressive loss of whatever gives significance to human existence.

Pope Paul John II, to be sure, rejects this, calling science a universal good, to be freely pursued. But could Nietzsche have been right? If the pursuit of truth and nihilism should indeed be linked, it becomes easy to understand those who would take a step beyond nihilism by showing that what science takes to be truth is itself only a fiction; and it is not surprising that such sentiments should have found a welcome focus in a re-evaluation of the condemnation of Galileo. Can human beings ever claim to have seized *the* truth? Richard Rorty's *Mirror of Nature*[8] gives symptomatic expression to such

---

[5] Arthur Schopenhauer, *Die Welt als Wille und Vorstellung,* vol 2 (Brockhaus: Wiesbaden, 1965), p. 3. Trans. *The World as Will and Representation,* vol. 2, trans. E. F. J. Payne (New York: Dover, 1966), p. 3.

[6] Friedrich Nietzsche, "Über Wahrheit und Lüge im aussermoralischen Sinne," *Kritische Studienausgabe,* vol. 1, p. 875; trans. "On Truth and Lie in an Unmoral Sense," *Philosophy and Truth. Selections from Nietzsche's Notebooks of the Early 1870's,* trans. and ed, Daniel Breazeale (Atlantic Highlands: Humanities Press, 1979), p. 79.

[7] See Hans Blumenberg, *Lebenszeit und Weltzeit* (Frankfurt am Main: Suhrkamp, 1996).

[8] Richard Rorty, *Philosophy and the Mirror of Nature* (Princeton: Princeton University Press, 1979), pp. 328–333.

a re-evaluation: in that book Rorty asks whether today we can "find a way of saying that the considerations advanced against the Copernican theory by Cardinal Bellarmine – the scriptural descriptions of the fabric of the heavens – were 'illogical' or 'unscientific'?" Rorty argues that today we have to answer this question with a "no".

> The argument … centers around the claim that the lines between disciplines, subject matters, parts of culture, are themselves endangered by novel substantive suggestions. … Bellarmine thought the scope of Copernicus's theory was smaller than might be thought. When he suggested that perhaps Copernican theory was just an ingenious heuristic device for, say, navigational purposes and other sorts of practically oriented celestial reckoning, he was admitting that the theory was, within its proper limits, accurate, consistent, simple, and perhaps even fruitful. When he said that it should not be thought of as having wider scope than this he defended his view by saying that we have excellent independent (scriptural) evidence for believing that the heavens were roughly Ptolemaic.

Rorty goes on to ask: "What determines that Scripture is *not* an excellent source of evidence for the way the heavens are set up?" He thus invites us to think Cardinal Bellarmine's attempt to limit the scope of Copernicus' astronomical claims as fundamentally no different from Galileo's attempt to limit the scope of Scripture. Both Galileo and the Bible claim to describe "the way the heavens are set up". As it turned out, the future made Galileo the victor. The establishment of science, as we tend to take it for granted, is part of that victory. But this, according to Rorty, does not justify the claim that Galileo had reason on his side.

> The notion of what it was to be "scientific" was in the process of being formed. If one endorses the value – or, perhaps, the ranking of competing values – common to Galileo and Kant, then indeed Bellarmine was being "unscientific." But, of course, almost all of us (including Kuhn, though perhaps not including Feyerabend) are happy to endorse them. We are the heirs of three hundred years of rhetoric about the importance of distinguishing sharply between science and religion, science and politics, science and art, science and philosophy, and so on. This rhetoric has formed the culture of Europe. … But to proclaim our loyalty to these distinctions is not to say that there are "objective" or "rational" standards for adopting them.

Galileo and Kant happened to win the argument. But Rorty is unwilling to say that they won it because they had reason on their side: we simply do not know how to draw a clear line between theological and scientific discourse. We do not possess an understanding of truth sufficiently robust to allow us to draw it.

I want to make the opposite claim: we can draw such a distinction by appealing to the nature of truth. We don't just happen to endorse the values common to Galileo and Kant because we are the heirs of a certain rhetoric "about the importance of distinguishing sharply between science and religion." The commitment to objectivity that is a presupposition of science is inseparable from the pursuit of truth concerning the things that make up our world. To claim this, however, is not yet to claim to have answered the Nietzschean question of the value of that pursuit.

2.

But how are we to understand this pursuit? What is truth? Most people, although perhaps no longer most philosophers, would seem to be quite untroubled by this old Pilate question, quite ready to say with Kant that the meaning of truth is correspondence and that this is so obvious that it can be "*geschenkt, und vorausgesetzt,*"[9] granted and presupposed without need for much discussion. The essence of truth is here thought to lie in the agreement of the judgment with its object.

To be sure, as Kant recognized, we use truth in different senses. He thus distinguished such "material (objective) truth" from a merely formal or logical truth, where knowledge agrees with itself, abstracting from all content, and from merely aesthetic or subjective truth, where our understanding agrees with the subject and what appears to it. Error results when we mistake what is merely subjective for what is objective, mistake appearance for truth.[10] In this essay I am concerned first of all with the meaning and value of material, objective truth.

But just because it calls such truth into question, Kierkegaard's claim, "Truth is subjectivity," deserves some attention. Truth is understood here as "An objective uncertainty held fast in an appropriation-process of the most personal inwardness" – Kierkegaard was thinking of love and faith. This he calls "the highest truth attainable for an *existing* individual." In such attainment

---

[9] Immanuel Kant, *Kritik der reinen Vernunft,* A 58/ B 82.

[10] Kant, *Logik,* A 69–A 83.

the individual perfects him- or herself. And did not Kant understand "truth" as "the essential and inseparable condition of all perfection of knowledge"?[11] Kant might have questioned whether such subjective truth deserves to be called a perfection of knowledge. And as the expression "objective uncertainty" suggests, Kierkegaard, knew very well that first of all "the question of truth is raised in an objective manner, reflection is directed objectively to the truth, as an object to which the knower is related."[12] But his distinction between subjective and objective truth helps to bring into focus what is at issue when Nietzsche raises the question of the value of truth: "The way of objective reflection makes the subject accidental, and thereby transforms existence into something indifferent, something vanishing. Away from the subject the objective way of reflection leads to the objective truth, and while the subject and his subjectivity become indifferent, the truth also becomes indifferent, and this indifference is precisely its objective validity; for all interest, like all decisiveness, is rooted in subjectivity."[13] How then can religion make its peace with the commitment to objectivity and a truth that threatens to transform the world into the totality of essentially indifferent facts? Galilean science had to call the Church's claim to a truth that saves into question. Not that the Church would have found it easy to accept Kierkegaard's Protestant "Truth is subjectivity": how can organized religion make its peace with a privileging of subjectivity that threatens to deny the Church its claim to truth? But what is truth?

Thomas Aquinas defined truth as "the adequation of the thing and the understanding": *Veritas est adaequatio rei et intellectus.*[14] The definition claims that there can be no truth where there is no understanding. But can there be understanding without human beings? Does truth then depend on human beings? This would imply that there can be no eternal truths, unless human beings will be forever. But must we not dismiss that implication? When I claim some assertion to be true, I claim it, not just subjectively, here and now, but for all time, provided that I have taken into account all the relevant relativities. "Today the sun is shining" may not be true tomorrow or in some other place; but that does not mean that the state of affairs expressed in the assertion is not true *sub specie aeternitatis* and can be restated in language that removes the relativities. But does the definition of truth as the adequation of the thing and the understanding allow for such an understanding of truth? Is human

---

[11] Kant, *Logik* A 69.

[12] Søren Kierkegaard, *Concluding Unscientific Postscript,* trans. David F. Swenson and Walter Lowrie (Princeton: Princeton University Press, 1974), pp. 182, 178.

[13] *Ibid.*, p. 173.

[14] Thomas Aquinas, *Questiones disputatae de veritate,* qu. 1, art. 1.

life here on earth more than an insignificant cosmic episode? Consider once more the fable with which Nietzsche, borrowing from Schopenhauer, begins “On Truth and Lie in an Extra-Moral Sense.” Nietzsche here calls attention to the disproportion between the human claim to truth and our peripheral location in the cosmos and the ephemeral nature of our being. Must the time not come, when there will no longer be human beings, when there will be no understanding, and hence no truth?

Thomas Aquinas, to be sure, like any believer in the Biblical God, including the self-proclaimed Catholic astronomer Galileo, would have had no difficulty answering Nietzsche. His understanding of God left no room for thoughts of a cosmos from which understanding would be absent. His was a theocentric understanding of truth where we should note that the definition *veritas est adaequatio rei et intellectus* invites two readings: *veritas est adaequatio intellectus ad rem*, “truth is the adequation of the understanding to the thing” and *veritas est adaequatio rei ad intellectum*, “truth is the adequation of the thing to the understanding.” And is the second not presupposed by the first? Is there not a sense in which the truth of our assertions presupposes the truth of things or ontological truth? If we are to measure the truth of an assertion by the thing asserted, that thing must disclose itself as it really is, as it is in truth. But what could “truth” now mean? Certainly not an adequation of the thing to our finite, perspective-bound understanding: that would substitute appearances for the things themselves.

Theology once had a ready answer: every created thing necessarily corresponds to the idea preconceived in the mind of God and in this sense cannot but be true. The truth of things, understood as *adaequatio rei (creandae) ad intellectum (divinum)* secures truth understood as *adaequatio intellectus (humani) ad rem (creatam)*.[15] Human knowing here is given its measure in the divinely created order of the cosmos. Copernicus and Galileo considered themselves good Christians. They would not have quarreled with any of this. And such talk of the truth of things does accord with the way we sometimes use the words “truth” and “true”: e. g., when we call something we have drawn “a true circle,” we declare it to be in accord with our understanding of what a circle is. What we have put down on paper accords with an idea in our intellect. Here the truth of things is understood as *adaequatio rei (creandae) ad intellectum (humanum).*

But what right do we have to think that we can bridge the abyss that separates God’s infinite creative knowledge from our finite human understand-

---

[15] See Martin Heidegger, “Vom Wesen der Wahrheit,” *Wegmarken*, *Gesamtausgabe*, vol. 9 (Frankfurt am Main: Klostermann, 1976), pp. 178–182.

ing? Nietzsche was to insist that there is no such bridge. If we were to seize the truth, he claims in “On Truth and Lie,” our designations would have to be congruent with things. Nietzsche here understands truth as, not just a correspondence, but as the congruence of designation and thing: pure truth, according to Nietzsche, thus would be nothing other than the thing itself.[16] This recalls the traditional view that gives human discourse its measure in divine discourse. God’s creative word is nothing other than the truth of things. Here, too, our speaking is thought to have its measure in the identity of word (logos) and being. In this strong sense, truth is of course denied to us finite knowers.

Kant would have agreed with this claim: if we understand truth as the correspondence of our judgments and things in themselves, understood as noumena, another term that names the truth of things, then there is no truth available to us for Kant either. But Kant does not conclude, as Nietzsche does, that therefore we cannot give a transcendental justification of the human pursuit of truth. To be sure, theory cannot penetrate beyond phenomena; things as they are in themselves are beyond the reach of what we can objectively know. But this does not mean that the truth pursued by science is therefore itself no more than a subjective illusion. The truth of phenomena provides sufficient ground for science and its pursuit of truth. Key to our understanding of that truth is this thought: to understand that what we experience is only an appearance, bound by a particular perspective, is to be already on the road towards a more adequate, and that means here first of all less perspective-bound and in this sense freer understanding. The pursuit of truth demands a movement of self-transcendence that, by leading us to understand subjective appearance for what it is, opens a path towards a more adequate, more objective understanding. The pursuit of truth demands objectivity. Copernicus relies on this familiar pattern of thought to make his readers more receptive to his break with Aristotle and Ptolemy.

> And why are we not willing to acknowledge that the appearance of a daily revolution belongs to the heavens, its actuality to the earth? The relation is similar to that of which Virgil’s Aeneas says: “We sail out of the harbor, and the countries and cities recede.” For when a ship is sailing along quietly, everything which is outside of it will appear to those on board to have a motion corresponding to the motion of the ship, and the voyagers are of the erroneous opinion that they with all that

---

[16] Nietzsche, “Über Wahrheit und Lüge,” *Kritische Studienausgabe* vol. 1, p. 879; trans. p. 82.

> they have with them are at rest. This can without doubt also apply to the motion of the earth, and it may appear as if the whole universe were revolving.[17]

Ornamenting his remark with a reference to the *Aeneid*, Copernicus, uses the simile likening the earth to a ship, a simile found already in Cusanus' *De docta ignorantia*, to call the reader's attention to the relativity of apparent motion. Reflection on the nature of perspective teaches us that whatever presents itself to the eye, to perception, is no more than subjective appearance. To get to "actuality" or objective reality we have to reflect on the way point of view governs what appears to us. Objective reality cannot in principle be seen as it is. It is invisible and can only be thought.

Copernicus' distinction between appearance and actuality is a presupposition of the emerging new science and of our modern understanding of reality. Nietzsche had good reason to celebrate Copernicus and Boscovich as *die beiden grössten Gegner des Augenscheins*, as the two greatest opponents of the deceptive appearances presented to us by our eyes.[18] Quite in the spirit of the quoted Copernican passage, Kant thus distinguishes subjective appearances, thought relative to the embodied self and its location and make-up and hence inescapably perspectival, from the objects themselves thought relative to the transcendental subject, which as the form of all possible experience is not tied to any particular point of view.[19] This allows us to think the truth of scientific propositions as their correspondence to the objects themselves, not to be confused with Kant's things in themselves, which transcend our understanding, while the objects themselves are presupposed by the scientific pursuit of truth as its goal. This pursuit would be vain, were we to place the pursued objects beyond the realm of the knowable.[20] But by their very nature, such

---

[17] Nicolaus Copernicus, *De revolutionibus orbium coelestium* I, 8; Trans. in *The Portable Renaissance Reader*, ed. James Bruce Ross and Mary Martin McLaughlin (New York: Viking, 1953), p. 591.

[18] See Nietzsche's letter to Heinrich Köselitz of March 20, 1882. *Sämtliche Briefe, Kritische Studienausgabe*, vol. 6, p. 183.

[19] Kant, *Kritik der reinen Vernunft*, B 70 fn; see also A 29 fn.

[20] The direction of that pursuit is indicated by the possibility of opposing to those aspects of what we experience that change with the changing circumstances of the experiencing subject those that appear unchanged. "That in our faculty of knowledge, which in all changes of the subject remains unchanged is what is objective; that, however, that is changed together with the change in the subject is what is subjective in knowledge." Salomon Maimon, *Versuch einer neuen Logik oder Theorie des Denkens. Nebst angehängten Briefen des Philalethes an Aenesidemus* (Berlin, 1794), quoted in Ernst Cassirer, *Das Erkenntnisproblem in der Philosophie und Wissenschaft der neueren Zeit*, vol. 3, *Die nachkantischen Systeme* (Darmstadt: Wissenschaftliche Buchgesellschaft, 1994), p. 84.

objects cannot present themselves in perception as they are, bound as that is by the condition of the experiencing subject, but, beginning with experience, must be reconstructed in thought. Such reconstruction is the task of science. Not that it can ever be fully adequate to the objects themselves, which function only as a regulative ideal, but as such are indispensable. In the scientific pursuit of truth the regulative ideal of the truth of phenomena substitutes for the truth of things. God has been replaced with the transcendental subject, an idea implicit, as Kant recognized, in the pursuit of truth. Purified of the distortions brought about by the body's temporal and spatial location, the transcendental subject's "point of view" is that of all possible knowers. The other side of the thought of the transcendental subject is thus the regulative ideal of a truly objective understanding of reality. This leads to the demand that thinking free itself as much as possible from all dependence on particular points of view and from the perspectival distortions that are bound up with such dependence; allows us to demand objectivity. Given that demand, all those aspects of reality that presuppose a reference to some particular perspective have to be understood as mere appearance. This includes all secondary qualities, which are essentially tied to our senses and thus to what happens to be the constitution of the human body. As Galileo puts this in *The Assayer*:

> Now I say that whenever I conceive any material or corporeal substance, I immediately feel the need to think of it as bounded and as having this or that shape; as being large or small in relation to other things, and in a specific place at a specific time; as being in motion or at rest; as touching or not touching some other body; and as being one in number, or few, or many. From these conditions I cannot separate such substance by any stretch of my imagination. But that it must be white or red, bitter or sweet, noisy or silent, and of sweet or foul odor, my mind does not feel compelled to bring in as necessary accompaniments. Without the senses as our guides, reason or imagination unaided would probably never arrive at qualities such as these. Hence I think that tastes, odors, colors, and so on are no more than mere names so far as the objects in which we place them is concerned, and that they reside only in the consciousness.[21]

Following Democritus, Galileo here anticipates Descartes' reflections on a piece of wax in the *Meditations*. We gain objective understanding only to the extent that sights and sounds yield to measurable shape and movement. The commitment to objectivity demands the mathematization of nature. Here we

---

[21] *Discoveries and Opinions of Galileo,* trans. and intro. Stillman Drake (Garden City: Doubleday, 1957), p. 274.

have a key to Galileo's Platonism. This commitment also has to lead to a demand that language be purified as much as possible from everything that would bind it to particular perspectives, that ties it too closely to a particular natural language. Logic must be freed from grammar.[22] The devaluation of rhetoric and metaphor is a corollary. So understood, all discourse that would serve the truth has to aspire to whiteness in the sense in which Jacques Derrida, following Anatole France, has spoken of the whiteness of metaphysics.[23] With an eye to Thomas Nagel we may want to speak instead of a view from nowhere.[24]

3.

For Copernicus and Galileo the meaning of truth was inseparable from the thought of a timeless understanding, unburdened by perspective, where their faith in God supported their understanding of the truth of things. Was not God the author of the book of nature, as he was the author of the Bible? And did not God create us in his image, making us sufficiently godlike to be capable of reading and understanding that book?

But how are we to build a bridge across the abyss that separates our finite, perspective bound understanding from the truth of things. This much is certain: if the truth of our judgments is to have its measure in the truth of things, must they not disclose themselves to us in such a way that they can provide such measures? But how are we to think such disclosure? It is not surprising that Galileo, too, should have looked first of all to perception, claiming to be in profound agreement with Aristotle, so much so that he can charge those who continue to hold on to a geocentric cosmology with being less faithful to the Stagirite than he with his trust in the eye.

> I should even think that in making the celestial material alterable, I contradict the doctrine of Aristotle much less than do those people who still want to keep the sky inalterable; for I am sure that he never took to be its inalterability as certain as the fact that all human reasoning must be placed second to direct experience.[25]

---

[22] Wittgenstein, *Tractatus* 4.003; see also Heidegger, *Die Lehre vom Urteil im Psychologismus* (Leipzig: Barth, 1914), pp. 99–101; reprinted in *Gesamtausgabe* (Frankfurt am Main: Klostermann, 1978), vol. 1, pp. 157–159.

[23] Jacques Derrida, "White Mythology: Metaphor in the Text of Philosophy," *Margins of Philosophy*, trans. Alan Bass (Chicago: Chicago University Press, 1982).

[24] See Thomas Nagel, *The View from Nowhere* (New York: Oxford University Press, 1986).

[25] *Discoveries and Opinions of Galileo*, p. 118.

In a letter to Kepler Galileo speaks of his colleagues at Padua, who, as he puts it, with the persistence of a snake, closed their eyes *contra veritatis lucem*, to the light of truth.[26] But Galileo knew better than to equate the light that allows us to see with the light of truth. He knew that while there is a sense in which reasoning must be placed second to direct experience, a distrust of such experience is a presupposition of the pursuit of truth. He could have cited the passage from Copernicus' *De revolutionibus* quoted above in support. Had Plato not shown long ago the evidence of direct experience to be inextricably bound by perspective, substituting appearance for reality? Galileo makes this point when he criticizes Sarsi in *The Assayer*:

> Your Excellency will note the great confidence which Sarsi places in the sense of sight, deeming it impossible for us to be deceived by a spurious object whenever that may be placed besides a real one. I confess that I do not possess such a perfect faculty of discrimination. I am more like the monkey that firmly believed that he saw another monkey in the mirror, and the image seemed so real and alive to him that he discovered his error only after running behind the glass to catch the other monkey.[27]

Before we can claim truth, we have to consider the perspectival distortions to which our position in space and time and the make-up of our senses subject us. But if direct perception does not secure access to the truth of things, how is such access to be gained? In *The Assayer* Galileo points to reason. Experience and experiment provide an indispensable ground, but what reason cannot help but ascribe to nature provides the key to the language science must speak if it is to claim truth.

In this respect, too, Galileo can claim to be faithful to the spirit of Copernicus. According to Copernicus there are at least these two conditions that must be met if we are to understand the propositions of a science as serious claimants to truth: 1. The hypotheses advanced by science must "save the appearances," i. e., they must agree with the best available observations. 2. They have to be arrived at by following a method based on principles that are certain (*certa principia*)[28] because supported by insight into the very essence of nature.

---

[26] Letter of August 10, 1610, in Galileo Galilei, *Opere*, 20 vols. ed. Antonio Favaro (1890–1909), cited in Hans Blumenberg, *Die Genesis der kopernikanischen Welt* (Frankfurt am Main: Suhrkamp, 1975), p. 763.

[27] *Discoveries and Opinions of Galileo*, p. 255.

[28] Nicolaus Copernicus, *De revolutionibus Orbium Coelestium*, "Proemium," in *Das Neue Weltbild. Drei Texte: Commentariolus, Brief gegen Werner, De revolutionibus* I, Lateinisch-deutsch, trans., ed., and intro. Hans Günter Zekl (Hamburg: Meiner, 1990), p. 72.

That the first condition cannot secure claims to truth Copernicus and Galileo knew very well. As Osiander was to put it in his phony preface to *De revolutionibus*: hypotheses that provide "a calculus consistent with the observations" need not be "true or even probable."[29] So understood astronomy need not be concerned with truth, but should be content to save the appearances. That was the position the Church wanted Galileo to endorse. Pierre Duhem later was to agree with Osiander. And Husserl, as Patrick A. Heelan points out approvingly, had a similar understanding of Galilean science: "Mathematical models according to Husserl provide technical computational power but, of themselves, independently of the life-world, do not illuminate the things that comprise nature or provide the categories for natural objects."[30] I shall have occasion to return to this point, which raises the question whether such a turn to the life-world will not substitute for objective truth some version of subjective truth.

What is clear is that Galileo did claim truth for his science and knew that Copernicus' first condition is insufficient to secure such a claim, reason enough for him to dismiss Osiander's preface. Copernicus, while he did not claim to have seized the truth once and for all, did indeed leave no doubt concerning his goal: to describe, as best he could, *mundi formam*, the true form of the world.[31] And his commitment to objective truth made it important to Galileo that, when leaving his professorship of mathematics at the University of Padua to take up a position at the court of Cosimo Medici and a professorship at Pisa, his title be mathematician and philosopher. The censure of 1616, addressed to the mathematician, not the philosopher, makes clear what is at issue: consider the Consultants' Report of February 24, 1616, which states that the propositions "The sun is the center of the world" and "The earth is not the center of the world" are "foolish and absurd in philosophy."[32] The importance of the word "philosophy" here is underscored by the authorization of the following day, warning "the mathematician Galileo" to abandon his opinions.[33] Eight days later Copernicus' *On the Revolution of Spheres* and Galileo's friend Foscarini's *Letter on the Pythagorean and Copernican Opinion of*

---

[29] "Ad Lectorem De Hypothesibus Huius Operis", in Nicolaus Copernicus, *Das neue Weltbild,* p. 62; trans. Edward Rosen, *Three Copernican Treatises, The Commentariolus of Copernicus, the Letter against Werner, The Narratio Prima of Rheticus,* 2nd ed. (New York: Dover, 1959), p. 25.

[30] Patrick A. Heelan, "Husserl, Hilbert, and the Critique of Galilean Science," *Edmund Husserl and the Phenomenological Tradition,* ed. Robert Sokolowski (Washington: Catholic University Press, 1988), p. 162.

[31] "Proemium," p. 70.

[32] Finocchiaro, *The Galileo Affair,* p. 146.

[33] *Ibid.*, p. 147.

the Earth's Motion are placed on the index of forbidden books. But at the time both the Church and Galileo seemed eager to avoid a confrontation and thus trouble. This is suggested by Cardinal Bellarmine's Certificate of May 26, 1616, declaring that Galileo had been notified that the doctrine that the sun is at the center of the world was contrary to Holy Scripture and could not be defended or held, but that, contrary to rumors that were being spread, he had not been asked to recant. The Church must have hoped that Galileo would be content with the part of a mathematician and not claim the mantle of a philosopher. But Galileo had to refuse that invitation. In a letter to Dini he states what was at stake:

> I should not like to have great men think that I endorse the position of Copernicus only as an astronomical hypothesis, which is not really true. Taking me as one of those most addicted to this doctrine, they would believe all its other followers must agree, and that it is more likely erroneous than physically true. This, if I am not mistaken, would be an error.[34]

Galileo is here concerned not only for the (physical) truth, but also for his reputation as its defender. Given his investment in that image, it was difficult to avoid collision with a Church that since the days of Copernicus, let alone those of Cusanus, had grown ever more conservative. It could not be reassured by a statement such as the following:

> To me, the surest and swiftest way to prove that the position of Copernicus is not contrary to Scripture would be to give a host of proofs that it is true and that the contrary cannot be maintained at all; thus, since no two truths can contradict one another, this and the Bible must be perfectly harmonious.[35]

Galileo knew of course that defenders of the tradition could point to many apparent contradictions. The Bible does seem to assume a geocentric cosmology. According to Galileo, and Pope John Paul II was to endorse such conviction, such "contradictions" can only be apparent, due either to deficient science or deficient theology:

> In regard to falsifying Scripture, this is not and will never be the intention of Catholic philosophers such as ourselves; rather our view is that Scripture corresponds very well to truths demonstrated about nature.

---

[34] *Ibid.*, p. 167.

[35] *Ibid.*, p. 166.

> Moreover, certain theologians who are not astronomers should be careful about falsifying Scripture by wanting to interpret it as opposed to propositions that may be true and demonstrable.[36]

The implications are clear: science is capable of the truth. As a Catholic astronomer, Galileo is also prepared to grant the truth of Scripture, but he is not willing to grant that its interpreters have grasped that truth.

> It might happen that we could have difficulties in interpreting Scripture, but this would occur because of our ignorance and not because there are really insuperable difficulties in reconciling Scripture with demonstrated truths.[37]

The tables have been turned: while the theologians insisted that the truth claims of science be brought in accord with Scripture, now their interpretations of Scripture are to be brought in accord with what science has to tell us. The natural philosopher, who relies only on experience and reason, rather than the theologian, who relies on Holy Scripture, tradition, and reason illuminated by faith and grace, has become the privileged custodian of truth.

Galileo's distinction between the real, although perhaps still undiscovered meaning of Scripture, which is taken to be in principle compatible with the new science, and its apparent meaning, which may well be incompatible, makes Scripture an uncertain guide to truth. How can we be sure that we have gotten hold of the real meaning of the Scriptural text and not just of an all too human and therefore fallible interpretation? Such questioning invites skepticism in matters of religion going far beyond the matter at hand. Just as we cannot trust the seemingly direct evidence of the eyes, we cannot trust the seemingly direct evidence of the Biblical text. Protestant appeals to God's Word as a solid base for genuine Christianity invite anarchy and skepticism, just as do appeals to direct perception. In both cases more is needed to secure claims to truth.

Against such skepticism the Counter-Reformation insisted on the authority of tradition. Appealing to the Council of Trent Bellarmine thus points out in a letter to Foscarini that that "Council prohibits interpreting Scripture against the common consensus of the Holy Fathers," supported by "the modern commentaries on Genesis, the Psalms, Ecclesiastes, and Joshua."[38] According to the cardinal it is this continuing community of interpreters guided

---

[36] *Ibid.*, p. 83.

[37] *Ibid.*, pp. 83–84.

[38] *Ibid.*, p. 68.

by the Holy Spirit that must be considered the guardian of truth. Bellarmine here presents us with a version of a consensus theory of truth. Hermann Lübbe speaks of "consensus objectivity" (*Konsensobjektivität*).[39]

But such objectivity, based on an intersubjectively acceptable reading of Scripture, is relative to the Church, an ever evolving establishment, and must therefore be distinguished from the kind of scientific objectivity insisted on by Galileo and his successors. The facts, they insist, are what they are, regardless of what human beings may think.

> If the earth de facto moves, we cannot change nature and arrange for it not to move. But we can rather easily remove the opposition of Scripture with the mere admission that we do not grasp its true meaning. Therefore the way to be sure not to err is to begin with astronomical and physical considerations, and not with scriptural ones.[40]

The truths of science are available to any unprejudiced inquirer. Experience and reason provide sufficient guidance. And in his defense Galileo could have reminded the Inquisitors that it was to Pope Paul III, who called the Council of Trent, that Copernicus dedicated *De revolutionibus* with words that left no doubt about the capability of human reason to grasp the truth. Was it not that Council that insisted, against the Protestants' cognitive pessimism, that original sin, while no doubt it had damaged reason and will, had not corrupted them so completely that sound judgment was now beyond our reach. The Council thus gave new legitimacy to a Christian humanism. As did Copernicus, Galileo understood himself to be such a humanist. Our reason testifies to our creation in the image of God. To be true to itself, reason cannot sacrifice what it has recognized to be true to the authority of tradition. This does not mean that the inquirer should not be open to the challenges presented by others. Kant knew that the pursuit of truth demands a willingness to test our judgments by the judgments of others and criticizes the "logical egoist" who claims not to need this *criterium veritatis externum.*[41] But this is an external criterion. The meaning of truth may not be sought in such a consensus, which provides hardly an adequate criterion. Objective truth is what it is, and transcends whatever particular human beings may hold to be true. That truth is made by Galileo the measure of all other claimants to the truth, and that includes theologians.

---

[39] See Hermann Lübbe, "Die Identitätspräsentationsfunktion der Historie," in *Praxis der Philosophie, Praktische Philosophie, Geschichtsphilosophie* (Stuttgart: Reclam, 1978), pp. 97–122.

[40] Finocchiaro, *The Galileo Affair,* p. 82.

[41] Kant, *Anthropologie,* BA 6.

But this does not answer the question: how does reason lead us from phenomena to the truth of things? What allowed Galileo to claim the mantle of the philosopher?

4.

Defending his claim to be not just another astronomer content to offer calculations that would save the phenomena, Galileo in his "Notes on the Copernican Opinion" appeals to Ptolemy in support of his claim that from the very beginning astronomers have also been philosophers:

> Astronomers have so far made two sorts of suppositions: some are primary and pertain to the absolute truth of nature; others are secondary and are imagined in order to account for the appearances of stellar motions, which appearances seem not to agree with the primary and true assumptions. For example, before trying to account for the appearances, acting not as a pure astronomer, but as a pure philosopher, Ptolemy supposes, indeed he takes from philosophers, that celestial movements are all circular and regular, namely uniform; that heaven has a spherical shape; that the earth is at the center of the celestial sphere, is spherical, motionless, etc. … Turning then to the secondary inequalities we see in planetary movements and distances, which seem to clash with the primary physical suppositions already established, he goes on to another sort of suppositions. … This secondary supposition is the one of which it could be said that the astronomer supposes it to facilitate his computations, without committing himself to maintaining that it is true in reality and in nature.[42]

The first kind of supposition claims absolute truth, as Ptolemy did, when he endorsed the Platonic axiom that the motion of the heavenly bodies is circular and uniform and placed the earth at the center of the spherical cosmos. In all of this, as it turned out, he was mistaken. Unwittingly he substituted for truth the appearance of truth. But that does not change the meaning of what he claimed. He asserted it to be "true in reality and in nature" and in support he could appeal to Aristotle's metaphysics of nature.

Galileo would have us understand Copernicus in the image of Ptolemy. To be sure, Copernicus assigns the central place to the sun and claims that the earth moves. But "the earth's motion and the sun's stability," Galileo insists, must be understood as "primary and necessary suppositions about na-

---

[42] Finocchiaro, *The Galileo Affair,* pp. 75–76 .

ture," claiming absolute truth, where the comparison with Ptolemy has to raise the question whether Copernicus, too, did not substitute the appearance of truth for truth. But is Galileo right here? Did Copernicus consider the earth's motion and the sun's stability primary truths? If so, he could not have appealed to an available metaphysics of nature for support. Nor did he attempt to furnish such a metaphysics, although we are given at least the trace of such a metaphysics with the Platonic axiom, which he retains. But that does little more than prescribe a certain mathematical form.

Galileo's distinction between primary and secondary suppositions can be supported by citing Ptolemy's *Almagest*: "We know, finally that some variety in the type of hypotheses associated with the circles [of the planets] cannot plausibly be considered strange or contrary to reason ...; for, when uniform circular motion is preserved for all without exception, the individual phenomena are demonstrated in accordance with a principle which is more basic and more generally applicable than that of similarity of the hypotheses [for all planets]." If hypotheses are not to be considered "strange or contrary to reason," they must accord with some more basic principle. But is such conformity to human reason sufficient to secure claims to what Galileo terms physical truth? Does it not threaten to make what such hypotheses assert relative to what human beings are able to comprehend?

Copernicus was to appropriate Ptolemy's claim that individual phenomena need to be demonstrated in accordance with some basic principle. And like Galileo he was convinced that if an astronomer's hypotheses were to warrant a claim of truth they had to be not just in accord with reason but based on *certa principia*. But Copernicus did not include heliocentrism among these certain principles. That the sun is at the center of the cosmos had to be demonstrated rather than presupposed. Copernicus does presuppose the Platonic axiom, which, he points out, was granted, by all his precursors, and is expressed in the title of Chapter Four of *De revolutionibus*. Copernicus presupposes its validity when he criticizes the speculations of his predecessors for not having been either "sufficiently absolute" (*satis absoluta*) or "sufficiently in agreement with reason" (*rationi satis concinna*).[43] One argument against the Ptolemaic system is that it violated the requirement of uniformity.

But the question returns: is conformity to human reason, as expressed in the Platonic axiom, sufficient to secure claims to the truth of things? Galileo, retaining this axiom, was convinced that there was no abyss that separated human from divine reason. God created us in his image so that we might read in the book of nature.

---

[43] *Commentariolus*, in Copernicus, *Das neue Weltbild*, p. 4.

> Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend such language and read the letters in which it is composed. It is written in the language of mathematics and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it; without these, one wanders as in a dark labyrinth.[44]

Long ago Plato had suggested this way out of the labyrinth: "And the arts of measuring and numbering and weighing come to the rescue of the human understanding – there is the beauty of them – and the apparent greater or less, or more or heavier, no longer have mastery over us, but give way before calculation and measure and weight?"[45] But unlike Galileo, Plato did not think that philosophy was written in nature. According to him it was written in the minds of men.[46] Within itself the mind finds access to the invisible cosmos of the ideas. To be sure, the material world is informed by the forms – think of the creation account in the *Timaeus* – but it also always offers a certain resistance to such formation. Plato thus thinks in terms of the opposition of matter and form. But the Biblical God is omnipotent: there can be nothing outside the creator's power. Galileo's claim that nature is a book written in the language of mathematics is thus just as much a Christian as a Platonic thought, although such a Christian Platonism also has to bring to mind Pythagoras. According to this Christian Platonism mathematics allows us to understand the very essence of nature.

But the core of Galileo's claim does not depend on the Christian God. Kant's transcendental subject is sufficient to legitimate the mathematization of nature demanded by Galileo. There is, however, this important difference: Kant would point out that nature so understood may not be equated with things in themselves; the truth of phenomena now substitutes for the truth of things. According to Kant such a substitution is demanded by the scientific pursuit of truth, which thus demands a certain cognitive resignation. Such a distinction between phenomena and things in themselves is foreign to Galileo. But, as Nietzsche recognized, its elision has to lead to nihilism, reason enough to revisit Pope John Paul II's praise of Galileo's understanding of the relationship of science and religion.

---

[44] Galileo, *The Assayer*, in *Discoveries and Opinions of Galileo*, pp. 237–238.

[45] Plato, *Republic,* X, 602 c-d, trans. Benjamin Jowett.

[46] Cassirer, "Galileo's Platonism," *Studies and Essays in the History of Science and Learning in Honor of George Sarton* (New York: Schumann, 1946), pp. 277–297.

5.

Kant had good reason to want to distinguish phenomena from things in themselves and to insist that what science pursues is the truth of phenomena. What is at stake is hinted at by Patrick Heelan when he agrees with Husserl that mathematical models, while they may provide computational power, "do not illuminate the things that comprise nature or provide the categories for natural objects." Heelan speaks of the "objectivism" of Galilean science. "Objectivism implies that the description provided by scientific theory (and its mathematical model) ought for the purposes of philosophy to replace the language of the direct experience of the life world."[47] I have argued here that scientific theory ought to replace the language of the direct experience of the life world to the extent that such theory is the pursuit of the truth of the phenomena that make up nature. Can a different meaning be given to the truth of things? No doubt, but, I would claim, only at the price of objectivity.

As Kant recognized, there is a sense in which nature or reality is elided by the very pursuit of objective truth. Such an elision is inscribed into the conception of reality or the metaphysics of nature that is presupposed by science, as inaugurated by Copernicus and Galileo. Science aims at a perspicuous representation of the world that ideally would include everything that deserves to be called real. In the *Tractatus* Wittgenstein offers us this example:

> 6.341 Newtonian mechanics … brings the description of the universe to a unified form. Let us imagine a white surface with irregular black spots. We now say: Whatever kind of picture these make I can always get as near as I like to its description, if I cover the surface with a sufficiently fine square network and now say of every square that it is white or black. In this way I shall have brought the description of the surface to a unified form. This form is arbitrary, because I could have applied with equal success a net with a triangular or hexagonal mesh. It can happen that the description would have been simpler with the aid of a triangular mesh; that is to say, we might have described the surface more accurately with a triangular, and coarser, than with the finer square mesh, or vice versa, and so on. To the different networks correspond different systems of describing the world. Mechanics determine a form of description by saying: All propositions in the description of the world must be obtained in a given way from a number of given

---

[47] Heelan, p. 159.

> propositions – the mechanical axioms. It thus provides the bricks for the building of the edifice of science, and says: Whatever building thou wouldst erect, thou shalt construct it in some manner with these bricks and these alone.

Reality is here pictured as a page bearing irregular black spots. Science covers this picture with a network and proceeds to represent the original picture by filling in the proper areas, where we should keep in mind what is sacrificed here for ease of representation: the irregularity of the black spots which stand here for what disinterested, unprejudiced observation determines to be the case. By its very project, science so understood tends to elide reality, tends to mistake reality for what it can represent. And it is therefore not surprising that in the *Tractatus* Wittgenstein himself should elide that rift between reality and its scientific representation to which his own picture calls our attention, when he identifies the world with the facts in logical space (1.13), instead of being content with the more modest formulation: the scientific world-picture represents nature in logical space (cf. 2.11).

Wittgenstein's scientist is a builder who uses for his building-blocks thoughts or propositions. That such objectification has to transform that reality in which we find ourselves first of all and most of the time is evident: our first access to reality is always bound to particular perspectives, mediated by our bodies, colored by our concerns and interests. But as soon as we understand a perspective as such, in thought at least we are already beyond the limits it would impose. Such reflection on perspective and point of view leads inevitably to the idea of a subject that, free of all perspectives, understands things as they really are. And it leads with equal necessity to the thought that the reality that gives itself to our eyes, and more generally to our senses, is the mere appearance of an objective reality no eye can see, no sense can sense, that only a rational thinking can attempt to reconstruct.

The pursuit of truth demands objectivity. And objectivity demands that we not allow our understanding to be clouded by our inevitably personal desires and interests. It wants just the facts. With good reason Wittgenstein could therefore say: "In the world everything is as it is and happens as it does happen. In it there is no value – and if there were, it would be of no value" (6.41). It would be just another fact that, like all facts, could be other than it happens to be. If there is something that deserves to be called a value, it will not be found in the world of science. To find it we have to step outside that world. And the same goes for freedom. That means that persons as persons are not part of the scientific world picture. They are ruled out by the form of representation that governs it. This is why Nietzsche can say, stone is more stone than it used to be.[48] Matter has become just a mute given that happens to be that way.

But is this not to say that whatever makes life meaningful must be sought outside the reality known to science? Heidegger makes this elision of meaningful reality a defining feature of our age, of what he calls the "Age of the World Picture": "When we think of a 'picture' we think first of all of a representation of something. Accordingly the world-picture would be, so to speak, a picture of what is in its entirety. But 'world-picture' says more. We mean by this term the world itself, what is in its entirety, as it measures and binds us."[49] To the world so understood we, too, belong, for it is said to include all that is. The world-picture thus transforms itself into something like a house, into a building, in which we, too, have our place. If this world-picture is to include all that is, it cannot have an outside. But this means the loss of what Kant calls things in themselves, and every time we experience a person as a person we experience such a thing in itself. There is no experience of persons without at least a trace of respect. In this sense we can agree with Kierkegaard that subjective truth is higher than objective truth, where we must resist the temptation to translate such subjective truth into some version of objective truth, as phenomenology so often has attempted to do. To the extent that the modern world is indeed what Heidegger calls "the age of the world-picture" it has become a prison that denies us access to the reality of persons and things. To experience the aura of the real that gives to persons and things their proper weight we have to escape from that prison, have to open a door, or at least a window in the world building scientific understanding has raised, a window to the truth of things, but now "truth" may no longer be understood as objective truth. The Church was thus right to deny that the truth that mattered to faith, and we can extend the point and, following Kierkegaard, say the truth that matters to existing individuals, should take second place to the truth that matters to science. But the Church was wrong to think that the truth that matters to faith be understood as objective truth. Copernicus and Galileo put the pursuit of objective truth on the right track. But just because they did, it remains important to consider both the legitimacy and the limits of that pursuit.

---

[48] Nietzsche, *Menschliches, Allzumenschliches*, I, 218, *Kritische Studienausgabe*, vol. 2, p.p. 178–179.

[49] Martin Heidegger, "Die Zeit des Weltbildes," in *Holzwege*, *Gesamtausgabe*, vol. 5 (Frankfurt am Main: Klostermann, 1977), p. 89.

Filozofski vestnik Volume/Letnik XXV • Number/Številka 2 • 2004 • 107–123

LYOTARD AND THE “SECOND COPERNICAN TURN”

Peter Klepec

At first glance it would seem that to even mention the name of Jean-François Lyotard in company with Nicolaus Copernicus is utterly out of place. What could a famous Polish astronomer and a notorious French contemporary philosopher have at all common? Lyotard’s special theory of Copernicus’ does not exist and there is nothing in particular in Copernicus’ writings that could elucidate Lyotard’s. But there is, however, a certain link between the two which could be of some help here. Is Copernicus’ theoretical gesture in its very nature revolutionary? There are two more popular contemporary answers. On one side there are those who claim that the emergence of Copernican astronomy is “a particularly famous case of paradigm change”,[1] on the other hand there are those scholars who claim that Copernicus himself is rather a conservative thinker, that the “Copernican revolution”, if there ever was one, did not take place in its full sense until Kepler and Newton. “For the sciences, the real impact of Copernican astronomy did not even begin to occur until some half to three-quarters of a century after the publication of Copernicus’ treatise (1543), when in the early seventeenth century considerations of the physics of a moving earth posed problems for the science of motion. These problems were not solved until a radical new inertial physics arose that was in no way Copernican but was rather associated with Galileo, Descartes, Kepler, Gassendi, and Newton. Furthermore, during the seventeenth century the Copernican astronomical system became completely outmoded and was replaced by the Keplerian system. In short, the idea that a Copernican revolution in science occurred goes counter to the evidence […] and is an invention of later historians. […] There is an obvious parallel here with the so-called English revolution of the mid-seventeenth century, which

---

[1] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, Third Edition, University of Chicago Press, Chicago and London 1996, p. 68.

was not generally conceived to have been a revolution until after the French Revolution, a century and a half later."[2]

There are then two major positions personified by Kuhn and I. B. Cohen concerning Copernicus' place in the history of science. There are many more, of course, as the present volume of *Filozofski vestnik* clearly and vividly testifies to. What if we add another possible approach and try to say "something completely different" as the Monty Pythons would say, i.e. how would it be, if we tried to tell the same old story from another point of view. In other words, it is time for Lyotard to make his entry on the scene. Not only because his major work *The Differend* is centered on the problem of testimony, but also because he constantly discusses themes that are tightly linked and which might throw new light on our discussion about Copernicus' theoretical gesture, and the themes of enthusiasm and the transition in art and literature from the invisible to the visible. Apparently this topic has nothing to do with science or Copernicus' gesture as such. But if even if we carefully distinguish between a Copernican and a scientific revolution as Cohen does in his otherwise brilliant work, nobody can deny the fact that the scientific revolution was at least partly carried out in the belief that with Copernicus something *did* happen. Whatever that something may have been, perhaps even for the wrong reasons, it has always been accompanied by a certain feeling, a feeling that we are perhaps dealing with *the event* in science. Here we are already on Lyotard's terrain, for his theory claims that an event is always accompanied by a feeling. This feeling "informs consciousness *that* there is something, without being able to tell *what* it is. It indicates the *quod* without the *quid*. The essence of the event: that *there is* 'comes before' *what* there is."[3] Does not our dilemma here concern the very status of Copernicus' gesture in exactly the same manner? Was it not only later elaborated what there was in Copernicus' original gesture? Even more, was not the scientific revolution also possible only because of the very enthusiasm of the spectators of the Copernican revolution, in other words, were Copernicus' successors not always driven by the belief that as regards Copernicus, something did happen, a belief which was crucial for the scientific revolution, which was going to make "the Copernican astronomical system completely outmoded" and "replaced it with the Keplerian system"? This feeling that something did happen with Copernicus – be it "turn", "revolution", "turning point", "paradigm-shift" – bears *a name*,

---

[2] I. B. Cohen, *Revolution in Science*, Belknap Press of Harvard University Press, Cambridge (Ma.) and London 1985, p. 106–107.

[3] Jean-François Lyotard, *Heidegger and "the jews"*, translated by Andreas Michel and Mark S. Roberts, University of Minnesota, Minneapolis 1990, p. 16.

Copernicus' name. Many thinkers from Kant[4] to Freud[5] used this name not only to reinforce the image of Copernicus as a brave thinker whose gesture changed the world, but also believed that their gesture was revolutionary, too. There are others, such as Nietzsche, for whom Copernicus also marks a turning point in Man, it is, however, uncertain whether we are dealing here with nihilism or a resort to an old Ideal.[6] But here, with Kant, Freud and Nietzsche, we have already slightly changed the terrain – we are no longer on the terrain of Copernicus, but the terrain of the "Copernican turn". But first a remark or two.

So, with Copernicus something undoubtedly occurred, something did happen, but this something, if there had not been others to develop it further, if there had not been a scientific revolution, would today be meaningless. This problematic of something which is too soon and shocking interests Lyotard, or, as he puts it in a different context, "something, however, *will make* itself understood, 'later'".[7] In his late opus Lyotard thus thematized the very emergence of something new and different, of something that had until then been thought to be impossible. This something not only emerges, so to speak, out of nothing, but also reformulates, or better stated, demands a reconfiguration of the entire situation.[8] Didn't exactly that happen with and especially after Copernicus in the field of science? Here we have three dimensions of the same problem: firstly, the emergence of something disrupting, something which throws new light on a particular problem, secondly, the elapse of some time between the "original" impact and later consequences, and thirdly, someone who will carry out what the original invention did not succeed in doing. This problem has different faces in Lyotard, for instance, when he in *The Differend* claims that "every wrong ought to be able to be put into phrases", he is mainly focusing on the ethical and legal territory, however, is not the very same thing happening in the field of science – every break, every invention must be followed, if we are allowed to use Lyotard's terminol-

---

[4] In the Preface to the second edition of *Critique of Pure Reason* (1787, B XVI). See Volker Gerhardt, "Kants kopernikanische Wende", in *Kant-Studien,* No. 78, Vol. 2, Walter de Gruyter, Berlin & New York 1987, pp. 133–151.

[5] See Sigmund Freud, *Introductory Lectures on Psychoanalysis,* Lecture XVIII, in: *Standard Edition of the Complete Psychological Works of Sigmund Freud,* vol. XVI, Hogarth Press, London 1953–74, p. 285.

[6] See Friedrich Nietzsche, *Genealogy of Morals,* III, 25.

[7] Jean-François Lyotard, *Heidegger and "the jews"*, p. 13.

[8] One is tempted here to evoke the theory of the perhaps leading contemporary philosopher, Alain Badiou, for whom truth is always fidelity to an event. For further reading see: Peter Hallward, *Badiou. A Subject to Truth,* University of Minnesota Press, Minneapolis & London 2003.

ogy, by inventing new rules for the formation and linking of the phrases and new genres of discourse. The same happens in painting concerning transition from the hitherto invisible to the visible. This transition, as we will see further on, is for Lyotard possible only if the subject himself retreats, retracts, withdraws, makes a void, a blank, so that the heterogeneous might appear. This demands a different role of the subject, it demands a new conception of the subject, a conception which would present another turn regarding the so-called "Copernican turn".

In the name of the Second Copernican turn

In philosophy the Copernican turn is usually connected with the Kantian revolution, which puts the subject in the center – cognition no longer follows the object, the constitution of objectivity itself becomes dependent upon the subject. It is T. W. Adorno, famous member of the Frankfurt school of Marxism, who first formulated the task of philosophy as being to accomplish the second Copernican turn, a turn which would turn the hierarchy of object and subject upside down, a turn that would give primacy to the object. Is not the whole history of philosophy in the twentieth century – from Heidegger to Adorno, Wittgenstein to Austin, structuralism and post-structuralism, nothing but an elaboration of this task? Adorno's leading premise, however, is that the first Copernican turn *has* already taken place and that it actually enthroned the entity called Subject. But today it is clear that things are far more complicated than that. To make a long story short, let us say that all this "leads one to ask skeptically: has there ever existed a unified conscious subject, a watertight Cartesian ego? Or is subject some phantasy or abstraction that is retrospectively attributed to a past that one wants either to exceed, betray or ignore? That is to say, is not the subject a fiction that Kant finds in Descartes without being in Descartes, that Heidegger finds in Kant without being in Kant, or that Derrida finds in Husserl without being in Husserl?"[9] Even for Kant things are far more complicated: after the publication of all three *Critiques,* which were suppose to form a system, Kant was still not satisfied – as his *Opus posthumum* testifies. His successors, Fichte, Schelling and Hegel, were all convinced that "everything is already there" (in Lacanese, Kant was their "subject suppose to know") and that in the name of fidelity to Kant only strict elaboration is needed. It was Nietzsche who, in the already mentioned interpretation of Copernicus, clearly influenced both authors of the *Dialectics of Enlightenment,* Horkheimer and Adorno, as well as Heidegger,

---

[9] Simon Chritchley, *Ethics-Politics-Subjectivity,* Verso, London & New York 1999, p. 59.

so Copernicus and the Copernican turn gained its place within a fatal diagnosis of modern and of Western civilization. It is in this context that one has to understand Lyotard's constant insistence on "guarding heterogeneity" and multiplicity against negativity, dialectics and subjectivity. Lyotard's thought always tries to maintain and preserve a gap between object and subject. Concepts of void, the elaboration of blankness, self-erasure and silence represent the main thread of his unfinished opus and are closely linked with the search for a new conception of the subject.

This may actually seem to be a surprise as Lyotard's project remains to be infamous for his declaring "the end of grand narratives". What actually proclaims this end? When this or that meta-discourse explicitly takes refuge in this or that grand narrative, states Lyotard, such as the dialectics of Spirit, hermeneutics of meaning, the emancipation of the rational or laborious subject, the development of wealth, then with the expression 'modern' we decide to name a science which referrers to those narratives in order to legitimate itself.[10] The problem of a "narrative" – be it "grand" or "little" narratives – is namely for Lyotard always a problem of a "social bond". In other words, knowledge ceases to be an end in itself, it loses its "use-value" and it has to speak and interact with others in a normative way through *savoir-entendre, savoir-dire,* and *savoir-vivre.* This topic is something which Lyotard already conceptualized in his work *Libidinal Economy,* published six years earlier: "The modern scientist no longer exists as a knower, that is to say as a subject, but as a small transitory region in a process of energetic metamorphosis, incredibly refined; he exists only as a 'researcher', which means on the one hand, of course, as part of a bureaucratic power."[11] Philosophy and science therefore cannot avoid some relationship with the community; terror is in a way unavoidable. Knowledge is therefore faced with the following alternative – be operative, commensurable or simply vanish![12] The main topics of *The Differend* are already there: terror, erasure, and incommensurability. The basic aim and task of philosophy in *The Differend* is: "to defend and illustrate philosophy in its differend with its two adversaries: on its outside, the genre of economic discourse (exchange, capital); on its inside, the genre of academic discourse (mastery)".[13] There are two main

---

[10] See Jean-François Lyotard, *Postmodern Condition: a Report on Knowledge,* translated by Geoffrey Bennington and Brian Massumi, Manchester University Press, Manchester 1984, p. 8.

[11] Jean-François Lyotard, *Libidinal Economy,* translated by Iain Hamilton Grant, Athlone Press, London 1993, p. 253–254.

[12] See *Postmodern Condition.,* p. 8.

[13] Jean-François Lyotard, *The Differend. Phrases in Dispute,* translated by Georges Van Den Abbelee, Manchester University Press, Manchester 1988, p. xiii.

dangers that lurk on the edge of philosophy: the outer world governed by the principle of efficiency, capitalism, and academic discourse with its hierarchical structure. There are many scientists, says Lyotard in the *Postmodern Condition,* whose singular novelties were suppressed sometimes even for decades because they would destabilize the established positions not just within the scholarly and scientific world but also within the given problematic.[14] Terror is for Lyotard not only a terror of the universal over the particular or singular, but also the terror of efficiency that threatens to eliminate those who do not cooperate – they are simply excluded. The arrogant message of those in power to scientists is: Adjust your efforts to our goals or else…[15] Though philosophy was always struggling with the outer world and competing with its rivals, its fight today has new and unprecedented dimensions, the struggle is today on the level of the "anonymous infinity which organizes and disorganizes a particular subject which regardless of its social rank is its voluntary or involuntary servant."[16] This danger of anonymous force is to be understood in connection with the following programmatic question: "Marxism has not come to an end, but how does it continue? […] Even if the wrong is not universal (but how you can prove it? it's an Idea, the silent feeling that signals a differend remains to be listened to. Responsibility to thought requires it. This is the way in which Marxism has not come to an end, as the feeling of the differend."[17]

The broader theoretical context of Lyotard's theoretical gesture with its claims that consensus is executing a violence upon heterogeneity,[18] that postmodern science does not produce a known but an unknown,[19] that little narratives are nothing but imaginative innovation and that inventions are always the result of disagreement,[20] would not be something completely original among his contemporaries. Take, for instance, Gilles Deleuze with his formulation that the task of philosophy is to create new concepts and to resist the present, the already known, then the other pole of Lyotard's opus, the theme of silence, silencing, the absence of a common denominator, idiom, or platform, would meet the principal program of Michel Foucault's work *Madness and Civilization: a History of Insanity in the Age of Reason,* that is, to write down an archeology of silence, a paradoxical program which was justifiably criticized by the recently deceased Jacques Derrida. There are many

---

[14] See *Postmodern Condition,* p. 108.

[15] See *ibid.*

[16] Jean Françoise Lyotard, *Moralités postmodernes,* Galilée, Paris 1993, p. 135.

[17] *Differend,* p. 171.

[18] See *Postmodern Condition,* p. 9.

[19] See *ibid.,* p. 102.

[20] See *ibid.,* p. 9.

other themes in Lyotard which would be interesting to compare with other contemporary philosophers such as Jacques Rancière, Alain Badiou, Giorgio Agamben etc., and, of course, also Adorno and Heidegger with Lyotard's incessant polemics with them.[21]

But to limit the originality of Lyotard's gesture only and foremost to the contemporary context would also be in a way misleading. Let us take Deleuze, for instance. For him philosophy can lead to heavy internal fights but it is still not such a force as religions, states or medias are. Philosophy for Deleuze can lead its war against them only as a kind of guerilla, it has nothing to tell them so it does not debate with them but leads them to what Deleuze calls "negotiations". These forces are traversing everyone; since they are too strong and too powerful for us, everyone experiences a kind of this excess. It is exactly this feeling, this sensation of "ce qui m'arrive est trop grand pour moi" which Lyotard conceptualizes in his treatment of the Kantian notion of the sublime. But precisely at the point where he seems to be nearest to Deleuze he is also the furthest from him. For Deleuze this point coincides with the theme of (artistic) creation, and of the compromise we are always forced into, while Lyotard is headed in a completely different direction. Even if "negotiations" for Deleuze can never lead to consensus, even if he too like Lyotard is a ferocious enemy of the categories of One, Totality, identity etc., it seems that for him "negotiations" silently presuppose two already existing sides with their more or less defined positions, identities, desires, a kind of "we know what we want or don't want" – while for Lyotard exactly this is a problem. What if there is no "other side", what if those which are supposed to be on the other side are eliminated either physically or legally? What if even their status is denied? What if we do not know who is on any side at all? What if we are a blank, a whiteness on the white background, a kind of *White Square on White Square*, what if we are nothing but forever erased and nullified as victims of gas chambers are? And if finally we manage to obtain two sides – what if an unsettled "issue" between them does not exist at all? What if the idioms, concepts, even the language that would serve as a medium of articulation have yet to be invented?

All these questions raised are faced with the original double bind described in *The Differend*:

> This is what a wrong [tort] would then be: a damage [dommage] accompanied by the loss of the means to prove the damage. This is the case if the victim is deprived of life, or of all his or her liberties, or of the

---

[21] See Jean-François Lyotard, *Heidegger and "the jews"*, pp. 3–5, 51–94.

> freedom to make his or her ideas or opinions public, or simply the right to testify to the damage, or even more simply, if the testifying phrase is itself deprived of authority. In all of these cases, to the privation constituted by the damage there is added the impossibility of bringing it to the knowledge of others, and in particular to the knowledge of a tribunal. Should the victim seek to bypass this impossibility and testify anyway to the wrong done to him or to her, he or she comes up against the following argumentation: either the damages you complain about never took place, and your testimony is false; or else they took place, and since you are able to testify to them, it is not a wrong that has been done to you, but merely a damage, and your testimony is still false.[22]

In other words, "I would like to call a differend [différend] the case where the plaintiff is divested of the means to argue and becomes for that reason a victim."[23] The differend thus cannot be solved in advance, however, the task is "to give the differend its due to institute new addressees, new addressors, new significations, and new referents in order for the wrong to find an expression and for the plaintiff to cease being a victim. This requires new rules for the formation and linking of phrases. No one doubts that language is capable of admitting these new phrase families or new genres of discourse. Every wrong ought to be able to be put into phrases. A new competence (or 'prudence') must be found"?[24] The task of philosophy is not to forget, to repress, to put aside, to minimize – "one's responsibility before thought, but consists, on the contrary, in detecting differends and in finding the (impossible) idiom for phrasing them. This is what a philosopher does. An intellectual is someone who helps forget differends, by advocating a given genre, whichever one it may be (including the ecstasy of sacrifice), for the sake of political hegemony".[25] The only necessary task is then to make *enchainements*, to make linkages: "It is necessary to make a linkage. This is not an obligation, a *Sollen*, but a necessity, a *Müssen*. To link is necessary, but how to link is not."[26] In other words, the rule of philosophical discourse is "to discover its rule: its *a priori* is what is at stake. It is a matter of formulating this rule, which can only be done in the end, if there is an end."[27] This attempt to discover and formulate a rule – forerun by Kant's distinction between determinate

---

[22] Jean-François Lyotard, *Differend*, p. 5.

[23] *Ibid.*, p. 9.

[24] *Ibid.*, p. 30–31.

[25] *Ibid.*, p. 142.

[26] *Ibid.*, p. 101.

[27] *Ibid.*, p. 60.

and reflective judgments in his *Critique of Judgment* – presents perhaps the main trait of Lyotard's philosophical project.

On two events or Lyotard's version of the modern

In essence this trait is connected with the task of making the invisible visible, of presenting the unpresentable. We should, however, admit that Lyotard is here more ambiguous then he seems – since every presentation is for him a "relativization",[28] since every witness is already a traitor",[29] it seems that a critique of representation in Lyotard's opus is faced with the same ambiguity as, for instance, in Deleuze, who hesitates between "thought without image" and the "new image of thought". The very same ambiguity is at work in Lyotard's interpretation of Auschwitz – "representing 'Auschwitz' in images and words is a way of making us forget this. I am not thinking here only of bad movies and widely distributed TV series, of bad novels or 'eyewitness accounts'. I am thinking of those very cases that, by their exactitude, their severity, are, or should be, best qualified not to let us forget. But even they represent what, in order not to be forgotten as that which is forgotten itself, must remain unrepresentable. Claude Lanzmann's film *Shoah* is an exception, maybe the only one. […] Whenever one represents, one inscribes in memory, and this might seem a good defense against forgetting. It is, I believe, just the opposite. Only that which has been inscribed can, in the current sense of the term, be forgotten, because it could be effaced. But what is not inscribed, through the lack of an inscribable surface, of duration and a place for the inscription to be situated, what has no place in the space nor in the time of domination, in the geography, and the diachrony of the self-assured spirit, because it is not synthesizable […] cannot be forgotten, does not offer a hold to forgetting, and remains present 'only' as an affection that one cannot even qualify, like a state of death in the life of the spirit. One *must,* certainly inscribe in words, images. One cannot escape the necessity of representing. It would be sin itself to believe oneself safe and sound. But it is one thing to do it in view of saving memory, and quite another to try to preserve the remainder, the unforgettable forgotten, in writing."[30]

As was recently shown by Gérard Wajcman[31], the Shoah is an event which

---

[28] Jean-François Lyotard, *L'Inhumain. Causeries sur le temps,* Galilée, Paris 1988, p. 138.

[29] *Ibid.,* p. 215.

[30] Jean-François Lyotard, *Heidegger and "the jews",* p. 26.

[31] See Gérard Wajcman, "L'art, la psychanalyse, le siècle", in: Aubert, Cheng, Milner, Regnault, Wajcman, *Lacan, l'écrit, l'image,* Flammarion, Paris 2000, pp. 27–78, and Gérard Wajcman, *L'objet du siècle,* Verdier, Paris 1998.

does not have the same status as any other event. The first reason for this being the fact that there are no documents or images, there are no archives. This absence is not accidental: the Nazis took every precaution and care to leave no trace, no documents, photographs or ruins. The Uniqueness of the Shoah for Wajcman is not to be found in the extensiveness of the crime, its systematicness and number of victims. The Shoah is incomparable to any other event because of the very effort of the Nazis who tried to erase the crime from every representation and from every possible memory. To erase the Jews not only from the face of the earth, but also from history, memory, past and future. Primo Levi reports that one German officer said to the newcomers in the camp: "Whatever the end of the war may be, we have already won and you have lost: no one will be alive among you to testify to it. Even if some of you might escape, the world will not believe you. Maybe there will be some suspicions, some doubts, discussions, maybe historians will investigate and research it, but there will be no certainty: because in destroying you, we are destroying the evidence itself. In case some proofs or any of you might get through all this, people won't believe you, what you will talk about will be too monstrous for people to believe."[32] It is this problematic that lies at the heart of *The Differend* and it is this that almost the entire history of contemporary art is about – i.e. how to make the invisible visible and how to render the uniqueness of the object. That is also one of the major reasons why Lyotard was so obsessed with painting, what he was looking in it for,[33] and why he went to look back in Freud and Kant. The reason for his elaboration of the Kantian theses on history, politics and enthusiasm might lie in the fact that for Lyotard "enthusiasm as such sees nothing, or better, sees nothing and connects it with the unrepresentable".[34] In this transition from the invisible to the visible we can see a Lyotardian version of the famous Freudian dictum *Wo Es war, soll ich werden*: where there was the unpresentable, a presentation should emerge, where there was the invisible, something visible should be, where there was nothing, a subject should occur. This is exactly the problem in, for instance, Malevitch's painting *Black Square on White Square* (1915). The mark of Malevitch's genius

---

[32] See Gérard Wajcman, "L'art, la psychanalyse, le siècle", p. 37.

[33] The task of the avant-garde painter is according to Lyotard's essay "Représentation, présentation, imprésentable" to show that within the visual there is the invisible-unrepresentable, which for its object has an Idea. This presentation is a product of hard work, the audience does not understands that "we need one year sometimes to make a white square [carré blanc], that is, to represent nothing". See *Inhumain*, p. 133.

[34] Jean-François Lyotard, *Enthousiasme. La critique kantienne de l'histoire*, Galilée, Paris 1986, p. 55.

> precisely consists of giving body to the nothing: this nothing is seen on the surface of the picture – as a black square. By seeing the depth we see nothing that is not already there: there, that is, in the foreground, on the surface, in the black square. Materialistically, how can nothing that is 'behind' the surface be seen? How can one see the transcendence that is at the heart of the immanence itself? Only by seeing/realizing that behind the surface there is nothing – but the surface itself. In this precise sense it can be said that, by seeing a black square on a white square, we see nothing as something.[35]

However, is it not paradoxical that Lyotard is interested in such dissimilar phenomena as the Shoah and enthusiasm embody? Let's take a look. If, on the one hand, Shoah is something unrepresentable, immeasurable, unique, precarious, on the other enthusiasm (of the spectators of the French Revolution), is a phenomenon that for Kant cannot be forgotten. Two extremities, then: here something impossible, unrepresentable, nothing in itself which resists every memory and which every rendering betrays; there something that cannot be annihilated, negated, abolished. Here terror and horror; there enthusiasm, excitement, joy, elation. Here horror without witnesses, unbelievable horror which separates forever not only victims and executioners, but also those who survived from the others; there, contagious elation which integrates, friendship, brotherhood. Furthermore. Horror and petrifying anxiety for something that makes us alive, something that revives, resurrects, reanimates. In the Shoah both victims and hangmen are for obviously different reasons not worthy of being considered human beings, they are both at a kind of bottom of the human condition, and as such are a stain, which pertains to all humanity. Revolution, on the other hand, brings about something which cannot ever again be forgotten in all its positivity, as Kant says, regarding the disposition of human nature and ability to improve. Both these two events are impossible and unpredictable, but each of them in its own way. The Shoah cannot be imagined or presented without already being betrayed, the French Revolution as a sign of constant progress cannot be erased, it is unimaginable that it is not present. So, if the Shoah cannot be presented because it is so thoroughly erased, a revolution cannot be erased because it is so present. The Shoah is, as Lacan would put it, something which "doesn't stop not being written", it is something impossible (to present and represent for Lyotard), while enthusiasm is something which "doesn't stop being written",

---

[35] See Rado Riha, "Seeing the Revolution, Seeing the Subject", *Parallax,* Issue 27, April-June 2003, Routledge, London 2003, p. 33.

it is necessary (it is "signum demonstrativum, rememorativum, prognosticon" as Kant put it).[36] And finally, Shoah seems to be a kind of a black hole that sucks everything into it, while the revolution is a kind of pure emanation of light, a lighthouse on our journey in history.

The first impression we get when faced with this list of numerous oppositions is that there is no possible connection between the two events. However, there are more than your philosophy dreams of, Horatio! Let us examine two of them. Firstly, is there a concept comprising all the above-mentioned paradoxes and contradictions? Without a doubt! But it is not found in Lyotard, one should look for it in Lacan. Lacan's *objet petit a* is an unrepresentable object, nothing in itself, however it can magically color any everyday object and it can render anything beautiful. It is something the Greeks called *agalma*, another name for this secret treasure which is "in you more than you". It makes you alive, and as a mask of *das Ding*, brings you close to death – if *das Ding* is approached too closely it triggers anxiety and horror. The unpresentable concept of *object petit a* is a kind of a-concept, it is absent from language, while at the same time it frames reality. As a stain in a picture, the *objet petit a* attracts the gaze, yet it is also the cause of the desire. At this point we approach the problematics of the Real – "the trauma qua real is not the ultimate kernel referent of the symbolic process, but precisely that X which forever hinders any neutral representation of external referential reality. To put it more paradoxically, that Real *qua* traumatic antagonism is, as it were, the *objective factor of subjectivization* itself; it is the object which accounts for the failure of every neutral-objective representation, the object which 'patologizes' the subject's gaze or approach, makes it biased, pulls it askew. At the level of gaze, the Real is not so much the invisible Beyond, eluding our gazes which can perceive only delusive appearances, but, rather, the very stain or spot which disturbs and blurs our 'direct' perception of reality – which 'bends' the direct straight line from our eyes to the perceived object."[37] In short, there is a theme in Lyotard which brings us into the midst of his eternal differend with Lacan that he tried to avoid by leaning on Freud.

However, there are other topics of the Real as well. One needs to remember that one of the pairs of oppositions of the Shoah and enthusiasm was also the pair of impossible and necessary, of something which "doesn't stop not being written" and something which "doesn't stop being written". This pair

---

[36] See Jacques Lacan, *The Seminar of Jacques Lacan, Book XX, Encore, On Feminine Sexuality: The Limits of Love and Knowledge*, trans. Bruce Fink, W. W. Norton & Co., New York and London 1998, pp. 132–133 and sq.

[37] Slavoj Žižek, *The Plague of Fantasies*, Verso, London & New York 1997, p. 214.

is of crucial importance for us here, for it presents something which is possible only on the background of the dispositive of modern science – maybe one should finally take seriously Lyotard's own classification of postmodern as a radical modern. Jean-Claude Milner, who is our guide here, has also classified Lyotard as modern, however different than here and in a different context.[38] We will use here his text on Lacan and science, especially the part which elaborates the link between contingency, impossibility and necessity in modern science:

> The letter is as it is, without any reason causing it to be what it is; by the same token, there is no reason for it to be other than it is. And if it were other than it is, it would solely be another letter. In truth, from the moment that it is, the letter remains and it does not change ("the unique number, which cannot be another"). At most, a discourse may not change the letter, but rather change letters. In this manner, and by a tricky turn of events, the letter takes on the traits of immutability, homomorphic to those of the eternal idea. Undoubtedly, the immutability of what has no reason to be other than it is, has nothing to do with the immutability of what cannot, without violating reason, be other than it is. But the imaginary homomorphism remains. It then follows that the capture of the diverse by the letter gives the letter, insofar as the diverse can be other than it is, the imaginary traits of what cannot be other than it is. This is what is called the necessity of the laws of science. It resembles in all points the necessity of the supreme Being, but it resembles it all the more insofar it has nothing to do with it. The structure of modern science is entirely based on the contingency. The material necessity that one recognizes in these laws is the scar of that very contingency. [...] In a moment of clarity, every point of every referent of every proposition of science appears to be infinitely other than it is, from an infinity of points of view; in the next moment, the letter has fixed each point as it is, and as not being able to be other than it is, save by changing letters, that is, field. But the condition of the latter moment is the earlier moment. To manifest that a point of the universe is as it is requires the dice to be thrown in a possible universe wherein this point would be other than it is. To the interval of time during the dice tumble, before falling, the doctrine has given a name: the emergence of the subject, which is not the thrower (the thrower does not exist), but the dice themselves insofar as they are in suspension. In the vertigo of these mutually exclusive

---

[38] See Jean-Claude Milner, "Jean-François Lyotard, du diagnostic à l'intervention", in: *Jean-François Lyotard. L'exercice du différend*, PUF, Paris 2001, pp. 261–272.

> possibilities, bursts finally, at the instant after the fall of the dice, the flash of the impossible – impossible that, once fallen, they bear another number on their upturned face. Here one sees that the impossible is not disjoined from contingency, but constitutes its real kernel.[39]

This longer passage can help us elucidate why Lyotard after *The Differend*, along with themes of making the invisible visible and presenting the unpresentable, also elaborated the knot of time, cause and subject. The latter for Lyotard is never something outside the Universe – one of the tasks in the *Differend is* to refute the prejudice "that there is a 'man'".[40] As such, Lyotard definitively and unambiguously belongs to the modern since one of the main theses of the modern is "There is nothing outside the Universe".[41] That is why for Lyotard "Man" cannot be the highest authority, the only authority is the "authority of the infinite, perhaps, or the heterogeneous".[42] To put it differently, "the universe presented by a phrase is not presented to something or to someone like a 'subject'. The universe is there as long as the phrase is the case. A 'subject' is situated in a universe presented by a phrase. Even when the subject is said not to belong to the world, qua addressee or addressor of the presentation – the thinking I in Descartes, the transcendental ego in Husserl, the source of the moral law in Kant, the subject in Wittgenstein – this subject is nevertheless situated at the heart of the universe presented by the philosophical phrase that says it does not belong to the world. This is the difference between universe and 'world'."[43]

A specific link between time and cause is especially elaborated in Lyotard's work *Heidegger and "the jews"* through a conceptualization of repression that Lyotard calls "the jews". "The jews" are for him not the Jews, neither are they to be confused with the Jewish nation, the political movement of Zionism and Judaism, or with the Jewish religion, "the "jews" are namely an object without a place. They are a name for a kind of a cause, a kind of double causality with a special temporal status. There is, states Lyotard, a double blow, a first blow, the first excitation, the shock, which upsets the apparatus with such a "force", that is not registered. It is best rendered by the Freudian term

---

[39] Jean-Claude Milner, "The Doctrine of Science", trans. Oliver Feltham, in: *Jacques Lacan. Critical Evaluations in Cultural Theory,* ed. by Slavoj Žižek, Vol. I: *Psychoanalitic Theory and Practice,* Routledge, London & New York 2003, p. 284. See also: Jean-Claude Milner, *L'Oeuvre claire. Lacan, la science, la philosophie,* Seuil, Pariz 1995.

[40] *Le différend,* p. xiii.

[41] See Jean-Claude Milner, *L'Oeuvre claire. Lacan, la science, la philosophie,* p. 123.

[42] *Le différend,* p. 31.

[43] *Ibid.,* p. 71–72.

Nachträglich, which implies a double blow, that is constitutively asymmetrical and a specific temporality which has nothing to do with the phenomenology of consciousness. Lyotard thus differentiates between a shock which affects the system without being registered, "it is like a whistle that is inaudible to humans but not to dogs, or like infrared or ultraviolet light. In terms of a general mechanics, the force of excitation cannot be 'bound', composed, neutralized, fixed in accordance with other forces 'within' the apparatus."[44] This first blow then "strikes the apparatus without observable internal effect, without affecting it. It is a shock without affect. With the second blow there takes place an affect without shock: I buy something in a store, anxiety crushes me, I flee, but nothing has really happened. The energy dispersed in the affective cloud condenses, gets organized, brings on action, commands a flight without a 'real' motive. And it is in this flight, the feeling that accompanies it, which informs consciousness *that* there is something, without being able to tell *what* it is. It indicates the *quod* without the *quid.* The essence of the event: that *there is* 'comes before' *what* there is."[45] "In this sense Freud understands his concept of *nachträglich.* The first blow hit the soul too early, the second will touch it too late. The first time as the thought is there, but is not being thought; the second time this unthought returns and demands to be thought, but then the first is not there."[46] That is the essence of an event, not only that *quod* is before *quid,* but also, moreover, the psychical apparatus is never prepared for a shock, this shock always throws it out of joint and surprises it. In this line Lyotard also situates "infancy" – infancy is a first blow, which never really happened, never was, because it is not re-presentable, but it still ex-sits and in-sists. For the purposes here – leaving other dimensions for another occasion – it is important that also in modern science we deal with a certain retroactive character of time: "In any case, science does not allow such passages; once the letter is fixed, necessity alone remains and imposes the forgetting of the contingency that authorized it." [47] What kind of causality is Lyotard searching for? In our view that would be a cause "not as inscribed in a law of regularity and continuity, but rather a cause which so preoccupied David Hume in the 18th century when he showed that the very term "cause" as separate, as primary, was non-conceptual".[48] This cause involves the breaking of the chain, it presents discontinuity, a cause breaks with the chain of

---

[44] Jean-François Lyotard, *Heidegger and "the jews",* p. 15.

[45] *Ibid.,* p. 16.

[46] Jean-François Lyotard, *Pérégrinations,* Galileé, Paris 1990, p. 26.

[47] Jean-Claude Milner, "The Doctrine of Science", p. 285.

[48] Jacques-Alain Miller, "To Interpret the Cause: From Freud to Lacan", in: *Newsletter of the Freudian Field,* Vol. 3, No. 1–2, Spring-Fall 1989, New York 1989, p. 33.

causes and effects, with determinism. Both conceptions of time and cause need a third one – a subject. While for Miller the subject as the missing link is always involved in the structure of causality versus legality, Lyotard seems to go in a different direction, while leaving his conception of the subject in fragments.

It seems that Lyotard with his concepts "infancy", "the jews", "phrase-affect", and "sensus communis" consciously leaves room for the heterogeneous, for something unarticulable, they are always something that is simultaneously too near and too far – philosophy cannot touch this "sensus communis".[49] One of the reasons might be that all his concepts were frequently undeveloped or simply negative (negative determinations like "ne… pas", what something is not.)[50] The main reasons lie in the fact that he never succeeded to develop a full conception of the subject, only a subject "in statu nascendi", a kind of subject before the subject. A major consequence of this "guarding of the heterogeneous" against the power of negativity, dialectics and the Subject, is that his thought remains bound to a preservation of the basic split, the fundamental disunion between the subject and the object. The task of thought, literature, art is to risk, to take chance, to venture and to "witness it".[51] This witnessing and analyzing is infinite and painful "what art can do, is bear witness not to the sublime, but to this aporia of art and to its pain. It does not say the unsayable, but says that it cannot say it."[52] The main emphasis is then on the incongruity of the object. In this sense we never own thoughts, because they are not "fruits of the earth. Thoughts are not kept in the some big land register, except for the convenience of people. Thoughts are clouds. The margins of a cloud cannot be exactly measured; thoughts form a fractal Mandelbrot line. Thoughts are set in motion i.e. driven by a different speed."[53] We can never dominate them, they always remain something heterogeneous to us. It seems that Lyotard is thus stuck in Adorno's "negative dialectics". He is clearly aware of this and that is why the problem of the void, blankness, and emptiness takes a prominent place in his late opus. The blank is for him another name for subjective retreat, for "making a slate clean", wherein an object in all its phenomenality can appear. This clearing of place is for Lyotard a kind of evacuation of the spirit, a withdrawal of the subject exemplified by the Japanese artist-soldier, "who must suspend the usual intentions of the

---

[49] *Misère de la philosophie,* Galilée, Paris 2000, p. 17.

[50] *Ibid.,* p. 21.

[51] *L'Inhumain,* p. 15.

[52] *Heidegger and "the jews",* p. 47.

[53] Jean-François Lyotard, *Pérégrinations,* p. 21.

soul connected with the habitus, with the dispositions of the body".[54] This "disarmament of the spirit",[55] this evacuation demands a certain suffering, an asceticism of body and soul. The making of a blank, a fabricated void, a self-withdrawal, guards a place for *éclair*, for an event, for *Ereignis,* which may or may not emerge at all. Only then in this world of ready made inscriptions "a certain place has to be made for this lack by making a blank [mise à blanc], that makes possible the emergence of something different which needs to be reflected."[56] This "lightning flash that makes something (a phrase universe) appear, but blinds as it blinds itself through what illuminates", this lightning flash which "takes place – it flashes and bursts out in the nothingness of the night, of clouds, or of the clear blue sky" also brings about a "feeling that the impossible is possible. That the necessary is contingent."[57] It is here, again, that we meet the problematic of modern science introduced last but not least by Copernicus, it is here that every scientific invention is nothing but "the emergence of something different which needs to be reflected", it is here, finally, that Lyotard's unfinished philosophical project carried out in the name of the second Copernican turn, stops.

---

[54] Jean-François Lyotard, *Inhumain*, p. 27.
[55] *Ibid.,* p. 164.
[56] *Ibid.,* p. 28.
[57] *Differend*, p. 75.

Filozofski vestnik Volume/Letnik XXV • Number/Številka 2 • 2004 • 125–142

COPERNICUS AND HIS ISLAMIC PREDECESSORS: SOME HISTORICAL REMARKS

F. Jamil Ragep

Based upon research over the past half century, there has been a growing recognition that a number of mathematical models used by Copernicus had originally been developed by Islamic astronomers. This has led to speculation about how Copernicus may have learned of these models and the role they played in the development of his revolutionary, heliocentric cosmology. Most discussion of this connection has thus far been confined to fairly technical issues related to these models; recently, though, it has been argued that the connections may go deeper, extending into the physics of a moving Earth and the way in which astronomy itself was conceived. The purpose of this article is to give an overview of these possible connections between Copernicus and his Islamic predecessors and to discuss some of their implications for Copernican studies.

The Mathematical Background

That Copernicus was acquainted with a number of his Islamic predecessors has been evident since 1543, when Copernicus in *De Revolutionibus* explicitly cited five Islamic authors.[1] The latest of these authors, al-Biṭrūjī,

---

[1] These are: al-Battānī, al-Biṭrūjī, al-Zarqāllu, Ibn Rushd, and Thābit ibn Qurra. Copernicus also refers to al-Battānī in his *Commentariolus*, which remained unpublished during his lifetime. "Islamic" here refers to the civilization of Islam, not the religion since a number of "Islamic" astronomers, such as Thābit, were not Muslims.

flourished in Spain in the last part of the twelfth century, so Copernicus's references end around 1200, which is the approximate terminus date for Islamic authors who were translated into Latin. Until recently, most historiography related to Copernicus has assumed that this was the end of the story, at least as far as Islamic influence goes. But since the 1950s, a series of discoveries has shaken this neatly constricted picture and caused a major reevaluation of the relation of Copernicus (as well as other Renaissance astronomers) to later Islamic astronomy.

The first modern acknowledgement of a connection between Copernicus and a later (i.e. post-1200) Islamic astronomer was made by J. L. E. Dreyer in 1906. In a footnote, Dreyer noted that the new device invented by Naṣīr al-Dīn al-Ṭūsī (d. 1274) was also used by Copernicus in Book III, Chapter 4 of *De Revolutionibus*.[2] Typical for the time, Dreyer offered no further explanation or speculation; nor did anyone else until the discovery in the 1950s of a connection between another Islamic astronomer and Copernicus. E. S. Kennedy, who was a professor of mathematics at the American University of Beirut, happened by chance to notice some unusual (i.e. non-Ptolemaic) astronomical models while browsing through the *Nihāyat al-sūl* of ʿAlā' al-Dīn ibn al-Shāṭir, a Damascene astronomer of the fourteenth century who had been the time-keeper of the Umayyad Mosque. Upon showing these to his friend and mentor, Otto Neugebauer of Brown University, Kennedy was amazed to learn that these models were ones that had been thought to have first appeared in the works of Nicholas Copernicus. This led to a series of articles by Kennedy and his students that discussed various aspects of these models by Ibn al-Shāṭir as well as by other late Islamic astronomers.[3]

The picture that emerged can be summarized as follows. Islamic authors from an early period were critical of Ptolemy's methods, observations, and models.[4] One particular irritant was the use of devices by Ptolemy that violated the accepted physical principles that had been adopted by most astrono-

---

[2] J. L. E. Dreyer, *History of the Planetary Systems from Thales to Kepler* (Cambridge: Cambridge University Press, 1906), p. 269. Dreyer knew of Ṭūsī's work from the translation by Carra de Vaux of a chapter of his *al-Tadhkira fī ʿilm al-hay'a* (Appendix VI of Paul Tannery, *Recherches sur l'histoire de l'astronomie ancienne* [Paris, 1893], pp. 337–361).

[3] These have been conveniently collected in E. S. Kennedy and Imad Ghanem (eds.), *The Life & Work of Ibn al-Shāṭir: An Arab Astronomer of the Fourteenth Century* (Aleppo, 1976) and in E. S. Kennedy et al., *Studies in the Islamic Exact Sciences* (Beirut, 1983), pp. 50–107. The most important of these is E. S. Kennedy, "Late Medieval Planetary Theory," *Isis* 57 (1966): 84–97.

[4] See, for example, the very critical remarks, most likely by the Banū Mūsā (ninth century), in Régis Morelon, *Thābit ibn Qurra: Œuvres d'astronomie* (Paris: Les Belles Lettres, 1987), p. 61.

mers in the ancient and medieval periods. Later Islamic astronomers came to list sixteen of these violations: six having to do with having the reference point for uniform motion of an orb being different from the actual center of the orb (often referred to as the "equant" problem); nine having to do with a variety of Ptolemaic devices meant to bring about latitudinal variation in the planets' motions (i.e. deviation north or south of the ecliptic); and, finally, an irregular oscillation of the lunar epicycle due to the reference diameter being directed to a "*prosneusis*" point rather than the deferent center of the epicycle.[5] The earliest systematic attempt in Islam to criticize Ptolemy's methods and devices occurred in *al-Shukūk ʿalā Baṭlamyūs* (*Doubts against Ptolemy*) by Ibn al-Haytham (d. ca. 1040), who was better known in Europe for his great work on optics. In addition to his blistering critique of Ptolemy, Ibn al-Haytham also wrote a treatise in which he attempted to deal with some of the problems of Ptolemy's planetary latitude models.[6] A contemporary of Ibn al-Haytham, Abū ʿUbayd al-Jūzjānī, who was an associate of Abū ʿAlī ibn Sīnā (=Avicenna, d. 1037), also dealt with these issues and proposed a model to deal with the equant problem.[7]

These early attempts notwithstanding, the major thrust to provide alternative models occurred in the twelfth century and continued for several centuries thereafter. In Islamic Spain, there were a number of criticisms that questioned the very basis of Ptolemaic astronomy, in particular his use of eccentrics and epicycles, which culminated in an alternative cosmological system by al-Biṭrūjī that used only orbs that were homocentric with the Earth.[8] But though Biṭrūjī's work had important influences in Europe – indeed Copernicus mentions his view that Venus is above the sun[9] – the Spanish "revolt" against Ptolemy should be seen as episodic rather than marking the beginning of a long-lived tradition of Islamic homocentric astronomy.

---

[5] F. J. Ragep, *Naṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy,* 2 vols. (New York: Springer-Verlag, 1993), 1: 48–51.

[6] Ragep, "Ibn al-Haytham and Eudoxus: The Revival of Homocentric Modeling in Islam," in *Studies in the History of the Exact Sciences in Honour of David Pingree,* edited by Charles Burnett et al. (Leiden: Brill, 2004), pp. 786–809.

[7] George Saliba, "Ibn Sīnā and Abū ʿUbayd al-Jūzjānī: The Problem of the Ptolemaic Equant," *Journal for the History of Arabic Science* 4 (1980): 376–403.

[8] See al-Biṭrūjī, *On the Principles of Astronomy,* edited and translated by Bernard Goldstein, 2 vols. (New Haven: Yale University Press, 1971). Cf. A. I. Sabra, "The Andalusian Revolt Against Ptolemaic Astronomy: Averroes and al-Biṭrūjī," in *Transformation and Tradition in the Sciences,* ed. E. Mendelsohn (Cambridge: Cambridge University Press, 1984), pp. 133–153.

[9] Nicholas Copernicus, *De revolutionibus orbium coelestium,* translated by Edward Rosen as *On the Revolutions* (Baltimore: The Johns Hopkins University Press, 1978), p. 18.

In the Islamic East the situation was otherwise. Beginning in the first half of the thirteenth century, a number of works appeared that proposed alternatives to Ptolemy's planetary models. This was the start of an extremely fruitful period in the history of science in Islam in which a series of creative mathematical models were produced that dealt with the problems of Ptolemaic astronomy. Among the most important of these new models were those of Naṣīr al-Dīn al-Ṭūsī (1201–1274), Mu'ayyad al-Dīn al-ʿUrḍī (d. ca. 1266), Quṭb al-Dīn al-Shīrāzī (1236–1311), ʿAlā' al-Dīn Ibn al-Shāṭir (d. ca. 1375), and Shams al-Dīn al-Khafrī (fl. 1525). In essence, these astronomers developed mathematical tools (such as the "Ṭūsī couple" and the "ʿUrḍī lemma") that allowed connected circular motions to reproduce approximately the effects brought about by devices such as Ptolemy's equant.[10] In the case of the rectilinear Ṭūsī couple, two spheres, one half the size and internally tangent to the other, rotate in opposite directions with the smaller twice as fast as the larger. The result of these motions is that a given point on a diameter of the larger sphere will oscillate rectilinearly. (There is an analogous curvilinear Ṭūsī couple in which the oscillation is meant to occur on a great circle arc on the surface of a sphere.) What this allowed Ṭūsī and his successors to do was to isolate the aspect of Ptolemy's equant model that brought about a variation in distance between the epicycle center and the Earth's center from the aspect that resulted in a variation in speed of the epicycle center about the Earth. Such mathematical dexterity allowed these astronomers to present models that to a great extent restored uniform circular motion to the heavens while at the same time producing motions of the planets that were almost equivalent to those of Ptolemy.[11]

The Connection to Copernicus

Noel Swerdlow and Otto Neugebauer, in discussing this Islamic tradition, famously asked: "What does all this have to do with Copernicus?" Their answer was: "Rather a lot."[12] In his commentary on Copernicus's *Commen-*

---

[10] Today we would say that these mathematical tools were equivalent to linkages of constant-length vectors rotating at constant angular velocities; but it is important to remember that Islamic astronomers conceived of their devices as physical, not simply mathematical. Cf. Ragep, *Naṣīr al-Dīn,* 2: 433–437.

[11] F. Jamil Ragep, "The Two Versions of the *Ṭūsī* Couple," in David King and George Saliba (eds.), *From Deferent to Equant: Studies in Honor of E. S. Kennedy* (vol. 500 of *The Annals of the New York Academy of Sciences,* 1987), pp. 329–356.

[12] N. M. Swerdlow and O. Neugebauer, *Mathematical Astronomy in Copernicus's De Revolutionibus,* 2 parts (New York: Springer-Verlag, 1984), p. 47.

tariolus, Swerdlow made the case for this connection through a remarkable reconstruction of how Copernicus had arrived at the heliocentric system. According to Swerdlow, Copernicus, somehow aware of this Islamic tradition of non-Ptolemaic astronomy, began his work to reform astronomy under its influence. In particular Copernicus objected explicitly to Ptolemy's use of the equant, something that had been a staple of Islamic astronomy for some five centuries at that point (but which seems to have been missing from European astronomy).[13] Swerdlow then proposed that although Copernicus was able to use some of these models, in particular those of Ibn al-Shāṭir, to deal with the irregular motion brought about by the first anomaly (the motion of the epicycle center on the deferent), it was the second anomaly (related to the motion of the planet on the epicycle) that remained problematic. For the outer planets this motion corresponds to the motion of the Earth around the sun, so a transformation of this motion from an epicyclic to an eccentric would lead to a quasi-heliocentric system, whereby the planet goes around the sun. Of course the Earth could still remain at rest while the sun, with the planets going around it, could then go around the Earth. In other words, Copernicus's transformations could have led to a Tychonic system. Swerdlow argued that this was not an option for Copernicus, since it led to the notorious intersection of the spheres of the sun and Mars, which simply was not possible in the solid-sphere astronomy to which Copernicus was committed. Thus Copernicus was compelled to opt for a heliocentric system with the Earth, as a planet, in motion around the sun.[14]

In his reconstruction, Swerdlow assumed that Copernicus *must* have had access to the models of his Islamic predecessors. Because of the scarcity of concrete evidence for this assertion (i.e. translated texts in Latin, earlier European references to these models, or the like), Swerdlow was clearly swayed by the similarity of complex geometrical models; independent discovery was simply not an option. As he stated with Neugebauer in 1984:

---

[13] Noel M. Swerdlow, "The Derivation and First Draft of Copernicus's Planetary Theory: A Translation of the Commentariolus with Commentary," *Proceedings of the American Philosophical Society* 117 (1973): 423–512 on p. 434.

[14] Admittedly, this is a grossly simplified version of a fuller and much more careful exposition that one may find in Swerdlow and Neugebauer, *Mathematical Astronomy,* 1: 41–64. A good summary is also provided by Michael H. Shank, "Regiomontanus on Ptolemy, Physical Orbs, and Astronomical Fictionalism: Goldsteinian Themes in the 'Defense of Theon against George of Trebizond,'" in *Perspectives on Science: Historical, Philosophical, Social* 10 (2002): 179–207.

> The planetary models for longitude in the *Commentariolus* are all based upon the models of Ibn ash-Shāṭir – although the arrangement for the inferior planets is incorrect – while those for the superior planets in *De revolutionibus* use the same arrangement as ʿUrdī's (*sic*) and Shīrāzī's model, and for the inferior planets the smaller epicycle is converted into an equivalent rotating eccentricity that constitutes a correct adaptation of Ibn ash-Shāṭir's model. In both the *Commentariolus* and *De revolutionibus* the lunar model is identical to Ibn ash-Shāṭir's and finally in both works Copernicus makes it clear that he was addressing the same physical problems of Ptolemy's models as his predecessors. It is obvious that with regard to these problems, his solutions were the same.
>
> The question therefore is not whether, but when, where, and in what form he learned of Marāgha theory.[15]

This has recently been reinforced by Swerdlow:

> How Copernicus learned of the models of his [Arabic] predecessors is not known – a transmission through Italy is the most likely path – but the relation between the models is so close that independent invention by Copernicus is all but impossible.[16]

Neugebauer and Swerdlow did have one bit of evidence that seemed to show a likely means of transmission between the Islamic world and Italy. This was a text contained in MS Vat. Gr. 211, in which one finds the Ṭūsī couple (rectilinear version) and Ṭūsī's lunar model. Apparently dating from about 1300, it is either a Greek translation or reworking of an Arabic treatise, made perhaps by the Byzantine scholar Gregory Chioniades.[17] The fact that this manuscript found its way to the Vatican, perhaps in the fifteenth century,

---

[15] Swerdlow and Neugebauer, *Mathematical Astronomy*, 1: 47. Cf. Neugebauer's earlier remark that "The mathematical logic of these methods is such that the purely historical problem of contact or transmission, as opposed to independent discovery, becomes a rather minor one" (O. Neugebauer, "On the Planetary Theory of Copernicus," in *Vistas in Astronomy* (ed. Arthur Beer), vol. 10, pp. 89–103, on. p. 90; reprinted in idem, *Astronomy and History*, pp. 491–505, on p. 492).

[16] Noel Swerdlow, "Copernicus, Nicolaus (1473–1543)," in *Encyclopedia of the Scientific Revolution from Copernicus to Newton*, ed. Wilbur Applebaum (New York/London: Garland Publishing, Inc., 2000), p. 165.

[17] Swerdlow and Neugebauer claim that it is a translation. The recent editors and translators of the text argue that it is an original Byzantine work that is simply influenced to some degree by Arabic or Persian sources (E. A. Paschos and P. Sotiroudis, *The Schemata*

provides a possible means for the transmission of knowledge of Ṭūsī's models. It is also noteworthy that Ṭūsī's models seem to have been widely known by contemporaries of Copernicus; examples include Giovanni Battista Amico and Girolamo Fracastoro.[18]

The historian of astronomy Willy Hartner also pointed to evidence for transmission from Islamic astronomers to Copernicus. Though he states that independent discovery of these models and devices by Copernicus was "possible," "it seems more probable that the news of his Islamic predecessor's model reached him in some way or other." Here Hartner was speaking of the model of Ibn al-Shāṭir; he was more certain that another example "proves clearly" the borrowing by Copernicus of the Ṭūsī couple inasmuch as the lettering in Copernicus's diagram in *De revolutionibus* follows the standard Arabic lettering rather than what one might expect in Latin.[19]

Historiographical Reactions

One would have expected that these historical discoveries, some of which are now almost a half-century old, would have caused a substantial reevaluation of the origins of the "scientific revolution" or at the least an attempt to deal with the role of Islamic science in that revolution. The fact that this has not yet occurred to any significant degree may be traced to several factors. First, recent trends in the historiography of science have resulted in critiques of the very notion of a "scientific revolution," which have tended to downplay the traditional preeminence of the Copernicus-Galileo-Newton narrative.[20] But even those who still hold to some notion of a scientific revolu-

---

of the Stars [Singapore: World Scientific Publishing, 1998], pp. 11–18). The closeness to Islamic sources, though, and the use of the standard Arabic corruption "Kakkaous" rather than the Greek Cepheus argues for a greater dependence than the authors wish to admit. Clearly more research on this question is needed.

[18] See Noel Swerdlow, "Aristotelian Planetary Theory in the Renaissance: Giovanni Battista Amico's Homocentric Spheres," *Journal for the History of Astronomy* 3 (1972): 36–48 and Mario Di Bono, "Copernicus, Amico, Fracastoro and Ṭūsī's Device: Observations on the Use and Transmission of a Model," *Journal for the History of Astronomy* 26 (1995): 133–154. In a passage in III.4 of *De revolutionibus* that was deleted prior to publication, Copernicus himself speaks of others who had used the Ṭūsī device; see Ragep, *Naṣīr al-Dīn,* 2: 431.

[19] Willy Hartner, "Copernicus, the Man, the Work, and Its History," in *Proceedings of the American Philosophical Society* 117, no. 6 (Dec. 1973), pp. 413–422, esp. p. 421.

[20] A session at a recent American History of Science Society annual meeting was entitled: "The Late, Great Scientific Revolution." Cf. Margaret J. Osler (ed.), *Rethinking the Scientific Revolution* (Cambridge: Cambridge University Press, 2000).

tion have tended to focus their attention on local contexts (usually European) for explanations and to look at the consequences rather than the origins of Copernicanism.[21] Second, the increasing realization that Copernicus was rather conservative in his scientific outlook, holding on, for example, to the traditional orbs and their uniform, circular motions, has called his revolutionary status into question. So there seems to be an underlying assumption that the enormous complexity in *De revolutionibus* is more or less irrelevant for the truly important innovation, heliocentrism, which, according to this view, is all that really mattered for Kepler, Galileo, et al. Thus the complicated story of "Copernicus and the Arabs," which is mostly about the complicated but supposedly irrelevant models, becomes more trouble than it is worth.[22] Third, despite, but in part due to, the trend towards "political correctness," there has been a tendency to essentialize different scientific traditions, sometimes because of a benign cultural relativism, sometimes for more invidious reasons. Thus the "essential" part of the scientific revolution, of which the de-centering of the Earth is fundamental, is seen as European.[23] Finally, the

---

[21] Two recent examples are Peter Dear's, *Revolutionizing the Sciences: European Knowledge and Its Ambitions*, 1500–1700 (Princeton, NJ: Princeton University Press, 2001) and Steven Shapin's, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996). Both ignore Islamic science entirely and scarcely discuss medieval European contributions to the scientific revolution.

[22] Copernicus's conservatism was emphasized in 1959 both in a scholarly and in a popular context. As for the former, Derek de Solla Price's "Contra-Copernicus" provided a technical account that showed that Copernicus was really still part of ancient and medieval astronomy. As Price concludes: "… Copernicus made a fortunate philosophical guess without any observation to prove or disprove his ideas, and … his work as a mathematical astronomer was uninspired. From this point of view his book is conservative and a mere reshuffled version of the *Almagest*" (Derek J. de S. Price, "Contra-Copernicus: A Critical Re-estimation of the Mathematical Planetary Theory of Ptolemy, Copernicus, and Kepler," in *Critical Problems in the History of Science*, ed. Marshall Clagett (Madison: The University of Wisconsin Press, 1969), pp. 197–218, on p. 216). The popular presentation of this viewpoint was made by Arthur Koestler in his *The Sleep Walkers: A History of Man's Changing Vision of the Universe* (London: Hutchinson, 1959), where Copernicus is referred to as the "timid canon." How Copernicus can be "saved" despite this conservatism and/or his connection to Islamic astronomy is well-illustrated by Erna Hilfstein's remarks regarding the significance of Copernicus's achievement: "Copernicus may have used the geometrical devices of his Greek or Arab predecessors, (for example, from the "Maragha School"), yet his system, and the perception of the cosmos it established, was entirely novel ("Introduction to the Softcover Edition" of *Nicholas Copernicus, On the Revolutions*, trans. and comm. by Edward Rosen (Baltimore: The Johns Hopkins University Press, 1992), p. XIII).

[23] Recent books by medievalists A. C. Crombie and Edward Grant advocate the European nature of modern science, thus reverting to the more traditional viewpoint. See Crombie's *Styles of Scientific Thinking in the European Tradition: The History of Argument*

simple fact of academic boundaries has played a role. Because historians of science specializing in Islamic civilization have tended to be marginalized, in part for disciplinary reasons, in part because of the arcane nature of many of their publications, it has been surprisingly difficult to initiate an on-going dialogue between medieval Latinists, Islamists, and early modernists.[24]

Although the larger history of science community seems so far to have resisted dealing with the implications of the Islamic connection to Copernicus, some historians of astronomy who do not specialize in Islamic science have been influenced by the discoveries of Kennedy and his colleagues. We have already discussed Neugebauer and Swerdlow. Jerzy Dobrzycki and Richard L. Kremer also explored possible connections between Islamic astronomy and early modern European astronomy in their incisive article "Peurbach and Marāgha Astronomy"; they raised the distinct possibility that Peurbach may well have developed non-Ptolemaic models based upon Islamic sources that were similar (if not the same) as ones that would be used in the next generation by Copernicus. Given this earlier possibility of transmission, they came to this interesting conclusion: "We may be looking for a means of transmission both more fragmentary and widespread than a single treatise, and at least one of the Marāgha sources must have been available to the Latin West before 1461, the year of Peurbach's death."[25] But not all historians of early modern astronomy have been so willing to accept a connection, even in the face of numerous coincidences. I. N. Veselovsky claimed that it is more likely that Copernicus got the Ṭūsī couple from a mathematically-related theorem in

---

and Explanation Especially in the Mathematical and Biomedical Sciences and Arts (London: Duckworth, 1994) and Grant's *The Foundations of Modern Science in the Middle Ages: Their Religious, Institutional, and Intellectual Contexts* (Cambridge: Cambridge University Press, 1996) and *God and Reason in the Middle Ages* (Cambridge: Cambridge University Press, 2001). This view is held both by western and Islamic scholars so cannot be simply ascribed to some biased antagonism towards Islamic civilization. For example, the Iranian expatriate S. H. Nasr has stated that although "all that is astronomically new in Copernicus can be found essentially in the school of al-Ṭūsī", Islamic astronomers were prescient enough not to break with the traditional Ptolemaic cosmology "because that would have meant not only a revolution in astronomy, but also an upheaval in the religious, philosophical and social domains" (S. H. Nasr, *Science and Civilization in Islam*, 2nd ed. [Cambridge, UK: The Islamic Texts Society, 1987]) p. 174).

[24] Cf. Sonja Brentjes, "Between doubts and certainties: on the place of history of science in Islamic societies within the field of history of science," *N.T.M.* 11 (2003): 65–79.

[25] Jerzy Dobrzycki and Richard L. Kremer, "Peurbach and Marāgha Astronomy? The Ephemerides of Johannes Angelus and Their Implications," *Journal for the History of Astronomy* 27 (1996): 187–237, on p. 211.

Proclus's *Commentary on the First Book of Euclid's Elements.*[26] More recently, Mario di Bono has maintained that independent rediscovery of the Islamic astronomical models by Copernicus and his contemporaries is at least as plausible as intercultural transmission. Somewhat surprisingly, he uses the number of similarities between Islamic and Copernican astronomy as evidence *against* transmission: "[If] derivation of Copernicus's models from Arab sources … is the case, it becomes very difficult to explain how such a quantity of models and information, which Copernicus would derive from Arab sources, has left no trace – apart from Ṭūsī's device – in the works of the other western astronomers of the time."[27]

The Conceptual Background to the Copernican Revolution

Di Bono's article serves to highlight what has been missing in the analysis of the connection between Islamic astronomy and Copernicus. The emphasis on the models alone obscures several crucial historiographical, conceptual, and physical issues that need to be considered when dealing with the Copernican transformations. Let us first look briefly at some of these historiographical issues. What seems to be overlooked by those who advocate a reinvention by Copernicus and/or his contemporaries of the mathematical models previously used by Islamic astronomers is the lack of a historical context for those models within European astronomy. At the least, one would expect to find some tradition of criticism of Ptolemy in Europe in which those models would make sense. But in fact this is not the case. Copernicus's statement of his dissatisfaction with Ptolemaic astronomy, which is the ostensible reason he gives for his drastic cosmological change, had no precedent in Europe but did have a continuous five-hundred-year precedent in the Islamic world. Here is what he says in the introduction to the *Commentariolus*:

> … these theories [put forth by Ptolemy and most others] were inadequate unless they also envisioned certain *equant* circles, on account of which it appeared that the planet never moves with uniform velocity either in its *deferent* sphere or with respect to its proper center. Therefore

---

[26] I. N. Veselovsky, "Copernicus and Naṣīr al-Dīn al-Ṭūsī," *Journal for the History of Astronomy* 4 (1973): 128–130. This turns out to be implausible because Copernicus probably did not know of the Proclus theorem (actually the converse of the Ṭūsī-couple) until many years after he used the device.

[27] Di Bono, "Copernicus, Amico, Fracastoro and Ṭūsī's Device," pp. 153–154.

> a theory of this kind seemed neither perfect enough nor sufficiently in accordance with reason.
>
> Therefore, when I noticed these [difficulties], I often pondered whether perhaps a more reasonable model composed of circles could be found from which every apparent irregularity would follow while everything in itself moved uniformly, just as the principle of perfect motion requires.[28]

Since the *Commentariolus* is the initial work in which Copernicus presents his new cosmology, one would assume that it would be here, and not in the much later *De revolutionibus*, in which we should search for his original motivations.[29] What do we learn from this passage? Copernicus puts himself squarely within the tradition of Islamic criticisms of Ptolemy's violations of uniform, circular motions in the heavens. It is important to keep in mind that this tradition began in the Islamic world as early as the eleventh century and led to the series of alternative models outlined above. Furthermore this tradition lasted for some six centuries in which there was a very vigorous discourse that led to various proposals, criticisms, and counter-proposals by an active group of astronomers from many regions of the Islamic world. Those who advocate parallel development would thus seem to be claiming that a centuries-long tradition with no analogue whatsoever in Europe was recapitulated, somehow, in the life of one individual who not only paralleled the criticisms but also the same models and revised models in the course of some 30 years. Needless to say, such an approach is ahistorical in the extreme.

Another point needs to be made here. Di Bono and others have pointed to the Paduan astronomers as a possible source for Copernicus's inspiration. But an important distinction needs to be made. The "return" to homocentric astronomy that was evidently advocated by the Paduans has its parallel and inspiration in the "Andalusian revolt" against Ptolemy in twelfth-century Spain. But this revolt, fomented by such figures as Ibn Bājja, Ibn Ṭufayl, Ibn Rushd (Averroes), and most importantly by al-Biṭrūjī, who advanced an alternative astronomical/cosmological system, needs to be clearly differentiated from

---

[28] Swerdlow, "The Derivation and First Draft of Copernicus's Planetary Theory," pp. 434–435.

[29] Recently Bernard R. Goldstein ("Copernicus and the Origin of His Heliocentric System," *Journal for the History of Astronomy* 33 (2002): 219–235) has sought to undermine Swerdlow's reconstruction of the origins of Copernicus's heliocentric system by emphasizing a passage in *De revolutionibus* (I.10). In it Copernicus points to the distance-period relationship of the planets to justify his system, which Goldstein takes to be the initial motivation. But again, it is odd that this is hardly mentioned in the *Commentariolus*.

the type of Islamic astronomy that most closely resembles that of Copernicus, i.e. the Eastern *hay'a* tradition of Ibn al-Haytham, Ṭūsī, ʿUrḍī, Shīrāzī, Ibn al-Shāṭir and others.[30] What we know from the Andalusian revolt is that its extreme position against Ptolemy's epicycles and eccentrics led to a failed project that had virtually no impact on the Eastern *hay'a* tradition. It would seem odd indeed that this Andalusian tradition, in the guise of Paduan astronomy, would have been a source for Copernicus's alternative models in which epicycles and eccentrics play such a prominent role. It is also important to note that neither among the Paduans nor among European astronomers and natural philosophers before Copernicus is there a criticism of the equant or other Ptolemaic devices that lead to a violation of uniform, circular motion.[31] One must be careful to distinguish a general criticism of Ptolemy's eccentrics and epicycles (and an advocacy of homocentric astronomy) from the tradition of criticism of Ptolemy's irregular motions that was initiated by Ibn al-Haytham, a tradition that clearly includes Copernicus.

Let us now turn to the conceptual issues involved with the Copernican revolution. In the traditional Aristotelian hierarchy of the sciences, the mathematical sciences (including astronomy) were dependent (or subalternate) to physics/natural philosophy, which itself was subordinate to metaphysics. Obviously in order to overturn the Aristotelian doctrine of a stationary Earth, a doctrine for Aristotelians firmly based upon both natural philosophical and metaphysical principles, Copernicus would have had to conceive of a different type of physics. This physics would need to be, somehow, formulated within the discipline of astronomy itself and somehow independent of Aristotelian natural philosophy. Luckily, he had a number of important precedents for this position.

The most authoritative of these precedents was Ptolemy himself. In the introduction to the *Almagest,* Ptolemy reverses the order of the sciences and places mathematics above natural philosophy and metaphysics (or "theology"), both of which, he claims, "should rather be called guesswork than knowledge." He goes on to say "that only mathematics can provide

---

[30] For this Spanish episode in Islamic astronomy, see Sabra, "The Andalusian Revolt," pp. 133–153.

[31] It is difficult, if not impossible, to prove a negative, but it is highly suggestive that one does not find the word "equant" in Edward Grant's monumental (816-page) *Planets, Stars, and Orbs: The Medieval Cosmos, 1200–1687* (Cambridge: Cambridge University Press, 1994). Even in the generation immediately before Copernicus, there seems to have been no precedent for what was a commonplace in Islamic astronomy. As Dobrzycki and Kremer state in their "Peurbach and Marāgha Astronomy?": "We know of no extant text by Peurbach or Regiomontanus in which the Ptolemaic models are criticized explicitly on the grounds that they violate uniform, circular motion" (p. 211).

sure and unshakeable knowledge to its devotees, provided one approaches it rigorously."[32] Though his position had the *potential* to free the astronomer from the natural philosopher, in actuality a kind of compromise emerged in which the astronomer and the natural philosopher were said to differ not on the actual set of doctrines but rather on the way to prove them. This is clearly laid out in a passage from Geminus preserved in Simplicius' commentary on Aristotle's physics:

> Now in many cases the astronomer and the physicist will propose to prove the same point, e.g., that the sun is of great size or that the Earth is spherical, but they will not proceed by the same road. The physicist will prove each fact by considerations of essence or substance, of force, of its being better that things should be as they are, or of coming into being and change; the astronomer will prove them by the properties of figures or magnitudes, or by the amount of movement and the time that is appropriate to it.[33]

Most Islamic astronomers followed this formulation, elaborating and clarifying it using the fact/reasoned fact (*quia/propter quid*) distinction of Aristotle's *Posterior Analytics.* Thus the astronomers were seen as giving the facts of various cosmological issues (e.g. that the Earth was spherical) using observational and mathematical tools as is done in Ptolemy's *Almagest,* whereas the proof of the natural philosopher, such as in Aristotle's *De caelo,* provided the reason or the "why" behind these facts.[34]

This relatively benign view of the relationship between the astronomer and the physicist came, over time, to be modified in significant ways. Most likely under the influence of Islamic theologians, who were fundamentally opposed to Aristotelian notions of natural cause, we can see subtle shifts in how physical principles were presented in the introductory parts of astronomical texts.[35] Naṣīr al-Dīn al-Ṭūsī, for example, presented the critical principle of the uniformity of celestial motion in such a way that it did not depend

---

[32] G. J. Toomer, *Ptolemy's Almagest* (London: Duckworth, 1984), p. 36.

[33] The translation is due to T. L. Heath in his *Aristarchus of Samos* (Oxford: Clarendon Press, 1913), p. 276; reprinted in Morris R. Cohen and I. E. Drabkin, *A Source Book in Greek Science* (Cambridge, MA: Harvard University Press, 1948), pp. 90–91. Cf. G. E. R. Lloyd, "Saving the Appearances," *Classical Quarterly,* 1978, *NS 28:* 202–222, esp. pp. 212–214 (reprinted with new introduction in idem*, Methods and Problems in Greek Science* [Cambridge, England: Cambridge University Press, 1991], pp. 248–277).

[34] Ragep, *Naṣīr al-Dīn,* 1: 38–41, 106–107, 2: 386–388.

[35] Much of what follows is elaborated in F. Jamil Ragep, "Freeing Astronomy from Philosophy: An Aspect of Islamic Influence on Science," *Osiris* 16 (2001): 49–71.

upon the ultimate cause. Thus the monoformity of falling bodies, and the uniformity of celestial motions, both of which moved “in a single way,” was what was important. It became irrelevant that the former was brought about by a “nature” while the latter was brought about by a “soul.”[36]

Slowly, then, we see an attempt in Islamic astronomy to provide a self-contained mathematical methodology that ran parallel to the methods of the natural philosophers. But Ṭūsī for one did not believe that this meant that the astronomer could be completely independent of the natural philosophers and metaphysicians, since there were certain principles that only the natural philosophers could provide the astronomer. In fact this was generally the position of Islamic astronomers with the notable exception of ʿAlī Qūshjī in the fifteenth century.

Qūshjī was the son of the falconer of Ulugh Beg (1394–1449), the Timurid prince who was a generous patron of the sciences and arts. Ulugh Beg was an active supporter and participant in the magnificent Samarqand observatory, which was one of the greatest scientific institutions that had been established up to that time. As a boy, Qūshjī became his protégé and student and eventually occupied an important position at the observatory. After the assassination of Ulugh Beg, Qūshjī was attached to various courts in Iran but would end his career in Constantinople under the patronage of Mehmet II, who had conquered the city for the Ottomans.

Qūshjī held that the astronomer had no need for Aristotelian physics and in fact should establish his own physical principles independently of the natural philosophers.[37] This position had profound implications for one principle in particular, namely that the element earth had a principle of rectilinear inclination that precluded it from moving naturally with a circular motion.[38] Ṭūsī had maintained that there was no way for the astronomer, using mathematics and observation, to arrive at the “proof of the fact” that the Earth was either moving or at rest. This was contrary to Ptolemy’s position in the *Almagest* (I.7), namely that one could establish a static Earth through observation. After Ṭūsī, we can trace a three-century discussion in which various authors argued whether he or Ptolemy was correct regarding the possibility of an observational proof of the Earth’s state of rest. Qūshjī, though, took a somewhat different approach. Starting with his view that the astronomer

---

[36] Ragep, *Naṣīr al-Dīn,* 1:44–46, 98–101, 2: 380–381.

[37] Ragep, “Freeing Astronomy,” pp. 61–63.

[38] A discussion of this Islamic discourse on the Earth’s possible rotation is in F. Jamil Ragep, “Ṭūsī and Copernicus: The Earth’s Motion in Context,” *Science in Context* 14, nos. 1–2 (2001): 145–163.

should not depend on the natural philosopher, but also rejecting Ptolemy's view that an observational test was possible, Qūshjī made the remarkable claim that nothing false follows from the assumption of a rotating Earth.[39]

The connection with Copernicus, though, might seem tenuous at best. What makes this an arguable possibility is the remarkable coincidence between a passage in *De revolutionibus* (I.8) and one in Ṭūsī's *Tadhkira* (II.1[6]) in which Copernicus follows Ṭūsī's objection to Ptolemy's "proofs" of the Earth's immobility.[40] This passage, which is quoted by numerous scholars after Ṭūsī, including Qūshjī, formed the starting point for the Islamic discussion of the Earth's possible motion after Ṭūsī. The closeness of the passage in Copernicus is one more bit of evidence that he seems to have been influenced not only by Islamic astronomical models but also by a conceptual revolution that was going on in Islamic astronomy. This conceptual revolution was opening up the possibility for an alternative "astronomical" physics that was independent of Aristotelian physics.

It is this point that has been missed up to now in seeking to understand the Islamic background to Copernicus. Clearly there is more to the Copernican revolution than some clever astronomical models that arose in the context of a criticism of Ptolemy. There also needed to be a new conceptualization of astronomy that could allow for an astronomically-based physics. But there is hardly anything like this in the European tradition before Copernicus.[41] The fact that we can find a long, vigorous discussion in Islam of this issue intricately-tied to the question of the Earth's movement should indicate that such a conceptual foundation was there for the borrowing. It will be argued, of course, that the mechanism for such borrowing has yet to be found. But again, in my opinion it is more important at this point in our knowledge to focus on the *products* rather than the mechanism of transmission. By doing so, we can get a clearer idea not only of the possible Islamic connection to Copernicus but also of the Copernican revolution itself.

---

[39] Ibid., p. 157.

[40] Ibid., p. 145–148.

[41] In the fourteenth century, one finds Nicole Oresme and Jean Buridan discussing the Earth's rotation. The former, in particular, presents quite cogent reasons why one might believe in this motion. But in the end he rejects them for theological reasons. In both cases, it is clear that they have no interest in a reconceptualization of astronomy along the lines that occurred in Islamic astronomy (ibid., pp. 158–160). The possibility that such a discussion might have taken place in the fifteenth century in the circle of Peurbach and Regiomontanus is being investigated by Michael Shank; cf. his "Regiomontanus on Ptolemy, Physical Orbs, and Astronomical Fictionalism."

Bibliography

al-Biṭrūjī, Nūr al-Dīn abū Isḥāq. *On the Principles of Astronomy.* Edited and translated by Bernard Goldstein. 2 vols. New Haven: Yale University Press, 1971.

Brentjes, Sonja. "Between doubts and certainties: on the place of history of science in Islamic societies within the field of history of science." *N.T.M.* 11 (2003): 65–79.

Carra de Vaux. "Les sphères célestes selon Nasīr Eddin-Attusī." In Paul Tannery, *Recherches sur l'histoire de l'astronomie ancienne,* Appendix VI, pp. 337–361. Paris, 1893.

Cohen, Morris R. and Drabkin, I. E. *A Source Book in Greek Science.* Cambridge, MA: Harvard University Press, 1948.

Copernicus, Nicholas. *De revolutionibus orbium coelestium.* Translated by Edward Rosen as *On the Revolutions.* Baltimore: The Johns Hopkins University Press, 1978.

Crombie, A. C. *Styles of Scientific Thinking in the European Tradition: The History of Argument and Explanation Especially in the Mathematical and Biomedical Sciences and Arts.* London: Duckworth, 1994.

Dear, Peter. *Revolutionizing the Sciences: European Knowledge and Its Ambitions,* 1500–1700. Princeton, NJ: Princeton University Press, 2001.

Di Bono, Mario. "Copernicus, Amico, Fracastoro and Ṭūsī's Device: Observations on the Use and Transmission of a Model." *Journal for the History of Astronomy* 26 (1995): 133–154.

Dobrzycki, Jerzy and Kremer, Richard L. "Peurbach and Marāgha Astronomy? The Ephemerides of Johannes Angelus and Their Implications." *Journal for the History of Astronomy* 27 (1996): 187–237.

Dreyer, J. L. E. *History of the Planetary Systems from Thales to Kepler.* Cambridge: Cambridge University Press, 1906.

Goldstein, Bernard R. "Copernicus and the Origin of His Heliocentric System." *Journal for the History of Astronomy* 33 (2002): 219–235

Grant, Edward. *Planets, Stars, and Orbs: The Medieval Cosmos, 1200–1687.* Cambridge: Cambridge University Press, 1994.

Grant, Edward. *The Foundations of Modern Science in the Middle Ages: Their Religious, Institutional, and Intellectual Contexts.* Cambridge: Cambridge University Press, 1996.

Grant, Edward. *God and Reason in the Middle Ages.* Cambridge: Cambridge University Press, 2001.

Hartner, Willy. "Copernicus, the Man, the Work, and Its History." *Proceedings of the American Philosophical Society* 117, no. 6 (Dec. 1973), pp. 413–422.

Heath, T. L. *Aristarchus of Samos.* Oxford: Clarendon Press, 1913.

Hilfstein, Erna. "Introduction to the Softcover Edition." *Nicholas Copernicus,* *On the Revolutions.* Translation and commentary by Edward Rosen. Baltimore: The Johns Hopkins University Press, 1992.

Kennedy, E. S. "Late Medieval Planetary Theory." *Isis* 57 (1966): 84–97.

Kennedy, E. S. and Ghanem, Imad (eds.). *The Life & Work of Ibn al-Shāṭir: An Arab Astronomer of the Fourteenth Century.* Aleppo, 1976.

Kennedy, E. S. et al. *Studies in the Islamic Exact Sciences.* Beirut, 1983.

Koestler, Arthur. *The Sleep Walkers: A History of Man's Changing Vision of the Universe.* London: Hutchinson, 1959.

Lloyd, G. E. R. "Saving the Appearances." *Classical Quarterly,* 1978, *NS 28:* 202–222; reprinted with new introduction in idem, *Methods and Problems in Greek Science* (Cambridge, England: Cambridge University Press, 1991), pp. 248–277.

Morelon, Régis. *Thābit ibn Qurra: Œuvres d'astronomie.* Paris: Les Belles Lettres, 1987.

Nasr, S. H. *Science and Civilization in Islam.* 2nd ed. Cambridge, UK: The Islamic Texts Society, 1987.

Neugebauer, O. "On the Planetary Theory of Copernicus." *Vistas in Astronomy* (ed. Arthur Beer), vol. 10, pp. 89–103; reprinted in idem, *Astronomy and History* (New York: Springer-Verlag, 1983), pp. 491–505.

Osler, Margaret J. (ed.). *Rethinking the Scientific Revolution.* Cambridge: Cambridge University Press, 2000.

Paschos, E. A. and Sotiroudis, P. *The Schemata of the Stars.* Singapore: World Scientific Publishing, 1998.

Price, Derek J. de S. "Contra-Copernicus: A Critical Re-estimation of the Mathematical Planetary Theory of Ptolemy, Copernicus, and Kepler." In Marshall Clagett (ed.), *Critical Problems in the History of Science.* Madison: The University of Wisconsin Press, 1969, pp. 197–218.

Ragep, F. Jamil. "The Two Versions of the Ṭūsī Couple." In David King and George Saliba (eds.), *From Deferent to Equant: Studies in Honor of E. S. Kennedy* (vol. 500 of *The Annals of the New York Academy of Sciences,* 1987), pp. 329–356.

Ragep, F. J. *Naṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy.* 2 vols. New York: Springer-Verlag, 1993.

Ragep, F. Jamil. "Freeing Astronomy from Philosophy: An Aspect of Islamic Influence on Science." *Osiris* 16 (2001): 49–71.

Ragep, F. Jamil. "Ṭūsī and Copernicus: The Earth's Motion in Context." *Science in Context* 14, nos. 1–2 (2001): 145–163.

Ragep, F. Jamil. "Ibn al-Haytham and Eudoxus: The Revival of Homocentric Modeling in Islam." In Charles Burnett, Jan P. Hogendijk, Kim Plofker and Michio Yano (eds.), *Studies in the History of the Exact Sciences in Honour of David Pingree.* Leiden: Brill, 2004, pp. 786–809.

Sabra, A. I. "The Andalusian Revolt Against Ptolemaic Astronomy: Averroes and al-Biṭrūjī." In E. Mendelsohn (ed.), *Transformation and Tradition in the Sciences.* Cambridge: Cambridge University Press, 1984, pp. 133–153.

Saliba, George. "Ibn Sīnā and Abū ʿUbayd al-Jūzjānī: The Problem of the Ptolemaic Equant." *Journal for the History of Arabic Science* 4 (1980): 376–403.

Shank, Michael H. "Regiomontanus on Ptolemy, Physical Orbs, and Astronomical Fictionalism: Goldsteinian Themes in the 'Defense of Theon against George of Trebizond.'" *Perspectives on Science: Historical, Philosophical, Social* 10 (2002): 179–207.

Shapin, Steven. *The Scientific Revolution.* Chicago: University of Chicago Press, 1996.

Swerdlow, Noel. "Aristotelian Planetary Theory in the Renaissance: Giovanni Battista Amico's Homocentric Spheres." *Journal for the History of Astronomy* 3 (1972): 36–48.

Swerdlow, Noel M. "The Derivation and First Draft of Copernicus's Planetary Theory: A Translation of the Commentariolus with Commentary." *Proceedings of the American Philosophical Society* 117 (1973): 423–512.

Swerdlow, N. M. and Neugebauer, O. *Mathematical Astronomy in Copernicus's De Revolutionibus.* 2 parts. New York: Springer-Verlag, 1984.

Swerdlow, Noel. "Copernicus, Nicolaus (1473–1543)." In Wilbur Applebaum (ed.), *Encyclopedia of the Scientific Revolution from Copernicus to Newton.* New York/London: Garland Publishing, Inc., 2000.

Toomer, G. J. *Ptolemy's Almagest.* London: Duckworth, 1984.

Veselovsky, I. N. "Copernicus and Naṣīr al-Dīn al-Ṭūsī." *Journal for the History of Astronomy* 4 (1973): 128–130.

Filozofski vestnik Volume/Letnik XXV • Number/Številka 2 • 2004 • 143–166

COPERNICUS' FIRST FRIENDS: PHYSICAL COPERNICANISM FROM 1543 TO 1610

Katherine A. Tredwell and Peter Barker

Early assessments of the Copernican Revolution were hampered by the failure to understand the nature of astronomy in the sixteenth century, as scholars took statements made in praise of Copernicus to be implicit endorsements of his heliocentric cosmology. Gradually this view has been supplanted by the acknowledgement that many supposed partisans of Copernicus only endorsed the use of his astronomical models for the calculation of apparent planetary positions, while rejecting or remaining silent on the reality of heliocentrism. A classic example of this shift in historiography concerns Erasmus Reinhold (1511–1553), a professor of mathematics at the University of Wittenberg. Reinhold's use of Copernican models in his *Prutenic Tables* (*Tabulae prutenicae,* 1551) has led to the mistaken belief that he sanctioned a Sun-centered cosmology as well. Careful reassessment of his published writings has revealed that he commended certain aspects of Copernicus' work, such as the elimination of the equant, but showed no interest in heliocentrism (Westman, 1975: pp. 174–178). Other supposed Copernicans, such as Robert Recorde (c. 1510–1558), expressed some openness to the Earth's motion but left no clear indication of what they thought to be the true system of the world (Russell, 1972: pp. 189–191).

Between the publication of Copernicus' epoch-making book *On the Revolutions of the Celestial Orbs* (*De revolutionibus orbium coelestium*) in 1543 and the year 1610, only a handful of individuals can be identified with certainty as Copernicans, in the sense that they considered heliocentrism to be physically real and not merely a calculational convenience. In this paper we discuss this tiny group of true Copernicans and their reasons for believing that Copernicus, not Ptolemy or Tycho Brahe, was correct. Most expressed their convictions in terms familiar to their contemporaries. For instance, they thought of the motions of the planets in terms of three-dimensional orbs or two-dimensional circles which defined the direction to the planet for an observer on the Earth, measured from some fixed line of reference. They did not think of planetary motions as continuous paths through space. Not until the seventeenth century did Copernicanism in the modern sense begin to appear, after the publications of Johannes Kepler's *New Astronomy* (*Astronomia nova,* 1609) and Galileo Galilei's *Sidereal Messenger* (*Sidereus Nuncius,* 1610) introduced new factors to the cosmological debate.

We take as our starting point the list of Copernicans before 1600 identified by historian of science Robert S. Westman: Georg Joachim Rheticus, Michael Maestlin, Christopher Rothmann, Johannes Kepler, Giordano Bruno, Galileo Galilei, Thomas Digges, Thomas Harriot, Diego de Zúñiga, and Simon Stevin (Westman, 1980: p. 136 n. 6). Two other figures will also be discussed in the paper. Gemma Frisius preferred the Copernican system to its Ptolemaic rival as a description of the true arrangement of the world. William Gilbert never endorsed heliocentrism explicitly, but he was favorably inclined towards Copernicus and accepted that the Earth rotated daily on its axis. He is included as a probable Copernican. One conspicuous absence is Thomas Harriot, whose astronomical works were not published and today are scattered among several manuscript collections. Possibly a very small number of Copernicans in the period up to 1610 have not been identified, so our list should not be regarded as exhaustive. However, the positions we discuss in this paper reflect the beliefs of a majority of early heliocentrists. We begin at the beginning, with the first followers of Copernicus.

1.

Georg Joachim Rheticus (1514–1574) was a professor of mathematics at Wittenberg, then in Leipzig; later, he studied medicine in Prague and became a physician in Cracow (Burmeister, 1967–68). In 1539, during a leave of absence from his position at Wittenberg, Rheticus visited Copernicus at his home in North Prussia. How much he had already heard of Copernicus is uncertain, but once in Frauenberg he became persuaded that his host's work offered many advantages over Ptolemy. Quickly he wrote a nontechnical treatise on the new astronomy, the *First Account* (*Narratio prima,* 1540), explaining Copernicus' models. This became the first printed description of Copernican heliocentrism. Soon after, he supervised the process of publishing *On the Revolutions,* but left the task to be finished by Andreas Osiander and Ioannes Petreius so that he could move from Wittenberg to Leipzig (Barker and Goldstein, 2003).

The *First Account* described many features of Copernican astronomy. Some, such as the new determination of the distances of the Sun and Moon from the Earth and the elimination of the equant, were compatible with geocentrism and therefore received positive attention from many sixteenth-century astronomers (Rheticus, 1971/1540: pp. 133, 135). But today the book is remembered chiefly for its identification of many advantages of heliocentrism over geocentrism. Its list may serve as a useful starting-point for our discussion of sixteenth-century Copernicanism.

Rheticus gives many reasons for accepting Copernicus over geocentric astronomy. Copernicus explains the motions of precession and the changing obliquity of the ecliptic by the motion of the Earth. The changing apparent eccentricity of the Sun appears in the eccentricity of the other planets. The centers of the planetary deferents seem to be near the Sun. Mars, for instance, has a parallax sometimes greater and sometimes less than the parallax of the Sun, so the Earth cannot be its center of motion. All circles have their own centers as their centers of motion, which eliminates the equant (though this did not require heliocentrism as Rheticus implied). Copernicus uses terrestrial motion to explain many inequalities of motion, so that one motion has multiple purposes. Geocentrism related many motions to the motion of the Sun, but heliocentrism creates harmony by linking a variety of inequalities to terrestrial motion as befits God's skill as Creator. For example, Copernicus explains, as Ptolemy cannot, why planetary stations and retrogradations are linked to the Sun; they are illusions created by the annual motion of the Earth on the Great Orb (Rheticus, 1971: 136–140 and passim).

Rheticus also pointed out that Copernicus eliminated the invention of invisible spheres beyond the sphere of fixed stars (used by geocentrists to explain daily rotation and other motions) by attributing all motions to the Earth instead. Furthermore, heliocentrism created a qualitative distance-velocity relation in which the largest planetary spheres were slowest and the smallest spheres were fastest (Rheticus, 1971: pp. 144–146). Finding a distance-velocity relationship may have motivated Copernicus to investigate heliocentrism (Goldstein, 2002). The motion of the Earth explains the bounded elongation of Mercury and Venus, and the motions of all planets in latitude. Rheticus stressed two advantages that he evidently found most convincing. First, in contrast to daily rotation and other terrestrial motions which could be attributed to the heavens, he could not see a way to reconcile precession to geocentrism. Second, he was impressed that heliocentrism created a harmony of interconnected motions and cited harmony more frequently than did Copernicus (Westman, 1975: p. 185). At the same time he stated in the *First Account* that he would leave it to mathematicians and philosophers to determine which of the two systems was correct. Rheticus did not write further in defense of heliocentrism. Perhaps he concluded on further reflection that the advantages of

Copernicanism did not prove beyond doubt that the Earth moved, though this must remain speculation given the current state of evidence.

2.

Gemma Frisius (1508–55) began his career as a mathematical practitioner, and made significant contributions to geography, but spent his later years practicing and teaching medicine at Louvain (Kish, 1967; Lammens, 2002). Gemma may have heard about Copernicus' theories even before their publication . He was briefly a client of Johann Flaschbinder (known from the place of his birth by the Latin name "Dantiscus") who later became Bishop of Ermland and Copernicus' superior. However, Gemma received a copy of the *First Account*, probably in 1540, and later made extensive annotations in a copy of *On the Revolutions* (Lammens, 2002: i: pp. 60–4 and ii, passim.).

In addition to praising Copernicus in letters written to Dantiscus in the early 1540s, Gemma endorsed physical Copernicanism in a 1555 letter published as a preface to an astronomical work by Ioannes Stadius (Gemma Frisius, 1555). He notes the increased accuracy of Copernican calculations, for example in determining the time of the equinox. Gemma then argues that Copernicus can explain things that Ptolemy can only assume, for example that the superior planets are always at the perigee of their epicycles (and hence in the middle of a retrogression) when they are diametrically opposite to the Sun in the sky. Gemma describes Copernicus' result as a demonstration of the true causes of the phenomenon (Gemma Frisius, 1555: fol. a 2 v). This is an unusual and strong claim. Although demonstration of the true cause of a phenomenon, according to the standards established by Aristotle in the *Posterior Analytics*, was an ideal in all areas of natural philosophy, this standard was generally held to be unobtainable in astronomy (Barker and Goldstein, 1998; Barker, 2000a, p. 80). Gemma not only asserts the physical reality of Copernicus' cosmic scheme but claims that it provides scientific explanations of previously unexplained facts according to the highest standards accepted at the time.

3.

Most early readers of Copernicus with the mathematical competence to appreciate his technical innovations nevertheless did not accept heliocentrism as a statement of physical reality. Reinhold, Rheticus' senior colleague at Wittenberg, figured prominently in the promotion of *On the Revolutions* because he prepared the *Prutenic Tables* (1551) based on Copernican astronomical models. Yet he never advocated a Sun-centered system and the aspects of Copernicus in which he took an interest, such as his lunar theory, did not require any motion of the Earth (Reinhold, 1542: fol. C 7 r). Reinhold was one of a group of mathematicians at Wittenberg during the sixteenth century who considered Copernican astronomy useful for the calculation of apparent planetary positions but physically objectionable, an attitude Westman has termed the "Wittenberg Interpretation of Copernicus" (Westman, 1975). Reinhold's successor Caspar Peucer (1525–1602) wrote a textbook of astronomy incorporating Copernicus' determination of the distances of the Sun and Moon as well as arguments upholding the centrality and immobility of the Earth on mathematical, physical, and religious grounds (Peucer, 1569: pp. 75–76, 100–107).

Reinhold and Peucer were among the students at Wittenberg who were encouraged to study mathematics by Philip Melanchthon (1497–1560), a Lutheran reformer who saw the certainty of mathematical astronomy as an unambiguous sign of providential design. Through his students, Melanchthon's influence was passed on to later generations of Lutheran mathematicians, including Michael Maestlin and Tycho Brahe (1546–1601). Tycho, who studied briefly at Wittenberg and was acquainted with Peucer, transformed Copernicus' heliocentric system into the geostatic system called "Tychonic": the Moon, Sun, and fixed stars circle the unmoving Earth, while the five planets circle the moving Sun. His system incorporated many advantages of heliocentrism, such as the bounded elongations of the inferior planets, while avoiding the difficulties of terrestrial motion. However, the distances of the celestial bodies required that the deferents of the Sun and Mars overlap, which would be impossible if the planets were carried by impenetrable orbs. Tycho overcame this difficulty by arguing that the heavens were composed of a fluid material, an idea that may have been suggested to him by a Copernican.

4.

Christopher Rothmann (born ca. 1560, d. before 1611) was educated, like Rheticus, at Wittenberg, where he studied theology, mathematics and astronomy. During the 1580s he served as *mathematicus* to Wilhelm IV, Landgraf of Hesse (1532–92). At court in Kassel he assisted the Landgraf in a program of systematic astronomical observation, corresponded with Tycho Brahe and wrote several books which remained unpublished at his death (Barker, 2000c). These included a handbook of astronomy in which he attempts to reconcile scripture with the abolition of celestial spheres (Rothmann, 2003/1589), and a book on the comet of 1585, which may have persuaded Brahe that the substance of the heavens was a fluid like air, through which the planets moved themselves (Goldstein and Barker, 1995). His endorsement of Copernicus occurs in correspondence published by Brahe in 1596, after Rothmann had visited Hven, and according to Brahe, recanted. Recent evidence suggests that Rothmann endorsed a geo-heliocentric position, rather than heliocentrism, around 1590 (Barker, 2004). Rothmann subsequently dropped out of sight and his final views are unknown, but, at least in a letter dated October 1588, he asserts the truth of the Copernican doctrine on the grounds that Copernicus not only shows that stations and retrogradations occur in positions linked to the positions of the Sun, but also shows why they occur there. In other words, Copernicus demonstrates, or explains, features of planetary motion that are described but not explained by Ptolemy. This is the same methodological argument for Copernicanism made by Gemma Frisius.

5.

Michael Maestlin (1550–1631) studied mathematics and theology (Barker, 2000b; Rosen, 1974). Save for a brief period as a pastor in Backnang (1577–1580) and a professor at Heidelberg (1580–1584), he spent his life teaching mathematics at Tübingen. From the nova of 1572 and the comets of 1577 and 1580 he concluded that these phenomena were beyond the Moon, contradicting the Aristotelian doctrine of an unchanging celestial realm. He entertained heliocentrism in an early work on the nova but did not become a committed Copernican until his work on the comet of 1577 (Westman, 1972). Maestlin calculated that the path of the comet would require it to pass through celestial orbs in the Ptolemaic system, an impossibility according to the reigning physics of the day. However, in the Copernican system the comet would be located on its own orb in the gap between the spheres of Venus and the Earth. He announced this discovery and his support of Copernicanism in *Observation and Demonstration of an Aethereal Comet* (1578) and did similar work on the comet of 1580 in *Astronomical Consideration and Observation of an Aethereal Comet* (Maestlin, 1578: pp. 38–39; Maestlin, 1581; Barker and Goldstein, 2001: pp. 93–95). In the classroom, Maestlin continued to teach old-fashioned Ptolemaic astronomy including the use of equants, but he also taught the Copernican system to some of his students (Methuen, 1996). In later editions of his textbook *An Epitome of Astronomy* (1610, 1624) he added a passage ridiculing geocentrism and geoheliocentrism and upholding heliocentrism as the best alternative (Tredwell, 2004).

When Kepler, Maestlin's most famous student, published his first book

Mystery of the Cosmos (1596), Maestlin on his own initiative added two other works to be included in the volume. One, an appendix written by Maestlin, explicated the sizes of the orbs and distances of the planets according to Copernican values. This appendix demonstrates his understanding that the apparatus of orbs for each planet extended further than the inner and outer boundaries defined by the three-dimensional motion of the planet itself (Grafton, 1973). Maestlin also added an extensively annotated new edition of the *First Account.* In the commentary he calculated the distance that a star must travel in a single second (1200 German miles) due to the daily rotation of the heavens in a geocentric system. Maestlin argued that the incredibly swift motion of such an immense sphere is far more absurd than the daily rotation of the comparatively tiny Earth. In the 1621 edition, and in the supplement to the *Epitome* mentioned above, he extended the argument to include the Tychonic system. He also appealed to the power of an omnipotent God to overcome objections to the Copernican system involving the size of the sphere of fixed stars and the unused space between Saturn and the sphere of stars (Tredwell, 2004).

6.

Simon Stevin (c.1548–c.1620) was a mathematical practitioner born at Bruges in the Netherlands. After 1584 he served as mathematical tutor to Maurice of Nassua, Prince of Orange. Stevin defended physical Copernicanism in the third book of his *Mathematical Memoirs*, composed to instruct the prince in astronomy and cosmology, and published between 1605 and 1608. Although this falls right at the end of our period, barely predating the publication of Kepler's *New Astronomy* and Galileo's *Sidereal Messenger*, the book probably records opinions developed before 1600 while Stevin was instructing the prince.

Stevin's main arguments for Copernicanism are by now familiar, although he is unusually concerned with their physical interpretation.

Following Rheticus, and Brahe, Stevin believes that observations made at two different times of the year may be used to directly establish the distance to an outer planet, "for the distance between two positions which the Earth has at different locations in its path serves us as the base of a triangle, whose ratio to the sides is very perceptible, ..."(Stevin, 1961: p. 124,) Both Rheticus and Tycho asserted that in the case of Mars such a measurement would demonstrate that a geocentric system was untenable. Stevin merely concludes that such measurements support the Copernican order of the world.

A major argument is the correlation between distances and velocities that exists in Copernicus' system but is absent in Ptolemy's. The most striking manifestation is the sphere of fixed stars, which being furthest from the center ought to move most slowly, but in Ptolemaic astronomy is made to move most swiftly of all celestial spheres, revolving around the Earth in 24 hours: "It is more in accordance with reason to believe and to assume that this fastest motion is to be assigned to the smallest circle, to wit, the circle of the Earth in its place" (Stevin, 1961: p. 125, tr. Dikshoorn), that is its rotation about its own axis. This, as we have seen, is a variant on Copernicus' main argument for his system, and similar arguments appear in Rheticus and Maestlin.

Like Copernicus, Stevin enumerates the resources of heliocentrism in explaining the connection between the motions attributed to the planets' epicycles in Ptolemaic astronomy and the motion of the Sun, also showing, for example, why outer planets are nearest the Earth at conjunction and furthest at opposition (Stevin, 1961: p. 139). Initially he emphasizes the economy of the Copernican model: the motion of the Earth eliminates the epicycles in Ptolemy's planetary models (Stevin, 1961: pp. 123–5). Stevin also suggests that it is implausible to believe that the sphere of fixed stars moves in one direction while all of the planets (at least in their proper motions) move in the other. This arrangement, which offends natural reason, can again be avoided by endowing the Earth with a daily rotation (Stevin, 1961: p. 125).

However, Stevin does not accept Copernicus' system uncritically. In particular he rejects the alleged third motion of the Earth (the rotation by means of which the axis maintains a fixed direction in space). An early adherent of Gilbert, Stevin appeals to the ability of magnets to maintain their orientation in space to explain this phenomenon, eliminating the need for a separate third motion (Stevin, 1961: pp. 127–31).

7.

Thomas Digges (ca. 1546–1595) was the son of English mathematician Leonard Digges (Johnson and Starkey, 1934; McIntyre, 2000). After his father's early death, Thomas Digges studied mathematics with John Dee. He published several works on applied mathematics, including surveying, ballistics, and astronomy, some of which had been begun by his father. His observations of the 1572 nova appeared in *The Wings or the Ladder of Mathematics* (*Alae sev scalae mathematicae*, 1573), a work that Tycho Brahe cited with some approval, and like Brahe he concluded that the nova was supralunar. He speculated that its dimming was caused by the annual motion of the Earth and rejected the possibility that the new star was physically dimming or shrinking on the grounds that such a change would be contrary to physics. He also expressed the hope that parallax observations would decide between the Copernican and Ptolemaic systems (Digges, 1573: fols. 2A 2 v-2A 3 v). Digges' enthusiasm for Copernicus manifested itself in the *Wings* but he did not yet commit himself fully.

In 1576, when Digges published a new edition of his father's popular almanac *A prognostication everlasting of righte good effecte*, he appended two texts. One, in which he listed the problems then current in navigation, has no direct bearing on astronomy. The other text, a free translation of sections of Book I of *On the Revolutions*, is entitled *A Perfit description of the Caelestiall Orbes.* Digges translated those chapters explaining the arrangement of planets in a heliocentric system and refuting philosophical arguments against terrestrial motion. However, he believed that the surest proof of heliocentrism lay in Copernicus' mathematical demonstrations of planetary motion, which could only be appreciated by mathematically skilled readers. Because only Copernicus produced "true and certaine" effects, his system was based on true causes, unlike the faulty geocentric system (Digges, 1576: fol. M 1 v).

Digges also stated as a certainty what Copernicus had diffidently mentioned as a possibility, namely the infinite extension of the sphere of fixed stars (Digges, 1576: fol. N 4 r; cf. Copernicus, 1543: fol. 6 r). The removal of the constraints of 24-hour rotation and outer invisible orbs which had explained precession and trepidation allowed the sphere of stars to become fixed and of indefinite size. Despite his shift to a heliocentric, unbounded universe, Digges retained elements of the traditional Ptolemaic-Aristotelian cosmology. A diagram shows the Earth and other planets carried by orbs in a heterogeneous cosmos, with a central Sun and an unchanging realm of non-planetary stars. The Earth alone remained the "globe of mortalitye" opposed to the eternal supralunar region, which was the dwelling place of angels and "the elect." (Digges, 1576: fol. 43 r).

8.

Diego de Zúñiga (also known as Diego Rodríguez Arévalo) (1536–ca. 1600) was a Spanish Augustinian who held the chair of Holy Scripture at the University of OSuna during the 1570s and published widely in an attempt to attract patronage from the papacy and the King of Spain. On leaving OSuna he made a clear endorsement of physical Copernicanism in a 1584 book, and an equally clear dismissal of the doctrine in a later one (Brotóns, 1995).

De Zúñiga's *Commentaries on Job* appeared at Toledo in 1584, and was reprinted in Rome in 1591. As evidence in favor of Copernicus' view he cites improved accuracy in specifying planetary positions, and especially Copernicus' explanation of the precession of the equinoxes and the length of the year. He also claims that the Sun is known to be forty thousand stades closer to the Earth than it was in ancient times. Zúñiga goes on to reconcile Copernicanism with the understanding of the Bible, using the common sixteenth-century strategy of Accomodationism. The Bible, he suggests, is written in the common speech, and is not, therefore, a reliable indication of the structure of the world revealed by learned investigation. Indeed the motion of the Earth could be taken as evidence of "the marvellous power and wisdom of God" who is able to maintain in motion such a heavy body (Zúñiga, 1584: pp. 205–7; cf. Brotóns, 1995: pp. 67–9).

Although Zúñiga's favorable tone is clear, it is perhaps significant that none of the evidence he brings forward supports either axial rotation or orbital motion unequivocally. The improved accuracy in specifying planetary positions could be achieved using Copernicus' mathematical models referred to a central, stationary Earth, as Reinhold and his successors at Wittenberg actually did. Neither the precession of the equinoxes nor the definition of the length of the year require the adoption of heliocentrism. The motions of the equinoxes can be referred to the sphere of fixed stars, or ancillary spheres enclosing it, although, as we have seen, some Copernicans, such as Rheticus, considered this objectionable. Similarly, the length of the year corresponds to a motion that can be attributed to a moving Sun leaving the Earth stationary. In a later work on motion, based on Aristotelian physics but employing the concept of impetus, Zúñiga argues persuasively against physical Copernicanism.

In *Philosophy, Part One* (*Philosophia prima pars*), the first of a projected trilogy which appeared at Toledo in 1596, Zúñiga rejects both the axial rotation and the annual motion of the Earth. Against axial rotation he uses standard Aristotelian arguments that falling objects, or objects thrown straight upward, would show perceptible effects if the Earth were in motion. Additionally, things in their natural element, such as birds and clouds, would be left behind by a rotating Earth. Also, the Earth is mutable and might be damaged by a daily rotation. The heavens are immutable and would suffer no similar damage. It is therefore preferable to locate the daily rotation in a movement of the heavens. The annual motion of the Earth is rejected on the curious grounds that the Sun, rather than the Earth, is responsible for the seasons. The only seeming vestige of Zúñiga's earlier position is his admission that the size of the universe may be so great that it is impossible to say whether the Earth or the Sun is at the center. (Brotóns, 1995: pp. 72–4).

Brotóns (1995) suggests that Zúñiga may have modified his position on Copernicanism after early indications that the doctrines of heliostatism and the motion of the Earth might prove theologically problematic. However, it is also notable that Zúñiga never considers any detailed arguments from the nature of planetary motion in Ptolemaic astronomy, such as the ability of Copernicus to explain the size, location and duration of retrogradations, or other advantages such as the abolition of the equant. By confining himself almost exclusively to the relations between the Earth, Sun and fixed stars, Zúñiga's claim that the universe is too large to be able to fix a center also allows him to attribute any motion he desires to either a moving Sun (in his 1584 book) or a stationary Earth (in his 1596 book). There is no indication that he saw Copernican astronomy as a pretext to criticize or abandon Aristotelian physical principles. Quite the contrary, he seems to continue to endorse one of the major current versions of Aristotle's account of motion, impetus theory. The 1596 rejection of Copernicanism may therefore also be seen as the natural consequence of Zúñiga thinking through the cases of motion treated by Copernicus in terms of Zúñiga's own preferred account, and finding in favor of a geocentric cosmos for physical rather than astronomical reasons.

9.

Giordano Bruno (1548–1600), born Filippo Bruno of the Italian town of Nola, took the name Giordano when he became a Dominican (Yates, 1970). He left the monastery after questioning the Trinity, and became an itinerant scholar who frequently moved to avoid trouble with authorities. From 1583 to 1585 he lived in England where he defended Copernicus against Oxford scholars in a debate he later made famous in *The Ash Wednesday Supper* (La *cena de le ceneri,* 1584/1977). He wrote a number of other works touching on cosmology; in this paper we shall focus on his remarks on Copernicus in *On Immensity and Innumerable Things, or On the Universe and the Worlds* (*De immenso et innumerabilibus, seu de universo et mundis,* 1591/1879–84). The recurring theme of the infinite universe that first surfaced in the Oxford debate suggests he was familiar with Digges' work. In 1593 he was taken to the Inquisition at Rome, where he was eventually executed for heresy.

Bruno modified his admiration of Copernicus with the charge that the latter neglected physics and gave a purely mathematical account of heliocentrism. (Bruno, 1879–84: i.i p. 395; 1977: p. 395). He felt that an exact mathematical description of celestial motion was impossible because material bodies moved irregularly, not in perfect circles (Bruno, 1977: pp. 221–24). As an atomist, Bruno rejected peripatetic physics according to which simple bodies moved with simple motions; therefore, he denied that planets were carried by orbs in combinations of circular motions. Instead he divided matter into hot and cold bodies. Cold bodies such as the Earth necessarily circled hot bodies such as the Sun in order to receive their warmth and generate life. In contrast to Digges, Bruno advocated a homogeneous cosmology, with each star another Sun accompanied by its own Earths (Granada, 1997). Our Sun no longer occupied a special place, and other cold bodies were not necessarily better than our Earth (Bruno, 1977: pp. 90–91).

Bruno's emphasis on physics may correlate with limited mathematical knowledge; he employed little mathematics in his writings and sometimes miSunderstood technical aspects of Copernican astronomy. At the time of the *Ash Wednesday Supper*, Bruno interpreted the cosmological diagram in *On the Revolutions* as depicting both Earth and Moon on the circumference of a single epicycle circling an empty central point, which he insisted was necessary to explain the annual variation in distance of the Earth from the Sun (Bruno, 1977: pp. 190–93). In *On Immensity and Innumerable Things* he adopted the conventional view that placed the Moon on an epicycle centered on the Earth. But he criticized Copernicus for placing Mercury and Venus closer to the Sun than the Earth-Moon system was. Instead, Bruno located Mercury on the same circle as the Earth but diametrically opposed to it, with Venus circling it as another Moon in a Pythagorean "counter-Earth" system. He then lapsed to the system of the *Supper* with the addition of Venus and Mercury on the circumference of their own shared epicycle (Bruno, 1879–84: i.i pp. 395–98). The slightly less radical *Immensity* version of Copernicanism loses the ability to explain the bounded elongation of Mercury (which should always be in conjunction with the Sun) and the distance-velocity relationship of the planets. In its most extreme version, it cannot explain the differing bounded elongations and periods of Mercury and Venus or even the monthly revolution of the Moon. Frances Yates concluded that for Bruno, the Copernicus diagram was less a depiction of physical reality than a Hermetic "hieroglyph" (Yates, 1964: p. 241). Nonetheless he insisted on the importance of a non-Aristotelian physics, with which heliocentrism seems to have been most compatible.

10.

William Gilbert (1540–1603), an English physician who began practicing medicine in London in the mid-1570s, was a prominent figure in English magnetic studies (Pumfrey, 2000). His only two published works, *On the Magnet* (*De magnete*, 1600) and *On the World* (*De mundo*, published posthumously in 1651), place magnetism at the center of an alternate physics which is friendly to heliocentrism, although Gilbert never committed to Copernicanism in print. *On the Magnet,* reported to have been finished in the 1580s, focused on studies of the magnet, with cosmology limited to Book VI; *On the World,* probably begun around the time *On the Magnet* was finished and still incomplete at Gilbert's death, attempted to give an account of the world based on magnetic forces (Gatti, 1999: pp. 86–87). According to Gilbert, the Earth itself is a giant spherical magnet rotating daily on its axis by virtue of its magnetic nature. Like Maestlin and Stevin, he argued that the rotation of a small body was more reasonable than the daily revolution of the entire heavens, and he attempted to quantify its speed (Gilbert, 1958/1600: pp. 318–27). Unlike Maestlin, but like Bruno, he rejected solid celestial orbs as fictions (Gilbert, 1651: pp. 147–58). The fixed stars lay at various distances from the Earth, some indeed at distances beyond comprehension; because an infinite body cannot move, he reasoned, both daily motion and precession must be attributed to the Earth instead of to an indefinitely large starry realm or a pretended ninth sphere.

In both books Gilbert openly endorsed terrestrial rotation but put off the question of the reality of heliocentrism. While his private opinion cannot be known with certainty, some Gilbert scholars regard him as a probable Copernican (Freudenthal, 1983; Gatti, 1999: pp. 96–98). Gilbert's magnetic philosophy eradicated the terrestrial-celestial distinction because all bodies were composed of the same fundamental matter, the magnetic element. The Sun imparted motion to the five planets; there is no reason why it should not cause the Earth to move in the same way. His diagram of the world, reproduced in *On the World,* shows the other planets on circles centered on the Sun. No circle is present to indicate whether Earth goes around Sun or *vice versa,* leaving open the option of a heliocentric or geoheliocentric system (Gilbert, 1651: p. 202). However, the stars freely scattered through space are centered on the Sun, and in a Tychonic interpretation of the diagram the outer planets would intrude on the region of stars (Freudenthal, 1983: p. 32).

11.

The appearance of Kepler's *Mystery of the Cosmos* in 1596 marks a change in Copernican doctrine which is completed in the *New Astronomy* of 1609. Although Kepler's ideas are slow to spread, the version of Copernicanism that he develops in these two works ultimately provides the foundation for the modern form of the doctrine. These books also mark the transition to a defense of Copernicanism based on factors extrinsic to astronomy. Although Kepler succeeds in providing a predictive astronomy more accurate than any predecessor, he links the subject in new ways to both physics and theology (Barker and Goldstein, 2001; Barker, 2002).

The *Mystery of the Cosmos* is the first book-length defense of Copernicanism to appear since *On the Revolutions* itself (Kepler 1981/1596). In the first chapter Kepler rehearses the main arguments offered by previous Copernicans. The new system can offer a causal explanation for the number, extent and duration of retrogradations, as Kepler explains in detail with the aid of diagrams. These are unusual in showing the Ptolemaic epicycles of the planets drawn to scale. Ptolemy never explains why the epicycle for Mars is vastly larger than the epicycle for Jupiter, which in turn is larger than that for Saturn. Copernicus offers a simple explanation for this scaling effect (in modern terms we would say that each epicycle corresponds to the Earth's orbit viewed from the planet's mean distance). The same considerations also explain the Ptolemaic linkage between the planetary models and the position and motion of the mean Sun. Copernicus' system is also economical; many motions follow from the introduction of a very few orbs. And, as a student of Maestlin, Kepler is aware that the motion of the comet of 1577 fitted into the Copernican orb for Venus (and, by implication, could not be fitted into a Ptolemaic or Aristotelian pattern of orbs). A final reason for preferring Copernicus' system is that it is more plausible to attribute the daily motion to a small body like the Earth than a large one like the sphere of fixed stars (Kepler, 1981: pp. 75–85). However, where most previous Copernicans continued to accept the Aristotelian doctrine that planets are passively carried through space by orbs in which they are embedded, Kepler rejects solid heavens for a continuous fluid substance in which the spheres and orbs are no more than geometrical boundaries.

Kepler's main, and original, argument for Copernicanism occupies the balance of the book. It is, simply put, that God employed the Platonic regular solids exactly once each in establishing the plan of the world. As there are five solids they may be used to define six circumscribed and inscribed orbs. This immediately explains another fact Ptolemy is silent about: why there are six planets. The most important demonstration, however, is that the geometrical construction provided by the solids and their inscribed spheres defines the distances between the planets and the Sun as they appear in Copernicus' system, and not as they appear in Ptolemy's. Kepler's derivation is motivated in part by the belief, common among Lutheran followers of Melanchthon, that the world has been providentially ordered by God, and that the truths of mathematics, and hence of astronomy, are certain because they are inscribed on the soul when it is created. Thus God has provided the means to uncover and to understand his providential design, and this is just what

Kepler believes he has done. The mystery of the universe is a sacred mystery. The obvious secret is that the Divine plan uses the Platonic solids as scaffolding. Behind that a further secret is implied – God is a Copernican. Kepler has therefore provided the strongest possible argument for the compatibility of the Copernican system with the Christian faith (Barker, 2000a; Barker and Goldstein, 2001).

The argument of the *Mysterium* leaves certain questions open. It defines the distances but does not explain the motions of the planets, and lacking the solid spheres that carried planets in earlier cosmological schemes, it demands an explanation for the causes of planetary motion. Kepler resolves all these questions in the *New Astronomy* (1992/1609). In short order he shows that a heliocentric "floating equant" model is more accurate in predicting planetary longtitudes than either Ptolemy's geocentric models, Copernicus' original models based on the mean Sun, or the hybrid geo-heliocentric model recently introduced by Tycho Brahe. Kepler also shows that the planes of planetary motions so defined coincide in the real Sun, and not the mean Sun which formed the center of Copernicus' system. Despite its relative success, Kepler rejects the "floating equant" model in turn as inaccurate and unphysical. He introduces a force, centered on the Sun but attenuating with distance, that sweeps the planets around as the Sun rotates. Based on this force he derives what we would now call the second law of planetary motion (the area law) first in the case of eccentric circular motions, and finally in the case of an ellipse. The ellipse is introduced specifically to accommodate data on both the longitude of a planet and its distance from the Sun. The motions on the ellipse is therefore a real physical motion in three-dimensional space and may properly be called an "orbit" – a term Kepler introduces (Stevenson, 1994; Barker and Goldstein, 2001).

Although planets might be imagined to have three-dimensional paths in earlier cosmic schemes, the astronomical theories associated with them, including that of Copernicus, are concerned only to calculate the angular position of planets with respect to some appropriate line of reference. Although it is possible to calculate distances in Ptolemaic astronomy (Van Helden, 1985), these items had never been combined to define a continuous track through space specifying both the planet's direction and distance at any moment. The modern concept of planetary motion is just that planets move freely through space, and that their orbits may be calculated to determine their positions. This formulation of Copernican doctrine begins with Kepler, and ultimately becomes canonical (through the work of Newton) despite being resisted by other Copernicans like Galileo.

To put the comparison in its starkest form: Copernicus provided a heliocentric system in which the planets were embedded in spheres or orbs which transported them through space. Copernicus' planets performed epicyclic motions but only their angular velocities, not their distances from the Sun and from each other, played a role in calculating their positions as viewed from the Earth. The reference point from which these motions began was not the position of the Sun itself but an empty point, the mean Sun. Kepler not only replaced circles by ellipses but more importantly replaced calculations that specified only the direction to a planet with calculations that defined an orbit, a path through space with both a definite direction and a definite distance. He described a heliocentric system in which planetary orbits intersected in the physical Sun, and planets moved freely through a fluid heaven in response to a force coming from the Sun. It remained for Newton to clarify the nature of this force in precise detail. Kepler, then, tied Copernicanism to physical questions such as the precise role of the Sun in astronomical calculations and the forces that create or sustain planetary motion.

12.

Concurrent with Kepler's intellectual revision of Copernicus came Galileo's introduction of significant new evidence in the cosmological debate of the early seventeenth century. Galileo attended the University of Pisa but never finished a degree, choosing to abandon the medical training his father wanted for him in favor of continuing his mathematical studies privately. In May of 1609 he was a professor of mathematics at the University of Padua in the Venetian Republic when he learned of the recent invention of the telescope by the Dutch lensmaker Hans Lipperhey. He began constructing his own telescopes and soon learned how to make superior instruments with greater magnifying power than available imports. Initially Galileo, like most of his contemporaries, only thought of using the device for terrestrial observations. One telescope he gave to the Republic in exchange for a salary increase and a lifetime position at the university, after demonstrating its utility for naval and military reconnaissance. By November he had finished manufacturing an even better instrument, with which he began to make observations of the heavens (Van Helden, in Galileo, 1989).

Galileo's first publication on his telescopic observations – indeed, the very first work published on the telescope as an astronomical instrument – was the *Sidereal Messenger* (1610), in which he describes his observations of the Moon, the fixed stars, and the moons of Jupiter, and draws strongly pro-Copernican conclusions. The Moon was the first subject of Galileo's study. Irregularities in the terminator led Galileo to conclude that the surface of the Moon itself was uneven. He interpreted the shifting patterns of light and shadow as mountains receiving illumination while valleys remained in shadow. Contrary to the Aristotelian doctrine of a perfect and immutable celestial realm, the Moon was a flawed and Earthlike body. Galileo emphasized this point by comparing its bright and dark regions to land and sea. He also noted that the dark part of the cresent Moon in reality shone with a faint light visible to the naked eye, a phenomenon he identified as Earthshine. Although it seems dark to its inhabitants, the Earth resembles a planet in its brightness and ability to illuminate other bodies (Galilei, 1989/1610: pp. 39–57; Cohen, 1985: pp. 58–64).

Galileo made two important discoveries when he turned his telescope to the fixed stars. Whereas the planets could be resolved into small disks, the stars remained points, meaning that they were very distant. Although not conclusive evidence, this supported heliocentrism, which required an enormous universe to explain the lack of observed stellar parallax. He also discovered many new stars invisible to the naked eye. Human senses were therefore not infallible and the ancients did not know everything about the heavens. The last discovery to make its way into the *Sidereal Messenger* was that Jupiter has four moons of its own, named by Galileo the "Medicean stars" after his patron Cosimo de Medici. The discovery removed one objection against Copernicanism, namely that it required multiple centers of motion. The moons circling Jupiter demonstrated that our Moon could also move around a moving Earth (Galilei, 1989: pp. 56–85; Cohen, 1985: pp. 64–65, 71–72).

Galileo continued to investigate the heavens with his telescope. In 1612 he entered into a debate with Christoph Scheiner over the interpretation of what appeared to be dark spots on the Sun; Galileo's side of the debate was published by the Lincean Academy as *History and Demonstrations Concerning Sunspots and Their Phenomena* (*Istoria e dimonstrazioni intorno alle macchie solari,* 1613). Scheiner identified them as small planets passing in front of the Sun, while Galileo maintained that they were imperfections on the surface of the Sun itself. Because the spots appeared, changed shape and size, moved with respect to each other, and then disappeared, the Sun must be subject to generation and decay. In the letters Galileo also described the phases of Venus. Through a telescope it became apparent that Venus goes through a complete set of phases similar to the Moon, appearing nearly full when smallest and crescent when largest. This is impossible in the Ptolemaic system, for Venus would always lie below the Sun and would never become full; therefore, Venus must circle the Sun (Galilei, 1957/1613; Cohen, 1985: pp. 72–74).

In these two publications, Galileo represented his discoveries as overthrowing Aristotle and upholding Copernicus. In reality, none of them contain irrefutable evidence for heliocentrism. His work on the Moon, the fixed stars, and Sunspots attacked the terrestrial-celestial distinction and lessened the difficulties of making the imperfect Earth a planet. The Jovian moons provided irrefutable evidence for more than one center of motion, and the phases of Venus removed one objection against Copernicus (whose system required such phases), but both findings equally supported the Tychonic system. Nevertheless, Galileo's telescopic work was significant because it increased the plausibility of the Copernican system while weakening the Ptolemaic one.

13.

Our survey of physical Copernicans before 1610 has revealed a great distance between early and modern forms of Copernicanism. For the first Copernicans, astronomy defined planetary motions in terms of angles viewed from a moving Earth, not continuous paths through space. Many continued to accept the mechanism that had explained planetary motion in pre-Copernican astronomy, namely non-overlapping orbs or spheres carrying planets around a fixed center. Copernicus himself continued to think in these terms. Spheres appear in the work of Rheticus, Gemma Frisius, Stevin, Digges, and Maestlin, while Zúñiga remains silent on the question of spheres in his writings on Copernicus. Only Rothmann, Bruno, Gilbert, Kepler and Galileo clearly reject the existence of solid spheres. None of the five worked in the period immediately after the publication of *On the Revolutions*, and the last two are key figures in the transition to modern Copernicanism. Most important, the abandonment of solid spheres was a necessary condition for the emergence of modern Copernicanism in Kepler's thought, since it allowed him to envision planets freely moving through space in noncircular orbits. The modern form of Copernicanism therefore presupposes non-Copernican answers to the questions of the substance of the heavens and the physical causes of planetary motion. However, rather than criticizing Copernicus for getting the answers to these question wrong, it would be more accurate to say that he simply did not raise them.

It is also worth noting, in passing, that reconciling religion and science was not a major problem for Copernicans before 1610. Although Wittenberg astronomers like Peucer had developed a canonical list of scriptural objections to Copernicanism by the early 1550s, both the Protestant Rothmann and the Catholic Zúñiga felt free to defend the compatibility of novel cosmological doctrines with the Bible, and both used the same strategy, Accomodationism. Kepler also defended Copernicanism against Biblical criticisms.

He also deployed Accomodationist arguments in the introduction to the *New Astronomy*, and the whole of the *Mystery of the Cosmos* may be read as a religious defense of Copernicanism, although it must be admitted that this particular attempt to reconcile heliocentrism and Christianity made few converts. The entire situation began to change with the controversies that embroiled Galileo leading up to the condemnation of 1616, although Zúñiga's 1596 rejection of Copernicanism may be an early indication that the climate within parts of the Catholic church was already changing. However, the hardening of Church opinion against Copernicanism must be understood primarily as a rejection of Copernicanism as it existed in the period we have considered, and not its later form. And it is apparent that none of the arguments offered before Kepler and Galileo were strong enough to convince many people or to shelter the new doctrine from theological sniping.

The first followers of Copernicus fall into two main groups. The larger group consists of mathematicians: Rheticus, Gemma Frisius, Rothmann, Maestlin, Stevin, and Digges. These authors articulated a coherent set of arguments for adopting heliocentrism based on the technical parts of *On the Revolutions*, though not every author presents all the arguments. We suggest two pro-Copernican arguments as especially significant in understanding the mathematical approach. First, Copernicus creates a relationship between the velocity of a planet and its distance from the center of the world: outer planets are necessarily slower. Second, he can explain, for the first time, the position, magnitude, and duration of retrogradations, which Ptolemy predicted by arbitrarily tying the motion of a planet's epicycle to the motion of the Sun. Thus Copernicus provides a potential methodological advantage, because he can explain these matters in a way that conforms to Aristotelian standards for causal explanations where Ptolemy cannot. A much smaller group consists of physicists: Zúñiga, Bruno, and Gilbert. Bruno, as we have seen, failed to understand even fundamental consequences of astronomical models and contradicted the first mathematical argument. Gilbert showed little interest in the mathematical arguments. The indecisiveness of these arguments is underlined by the observation that not all early Copernicans retained their favorable opinion of his cosmology. Rothmann and Zúñiga first accepted and then rejected heliocentrism. Rheticus' silence about the issue in later life may indicate a retraction of his initial enthusiasm. Even Gilbert's status as a heliocentrist is marginal.

The situation changes with the entry of Kepler and Galileo into the cosmological debate. In contrast to earlier Copernicans, they use mathematics primarily to make physical claims. (In the case of Galileo, this approach becomes clearer in his later publications, which fall outside the scope of this paper.) Where Aristotelians had emphasized qualitative, causal demonstration, Kepler and Galileo turned to mathematical demonstration as the preferred methodology. After 1610 the two groups of early Copernicans, the mathematicians and the physicists, are replaced by the new "mathematical physicists" advocating a form of Copernicanism much more familiar to modern readers.

The work of Copernicus and his immediate followers is conceptually consistent with Ptolemaic astronomy, and employs an equally consistent methodology and epistemology; however, the work of Kepler and Galileo, to which this led, breaks with Ptolemy and introduces new epistemological themes. Hence the work of Copernicus set in motion a train of events that led to a decisive epistemological shift, but did not itself represent such a shift. There is no abrupt adoption of Copernicus in the period immediately following 1543. The real revolution is the replacement of the methods and goals of Ptolemaic astronomy and Aristotelian physics with Copernicanism in its modern form, which incorporates the conceptual structure of Kepler and the astronomical evidence of Galileo. Such a version of Copernicanism is not available before 1610. Understanding the revolution requires careful analysis of the process up to that point. Our study shows that the change in astronomy after the publication of *On the Revolutions* constitutes a "revolution" as understood by philosophy of science. However, it was not a single great event. The Copernican Revolution was a protracted process consisting of many small steps, and the changes within Copernicanism were almost as great as those separating heliocentrism from geocentrism.

Bibliography

Barker, Peter. 2000a. "The role of religion in the Lutheran response to Copernicus". In: Margaret J. Osler (Ed.), *Rethinking the Scientific Revolution*, pp. 59–88. Cambridge University Press, Cambridge.

Barker, Peter. 2000b. "Maestlin, Michael (1550–1631)". In: Wilbur Applebaum (Ed.) *Encyclopedia of the Scientific Revolution from Copernicus to Newton*, pp. 378–379. Garland, New York.

Barker, Peter. 2000c. "Rothmann, Christoph (fl. 1555–1597)". In: Wilbur Applebaum (Ed.) *Encyclopedia of the Scientific Revolution from Copernicus to Newton*, pp. 579–580. Garland, New York.

Barker, Peter. 2002. "Constructing Copernicus". In: Peter Barker (Ed.) *New Foundations in the History of Astronomy. Perspectives on Science.* Cambridge, Mass., 10 (2/2002), pp. 208–27.

Barker, Peter. “How Rothmann Changed His Mind”. In: Peter Barker, A. Bowen et al. (Eds.) *Astronomy and Astrology from the Babylonians to Kepler. Centaurus.* Copenhagen 46 (1/2004), pp. 41–57.

Barker, Peter, and Bernard R. Goldstein. 1998. “Realism and Instrumentalism in Sixteenth Century Astronomy: A Reappraisal”. *Perspectives on Science,* Cambridge, Mass., 6 (3/1998), pp. 232–258.

Barker, Peter, and Bernard R. Goldstein. 2001. “Theological Foundations of Kepler's Astronomy”. In: John Hedley Brooke, Margaret J. Osler, and Jitse van der Meer (Eds.) *Science in Theistic Contexts: Cognitive Dimensions. Osiris,* 2nd series. Ithaca 16, pp. 88–113.

Barker, Peter, and Bernard R. Goldstein. 2003. “Patronage and the Production of *De revolutionibus*”. *Journal for the History of Astronomy,* Cambridge, 34 (4/2003), pp. 345–368.

Brotóns, Victor Navarro. 1995. “The Reception of Copernicus in Sixteenth-Century Spain: The Case of Diego de Zúñiga”. *Isis,* Chicago 86 (1/1995), pp. 52–78.

Bruno, Giordano. 1879–84. *De immenso et innumerabilibus, seu de universo et mundis.* In *Opera latine conscripta.* F. Fiorentino, V. Imbriani, et al. (Eds.). i.1 p. 191–1.2 p. 318. Dom. Morano, Naples/Florence. [Facsimile reprint: Friedrich Fromman Verlag, 1961–62.]

Bruno, Giordano. 1977. *The Ash Wednesday Supper.* Edward A. Gosselin and Lawrence S. Lerner (Ed. and Transl.). Archon Books, Hamden. English translation of *La cena de le ceneri,* J. Charlewood, London, 1584.

Burmeister, Karl Heinz. 1967–68. *Georg Joachim Rhetikus: Eine Bio-Bibliographie.* 3 Vols. Pressler-Verlag, Wiesbaden.

Cohen, I. Bernard. 1985. *The Birth of a New Physics.* Revised ed. W. W. Norton & Co., London.

Copernicus, Nicolaus. 1543. *De revolvtionibvs orbium coelestium, Libri VI.* Ioh. Petreium, Nuremberg.

Digges, Thomas. 1573. *Alae sev scalae mathematicae …* . Thomas Marsh, London.

Digges, Thomas. 1576. *A perfit description of the Caelestiall Orbes according to the most auncient doctrien of the pythagoreans &c.* In: Leonard Digges, *A prognostication euerlastinge of right good effect …* . Thomas Marsh, London.

Freudenthal, Gad. 1983. “Theory of Matter and Cosmology in William Gilbert's *De magnete*”. *Isis,* Philadelphia, 74 (1/1983), pp. 22–37.

Galilei, Galileo. 1957. “Letters on Sunspots”. In: *Discoveries and Opinions of Galileo.* Stillman Drake (Transl.), pp. 87–144. Doubleday, New York. English translation of *Istoria e dimonstrazioni intorno alle macchie solari e loro accidenti …,* Giacomo Mascardi, Rome, 1613.

Galilei, Galileo. 1989. *Sidereus Nuncius or The Sidereal Messenger.* Albert Van Helden (Transl.). University of Chicago, Chicago. English translation of *Siderevs Nvncivs …* . Thomas Baglionus, Venice, 1610.

Gatti, Hilary. 1999. *Giordano Bruno and Renaissance Science*, Cornell University Press, Ithaca.

Gemma Frisius. 1555. "Epistola ad I. Stadius". In: I. Stadius, *Ephemerides novae et exactae ab a. 1554 ad a. 1570*, fols. a 1 r – a 2 v. A. Birkmann, Cologne.

Gilbert, William. *De Magnete*. P. Fleury Mottelay (Transl.). Dover, New York, 1958. English translation of *De magnete, magneticisqve corporibvs, et de magno magnete tellure; physiologia noua …* . Petrvs Short, London, 1600.

Gilbert, William. 1651. *De Mundo nostro Sublunari Philosophia Nova. Opus posthumum …* . Ludovicum Elzevirium, Amsterdam.

Goldstein, Bernard R. 1987. "Remarks on Gemma Frisius' *De radio astronomico et geometrico*". In: J. L. Berggren and B. R. Goldstein (Eds.), *From Ancient Omens to Statistical Mechanics: Essays in the Exact Sciences Presented to Asger Aaboe*, pp. 167–79. University Library, Copenhagen.

Goldstein, Bernard R. 2002. "Copernicus and the Origins of His Heliocentric System". *Journal for the History of Astronomy*, Cambridge, 33 (3/2002), pp. 219–235.

Goldstein, Bernard R., and Peter Barker. 1995. "The Role of Rothmann in the dissolution of the celestial spheres". *British Journal for the History of Science*, Cambridge, 28 (4/1995), pp. 385–403.

Grafton, Anthony. 1973. "Michael Maestlin's Account of Copernican Planetary Theory". *Proceedings of the American Philosophical Society*, Philadelphia, 117 (6/1973), pp. 523–50.

Granada, Miguel A. 1997. "Thomas Digges, Giordano Bruno e il copernicanesimo in Inghilterra". In: Michele Ciliberto and Nicholas Mann (Eds.), *Giordano Bruno, 1583–1585: The English Experience*, pp. 125–55. S. Olschki, Florence.

Johnson, Francis R., and Sanford V. Larkey. 1934. "Thomas Digges, The Copernican System, and the Idea of the Infinity of the Universe in 1576". *Huntington Library Bulletin*, Cambridge, 5 (April/1934), pp. 69–117.

Kepler, Ioannes. 1981. *Mysterium Cosmographicum: The Secret of the Universe*. A. M. Duncan (Transl.). Norwalk, CT, Abaris Books. English translation of *Prodromus dissertationem cosmographicarum, continens mysterium cosmographicum*. Gruppenbach, Tübingen, 1596.

Kepler, Ioannes. 1992. *New Astronomy*. William H. Donahue (Transl.). Cambridge University Press, Cambridge. English translation of *Astronomia nova AITIOLOGETOS, sev physica coelestis*. Voeglinus, Heidelberg, 1609.

Kish, George. 1967. *Medicina, Mensura, Mathematica: The Life and Works of Gemma Frisius, 1508–1555*. Associates of the James Ford Bell Collection, Minneapolis.

Lammens, Cindy. 2002. *Sic patet iter ad astra: A critical examination of Gemma Frisius' annotations in Copernicus' De Revolutionibus and his qualified appraisal of Copernican theory*. 3 vols. Ph.D. dissertation, Universiteit Gent.

Maestlin, Michael. 1578. *Observatio et demonstratio cometae aetherei, qui in anno 1577 et 1578 constitutus in sphaera Veneris, apparuit.* Gruppenbach, Tübingen.

Maestlin, Michael. 1581. *Consideratio et observatio cometae aetherei astronomica, qui anno MDLXXX … apparuit.* Jakob Muller, Heidelberg.

McIntyre, Gary. 2000. "Digges, Thomas (ca. 1546–1595)". In: Wilbur Applebaum (Ed.) *Encyclopedia of the Scientific Revolution from Copernicus to Newton,* pp. 191–192, Garland, New York.

Methuen, Charlotte. 1996. "Maestlin's Teaching of Copernicus: The Evidence of His University Textbook and Disputations". *Isis,* Chicago, 87 (2/1996), pp. 230–47.

Peucer, Caspar. 1569. *Elementa doctrinae de circvlis coelestibvs, et primo motu, recognita et correcta.* Iohannes Crato, Wittenberg.

Pumfrey, Stephen. 2000. "Gilbert, William (1544–1603)". In: Wilbur Applebaum (Ed.) *Encyclopedia of the Scientific Revolution from Copernicus to Newton,* pp. 266–68. Garland, New York.

Reinhold, Erasmus. 1542. *Theoricae novae planetarum Georgii Purbacchii, Germani, ab Erasmo Reinholdo Salveldensi …* . Lufft, Wittenberg.

Reinhold, Erasmus. 1551. *Prutenicae tabulae coelestium motuum.* Morhard, Tübingen.

Rheticus, Georg Joachim. 1971. *Narratio prima.* In: Edward Rosen (Transl.), *Three Copernican Treatises,* pp. 107–196. 3rd. ed. Octagon, New York. English translation of *Ad clarissimvm virvm D. Ioannem Shonervm, de libris revolvtionum … narratio prima,* Franciscus Rhodus, Danzig, 1540.

Rosen, Edward. 1974. "Mästlin, Michael". In: Charles Coulston Gillispie (Ed.), *Dictionary of Scientific Biography,* vol. 9, pp. 167–170. Charles Scribner's Sons, New York.

Rothmann, Christopher. 2003. *Christoph Rothmanns Handbuch der Astronomie von 1589: Kommentierte Edition der Handschrift Cristoph Rothmanns "Observationum stellarum fixarum liber primus", Kassel 1589.* Miguel A. Granada, Jürgen Hamel, Ludolf von Mackensen (Eds.). Harri Deutsch, Frankfurt am Main.

Russell, John L.1972. "The Copernican System in Great Britain". In: Jerzy Dobrzycki (Ed.), *The Reception of Copernicus' Heliocentry Theory,* pp. 189–239. D. Reidel, Dordrecht.

Stephenson, Bruce. 1994. *Kepler's Physical Astronomy.* Princeton University Press, Princeton.

Stevin, Simon. 1605–8. *Wisconstighe gedachtenissen. Hypomnemata mathematica …* Willebrodus Snellius (Tr.). Johannes Patius, Leiden.

Simon Stevin. 1961. A. Pannekoek (Ed.), C. Dikshoorn (Tr.). *Principle Works of Simon Stevin.* Vol 3: *Astronomy.* C. V. Swets & Zeitlinger, Amsterdam.

Tredwell, Katherine A. 2004. "Michael Maestlin and the Fate of the *Narratio prima*". *Journal for the History of Astronomy,* Cambridge, 35, forthcoming.

Van Helden, Albert. 1985. *Measuring the Universe: Cosmic Dimensions from Aristarchus to Halley*. Chicago University Press, Chicago.

Vermij, Rienk. 2002. *The Calvinist Copernicans*. Royal Netherlands Academy of Arts and Sciences, Amsterdam.

Westman, Robert S. 1972. "The Comet and the Cosmos: Kepler, Mästlin and the Copernican Hypothesis". In: Jerzy Dobrzycki (Ed.), *The Reception of Copernicus' Heliocentric Theory*, pp. 7–30. D. Reidel, Dordrecht.

Westman, Robert S. 1975. "The Melanchthon Circle, Rheticus, and the Wittenberg Interpretation of the Copernican Theory". *Isis*, Washington, D.C., 66 (232/1975): pp. 164–193.

Westman, Robert S. 1980. "The Astronomer's Role in the Sixteenth Century: A Preliminary Survey." *History of Science*, Bucks, England, 18 (2/1980), pp. 105–147.

Yates, Frances A. *Giordano Bruno and the Hermetic Tradition*. University of Chicago Press, Chicago 1964.

Yates, Francis A. 1970. "Bruno, Giordano". In: Charles Coulston Gillispie (Ed.), *Dictionary of Scientific Biography*, vol. 2, pp. 539–544. Charles Scribner's Sons, New York.

Zúñiga, Diego de. 1584. *Didaci a Stunica … in Iob commentaria, quibus triplex eius editio vulgata Latina, Hebrææa, & Grææca septuaginta interpretum, necnon & Chaldææa explicantur*. I. Rodericus, Toledo.

Zúñiga, Diego de. 1596. *Philosophia prima pars, qua perfecte et eleganter quatuor scientiae metaphysica, dialectica, rhetorica et physica declarentur*. I. Rodericus, Toledo.

Filozofski vestnik Volume/Letnik XXV • Number/Številka 2 • 2004 • 167–186

WHAT IS REVOLUTIONARY IN THE COPERNICUS' *REVOLUTIONS*

Matjaž Vesel

1.

For a long time the name Copernicus was a synonym for revolution in astronomy. Moreover, for some historians of science, the year 1543 – the year of the publication of *De Revolutionibus* – marked the beginning of a new strain of scientific thought not only in the field of astronomy but natural science as a whole. According to this "'Vulgar Triumphalist' view," as R. S. Westman put it,[1] Copernicus is a revolutionary who decisively and completely broke with the ancient and medieval scientific principles; one who put an end to the finite universe of Aristotle and Ptolemy and replaced it with the infinite world of stars; one who, relying on extensive calculations, dealt a deathblow to the crystalline spheres that had carried the planets around the earth ever since antiquity; and one who, after all, made a bold move of radical simplification and reduced the inconvenient number of eighty (or so) epicycles, introduced by Ptolemy in order to be able to predict the position of the planets, to just forty (or so) epicycles.

However, a closer reading of Copernicus' work reveals an entirely different picture. It is not difficult to find elements that unmistakably point to the fact that, viewed from an epistemological perspective, Copernicus is a conservative rather than a revolutionary. Today, it is more or less known that Copernicus relied on the traditional technical apparatus used by Ptolemaic astronomy, including eccentrics, deferents, epicycles, and epicycles upon epicycles,[2] that he still believed in the solid celestial spheres (or orbs) whose

---

[1] R. S. Westman, "Proof, Poetics, and Patronage: Copernicus's Preface to 'De revolutionibus'", in D. C. Lindberg and R. S. Westman (eds.), *Reappraisals of the Scientific Revolution,* Cambridge University Press, Cambridge 1990, p. 169.

[2] Cf. for example Derek, J.de S. Price, "Contra-Copernicus: A Critical Re-estimation of the Mathematical Planetary Theory of Ptolemy, Copernicus, and Kepler", in M. Clagett (ed.),

task was to bear celestial bodies,[3] and that his theory did not predict the positions of celestial bodies any better than that of Ptolemy. It is also well known that, by eliminating the Ptolemaic mechanism of equants, Copernicus did indeed eliminate several epicycles but also added new ones, meaning that his planetary system was no less entangled than that of Ptolemy.[4] Furthermore, although bigger in size than the Ptolemaic universe, Copernicus' universe was still finite, delimited by the sphere of fixed stars. Finally, Copernicus' physics was firmly rooted in the physics of high scholasticism although he partly transformed some of its concepts.[5]

Neither did Copernicus himself think of his work as revolutionary. On the contrary, his aim was by no means to "turn upside down the entire science of astronomy" ("die ganze Kunst Astronomiae umkehren"), as Luther is supposed to have accused him of doing in 1439 in his famous *Tischreden* (*Tabletalks*). His goal was the renewal of astronomy, a task on which he embarked by relying on the authentic principles and postulates of ancient astronomy that later came to be violated by the Ptolemaic astronomical tradition. Copernicus' motivation for this renewal was entirely conservative in character – he wished to preserve the principle of the uniformity of planetary motion that was distorted by the Ptolemaic astronomic tradition with its concept of the equant.[6] In addition, in his dedicatory letter to Pope Paul III, he also

---

Critical Problems in the History of Science, The University of Winsconsin Press, Madison 1969, p. 216: "... his work as a mathematical astronomer was uninspired. From this point of view his book is conservative and a mere re-shuffled version of the *Almagest.*"

[3] There is practically no room left for doubt about this following the polemic between N. Swerdlow and E. Rosen. Cf. E. Rosen, "Copernicus' Spheres and Epicycles", *Archives internationales d'histoire des sciences* 25 (1975), pp. 82–92; N. Swerdlow, "Pseudoxia Copernicana: or, Inquiries Into Very Many Received Tenets and Commonly Presumed Truths, Mostly Concerning Spheres", *Archives internationales d'histoire des sciences* 26 (1976), pp. 108-158; E. Rosen, "Reply to N. Swerdlow", *Archives internationales d'histoire des sciences* 26 (1976), pp. 301–304.

[4] Cf. for example O. Neugebauer, "On the Planetary Theory of Copernicus", *Vistas in Astronomy* 10 (1968), p. 103: "Modern historians, making ample use of the advantage of hindsight, stress the revolutionary significance of the heliocentric system and the simplifications it had introduced. In fact, the actual computation of planetary positions follows exactly the ancient pattern and the results are the same."

[5] Cf. M. Wolff, "Impetus Mechanics as a Physical Argument for Copernicanism. Copernicus, Benedetti, Galileo", *Science in Context* 1 (2/1987), pp. 215–256.

[6] Cf. *Commentariolus*: "Nevertheless, the theories concerning these matters that have been put forth and wide by Ptolemy and most others, although they correspond numerically [with the apparent motions], also seemed quiete doubtful, for these theories were inadequate unless they envisioned certain *equant* circles, on account of which it appeared that the planet never moves with uniform velocity either in its deferent sphere or with respect to its proper center. Therefore a theory of this kind seemed neither perfect enough

mentions the fact that the astronomers of the Ptolemaic tradition were not able to "elicit or deduce" the most important thing: "the structure of the universe and the fixed symmetry of its parts."[7] However, in order to be able to renew astronomy by drawing on its correct, original principles, Copernicus had to sacrifice another fundamental premise governing practically all sciences of the time – the stationary earth at the center of the universe. He had to introduce the new and, for all contemporary articulations of knowledge – i.e. theology, philosophy and *sensus communis* – absurd concept of a moving earth.

2.

In this essay I argue that, despite all traditionalist elements in his astronomy and cosmology, and despite predominantly conservative motives for the introduction of the concept of the earth's motion into science, Copernicus did make a kind of radical, even revolutionary, rupture in natural philosophy, as science was called in his time. The nature of this rupture, or epistemological shift, can best be illuminated through an analysis of the introduction of this concept in Book 1 of *De Revolutionibus Orbium Coelestium.*

When considering the possibility of the earth's motion in Chapter 5 of Book 1, Copernicus's point of departure is the shape of the earth. In Chapter 2 he shows that the earth is spherical,[8] and in Chapter 4 he argues that "the motion appropriate to a sphere is rotation in a circle."[9] Since the earth is of the same shape as other celestial bodies, that is, spherical, and since "the motion appropriate to a sphere is rotation in a circle," the most natural question that arises at this point is whether the earth could also be ascribed circular motion, despite the fact that "there is general agreement among the authorities that the earth is at rest in the middle of the universe" and al-

---

nor sufficiently in accordance with reason." Quoted after N. M. Swerdlow, "The Derivation and First Draft of Copernicus's Planetary Theory. A Translation of the Commentariolus with Commentary", *Proceedings of the American Philosophical Society* 117 (6/1973), p. 434.

[7] "To his Holiness …", p. 6. All references from *De revolutionibus* are from E. Rosen's translation, sometimes slightly changed, of *On the Revolutions,* The Johns Hopkins University Press, Baltimore/London 1992.

[8] Cf. *De revolutionibus* I, 2: "The Earth too is spherical."

[9] Cf. ibid. I, 4: "I shall now recall to mind that the motion of the heavenly bodies is circular, since the motion appropriate to a sphere is rotation in a circle. By this very act the sphere expresses its form as the simplest body, wherein neither beginning nor end can be found, nor can the one be distinguished from the other, while the sphere itself traverses the same points to return upon itself."

though "they hold the contrary view to be inconceivable or downright silly."[10] Yet, what needed to be explained first is what motion actually is. Copernicus first briefly recapitulates the Euclidean theory of motion, albeit without citing the source:

> Every observed change of place is caused by motion of either the observed object or the observer or, of course, by an unequal displacement of each. For when things move with equal speed in the same direction, the motion is not perceived, as between the observed object and the observer, I mean.[11]

The question of the earth's motion is therefore subsumed under the more general question of what motion is in essence. According to Copernicus, when considering the nature of local motion, which is an issue relevant for the study of the earth's motion, the essential question is when one actually observes or sees that an object or a body is in motion, i.e. that it has changed its position. Accordingly, the point at issue here is not motion as such, but motion that one can see and perceive. In simple words, Copernicus is interested in the phenomenon (or appearance) of motion. There are three situations that cause us to perceive the phenomenon of motion, with the third one being irrelevant for our purpose.

In the first of those possible situations, it is the observed object that moves while the observer is stationary. Undoubtedly, this situation is the most "natural" one, so our natural consciousness, our *sensus communis*, accepts it as the only truthful one. If something appears to be in motion then it moves. But there is also another possible situation in which we perceive motion, one which is essential for Copernicus' purpose, which is diametrically opposite to the first. According to Euclid, whose postulate Copernicus summarizes here, motion also occurs when the observer moves and the observed object is motionless. In this case, too, if certain conditions are met, one experiences the phenomenon of motion, yet it is not the motion of a moving observer that is perceived but – and this is the crucial point – the motion of the observed object which is stationary in reality. No doubt both Euclid and Copernicus had in mind the common experience of a moving person who has the impression that he/she is motionless and that the object observed is in motion.

The motion then is a phenomenon, and since it is a phenomenon, immobility can be mistaken for motion: under certain circumstances, certain

---

[10] Ibid., I, 5.

[11] Ibid.

motionless objects appear to us to move, although it is we who are actually moving. Copernicus hence concludes that the second phenomenon of motion is possible in the universe as well, that is to say, that a person who moves with the rotating earth perceives motion of the immovable heavens. Or, in other words, even if the earth moved and the heavens did not, we would see the same phenomena that we see while assuming that the heavens move and the earth is stationary:

> It is the earth, however, from which the celestial ballet is beheld in its repeated performances before our eyes. Therefore, if any motion is ascribed to the earth, in all things outside it the same motion will appear, but in the opposite direction, as though they were moving past it. Such in particular is the daily rotation, since it seems to involve the entire universe except the earth and what is around it. However, if you grant that the heavens have no part in this motion you will find that this is the actual situation concerning the apparent rising and setting of the sun, moon, stars and planets.[12]

This means that the motion we observe in the heavens can be the result of our own motion as well. It is the observer who moves, but to that observer it seems that the observed object is in motion. It is the earth that moves, but it seems that the heavens move. By applying the general rule of the relativity of motion perception to the earth-heavens relation, Copernicus rejects the existence of an *a priori* structure of motion in the universe: on the "phenomenological" level, the movement of the heavens can be explained by the motion of either the earth or heaven.

However, this is just the first step, and it does not yet bring Copernicus to assert categorically that the earth actually moves. The assertion that it is "more likely that the earth moves than that it is at rest" and that it "is especially true of the daily rotation, as particularly appropriate to the earth", comes later, in the renowned Chapter 8 of Book 1, where he again places the heavens and the earth in a comparative relationship. Even at this point, after exposing some inherent contradictions in peripatetic cosmology, and after stressing the spherical shape of the earth, Copernicus's presentation is a concretization of the abstract rules of the optical argument. In this famous comparison, he draws a parallel between the daily revolution of the heavens and earth and a ship that sails out of the harbor, where the sailors aboard the ship have the impression that the shore and the harbor are moving away from

---

[12] Ibid.

them. For the sailors, the movement of the ship is mirrored in the movement of the shore and city. Copernicus extends the comparison, saying that the appearance of a city moving away is an image of the ship's movement. And this image leads to the conclusion that the motion of the city is real. In other words, in this example the image replaces reality, and *vice versa.* The same happens, says Copernicus, in the case of the motion of the heavens. The motion of the heavens is an illusion (*apparentia*), the mirror image of the earth's motion; it is not reality – its reality is the motion of the earth. What happens in reality is that the earth revolves around its axis, while the heavens remain stationary:

> Why should we not admit, with regard to the daily rotation, that the appearance is in the heavens and the reality in the earth? This situation closely resembles what Vergil's Aeneas says: 'Forth from the harbor we sail, and the land and the cities slip backward.' For when a ship is floating calmly along, the sailors see its motion mirrored in everything outside, while on the other hand they suppose that they are stationary, together with everything on board. In the same way, the motion of the earth can unquestionably produce the impression that the entire universe is rotating.[13]

Copernicus uses the "optical argument" in both chapters, and while it seems that in Chapter 5 he uses it merely in order to point to the phenomenal, i.e. observational, equivalence between the hypothesis that the universe moves and the earth is stationary and the hypothesis that the universe is stationary and the earth is in motion, he is slightly more categorical in Chapter 8: the motion of the earth (its rotation) is reality whose mirror image is the motion of the heavens. In much the same way as it appears to the sailors that the shore and the harbor move away, to us, the inhabitants of the earth, it appears that the heavens move, although in both cases this phenomenon of motion is just a consequence, or an image, of the observer's own motion. It seems that Copernicus is no longer using the optical argument to argue just the general, observational (optical, phenomenal) equivalence of both hypotheses (immobility of the earth : motion of the heavens = motion of the earth : immobility of the heavens), but that this optical argument has now somehow enabled him to affirmatively conclude that the earth moves and the heavens do not (or that it is at least more probable that it moves than that it is at rest).

---

[13] Ibid. I, 8.

3.

The question that naturally occurs at this point is what legitimizes Copernicus to maintain that one motion is reality and the other only a mirror image of that reality? On what basis does he argue that the motion of the earth is reality and the motion of the heavens just an illusory effect of the earth's motion, in the same way that the phenomenon of the movement of the harbor and the shore is a mirror image of the ship's movement? Is it in the field of "optics" that Copernicus can find support and legitimacy for this shift, given that his affirmation of the earth's motion occurs within the context of the optical argument? How can the optical argument bring Copernicus to the conclusion that, in the case of daily rotation, "the appearance is in the heavens and the reality in the earth"? Is there any criterion that enables one to judge which movement is real and which only an illusion? In attempting to answer these questions, we will make use of the two examples of the illusion of movement analysed by Ptolemy in his *Optics,* as well as the example given by Buridan and Oresme.

Let us first consider Ptolemy's second (and less complex) example[14] of the illusion of movement which is similar to the one presented by Copernicus in Chapter 8. To a person gliding along the coast in a boat but not perceiving the movement of the boat, the shore and the trees on the shore appear to move. This situation is similar to that of the sailors to whom the shore and the city appear to move away, although it is the ship that moves. But how can these sailors know which is actually moving, the ship or the shore? The answer is: on the basis of their knowledge that the shore cannot move. Therefore, it must be they who move. So, when judging motion, the first possible criterion that can be used to distinguish between the illusion (image) and reality is banal. Common sense, supported by our own and others' experience, tells us what can and what can not be in motion. Since we already know that the shore is stationary, the fact that it appears to move can only be attributed to the mapping of the ship's movement onto the shore.

---

[14] Cf. Ptolemy, *Optics* II, 132: "Likewise, if we sail in a boat along the shore during twilight, or if we move in something other than a boat, and if we do not sense the motion of the thing carrying us, than we judge the tress and typographical features of the shoreline to be moving. This illusion stems from the fact that, when the visual rays are displaced [laterally], we infer that the visible objects are moving because of the displacement of the visual ray. Although the visible objects are stationary, then, it is assumed that the apparent motion belongs to them." Quoted after A. M. Smith, *Ptolemy's Theory of Visual Perception: An English Translation of the Optics*, The American Philosophical Society, Philadelphia 1996, pp.124–125.

Ptolemy's first example[15] is somewhat more complex. To a person sitting in a motionless boat anchored in the middle of a huge river, with his gaze fixed on the water, the boat will appear to be moving against the current because of the movement of the water surface. Since the water appears to be calm, the boat appears to be in motion. So, how do we know which object is actually moving in this example? Is it we who move along with the boat, or is it the water surrounding us? In this case our advance knowledge cannot be of much help. While in the Ptolemy's second example it is clear that the shore as such cannot move, in this particular case both elements in the comparison are mobile as such. How, then, can one resolve this predicament? How can we know whether or not we are moving? In other words, how can we establish what is reality and what its mirror image? In this case, the illusion of our own movement can be dispelled by resorting to a "third point" – a referential point external to the relationship observer–observed object. This third point is the shore, about which we know with certainty that it is motionless by virtue of its nature. By referring to the shore, we can now establish whether or not we are in motion.

The third example is an interesting situation that transcends both examples mentioned above, although it is not found either in Ptolemy or Copernicus. It is the situation cited by Buridan in *Questiones In Aristotelis De caelo,* here recapitulated after Oresme's *Le Livre du ciel et du monde.*[16] Once again we

---

[15] Cf. ibid. II, 131: "Furthermore, when a boat stands still in a calm, waveless river that flows swiftly, anyone in the boat who does not look at the shoreline beyond [but focuses on the river] judges that the boat is moving swiftly upriver while the water is standing still. The reason for this illusion is that the motion of the water sensed by the visual flux, being opposite to that with which the boat is assumed to move, is manifested by the contrast between the color of the boat and the color of water. Now the contrast created by the motion of the parts of water's surface alone is not clear to the senses because of the uniformity of the parts of the [water's] surface and similarity [throughout] of its color. Yet according to the motion of the visual flux upon the parts of the visible object's surface, it is necessary that either the water or the boat appear to move. Thus, since the water will appear calm, the motion must appear to belong to the boat. On the other hand, if we look at the water, the shoreline, and the boat all at the same time, and if we take cognizance of the fact that the shoreline is stationary, since the boat is seen by the same rays that see the shoreline. We will also see the water moving since we will have realized that the boat and the shorelines are stationary."

[16] Cf. *Le Livre du ciel et du monde* II, 25: "Now, I take as a fact that local motion can be perceived only if we see that one body assumes a different position relative to another body. For example, if a man is in a boat a, which is moving very smoothly either at rapid or slow speed, and if this man sees nothing except another boat b, which moves precisely like boat a, the one in which he is standing, I maintain that to this man it will appear that neither boat is moving. If a rests while b moves, he will be aware that b moving; if a moves and b rest, it will seem to the man in a that a is resting and b is moving, just as before. Thus, if

encounter the sailors and the ships, only in this case the sailor aboard ship A observes ship B in the open sea. Suppose that ship A is in motion while ship B is at rest. After some time, ship A slowly comes to a halt, but the sailor does not perceive this change, and ship B starts to move. Since the sailor still sees ship B moving away, it appears to him that he, along with ship A, is still moving and that ship B is motionless. The point is that the sailor can by no means know whether it is he or the observed object that is in motion. In fact, the sailor cannot make a valid judgment about which object is moving and which is at rest, either on the basis of advance knowledge (both ships can be in motion) or by referring to a third, immobile object, since there is no such referential object in the open sea. Consequently, there is no solution in this case: on the basis of "optical data" alone, the sailor cannot know whether he or the observed ship is in motion.

4.

This situation described by Oresme is identical to the one that causes the dilemma about the motion of the earth and the heavens. By admitting that the earth, too, is capable of motion, we find ourselves in a situation that prevents us from legitimately concluding, solely on the basis of what we can see, whether it is the earth or the universe that moves. Copernicus, too, is in the situation of a sailor in the open sea with no third point of reference available to legitimate his conclusion about the motion of one or the other. Being a sailor aboard the ship called earth, he cannot rely on any third, stationary object to legitimate his conclusion that it is he who moves along with the earth, or that it is the heavens that move: he cannot know which movement is an illusion and which reality. This means that it is not possible to draw conclusions legitimately about the motion of the earth, or the absence of motion thereof, solely on the basis of optical observations. The optical argument alone takes us only as far as the agnostic position, but it can by no means be

---

a rested an hour and b moved, and during the next hour it happened conversely that a moved and b rested, this man would not be able to sense this change or variation; it would seem to him that all this time b was moving. This fact is evident from experience, and the reason is that the two bodies a and b have a continual relationship to each other so that, when a moves, b rests, and, conversely, when b moves, a rests. It is stated in Book Four of The Perspective of Witelo that we do not perceive motion unless we notice that one body is in the process of assuming a different position relative to another." Quoted after Nicole Oresme, *Le Livre du ciel et du monde,* ed. A. D. Menut and A. J. Denomy, translated with an introduction by A. D. Menut, The University of Wisconsin Press, Madison/Milwaukee/ London 1968, p. 523.

a decisive moment for Copernicus' affirmation of the earth's motion. Viewed from this perspective, his assertion in Chapter 8 of *De Revolutionibus* is even more surprising, i.e. that we should "admit, with regard to the daily rotation, that the appearance is in the heavens and the reality in the earth" and that "this situation closely resembles what Vergil's Aeneas says: 'Forth from the harbor we sail, and the land and the cities slip backward'".

On what grounds, then, does Copernicus assert that the revolution of the universe around the earth is actually an mirror image of the earth's rotation? Where does he find legitimacy for the comparison of the motion of the heavens with the apparent motion of a shore observed from a moving ship? Since Copernicus cannot rely on a third, stationary point as a reference when concluding that the earth moves, because he is a sailor on the ship called earth which determines his point of observation and from which he cannot step down, we can conclude that Copernicus is, in some way, convinced in advance that the earth moves and the heavens do not, in the same way that the sailors sailing out of the harbor towards the open sea are convinced that it is they who move despite the fact that the shore and the harbor appear to be moving away from them. However, what is the foundation of this conviction of Copernicus, if it is not "optics"?

The conviction of the sailors that it is they who move rather than the shore is, on the one hand, rooted in common sense, and on the other, it is a result of the general philosophical consensus that the shore, that is to say, the earth (in its natural place), is motionless (and that it can be displaced from its natural place only by force). The earth cannot move. But why can it not move? Why, according to Aristotle and the "peripatetic" tradition, is the earth stationary and the heavens in motion?

In his book *On the Heavens,* Aristotle seems to have arrived at this conclusion – one supported by all ancient science with only rare exceptions – by way of abstract deduction or of conceptual analysis. Both his arguments against the movement of the earth and his explanation of why the earth does not move are predominantly, although not fully, derived from his theory of the natural movement(s) and natural places of simple bodies (earth, water, air, fire and ether), which, in turn, are derived from the principles that could be described as being *a priori,* i.e. not based on perception. Aristotle speaks of them as "first assumptions"[17] (or "assumptions concerning

---

[17] Cf. *On the Heavens* I, 7, 274a34: "Now, that it cannot be made up from an unlimited number of kinds is clear if one allows us our first assumptions."; ibid. b11: "This, however, is impossible, if we are to lay down that our first assumptions are true." All references from *On the Heavens* are from Aristotle, *On the Heavens*, I and II, edited and translated by S. Leggatt, Aris and Phillips, Warminster 1995.

movements"),[18] by which he probably refers to the principles introduced in Chapters 2 and 3 (these pertain to the theory of natural movement)[19] and in Chapter 8 of Book 1 (pertaining to the theory of natural places).

In his first argument against the motion of the earth,[20] Aristotle relies on the theory of the earth's natural motion, i.e. motion in a straight line towards the center of the universe, and on the assumption that a part moves with the same motion as the whole. Since the natural motion of the earth is rectilinear motion towards the center, its rotation or revolution around the center, meaning circular motions, could only be forced motions; had these motions been natural rather than forced, every individual piece or portion of the earth would move in a circle. If the earth followed this circular, unnatural path, its motion would not be eternal because no forced motion is eternal, but this contradicts the eternal order of the universe.

Similarly in his third argument against the motion of the earth,[21] Aristotle relies on the assumption that the earth as a whole and all of its parts move towards the center of the universe. Or, to be more precise: if the earth moved at all it would move towards the center and not around the center of the universe. And if this were so, the earth at the center would be stationary. Aristotle finds confirmation that the earth actually lies at the center of the universe in "a sign," (*semeion*), as he himself calls it, or rather the fact that heavy objects that move towards the earth hit the earth at right angles. In addition, the central position of the earth in the universe and its immobility are also supported by the observational fact that objects thrown into the air return to the point whence they were thrown. For example, a stone thrown into the air at right angles falls to the earth precisely at the point from which it was thrown, but this phenomenon would not be possible if the earth moved, since in such a case the stone thrown at the right angles would hit the ground behind the point from which it was thrown.[22]

---

[18] Cf. ibid. I, 8, 276b7–8: "That things must be so, however, is clear from the assumptions concerning movements."

[19] In his commentary on the treatise, Simplicius adduces seven "first assumptions", while S. Leggatt in his *Introduction* (p. 14, n. 26), argues that it is possible to list at least fourteen of these if not more. Let me quote just some of them: 1. There is such a thing as simple motion; 2. Movement in a circle is simple; 3. A simple body's movement is simple and a simple movement belongs to a simple body (269a2–4); 4. The natural motion of each natural body is unique (269a8–9); 5. Counter-natural movement is contrary to natural motion, etc.

[20] Cf. *On the Heavens* II, 14, 296a24–34.

[21] Cf. ibid., 296b6-25. Aristotle's third argument against the movement of the earth is not aimed directly at those supporting the opposite view, but rather serves to "state his considerate alternative to their conception of a moving earth." (Leggatt, p. 264).

[22] Cf. ibid., 296b21–25.

But the most typical example of the application of Aristotle's cosmological principles is his explanation of why the earth rests at the center of the universe. It is worth quoting in full:

> That, then, the earth neither moves nor lies outside the centre, is evident from these points; in addition to them, the reason for its rest is clear from what has been said. For it is such as to move by nature from anywhere towards the centre, as it is observed to do, and fire such as to move from the centre to the extremity, it is impossible for any part of it to move from the centre unless by being forced; for a single body has a single locomotion and a simple body has a simple locomotion, but not contrary locomotion, and locomotion from the centre is contrary to that to the centre. If, therefore, it is impossible for any part to move from the centre, it is evident that it is in fact still more impossible for the earth as a whole; for the place to which the part is such as to move is also the place to which the whole is such as to move; consequently, if it cannot move with a stronger force, it would have to stay at the centre.[23]

Therefore, Aristotle arrives at the conclusion that the earth rests at the center of the universe and that the universe is in motion primarily by way of a deductive, abstract method – on the basis of the theories of natural places and movement of things, both of which are in turn largely derived from "first assumptions" about movement and natural places. Although Aristotle does not expound much on the source of these "first assumptions", quite indicative is his mention of induction (*epagoge)*,[24] suggesting that he had in mind something similar to what we find at the end of the *Second Analytics,* i.e. that the point of departure for these assumptions is perception.[25]

---

[23] Ibid., 296b25-297a1. For Aristotle, the fact that the earth is immobile at the center of the universe is also confirmed by astronomers' claims. Cf. ibid., 297a2–5: "What the mathematicians say in astronomy also testifies to this, since the apparent facts – that is, the changing of the configurations in terms of which the arrangement of the stars is determined – result from the supposition that the earth lies at the centre."

[24] Cf. ibid. II, 7, 276a12–15: "Further, if the place where a thing remains or to which it moves contrary to nature has to belong to something else according to nature (this can be believed on the basis of induction (*ek tes epagoges*), then necessarily not all things posses either weight or lightness, but some possess one, while others do not possess it".

[25] Cf. ibid. II, 4, 287a11, where he mentions observation (seeing) and "assumption" side by side: "Further, since the whole is seen, and being assumed, to rotate in a circle, and has been shown that outside of the outermost revolution is neither void nor place, it also must be therefore spherical." Cf. also *De caelo* 272a5–7: "But we see the heavens turning about in the circle, and we have determined by argument as well that movement in a circle belongs to some particular body."

That the point of departure for these "assumptions" and for the theories of natural movement and natural places is perception, or to be more precise, that which can be seen with the naked eye, is also confirmed by Aristotle's identification of upward movement with the movement of fire and air, and of downward movement with the movement of water and earth. In much the same way as one can observe that the earth always moves downwards, it is possible to notice that water, too, moves downwards, while fire and air always move upwards. Harmonious with these observable facts are the theory of natural movement (each simple body has one simple movement: ether moves in a circle, earth and water fall downwards and fire and air rise upwards), the theory of natural places (the natural places of elements are places towards which they naturally move: the natural place of the earth is at the center of the universe, that of fire at the extreme edge of the sub-lunar universe, of water above the earth, of air under fire and of ether above the sub-lunar sphere), and the theory of weight and lightness (light bodies have the impulse to move towards their natural place upwards, i.e. towards the periphery of the universe, while heavy ones have the impulse to move downwards towards their natural place, i.e. towards the center of the universe). All this clearly shows that the point of departure for "first assumptions" and for Aristotle's apparently abstract deduction is, as P. Moraux put it, "une vision du monde qui devait être, pour Aristote, d'evidence immédiat",[26] and that this "direct evidence" is a "vision d'un univers spherique, dont la terre, immobile, occupe le centre, lequel centre est à son tour pris comme point de référence pour la définition des mouvements simples."[27]

To sum up, it is possible to discern three interlinked lines of reasoning in Aristotle's argumentation against the movement of the earth and in his explanation of the earth's immobility. On the one hand, the immobility of the earth at the center of the universe is for Aristotle the result of direct, perceptual evidence: he sees that the heavens move and that the earth is at rest.[28] This is an example of the most direct *sensus communis,* relying on what can be seen. On the other hand, Aristotle also finds confirmation for the earth's im-

---

[26] P. Moraux, "Introduction", p. CXV, in Aristote, *Du ciel,* texte établi et traduit par P. Moraux, Les Belles Lettres, Paris 1965.

[27] Ibid., p. CXVI.

[28] Cf. *On the Heavens* II, 13, 295b16–23: "This is put cleverly, but not truly, since on this argument anything placed at the centre must stay put, and so fire will rest there as well; for what was mentioned is not a property of earth. Yet it is not necessary: for the earth is not just seen to remain at the centre but also moves to the centre. For where any part of it moves, there must the whole earth move too; and where it moves according to the nature, there it remains according to the nature as well."

mobility and the heavens' motion in what he does not see but would be able to see if the earth moved: a stone thrown into the air at right angles would touch ground behind the place from which it was thrown if the earth really moved. The third confirmation of the earth's immobility is furnished by theory (the theories of the natural motion and of the natural places of bodies), which, as we have seen, also relies on direct evidence of the motionless earth placed at the center of the spherical universe. In other words, Aristotle translates directly observable phenomena into theory, starting from a fundamental hypothesis upon which he does not reflect, but which lends sense to these theories – that the earth is stationary at the center of the spherical universe – and then uses this theory to explain that which he can see. His speculation is, despite various argumentative strategies, predominantly dependent on the theories of the natural motion of elements and their natural places, which are based on ordinary observation that heavy bodies fall and light bodies rise in the air. His discussion of the earth is in this respect well described, as S. Legatt put it, as "a common sense account."[29]

This "common sense account" of the earth can be observed in all pre-Copernican astronomical and cosmological traditions. One can find the same types of arguments against the rotation of the earth in Ptolemy's *Almagest* or in Buridan's *Quaestiones in Aristotelis De caelo* and Oresme's *Le livre du ciel et du monde*, where the question of the earth's movement is considered very seriously, but denied on theoretical or observational grounds. This means that the argumentation *pro* and *contra* earth's motion is basically always dependent on what could be seen[30] – either indirectly (in the form of the theory of natural motions and natural places of simple elements, which depended on the "direct evidence") or directly in the form of sensible experiments "here on earth and in the air." On a more abstract level, this means that the concept of a stationary, motionless earth around which celestial bodies revolve is based on direct and indirect perceptual experience. The geostatic and geocentric conception of the universe is a result of a non-explicated hypothesis that equates, to simplify somewhat, the *voir* and the *savoir* or, in other words, makes *savoir* dependent on *voir*. More precisely, knowledge is dependent, at least in the case of the hypothesis of the earth's immobility, on observation that is determined by a non-reflected-upon natural perspective – it is a viewpoint taken by the "natural", "perceptual", "common-sensical" consciousness that is placed on a stationary earth at the center of the universe. The observer

---

[29] S. Leggatt, p. 263.

[30] The only exception to my knowledge is Oresme, who concludes against the earth's movement on theological grounds.

located on the stationary earth is a stationary pole around which the entire universe revolves; and the criteria for distinguishing between appearance and truth (that is to say, whether it is the earth or the universe that moves) are derived from a vision of the world which is (for Aristotle and others) direct evidence.

5.

The radicalism of Copernicus's thesis about the movement of the earth, by which he challenged the "consensus of many centuries"[31] lies firstly in the fact that he puts a question mark over this "direct evidence": although we can see that the heavens are in motion and the earth is stationary at the center of the universe and that this is confirmed by theory and perception, this is not the truth but an illusion – in reality it is the earth that moves while the heavens are stationary. The instrument that enables him to question "direct evidence" is the optical argument, which maintains the relative nature of motion perception: what can be seen is explainable by two optically, phenomenologically equivalent hypotheses. That is the role of the optical argument in Copernicus' discourse: to refute apparent and *a priori* conviction and "knowledge" about the earth's immobility and the heavens' motion. This provides ample, even comfortably ample grounds, for a positive affirmation of earth's motion, but not sufficient grounds. If both hypothesis are possible, there must be "some third argument" that tips the scales to one side or the other.

This is where another radical dimension of Copernicus' achievement comes to light. What is radical, even revolutionary, in Copernicus is not just that he questions apparent evidence, but even more importantly, on what basis he does it.

As it happens, it was Ptolemy[32] who had already unambiguously stated that both possibilities (earth's motion while the heavens are at rest and *vice*

---

[31] Cf. "To His Holiness …", p. 3: "Those who know that the consensus of many centuries has sanctioned the conception that the earth remains at rest in the middle of the heaven as its centre, I reflected, regard it as an insane pronouncement if I made the opposite assertion that the earth moves."

[32] Ptolemy, *Almagest* I, 7: "However, they do not realise that, although there is perhaps nothing in the celestial phenomena which would count against that hypothesis, at least from simpler considerations, nevertheless from what would occur here on earth and in the air, one can see that such a notion is quite ridiculous." Quoted after *Ptolemy's Almagest*, translated and annotated by G. J. Toomer, Princeton University Press, New Jersey 1998, pp. 4–5.

versa) are optically equivalent, or, in his words: “there is perhaps nothing in the celestial phenomena which would count against that hypothesis” (i.e. against the hypothesis of the earth’s rotation). However, for Ptolemy this optical equivalence is of secondary importance. It was introduced as a purely hypothetical possibility because, had the rotation of the earth been taken seriously, the entire complex system of established physics and cosmology would have been shaken. In addition to that, we should see “here on earth and in the air” phenomena which we do not see, *ergo* the earth rests.[33]

On the contrary, for Copernicus – as for Buridan and Oresme before him – the thesis of optical equivalence is an epistemological point of departure, one that in fact makes possible the contemplation of the earth’s motion. Copernicus maintains from the very beginning that both possibilities are equivalent, while not allowing that any cosmological or physical principle could contradict these two possibilities. Since the relativity thesis is universal and applies to all motion in the universe, it must the basic principle from which one should start when contemplating the motion of the heavens and earth. But what, against the background of the optical equivalence, determines which possibility is real and which illusion?

Buridan, for example, concluded that the earth was stationary because of physical reasons derived from his theory of impetus. Copernicus’s conviction that the earth moved and that the heavens was motionless stemmed not from physical but from astronomical arguments. Copernicus put behind him the spheres of cosmology and physics that relied on the non-reflected-upon and direct evidence, i.e. observation, as well as observational tests that similarly relied on what we should see but do not actually see “on the earth and in the air.” Instead he transferred the discussion to the sphere of mathematical astronomy. Of course, this is not to say that Copernicus did not offer a physical explanation compatible with the hypothesis of the earth’s motion. On the

---

[33] Cf. ibid.: “… the result would be that all objects not actually standing on the earth would appear to have the same motion, opposite to that of the earth; neither clouds nor other flying or thrown objects would ever be seen moving towards the east, since the earth’s motion towards the east would always outrun and overtake them, so that all other objects would seem to move in the direction of the west and the rear. But if they said that the air is carried around in the same direction and with the same speed as the earth, the compound objects in the air would none the less always seem to be left behind by the motion of both [earth and air]; or if those objects too were carried around, fused, as it were, to the air, then they would never appear to have any motion either in advance or rearwards; they would always appear still, neither wandering about nor changing position, whether they were flying or thrown objects. Yet we quite plainly see that they do undergo all these kinds of motion, in such a way that they are not even slowed down or speeded up at all by any motion of the earth.”

contrary, he did propose a type of physics compatible with his hypothesis, and he also responded to/countered all arguments against the earth's motion that were based on observational tests, i.e. observations as to what should happen "here on earth and in the air" if the earth really moved. However, as Wolff argues, Copernicus "justifies his system, not by showing that it can successfully explain physical facts, but rather by attempting to make the current and more or less traditional ways of explaining motion compatible with the earth's motion."[34] Copernicus was not primarily concerned with presenting physical arguments for his system, but rather with "the idea that the earth's motion is physically possible and not completely incompatible with reasonable views about nature."[35] To put it differently, Copernicus had to introduce physics into his argument because the earth, for astronomical, i.e. mathematical reasons, "simply must be in motion".

Copernicus's conviction that the earth moves and the heavens do not is rooted in astronomical reasons explained in more detail in Book 1 of *De Revolutionibus*, more precisely in Chapter 9 and particularly Chapter 10.[36] Copernicus is ("already") convinced that the earth moves because this thesis enables him to eliminate two, in his view crucial, deficiencies of the Ptolemaic astronomical tradition: the equant and an arbitrariness in the arrangement of the universe. For Copernicus, the earth's rotation is also the first step necessary to introduce the second kind of earthly motion – the earth's revolution around the sun.[37] If there is nothing that contradicts the rotation of the earth, he is perfectly legitimized to also raise the question of whether the earth can have different motions "so that it can be regarded as one of the planets."[38] Since the varying speeds of the movement of planets and their varying distances from the earth point to the fact that the earth is not the center around which the planets revolve, because there are several centers of their revolution, he can pose the question of whether the center of the earth (i.e. the center of earth's gravity) is also the center of the universe, or whether this center is occupied by the sun, around which the earth revolves along with other planets. Whether it is the earth that revolves around the stationary sun, or the sun that moves while the earth is motionless, the observable phenomena are the same:

---

[34] M. Wolff, "Impetus Mechanics as a Physical Argument for Copernicanism. Copernicus, Benedetti, Galileo", p. 218.

[35] Ibid.

[36] This is also a chapter which was probably written before all the others chapters and books of *De revolutionibus.*

[37] And it is also an introduction to the motion of the earth's axis.

[38] *De revolutionibus* I, 9.

> For if this is transformed from a solar to a terrestrial movement, with the sun acknowledged to be at rest, the risings and settings which bring the zodiacal signs and fixed stars into view morning and evening will appear in the same way. The stations of the planets, moreover, as well as their retrogradations and [resumptions of] forward motion will be recognised as being, not movements of the planets, but a motion of the earth, which the planets borrow for their own appearances.[39]

But the revolution of the earth around the stationary sun located near the center of the universe is the premise that enables Copernicus to arrange the universe in a rational, non-arbitrary and harmonious manner that does not leave room for Ptolemy's equant that violates the principle of the uniformity of circular motion. For Copernicus, the crucial reason that the earth moves is the arrangement of the planets relative to the sun and the harmony of the entire universe. "All these facts are disclosed to us," says Copernicus, "by the principle governing the order in which the planets follow one another, and by the harmony of the entire universe, if we only look at the matter, as the saying goes, with both eyes."[40] In fact, insistence on the central position of the earth (and its immobility) leads to the irrational and arbitrary arrangement of the universe. "Then one of two alternatives will have to be true. Either the earth is not the center to which the order of the planets and spheres is referred, or there really is no principle of arrangement nor any apparent reason why the highest place belongs to Saturn rather than to Jupiter or any other planet."[41] By accounting for the movement of the earth, Copernicus is able to arrange the heavenly spheres in a way that in his view presents "a marvelous symmetry of the universe, and an established harmonious linkage between the motion of the spheres and their size, such as can be found in no other way."[42] In short, what makes Copernicus convinced that the earth is in motion is the "symmetry of the universe" and a firm "harmonious linkage between the motion of the spheres and their size."

By transposing the argumentation from the physical and cosmological sphere to the astronomical sphere, Copernicus rendered irrelevant the field of the observable, i.e. "observational evidence" in all of its forms that constituted the foundation of geocentric cosmology and astronomy. In fact, the essence of Copernicus' "Copernican revolution" lies precisely in the fact that he transcended the sensory-perceptional evidence. The law that applies to

---

[39] Ibid.

[40] Ibid.

[41] Ibid. I, 10.

[42] Ibid.

the homogeneous universe in which the dividing line between the sub-lunar and supra-lunar spheres no longer exists, as well as the geometrized space of spheres which (in principle) obeys the same rules and laws and the universe in which the earth is just one among many planets, is the universal law of the relativity of motion perception. In such a universe it is not possible to judge whether or not the earth moves solely on the basis of what we see (i.e. phenomena); it is not possible to conclude whether or not the earth moves on the basis of our observation of either celestial or earthly phenomena. In order to be able to conclude which motion is an appearance and which reality in the earth-heavens relation, it is necessary to venture beyond direct sensory perception and observation. For Copernicus, the direct, sensory-perceptual evidence cannot govern knowledge; on the contrary, our knowledge determines what we see. He does not subscribe to the dictate of the body but shows that what we see is invariably dependent on what we know. He believes that the Aristotelian-Ptolemaic image of the world has nothing natural or extra-theoretical about it and that it is not supported by neutral, sensory-perceptual experience. His conviction that the earth moves does not stem from sensory-perceptual evidence, or "the eye of the body," but from a look at the universe through the "eye of reason" guided and legitimized by astronomy.

While the geocentric universe had been tailored to the needs of "natural" man, who by way of direct experience is part of an integral Whole along with the heavens and the earth, the heliocentric universe is a universe of the astronomer-mathematician who emerged as a result of the separation of reason from live, direct experience. We know that the sun, the planets and the earth do not rise and set, but that the earth rotates around its axis but our knowledge is not obtained through experience and cannot possibly be obtained through experience. Nor could science arrive at such a conclusion through direct experience, but by means of reason. The subject of the science of astronomy has to leave behind the "natural" viewpoint from which it observes phenomena, assume an "unnatural" position and from there observe and reflect on what one can see from a "natural" position. Or, in the words of Leibniz:[43]

> It is only with the eyes of the understanding that we can place ourselves in a point of view which the eyes of the body do not and can not occupy. For example, if we consider the course of the stars from where we stand on our earth's sphere, we obtain a wonderfully complicated structure,

---

[43] Leibniz, *Von dem Verhängnisse*, quoted after Leibniz, *Selections*, ed. by P. E. Wiener; Charles Scribner's Sons, New York 1951, pp. 572–73.

> which astronomers, just in the last few thousand years, have been able to reduce to a few certain laws, and these laws are so difficult and confusing that King Alfonso of Castille, having let tables be drawn up of celestial motions to fill up the lack of accurate knowledge, is supposed to have said that if he had been God's counsellor, the world would have been laid out better.
>
> However, after it had been finally discovered that we must place our eye at the sun if we want to view the celestial motions correctly, and that as a result everything comes out wonderfully beautiful, then we see that the supposed disorder and complication were the fault of our understanding and not of nature.

What is appearance and what reality can according to Copernicus be determined only by employing the criteria of mathematical theoretical constructions and not on the basis of sensory-perceptual evidence. Hence Copernicus preserves the traditional disparity between reality and appearance, but on the conceptual level this dividing line is contemplated differently from that in the (Aristotelian-Ptolemaic) tradition. Copernicus replaces "direct evidence", which lies at the foundation of peripatetic cosmology and astronomy, by a theory in which the decisive role is played by the "eye of the mind", which means that the viewpoint that enables one to understand the truth of a phenomenon is theoretically constructed. Or, to put it differently, it is the mathematical astronomy which decides whether earth moves (or not), not cosmology or physics.[44]

---

[44] On this point see R. S. Westman, "The Astronomer's Role in the Sixteenth Century: a Preliminary Study", *History of Science* 18 (1980), pp. 105–147.

NOTES ON CONTRIBUTORS

Peter Barker is Professor of the History of Science at the University of Oklahoma. His main research interests are the application of methods from cognitive psychology to problems of conceptual change in the history of science, and especially the history and historiography of the Scientific Revolution. His recent publications include: "Kuhn on concepts and categorization" in T. Nickles (ed.) *Thomas Kuhn.* Cambridge: Cambridge University Press, 2003, 212–45 (with X. Chen and H. Andersen), and "Constructing Copernicus" in *New Foundations in the History of Astronomy*, P. Barker (ed.) *Perspectives on Science*, 10 (2002), 208–27 (published 2003).

Richard DeWitt is an Associate Professor and Chair of the Department of Philosophy at Fairfield University, Fairfield, CT, USA. His research interests include the history and philosophy of science, logic, and the philosophy of mind. He is the author of the recently published *Worldviews: An Introduction to the History and Philosophy of Science.*

Myriam Gerhard is *wissenschaftliche Mitarbeiterin* at the *Hegel-Archiv*, University of Bochum. Her areas of research include the philosophy of science, metaphysics, epistemology, the philosophy of nature, german idealism, and 19th century philosophy. She has recently published "Das Prinzip des Wissens. Zur Entwicklung des Selbstbewußtseins bei Schelling und Hegel", in A. Arndt, K. Bal, H. Ottmann (Hg.), *Hegels "Phänomenologie des Geistes"*, Hegel-Jahrbuch 2001, Berlin 2002, pp. 127–132; "Das Wissen der absoluten Idee", in A. Arndt, K. Bal, H. Ottmann (Hg.), *Hegels "Glauben und Wissen", Hegel-Jahrbuch* 2003, Berlin 2003/04; "Die philosophische Kritik am naturwissenschaftlichen Materialismus", in K. Bayertz/W. Jaeschke, *Der Materialismus-Streit. Naturwissenschaft, Philosophie und Weltanschauung im 19. Jahrhundert*, Hamburg 2004; "Die Logik des Begriffs und seine Geschichte. Eine Überlegung zu Hegels logischer Bestimmung des Begriffs", in T. Boiadjiev/ G. Kapriev/ G. Mensching (Hg.), *Die Geschichtlichkeit des philosophischen Denkens in Europa*, Sofia 2004.

Hilary Gatti is Associate Professor at the Faculty of Philosophy at the La Sapienza University of Rome, where she has taught since 1971. Her principal field of research is renaissance studies, particularly the life and works of Giordano Bruno. As well as numerous essays in scholarly journals, she has published *The Renaissance Drama of Knowledge: Giordano Bruno in England* (Routledge, London 1989) and *Giordano Bruno and Renaissance Science* (Cornell University Press, Ithaca NY, 1999). She is also editor of *Giordano Bruno: Philosopher of the Renaissance* (Ashgate, London 2003), and has presented papers at a conference sponsored by The British Society for the History of Philosophy held at University College London in 2000 to commemorate the four-hundredth anniversary of the philosopher's death.

Fernand Hallyn is director of the Centre for the History of Science at the University of Ghent, Belgium. He has published: *The Poetic Structure of the World: Copernicus and Kepler* (New York, Zone Books, 1990), *Galilée: le Messager des étoiles* (Paris, Seuil, 1993), *Les structures rhétorique de la science* (Paris, Seuil, 2004), and is the editor of: *Metaphor and Analogy in the Sciences* (Dordrecht, Kluwer, 2000).

Karsten Harries is Professor of Philosophy at Yale University. He has published and lectured widely on Heidegger, early modern philosophy, and the philosophy of art and architecture. He is the author of more than 170 articles and reviews and of five books: *The Meaning of Modern Art* (1968), *The Bavarian Rococo Church: Between Faith and Aestheticism* (1983), *The Broken Frame: Three Lectures* (1990), *The Ethical Function of Architecture* (1997) and *Infinity and Perspective* (2001).

Peter Klepec is a Research Fellow at the Institute of Philosophy at ZRC SAZU, Ljubljana, Slovenia. His research focuses on contemporary philosophy, German classical idealism and Lacanian psychoanalysis. He is the author of numerous articles.

F. Jamil Ragep is Professor of the History of Science and Co-Director of the Center for Peace Studies at the University of Oklahoma. His research focuses on science in the Islamic world as well as its cultural context and its relationship to Greek and early modern science.

Katherine A. Tredwell is a doctoral candidate at the History of Science Department of the University of Oklahoma. Her dissertation is entitled "The Exact Sciences in Lutheran Germany and Tudor England". She is the author of "Michael Maestlin and the Fate of the *Narratio prima*" in the *Journal for the History of Astronomy*, Cambridge, 35 (2004), forthcoming.

Matjaž Vesel is a Research Fellow at the Institute of Philosophy at ZRC SAZU, Ljubljana, Slovenia. His research focuses on the relation between philosophy and science in the pre-modern era and during the scientific revolution. He is the author of numerous articles on these issues. He recently published *Nicolas Cusanus' Learned Ignorance. Nicolas Cusanus and the Constitution of the Universe of Modern Science*, ZRC SAZU, Ljubljana 2000 (in Slovenian) and the bilingual edition of Copernicus' *De revolutionibus. Liber primus,* ZRC SAZU, Ljubljana 2003. He is currently working (as the editor) on the Slovenian edition of Aristotle's *De caelo.*

ABSTRACTS • IZVLEČKI

Richard DeWitt

The Beginnings of a Modern Copernican Revolution

Key words: *Copernican revolution, locality, Bell's theorem, quantum theory, Aspect experiments*

The Copernican revolution of the 1500s and 1600s was in large part due to new theories and discoveries, which indicated that the general view of the universe – the more or less Aristotelian, teleological view – was no longer viable. This revolution eventually resulted in a substantially different view on the sort of universe we inhabit. New discoveries in recent years, involving Bell's theorem, quantum theory, and the outcome of carefully designed and replicated experiments, strongly suggest that the general view of the universe we have had since the Copernican revolution is no longer viable. The main goals of this paper are (i) to present Bell's theorem and the results of these recent experiments in a way accessible to a non-technical audience, and (ii) to explore the question of whether these new discoveries place us in a similar situation to that of our predecessors in the early years of the 1600s, or roughly, whether we are in the beginning stages of a modern Copernican revolution.

Richard DeWitt

Začetki moderne kopernikanske revolucije

Ključne besede: *kopernikanska revolucija, lokaliteta, Bellov teorem, kvantna teorija, Aspectovi eksperimenti*

Kopernikanska revolucija šestnajstega in sedemnajstega stoletja je bila v veliki meri rezultat novih teorij in odkritij, ki so pokazali, da splošen pogled na vesolje – bolj ali manj aristotelski, teleološki pogled – ne more več veljati. Ta revolucija je v končni fazi vzpostavila precej drugačen pogled na vesolje, v katerem živimo. Nova odkritja v zadnjih letih, med njimi Bellov teorem, kvantna teorija ter rezultati skrbno načrtovanih in ponovljenih eksperimentov, dokaj trdno kažejo, da splošen pogled na vesolje, ki je veljal po kopernikanski revoluciji, ne more več veljati. Glavni cilji tega prispevka so (i) predstaviti Bellov teorem in rezultate teh nedavnih eksperimentov tako, da bodo razumljivi širši, manj strokovni javnosti, in (ii) raziskati vprašanje, ali nas ta nova odkritja postavljajo v položaj, podoben našim predhodnikom v prvih letih sedemnajstega stoletja, oziroma, v grobem, ali smo na začetni stopnji moderne kopernikanske revolucije.

Hilary Gatti

Giordano Bruno's Copernican Diagrams

Key words: *Copernicanism, nature, realism, infinite, diagrams*

The paper considers the Copernicanism of Giordano Bruno (1548–1600) as a central moment of his philosophy of nature, concentrating on his two principal cosmological works, *La cena de le ceneri (The Ash Wednesday Supper)*, written and published in London in 1584, and the Latin *De immenso,* published in Frankfurt in 1591. The principal characteristic of Bruno's reading of Copernicus which is underlined is his physical realism, which was particularly complex due to his extension of the still finite Copernican cosmology to infinite dimensions. The paper shows how Bruno's use of diagrams was essential in defining the terms of his new infinite, post-Copernican cosmology, which constitutes an essential if much debated link between Copernicus himself and the great astronomers of the early seventeenth century such as Kepler and Galileo.

Hilary Gatti

Kopernikanski diagrami Giordana Bruna

Ključne besede: *kopernikanizem, narava, realizem, neskončno, diagrami*

Članek obravnava kopernikanizem Giordana Bruna (1548–1600) kot osrednjo točko njegove filozofije narave in se osredotoča na dve njegovi glavni kozmološki deli, *La cena de le ceneri* (*Pepelnična večerja*), ki je bila napisana in izdana v Londonu leta 1584, in latinsko delo *De immenso,* izdano v Frankfurtu leta 1591. Glavna značilnost Brunovega branja Kopernika, ki je poudarjena, je njegov fizikalni realizem, ki je bil še posebej kompleksen zaradi njegove razširitve še vedno končne kopernikanske kozmologije v neskončne dimenzije. Članek pokaže, kako je bila Brunova uporaba diagramov bistvenega pomena pri definiranju terminov njegove nove, postkopernikanske kozmologije, ki tvori bistveno, četudi sporno, povezavo med samim Kopernikom in velikimi astronomi zgodnjega sedemnajstega stoletja, kot sta Kepler in Galilej.

Myriam Gerhard

»Certe rationem ordinis non esse«?: Zur Konstituierbarkeit einer vernünftigen Ordnung der Natur bei Copernicus, Bruno und Schelling

Key words: *vernünftige Ordnung, Ungleichmässigkeit der Planetenbewegung, Prinzip der Naturerklärung, Unendlichkeit, Universum*

Ob "nicht etwa eine vernünftigere Anordnung von Kreisen zu finden sei, von welchen alle erscheinende Ungleichmäßigkeit abhinge", ist die Frage, die Copernicus umtreibt. Eine einheitliche, eine systematische Berechnung aller Planetenbewegungen – auch der der sogenannten irrenden Sterne – sucht Copernicus durch die Einführung einer Hypothese, die über eine bloß mathematische Annahme hinausgeht, zu begründen. Die Erkenntnis der einheitlichen Weltgestalt und des festen Ebenmaßes ihrer Teile hat die Annahme eines die systematische Einheit konstituierenden Prinzips zur Voraussetzung. Als dieses Prinzip versteht Copernicus die Erdbewegung. So schließt Copernicus, daß entweder die Erde nicht ruhe oder eine vernünftige

Ordnung der Planeten nicht zu begründen sei. Für Bruno und Schelling ist das Prinzip zur Ordnung des Universums keine mathematische Hypothese, sondern ein naturphilosophisches Prinzip. Schelling schließt sich Bruno in der Behauptung an, daß eine Ordnung nur unter der Voraussetzung möglich sei, daß das Subjekt wie das Objekt der Ordnung sich auf ein Prinzip zurückführen ließen. Damit droht die *Kopernikanische Wende* auf den Kopf gestellt zu werden.

MYRIAM GERHARD

»Certe rationem ordinis non esse«?: k zmožnosti vzpostavitve razumnega reda narave pri Koperniku, Brunu in Schellingu

Ključne besede: *razumni red, neenakomernost gibanja planetov, načelo razlage narave, neskončnost, univerzum*

Vprašanje, ali "ne obstaja neka razumnejša ureditev krožnega gibanja planetov, od katere bi bila odvisna vsa pojavna neenakomernost", Koperniku ni dalo miru. Enoten, sistematičen izračun gibanj vseh planetov – tudi tako imenovanih tavajočih zvezd – je Kopernik poskušal utemeljiti z vpeljavo hipoteze, ki je več kot zgolj matematična predpostavka. Poznavanje enotnega ustroja sveta in trdne simetrije njegovih delov ima za predpostavko sprejetje načela, ki vzpostavlja sistematično enotnost. Po Koperniku je bilo to načelo gibanje Zemlje. Tako je prišel do zaključka, da bodisi Zemlja ne miruje bodisi ni mogoče utemeljiti razumnega reda planetov. Za Bruna in Schellinga načelo ureditve univerzuma ni matematična hipoteza, ampak načelo filozofije narave. Schelling sledi Brunu v trditvi, da je red mogoč samo pod pogojem, da je mogoče tako subjekt kot objekt reda zvesti na eno načelo. S tem pa grozi, da bo *kopernikanski obrat* postavljen na glavo.

FERNAND HALLYN

Gemma Frisius: A Convinced Copernican in 1555

Key words: *absurdity, demonstration, epistemology, hypothesis, reception*

Gemma Frisius (1508–1555), who worked at the university of Louvain, heard about the Copernican system already around 1530 and afterwards was a careful reader of the *Narratio prima* and the *De Revolutionibus.* The article argues that his posthumous preface to the *Ephemerides* (1556) by his pupil Stadius expresses his ultimate opinion on the system of the world. Moreover, it is also the only text where he tackles the epistemological problems of the question. A careful analysis of this preface shows that at the end of his life, on the ground of observations as well as philosophical demands, he admitted at least the first two movements ascribed to the earth by Copernicus.

FERNAND HALLYN

Gemma Frisius: prepričan kopernikanec leta 1555

Ključne besede: *absurdnost, dokazovanje, epistemologija, hipoteza, recepcija*

Gemma Frisius (1508–1555), ki je deloval na univerzi v Louvainu, je že okoli leta 1530 slišal za kopernikanski sistem, kasneje pa je skrbno prebiral *Narratio prima* in

De revolutionibus. Prispevek poskuša pokazati, da je v njegovem posthumnem uvodu v delo *Ephemerides* (1556), ki ga je napisal njegov učenec Stadius, izraženo njegovo mnenje o sistemu sveta. Poleg tega je to edino besedilo, v katerem se ukvarja z epistemološkimi problemi tega vprašanja. Podrobna analiza tega uvoda kaže, da je na koncu svojega življenja, na osnovi opazovanj, pa tudi filozofskih zahtev, dopustil vsaj prvi dve gibanji, ki jih je Zemlji pripisal Kopernik.

KARSTEN HARRIES

Truth and Value Today: Galileo contra Bellarmine

Key Words: *science, religion, value, truth, pope John Paul II*

In a speech celebrating the centenary of Einstein's birth Pope John Paul II admitted that Galileo had been treated unjustly by the Church and praised his understanding of the relationship of science and religion. Is such praise deserved? At issue is not so much the truth of the Copernican position, as the meaning and value of truth. There is a sense in which reality is elided by the science inaugurated by Copernicus and Galileo. The Church was right to deny that the truth that mattered to faith should take second place to the truth that matters to science. But it was wrong to think that the former truth be understood as objective truth. Copernicus put the pursuit of objective truth on the right track. But just because he did, we must consider legitimacy and limits of that pursuit.

KARSTEN HARRIES

Resnica in vrednota danes: Galilej proti Bellarminu

Ključne besede: *znanost, religija, vrednota, resnica, papež Janez Pavel II*

Janez Pavel II je v govoru ob stoletnici Einsteinove smrti priznal, da je katoliška cerkev Galileju storila krivico in pohvalil njegovo razumevanje razmerja med znanostjo in religijo. Je ta hvala utemeljena? Tu ne gre toliko za resnico kopernikanske pozicije kot za pomen in vrednost resnice. V nekem smislu se znanost, ki sta jo ustoličila Kopernik in Galilej, lahko izogne realnosti. Cerkev je upravičeno zanikala, da bi morala biti resnica, ki je bila pomembna za vero, na drugem mestu za resnico, ki je bila pomembna za znanost. Napačno pa je bilo njeno mnenje, da je treba prvo resnico razumeti kot objektivno resnico. Kopernik je iskanje objektivne resnice zastavil pravilno. A prav zaradi tega moramo razmisliti o legitimnosti in omejitvah tega početja.

PETER KLEPEC

Lyotard and the "Second Copernican Turn"

Key words: *Copernicus, revolution, science, Lyotard, Copernican turn, modern*

In the essay possible thematic connections between Copernicus and Lyotard are elaborated. In his late opus Lyotard elaborates the problematic of making the invisible visible, presenting the unpresentable, the emergence of something new. This theme not only throws new light on the very emergence of the Copernican revolution, if there ever was one, but also presents something which is at the very heart of the dispositive of modern science as such: a link between contingency, necessity and impossibility, elaborated by Lyotard through his new yet unfinished conceptions of time, cause and subject. Finally, some paradoxes of Lyotard's project carried out in the name of the second Copernican turn are shown.

Peter Klepec

Lyotard in "drugi kopernikanski obrat"

Ključne besede: *Kopernik, revolucija v znanosti, Lyotard, kopernikanski obrat, moderna*

Prispevek se loteva možnih tematskih povezav med Kopernikom in Lyotardom, ki je v svojem poznem opusu obravnaval problematiko prehoda nevidnega v vidno, prikaza neprikazljivega, vznika novega. Ta tematika ne le postavlja v nekoliko drugačno luč sam vznik revolucije, katere avtor naj bi bil Kopernik – če seveda kaj takega sploh obstaja –, pač pa predstavlja tudi nekaj, kar se nahaja v samem dispozitivu moderne znanosti, katere pričetek naj bi predstavljal ravno Kopernik: vez med naključjem, nujnostjo in nemožnim, ki se je je Lyotard loteval v svojem nedokončanem pojmovanju časa, vzroka in subjekta. Na koncu sledi nekaj paradoksov Lyotardovega projekta, ki sicer poteka v znamenju drugega kopernikanskega obrata.

F. Jamil Ragep

Copernicus and his Islamic Predecessors: Some Historical Remarks

Key words: *Islam, Copernicus, astronomy, models, cosmology*

Based upon research over the past half century, there has been a growing recognition that a number of mathematical models used by Copernicus had originally been developed by Islamic astronomers. This has led to speculation about how Copernicus may have learned of these models and the role they played in the development of his revolutionary, heliocentric cosmology. Most discussion of this connection has thus far been confined to fairly technical issues related to these models; recently, though, it has been argued that the connections may go deeper, extending into the physics of a moving Earth and the way in which astronomy itself was conceived. The purpose of this article is to give an overview of these possible connections between Copernicus and his Islamic predecessors and to discuss some of their implications for Copernican studies.

F. Jamil Ragep

Kopernik in njegovi islamski predhodniki: nekatere zgodovinske opazke

Ključne besede: *islam, Kopernik, astronomija, modeli, kozmologija*

Na podlagi raziskav preteklega pol stoletja vse bolj priznavamo, da so islamski astronomi razvili precej matematičnih modelov, ki jih je uporabljal Kopernik. To je vodilo v spekulacije o tem, kako je Kopernik izvedel za te modele, in o vlogi, ki so jo imeli pri razvoju njegove revolucionarne heliocentrične kozmologije. Razprava o tej povezavi se je do sedaj večinoma omejevala na dokaj tehnična vprašanja, povezana s temi modeli. Nedavno pa je bilo ugotovljeno, da so te povezave lahko globlje in da se širijo v fiziko gibajoče Zemlje in način, kako je bila razumljena sama astronomija. Namen članka je podati pregled mogočih povezav med Kopernikom in njegovimi islamskimi predhodniki ter predstaviti nekatere posledice le-teh za kopernikanske študije.

KATHERINE A. TREDWELL AND PETER BARKER

Copernicus' First Friends: Physical Copernicanism from 1543 to 1610

Key words: *Copernicus, Copernican revolution, astronomy, Kepler, Galileo*

Between the appearance of Copernicus' *De Revolutionibus* in 1543 and the works of Kepler and Galileo that appeared in 1609–10, there were probably no more than a dozen converts to physical heliocentrism. Following Westman we take this list to include Rheticus, Maestlin, Rothmann, Kepler, Bruno, Galileo, Digges, Harriot, de Zúńiga, and Stevin, but we include Gemma Frisius and William Gilbert, and omit Thomas Harriot. In this paper we discuss the reasons this tiny group of true Copernicans give for believing that Copernicus, not Ptolemy or Tycho Brahe, was correct. We conclude that the early followers of Copernicus can be divided into two main groups, designated mathematicians and physicists. Two main arguments appear in the works of the former: first, the relationship between the velocity of a planet and its distance from the center of the world; second, the explanation of retrogradations. Early Copernicans differed on the reality of celestial spheres, and several attempted to reconcile heliocentrism with scripture. The mathematicians continued to accept a traditional definition of the scope of astronomy and the methods of science, both issues challenged by Kepler and Galileo. Hence the work of Copernicus set in motion a train of events that led to a decisive epistemological shift, but did not itself represent such a shift. The real revolution is the replacement of the methods and goals of Ptolemaic astronomy and Aristotelian physics with Copernicanism in its modern form, which incorporates the conceptual structure of Kepler and the astronomical evidence of Galileo.

KATHERINE A. TREDWELL IN PETER BARKER

Prvi Kopernikovi prijatelji: fizikalni kopernikanizem od leta 1543 do 1610

Ključne besede: *Kopernik, kopernikanska revolucija, astronomija, Kepler, Galilej*

Med izidom Kopernikovega dela *De revolutionibus* leta 1543 ter izidi del Keplerja in Galileja iz let 1609–10 najbrž ni bilo več kot ducat spreobrnjencev v fizikalni heliocentrizem. Po Westmanu naj bi ta seznam vključeval Retika, Maestlina, Rothmanna, Keplerja, Bruna, Galileja, Diggsa, Harriota, de Zúńigo in Stevina, midva pa vključujeva še Gemmo Frisiusa in Williama Gilberta, hkrati pa izpuščava Thomasa Harriota. V tem prispevku razpravljava o razlogih, ki jih navaja ta majhna skupina ljudi, zakaj menijo, da je imel prav Kopernik, ne pa Ptolemaj ali Tycho Brahe. Zaključiva, da je zgodnje Kopernikove privržence mogoče razdeliti v dve glavni skupini, matematične in fizikalne pristaše. V delih prvih se pojavljata dva glavna argumenta: prvič, razmerje med hitrostjo gibanja planeta in njegovo oddaljenostjo od centra sveta; drugič, razlaga retrogradacij planetov. Zgodnji kopernikanci se niso strinjali glede realnosti nebesnih sfer in več jih je poskusilo združiti heliocentrizem z Biblijo. Matematiki so še naprej sprejemali tradicionalno definicijo dometa astronomije in znanstvenih metod, čemur sta oporekala Kepler in Galilej. Tako je Kopernikovo delo sprožilo vrsto dogodkov, ki so vodili v odločilen epistemološki premik, samo pa ni predstavljalo takega premika. Pravo revolucijo predstavlja šele nadomestitev metod in ciljev ptolemajske astronomije in aristotelske fizike s kopernikanizmom v moderni obliki, ki vključuje Keplerjevo konceptualno strukturo in Galilejev astronomski dokaz.

MATJAŽ VESEL

What is Revolutionary in Copernicus' **Revolutions**

Key words: *Copernicus, epistemological shift, physics, mathematical astronomy, optical argument*

Copernicus' work was for long considered a turning point in astronomy; some historians even consider it a turning point in science in general. But numerous recent studies have turned this image upside-down. It was revealed that Copernicus' work was firmly rooted in the traditional conceptual apparatus. The aim of the article is to show that Copernicus' work, in spite of everything, does indeed represent a radical epistemological shift regarding a certain point, which can be appropriately illuminated by the analysis of the Copernicus' introduction of the concept of Earth's motion in astronomy. Copernicus, in contrast to the pre-Copernican tradition, finds mathematical-astronomical reasons that transcend the field of sensory perceptions to be decisive, and rejects the physical or cosmological reasons given by the traditional natural sciences, which are eventually all based on direct or indirect "*evidence immediate*".

MATJAŽ VESEL

Kaj je revolucionarno v Kopernikovih **Revolucijah**

Ključne besede: *Kopernik, epistemološki obrat, fizika, matematična astronomija, optični argument*

Kopernikovo delo je dolgo časa veljalo za prelomnico v astronomiji, za nekatere zgodovinarje znanosti pa tudi v celotni znanosti. Številne nedavne študije so to podobo postavile na glavo, in pokazalo se je, da je Kopernik še popolnoma zakoreninjen v tradicionalnem konceptualnem aparatu. Namen članka je pokazati, da Kopernikovo delo, kljub vsemu, v eni točki predstavlja radikalen epistemološki obrat, ki ga je mogoče dobro osvetliti z analizo vpeljave koncepta gibanja Zemlje. Za Kopernika so, v nasprotju od celotne predkopernikanske tradicije, za vprašanje gibanja ali mirovanja Zemlje odločilni matematično-astronomski razlogi, ki transcendirajo polje čutnozaznavnega, in ne fizikalni ali kozmološki razlogi tradicionalne znanosti o naravi, ki v zadnji instanci temeljijo na neposredni ali posredovani »*evidence immediate*«.