Heaven and Earth in Ancient Greek Cosmology

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Dirk L. Couprie

Heaven and Earth in Ancient Greek Cosmology

From Thales to Heraclides Ponticus

Springer

Dirk L. Couprie
St. Maartenslaan 51d
6221AW Maastricht
Netherlands

ISBN 978-1-4419-8115-8 e-ISBN 978-1-4419-8116-5
DOI 10.1007/978-1-4419-8116-5
Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2011923655

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Printed on acid-free paper

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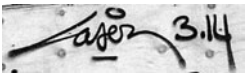
Dedicated to the memory of my father
Leendert Couprie
September 20, 1896 – September 16, 1983
who showed me the panorama of the celestial vault

MOTHER
THERE'S SOMETHING
WRONG WITH THE SKY

RADIANT THE OCEAN SKY
SERENITY AND BLIGHT

graffiti by 

somewhere in Amsterdam

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The picture on the front cover is a detail of the triptych *The Seven Wonders of the World* by Hans Exterkate. It is a pastiche of a well-known photograph of two Bornean tribesman with their gnomon. In the two figures one recognizes the artist and the author (left).

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Foreword

Early Greek cosmology is a very difficult subject to deal with. First, the evidence we possess is fragmentary. Second, one cannot easily imagine what could be rational, but still mistaken, scientific theories – theories based on facts and reasoning, on the one hand, but quite different from modern views, on the other hand. Their reconstruction requires both sophisticated competence and compassion, even admiration for the early thinkers. But reconstruction is very well worth trying because all theoretical science has its beginning in early Greek cosmology. In this book, Dirk L. Couprie presents his efforts at clarifying the views of the pioneers of theoretical cosmology. It covers the crucial period from about the middle of the sixth until the middle of the fourth century B.C., with its focus on the magnificent figure of Anaximander. It is a sincere, modestly written, in no way pretentious, but clear book. Dirk Couprie invariably approaches opinions he criticizes with both due respect and straightforwardness. The author is particularly strong in visualizing the reconstructed views of the heaven and earth; he has no rivals in that among his predecessors. Despite various scholarly publications that appeared over the past century and a half, the history of early Greek cosmology is still a field in development. The book by Dirk Couprie constitutes an important and in several respects indispensable contribution to this field.

St. Petersburg State University Dmitri Panchenko

Preface and Acknowledgements

This book is about the origin of our Western world-picture in Greek cosmology. The late Cornelis Verhoeven from the University of Amsterdam guided my first steps in the study of Anaximander, which in 1989 resulted in my doctoral dissertation on the translation and interpretation of the text of his only surviving fragment. At that time, I had the opportunity to discuss my earliest thoughts about Anaximander's cosmology with the also late Jan van Paradijs, who was, being a famous astronomer himself, interested in ancient astronomy as well. With Robert Hahn from Southern Illinois University Carbondale, I have had intensive discussions for many years, by email and during visits, on the understanding of Anaximander's cosmology. The fact that I disagree with a good deal of the tenor of his work does not diminish in the least the importance of this contact. I am especially grateful that he scrutinized the whole manuscript and made a lot of wise and helpful comments. This manuscript was already finished when his latest book, *Archaeology and the Origins of Philosophy*, appeared, on which I have been able, therefore, to insert only a few incidental remarks. For an extensive review, see Couprie (2010). Less frequent, but always stimulating, were the personal and email contacts with Gerard Naddaf from York University, Toronto. The book that the three of us wrote about Anaximander in 2003 has added much to my insights in ancient Greek cosmology. The exchange of thoughts by email with István Bodnár from Eötvös University, Budapest, Andrew Gregory from the University College London, and Carlo Rovelli from the Centre de Physique Théorique de Luminy, were very fruitful. The same holds especially for Dmitri Panchenko from the State University of St. Petersburg, who was so kind as to write a Foreword to my book. The contacts with Patricia O'Grady from Flinders University of South Australia at Adelaide were inspiring, although I fundamentally disagree with her interpretation of Thales. F. Richard Stephenson from the University of Durham kindly placed at my disposal his computer computations, based on the most recent insights, of some relevant solar eclipses. I was lucky to have had a couple of discussions with Teije de Jong from the University of Amsterdam on the prediction of eclipses as well as on the measuring of the size of the sun on a flat earth. I had

the opportunity to discuss several items with other members of the Utrecht Study Group for the History of Astronomy (USHA) as well. W.H. von Soldt from the University of Leiden drew my attention to the text of a cuneiform tablet on the distances of celestial bodies. B.J. Mansvelt Beck, also from the University of Leiden, kindly answered my questions on Chinese astronomy. The same holds for J.J. de Jong as regards the measurements of columns and column drums. Olaf Kaper from Leiden University was so kind as to help me with the translation of a hieroglyphic text, although on a vital point I was so stubborn as not to follow his advice. With my wife Heleen Pott (Erasmus University of Rotterdam), together with whom I have written a couple of articles, I discussed continually every thought incorporated in this book. Ton Verschoor and Liesbeth van der Sluijs read earlier versions and offered many useful comments. My brothers Jan and Leendert Couprie helped me with the calculations in Chaps. 15 and 16. If not otherwise indicated, the pictures are drawn by myself. Hans Exterkate not only meticulously produced the illustrations for several figures, but also allowed me to include the beautiful picture of Anaximander teaching (detail of his triptych *The Seven Wonders of the World*) in the Introduction. The picture on the front cover shows another detail of the same triptych. Ton Lecluse was so kind as to make the figure of a dodecahedron inscribed in a sphere in Chap. 17 according to my directions. The acknowledgments for permission to print the other pictures are mentioned in the captions of figures. I am grateful to the editors and publishers of *Apeiron*, *Hyperboreus*, *Early Science and Medicine*, and *Greek Research in Australia*, who allowed me to make use of (parts of) formerly published articles. Where needed I have updated and (sometimes strongly) adapted the texts. I also took the opportunity to redress misunderstandings that some passages and drawings have given rise to.

Special thanks to my physical therapist Jos ("Jesus") Kremer, who cured me from the serious after effects of a whiplash. Without his healing hands, I would not have been able to finish this book.

Last but not least, I am very glad to mention Zdeněk Kratochvíl, Radim Kočandrle, and Vojtěch Hladký of the Charles University in Prague, who invited me to give a series of lectures on Anaximander and ancient Greek cosmology in June 2009. This visit offered me the opportunity to discuss at length the gist of this study as well as many details with them and with their students and colleagues.

Introduction

One of the dearest memories of my childhood is that my father took my brother and me with him to the Zeiss planetarium in the Hague (which unfortunately burned down in 1976). We were sitting under the white cupola, where after some time the light gradually dimmed. On the darkening vault, luminous points became visible. A few moments later a sigh of admiration passed through the crowd: from an inky black sky a magisterial legion of stars shone down upon us, a representation of a moon- and cloudless night, far from all city lights. It was only many years later that I began to realize that the planetarium is a perfect illustration of the fact that we cannot see how far away the stars are: whether they are at a distance of only a dozen meters or hundreds of light years, the image we experience is the same. This holds not only for all the celestial bodies taken together, but also for their mutual distances. As Upgren says: "The moon and a distant star look to be at the same distance, despite the ratio of many billions to one in their true distances" (2002: 121). I also realized that a planetarium is in fact a representation of the archaic world-picture, in which the flat earth is overarched by a hemispherical celestial vault that is cut off by the horizon, and on which the celestial bodies are painted, all at the same distance from us.

Immanuel Kant was one of the last philosophers who studied the stars. Since his time, this has become out of philosophical fashion. The tradition of stargazing, however, is as old as philosophy itself. Diogenes Laertius relates how Thales was looking at the stars while walking, and unfortunately fell into a well that he had not seen because his eyes were directed to the firmament. That event provoked a maidservant's laughter. Thus, the stage was set: whereas a normal person looks down and in front of him to find his way among the everyday obstacles, the philosopher has his eyes fastened upon the starry sky, trying to fathom the universe and man's place within it. For an astronomical interpretation of this anecdote, see Chap. 2. Tradition has it that Anaximander, a disciple of Thales, made a representation of the cosmos of sun, moon, and stars that unfortunately has been lost. Pythagoras could lose himself in the image of the literally unheard harmony of the celestial spheres. In Plato's dialog, the *Phaedo* that contains the conversation at Socrates' death bed, for the first time in history the sphericity of the earth is

alluded to. Aristotle describes his astronomical convictions in his book *On the Heavens*, in which the question why the earth does not fall plays an important role, and in which proofs for the sphericity of the earth are put forward. Aristotle's opinion concerning the structure of the universe has for many centuries molded the picture of the world. In that conception, the earth floats in the center of a spherical universe that consists of a system of concentric spheres of sun, moon, and planets, within the surrounding sphere of the fixed stars.

Even much later, it continued to be a matter of course that a philosopher occupies himself with the structure of the universe and the place of the earth within it. Descartes, for instance, revived an old Greek idea when he imagined the universe as a system of gigantic vortices that produce the movements of the celestial bodies. But since the same Descartes made a clear distinction between thought and matter, the former became increasingly the dominion of philosophy and the latter that of science. It is typical that in the thin paper edition of his *Oeuvres et Lettres*, published in 1953, exactly those parts of *Les Principes de la Philosophie* were omitted that contain his ideas on the construction and origin of the universe and his theories about the universe of vortices.

Immanuel Kant is commonly known as the author of the *Kritik der reinen Vernunft*, a book that has had decisive influence on modern philosophy. Less known is that in the year 1755, when he was 31 years old, he wrote a fascinating anonymous book that bears the title *Allgemeine Naturgeschichte und Theorie des Himmels, oder Versuch von der Verfassung und dem mechanischen Ursprunge des ganzen Weltgebäudes nach Newtonischen Grundsätzen abgehandelt*. In those days, one did not bother about a word more or less in a book title. Unfortunately, the publisher went bankrupt and the book never appeared, but was published only posthumously. A short résumé of the main line of his argumentation appeared in *Der einzig möglichen Beweisgrund zu einer Demonstration des Daseyns Gottes* (1763). According to Kant's famous statement at the end of the *Kritik der praktischen Vernunft*, two things have always filled him with astonishment and awe: the starry sky above him and the moral law within him. The *Allgemeine Naturgeschichte und Theorie des Himmels* is the product of his astonishment and awe of the heavens. In this book, Kant not only speculates about the inhabitants of other planets, but also more in particular he unfolds his theory about the origin of the solar system which later became known as the theory of Kant–Laplace. Moreover, in this book, he is the first to give a correct explanation of the Milky Way and rightly explains the recently discovered nebulous spots as other galaxies.[1] He did all this, probably without ever having looked through a telescope, or perhaps only through the rather primitive instrument of Martin Knutzen, with whom he had studied philosophy and natural sciences.

However, it was Kant himself who eventually set philosophy on the track that led away from speculations about the universe. Since he, with the transcendental turn that was introduced in the *Kritik der reinen Vernunft*, looked for the conditions of the possibility of all knowledge and of metaphysical knowledge in particular, and

[1] For an extensive discussion of Kant's cosmological ideas, see Couprie (1996).

located them in the aprioristic categories that are hidden in the mind, philosophy has never been the same.[2] If philosophers after Kant dared to utter astronomical speculations at all, they went terribly wrong, like Georg Wilhelm Friedrich Hegel, who in 1801, in his *Dissertatio philosophica de orbitis planetarum*, solemnly declared that the relations of the distances between the planets, as settled by the Pythagoreans, rule out the existence of a celestial body between Mars and Jupiter. In the very same year, Giuseppe Piazzi discovered the asteroid Ceres, and in the next year Wilhelm Olbers discovered Pallas and Vesta. Yet 15 years later, in his *Vorlesungen über die Geschichte der Philosophie*, Hegel still stuck to his conviction, although it was already proven false.

Today, we are no longer inclined to associate philosophy, of whatever school of thought, with the study of the universe or with astronomical phenomena. Who thinks, when hearing the names of Husserl, Heidegger, Wittgenstein, Derrida or Rorty, of speculations about the nature and origin of the universe? Philosophers no longer fall into wells because they look up to the infinity of the heavens, but because they are absorbed by the infinity within themselves. Wonder, which has always been the source of philosophy, has for the last three centuries been less and less directed to the infinity outside us and seems to have lost sight of it almost completely. Present-day philosophers rather leave speculations about the universe to theoretical physicists like Stephen Hawking.

Although cosmology and philosophy have definitely separated, cosmological speculations are fundamental to the study of the history of Greek philosophy from Thales to Aristotle. The cosmology of the ancient Greeks initiated what we may call the Western world-picture. Usually, the discovery of the sphericity of the earth is seen as the start of the new world-picture and of modern astronomy at that. An example of this traditional opinion is Burkert: "From the point of view of the history of science, the most important points are the discovery of the spherical shape of the earth, the recognition of the five planets, and the explanation of the apparent irregularities of their courses" (1972: 302). I will argue, however, that the idea that the earth is a sphere, although it certainly was an epoch-making insight, is rather the coping-stone of the building of the new world-picture and was preceded, both temporally and logically, by other far-reaching insights that now perhaps look trivial to us. They can be enumerated thus:

1. The orbits of the celestial bodies do not stop at the horizon
2. The earth floats unsupported in the universe
3. The celestial bodies are at different distances from us

In all probability, we owe these three insights to Anaximander of Miletus (610–547 B.C.), which makes him the founding father of cosmology. The replacement of the archaic world-picture by the new one was not accomplished all at

[2] As regards the so-called schematism of categories, which is the rule of unity that expresses the category, Kant says: "Dieser Schematismus unseres Verstandes (. . .) ist eine verborgene Kunst in den Tiefen der menschlichen Seele" (*Kritik der reinen* Vernunft: A141, B180).

one stroke, and in particular the concept of a flat earth was still vindicated by most, if not all, Presocratic thinkers although they adopted these three insights of Anaximander. This means that a strictly diachronic exposition is not always appropriate, especially when important features of the archaic world-picture are discussed in Part I of this book.

We are so used to our modern world-picture that was introduced by the Greeks that we are hardly able to realize how unique in fact it is. Yet, our Western culture is the only one in which this picture has ever developed. Chapter 8 refers to an intriguing theory that might explain why this is so, as it throws a light on one of Anaximander's most strange-looking conceptions. All other cultures favored one or another variety of the picture of a flat earth, over which the heaven arches as a firmament, a big cupola, onto which the celestial bodies are attached, like in a planetarium. We may express the difference between the two world-pictures as a difference of opinion about space, with which I mean in this context the space of the universe. The Western concept of the universe is, so to speak, three-dimensional; it is a universe with *depth*, in which the celestial bodies are *behind* one another. The little story of the planetarium at the beginning of this Introduction already made clear that the depth of the universe is not something we can *see*. It is something we *know*. We do not *see* the celestial bodies standing behind each other, but we *know* it. The universe in our Western conception is, thus considered, to a high degree artificial, and it differs completely from the archaic conception of the universe as a firmament vaulted over a flat earth. Dreyer expresses the difference between what I call the archaic way of thinking and the new world-picture with these words: "Astronomy may be said to have sprung from Babylon, but cosmology (. . .) dates only from Greece." He does, however, not connect this with Anaximander, of whom he says: "Anaximander (. . .) did not advance much further in his ideas of the construction of the world." And elsewhere: "His cosmical ideas were as primitive as those of Homer" (1953: 1 and 11). The thesis defended in this book is that the opposite is the case. I try to reveal how the unique Western conception has originated, and therewith perhaps contribute to a better understanding of ourselves.

To achieve this, we have to place ourselves, both into the archaic way of thinking, and into the thought of those who developed the new world-picture, and especially into that of Anaximander. Accordingly, we have to suspend our own world-picture, as we have to learn to look "with Anaximander's eyes." This proves to be a difficult task. Time and again the danger of anachronism lies in wait. An anachronism, a pitfall into which many an author on early Greek cosmology has fallen, is nothing but a manifestation of our inability to put ourselves in the position of early thinkers. We encounter several instances of it.

The greatest hero of this book, Anaximander of Miletus, was a contemporary and co-citizen of Thales (Fig. 0.1). Thales is not only known as the most important of the Seven Sages, but also as the first Greek philosopher. Tradition has it that he was occupied with various questions of astronomy which still fall within the framework of the archaic world-picture. One may surmise that he awakened Anaximander's interest. As far as we know, Thales has not laid down his ideas in writing. Anaximander is said to have been the first to write a book in prose. Of this book,

Fig. 0.1 Artist's impression of Anaximander teaching his cosmological conceptions[3]

only a few lines and a few disconnected words have survived. These lines make up one of the most commented texts in the history of philosophy, the famous fragment of Anaximander. That Anaximander's book has been lost is not exceptional since no book of a Presocratic thinker has been preserved. All we know about Anaximander's cosmology or astronomy is handed down by the so-called doxography (a Greek neologism, meaning "the description of opinions"), that is to say from books of authors (the doxographers) who lived centuries after the Presocratics. These doxographers mainly borrowed from the work of Aristotle as well as from a book of his pupil and successor Theophrastus, called Φυσικῶν Δόξαι ("the opinions of the natural philosophers") that also has been lost.

[3] The picture is a detail of the triptych "The Seven Wonders of the World" by Hans Exterkate. As the artist is fond of anachronisms, the Greek letters on the plinth in the right under corner are written in characters that could not have been used in Anaximander's time. The person on the right shows admirable likeness with a well-known Dutch politician. The person left of him suggests with the gesture of his hands that he already thinks that the earth is spherical. The man with the staff points to Miletus on Anaximander's map which is drawn on a column drum with a diameter that is three times its height, as in Anaximander's conception of the earth. The numbers on the stone behind Anaximander indicate the dimensions of the universe according to Anaximander that is drawn on that stone. Anaximander himself makes theatrical gestures and wears pompous garments, as Diogenes Laertius tells (DK 12A8).

In his classic work *Doxographi Graeci*, published in 1879, Hermann Diels, a German scholar, has shown that the doxographers did not borrow immediately from Theophrastus, but made use, directly or indirectly, of a compilation by Aëtius (first century A.D.), who in his turn used a still older work that Diels named *Vetusta Placita* ("the oldest opinions"). Both books have been lost as well, but Aëtius' book was largely reconstructed by Diels. In 1903, the same Hermann Diels published a collection of classical texts from and about the Presocratic philosophers, called *Fragmente der Vorsokratiker*. Later imprints were edited by Walther Kranz, and usually the sixth impression (1952) in three volumes is quoted. The authors distinguish between A: the description of the opinions of the Presocratics, and B: *verbatim* quotations. An indication like "DK 12B1" means: the first literal quotation (=B1) of Anaximander (=no.12) in H. Diels and W. Kranz, *Die Fragmente der Vorsokratiker*. DK 12B1 is the abovementioned fragment that is handed down by Simplicius (sixth century A.D.) but goes back to Theophrastus. The material on Anaximander's astronomy belongs, with the exception of a few disconnected words and phrases, completely to the A-texts. For more elaborate expositions of the sources, see Mansfeld (1999: 22–44), and recently Runia (2008: 27–54).

The common consent is that when studying the Presocratics one has to start with the literal quotations (the B-texts), and draw upon the doxography (the A-texts) only with the utmost caution. This usual approach as regards the doxography has been expressed thus: "It is legitimate to feel complete confidence in our understanding of a Presocratic thinker only when the Aristotelian or Theophrastean interpretation, even if it can be accurately reconstructed, is confirmed by relevant and well-authenticated extracts from the philosopher himself" (Kirk et al. 2009: 6). As such, this is of course a reasonable rule to follow. We have to recognize, however, that the distinction between A- and B-texts is less sharp then one might perhaps expect. It has become an increasing matter of debate whether what Diels regarded as a literal quotation really is one. Gershenson and Greenberg, for instance, are very critical about the value of DK. Regarding the division between A- and B-texts, they say: "We find (...) the extent of the citations it brings as testimony arbitrary" (1964: xxiii). The ancient authors did not yet use our practice of putting quotations between quotation marks, and they did not always quote *verbatim*. The other way round, a paraphrase in an A-text may very well reproduce the thought of a Presocratic philosopher correctly. In the case of Anaximander, strict observing of Kirk's abovementioned rule would mean that we are definitely not able to put forward anything significant about his cosmology. Several scholars actually take this position. A typical representative of those who, more specifically, deny the importance of the doxography for the knowledge of Anaximander's astronomy is Detlev Fehling (1994: 67–70 and 149–157, 1985b: 222).[4] I, on the contrary, am of the opinion that in this case too much skepticism leads nowhere. The next section is meant to endorse a more positive attitude against the doxography on Anaximander.

[4] A critical confrontation with Fehling's ideas in Couprie (2004a: 127–143).

Diogenes Laertius reports that Apollodorus of Athens (second century B.C.) had laid hands on a copy of Anaximander's book, perhaps in the famous library of Alexandria, as Diels and Heidel suppose (DK 12A1(2); Diels 1879: 219, n. 3; Heidel 1921: 261). Recently, this report has won credibility by an interesting discovery in Taormina in Sicily. A fragment of the catalog of the gymnasium has been found there, on which the name of Anaximander can be read (see Fig. 7.1).[5] Since this discovery, we may take for granted "that in the second century B.C. Anaximander's text was still available at a Hellenistic gymnasium on Sicily", as the proud discoverer writes (Blanck 1997a: 507). However, this may be, as already said a bigger part of the doxography goes back to Theophrastus and Aristotle, who were still able to read the works of the Presocratics. One may suppose that Aristotle, Theophrastus, and maybe some others as well, who had before their very eyes the books of Anaximander and the other Presocratics, have rendered truthfully what they considered to be important, albeit that they read them through the spectacles of their own philosophical and astronomical conceptions, and sometimes with the intention to refute those opinions. Where we can check it with other Presocratics of whom relatively many original fragments have been preserved, we may conclude that the doxography, generally speaking and taking for granted the subjective and sometimes hostile coloration, provides a rather true rendering of the thoughts of these philosophers. This does not mean, of course, that any and every doxographical report can simply be trusted. We have to be continually on our guard to avoid the danger of an anachronistic interpretation, both from the doxographers and from ourselves. As concerns the doxography on Anaximander's cosmology in particular, I would like to add as a further condition that it has to allow a coherent and significant interpretation of the celestial phenomena for someone who thinks that the earth is flat. Unfortunately, the case of Thales is different because he has not left a written text. When no writings exist, the doxography has nothing serious to rely upon and has to be handled accordingly with utmost caution.

This book consists of three parts. In Part I, several aspects of the archaic world-picture are discussed. This part also has the purpose to familiarize the reader with looking at the heavens with archaic eyes, which is of help in appreciating the difference between the archaic and the new world-picture. The first chapter describes the main features of the archaic world-picture: the flat earth with the celestial vault. Special attention is paid to the bearers of the celestial vault, who or which prevent it from collapsing. In the second chapter, which is by far the largest, the archaic astronomical instruments are discussed, including new suggestions for how they might have been used. As far as I know, this subject never has been treated so extensively elsewhere. Special attention is paid to the gnomon, a very simple, but multifunctional instrument that it is argued to have stood at the cradle of science. In this context, also an attempt is made of a reconstruction of Anaximander's sundial. As a proponent of the archaic world-picture, Thales of Miletus has two chapters.

[5] Robert Hahn informed me that he looked for it at Taormina in June 2009 and that he was told that it is now in the museum of Giardini-Naxos, also on Sicily.

Chapter 3 explains by what kind of observations and by which mistake he could have "predicted" a solar eclipse, without taking refuge to alleged Mesopotamian wisdom. Chapter 4 is polemical against a recent author who claims that Thales already knew of the sphericity of the earth. Chapter 5 is about the much neglected and misinterpreted issue of the tilting of the celestial axis on the flat earth. It shows the kind of anachronistic misunderstandings which inhere in both ancient and modern expositions of the archaic world-picture. In Chap. 6, Anaximander's first map of the earth is reconstructed and is shown how it was linked with the astronomy of a flat earth.

Part II presents the transition from the archaic to the new world-picture by means of an exposition of Anaximander's opinions. In Chap. 7, a survey is presented of what we know about him. In Chaps. 8–10, Anaximander's "discovery of space" is extensively described and illustrated. These chapters cover the same field as my previous publications on Anaximander's cosmology, but with essential additions and improvements. Anaximander's three aforementioned main insights are exposed in Chap. 8. The issue of depth in the universe is elucidated by a discussion of Anaximander's numbers in Chap. 9. A three-dimensional visualization of his universe is offered in Chap. 10. In Chap. 11, the rather technical question of the interpretation of the translation of an image, used by Anaximander as an explanation of the light of the celestial bodies, is treated. It shows how a wrong translation, proposed by Diels, still haunts the contemporary reading of Anaximander. Chapter 12 is a polemic against a recent author who links Anaximander and the architects of his time.

The seven chapters that make up part III are about the reception of the new world-picture introduced by Anaximander, with special attention to the debate on the shape of the earth. Some of the additional insights that completed the new world-picture, such as the distinction between fixed stars and planets, the order and distances of the celestial bodies, and the explanation of eclipses are discussed in Chap. 13. Chapters 14–16 are devoted to Anaxagoras, who wholeheartedly accepted the new world-picture, but still believed, just like Anaximander himself, in a flat earth. Chapter 14 contains an exposition of his heretical conception of the celestial bodies as fiery stones. In Chap. 15, Anaxagoras' proof of the flatness of the earth is discussed, and Chap. 16 offers a reconstruction of what I think was his attempt to measure the distance and size of the sun, taking for granted that he believed in a flat earth. The development of the idea of the sphericity of the earth in Plato and Aristotle is the subject of the Chaps. 17 and 18. In the final chapter, it is shown how Anaximander's revolutionary destruction of the celestial vault, which was made undone by his successors, especially Aristotle, was only defended by the almost forgotten figure of Heraclides Ponticus. It is also described how he, as a consequence of his conception of the axial rotation of the earth, taught the infinity of the universe.

At this point of the Introduction, it is appropriate to make some remarks on the terminological distinction between astronomy and cosmology. To illustrate the terminological difficulty, let us look at the titles of two standard works that cover practically the same field. In 1970, *Early Greek Astronomy* by D.R. Dicks was

published. The announced second volume of this book never appeared. In 1987, David Furley published his book *The Greek Cosmologists*. It was also intended as the first of two volumes but in this case, too, the second volume has never appeared. Although Furley's book is about cosmology and Dicks' book about astronomy, both works discuss practically the same issues.

Dicks reserves the word "astronomy" for what he calls "scientific astronomy.[6]" He does not define this any further, but it is clear that for Dicks astronomy is the careful and systematic observation of the celestial phenomena. This kind of astronomy reaches its summit in "mathematical astronomy," which is the mathematical description of the movements of the celestial bodies, resulting in predictions of when and where to find a celestial body, and of special phenomena as eclipses. So he may write, for instance: "The development of a mathematical theory to account for the planetary movements belongs to the most sophisticated stages of Greek astronomy" (1970: 26). Dicks contrasts Greek astronomy with cosmology and cosmogony, and particularly with the "cosmological fantasies of the Presocratics" (1970: 7). For him, the word "cosmology" has a pejorative flavor and is associated with wild speculations.

Furley describes the relation between the underlying world-picture and the science of astronomy that is based on it, although he never in so many words identifies world-picture with cosmology. He speaks, for instance, of the "picture of the world" of Homer and Hesiod as the starting-point of Greek astronomy, and of the "spherical picture" or the "spherical model" that marks the end of Greek astronomy (1987: 26–27). Such a world-picture is "a framework for explanations of the natural world"; it is a "cosmological system" (1987: 2 and 3). However, Furley is not always consistent, for instance, when he speaks of "the astronomy of the Pythagoreans," or the "astronomy of the atomists," obviously meaning their world-pictures (1987: 57 n.15, and 145). Dicks, too, describes time and again exactly the same relation between underlying world-picture and (scientific) astronomy, but without using the word "cosmology." For instance: "This quantity of empirical knowledge needed to be fitted into a *general picture of the universe as a whole*, *a celestial model*, in which the earth would occupy a special position as the standpoint of the observer, and the sun, moon, stars, and planets would follow their individual courses *inside the general framework*." And also: "*The general framework or model* that was eventually adopted was the celestial sphere with the spherical earth set immovably at the center" (1970: 60–61, both times my italics). On the other hand, Dicks speaks of the spherical shape of the earth as an *astronomical* discovery and of the spherical shape of the universe as an *astronomical* assumption. The same holds for the question whether the earth is or is not at the center of the universe, when he writes: "In *astronomy* the Pythagoreans also introduced a startling innovation. This was to displace the earth from the central position in the cosmos" (1970: 65, my italics). These are, I would say, ingredients of

[6] In the same sense O. Neugebauer: "We shall here call 'astronomy' only those parts of human interest in celestial phenomena which are amenable to mathematical treatment" (1983: 35).

what he calls the "general picture of the universe," and not results of scientific astronomy.

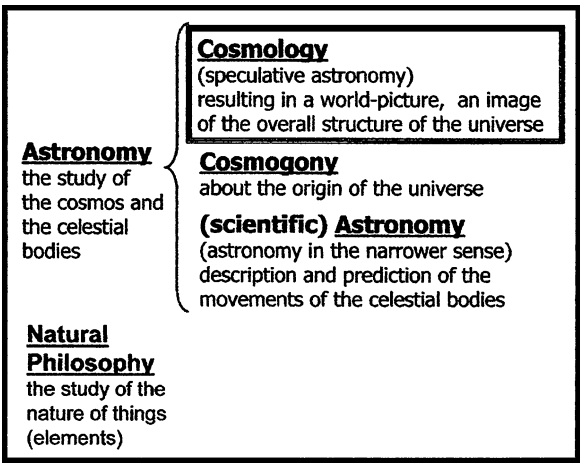
To make matters even more complicated, generally speaking the word "cosmology" is used by many authors to indicate the sum-total of opinions concerning what the Greeks called "nature" (φύσις), for instance, whether all things in the end consist of combinations of the four elements earth, water, air, and fire (and eventually a fifth, the aether), or of atoms. Characteristically, Furley's book bears the subtitle: *The Formation of the Atomic Theory an its Earlier Critics*. I would rather call this "natural philosophy" or "philosophy of nature." Cosmogony, which is about the origin of the cosmos, is also often treated under the head "cosmology." Recently, a thorough book on ancient Greek cosmogony has come available, in which there is hardly a word on cosmology in the sense intended here (Gregory 2007). With a certain amount of overstatement, one might say that my book starts where Gregory's stops. Important chapters of Charles Kahn's *Anaximander and the Origins of Greek Cosmology* are concerned with Anaximander's fragment, with the elements (philosophy of nature), and with the *apeiron*, out of which everything originates (cosmogony), as he acknowledges himself (1994: 7–8). Strictly speaking, only the pages 46–63 (the doxography) and 75–98 of chapter I cover the field of Anaximander's cosmology.

I prefer to use "astronomy" as the general term for the study of the cosmos and the celestial phenomena, and to distinguish within it between "speculative astronomy" or "cosmology," which is concerned with forming a general picture of the overall structure of the universe, "cosmogony," which is the study of the origin of the cosmos, and "descriptive astronomy" or "scientific astronomy" (or "astronomy in the narrower sense"), which is concerned with providing as accurate as possible a description (and thus prediction) of the movements of the celestial bodies. The relation between cosmology and astronomy in the narrower sense can be described more precisely. Cosmology results in a picture of the world, within which astronomy as the description of celestial phenomena becomes possible. Such a world-picture delivers the framework for the development of (scientific) astronomy.

This book is about cosmology in the sense meant above. This means that not only scientific astronomy, but also cosmogony and natural philosophy fall outside its scope. Yet, now and then some attention is paid to these three subjects, but only in so far as it is clarifying for the main theme. Thus, for instance, chapters are dedicated to archaic astronomy and the oldest astronomical instruments. By "archaic astronomy" is meant the observation and description of celestial phenomena as they appear to an observer who thinks that the earth is flat and that the celestial bodies are all at the same firmament. The study of archaic astronomy is important when we want to understand the kind of revolution Anaximander initiated in the way people imagine heaven and earth. The distinctions made above are visualized in Table 0.1.

The Presocratic Greeks, but Plato and Aristotle as well, were concerned with cosmological speculations, rather than with astronomical observations. As Von Fritz remarks: "Die Beobachtung der Himmelserscheinungen, die bei den Babyloniern mit solcher Konsequenz weiter getrieben worden ist, spielt in der frühen

Table 0.1 Terminological distinctions



kosmologischen Astronomie der Griechen (. . .) eine untergeordnete Rolle" (1971: 151). Anaximander's cosmology was not descriptive astronomy, but *speculative* astronomy. Speculative astronomy or cosmology is the product of what I would call "creative imagination." Creative imagination is quite something other than fantasy or the "wilder flights of fancy" of which Dicks accuses the Presocratics (1966: 39). Fantasy creates things or images that do not help in understanding the celestial phenomena, but rather adapts them to a preconceived idea. Creative imagination, on the other hand, puts known empirical data into a new interpretative arrangement that helps us to understand the phenomena. Also the so-called discovery of the sphericity of the earth by Plato and Aristotle, as well as Anaxagoras' interpretation of the celestial bodies as fiery stones, belong to speculative astronomy or cosmology.

To illustrate the difference between fantasy and creative imagination one might say that the division of the celestial vault into starry constellations is a product of fantasy, whereas Kant's hypothesis of the band of light which is called the Milky Way as a gigantic disk of stars is the product of the power of creative imagination. Or with perhaps a rather tricky example, on which more in Chap. 13: the Pythagorean conception of the universe is a product of fantasy, based on the magic of numbers and other preconceived a priori or metaphysical ideas that as such have nothing to do with astronomy or cosmology. In their vision, for instance, the distances of the celestial bodies have to be derived from the musical harmonies. The earth had to be displaced from its central position because only the noble fire is worth to occupy that most honorable place. The counter-earth had to be invented because there must be ten celestial bodies, for ten is the sacred number. The same criticism was expressed by Aristotle when he said that the Pythagoreans are "not seeking accounts and reasons to explain the phenomena, but forcing the phenomena and trying to fit them into arguments and opinions of their own" (*On the Heavens* 293a25). Heraclitus already called Pythagoras a clever charlatan with fraudulent wisdom (DK 22B129, see also DK 22B40). I for one do not understand why Dicks,

who treats the Ionian speculations with so much contempt, can talk about the Pythagoreans with great awe. A few examples, out of many: "The great novelty that the Pythagoreans introduced into Greek philosophical thought as a whole was their insistence on the concept of number"; and "In astronomy the Pythagoreans also introduced a startling innovation. This was to displace the earth from the central position in the cosmos" (1970: 64 and 65). The Pythagorean way of using numbers has nothing at all to do with the mathematical astronomy which Dicks so admires, and the position of the earth in their system was not an astronomical innovation but a metaphysical makeshift.

Anaximander's cosmological speculations, on the contrary, were not images of his fantasy, but they were meant to yield a better understanding of the celestial phenomena as they are observed. They created a completely new paradigm, a new world-picture within which empirical data got another meaning than they had before in the archaic world-picture. Sometimes, Dicks himself seems to understand this. See, for instance, his adequate formulation: "The attempt to look at the earth from the outside, as it were, and to consider its position in relation to the cosmos as a whole and in particular to the other celestial objects (...). This represents *a new departure in astronomical speculation*, though not in factual astronomical knowledge" (1970: 44, my italics).