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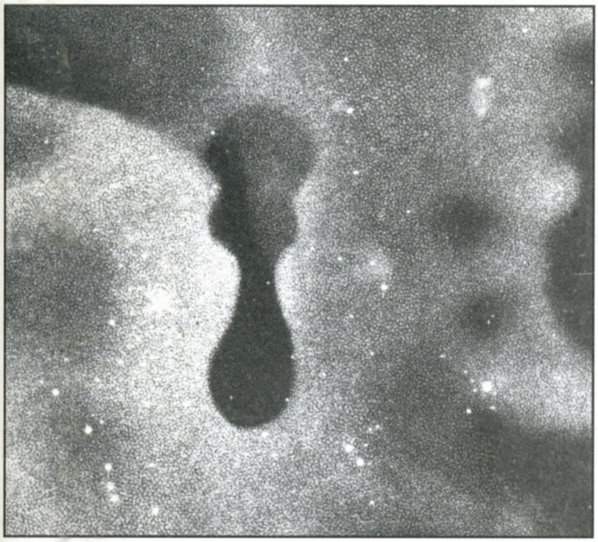

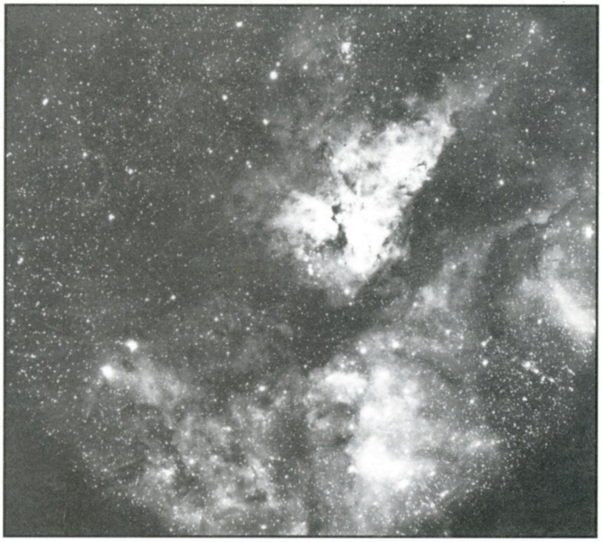

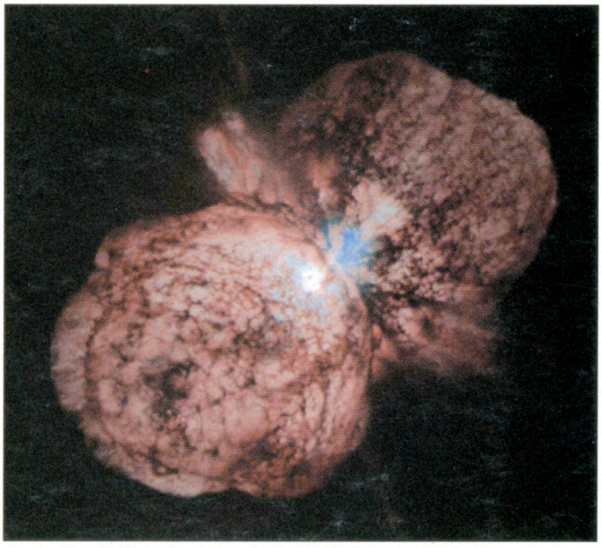

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A century of drivers of astronomical progress

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Abstract
The main focus of the session of papers reported here was on the interaction between new technology and astronomical discoveries in the 20th century in the areas of optical, radio, X-ray, and computational astronomy. The advent of new ideas and new people (and kinds of people) in the discipline have also been major drivers of progress. Some of these are discussed briefly here, along with a few technological items from other parts of astronomy. It is intended that the four main presentations appear in later issues of JAH^2.

Key words: steady state cosmology, gamma ray astronomy, twentieth century astrophysics, spectroscopy, particle physics

1 INTRODUCTION

The American Physical Society Centennial session on technological drivers of astronomical progress had its origins in the realization by Astrophysics Division chair (Trevor Weekes) and chair-elect (Virginia Trimble) that the American Astronomical Society would complete its first century (DeVorkin, 1999) in the same year and in the feeling that the sister societies ought to celebrate together somehow. (Indeed the AAS centennial meeting also had an APS centenary talk by Harry Lustig on its programme.) Within the allotted half day, one could not possibly explore all the ways astronomy has changed in the 20th century. Hence the decision was made to focus on technological drivers, relegating issues of theory and person-power to a brief introduction, of which this is the written version.

The four main talks dealt with optical, including infrared and ultraviolet, astronomy (Judith G. Cohen, California Institute of Technology), radio astronomy (Kenneth Kellermann, National Radio Astronomy Observatory), X-ray astronomy (Herbert Gursky, Naval Research Laboratory), and computational astronomy (David Arnett, University of Arizona). All four have made major contributions to the widgetry and its use in their own territories. Some additional wavebands and non-electromagnetic astronomy were also relegated to the outer darkness of the introduction.

2 STEADY-STATE COSMOLOGY: THE CLASSIC EXAMPLE

An astronomer asked to illustrate the concept that a new idea does not have to be right to make important contributions to a field will invariably come up with the example of steady-state cosmology. First enunciated in 1948 as an alternative to a general-relativistic evolutionary (big bang) universe, it remained a viable, though never enormously popular, model for a decade or more. During this period, a great deal of work in observational cosmology, at both radio and optical wavelengths, was to some extent motivated by the desire to 'test' (that is, disprove) steady state, and by the mid 1960s, one could describe a test (like angular diameters or apparent magnitudes of galaxies vs. redshift) as not very powerful by saying that "It doesn't even disprove steady state."

The three propounders, Hermann Bondi, Thomas Gold, and Fred Hoyle were 29, 27, and 32 years old when their initial steady-state papers were written (Bondi and Gold, 1948; Hoyle, 1948) and had recently completed several years of war-related radar work together. All had shown early promise in mathematics and science in general, though none had intended to become an astronomer at the time he arrived in Cambridge. All were to a certain extent outsiders in Cambridge as well as cosmology (Bondi and Gold being Austrian-born Jews, and Hoyle firmly maintaining his strong Yorkshire accent throughout). Hoyle had published several astronomical papers (but none on cosmology) during the war years, and all three brought relatively-unsullied minds to the issues of whether creation might be amenable to scientific study and, if so, whether this might improve our understanding of the large-scale behaviour of the universe in other ways, for instance in accounting for objects, including Earth, with ages larger than the reciprocal of the Hubble constant. Kragh (1996) includes a number of details about their education and early work as well as the definitive study of the subsequent fate of the steady-state idea and its spin-offs.

There are undoubtedly a great many lessons to be learned from the history of the steady-state cosmological model and its continuing defence, in modified form, by a handful of early supporters, but they do not undermine the point that a wrong idea can be enormously powerful in driving scientific research.

Another earlier and less well-known example is the giant-and-dwarf theory of stellar evolution, put forward by Henry Norris Russell (Russell 1913; Russell *et al.*, 1926), which guided, or sometimes misguided, stellar astronomy for more than a decade, until nuclear reactions came into their own.

3 OTHER NEW IDEAS AND PEOPLE

Astronomy has changed large fractions of its spots a number of times; none of the changes was wholly driven from within. The last quarter of the 19th century was marked by increasing friction between proponents of 'the old astronomy' (meaning celestial mechanics and astrometry) and 'the new astronomy' (meaning spectroscopy and astrophysics). The core idea, that absorption features in the solar spectrum could be attributed to sodium, iron, and other specific elements known on Earth, came from Robert Bunsen (a chemist) and Gustav Kirchhoff (a physicist) in 1859. In the half century before all the shouting was over, astrophysics and solar physics had recruited many of their most vigorous practitioners from outside traditional astronomy (Hufbauer, 1991; Lankford, 1997), a new journal was needed (Abt, 1999), and the American community nearly failed to form a single professional society before compromising as the Astronomical and Astrophysical Society of America (Osterbrock, 1999)

That the source of energy for the Sun and stars was a problem was recognized by Eddington, Russell, and others within the astronomical community early in the 20th century when it became clear that Earth was very much older than the potential lifetime of the Sun if contraction were its only resource. Since the answer turned out to be nuclear (once called 'subatomic') energy, it is not surprising that much of it came from people whose background was in nuclear physics. Hans Bethe is, of course, the most famous example, at least to American readers (Bethe, 1939). Also frequently cited (especially in Europe) is the work by von Weizsäcker (1937), whose most influential previous paper was a semi-empirical formula for the mass or binding energy of nuclei (von Weizsäcker 1935). Least well known is the contribution of Atkinson and Houtermans (1929) who considered proton captures (interspersed with electrons, since the neutron was not yet part of the available inventory) that might either build up heavy elements from light ones or add up to helium nuclei that would drop off in a recycling, catalytic process. Atkinson was recruited to the American astronomical community, remaining an AAS member until his death in the mid 1980s, after a long career at Indiana University.

The most recent interaction between standard astronomy and physics has been in the area of particle physics and cosmology, and whether you call it a partnership or an invasion is a matter of taste. Curiously, the 'invasion' point of view is taken by the last defenders of a quasi-steady-state universe (Hoyle *et al.*, 1997). They draw an analogy between the 'fragmentation' of effort in observational and theoretical cosmology caused by the QSS model and a supposedly similar fragmentation caused by particle physics providing new problems (like monopoles) and proposing new solutions to them (like inflation). They seem to have forgotten how unpopular spectroscopy was with many astronomers a century ago, saying, "If the invasion had the precision and the certainty of earlier invasions of astrophysics by atomic theory and nuclear physics, the consequences would obviously be positive. However ... "

Other important parts of 20th century astronomy have also been new ideas in their time. Two that can be traced directly to young astronomers and that were initially fairly unpopular with the older generation were (1) star formation as an on-going process as proposed by Martin Schwarzschild and Lyman Spitzer, when they were brand new assistant professors at Princeton (Trimble, 1997) and (2) evolution in the luminosity of elliptical galaxies as an important and calculable process, as presented in the thesis of Beatrice M Tinsley, with opposition coming from cosmologists who wanted the galaxies to be standard candles and metre sticks so that observations of them could be used to rule out steady state. Conversely, as it were, opposition to the extreme energetics and violence of quasars and related objects that were implied by radio and X-ray data (if the sources were at the distances indicated by their redshifts) came largely from the lingering steady-state sympathizers.

4 THE PEOPLE-TECHNOLOGY CONNECTION

That radio astronomy grew out of the dishes of World War II radar installations is well known (Sullivan, 1984). The dishes and yagi stacks sometimes came with people attached, and (especially in England and Australia) the founders of the field were radar experts, often without advanced university degrees. A probably apocryphal story has E G (Taffy) Bowen (the dean of post-war Australian scientific research) saying to John Bolton (one of the founders of radio astronomy there), "That's an S-band radar dish. You can have it, if you can figure out what to do with it. That's Mr X Y. You can have him, if you can figure out what to do with him." Dutch radio astronomy was sponsored by a traditional astronomer, Jan Oort; the Russian programme by theorists (Josef Shklovsky first and foremost); and Americans were left at the starting gate for some years. Decades down stream, Arno Penzias and Robert Wilson, the Bell Telephone Laboratories discoverers of the cosmic microwave background radiation were not primarily astronomers either.

Moving away from electromagnetic radiation, we find neutrino astronomy, with at least two sources to its credit. The pioneering detector for solar neutrinos (the famous chlorine experiment at Homestake Mines in Lead, South Dakota) was developed by a chemist, Ray Davis, Jr.; and the experiments that saw neutrinos from supernova 1987A were main-stream particle physics installations. originally intended to look for decaying protons. Indeed the word 'experiment' rather than observation, telescope, or observatory is a signature of 'not invented here' (where here is astronomy). The developers of LIGO (again mostly physicists, and funded from physics pockets) seem to have caught on to the distinction, since the "O" in the acronym stands for 'observatory.' The pioneer of the field, Joseph Weber, had a background in electronic counter-measures and microwave spectroscopy (as well, interestingly, as in amateur astronomy) and has always called his widgets 'antennas'.

5 THE CURIOUS INCIDENT OF THE GAMMA RAYS IN THE SKY

The founder of optical astronomy was presumably a Zinjanthropus named Og. The infrared and ultraviolet regions opened gradually out from the visible, using slightly modified photographic plates and looking where Herschel and Ritter had shown in 1800-01 that there was solar flux.

The first astronomical sources of radio waves were a complete surprise (Sullivan, 1984; Christiansen, 1963) and eventually required a complete new radiation mechanism (synchrotron) for their explication. X-rays from the Sun had been predicted at more or less the level seen (Friedman, 1962), but the rocket flight that found Sco X-1 (Giacconi *et al.*, 1962) had to be sold as a search for X-ray fluorescence from the Moon (a phenomenon eventually detected by ROSAT about 30 years later). Notice also that many of the first X-ray astronomy papers appeared in physics journals, a marker of new people in the field as well as new technology.

Extra-solar gamma-ray astronomy, in contrast, was a subject with a considerable literature but no photons for nearly a decade. This period shows all the signatures of new ideas and new kinds of people, as well as new widgets. The most optimistic theoretical predictions of gamma ray fluxes came from the steady-state camp, based upon the beliefs that radio-galaxies were powered by annihilation when a galaxy met an anti-galaxy (Burbidge and Hoyle, 1956), and that supernova light-curves reflected the decay of Californium-254 (Burbidge *et al.*, 1957). Both active galaxies and the Crab Nebula were among the first dozen gamma-ray sources, but at flux levels smaller than these predictions by factors of 100 to 1000.

Two major early theory papers appeared in *Nuovo Cimento* (Morrison, 1958) and *Progress of Theoretical Physics* (Hayakawa *et al.*, 1958), with authors from the cosmic ray and nuclear physics communities. And when Alessandro Bracessi flew the first balloon experiment (note the word!) motivated by these predictions, the detector was a nuclear emulsion stack that he had originally meant to use for collecting cosmic ray tracks, and the results were published in *Nuovo Cimento* (Bracessi *et al.*, 1960). The next few upper limits, false alarms, and results of modest statistical significance also appeared in *Physical Review Letters* and other places one does not necessarily expect to find observational astronomy (Cline, 1961; Kraushaar and Clark, 1962; Arnold *et al.*, 1962; Duthie, 1966).

Only in 1968, with the first two positive reports that are still generally credited and cited (Clark *et al.*, (1968) on the galactic background and Haymes *et al.*, (1968) on the Crab) does the literature break into the *Astrophysical Journal*. This is also the time frame in which the X-, gamma-, and cosmic-ray physicists and astronomers found a home in the American Astronomical Society, via the formation of a High Energy Astrophysics Division.

Just in case the title of this section rang an incomplete bell, the allusion is to Sherlock Holmes' "the curious incident of the dog in the night-time." The dog did nothing in the night-time, and for a while it looked as if there were no gamma rays in the sky.

6 ACKNOWLEDGEMENTS

I am deeply indebted to Barbara Welther of the Center for Astrophysics (Harvard) for chairing the astrophysics and technology session and delivering the talk on the basis of my totally-inadequate notes, when circumstances prevented my getting to Atlanta for the APS centenary meeting.

7 REFERENCES

Abt, H.A., 1999. The American Astronomical Society and *The Astrophysical Journal*. In D.H. DeVorkin (Ed.), *The American Astronomical Society's First Century*, American Astronomical Society, Washington DC, pp. 176-184.

Arnold, J., Metzger, A.E. and Van Dilla, M.A., 1962. Gamma Rays in Space, Ranger 3. *Journal of Geophysical Research*, **67**:4878-4880.

Atkinson, R. d'E. and Houtermans, F.G., 1929. Building Up of the Elements in Stars. *Zeitschrift für Physik*, **54**(9-10):656-665.

Bethe, H.A., 1939. Energy Production in Stars. *Physical Review*, **55**:434-456.

Bondi, H. and Gold, T., 1948. The Steady-State Theory of the Expanding Universe. *Monthly Notices of the Royal Astronomical Society*, **108**(3):252-270.

Bracessi, A., Ceccarelli, M. and Salanan, G., 1960. Search for γ Radiation from the Cygnus A Radiosource. *Nuovo Cimento*, **17**(5):691-694.

Burbidge, G.R. and Hoyle, F., 1956. Matter and Anti-matter. *Nuovo Cimento*, **4**(3):558-564.

Burbidge, E.M., Burbidge, G.R., Fowler, W.A. and Hoyle, F., 1957. Synthesis of the Elements in Stars. *Reviews of Modern Physics*, **29**(4):547-650.

Christiansen, W.N., 1963. Radio Telescopes. *Annual Reviews of Astronomy and Astrophysics*, **1**:1-18.

Clark, G.W., Garmine, G.P. and Kraushaar, W.L., 1968. Observation of high-energy cosmic gamma rays. *Astrophysical Journal*, **153**:L203-L207.

Cline, T.L., 1961. Search for High-Energy Cosmic Rays. *Physical Review Letters*, **7**(3):109-112.

DeVorkin, D.H. (Ed.), 1999. *The American Astronomical Society's First Century*, American Astronomical Society, Washington DC.

Duthie, J.G., Cobb, R. and Stewart, J., 1966. Evidence for a Source of Primary Gamma Rays. *Physical Review Letters*, **17**(5):263-267.

Friedman, H., 1962. Solar Observations obtained from Vertical Sounding. *Reports on Progress in Physics* **25**:163-217.

Giacconi, R., Gursky, H., Paolini, F.R. and Rossi, B.B., 1962. Evidence for X-Rays from Sources Outside the Solar System. *Physical Review Letters*, **9**(11):439-443.

Hayakawa, S., Ito, K. and Terashima, Y., 1958. Origin of Cosmic Rays. *Progress in Theoretical Physics Supplement*, **6**:1-92.

Haymes, R.C., Ellis, D.V., Fishman, G.J., Kurfess, J.D. and Tucker, W.H., 1968. Observation of gamma radiation from the Crab Nebula. *Astrophysical Journal*, **151**:L9-L14.

Hoyle, F, 1948., A New Model for the Expanding Universe. *Monthly Notices of the Royal Astronomical Society*, **108**(5):372-382.

Hoyle, F., Burbidge, G.R. and Narlikar, J., 1997. On the Hubble constant and the cosmological constant. *Monthly Notices of the Royal Astronomical Society*, **286**:173-182.

Hufbauer, K., 1991. *Exploring the Sun*. Johns Hopkins University Press., Baltimore.

Kragh, H., 1996. *Cosmology and Controversy*, Princeton University Press, Princeton.

Kraushaar, W.L. and Clark, G.W., 1962. Search for Primary Cosmic Gamma Rays with the Satellite Explorer XI. *Physical Review Letters*, **8**(3):106-109.

Lankford, J., 1997. *American Astronomy, Community, Careers, and Power 1859-1940*. University of Chicago Press, Chicago.

Morrison, P., 1958. On Gamma-Ray Astronomy. *Nuovo Cimento*, **7**(6):858-865.

Osterbrock, D.E., 1999. AAS Meetings Before There Was an AAS: The Pre-History of the Society. In D.H. DeVorkin (Ed.), *The American Astronomical Society's First Century*, American Astronomical Society, Washington DC, pp. 3-19.

Russell, H.N., 1913. "Giant" and "Dwarf" Stars, *The Observatory*, **36**(464):324-329.

Russell, H.N, Dugan, R.S. and Stewart, J.Q., 1926. *Astronomy*, Ginn & Co. Boston, sect. 973-978

Sullivan, W.T. (Ed.), 1984. *The Early Years of Radio Astronomy*. Cambridge University Press, Cambridge.

Trimble, V., 1997. The Fourth Day of Creation: The Search for a History of Star Formation. In S.S. Holt and L.G. Mundy, (Eds.) *Starformation Near and Far*. AIP Conference Series 393, 15-37.

von Weizsäcker, C.F., 1935. Theory of Nuclear Masses. *Zeitschrift für Physik*, **96**(7-8):431-458.

von Weizsäcker, C.F., 1937. Nuclear Transformations in the Interior of Stars. *Physikalsche Zeitschrift*, **38**:176-191.

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Plato's place in the history of Greek astronomy: restoring *both* history *and* science to the history of science

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I am the owner of the sphere,
Of the seven stars and the solar year,
Of Caesar's hand and Plato's brain,
Of Lord Christ's heart and Shakespeare's strain.
Ralph Waldo Emerson
May-Day and Other Pieces. History

Abstract
The history of ancient Greek geometrical astronomy often is written as a mathematical *tour de force* rather than history, with technical details of quantitative geometrical constructions the centre of attention, studied as if they were independent of the culture within which they flourished. Much of science is eliminated as well in focusing only on observations and the mathematical consequences of an initial hypothesis about the fundamental character of the movements of the planets. Plato with his philosophical vision exemplifies the influence of humanistic concerns in ancient science more broadly conceived. This study casts new light on both the ruling paradigm of Greek geometrical astronomy and the long-standing debate over whether ancient Greek astronomers were instrumentalists or realists, and also opens to view a deeper and richer understanding of science.

Key words: *Plato, Eudoxus, Ptolemy, Greek astronomy instrumentalism, realism*

1 INTRODUCTION

An intellectual fault line cleaves the history of science. On one side are internalists knowledgable about the effect of observation and the consequent advance of scientific theory, but dismissive of possible societal factors. Across the chasm, externalists ignore the science for the history.

No where is the rift between internalists and externalists greater than in the history of ancient Greek astronomy. The late, great, Otto Neugebauer, for whom the history of ancient astronomy became a mathematical *tour de force*, saw:

> ... no need for considering Greek philosophy as an early stage in the development of science ... Astronomy had at its basis simple observable facts, and elementary mathematics sufficed to lead to significant results, leaving only little room for philosophical doctrines. (Neugebauer, 1975:*ii*, 572)

In his magisterial history of ancient mathematical astronomy, Neugebauer chose to deal:

> ... neither with early cosmogony nor with philosophy, but exclusively with mathematical astronomy, i.e. with the numerical, geometrical, and graphical methods devised to control the mechanism of the planetary system. (Neugebauer, 1975:*i*, 1)

This is all he considered worthy of his effort:

> In many years of study I have tried to become familiar with the ancient methods of mathematical astronomy, to realize their problems, and to understand their

> interconnections and development. ... I have tried to come as close as possible to the astronomical problems themselves without hiding my ignorantia behind the smoke-screen of sociological, biographical, and bibliographical irrelevancies. (Neugebauer, 1975:*i*, 7)

Working out the technical details in quantitative geometrical constructions was central to Neugebauer's endeavour, to the exclusion of almost every other issue imaginable.

Neugebauer also refrained from comparisons of ancient with modern numerical data; rather than explain how 'good' or 'bad' ancient astronomy was, he tried instead "to describe what seemed to be the essential problems and the methods developed toward their solution" (Neugebauer, 1975:*i*, 2). The goal of studying science in its historical technical context could scarcely be articulated better. Enforced, Neugebauer's strictures would preclude much intellectual pollution of scholarly literature.

Nonetheless, it seems worth the risk to attempt to transcend Neugebauer's sharply-focused vision of both science and its history and to trace the influence of broad humanistic concerns in the work of ancient scientists, if indeed such concerns can be shown to exist. The history of science encompasses both internalist and externalist approaches, and is the richer for it.

Potential rewards from an expanded historical study of ancient Greek astronomy are considerable. First, the astronomy might be more fully understood as not merely a continuation of Mesopotamian science, but rather a new creation following from speculative theories and inseparable from Greek philosophy (Hetherington, 1997a; Høyrup, 1996; Kahn, 1991); the history could be restored to the history of science. Furthermore, much of the science could be regained as well. Neugebauer (1946) admitted only mathematical computation together with empirical observation as the necessary characteristics of science. The ancient activity he so ably recovered is little more than a set of mechanical procedures, albeit comprehending much observational data, but with scarcely more theoretical content than recipes in a cookbook. Narrow, mathematically-based activity, with no role for speculative hypotheses of a theoretical nature, is not all of science, nor even the heart of science.

Neugebauer (1969:152), emphasizing exact over theoretical science, explicitly chose to exclude Plato from his version of history. *Contra* Neugebauer, the following study focuses on Plato and his philosophical vision of reality. New light is cast upon both the ruling paradigm of Greek geometrical astronomy and the long-standing debate over whether ancient Greek astronomers were instrumentalists or realists. Furthermore, a deeper understanding of science emerges.

Though ambitious to expand the boundaries of what legitimately constitutes the history of ancient astronomy, this study nevertheless remains very limited in scope. It does not, for example, explore changes in Greek philosophy of nature from Plato onward and corresponding changes in Greek astronomy, as will be necessary for a more nuanced history, nor are other essential elements of cultural context included in this initial examination limited largely to Platonic philosophy.

2 UNIFORM MOTION AND THE PLAN OF THE WORLD

Little in Plato's surviving writings explicitly links him to the Greek tradition of representing the motions of the planets with a combination of uniform circular motions. His thoughts on the structure of the universe appear in the *Timaeus*. Some scholars believe that Plato intended his cosmology as a literally-true account of the cosmos (even including the prefatory narrative on an ancient maritime empire of Atlantis overwhelmed by a sudden catastrophe and disappearing into the sea). Others, including Plato's immediate disciples, have favoured a metaphorical reading (Knorr, 1993).

The object of scientific study was not a description of the world of the senses, wrote Plato, but discovery of the plan of the Creator for the world. Confusion and disorder were bad; therefore the Divinity fabricated an orderly and hence beautiful universe. Anything moving with confusion and disorder was evil, and to be reduced to order:

> And for shape he [the Divinity] gave it [the world] that which is fitting and akin to its nature ... he turned its shape rounded and spherical ... a figure the most perfect and uniform of all; for he judged uniformity to be immeasurably better than its opposite ... he assigned to it the motion proper to its bodily form, namely that one ... which above all belongs to reason and intelligence; accordingly, he caused it to turn about uniformly in the same place and within its own limits and made it revolve round and round ... he made it smooth and uniform ... one world alone, round and revolving in a circle ... (*Timaeus*, 33b-34b)

The planets moved in circular orbits, with the circles apparently varying in size. The orbits also revolved with a spiral motion that produced the wandering (retrograde) motion of the planets:

> ... Sun and Moon and five other stars [planets] – 'wanderers', as they are called – were made ... in seven circuits seven bodies: the Moon in the circle nearest the Earth; the Sun in the second above the earth; the Morning Star [Venus] and the one called sacred to Hermes [Mercury] in circles revolving so as, in point of speed, to run their race with the Sun [seen always at but a small angle from the Sun], but possessing the power contrary to his; whereby the Sun and the star of Hermes and the Morning Star alike overtake and are overtaken by one another [retrograde motion] ... revolve by way of the Different, which was aslant, crossing the movement of the Same and subject to it; some moving in greater circles, some in lesser; those in the lesser circles moving faster, those in the greater more slowly....
>
> So, by reason of the movement of the Same, those which revolve most quickly appeared to be overtaken by the slower, though really overtaking them. For the movement of the Same, which gives all their circles a spiral twist because they have two distinct forward motions in opposite senses, made the body which departs most slowly from itself – the swiftest of all movements – appear as keeping pace with it most closely....
>
> To describe the evolutions in the dance of these same gods, their juxtapositions, the counter-revolutions [retrograde motions] of their circles relatively to one another, and their advances [increase in speed following retrogradation]; to tell which of the gods come into line with one another at their conjunctions, and which in opposition, and in what order they pass in front of [transit] or behind one another [occultation], and at what periods of time they are severally hidden from our sight [eclipse] and again reappearing send to men who cannot calculate panic fears and signs of things to come – to describe all this without visible models of these same would be labour spent in vain. So this much shall suffice on this head, and here let our account of the nature of the visible and generated gods come to an end. (*Timaeus*, 38c-40d)

Plato had a good sense of the qualitative problem posed by planetary motions, but begged off presenting anything approaching a detailed, quantitative solution. Nonetheless, later attributions to Plato of the paradigm of Greek geometrical astronomy – to save the appearances with uniform circular motions – are not incompatible with what Plato wrote in the *Timaeus*.

3 SIMPLICIUS' COMMENTARY

Plato's place in the history of Greek geometrical astronomy traditionally has followed from Simplicius' sixth-century AD commentary on Aristotle's *De caelo*. The chain of transmission between Plato and Simplicius is uncertain, and not without justification have some scholars doubted Simplicius' authority and questioned Plato's putative role in the development of Greek planetary astronomy (Goldstein and Bowen, 1983). Perhaps it was only later commentators who saw adumbrations of later astronomical models in Plato's earlier cosmological accounts (Knorr, 1990). Passages from the *Timaeus*, however, leave little doubt of Plato's intellectual infatuation with circular motion, and there are resonances between Plato's philosophical values and Simplicius' comments on astronomy.

Plato taught his ideas to pupils at the Academy, which he founded in Athens in about 380 BC. Eudoxus, the greatest genius in mathematics and astronomy of his time, may have attended Plato's lectures at the Academy, and certainly he was familiar with Plato's ideas. Upon Eudoxus' report of what Plato said a string of statements followed. Eudoxus' report is lost; however, it was summarized by Eudemus (around 350 BC; a pupil of Aristotle) in his own *History of Astronomy*. This work, too, is lost; but it was commented upon by Sosigenes in the second century AD (not the Sosigenes who lived in the time of Julius Caesar and advised Caesar on the calendar reform of 45 BC). Sosigenes' work also is lost; it was used, however, by Simplicius, with whom the string of lost but summarized works ends, in sixth-century Athens. Simplicius wrote:

> Plato lays down the principle that the heavenly bodies' motion is circular, uniform, and constantly regular. Thereupon he sets the mathematicians the following problem: what circular motions, uniform and perfectly regular, are to be admitted as hypotheses so that it might be possible to save the appearances presented by the planets? (Duhem, 1969:5)

Continuing, Simplicius explained:

> The curious problem of astronomers is the following: first, they provide themselves with certain hypotheses ... Starting from such hypotheses, astronomers then try to show that all the heavenly bodies have a circular and uniform motion, that the irregularities which become manifest when we observe these bodies ... are but appearances and not realities. (Duhem, 1969:23)

4 PLATO'S PHILOSOPHY OF REALITY

As Simplicius noted, astronomers pursuing the problem set by Plato deemed real not the irregularities observed in planetary motions – the actual appearances – but instead believed that reality consisted of uniform circular motions. However absurd such a stance on first glance may seem to modern-day empiricists, it is readily understandable in the context of Plato's philosophy.

For Plato, the only real world existed in the mind. This concept is nicely illustrated in a letter of Plato's, albeit a letter whose authenticity is not beyond question (Morrow, 1962:3-16; Friedlander, 1969:236-245). Plato wrote:

> There is something called a circle ... 'The figure whose extremities are everywhere equally distant from its centre' is the definition of precisely that to which the names 'round', 'circumference', and 'circle' apply ... what we draw or rub out, what is turned or destroyed; but the circle itself to which they all refer remains unaffected, because it is different from them. (*Epistles*, VII:342a-344a)

The circle scratched on a slate is not a real circle, no matter how skilled the draftsman. The drawn circle is an imperfect representation in the visible world of experience of a perfect circle. The perfect circle exists only in the mind, only in the world of thought.

Plato's emphasis on idea over sense experience recalls the famous meeting between Goethe and Schiller in Italy on 1794 July 14. Goethe created with a few strokes of his pen a symbolic plant, or *Urpflanze*. Schiller responded: "That is not experience, that is an Idea." Goethe replied: "That's a strange business, that I have ideas without knowing it, and *that I even see them with my own eyes*." As had Plato, Goethe now saw with the eyes of his soul (Friedlander, 1969:20-21).

Plato argued that reality exists not in the visible world but rather in the world of ideas. The implications of this argument for the study of astronomy are presented in Plato's *The Republic*. Here Plato took up the question of how society might be shaped to bring out the best in people. He asked what justice is and how it is to be attained, and concluded that a philosopher-king is needed to bring the ideal state into existence. How such a person might be educated was one of Plato's concerns. In this context, the nature of reality and the study of astronomy were introduced.

In a parable to illustrate the degrees to which man may be enlightened, Plato presented his famous allegory of the cave. He imagined men chained from childhood in a cave, so shackled that they must sit still, looking in only one direction. A fire behind them casts shadows of objects upon the cave wall in front of them. In the absence of any other experience, the prisoners accept the shadows as reality. Furthermore, the objects casting the shadows are not real men, but statues of men. Plato explained that the prison of the cave corresponds to the part of the world revealed by the sense of sight. Escape from the cave corresponds to the use of intelligence to reach the real world of knowledge (*The Republic*, VII, 514a-517a).

The next issue in *The Republic* is how to bring people to a state of enlightenment: how to convert the soul. Education is the answer. Education will enable the soul to look in the right direction and learn the truth. The forms of study leading the soul away from the world of change and to the world of reality are the sciences. They deal with certain knowledge and immutable truths. Arithmetic, geometry, solid geometry, astronomy, and harmonics quicken the mind and help a pupil gain understanding of the essential form of goodness, so Plato believed. Studying these subjects for ten years would release the prisoner from the cave and enable him to look at shadows and reflections. Five more years of study were devoted to dialectics.

Discussing astronomy, Plato first mentioned its utilitarian benefits: agriculture, navigation, and war. Not for these purposes, however, was astronomy to be esteemed. The true utility of the regimen of study prescribed in *The Republic* was saving the soul. An obvious approach to astronomy was to observe the motions of the objects in the heavens, but only a discipline dealing with unseen reality would lead the mind upward. True motions were not to be seen with the eye; not by looking at the heavens could one become truly acquainted with astronomy. As he often did, Plato put his ideas in a dialogue, in this instance between Socrates and Glaucon (one of Plato's older brothers):

> [Socrates] Then let us assign the fourth place in our studies to astronomy.
> [Glaucon] *It is a reasonable idea. And to return to the rebuke which you gave me a little while ago for my vulgar commendation of astronomy, I can now praise the plan on which you pursue it. For I suppose it is clear to everyone that astronomy, at all events, compels the soul to look upward and draws it from the things of this world to the other.*
>
> It may be clear to everyone else, but it is not clear to me.
>
> *What is your opinion?*
>
> It seems to me that astronomy, as now handled by those who study philosophy, positively makes the soul look downward.
>
> *How so?*
>
> I think you have betrayed no want of intrepidity in the conception you have formed of the true nature of that learning which deals with the things above. For probably if a person were to throw his head back and learn something from the contemplation of a carved ceiling, you would suppose him to be contemplating it not with his eyes but with his reason. Now perhaps your notion is right; perhaps mine is foolish. But I cannot conceive that any science makes the soul look upward unless it has to do with the real. And the real is invisible. It matters not whether a person stares at the ground or at the heavens. As long as he is trying to study any sensible object, he cannot be said to have learned anything, because no objects of sense admit of scientific treatment. And I maintain that his soul is looking downward, not upward, though he may be lying on his back staring upward.
>
> *I am rightly punished, for I deserved your rebuke. But what did you mean by saying that astronomy ought to be studied on a system very different from the present one if it is to be studied profitably for the purposes that we have in view?*
>
> I will tell you. Since this decorated sky is still a part of the visible world, we are bound to regard it, though the most beautiful and perfect of visible things, as far inferior to those true revolutions which real velocity and real slowness, existing in

> true number and in all true forms, accomplish relatively to each other, carrying with them all that they contain, which are truly discerned by reason and thought, but not by sight. Or do you think differently?
>
> *No, indeed.*
>
> Therefore we must use observations of this decorated sky as a pattern or plan to forward the study which aims at those higher objects, just as we might use the drawings of a draftsman as a model or pattern of the true and real but not reality itself. For, I imagine, a person acquainted with geometry, on seeing such diagrams, would think them most beautifully finished, but would regard it as ridiculous to study them seriously in the hope of detecting the truths of equality or duplicity or any other ratio.
>
> *No doubt it would be ridiculous.*
>
> And do you not think that the genuine astronomer will view with the same feelings the motions of the stars? That is to say, will he not regard the heaven itself and the bodies which it contains as framed by the heavenly architect with the utmost beauty of which such works are susceptible? But as to the proportion which the day bears to the night, both to the month, the month to the year, and the other stars to the sun and moon and to one another – will not the genuine astronomer look with scorn upon whomever believes such corporeal and visible objects to be changeless and exempt from all perturbations. And will he not believe it absurd to devote extraordinary effort to the attempt to observe and record the motions of the stars, sun, and moon?
>
> *Yes, I think so, now that I hear you suggest it.*
>
> Therefore we shall study astronomy with the help of problems, just as we study geometry. But we shall let the heavenly bodies alone, if it is our design to become really acquainted with astronomy and by that means to convert the natural intelligence of the soul from a useless into a useful possession. [*The Republic*, VII, 529d-530c]

Plato's instruction to 'let the heavenly bodies alone' has dismayed supporters and delighted detractors. On its face, the admonishment is anti-empirical, especially so if the translation produces in place of 'let alone' or 'leave' the stronger sense of 'dismiss' or 'abandon'. An injunction to astronomers to dismiss celestial phenomena from the subject matter of their science and to ban sense-perception would mean not a reform of astronomy but its liquidation (Vlastos, 1980).

A few lines earlier Plato instructed his followers to 'use observations of this decorated sky as a pattern or plan to forward the study which aims at those higher objects ...' This phrase Plato's supporters might construe as scientific. Plato's science cannot be equated with modern science, however, because Plato began with an a priori assumption regarding the true nature of the movements of the heavenly bodies and then sought to fashion the details of the scheme to explain away the apparent irregularities observed (Wasserstein, 1962).

Plato's interest lay not so much in inquiry into nature, but in how astronomy could be used in the education of philosopher-kings. Plato was talking not to astronomers but to educators. The astronomy that Plato would have eschew observation was not the science of astronomy as we think of it, but a propaedeutic to dialectic (Lloyd, 1981; Mourelatos, 1980). Plato's astronomy was highly abstract, with an emphatic contrast between the domain of the visible heavens and that of intelligible truth and reality. Plato intended to assimilate astronomy to a pure intellectual vision of points and lines, with the observed motions suggestive exemplars, at most. It is in this sense that Plato instructed his readers to 'use observations of this decorated sky as a pattern or plan to forward the study ...' He did not intend that observations be in any way central to the subject of astronomy as designed for educational purposes. Plato's astronomy was one of pure kinematics focusing on rotatory motion, of which the best visible concrete realization happened to be in the heavens. This is why he called it astronomy, but it is better thought of as a purely mathematical study, with selective empirical interpretations (Berggren, 1991; Mourelatos, 1981; Mueller, 1980).

This is not to say, as some might, that Plato abandoned a quest for reality. He could not 'conceive that any science makes the soul look upward unless it has to do with the real.' Plato's science of astronomy had as its subject reality – just not reality as is now commonly understood. This is evident from the sentence immediately following: 'And the real is invisible.' The type of reality discussed in the allegory of the cave is real for Plato; the idea of a perfect geometrical figure rather than its imperfect realization in the world of the senses is real. Plato continued: 'It matters not whether a person stares at the ground or at the heavens. As long as he is trying to study any sensible object, he cannot be said to have learned anything, because no objects of sense admit of scientific treatment.' This statement may be anti-empirical and anti-observational, but it is not anti-reality.

Plato's mathematical structures exiting in a realm of reality other than the physical world we observe are characterized most concisely and most wittily as 'π in the sky' (Brown, 1991:49). A serious case can be made, though, for the reality of Platonic entities. For those seeking empirically-testable knowledge, it is reasonable to think that sensibles are real; for those seeking logical certainty, it is equally reasonable to think that Platonic Forms are real. Plato thought that Forms were cognitively more real than their sensible instances because logical necessity or logical certainty is more binding than contingent truth, which is fallible: capable of being proved false by refinements and extensions. Logical inference and analysis produce more secure statements than does sensory observation; hence sensible particulars are judged to be less real than their respective Forms (Vlastos, 1965).

5 PLATO'S LIFE

The philosophy of an individual can be studied using the assumption, or working hypothesis, that philosophy is a response to the environment. Intellectual historians prefer this approach. Philosophers, in contrast, typically concentrate upon the ideas themselves, not biographical details or societal context. In what follows, causal connection between environment and philosophy is suggested but not necessarily asserted. A selective biographical sketch serves as a heuristic analogy for Plato's ideas. His philosophy and its implications for the study of astronomy are particularly understandable as a response to social and political troubles in which Plato found himself.

In 479 BC, a year after the Persians under Xerxes I had captured and burned Athens, thirty-one Greek city-states defeated the Persians in decisive land and sea battles. The victory brought to a successful resolution some twenty years of struggle to stop the westward expansion of the great Persian Empire and began for Greece a 'Golden Age'. Increasingly, Greece was dominated by Athens, whose population rose to perhaps 400,000. Tribute poured in from other city-states, furnishing liberal support for Athenian writers and artists. The subject city-states shared in the general prosperity, but resentment at the loss of political independence grew. Led by Sparta, several Greek city-states revolted against Athenian rule, setting off the Peloponnesian War of 431-404 BC. Initially Athens had no great difficulty maintaining dominance, but the fortunes of battle shifted after an unsuccessful attack by Athens on Syracuse in 413 BC, and Athens surrendered to Sparta in 404 BC.

Political conditions in Athens and then the death of Socrates, Plato's teacher and close friend, could well have affected Plato. Born in 427 BC, Plato was of an age to enter public life at the time of the defeat of Athens. Furthermore, both his mother's brother and cousin were members of the oligarchy of the Thirty Tyrants designated by Sparta to rule Athens. As can be read in an autobiographical letter, purportedly Plato's and accepted by many, but not all, scholars as genuine:

> When I was a young man I had the same ambition as many others: I thought of entering public life as soon as I came of age. And certain happenings in public

> affairs favoured me, as follows. The constitution we then had ... was overthrown; and a new government was set up consisting of ... and above them thirty other officers with absolute powers. ... Some of these men happened to be relatives and acquaintances of mine, and they invited me to join them at once ... (*Epistles*, 324c-d)

But the actions of the tyrants – they quelled criticism by intimidation and opposition by assassination, and met treasury deficits by the arbitrary execution of wealthy individuals for treason, followed by confiscation of the alleged traitors' properties – disgusted Plato. Also, they attempted to involve Socrates in their illegal actions. Plato chose not to join the government:

> I thought that they were going to lead the city out of the unjust life she had been living and establish her in the path of justice ... But as I watched they showed in a short time that the preceding constitution had been a precious thing. ... I was appalled and drew back from that reign of injustice. (*Epistles*, 325b-c)

A year later, the democratic faction having driven out the tyrants, Plato again considered entering politics:

> Not long afterwards the rule of the Thirty was overthrown and with it the entire constitution; and once more I felt the desire, though this time less strongly, to take part in public and political affairs. (*Epistles*, 325a-b)

But then the democracy persecuted Socrates. Plato now thought to set aside political ambition and begin his search for unchanging standards to hold against the shifting judgments of men:

> ... certain powerful persons brought into court this same friend Socrates, preferring against him a most shameless accusation ... and the jury condemned and put to death the very man. The more I reflected upon what was happening ... the more I realized ... the corruption of our written laws and our customs was proceeding at such amazing speed that whereas at first I had been full of zeal for public life, when I noted these changes and saw how unstable everything was, I became in the end quite dizzy ... At last I came to the conclusion that all existing states are badly governed and the condition of their laws practically incurable, without some miraculous remedy and the assistance of fortune; and I was forced to say, in praise of true philosophy, that from her height alone was it possible to discern what the nature of justice is, either in the state or in the individual, and that the ills of the human race would never end until either those who are sincerely and truly lovers of wisdom come into political power, or the rulers of our cities, by the grace of God, learn true philosophy. (*Epistles*, 325b-326b)

Subsequent experiences confirmed Plato in this opinion. In about 388 BC he was in the presence of the dictator of Syracuse, Dionysius I. According to legend, the tyrant asked Plato if he did not think that he, Dionysius, was a happy man. Plato answered that he thought no one who was not mad would become a tyrant. Enraged, Dionysius supposedly ordered Plato sold into slavery, from which he was rescued by a friend arriving just in time with ransom money. More likely, whatever the exchange between Plato and Dionysius, on Plato's return voyage to Athens his ship was captured and he was put up for sale in the slave market at Aegina, where a friend ransomed him. Of all this, however, there is no mention in Plato's autobiographical letter.

Plato does describe his association with Dion, Dionysius' brother-in-law, to whom Plato imparted his ideas, particularly the love of virtue above pleasure and luxury. When Dionysius died, Dion in 367 BC asked Plato to return to Syracuse to help arouse in his nephew, the new tyrant Dionysius II, the desire for a life of nobility and virtue. Dion even persuaded the young ruler to send for Plato. Plato went, though not without trepidation. His worst apprehensions quickly were surpassed:

> When I arrived – to make the story short – I found the court of Dionysius full of faction and of malicious reports to the tyrant about Dion. I defended him as well as I

> could, but was able to do very little; and about the fourth month Dionysius, charging Dion with plotting against the tyranny, had him put aboard a small vessel and exiled in disgrace. Thereupon we friends of Dion were all afraid that one of us might be accused and punished as an accomplice in Dion's conspiracy. About me there even went abroad in Syracuse a report that I had been put to death by Dionysius as the cause of all that had happened.... Dionysius ... devised a means for preventing my departure by bringing me inside the citadel and lodging me there, whence no ship's captain would have dared to take me away ... Nor would any merchant or guard along the roads leading out of the country have let me pass alone, but would have taken me in charge at once and brought me back to Dionysius ... I made every effort to persuade Dionysius to let me depart, and we came to an agreement that when peace was restored [war was then going on in Sicily] and when Dionysius had made his empire more secure, he would recall both Dion and me.... On these conditions I promised that I would return. (*Epistles*, 329b-e; 338a)

With peace restored, Plato initially disregarded the summons from Dionysius. But, lest reports of Dionysius' new-found appreciation of philosophy prove true, Plato did not want to be blamed for denying assistance. The enterprise ended badly, and some readers may sense in Plato's apologetic and self-exculpatory explanation a whining tone; scholars have divined a more noble and principled stand. It may also have flattered Plato that Dionysius sent a trireme to ease his journey. Furthermore, Dionysius threatened to cut off Dion's income if Plato did not come. On arriving in Syracuse, Plato was not pleased:

> When I arrived, I thought my first task was to prove whether Dionysius was really on fire with philosophy ... those who are really not philosophers but have only a coating of opinions, like men whose bodies are tanned by the sun, when they see how much learning is required, and how great the labour, and how orderly their daily lives must be to suit the subject they are pursuing, conclude that the task is too difficult for their powers ... I went through the matter [the first and highest principles of nature] with him once only ... Was it that Dionysius ... thought he understood well enough ... Or did he think that what I said was of no value? Or ... did he realize that this teaching was beyond him ... (*Epistles*, 340b-e; 345a-b)

Dionysius now cut off Dion from the revenues of his properties. An indignant Plato again wanted to leave Syracuse, and again was held against his will.

The changing, visible world all too evidently was without permanent values. For Plato in his time this was far more of a disappointment than it would be today, with a plethora of alternative professions beckoning. Even the haven and the professional and intellectual opportunity offered by the Christian church lay centuries ahead. If Plato could not become a political being, the essential part of human existence was denied him. He turned to the world of ideas in which he might hope to find the real and unchanging standards absent in the world of experience.

6 THE ONTOLOGICAL STATUS OF ASTRONOMICAL HYPOTHESES

Plato believed that astronomical hypotheses were descriptions of reality. This much is clear from brief glances at his life and philosophy. It is also clear that Plato's reality existed in the world of ideas rather than in the world of the senses.

For subsequent Greek astronomers, the claim on reality of any particular combination of uniform circular motions might well have been diminished after Hipparchus (*c*. 150 BC) showed that the eccentric hypothesis (Figure 1) and the epicycle hypothesis (Figure 2) for the Sun's motion were mathematically and observationally equivalent.

In addition to the need to save the phenomena with some scheme of uniform circular motions, the ontological status of astronomical hypotheses also received attention from Simplicius in his commentary on Aristotle's *De caelo*:

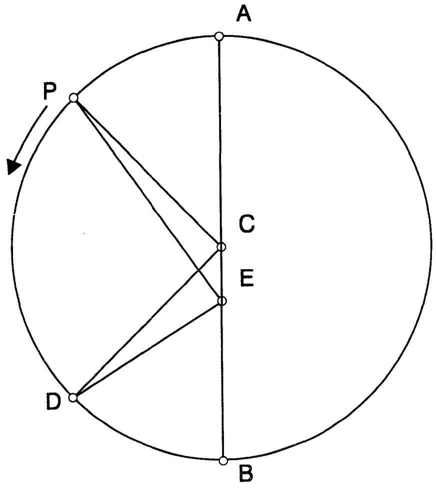

Figure 1. In the eccentric hypothesis, the planet/Sun, P, moves with uniform circular motion along the circle APDB with its centre at C. The observer on Earth is at E, thus the planet's circular orbit is not around Earth, but is eccentric. The planet is at apogee at A and perigee at P.

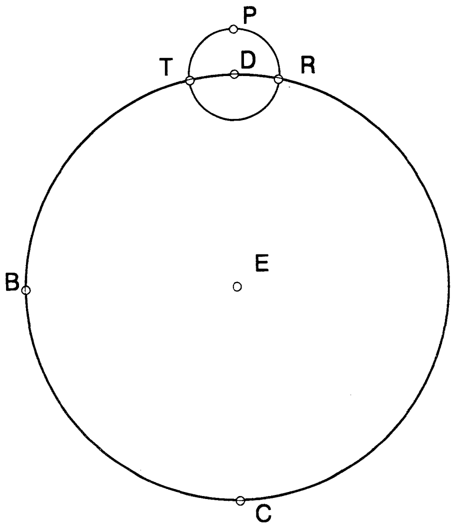

Figure 2. In the epicycle hypothesis, the planet/Sun, P, moves with uniform circular motion along the epicycle, circle PRT, whose centre, D, simultaneously travels along the deferent, circle DBC with Earth, E, at its centre.

> ... so an explanation which conforms to the facts does not imply that the hypotheses are real and exist. By reasoning about the nature of the heavenly movements, astronomers were able to show that these movements are free from all irregularity, that they are uniform, circular, and always in the same direction. But they have been unable to establish in what sense, exactly, the consequences entailed by these arrangements are merely fictive and not real at all. So they are satisfied to assert that it is possible, by means of circular and uniform movements, always in the same direction, to save the apparent movements of the wandering stars. (Duhem, 1969:23)

Simplicius also addressed the ontological status of astronomical hypotheses in his commentary on Aristotle's *Physics*. Here Simplicius reported Geminus' abridged version (in an elementary astronomical handbook written at Rhodes in about 70 BC) of what Posidonius (at Rhodes sometime between 135 and 51 BC) had asserted in his *Meteorology*. Astronomy differed from physics:

> To physical theory belongs the study of all that concerns the essence of the heavens and the stars ... Astronomy, on the other hand, is not prepared to say anything about the former. Its demonstrations concern the order of the heavenly bodies ... the shapes, sizes, and relative distances ... Often the physicist will fasten on the cause and direct his attention to the power that produces the effect he is studying, while the astronomer draws his proofs from circumstances externally related to that same effect. The astronomer is not equipped to contemplate causes ... he feels obliged to posit certain hypothetical modes of being which are such that, once conceded, the phenomena are saved. For example, the astronomer asks why the sun, the moon, and the other wandering stars seem to move irregularly. Now, whether one assumes that the circles described by the stars are eccentric or that each star is carried along by the revolution of an epicycle, on either supposition the apparent irregularity of their course is saved. The astronomer must therefore maintain that the appearances may be produced by either of these modes of being ... (Duhem, 1969:10-12)

Continuing his explanation of the difference between astronomy and physics, Simplicius considered a heliocentric hypothesis:

> This is the reason for Heraclides Ponticus' contention that one can save the apparent irregularity of the motion of the sun by assuming that the sun stays fixed and that the earth moves in a certain way. The knowledge of what is by nature at rest and what

> properties the things that move have is quite beyond the purview of the astronomer. He posits, hypothetically, that such and such bodies are immobile, certain others in motion, and then examines with what [additional] suppositions the celestial appearances agree. His principles, namely, that the movements of the stars are regular, uniform, and constant, he receives from the physicist. (Duhem, 1969:18)

Seemingly according the standard geocentric hypothesis and Heraclides Ponticus' heliocentric hypotheses equal standing, Simplicius apparently opted for a merely fictive status for astronomical hypotheses.

The ancient discussion of possibly fictive astronomical hypotheses was continued in modern times by the physicist and historian of science Pierre Duhem. A hypothetical status for hypotheses about nature had become particularly convenient for French Catholic scientists during the middle ages. Nicole Oresme (1320-1382), for example, in discussing the possible rotation of Earth, came too close to asserting truths that could be contradictory to dogmas of the Christian faith, and wisely chose to present his work in the context of a nominalist thesis: that we cannot insist upon the truth of any particular working hypothesis because God could have made the world in some different manner that nonetheless has the same set of observational consequences (Hetherington, 1993b). While conceding the divine omnipotence of Christian doctrine, the nominalist thesis would free natural philosophy from religious authority. Duhem, both Catholic and French, became an eager champion of his earlier compatriots. His personal philosophy of science also resonated with what he understood theirs to be.

In his study of the history of astronomy from Plato to Galileo, Duhem seized upon ancient Greek astronomy, especially as purveyed in Simplicius' commentaries, to establish early in the twentieth century an instrumentalist view – an understanding of scientific theories as useful fictions – of the relationship between theory and observation. The better to contrast Greek with Arab science, Duhem emphasized supposed Greek instrumentalism more than was warranted. In rendering Greek text into French, Duhem occasionally produced translations of ancient opinion more in line with instrumentalism than other scholars will willingly concede (Duhem, 1969:10, footnote 13; Lloyd, 1991:267-268).

Later, Duhem would display a more subtle understanding of Greek astronomers and recognize that many of them subordinated mathematical astronomy to physical theory (Ragep, 1990). Indeed, Duhem would come to seek a middle way between realism and instrumentalism, rejecting along with realism also the reduction of science to a set of practical prescriptions for action, which would have deprived science of its status of objective knowledge (McMullin, 1990).

At the centre of a partisan polemical battle, Duhem initially carried nearly single-handedly the instrumentalist standard into battle against British mechanistic philosophy (Duhem, 1969:ix-xxvi). Only the briefest of sketches anent the debate must suffice here. For William Thompson (Lord Kelvin), theories were presented in terms of mechanical models; he wrote: 'I never satisfy myself until I can make a mechanical model of a thing. If I can make a mechanical model I can understand it.' The reality of theoretical entities depended upon the ability to sense their behaviour. Theoretical expressions were acceptable only to the degree that they were accessible to seeing and feeling, to direct sensory perception (Smith and Wise, 1989:464-465). Duhem, observing the British recourse to mechanical models, wondered if the scientists had been inspired by the mills and factories of Victorian Britain: 'We thought we were entering the tranquil and neatly ordered abode of reason but we found ourselves in a factory' (Duhem, 1962:71).

Physicists generally believed that their work related to physical reality. Duhem's extreme opposite view was that laws are merely convenient formulae, to be reshuffled at will. For example, the interaction of charged particles in an electromagnetic field need not rely on the postulation of an underlying medium; instead, the scientific law is a mathematical fiction, its sole function to save the phenomena (Duhem, 1969:xv-vi). Duhem rejected scientific realism in which the explanatory success of a theory was taken as reason to believe in the existence of underlying entities postulated by the theory; he associated model-realism with the 'broad but weak' English mind (McMullin, 1990). Such, caricatured in broad strokes, were the rival views of scientific theory at the turn of the century.

Some scholars see as a dominant strand in ancient Greek astronomy 'a lack of concern with the physics of the problem in favour of a preoccupation with the mathematics, the construction of models that are purely calculating devices with nothing to do with any underlying physical realities' (Lloyd, 1987:312). Known empirical data were suspended and the study then became one of pure geometry, not solving but still relevant to the astronomical problem. What remained were simple mathematical fictions and pure conceptions, with no question of their being true or in conformity with the nature of things, or even probable (Lloyd, 1987:312-313; Musgrave, 1991). For so-called instrumentalists, it is enough that a scientific theory yields predictions corresponding to observations; theories are simply calculating devices.

Realists, on the other hand, insist that theories pass a further test: that they correspond to underlying reality. Greek astronomers were describing concrete bodies and movements that actually were accomplished. Realists believe that scientific theories are descriptions of reality. *Dogmatic* realists insist on the truth of a theory; *critical* realists concede a theory's conjectural character without necessarily becoming instrumentalists. A disappointed realist may appear to be a *local* instrumentalist with regard to a particular failed theory retaining instrumental value, but is far from becoming a *global* instrumentalist (Musgrave, 1991:244).

As Duhem recapitulated:

> the hypotheses of astronomy can be viewed as mathematical fictions which the geometer combines for the purpose of making the celestial motions accessible to his calculations; or they can be viewed as a description of concrete bodies and of movements that are actually realized. In the first case, only one condition is imposed on hypotheses, namely, that they save the appearances; in the second, the intellectual freedom of the astronomer turns out to be much more limited, for if he is an advocate of a philosophy which claims to know something about the celestial essence, he will have to reconcile his hypotheses with the teachings of that philosophy. (Duhem, 1969:28)

Modern debate over the ontological status of ancient astronomical hypotheses has been confined largely to the terminology and classifications developed in the battle between instrumentalists and realists. A fresh look at this issue viewed from the perspective of Plato's philosophy may be productive.

6 EUDOXUS

Whether there would be progress toward a solution to the astronomical problem purportedly set by Plato, that of saving the phenomena, or indeed any sustained attention to any scientific project, depended, in part, upon the level of encouragement and support furnished by society to individual philosopher-scientists. Greek society supported playwrights when the citizens of Athens paid to see the productions of Aeschylus, Sophocles, and Euripides, and prizes were offered at festivals for the labours of poets and musicians. Scientists, however, were not as generously supported, at least not until the establishment of the Museum and the Library in Alexandria. Plato lamented that inasmuch as no city held geometry in high regard, inquiries in the subject languished. The practicing physician and architect charged fees for their services, and so could the theoretically-inclined scientist or philosopher, were he able to attract a group of pupils. Alternatives included inherited wealth and the beneficence of a wealthy patron.

Eudoxus, thought to have lived from 408 to 355 BC, came to Athens as a poor youth, about 23 years old, travelling as assistant to a physician. Later Eudoxus proceeded to Egypt with another physician. There Eudoxus stayed for more than a year, perhaps for several years, and became familiar with the priests' astronomical observations. Later he established a school at Cyzicus, a city on the southern coast of the Sea of Marmara, and later yet he moved with some of his pupils to Athens, where presumably he renewed discussions with Plato and others at the Academy (Santillana, 1949).

Unfortunately, nothing Eudoxus wrote on astronomy has survived. His system was described briefly by Aristotle in the *Metaphysics* (Hope, 1952), and many centuries later in Simplicius' commentary on Aristotle's *De caelo*. According to Aristotle, Eudoxus's system consisted of spheres rotating with uniform speeds:

> Now, Eudoxus taught that the paths of the sun and of the moon each encompassed three spheres, the first of these being the sphere of the fixed stars, the second being along the middle line of the zodiac, and the third being inclined across the breadth of the zodiac; the path of the moon is inclined at a greater angle than the path of the sun. And the path of the planets is in each case within four spheres, the first and the second of these also being the same as the first two just mentioned (for the sphere of the fixed stars moves all the spheres, and the sphere placed next inward from this and having its path bisecting the zodiac is common to all), but the third sphere of each planet having its poles in the circle bisecting the zodiac, and the fourth sphere having its path inclined to the equator of the third; the poles of the third sphere being different for each of the other planets, but the poles of Venus and Mercury being the same.
>
> Callippus made the position of the spheres the same as did Eudoxus and assigned the same number as did Eudoxus to Jupiter and to Saturn; but he held that two more spheres are to be added to the sun as well as to the moon, if one is to account for the phenomena, and one more to each of the other planets.
>
> However, if all the spheres combined are to account for the phenomena, there must be for each of the planets other spheres, one less than those enumerated, moving counter to these and bringing back to the same position the outermost sphere of the star [planet] located inwards from the respective star [planet]; for thus alone can all the movements combine to produce the complex movement of the planets.
>
> Summing up, the spheres required by the movements of the planets themselves are: for Saturn and Jupiter, eight; for the others, twenty-five; and of these only those need to have countermoving spheres which are required by the movement of the innermost planet, that is, the spheres moving counter to those of the next two must be six, and the spheres moving counter to those of the next four must be sixteen; so that the total number of moving and countermoving spheres is fifty-five. But if one does not add to the sun and to the moon the movements we have suggested, all the spheres will number only forty-seven. So much for the number of the spheres. (*Metaphysics* I 8, 1073b17-1074a15)

Neither Aristotle's nor Simplicius' surviving descriptions of Eudoxus' astronomical system was sufficiently precise to stimulate much interest in the model until little more than a century ago, when Giovanni Schiaparelli, an Italian astronomer more widely known for his observation of 'canali' on Mars, attempted to reconstruct Eudoxus' system (Dreyer, 1953; Forbes, 1973; Hargreave, 1970; Heath, 1913; Hetherington, 1993a; Maula, 1974; Neugebauer, 1953). The reconstruction is compatible with what Aristotle and Simplicius wrote about Eudoxus, but also depends upon the assumption that Eudoxus' system accounted for many of the astronomical phenomena known in Schiaparelli's time. There is a decided danger of attributing to Eudoxus a more advanced knowledge of astronomy than he actually possessed and a more accurate astronomical model. Nor is it necessarily safe to assume that every astronomical phenomenon known in Eudoxus' time also was recognized as in need of explanation within his system.

Eudoxus could easily have accounted for the apparent movement of the stars overhead each evening by placing them on a sphere rotating with a uniform speed around the central Earth, with a period of twenty-four hours. For the Sun, Eudoxus would have needed two spheres, one rotating with the 24-hour period and another, its axis tilted to that of the first, to move the Sun higher in the sky in summer and lower in winter and around the heavens with a period of a year. Eudoxus apparently ignored the changeable velocity of the Sun, already discovered by his time, but did add a third sphere to account for a belief now known to have been mistaken. A similar system of spheres took care of the Moon, though the arrangement as reported by Aristotle and Simplicius cannot produce the variations in latitude now known (reversing the reported order of the middle and inner spheres brings the model into better agreement with modern observations). Planetary motions presented a more difficult problem, but a clever combination of third and fourth spheres would have been capable of producing in approximate fashion the observed retrograde motions (Figures 3 and 4).

Neither Aristotle nor Simplicius provides Eudoxus' inclination for any planet, and they give his planetary periods only in round numbers of years. Perhaps Eudoxus, once he had solved the problem of the stations and retrogradations of the planets qualitatively and geometrically, did not proceed to provide complete parameters for the individual planets (Lloyd, 1979:170). Perhaps the mathematical work of determining the various curves traced by a point on the innermost sphere was so

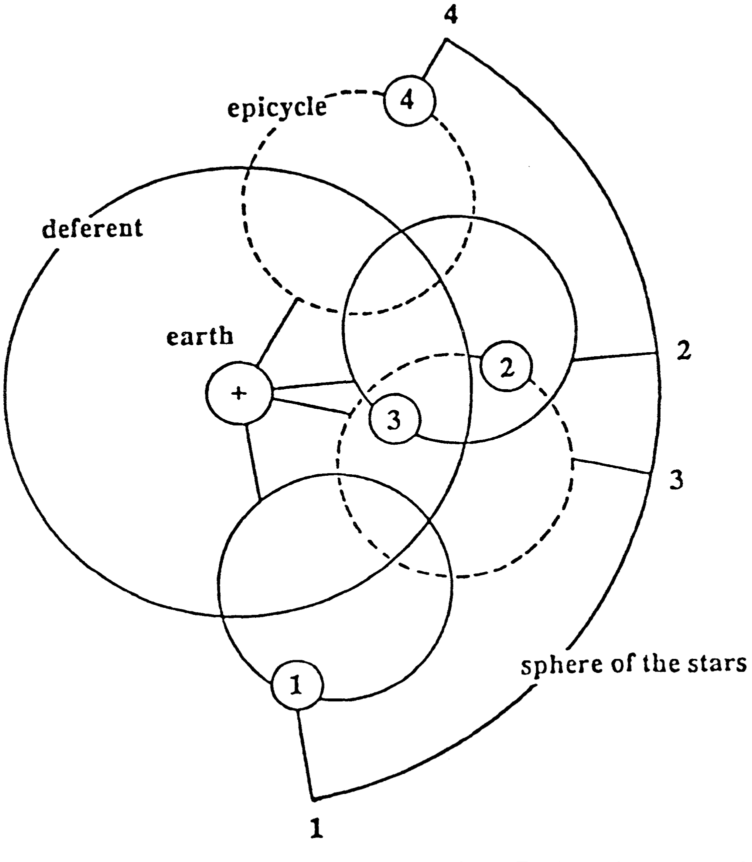

Figure 3. Apparent Retrograde Motion of a Planet. As seen from Earth at times 1, 2, 3, and 4, the planet apparently moves against the sphere of the stars from 1 to 2, turns back to 3, and then resumes its forward motion to 4. Earth, moving faster than the outer planet, overtakes and passes it.

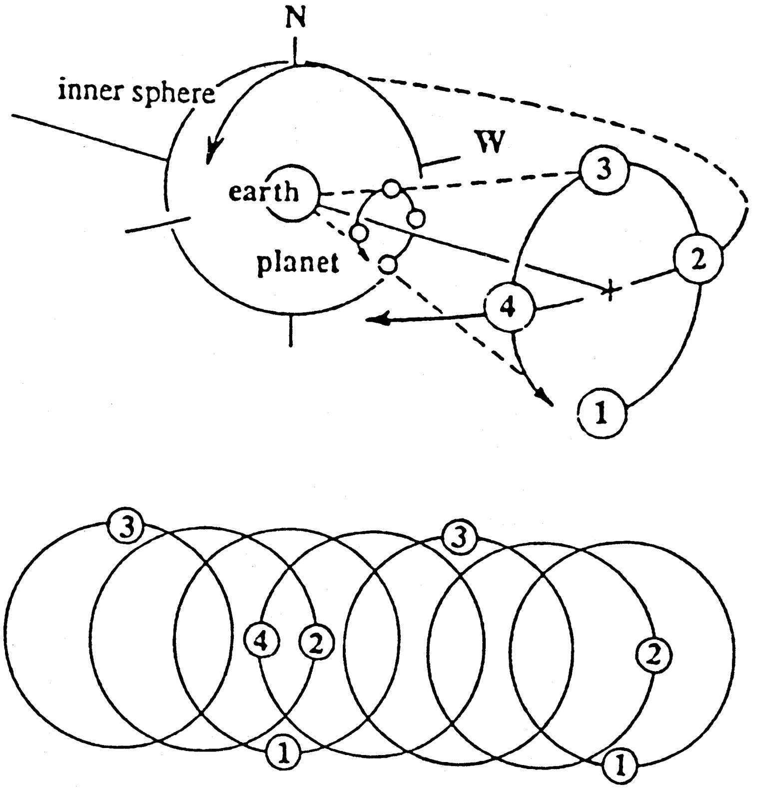

Figure 4. Retrograde Motion from Homocentric Spheres. Eudoxus could have, but did not necessarily, account for retrograde motion in the following manner. The apparent path of the planet, generally from right to left as seen against the sphere of the stars, due to the motions of the inner and outer spheres is shown immediately above, moving slightly right from 1 to 2, largely left to 3 and then to 4, slightly right to 1 and to 2, and then largely left to 3 and onward. The two spheres at the top of this figure have the same centre; they are concentric. The outer sphere is not shown in the drawing. Its axis of rotation is vertical, in the plane of the paper, in a north-south direction. The outer sphere carries everything within it eastward. The axis of the inner sphere is horizontal and in the plane of the paper. The motion of a planet carried about by the inner sphere is up (north) and down (south) and into (west) and out of (east) the plane of the paper. The planet appears to move north and west from 1 to 2, north and east to 3, south and east to 4, and south and west back to 1. When the inner sphere is imparting an eastward motion to the planet, moving the planet from 2 to 3 to 4, the total eastward motion, including the steady eastward motion imparted by the outer sphere, will be very rapid. If the westward speed imparted by the inner sphere is greater than the steady eastward motion imparted by the outer sphere, then the planet will appear to slow down and briefly move west during the passage from 4 to 1 to 2, when the westward velocity of the inner sphere is greater than the eastward velocity of the outer sphere. (After Hetherington, *Astronomy and Civilization*)

stupendous and absorbing that it provided its own justification for the project (Mourelatos, 1981). Lack of descriptive and predictive accuracy would not necessarily have weighed heavily against a theory intended primarily to give conceptual unity to the celestial motions, intended to show in a rather coarse and general way that the assumption of a very few principles could account for a large number of phenomena (Wright, 1973).

Four homocentric spheres cannot simultaneously produce with complete quantitative accuracy both the length of the retrograde motion westward and the length of the motion in latitude for all the planets. Evidently Eudoxus' contemporaries detected flaws in his system, because a series of modifications occurred after his death, first at his school in Cyzicus by his pupil, Polemarchus, and then by Polemarchus' pupil, Callippus. Later the work was continued in Athens, to which city both Polemarchus and Callippus moved, and where Callippus worked with Aristotle.

Aristotle would not have been content with a purely geometrical system; he would have sought to understand the forces causing the motions of the planets. For

Aristotle, the spheres were not merely representations of mathematical formulae, but physically existing parts of a vast machinery by which the celestial bodies were kept in motion (Dreyer, 1953:112). One historian of astronomy has complained of Aristotle that 'he adopted the planetary scheme of Eudoxus and Callippus, but imagined on "metaphysical grounds" that the spheres would have certain disturbing effects on one another, and to counteract these found it necessary to add 22 fresh spheres, making 56 in all. At the same time he treated the spheres as material bodies, thus converting an ingenious and beautiful geometrical scheme into a confused mechanism' (Berry, 1961:29). Aristotle was not attempting to improve on Eudoxus' geometrical solution, or to give a new solution; he was making changes necessary if the mathematical solution were to be applicable as a physical model (Bechler, 1970).

Eudoxus' system of homocentric spheres was improved and brought into better agreement with observed planetary motions, but there was one phenomenon for which it could not account: the movement of the planets closer to and farther from Earth. A system of homocentric spheres cannot produce changes in distances of objects from the centre of the spheres.

This oversight led one scholar to characterize Eudoxus as seeking a geometrical construction accounting for a selected set of phenomena, not a physical or mechanical model true to reality. He was not talking about the world as it is, but was giving a possible solution to a geometrical problem. It was not a real problem, but purely a geometrical exercise (Wasserstein, 1962). Other scholars argue that if Eudoxus' system had been intended merely as a computational device, it could have been less complex and more accurate (Musgrave, 1991; Wright, 1973).

Neither interpretation of Eudoxus, as an instrumentalist or as a realist, is without difficulty. An instrumental scheme, intended merely as a computational device, could have been less complex and more accurate. And a realist should have dealt with changing distances from the centre. Eudoxus is better understood as following in the same vein as Plato, with a highly idealized, but not instrumentalist, vision of what it meant to practice astronomy. Eudoxus' system of homocentric spheres was far more than a mere calculating device, but less – and more – than the concrete empirical reality of realists. Eudoxus' reality was the reality of Plato: a penetrating intellectual understanding of the world.

7 PTOLOMY

The most substantial surviving body of ancient Greek geometrical astronomy in which Platonic resonances might be sought is Ptolemy's *Almagest*. Intervening advances toward the goal of saving the phenomena achieved during the half a millennium between Eudoxus and Ptolemy were summed up so well by Ptolemy in his handbook on mathematical astronomy that 'his treatise became canonical and eliminated its predecessors' (Toomer, 1970). 'Being obsolete, they ceased to be copied' (Toomer, 1984).

After the death of Aristotle, the preponderance of scientific activity in the Greek intellectual world shifted from Athens to the new and wealthy port city of Alexandria, founded on the western edge of the Nile River Delta by Alexander the Great. The Museum, created around 290 BC, became home to as many as a hundred scholars subsidized by the government. Much prestige attached to scholarship and scientific research, and kings sought thus to enhance their reputations. Not to be outdone, a subsequent ruler established the Library, whose large and famous collection of books, built up from the purchase of private libraries, possibly including Aristotle's, may have numbered as many as half a million. Astronomical instruments were constructed for use at the Library, and observations and the matching of theory with fact were undertaken on a systematic and sustained basis. Galen in the biological sciences, Euclid in geometry, and Ptolemy in astronomy all flourished in Alexandria. Of

Ptolemy, the man, almost nothing is known. His own recorded observations purportedly were made (some assert they were fabricated; Hetherington, 1997b) between AD 125 and 141. The Library provided Ptolemy with observations of his predecessors, upon which he constructed his great synthesis.

The *Almagest* proceeds in logical order, beginning with a brief introduction to the nature of astronomy. Ptolemy makes a distinction between mathematics and physics, and also between these two disciplines and theology. He chooses the mathematical discipline to cultivate, particularly with respect to divine and heavenly things. His task is to describe what has already been discovered and to add his own original contributions. The motivation for studying astronomy echoes that given earlier by Plato. Ptolemy wrote:

> ... Hence we thought it fitting to guide our actions ... to strive for a noble and disciplined disposition ... to devote most of our time to intellectual matters, in order to teach theories, which are so many and beautiful, and especially those to which the epithet 'mathematical' is particularly applied. The division [of theoretical philosophy] which determines the nature involved in forms and motion from place to place, and which serves to investigate shape, number, size, and place, time, and suchlike, one may define as 'mathematics'. ... it can be conceived of both with and without the aid of the senses, and, secondly, it is an attribute of all existing things without exception, both mortal and immortal: for those things which are perpetually changing in their inseparable form, it changes with them, while for eternal things which have an aethereal nature, it keeps their unchanging form unchanged.
>
> ... only mathematics can provide sure and unshakeable knowledge to its devotees provided one approaches it rigorously. For its kind of proof proceeds by indisputable methods, namely arithmetic and geometry. Hence we were drawn to that part of theoretical philosophy ... concerning divine and heavenly things. For that alone is devoted to the investigation of the eternally unchanging. For that reason it too can be eternal and unchanging (which is a proper attribute of knowledge) in its own domain, which is neither unclear nor disorderly. ... it ... only ... can make a good guess at that activity which is unmoved and separated; it is familiar with the attributes of those beings which are on the one hand perceptible, moving and being moved, but on the other hand eternal and unchanging, having to do with motions and the arrangements of motions. ... almost every peculiar attribute of material nature becomes apparent from the peculiarities of its motion from place to place. ... the corruptible from the incorruptible by motion in a straight line or in a circle ... With regard to virtuous conduct in practical actions and character, this science, above all things, could make men see clearly; from the constance, order, symmetry, and calm which are associated with the divine, it makes its followers lovers of this divine beauty, accustoming them and reforming their natures, as it were, to a similar spiritual state.
>
> It is this love of the contemplation of the eternal and unchanging which we constantly strive to increase, by studying those parts of these sciences which have already been mastered by those who approached them in a genuine spirit of enquiry, and by ourselves attempting to contribute as much advancement as has been made possible by the additional time between those people and ourselves. (*Almagest*, I, 1)

Ptolemy would teach beautiful theories conceived of with, and without, the aid of the senses, concerning divine and heavenly things, eternally unchanging the incorruptible by motion in a circle. Astronomy could make men see clearly, reforming their natures. Admittedly a different selection of excerpts could equally make of Ptolemy an Aristotelian (Taub, 1993); the object here is not to choose one influence over the other, but to demonstrate links to Plato's philosophy.

In Book III of the *Almagest*, Ptolemy took up the problem of the Sun's motion. He described previous observations of the length of the year and summarized in a table the results of the Sun's regular movement. The next task, he wrote, was to explain the apparent irregularity of the Sun's motion as a combination of regular circular motions:

> Our next task is to demonstrate the apparent anomaly [irregularity in motion] of the sun. But first we must make the general point that the rearward displacements [retrograde motions] of the planets with respect to the heavens are, in every case, just like the motion of the universe in advance, by nature uniform and circular. That is to say, if we imagine the bodies or their circles being carried around by straight lines, in absolutely every case the straight line in question describes equal angles at the centre of its revolution in equal times. The apparent irregularity in their motions is the result of the position and order of those circles in the sphere of each by means of which they carry out their movements, and in reality there is in essence nothing alien to their eternal nature in the 'disorder' which the phenomena are supposed to exhibit. *(Almagest*, III, 3)

At the end of the *Almagest*, realizing that his readers would react unfavourably to the plethora of devices he had found necessary to incorporate into theory if it were to save the phenomena, Ptolemy pleaded that when it was not possible to fit the simpler hypotheses to the movements in the heavens, it was proper to try any hypotheses:

> Now let no one, considering the complicated nature of our devices, judge such hypotheses to be over-elaborated. For it is not appropriate to compare human [constructions] with divine, nor to form one's beliefs about such great things on the basis of very dissimilar analogies. For what more dissimilar than the eternal and unchanging with the ever-changing, or that which can be hindered by anything with that which cannot be hindered even by itself? Rather one should try, as far as possible, to fit the simpler hypotheses to the heavenly motions, but if this does not succeed, [one should apply hypotheses] which do fit. For provided that each of the phenomena is duly saved by the hypotheses, why should anyone think it strange that such complications can characterize the motions of the heavens when their nature is such as to afford no hindrance, but of a kind to yield and give way to the natural motions of each part, even if [the motions] are opposed to one another? Thus, quite simply, all the elements can easily pass through and be seen through all other elements, and this ease of transit applies not only to the individual circles, but to the spheres themselves and the axes of revolution. We see that in the models constructed on earth the fitting together of these [elements] to represent the different motions is laborious, and difficult to achieve in such a way that the motions do not hinder each other, while in the heavens no obstruction whatever is caused by such combinations. Rather, we should not judge 'simplicity' in heavenly things from what appears to be simple on earth especially when the same thing is not equally simple for all even here. For if we were to judge by those criteria, nothing that occurs in the heavens would appear simple, not even the unchanging nature of the first motion, since this very quality of eternal unchangingness is for us not [merely] difficult, but completely impossible. Instead [we should judge 'simplicity'] from the unchangingness of the nature of things in the heaven and their motions. In this way all [motions] will appear simple, and more so than what is thought 'simple' on earth, since one can conceive of no labour or difficulty attached to their revolutions. (*Almagest*, XIII, 2)

This passage, especially the argument that parts of the models must pass through each other without hindrance or obstruction, raises the question of whether Ptolemy envisioned actual physical structures in the heavens carrying around the planets. Duhem concluded that Ptolemy had refused to impose on the movements of the heavenly bodies the obligation of letting themselves be modelled by wooden or metal contraptions, and thus Ptolemy's many motions compounded to determine the trajectory of a planet 'have no physical reality; only the resultant motion is actually produced in the heavens' (Duhem, 1969:17).

The passage in question, however, seems more straightforwardly understood as indicating that there is a construction in the heavens controlling the motions of the planets, and that it is made not of wood, nor of metal, nor of other earthly material, but of some divine celestial material offering no obstruction to the passage of one part of the construction through another. If Ptolemy were interested only in the resulting motion, he would not have had to trouble himself with a discussion of the complicated nature of his devices. Ptolemy at the end of the Almagest seems closer in spirit to Lord Kelvin than to Duhem, not satisfied until he could make a mechanical model, or at least imagine such a model.

The most persuasive point advanced in arguments for Ptolemy as an instrumentalist involves his lunar theory. While it predicted lunar longitude and latitude accurately, the theory greatly exaggerated the monthly variation in the Moon's distance from Earth. Since the theory of the Moon, realistically interpreted, would yield an obviously false prediction about the variation in the apparent size of the Moon, Ptolemy – so the argument goes – could not have intended that the theory be interpreted realistically. Ptolemy had measured the variation in the angular diameter of the Moon, and he must have known that his theory failed in this aspect (Dreyer, 1953:196). Ptolemy, however, is silent on the matter; he does not explicitly recognize the fact of instrumentalism that some scholars have been so ready to discern nearly two millennia later.

Ptolemy's silence is not inconsistent with an implicit understanding that theory was merely a calculating device. His silence, however, does not prove beyond reasonable doubt that he set aside the problem as one of purely mathematical complexity. He could equally have been overcome by the physical complexity of the situation (Lloyd, 1978). A disappointed realist is not automatically rendered an instrumentalist. Ptolemy addressed at great length in the concluding section of the *Almagest* the issue of the physical complexity of his system. 'He adduces physical arguments from the nature of the substance of the heavenly region ... to support the possibility of the types of motion he proposes. Here too, then, the influence of his underlying realist assumptions is apparent' (Lloyd, 1978).

Proponents of Ptolemy as a realist cannot entirely deny the argument from lunar distances; they must try to overwhelm it with an abundance of contrary evidence. In one of his other books, the *Planetary Hypotheses*, Ptolemy nested the mechanism of epicycles and deferents for each planet inside a spherical shell between adjoining planets (Evans, 1993; Murschel, 1995). Even more so than in the *Almagest*, Ptolemy here showed his concern with the physical world.

Proponents of the instrumentalist interpretation must resort to a schizophrenic Ptolemy, now a realist but earlier, in the *Almagest*, an instrumentalist. Duhem wrote of the author of the *Almagest* and the author of the *Planetary Hypotheses* without noting that they were the same person, and another scholar spoke of the two souls dwelling together in the breast of many a scientist. Either Ptolemy was a 'bundle of contradictions' or he was a realist; the later interpretation has the decided advantage of simplicity (Musgrave, 1991).

Ptolemy shared Plato's philosophy, as selected excerpts from the preface to the *Almagest* demonstrate. Seemingly Ptolemy did not carry Plato's analogy of the cave to the extreme conclusion that reality exists only in the mind, that reality is found not in the visible façade of phenomena but in the mathematical structures that generate the phenomena (Graßhoff, 1990:199). Ptolemy's reality existed in the heavens, but it was not made of wood or metal. Ptolemy was not an instrumentalist. Nor was he a realist, at least in the strict sense of believing in wood and metal constructions filling the heavens. In changing the location of reality from the mind to the heavens, if that is what he did, Ptolemy was more of a realist than was either Plato or Eudoxus. Ptolemy's reality was not, however, an earthly materialistic reality, but rather an aethereal reality corresponding to nothing on earth: still π in the sky.

8 AN ALTERNATIVE MODEL OF SCIENCE

In ancient Greek geometrical astronomy the calculating or predictive power of theory apparently received less weight than modern instrumentalists and realists accord it, and reality was sought more in the world of ideas than in the empirical world (Hetherington, 1996). This philosophy might be likened to Gerald Holton's (1978) description of modern science, in which themata lie behind the quasi-aesthetic choices scientists make and guide their leaps across the chasm between experience and basic principle.

Regarding the relative importance of theory and observation, Einstein wrote: "I do not by any means find the chief significance of the general theory of relativity in the fact that it has predicted a few minute observable facts, but rather in the simplicity of its foundation and in its logical consistency" (Brush, 1989; see also Hetherington, 1989 and 1990). The astronomer Arthur Eddington, one of the first to understand relativity theory, elaborated: "For those who have caught the spirit of the new ideas the observational predictions form only a minor part of the subject. It is claimed for the theory that it leads to an understanding of the world of physics clearer and more penetrating than that previously attained" (Brush, 1989).

Might not Plato and his followers have believed their vision of the universe so penetrating that observation was rightly to be consigned to a minor role? And if they did, can modern scientists aware of their own heritage in Einstein, Eddington, and others, reject such an attitude as non-scientific?

Copernicus saw in his own heliocentric version of Greek geometrical astronomy a penetrating vision of reality, however much the unsigned preface to *De revolutionibus*, added without Copernicus' knowledge, argued for an instrumentalist approach to science (Goddu, 1990; Jardine, 1979 and 1982). Copernicus' understanding of the ontological status of his combination of uniform circular motions was quite otherwise, as a single example suffices to show.

His objection to Ptolemaic astronomy was not on observational grounds; Ptolemy had saved the phenomena about as well as Copernicus managed to. It was with the manner in which Ptolemy saved the phenomena that Copernicus quarrelled. One point of criticism, noted by Copernicus in his prefatory letter to *De revolutionibus*, was that the ancients had not been able:

> ... to discern or deduce the principal thing – namely the shape of the Universe and the unchangeable symmetry of its parts. With them it is as though an artist were to gather the hands, feet, head and other members for his images from diverse models, ... and since they in no way match each other, the result would be monster rather than man. [Kuhn, 1957:139]

This objection is amplified and clarified in section 10 of Book I. Various ancient opinions existed on the order (distance from the central body) of the planets, but planetary arrangements arbitrary in Ptolemy's system followed automatically in the heliocentric hypothesis; connections in the Copernican arrangement of the planets were more than happenstance. In such determination was perceived the theory's penetrating understanding of reality, and hence its own reality. Copernicus found:

> ... underlying this ordination an admirable symmetry in the Universe, and a clear bond of harmony in the motion and magnitude of the Spheres such as can be discovered in no other wise. For here we may observe ... why Saturn, Jupiter and Mars are nearer to the Earth at opposition to the Sun than when they are lost in or emerge from the Sun's rays. ... All these phenomena proceed from the same cause, namely Earth's motion. [Kuhn, 1957:180]

To keep Saturn, Jupiter, and Mars nearer to Earth at opposition (on the opposite side of Earth from the Sun) than at conjunction (seen in the same direction as the Sun) required careful juggling of orbit sizes and speeds in Ptolemy's system, but was a necessary consequence of the Copernican system (Figures 5 and 6). In a similar manner other observed phenomena that were *ad hoc*, arbitrary arrangements in a geocentric system followed automatically from a heliocentric hypothesis. The element of completeness of the heliocentric hypothesis gave Copernicus confidence that he had discovered the real order of the cosmos, not merely a mathematical fiction.

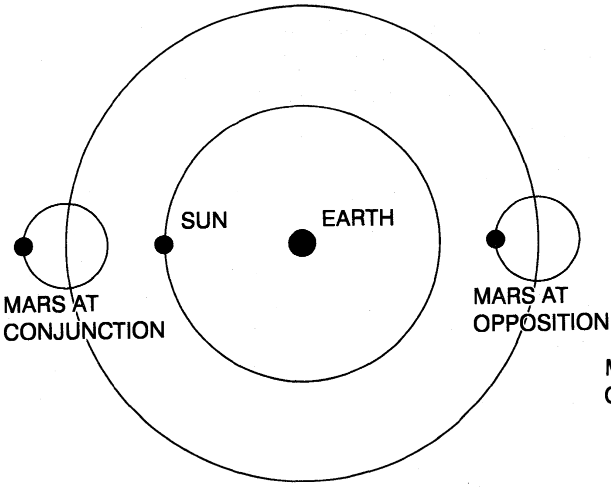

Figure 5. Earth, Sun, and Mars in the Ptolemaic System. Mars is carried on the small circle, its epicycle, which in turn is carried around Earth on the large circle, its deferent. Great care must be taken with the sizes and speeds of the circles to ensure that Mars is at the appropriate place on its epicycle at opposition and at conjunction.

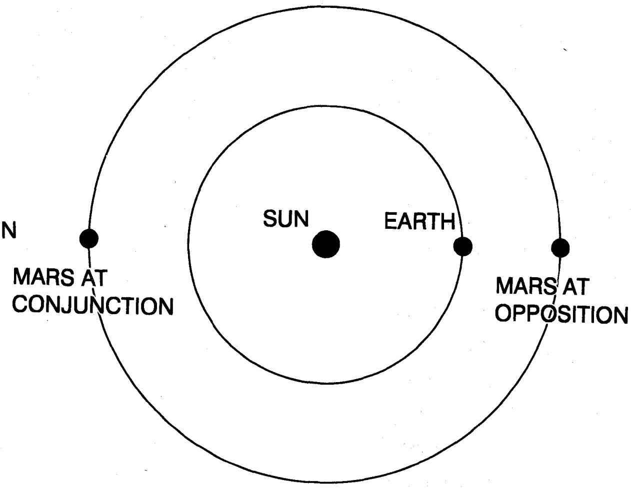

Figure 6. Sun, Earth, and Mars in the Copernican System. In the Copernican system Mars at opposition automatically is closest to Earth, and automatically is farthest from Earth at opposition.

The mathematical realism of Copernicus, as it has been called (Duhem, 1969:xxiv), is not entirely dissimilar to considerations present in contemporary cosmology. The standard big bang theory is in agreement with observation, as was Ptolemaic astronomy in Copernicus' time, but the standard theory requires some extremely stringent initial conditions to be 'put in by hand', as did Ptolemaic astronomy (to ensure, among many arrangements, that Mars always was nearest Earth at opposition and farthest from Earth at conjunction). The inflationary universe theory, in contrast to the standard theory and in comparison to the advantage of Copernican over Ptolemaic theory, does not require that the initial energy density be incredibly close to unity nor does it require a primordial spectrum of inhomogeneities; these follow automatically from the initial inflation and phase transition in the first fraction of a second of the history of the universe (Guth, 1993).

The greater degree of completeness of a theory relative to its rivals does not, of course, guarantee continued agreement between the theory and observation, nor continued acceptance of the theory. A single example from Kepler suffices here. In his *Mysterium Cosmographicum* of 1595, Kepler wrote that he had spent an entire summer racking his brain to discover how the cosmos expressed the nature of its Creator. What Kepler hit upon in a moment of divine inspiration was nothing less than a convincing explanation for the observed fact that there were six planets (his theory was Copernican, in the sense that the Sun and Moon were not planets, but Earth was). There are exactly five regular solids (each with all sides and faces identical), no more and no less. If one of these regular solids is circumscribed about the first circular planetary orbit, and the next planetary orbit put around that solid, etc., one has exactly six planets and five intervening regular solids, no more and no less. Here, seemingly, was the reason for the number of the planets. For Kepler, regular solids did not exist physically in the heavens; rather they were conceived of as archetypes governing the disposition of the planetary orbits (Donahue, 1993a, 1993b).

A scientific theory is, at least for some connoisseurs, more penetrating and more complete and more satisfying to the extent that observed phenomena follow automatically from theory rather than require arbitrary and meticulous adjustments to initial conditions if they are to be reproduced. Rival theories may be equal in an instrumentalist sense, in that both save the same phenomena, but the greater ease with which one saves phenomena can evoke a greater sense of satisfaction, even a sense of beauty. Furthermore, a sense of having discovered reality may well be invoked, but not necessarily on the basis of agreement between theory and observation. If restricted to classification as either instrumentalism or realism, much of science may be closer to realism than instrumentalism – but more a realism of Platonic ideas than an empirical realism.

9 CONCLUSION

Historians need exercise care, of course, lest they read current understanding of the nature of science back into the past and force into a procrustean bed ancients who may have been thinking and doing something very different. Yet at the same time, historians would be foolish not to take advantage of modern formulations of issues and use them to probe the past. The charge of 'presentism' or 'Whig history' is a potent but indiscriminate club, too quickly raised by contextualists and prigs against historians who would use their own experience in science to help understand and empathize with the emotional state of past researchers (Harrison, 1987; Brush, 1995).

The nature of modern science, itself, remains in debate as well. On a personal note, one of the long-term, festering incentives for this study of Plato and science was hearing an otherwise seemingly knowledgeable and sensible philosopher of science deny that a sense of beauty could ever be evoked in anyone by a scientific theory because he, himself, was blind and deaf (these may not be his exact words) to such beauty.

Modern science has an aesthetic element, possibly comparable to that found in ancient Greek geometrical astronomy. The continuation of a cultural value over millennia and over vastly different civilizations would be a remarkable occurrence. No less remarkable would be genetic wiring of the human brain, shaping our requirements for an aesthetically-satisfying understanding of nature. Such speculations are premature, but do suggest further study of the nature of ancient and modern science and possible similarities between ancient and modern aesthetic philosophical values and ways of thinking.

10 REFERENCES

Bechler, Z., 1970. Aristotle corrects Eudoxus. Met 1073 b 39 - 1074 a 16. *Centaurus*, **15**:113-123.

Berggren, J.L., 1991. The relation of Greek spherics to early Greek astronomy. In A.C. Bowen (ed.), *Science and Philosophy in Classical Greece*. Garland, New York, pp. 227-248.

Berry, A., 1961. *A Short History of Astronomy from Earliest Times through the Nineteenth Century*. Dover, New York. Published originally in 1898 by John Murray, London.

Brown, J.R., 1991. *The Laboratory of the Mind: Thought Experiments in the Natural Sciences*. Routledge, London.

Brush, S.G., 1989. Prediction and theory evaluation: the case of light bending. *Science*, **246**:1124-1129.

Brush, S.G., 1995. Scientists as historians. *Osiris*, **10**:215-231.

Cornford, F.M., 1937. *Plato's Cosmology, The Timaeus of Plato*. K. Paul, Trench, and Trubner, London.

Cornford, F.M., 1945. *The Republic of Plato*. Oxford University Press, New York.

Donahue, W.H., 1993a. Kepler's cosmology. In N.S. Hetherington (ed.), *Encyclopedia of Cosmology: Historical, Philosophical, and Scientific Foundations*. Garland, New York, pp. 346-353.

Donahue, Kepler, 1993b. In N.S. Hetherington (ed.), *Cosmology: Historical, Literary, Philosophical, Religious, and Scientific Perspectives*. Garland, New York, pp. 239-62.

Dreyer, J.L.E., 1953. *A History of Astronomy from Thales to Kepler*. Second edition, revised by W. Stahl, with a supplementary bibliography. Dover, New York.

Duhem, P., 1962. *The Aim and Structure of Physical Theory*. Originally published by Princeton University Press, 1954. Translated by P.P. Wiener from the second edition, 1914, *La Théorie Physique: Son Object, Sa Structure*. Marcel Rivière & Cie, Paris.

Duhem, P., 1969. *To Save the Phenomena*: An Essay on the Idea of Physical Theory from Plato to Galileo. Translated by E. Doland and C. Maschler, with an introductory essay by S.L. Jaki. University of Chicago Press, Chicago.

Epistles – see Morrow, 1962.

Evans, J., 1993. Ptolemy's cosmology. In N.S. Hetherington (ed.), *Encyclopedia of Cosmology: Historical, Philosophical, and Scientific Foundations*. Garland, New York, pp. 528-544.

Forbes, E., 1973. The spheres of Eudoxus. *Journal of the British Astronomical Association*, **83**:196-198.

Friedlander, P., 1969. *Plato: I, An Introduction*, second edition with revisions. Translated by H. Meyerhoff. Princeton University Press, Princeton.

Goldstein, B.R. and Bowen, A.C., 1983. A new view of early Greek astronomy. *Isis*, **74**:330-340. Reprinted in Goldstein, 1985. *Theory and Observation in Ancient and Medieval Astronomy*. Variorum Reprints, London, pp. 1-11.

Goddu, A. 1990. The realism that Duhem rejected in Copernicus. *Synthese*, **83**:301-15.

Graßhoff, G., 1990. *The History of Ptolemy's Star Catalogue*. Springer-Verlag, New York.

Guth, A. H., 1993. Inflationary universe. In N.S. Hetherington (ed.), *Encyclopedia of Cosmology: Historical, Philosophical, and Scientific Foundations*. Garland, New York, pp. 301-322

Hargreave, D., 1970. Reconstructing the planetary motions of the Eudoxean system. *Scripta Mathematica*, **28**:335-345.

Harrison, E., 1987. Whigs, prigs, and historians of science. *Nature*, **329**:213-224.

Heath, T., 1913. *Aristarchus of Samos: the Ancient Copernicus. A History of Greek Astronomy to Aristarchus together with Aristarchus' Treatise on the Sizes and Distances of the Sun and Moon. A New Greek Text with Translation and Notes*. Clarendon Press, Oxford.

Hetherington, N.S., 1989. Geological time versus astronomical time: are scientific theories falsifiable? *Earth Sciences History*, **8**:167-169.

Hetherington, N.S., 1990. Hubble's cosmology. *American Scientist*, **78**:141-151.

Hetherington, N.S., 1993a. Eudoxus' cosmology. In N.S. Hetherington (ed.), *Encyclopedia of Cosmology: Historical, Philosophical, and Scientific Foundations*. Garland, New York, pp. 198-201.

Hetherington, N.S., 1993b. Oresme, Nicole. In N.S. Hetherington (ed.), *Encyclopedia of Cosmology: Historical, Philosophical, and Scientific Foundations*. Garland, New York, pp. 451-453.

Hetherington, N.S., 1996. Plato and Eudoxus: instrumentalists, realists, or prisoners of themata? *Studies in History and Philosophy of Science*, **27**:271-289.

Hetherington, N.S., 1997a. Early Greek cosmology; a historiographical review. *Culture and Cosmos*, **1**:10-33.

Hetherington, N.S., 1997b. Ptolemy on trial for fraud: a historiographical review. *Astronomy and Geophysics*, **38**:24-27.

Holton, G., 1978. Themata in scientific thought. In G. Holton (ed.), *The Scientific Imagination: Case Studies*. Cambridge University Press, Cambridge, pp. 3-24.

Hope, R., 1952. *Aristotle, Metaphysics; newly translated as a postscript to natural science, with an analytical index of technical terms*. Columbia University Press, New York.

Høyrup, J., 1996. Changing trends in the historiography of Mesopotamian mathematics: an insider's view. *History of Science*, **34**:1-32.

Jardine, N. 1979. The forging of modern realism: Clavius and Kepler against the sceptics. *Studies in the History and Philosophy of Science*, **10**:141-173.

Jardine, N, 1982. The significance of the Copernican orbs. *Journal for the History of Astronomy*, **13**:168-94.

Kahn, C.H., 1991. Some remarks on the origins of Greek science and philosophy. In A.C. Bowen (ed.), *Science and Philosophy in Classical Greece*. Garland, New York, pp. 1-10.

Knorr, W.R., 1990. Plato and Eudoxus on the planetary motions. *Journal for the History of Astronomy*, **21**:313-329.

Knorr, W.R., 1993. Plato's cosmology. In N.S. Hetherington (ed.), *Encyclopedia of Cosmology: Historical, Philosophical, and Scientific Foundations*. Garland, New York, pp. 499-502.

Kuhn, T.S., 1957. *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought*. Harvard University Press, Cambridge, Massachusetts.

Lloyd, G.E.R., 1978. Saving the appearances. *Classical Quarterly*, 72, new series 28: 202-222. Reprinted, with an introduction assessing subsequent scholarly debate on the topic and Lloyd's modifications and developments in his own position, in Lloyd, 1991. *Methods and Problems in Greek Science*. Cambridge University Press, Cambridge, pp. 248-280.

Lloyd, G.E.R., 1979. *Magic, Reason, and Experience: Studies in the Origin and Development of Greek Science*. Cambridge University Press, Cambridge.

Lloyd, G.E.R., 1981. Plato on mathematics and nature, myth and science. Lecture, subsequently published, with an introduction assessing scholarly debate on the topic and Lloyd's modifications and developments in his own position, in Lloyd, 1991. *Methods and Problems in Greek Science*. Cambridge University Press, Cambridge, pp. 333-351. Supersedes Lloyd's 1968 article: Plato as a natural scientist. *Journal of Hellenic Studies*, **88**:78-92.

Lloyd, G.E.R., 1987. *The Revolutions of Wisdom: Studies in the Claims and Practice of Ancient Greek Science*. University of California Press, Berkeley.

Lloyd, G.E.R., 1991. *Methods and Problems in Greek Science*. Cambridge University Press, Cambridge.

Maula, E., 1974. Studies in Eudoxus' homocentric spheres. *Commentationes Humanarium Litterarum*, **50**:3-124.

McMullin, E., 1990. Comment: Duhem's middle way. *Synthese*, **83**:421-430.

Metaphysics – see Hope, 1952.

Mourelatos, A.P.D., 1980. Plato's 'real astronomy'; Republic 527D-531D. In J.P. Anton (ed.), *Science and the Sciences in Plato*. Caravan Books, New York, pp. 33-73.

Mourelatos, A.P.D., 1981. Astronomy and kinematics in Plato's project of rationalist explanation. *Studies in the History and Philosophy of Science*, **12**:33-73.

Morrow, G.R., 1962. *Plato's Epistles: A Translation, with Critical Essays and Notes*, revised edition. Bobbs-Merrill, Indianapolis.

Mueller, I., 1980. Ascending to problems: astronomy and harmonics in Republic VII. In J.P. Anton (ed.), *Science and the Sciences in Plato*. Caravan Books, New York, pp. 103-122.

Murschel, A., 1995. The structure and function of Ptolemy's hypotheses of planetary motion. *Journal for the History of Astronomy*, **25**:33-61.

Musgrave, A., 1991. The myth of astronomical instrumentation. In G. Munèvar (ed.), *Beyond Reason: Essays on the Philosophy of Paul Feyerabend*. Kluwer Academic Publishers, Dordrecht, pp. 243-280.

Neugebauer, O., 1946. The history of ancient astronomy: problems and methods. *Publications of the Astronomical Society of the Pacific*, **58**:17-43 and 104-142. Reprinted in Neugebauer, 1983. *Astronomy and History: Selected Essays*. Springer-Verlag, New York, pp. 33-98.

Neugebauer, O., 1953. On the 'hippopede' of Eudoxus. *Scripta Mathematica*, **19**:225-229.

Neugebauer, O., 1969. *Exact Sciences in Antiquity*, second edition. Dover, New York. Originally published in 1957 by Brown University Press, Providence, Rhode Island.

Neugebauer, O., 1975. *A History of Ancient Mathematical Astronomy*, 3 vols. Springer-Verlag, New York.

Ragep, F.J., 1990. Duhem, the Arabs, and the history of cosmology. *Synthese*, **83**:201-214.

Santillana, G., 1949. Eudoxus and Plato: a study in chronology. *Isis*, **32**:248-262.

Smith, C. and Wise, N.M., 1989. *Energy and Empire: A Biographical Study of Lord Kelvin*. Cambridge University Press, Cambridge.

Taub, L.C., 1993. *Ptolemy's Universe. The Natural Philosophical and Ethical Foundations of Ptolemy's Astronomy*. Open Court, Chicago.

The Republic – see Cornford, 1945.

Timaeus – see Cornford, 1937.

Toomer, G.J., 1970. Apollonius of Perga. In C.C. Gillispie (ed.), *Dictionary of Scientific Biography*, vol. i. Scribners & Sons, New York, pp. 179-193.

Toomer, G.J., 1984. *Ptolemy's Almagest*. Springer-Verlag, New York.

Vlastos, G., 1965. Degrees of reality in Plato. In R. Bambrough (ed.), *New Essays on Plato and Aristotle*. Routledge & Kegan Paul, London, pp. 1-19.

Vlastos, G., 1980. The role of observation in Plato's conception of astronomy. In J.P. Anton (ed.), *Science and the Sciences in Plato*. Caravan Books, New York, pp. 1-30.

Wasserstein, A., 1962. The role of observation in Plato's conception of astronomy. *Proceedings of the Cambridge Philological Society*, **188** (new series 8):51-63.

Wright, L., 1973. The astronomy of Eudoxus: geometry or physics? *Studies in the History and Philosophy of Science*, **4**:165-172.

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The rise and fall of small astronomical observatories: a case study Dorpat/Tartu Observatory

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Abstract
The history of the Astronomical Observatory of Dorpat/Tartu University is outlined in terms of the activities of its most outstanding astronomers and interpreted, in particular, with allowance for some background factors. Some emphasis is laid on describing and analysing the role of Ernst Öplk, whose life and heritage has so far not been treated adequately by historians of science. The problem of preserving the treasures of the Observatory is reviewed.

Keywords: *Dorpat/Tartu Observatory, F G W. Struve, J H Mädler, E J Öplk.*

1 INTRODUCTION

Present-day scientific research is concentrating more and more at big institutions, the small ones often having become obsolete. Typically, this is the case with astronomy. Many of the small observatories which once flourished have given up astronomical research to become a museum or, in some instances, have closed. Their stories form completed chapters in the annals, and their past role and contribution to the development of ideas and instrumentation are awaiting evaluation. This article is devoted to one of those modest institutions which has changed direction.

The retrospective assessment of the heritage of the lost observatories has at least two important aspects. Firstly, if an observatory building together with its equipment and archives is still extant, its museological value can and is to be determined. Secondly, if leading astronomers happened to work there, their meaning for the history of astronomy can be best explained by identifying them with 'their' institution.

Among small astronomical observatories which functioned in the late nineteenth and the first half of the twentieth centuries, the University Observatory at Tartu (former Dorpat in the autonomous province Livonia of Tsarist Russia) presents a remarkable case. This is so because the activities of as many as three leading pioneers can be related to it. The story of Dorpat/Tartu Observatory, if told on the level of world science, can essentially be reduced to describing and evaluating the work and life of three outstanding astronomers: Friedrich Georg Wilhelm Struve (1793 Altona, Denmark – 1864 Pulkowa, Russia), Johann Heinrich Mädler (1794 Berlin, Prussia – 1874 Hannover, Prussia) and Ernst Julius Öpik (1893 Port Kunda, Province Estonia – 1985 Bangor, Northern Ireland). Each of them spent their most fertile working years (20 - 30) at Dorpat/Tartu Observatory.

Struve's and Mädler's lives, together with their contributions to science, have recently been documented after a critical revision of their respective earlier biographies (Batten, 1988; Eelsalu and Herrmann, 1985). Surprisingly, no full-scale biography has so far been devoted to Öpik [some biographical details may be found in Lindsay (1972) and Öpik (1977), Ed.]. To overcome this, we shall focus some attention to him, while we try to describe the rise and fall of Dorpat/Tartu Observatory as a university institution in broad terms with particular reference to the activities of all three astronomers.

In 1979, Kenneth Lang and Owen Gingerich published a carefully-selected collection of those articles which, to their minds, had brought about the most important changes in our understanding of astronomy, astrophysics, and cosmology (Lang and Gingerich, 1979). The collection contains 160 articles issued between 1900 and 1975; Dieter Herrmann subjected the body of references annexed to these articles to a statistical analysis (Herrmann, 1984).

From the relative frequency of the authors quoted in this collection, Herrmann deduced a list of the 24 leading astrophysicists and cosmologists of this century, or, more strictly speaking, of its first three-quarters. Since then, astronomy is becoming more and more impersonal and anonymous with every decade due to the growing importance of teamwork based upon the use of modern super-equipment such as space observatories and global interferometry. Therefore, 1975 may have been a reasonable milestone indeed.

As expected, the list includes such names as Hans Bethe, Arthur Eddington, Albert Einstein, Enrico Fermi and Fred Hoyle, all known far beyond the community of scientists. Edwin Hubble has later joined this group by means of the space telescope named after him. The remaining names are familiar at least to everyone concerned with astronomical research. Ernst J Öpik belongs to that group.

In Estonia, and probably in Northern Ireland, Öpik's name is known to a wider community since it was in those two countries that he spent most of his life and wrote the bulk of his works. His life was rather dramatic because twice he had to change his country of residence under menacing circumstances. This happened first in 1921 when he reached the newly-independent Estonia from his temporary work place in Central Asia, a region controlled by the Russian Bolsheviks. In 1944 he left Estonia hurriedly to the West together with tens of thousands of his compatriots in the face of the anticipated invasion by the Red Army.

It is interesting to note that so far nobody has attempted to draw up a full-scale biography of E J Öpik. He seems to have been a genius sometimes difficult to get along with, whose personality and philosophy can best be reconstructed without mythologization of the hero by questioning his former colleagues and critics. Öpik made a number of 'strong' emotional statements extending to expressions of "wishful thinking" recalled in some obituaries. All these should be evaluated against a balanced historical background. With every year, the number of his contemporaries diminishes, thus rendering the task of writing a critical biography more difficult.

Öpik was a prolific writer (Öpik, 1972; Astronomy and Geodesy ... ,1969; Öpik, 1989) with these lists adding up to more than 800 books, papers, articles, and short notes. The Armagh bibliography (Lindsay, 1972) is systematic, the publications being divided between 11 subject matters. Seven of these cover original astronomical research. which can be characterized by the following labels:

a) Small bodies and diffuse matter in the Solar System;
b) Major bodies of the Solar System;
c) Movements and collisions of the bodies of the Solar System;
d) Stars, interstellar medium, and stellar systems;
e) The structure and evolution of the Sun and the stars;
f) Palaeoclimatology and solar-terrestrial relationships; and
g) Cosmology, cosmogony, and astrobiology.

As we see, this classification is entirely based upon the classes of all the objects in the universe. The ideal suitability of the adopted object-bound classification to Öpik's heritage speaks of his physically, not mathematically, orientated approach to astronomy. However, since his pre-university years, he was able to adapt probability theory to the needs of meteor and, later, stellar statistics. He summed up his contribution to statistical methods in a lecture course (Öpik, n.d.).

Öpik was guided by a practical philosophy which departed from the understanding that mankind's life and future is ultimately determined by the Sun. He summed up his early studies of the nature of the Sun in a monograph written in the popular style. The book was entitled *The Sun in the Light of the Latest Investigations* and was published in Russian twice (in 1922 and 1927) and also in Estonian (1928).

Consequently, he gave clear priority to investigations into the fate of the Sun. Hence it follows that the system of Öpik's written heritage or, at least a substantial part of it, might be rearranged to assume the form of a pyramid of studies with the Sun on the top.

By the time Öpik decided to leave his homeland, he seems to have already accomplished his life's main mission. This can be explained best by resorting again to Herrmann's conclusions. After having arranged the major astronomical discoveries of the period 1900 to 1975 into a time series, he could single out six definite peaks. The 1938-1942 peak was clearly identifiable with the time span where the internal nature of the stars, in particular that of the Sun, was explained in terms of nuclear reactions. From among the leading 20, H A Bethe, G Gamow, and E Öpik (together with C F Freiherr, C F v Weizsäcker, and R Oppenheimer) were the independent main contributors to that major breakthrough in astrophysics, as well as in physical science as a whole.

Öpik published his investigations into stellar structure, energy sources, and evolution in the publication series of the Tartu University Astronomical Observatory. Obtaining access to prestigious international journals seems not have been a priority for him, while at Tartu unlimited publishing space was available to him.

Although Öpik was not unknown to some circles in the English-speaking community since his participation in the 1928 General Assembly of the International Astronomical Union in Leyden, and his stay at Harvard as visiting lecturer and research associate between 1930 and 1934, it took a long time for him to make his mark in that community.

It is noticeable that the forerunner of Lang's and Gingerich's *Source Book* published by H Shapley in Harvard as late as 1960 still ignored Öpik (Shapley, 1960). There may have been political deliberations behind that. Indeed, Öpik's fiercely anticommunist attitude was, without doubt, known to Shapley, until 1952 Head of Harvard University Observatory [Shapley's politics were regarded as left wing by his contemporaries and compatriots and he advocated a more co-operative attitude towards the Soviet Union at the beginning of the Cold War period. Ed.].

If Öplk had stayed at Tartu, instead of fleeing to the West, he probably would have remained a somewhat exotic figure for the western astronomers. Already in 1932, he had declined an offer by Shapley for a permanent professorship in Harvard. So, paradoxically, Öpik's *bête noire*, the Soviets, rendered him a service by forcing him to emigrate, which eventually brought him out of the provincial dullness. On the other hand, between the two World Wars Öpik saved the sinking renown of Tartu Observatory, above all as the main contributor to the its Publications and the only member of the International Astronomical Union from Estonia. At Tartu he conducted astronomical classes, where a new generation of astrophysicists were trained. These were capable of taking over after Öpik had left. Nevertheless, after his departure the Observatory fell back to almost obscurity, where it had remained for a long time before him. The eclipse of Dorpat Observatory began in the 1870s with its failure to carry out the measurement of the Dorpat zone of the prestigious astrometric general catalogue of the Astronomische Gesellschaft.

Paradoxically again, at Tartu Öpik was not the Observatory's Director, a post coupled with a professorship, but carried only the observer's modest title. It has been argued that a directorship would not have suited his character anyhow. His merits were yet recognized by the Estonian State in 1938, when, together with a dozen of other leading scientists, he was invited to create the (unfortunately short-lived) Estonian Academy of Sciences.

The old Dorpat University, closed in 1710 and refounded in 1802 as a German language institution, built its Astronomical Observatory (Figure 1) at the beginning of the 1810s. The famous founder of the Struve astronomical dynasty and an alumnus of

Figure 1. The Tartu Observatory, *circa* 1825. (Courtesy of Tartu Observatory.)

Dorpat University F G W Struve (Figure 2) was charged with equipping and running it. In the early 1820s it was turned into the centre for training the Russian Imperial Army and Navy officers in the matters of geodesy and cartography (Dick and Eelsalu, 1996).

The quick rise of the Observatory is attributed, on the one hand, to Struve's extraordinary scientific and diplomatic abilities and, on the other hand, to the military experience gathered by the Tsar and his supreme military command. Obviously, the 1812 war against Napoleon together with campaigns in Central Asia and elsewhere showed the importance of military optics as well as all kinds of instruments for and skills in mapping and topographic positioning. In Struve, the Tsar's Headquarters discovered a man who could be trusted with training the officer corps in those matters.

When returning from the 1814/1815 Vienna Conference, the Tsar, Alexander I, and his wife visited Munich, famous for its optical workshops. These were inspected by the Empress, a German by birth[1]. In 1824, the Observatory, generously financed by the Tsar, was equipped with an achromatic and equatorially-mounted refracting telescope produced by J v Fraunhofer in his Munich workshop to become the largest and most modern instrument of its kind at that time (Sang, 1987). A year later, Fraunhofer provided his telescope with an excellent ocular micrometer.

However, in the early 1830s the Imperial St. Petersburg Academy of Sciences decided to establish a central astronomical observatory. Struve together with his colleagues chose the Pulkowa (Pulkovo) hill to become its site. This decision implied moving the officers' training centre closer to the capital St. Petersburg. In Pulkowa, Struve seized opportunities to strengthen his collaboration with the Imperial Headquarters. Notably one of Struve's earliest pupils F W R v Berg (1794 Sagnitz, Livonia – 1874 St Petersburg), later a Count, a Field Marshal, Chief of the Tsar's Headquarters and his vice ruler in Poland and Finland, became his close friend and a vigorous promoter of his geodetic activities (Dick and Eelsalu, 1996).

Beginning with the 1840s, Dorpat Observatory became inevitably eclipsed by the Imperial Main Observatory at Pulkowa and was doomed to provinciality. After having shuttled between Dorpat and St. Petersburg for almost a decade, Struve left Dorpat definitely in 1839 together with his lieutenants. He did so without having secured a successor to himself. The University succeeded in reviving the activities of its Observatory a year later when J H Mädler (Figure 3) agreed to take it over. In the late 1830s he had become world renown as a selenographer in Berlin, where he, together with W Beer the owner of a private observatory, had published a full set of extremely accurate maps of the moon (Maurer, 1999).

Figure 2. Friedrich Georg Wilhelm Struve. (Courtesy of Tartu Observatory.)

Mädler succeeded in slowing down the decline of the Observatory for a quarter of a century. Like Struve, he made micrometric measurements of double stars and planets with the Fraunhofer telescope (Figure 4). However, his greatest service to Dorpat University is to be seen in his literary campaign of making Dorpat Observatory known all over Europe. He not only published a considerable number of astronomical books, but also flooded the major German language journals with hundreds of his writings about astronomy and Dorpat's contribution to this science (Eelsalu and Herrmann, 1985; Eelsalu, 1999).

Did Struve and Mädler also belong to the leading astronomers of their time as Öpik did? No comparable investigation seems to be available. The list of the prominent astronomers of the 1800s drawn up by F. Kempf (1911) includes some 50 of their contemporaries. A comparison of those with the name index of

Figure 3. Johan Heinrich Mädler. (Courtesy of Tartu Observatory.)

D B Herrmann's (1975) authoritative review of 19th century astronomy shows that a few names do not appear in the latter book at all, while most of the others are mentioned less frequently than Struve and Mädler. Although Mädler's achievements in selenography were performed earlier in Berlin, in Dorpat he laid the foundations of what became later known as stellar dynamics. Struve had accomplished his fundamental investigations into double star astronomy and stellar parallaxes with the Fraunhofer micrometer before leaving Dorpat for Pulkowa.

Struve's and Mädler's visions of the role of Dorpat Observatory differed radically. Wilhelm Struve and his son (and successor in Pulkowa) Otto were of the opinion that Dorpat's decline was caused above all by Mädler's inability to use the Observatory's potential properly and they successfully tried to discredit him (Eelsalu and Herrmann, 1985). Their clumsy pressure upon Mädler's successors, loyal to them, to revert to positional astronomy, was a failure, as mentioned above. Their conservatism later led them even to a clash with their Swedish speaking colleagues in Pulkowa, who had arrived there with a different philosophy and who later took Pulkowa over (Krisciunas, 1984). A similar ideological conflict later flared up in Babelsberg Observatory presided over by Herrmann Struve, a grandson of Wilhelm Struve working in Germany (Dick, 1997).

The successful attempt by Struve to demonstrate the possibility of measuring relative parallaxes of stars remained the culmination point for the whole history of

Dorpat/Tartu Observatory. No serious astronomical history can avoid mentioning this milestone in astronomy. Yet the parallax story, above all the problem of how the priority in that achievement should be shared between Struve, and F W Bessel in Königsberg, who both accomplished the same task almost simultaneously, seems to have become more or less exhausted only recently after the publication by W R Dick (1988) of their correspondence about that matter. One inevitably has to agree with A H Batten (1991), who says "Although at least one of the earlier measurements (Bessel's on 61 Cygni) was partly or entirely stimulated by Struve's work, the time was ripe, the instruments were available and someone would have succeeded at about that time." This is true all the more so because by that time more than one type of exact instruments were elaborated; while Struve used an ocular micrometer, Bessel resorted to a so-called heliometer consisting of two half-lenses mutually shifted by a micrometric screw.

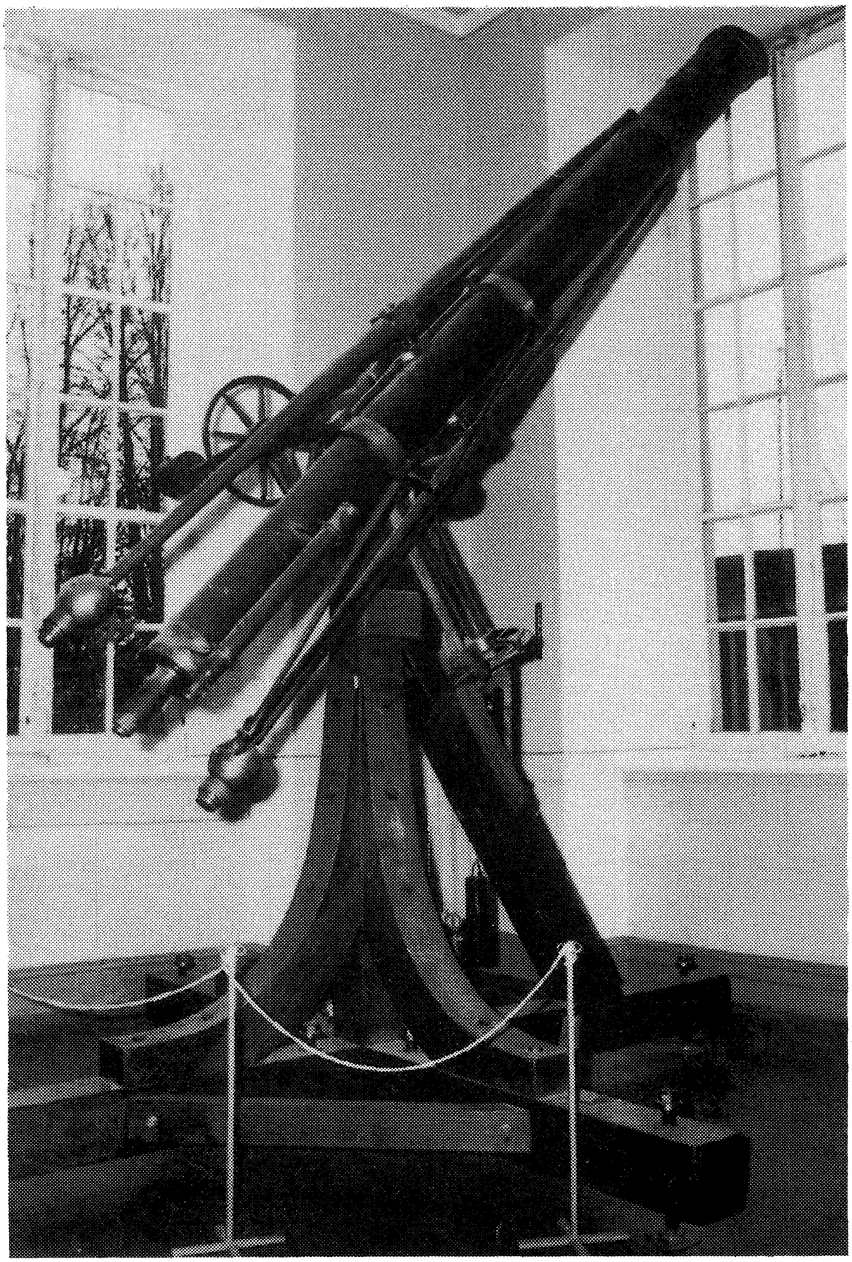

Figure 4. The 9-inch Fraunhofer refractor. Courtesy of Tartu Observatory.)

Later in the 1800s, astronomical activities at Tartu came to almost standstill due to the outdated equipment, while the Observatory became the ground of considerable geodetical and seismological undertakings. In the 1860s, the Tsarist central authorities gradually started to introduce a new policy line in respect of the Baltic Provinces with the aim of reducing their domination by the Baltic German elements. The German-speaking Dorpat University was chronically under-financed because it staunchly resisted the russification by sticking to its (outdated) autonomy (Siilivask, 1985).[2] In the 1890s the resistance was broken and the German-speaking professors were ousted. Among others, W Struve's grandson Ludwig, who held at Dorpat the observer's post and was expected to assume the directorship, had to go. These steps were reminiscent of the purge in Pulkowa, where W Struve's son Otto was forced to leave together with the German-speaking part of his staff.

The russification was accompanied by an improvement in the financing of the University. A project for reconstructing the Observatory was proposed and subsequently approved by the State (Traat, n.d.). The work was to begin in 1915. Unfortunately, World War I forced the University to shelve its ambitious projects. However, already in 1911 it had received a Zeiss refracting telescope coupled with a Petzval-type wide-field camera. It was in the 1920s that Öpik made a long series of micrometric double star measurements with this telescope, so reviving the tradition of his distant forerunners.

In 1938, Öpik submitted to the Estonian Academy of Sciences not only a list of his papers (Öpik, 1989), but also his curriculum vitae including a classification of his printed scientific production since 1912 (Akadeemik Ernst Julius Öpik, 1988). Although the bulk of his papers belongs to his Tartu period begun with 1922, some are to be associated with his four-year stay in Harvard. The following is a translation of this classification outlining Öpik's contribution to the Tartu Observatory in an abbreviated and slightly-modified form:

1. Telescopic observations of planets, 1912-1937, 43 pp.;
2. Observations of meteors and the treatment of observations, 1913-1937, 444 pp.;
3. Meteor physics, meteor craters, meteor flight dynamics, 1916-1937, 160 pp.;
4. Visual and photographic photometry, etc., 1912- 1935, 258 pp.;
5. Theoretical photometry and spectrophotometry, photometric catalogues, stellar colour parallaxes, brightness distribution on the planets' and the Sun's disc, 1914- 1931, 346 pp.;
6. Measurements of double stars, determinations of positions of comets, observations of solar eclipses, etc., 1914- 1932. 99 pp.;
7. Determination of stellar spectroscopic parallaxes, 1931-1932, 76 pp.;
8. Star counts from copies of Carte du ciel maps, 1924-1933, 223 pp.;
9. Stellar statistics, 1922-1933, 348 pp.; and
10. Theoretical astrophysics: densities of double stars, distances to spiral nebulae, dust dynamics, stellar interiors, subatomic energy sources stellar evolution differences in chemical composition of stellar atmospheres, 1915-1938, 274 pp.

The list deserves at least the following comments:

(i) Works classified under Items 1 and 7 were performed entirely outside Tartu;
(ii) Most of the Items were initiated before Öpik's return from Russia;
(iii) Item 8 representing the use of one particular method of stellar statistics need not be separated from Item 9;
(iv) Item 10 is to be split into two separate items because the distances to spiral nebulae and galactic dust concern dynamics of stellar systems, while the rest deals with stellar physics;
(v) Those works which secured to Öpik a place among the leading 20 in the above sense belong to Item 10 or, rather, to its stellar and solar part;
(vi) While the Armagh classification of Öpik's printed heritage, discussed at the beginning of this paper, was object-bound, Öpik's own classification was method-bound, so that it is not easy to juxtapose the two; and
(vii) One notices that the theoretical tools used by Öpik did not include quantum mechanics.

As already pointed out, Struve succeeded because of his skilful co-operation with the Tsarist military authorities. Öpik attempted to proceed similarly, although on a scale commensurable with the small dimensions of the Republic of Estonia and its defence forces. As a patriot, Öpik joined the paramilitary Defence League after the abortive Komintern-led bloody Communist coup in 1924, where he was put in charge of the local anti-chemical unit. Öpik as schoolboy had used the facilities of his gymnasium (secondary school) at Reval/Tallinn) to make lots of chemical experiments.

Öpik's research relevant to defence forces brought him grants, which he could also use for astronomical research. Defence against gas warfare required knowledge of the evaporation properties of liquids, as well of the evaporation conditions and turbulence parameters of poisonous gas clouds. Öpik had encountered evaporation problems in his research of meteor flight in the atmosphere. His investigations into defence problems can be illustrated by quoting an extract from a letter which he sent in 1938 to a Canadian scientist. The extract goes as follows:

> ... your reprint: 'Evaporation from Free Water Surfaces' ... is of considerable value from the standpoint of defence in chemical warfare, a question which perhaps is of more vital interest to us than to the Dominion of Canada.
>
> As to my Universal Hand Anemometer and my pamphlet referring to the diffusion of gas clouds, the subject is indeed intimately related to your problem. I have a more extensive manuscript 'On the Diffusion of Gas Clouds', where I treat the subject theoretically, and which I never intend to publish; a copy of it has been sent to the Chemical Warfare Service, London, at their request. (Eelsalu, 1988)

In 1967, Öpik (Figure 5) recalled his pre-war defence research in a memoir (Öpik. 1967).

The fierce battles of 1944 miraculously saved the building of the Observatory as it had been the case with the battle of 1941, when the Red Army was driven out. Unfortunately, the looting accompanying the chaos caused considerable damage to the collection of old instruments. The Soviet style science left for the universities only a secondary role. That style copied and refined the Tsarist tradition of centralized science. In pre-revolutionary Russia science was dominated by the St. Petersburg Academy. In particular, its Pulkowa Observatory had initially been given a supervisory status over all the astronomical institutions (e.g. see Krisciunas, 1984) In practice, as Mädler once recalled, this role turned out to be inapplicable (Eelsalu and Herrmann, 1985). Yet in the Soviet Union, the Astronomical Council of the Soviet Academy of Sciences achieved this goal. The Academy, as an instrument of a totalitarian state, carried out its control through the puppet academies created in the so-called Soviet Republics, the Soviet Estonia included, while the universities were degraded, except that of Moscow. In 1948, the newly-founded Academy of Sciences of the Estonian SSR. took over the premises and inventory of the University Observatory, which thereby ceased to exist as such.

After having recruited a number of astrophysicists, among them a few disciples of Öpik, the Soviet Estonian Academy, strongly backed by the USSR Astronomical Council, built its own observatory outside Tartu in the early 1960s. The choice of the site was inspired by Öpik's pre-war search for a future observatory. A pretext for the rebirth of observational astronomy was found in the launching of the Soviet Earth satellites and their eventual telescopic monitoring for military purposes. As a propagandistic argument for achieving an approval to build the Academy's observatory, a Struve-myth was created and his name assigned to it, while, of course, Öpik's name was a taboo at that time. Now the trends have reversed since attempts are made to mythologize Öpik in the interests of national pride (e.g. Jõveer, 1993).

While the Academy used the premises of the old Observatory as a springboard to its own observatory, its historical instrument collection, library, and archives were

Figure 5. Ernst Julius Öpik. (Courtesy of Tartu Observatory.)

neglected. The first step in dissipating its treasures began in the 1960s with the transfer of its library to the Academy's observatory. The story of how the partially unsuccessful fight for appraising and saving the treasures went on until the end of the 1980s has already been told (Eelsalu, 1991).

At the beginning of the 1990s, the present writer launched an international campaign for overhauling the Big Fraunhofer Telescope. The operation was successful thanks to support from abroad (Eelsalu, 1994; Ruusalepp and Pehk, 1994). The completion of the repair coincided with an international conference in 1993 at Tartu devoted to Struve's and Mädler's bicentenary and Öpik's centenary (Geodeet, 1994). The conference produced two resolutions to the effect of (a) ensuring the future of the Big Refractor and (b) preserving all the relics of the Meridian Arc Measurement from the Arctic to the Danube 1818-1848, including the building of Tartu Observatory. The latter resolution, proposed by Finnish geodesists and later submitted by A H Batten to the 1994 General Assembly of the International Astronomical Union in The Hague, was passed there, but, apparently, has so far remained ineffective.[3]

A heavy blow to the efforts of preserving the treasures of the Observatory was caused by the disorderly return of the building of the Observatory to the University in 1996 without any stock-taking or agreement between the University and the Academy's observatory about the future of the treasures. The interests of Tartu City Museum, which earlier had contributed to the preservation of the inventory, were ignored altogether. The University has expressed no desire to preserve the treasures as a museum. The library and the archives have been dissipated further, and. the same fate may be eventually shared by the minor instruments. There seems to be no certainty about the whereabouts of, for example, such documents as Struve's travel report of 1820 (Raudsepp, 1987), his MS of *Mensurae micrometricae* (Eelsalu, 1987), or Öpik's personal files (Jõeveer, 1987).

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NOTES

1 Tsar Alexander's short visit to Munich is mentioned on page 336 of his biography: Russkii biograficheskii slovarj, vol. 1, St-Petersburg, 1896 (in Russian). In a private communication to the present author, Mr Rolf Riekher has called his attention to Joseph v. Utzschneider's diary, who was in charge of the Munich workshops at that time. According to the diary, quoted by Mr Riekher, the workshops were visited only by the Empress Luise Marie, while the Tsar himself had given up his plans to drop in on Munich on his way back from Vienna.

2 V K Abalakin (in his introduction to the Russian language review book "150 years of Pulkovo Observatory", Leningrad, 1989) recalls that the Tsar quadrupled the budget of Dorpat Observatory in connection with his order to start erecting Pulkovo Observatory. From V Lewitzky's monograph "Astronomers of Yuryev University 1802-1894" (Yuryev, i.e. Dorpat, 1899, in Russian) one gets the impression that Struve used this money mainly in the interests of his Meridian Arc Project. At the same time Struve replaced his order to the instrument-maker Repsold in Hamburg for a new meridian circle for Dorpat by a similar order for Pulkovo.

3 As a result of the 1993 conference, the Director of Armagh Observatory together with E Öpik's son, Uno, arranged the transfer of a photocopied set of Öpik's writings to Tartu. The set, bearing the title *The Collected Works of Ernst Julius Öpik*, had originally been produced in Armagh between 1983 and 1985. It consists of the following volumes:

Vol. 1, 1912-1921, 145 pp.;
Vol. 2, 1920-1929, 645 pp.;
Vol. 3, 1930-1949, 591 pp.;
Vol. 4, 1950-1959, 915 pp.;
Vol. 5, 1960-1969, 979 pp.;
Vol. 6, 1970-1980, 664 pp.;
Supplement, 1910-1976, 259 pp.

The collection contains neither the copies of the two Russian editions of the above-mentioned monographs "The Sun ... " nor the posthumous editions of Öpik's writings in Estonia.

REFERENCES

Akadeemik Ernst Julius Öpik. Eluloo-andmeid. (In Estonian, with a foreword by H. Eelsalu). 50 aastat Eesti Teaduste Akadeemiat. *Teaduslugu ja nüüdisaeg*. (V vabariikliku teaduskonverentsi materjalid) Tallinn, pp. 70-73 (1988).

Astronomy and Geodesy in the Estonian SSR (in Russian). Tartu, pp. 168-170 (1969).

Batten, A.H., 1988. *Resolute and Undertaking Characters: The Lives of Wilhelm and Otto Struve*. Reidel Publishing Company. Astrophysics and Space Science Library, vol. **139**.

Batten, A.H., 1991. The Roles of Ideas, Instruments and Individuals in the History of Knowledge. *Tartu ülikooli aialoo kusimusi*. **XXV**, Tartu, pp. 222-226.

Dick, W.R., 1988. Aus dem Briefwechsel von F. W. Bessel und W. Struve. Die Parallaxenmessungen 1835-1840. *Archivalia astronomica*. Tartu, pp. 23-31. (*Tartu Teated* nr. 90).

Dick, W.R., 1997. Die Verlegung der Berliner Sternwarte nach Babelsberg – ein konservativer Neubeginn. *Berichte zur Wissenschaftsgeschichte*, **20**:297-305.

Dick, W.R. and Eelsalu, H., 1996. Die Dorpater Struves und der Generalfeldmarschall Friedrich Wilhelm Rembert Berg. *Jahrbuch der akademischen Gesellschaft für deutschbaltische Kultur in Tartu/Dorpat*, Band 1, Tartu, pp. 61-66.

Eelsalu, H., 1987. The archives of the old Tartu Observatory – an outline. *Archivalia cosmographica*, Tartu, pp. 4-5. (*Tartu Teated* nr. 88).

Eelsalu, H., 1988. About astronomical research trends in Tartu (in Estonian). 50 aastat Eesti Teaduste Akadeemiat. *Teaduslugu ja nüüdisaeg*. (V vabariikliku teaduskonverentsi materjaild). Tallinn, pp. 70-73.

Eelsalu, H., 1989. Die Dorpater Sternwarte und die Staatsmacht. In F. Krafft and C. *J. Scriba (eds.). XVIII* International Congress of History of Astronomy. Abstracts. ICHS, Hamburg und München. Abstract J4-1.

Eelsalu, H., 1991. The Tartu (Dorpat) Observatory – a neglected astronomical monument of the history of Tartu University. *Tartu ülikooli ajaloo küsimusi* **XXV**, Tartu, pp. 218-2l1.

Eelsalu, H., 1994. Big Fraunhofer's "short" story. (With a foreword by A. Haas). *Journal of the Antique Telescope Society*, **6**:13-15.

Eelsalu, H., 1998. Ergänzungen und Quellen zur Mädler-Forschung. *Beiträge zur Astronomiegeschichte*, Nr. 1, 115-124.

Eelsalu, H. and Herrmann, D.B., 1985. Johann Heinrich Mädler (1794-1874). *Eine dokumentarische Biographie*. Akademie-Vertag, Berlin. Veröffentlichungen des Forschungsbereichs Geo- und Kosmoswissenschaften, Heft 12.

Herrmann, D.B., 1975. *Geschichte der Astronomie von Herschel bis Hertzsprung*. VEB Vert. der deutschen Wissenschaften, Berlin.

Herrmann, D.B., 1984. Astronomie im 20. Jahrhundert. Eine quantitative Analyse des "Source Book of Astronomy and Astrophysics". *Die Sterne*, Heft 5, pp. 284-290 (Mitteilungen Archenhold-Sternwarte Berlin-Treptow, Nr 151).

Jõeveer, M., 1987. Ernst Öpik's file in the archives of the old Tartu Observatory. *Archivalia cosmographica*, Tartu, pp. 17-18. (Tartu Teated nr. 98).

Jõeveer, M., 1993. Ernst Öpik – the last all-knower (in Estonian). *Akadeemia*, Tartu, nr 10, pp. 2051-2061.

Kempf, P. (ed.), 1911. Newcomb-Engelmann. *Populäre Astronomie*. Verl. W. Engelmann, Leipzig. Anhang.

Krisciunas, K., 1984. The End of Pulkovo Observatory's Reign as the 'Astronomical Capital of the World'. *Quarterly Journal of the Royal Astronomical Society*, **25**:301-305.

Lang, K.R. and Gingerich, O. (eds.), 1979. *A Source Book of Astronomy and Astrophysics*. Harvard University Press, Cambridge, Mass.

Lindsay, E.M., 1972. Ernst Julius Öpik, Dr. Phil. Nat., D.Sc. (Hon.), M.R.I.A., M. New York A.S.C. *The Irish Astronomical Journal*, Special Issue, **10**:1-8.

Maurer, A., 1998. Die Mondkarte von W. Beer und J. H. Mädler. *Beiträge zur Astronomiegeschichte*, Nr. 1, 125-140.

Öpik, E., 1967. A study in microturbulence in channeled flow of air near the ground. *The Irish Astronomical Journal*, **8**:76-89. (Contributions from the Armagh Observatory No. 61.)

Öpik, E., 1972. Classified list of astronomical publications, 1912-1969. *The Irish Astronomical Journal*, Special Issue, **10**:9-22.

Öpik, E., 1977. About dogma in science, and other recollections of an astronomer. Annual Reviews of Astronomy and Astrophysics, **15**:1-17.

Öpik, E., 1989. A list of printed works (in Estonian). 50 aastat Eesti Teaduste Akadeemiat. *Teaduslugu ja nüüdisaeg*. (V vabarilkliku teaduskonverentsi materjalid. Tallinn, pp. 74-79.

Öplk, E., n.d.. *Astronomical Statistics*. Harvard University. A mimeographed copy at Tartu.

Raudsepp, M., 1987. W. Struves Reisebericht aus dem Jahre 1820 betreffend die damalige astronomische Instrumentenkunde. *Archivalia cosmographica*, Tartu, pp. 6-16. (*Tartu Teated* nr. 88).

Ruusalepp, E. and Pehk, M., 1994. Die Überholung des Fraunhoferschen Refraktors. *Geodeet*, nr. 6, Tartu, pp. 24-25.

Sang, H.-P., 1987. *Joseph von Fraunhofer, Erfinder, Unternehmer*. Verl. Dr. P. Glas, München.

Shapley, H. (ed.), 1960. *Source Book in Astronomy 1900-1950*. Harvard University Press, Cambridge, Mass.

Siilivask, K. (ed.), 1985. *History of Tartu University 1632-1982*. Perioodika, Tallin, pp. 94-95.

The resolutions and the reports of lthe international scientific conference devoted to the 200th anniversary of F. G. W. Struve and J. H. Mädler and the 100th anniversary of E. J. Öpik. *Geodeet*, nr. 6, Tartu (1994).

Traat, P., n.d. An unpublished conference report. Private communication.

* * *

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A presocratic cosmological proposal

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Abstract

Alcman is known as one of the greatest lyric poets of the ancient world. However, the publication of the Oxyrhynchus papyrus No. 2390 in 1957 caused a great deal of excitement. This papyrus, from the second century AD, contains parts of a comment written in prose, which implies that in one of his poems Alcman deals with a kind of a god-created cosmogony. That cosmogonical view, formulated by Alcman in the middle of the seventh century BC, describes much older considerations that resemble certain modern cosmological conjectures. In terms of the latter, the observable universe emerged out of a point singularity interior to a white hole which, due to the time symmetry of Einstein's field equations, can be considered as a time-reversed black hole.

Key words: *history, Alcman, cosmogony, cosmology*

1 INTRODUCTION

One of the most important Greek lyric poets of antiquity, who shaped 'choral' poetry in Sparta as a special literary form in the middle of the seventh century BC, was Alcman, son of Damas or Titarus (Voutierides, n.d.). Due to his incomparable art, Alcman held the first position in the Alexandrian canon. According to Athenaeus, "Alcman was the best of the erotic poets." (Skiadas, 1981). The name 'Alcman' is an adjustment to the Doric idiom of the Ionic name Alcmaeon, but it should not be confused with the Pythagorean Alcmaeon (*c*. 500 BC), son of Perithos from Kroton, the Greek colony in South Italy (Tsantsanoglou, 1973).

As Skiadas (ibid.) reports, according to *Suidae* (under the lemma 'Alcman'), the poet lived during the XXIVth Olympiad (672-668 BC) when Ardys was governor of Lydia, while according to the ecclesiastic writer, Eusebius, Alcman flourished around 659 BC. Similarly, in a fragment of the Oxyrhynchus Papyrus No. 2390 it is reported that Alcman mentions 'Leotychis', king of Sparta, by name (Harvey, 1967). We can assume that Alcman lived during the second half of the seventh century BC.

According to *Suidae* (A.P. 7, 709, Alexandros Aetolos), Alcman came from Greek Ionia (the city of Sardes, in Lydia) and then moved to Sparta. This view can be found in a memorandum in the Oxyrhynchus Papyrus No. 29 (P. 0xy. XXIX fr. 1, col III, 30 κ. ε. (=10 (α), 30 κ. ε. P.)) which states: "... then, the Lacedaemonians appointed Alcman, descending from Lydia, as a teacher [tutor] to the daughters and ephebes ..." However, this view may not hold, since the Oxyrhynchus Papyrus No. 2389 (P. Oxy. 2389, fr. 9 col. 1(=13(α), P. 11 κ. ε.)) states that "... it seems that Aristoteles and the rest were deceived and they thought him [Alcman] to be a Lydean ..." As for the disagreement concerning the birthplace of Alcman, Antiparus from Thessalonike (*Suidae*, A. P. 7, 18, 5) remarks:

> There is a dispute between the two mainlands [cities-regions] whether [Alcman] descended from Lydia or Lacedaemona. Many [cities] are considered as the native country of the servants of poetry ...

Pausanias (III, 15, 2) certifies that at Servion, a region near Sparta and called 'Road', next to the altars of the Hippokontides and Hercules, a memorial in honour of Alcman existed until the second century BC.

2 THE POET'S WORK

Alcman's work (according to *Suidae*, ap. 158P) was classified by the Alexandrians into six or seven books and contained hymns, paeans, and partheniads (hymns sung by young virgins for worship purposes): "... he wrote six erotic poems and the Κολυμβώσες." The latter work probably constitutes an unknown seventh work of the poet (e.g. see Davison, 1961:35-38; Huxley, 1964). The language used by Alcman is mainly the Doric idiom of his time, mixed with elements from the Ionic and Aeolian idiom. Pausanias calls this language 'ήκισταεύωνου' (i.e. least euphonic).

Only a few fragments have been found of the work of this great lyric poet (Campbell, 1967; Diehl, 1925). In 1855, the French Egyptologist Mariette discovered a tomb near the second great Pyramid[1] which contained a papyrus with 100 verses from one of Alcman's parthenian-hymns (in honour of Orthia (standing) Artemis). This fragment was published by Egger in 1863.

However, the big surprise came in 1957 with the publication of Oxyrhynchus Papyrus No. 2390, which dates to the second century AD (Lobel *et al*., 1957). This papyrus contains parts of a comment written in prose, in which Alcman deals with a kind of theogonical cosmogony in one of his poems (Apicella, 1979; Penwill, 1974). The central part of this comment, presented in the following section, also contains 'lemmas' (i.e. short phrases) by Alcman himself.

2.1 The Text of the Comment

An English translation of the text contained in the Oxyrhynchus Papyrus No. 2390 follows (the original Greek text is given in Appendix I).

> ... since as matter started to settle, a kind of a pore [passage] was created, something like a beginning. So, Alcman says, the matter of all things was stirred and uncreated, then someone who arranged everything was born, then a pore was created and when this pore passed by, a bound [or end, τέκμωρ] followed. And the pore is the beginning, while the bound is like an end. When Thetis was born, these became the beginning and the end of everything and all things' nature is similar to the material of copper, while Thetis to that of the worker and the pore and the bound [τέκμωρ] similar to that of the beginning and the end.
>
> ... and third in the row comes darkness, as until then neither the Sun nor the Moon had been created, but matter was still formless. So they were created under ... the pore and the bound and the darkness. The day and the Moon and thirdly the darkness. The shining of the day was not dense but was assisted by [the shining] of the Sun, [since] before that there was only darkness and after these [this procedure] it discerned from it ...

3 DISCUSSION

According to the previous text, we can summarize Alcman's cosmogonic model as follows:

1. Initially, matter was stirred, formless, and invisible.
2. Then, within the space that was filled by this non-observable material (i.e. non-matter), someone who arranged everything was born (Thetis, Θέτις, whose name comes from the root of τιθένναι, θέσθαι, meaning 'to put' or 'set in order'), as a worker (Hofmann, 1950; Stamatakos, 1949). The involvement of Thetis, a sea goddess worshipped in Sparta, leads to the thought that we can probably identify the situation holding before the creation of the observable

universe with that of the primordial Ocean, which, according to Aristoteles was, together with Tethys, the father of the world:

> ... there are people who believe that the post ancient, the very first indeed, who thought about the gods long before the present time, set the same assumption about nature, since they wrote that Ocean and Tethys were the parents of the world and that the oath of the gods is water, what the poets call Styga, as whatever is the most ancient it is also the most respectful and the most respectful serves as oath ... (Metaphysics A′ 3, 983 b 27).

The assumption that the Ocean was the father of the world denotes, according to Kirk *et al.* (1983), the existence of non-Greek cosmogonic considerations and reminds us of the Babylonian view, that the mainland emerged out of the primordial waters (from the Creation Epos – see Pritchard, 1969:60).

3. Then, in the space of non-matter, a pore (a narrow passage – see West, 1963) was created which served as the beginning. In other words, this narrow passage constituted an exit cord for the stirred, formless, and non-observable matter, from the space of the initial, perceivable non-existence to the perceivable space of the observable universe.
4. The creation of a bound (τέκμωρ) followed (Hofmann, 1950; Stamatakos, 1949), which was a leading mark inside the pore (West, 1963) or inside the stars (Vernant, 1970:38-39). Apparently, the τέκμωρ was the end of the situation which existed before the universe was perceivable by humans. This means that when the uncreated and formless matter passed through this bound it automatically became shaped and perceivable, as it could form perceivable objects like the Sun and the Moon. According to Kirk *et al.* (1983), τέκμωρ as a bound can probably be identified with the notion of infinity given by Anaximandros, who visited Sparta a generation later.
5. The pore and the bound coexisted with darkness as one set of discrete events. Of course, as it is implied by what follows, the whole system of pore-bound-darkness was lying exterior to the perceivable universe (ibid.). According to Page (1968: 6), the pore can probably be identified with Hesiodos' Chaos, in the sense of the darkness, but this interpretation is rejected by Kirk *et al.* (1983). In their view, the pore as a passage cannot be identified with Chaos or darkness, or the formless matter, but it should succeed them or act upon them.
6. After the bound (τέκμωρ), the day (probably the luminous part of it, hence the Sun), the Moon, and the darkness (probably the night, the non-luminous dark part of the day) were created.
7. The daylight (radiation) was not dense, but it was assisted by the Sun's radiation. At this point it is worth noting that the commentator denotes that the daylight (radiation) was 'assisted' by the Sun, meaning that the latter was not the only source of the light. This fact lead us to conclude that the day, at this point of the comment, is probably not identified with the luminous part of the solar day but rather with the modern, generalized notion of the radiation (i.e. with the concept of light).

4 CONCLUDING REMARKS

The aforementioned cosmogonic consideration was stated by Alcman in the mid-seventh century BC but describes much older views. Of course it is a mere coincidence that there is a similarity between Alcan's proposal and some current cosmological concepts, and no connection between the two should be inferred. According to modern cosmological hypotheses, the observable universe was born out of a point singularity interior to a white hole, which can by considered – due to the time symmetry of Einstein's equations – as a reversed-in-time black hole (Novikov and Frolov, 1989).

As early as the mid-1960s, it was conjectured that white holes constituted regions of the universe where the Big Bang took place (D'Inverno, 1992). Conceptually, Alcman's 'pore' can be identified with the Einstein-Rosen bridge (Ne'eman, 1965), the point singularity with the bound (τέκμωρ), and the antiparallel universe interior to which the bridge begins with the space of the uncreated, formless, and unperceivable matter.

However, as Einstein's equations determine the local but not the global geometry or topology of spacetime, the Einstein-Rosen bridge can be considered as connecting either two different universes or two different (asymptotically flat) regions of the same universe. It is possible to discard this latter option on physical grounds (see Ohanian, 1976:320), while the dynamics of the Einstein-Rosen bridge raises certain questions about a more general interpretation which still remain unanswered (Misner *et al.*, 1973:838-840).

The notion of a white hole results from the fact that the 'τέκμωρ', as a bound of the 'pore', is according to Alcman the region of an 'out of nowhere' manifestation of perceivable matter and of luminous energy as well, since the day has been born immediately hereafter.

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6 NOTES

1 In the region of the Nile's western bank was the city of Lower Egypt called Oxyrhynchus, capital of the county of Oxyrhynchus. Today, the village of Vachnasa lies near the ruins of the ancient city. When this Ptolemaeic city was excavated, a large number of papyruses were found, the majority of which contain Greek texts. These papyruses, among the most important of which are Aristoteles' "Αθηναίων Πολιτεί", Sophocles' drama "Ιχνευταί", and Alcman's "Τα Παρθένια", are named after the name of the city, accompanied by a code number.

Κολυμβώσι

7 References

Apicella, G R., 1979. La cosmogonia di Alcmane. *Quaderni Urbinati di Cultura Classica*, Nuova Serie 3, **32**: 7-27.

Campell, D.A., 1967. *Greek Lyric Poetry – A selection of Early Greek Lyric, Elegiac and Lambic Poetry*. Macmillan, New York.

Davison, J.A., 1961. Notes on Alcman. *Proceedings of the Ninth International Congress of Papyrology*, **61**:35-38.

Diehl, E., 1925. *Anthologia Lyrica Graeca*. Teubner, Leipzig.

D'Inverno, R., 1992. *Introducing Einstein's Relativity*. Clarendon Press, Oxford.

Harvey, F.D., 1967. Oxyrhynchus Papyrus 2390 and Early Spartan History. *Journal of Hellenic Studies*, **87**: 62-73.

Hofmann, J.B., 1950. *Etymologisches Woerterbuch des Griechischen*. Oldenbourg, Muenchen.

Huxley, G., 1964. Alcman's Κολυμβώσι. *Greek, Roman and Byzantine Studies*, **51**:26-28.

Kirk, G.S., Raven, J.E. and Schofield, M., 1983. *The Presocratic Philosophers. A Critical History with a Selection of Texts*. Second Edition. Cambridge University Press, Cambridge.

Lobel, E., Roberts, C.H., Turner, E.G. and Barns, J.W.B., 1957. *The Oxyrhynchus Papyri. Part XXIV*. Egypt Exploration Society, London (Graeco-Roman Memoirs, No. 35).

Misner, C., Thorne, K. and Wheeler, J., 1973. *Gravitation*. Freeman, San Francisco.

Novikov, I.D., and Frolov, V.,1989. *Physics of Black Holes*. Kluwer, Dordrecht.
Ne'eman, Y., 1965. Expansion as an energy source in quasi-stellar radio sources. *Astrophysical Journal*, **141**:1303-1305.
Ohanian, H.C., 1976. *Gravitation and Spacetime*. Norton, New York.
Page, D.L., 1968. *Lyrica Graeca Selecta. Edidit Brevique Adnotation Critica Instuxit.* Oxford.
Penwill, J.L., 1974. Alcman's cosmogony. *Apeiron*, **8**:13-39.
Pritchard, J.B., 1969. *Ancient Near Eastern Texts Relating to the Old Testament*. Third Edition. Princeton.
Skiadas, AD, 1981. *Ancient Lyrics – 2*. Kardamitsas, Athens. [In Greek].
Stamatakos, I., 1949. *Lexicon of the Ancient Greek Language*. Volume 1. Dimitrakos, Athens. [In Greek].
Suidae Lexicon. Volumes I and II. Ex Recognitione, Immanuelis Bekkeri. Berolini. Typis et impensis Georgii Reimeri. A. (1854).
Tsantsanoglou, K., 1973. Two Alcmans – P. Oxy. 2802. *Hellenica*, **26**:107-112. [In Greek].
Vernant, J.-P., 1970. *Thetis et le Poeme Cosmogonique d'Alcman. Hommages a Marie Delcourt*. Brussels.
Voutierides, H., n.d. *Ancient Greek Lyrics*. Third Edition. Papademas, Athens. [In Greek].
West, M.L., 1963. Three Presocratic cosmologies. *Classical Quarterly*, New Series, **13**:154-176.

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APPENDIX I

.ν.[
πάντων...[
τις ἐκ δὲ τῶ π[τέ-
κμωρ ἐγένετο τ[
μο[.] ἐντεῦθεν ει.[
πόρον̣ ἀπὸ τῆς πορ.[..].[
ὡς γὰρ ἤρξατο ἡ ὕλη κατασκευα[σθῆναι
ἐγένετο πόρος τις οἱονεὶ ἀρχή· λ[έγει
οὖν ὁ Ἀλκμὰν τὴν ὕλην πάν[των τετα-
ραγμένην καὶ ἀπόητον· εἶτα [γενέ-
σθαι τινά φησιν τὸν κατασκευά[ζοντα
πάντα, εἶτα γενέσθαι [πό]ρον, τοῦ [δὲ πό-
ρου παρελθόντος ἐπακολουθῆ[σαι] τέ-
κμωρ· καὶ ἔστιν ὁ μὲν πόρο̣ς οἷον ἀρχή, τὸ δὲ τέ-
κμωρ οἱονεὶ τέλος. τῆς Θέτιδος γενο-
μένης ἀρχὴ καὶ τέ[λ]ο[ς ταῦτ]α πάντων ἐ-
γένε[τ]ο, καὶ τὰ μ̣ὲ̣ν πάντα̣ [ὁμο]ί̣αν ἔχει
τὴν φύσιν τῆι τοῦ χαλκοῦ ὕλῃι, ἡ δὲ
Θέτις τ[ῆι] τοῦ τεχνίτου, ὁ δὲ̣ πόρος καὶ τὸ τέ-
κμ̣ω̣ρ τῆι ἀρχῆι καὶ τῶι τέλει. πρέσγ[υς
δὲ ἀντὶ τοῦ πρεσβύτης. καὶ τρίτος σκότος·
διὰ τὸ μηδέπω μήτε ἥλιον μήτε σε-
λ]ήνην γεγονέναι ἀλλ' ἔτι ἀδιάκριτ[ο]ν εἶναι
τ]ὴν ὕλην· ἐγένοντο οὖν ὑπο.[.]... πό-
ρος καὶ τέκμωρ καὶ σκότ[ος].[ἆμάρ
τε καὶ σελάνα καὶ τρίτον σκότος· τας
μαρμαρυγάς· ἆμαρ οὐ ψιλῶς ἀλλὰ
σὺν ἡλίωι· τὸ μὲν πρότερον ἦν σκότος μό-
νον, μετὰ δὲ ταῦτα διακριθέ[ντο]ς αὐτοῦ

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Recent publications relating to the history of astronomy

Books and Pamphlets

Allen, Hubert A. The petroglyph calendar: an archaeoastronomy adventure. Albuquerque, NM, H. Allen and Associates, 1998. 151 p. illlus., map.

L'Apparence des cieux: astronomie et astrologie en terre d'Islam. Rédigé par Sophie Makariou. Paris, Réunion des Musées nationaux, 1998. 128 p. illus. (part col.), facsims. (part col.) (Les Dossiers du Musée du Louvre, 54)

Exhibition held at the Musée du Louvre, June 18-Sept. 1, 1998.

Contents: Rosenberg, P. Préface.—Makariou, S. Avant-propos.—Defrade, N. Sources et développement de l'astronomie en terre d'Islam.—Balty-Guesdon, M., F. Richard, and A. Berthier. Les manuscrits d'astronomie et d'astrologie au Département des Manuscrits orientaux de la Bibliothèque nationale de France.—Bittar, T. L'astrologie et le décor des métaux.—King, D. A. Les instruments scientifiques en terre d'Islam.—Makariou, S., and A. Caiozzo. La traidition des *Étoiles fixes* sur les globes célestes et dans les manuscrits illustrés d'al-Sufi.—Liste des œuvres.

Baldi, Bernardino. Le vite de' matematici. Edizione annotate e commentate della parte medievale e rinascimentale. A cura di Elio Nenci. Milano, FrancoAngeli, 1998. 524 p. (Filosofia e scienza nel Cinquecento e nel Seicento)

This late 16th- early 17th-century collection includes sketches of many astronomers.

Barnett, Jo Ellen. Time's pendulum: the quest to capture time—from sundials to atomic clocks. New York, Plenum Trade, 1998. 340 p. illus., facsims., maps.

Bertola, Francesco. Imago mundi: la représentation de l'univers à travers les siècles. Traduit de l'italien par Avram Hayli, pour les conceptions de l'univers, une breve histoire, et Étienne Schelstraete pour l'intruduction et les commentaires des illustrations. Bruxelles, La Renaissance du livre, 1996. 231 p. col. facsims.

An English translation of the text and captions appears on p. 195–230.

Bodnár, Szilvia. Csillagsorsok és embersorsok. Sternenschicksale und Menschenschicksale. Grafikai kiállítás/graphische Ausstellung. Budapest, Szépművészeti Múzeum, 1990. 67 p. illus., facsims.

Hungarian and German on facing pages.

Another illustration is reproduced on the outside front cover.

Böhm, Conrad A. 250 anni di astronomia a Trieste. Trieste, MGS Press, 1998. 121 p. illus., facsims., plans, ports.

Boss, Alan. Looking for earths: the race to find new solar systems. New York, J. Wiley, 1998. 240 p., [8] p. of plates. illus., ports.

From the early efforts of Peter van de Kamp and others to the successes of 1996.

Boxmeer, Henri van. Instruments anciens de l'Observatoire royal de Belgique. Bruxelles, Observatoire royal de Belgique, 1996. 110 p. illus.

Buła, Janina. Katalog kalendarzy polskich od XVI do XVIII wieku w zbiorach Biblioteki Czartoryskich. Kraków, Muzeum Narodowe w Krakowie, 1994. 194 p., [24] p. of plates. facsims.

Burnett, Charles S. F. The introduction of Arabic learning into England. London, British Library, 1997. 110 p. facsims. (part col.) (The Panizzi lectures, 1996)

Contents: Preface.—Lecture 1. The books of King Harold.—Lecture 2. The education of Henry II.—Lecture 3. The beginnings of Oxford University.—Epilogue.—Appendix: Didactic rhymes and jingles.—Notes.—Manuscripts.

Among the rhymes and jingles for memorizing the contents of the quadrivium is the following:

"Abdebaran Tauro, Geminis Menkeque Rigelque
Frons et Calbalazet prestant insigne Leoni;
Scorpie, Galbalagrab, tua sit, Capricornie, Deneb,
Tu, Batanalhaut, Piscibus es satis una duobus."

Attributed to Fulbert of Chartres and said to be the "earliest example of verse with Arabic words in the Latin language," it is translated as follows:

"*Ad-dabarān* is prominent in Taurus, *mankib* and *rijl* (the shoulder and leg of the *Twins*) in Gemini, the forehead and *qalb al-asad* (the heart of the Lion), in Leo. Yours, Scorpio, is *qalb al 'aqrab* (the heart of the Scorpion); yours, Capricorn, *dhanab* (the tail). You, *baṭn al-ḥūt* (the belly of the Fish), are enough for both Fishes."

A Calendar of the correspondence of Sir John Herschel. Editor, Michael J. Crowe; associate editors, David R. Dyck, James J. Kevin. Cambridge, New York, Cambridge University Press, 1998. 828 p.

The calendar is supplemented by four appendices: 1, "Bibliography of Publications by John Herschel," p. 702–713; 2, "Bibliography of Works Containing Printed Herschel Correspondence," p. 714–715; 3, "Bibliography of Publications on John Herschel," p. 716–724, and 4, "Biographical Register and Index to Correspondents, With a Bibliography of Sources," p. 725–791.

The Cambridge companion to Galileo. Edited by Peter Machamer. Cambridge, New York, Cambridge University Press, 1998. 462 p. illus.

Contents: Preface.—Machamer, P. Introduction.—Wallace, W. A. Galileo's Pisan studies in science and philosophy.—Machamer, P. Galileo's machines, his mathematics, and his experiments.—Feldhay, R. The use and abuse of mathematical entities: Galileo and the Jesuits revisited.—Hooper, W. E. Inertial problems in Galileo's preinertial framework.—Redondi, P. From Galileo to Augustine.—Shea, W. R. Galileo's Copernicanism: the science and the rhetoric.—Swerdlow, N. M. Galileo's discoveries with the telescope and their evidence for the Copernican theory.—McMullin, E. Galileo on science and Scripture.—Blackwell, R. J. Could there be another Galileo case?—Pera, M. The never-ending Galileo story.—Galluzzi, P. The sepulchers of Galileo: the "living" remains of a hero of science. Translated by Michael John Gorman.

Carl Zeiss und Ernst Abbe: Leben, Wirken und Bedeutung. Wissenschaftshistorische Abhandlung. Hrsg. von Rüdiger Stolz und Joachim Wittig, unter Mitwirkung von Günter Schmidt. Jena, Universitätsverlag, 1993. 566 p., [16] p. of plates. illus., facsims., ports.

Partial contents: 3. Ernst Abbes Beziehungen zu anderen Gelehrten. Tiemann, K. H. Wilhelm Julius Foerster.—4. Ernst Abbes Einfluss auf die Universität Jena. Schielicke, R. Astronomie und Zeiss-Werk.—5. Wissenschaftliches Nachwirken Ernst Abbes. Wolfschmidt, G. Die Weiterentwicklung von Abbes Geräten bei Zeiss Jena und ihre Bedeutung für die Astronomie in der ersten Hälfte des 20. Jahrhunderts.

Carrazzoni, José A. Semblanzas y curiosidades científicas argentinas. Buenos Aires, Orientación Gráfica Editora, 1998. 191 p. illus., facsims., ports.

Partial contents: Un meteorito tan antiguo como famoso.—Buenaventura Suárez: su conmovedora actividad astronómica.—Octaviano F. Mossotti: entre telescopios y pluviómetros.—Benjamín A. Gould: el pescador de estrellas.

Chaudhuri, Puspendu. History revealed by the Rāmāyaṇa astronomy. Calcutta, Firma KLM, 1998. xix, 136 p.

Christianson, Gale E. Isaac Newton and the scientific revolution. New York, Oxford University Press, 1996. 155 p. illus., facsims., plan, ports. (Oxford portraits in science)

De Meis, Salvo, *and* Hermann Hunger. Astronomical dating of Assyrian and Babylonian reports. Roma, Istituto italiano per l'Africa e l'Oriente, 1998. 95 p. illus. (Serie orientale Roma, 81)

Deutsches Museum Bonn. Mechanik aus der Wunderkammer—die Vorläufer der Computer. Hrsg. von Peter Friess und Eva Langenstein. München, Weltkunst Verlag, 1996. 72 p. col. illus., facsims.

Among the works depicted and described are astronomical clocks and watches, sundials, an astrolabe, a celestial globe, and the reconstruction of the antikythera mechanism made by Derek de Solla Price.

Dick, Steven J. Life on other worlds: the 20th-century extraterrestrial life debate. Cambridge, New York, Cambridge University Press, 1998. 290 p. illus., facsims., ports.

An abridgment and update of his *The Biological Universe* (1996).

Evans, James. The history & practice of ancient astronomy. New York, Oxford University Press, 1998. 480 p. illus.

Contents: 1. The birth of astronomy.—2. The celestial sphere.—3. Some applications of spherics.—4. Calendars and time reckoning.—5. Solar theory.—6. The fixed stars.—7. Planetary theory.—Frequently used tables.—Appendix: Patterns for models.

Folley, Tom, *and* Iain Zaczek. The book of the sun. With a foreword by Sir Arnold Wolfendale. Philadelphia, Courage Books, 1997. 128 p. illus. (part col., part fold.), facsims. (part col.), ports. (part col.) (A Quarto book)

Friedman, Herbert. The astronomer's universe: stars, galaxies, and cosmos. Rev. and updated. New York, W. W. Norton, 1998. xvii, 365 p. illus., ports.

Giornata lincea in ricordo di Bruno Rossi: maestro, fisico e astrofisico. (Roma, 21 aprile 1994.) Roma, Accademia nazionale dei Lincei, 1995. 50 p. illus. (part col.) (Atti del convegni lincei, 117)

Contents: Salvini, G. [Introduzione]—Puppi, G. Relazione commemorativa.—Pacini, F. Bruno Rossi, dai raggi cosmici all'astrofisica della alte energie.—Giacconi, R. L'astronomia a raggi X: i risultati del passato e le prospettive per il futuro.—Cocconi, G., L. Scarsi, and V. Tusa. Interventi.—-Salvini, G. Parole di chiusura.

Hack, Margherita. L'amica delle stelle: storia di una vita. Milano, Rizzoli, 1998. 301 p., [4] p. of plates. illus., ports.

Contents: 1. Dall'infanzia all'università.—2. L'università e le prime osservazioni astronomiche.—3. I primi lavori: macchine fotografiche e stelle Be.—4. La prima avventura all'estero: Parigi.—5. Merate e Utrecht.—6. America. Da New York a Berkeley, con una parentesi in Unione Sovietica.—7. 1958–1961.—8. In attesa del concorso a cattedra.—9. Trieste.—10. 1965–1973: ricerca, congressi e burocrazia.—11. La ricerca spaziale e gli anni di piombo.—12. Nascono la rivista "L'Astronomia" e il dipartimento di astronomia.—13. Di San Vito a Roiano.—14. Un decennio straordinario. Sonde, satelliti e Ufo.—15. Esperienze extrascientifiche.

Hamel, Jürgen. Bibliographia Kepleriana. Verzeichnis der gedruckten Schriften von und über Johannes Kepler. Im Auftrag der Kepler-Kommission der Bayerischen Akademie der Wissenschaften. Ergänzungsband zur zweiten Auflage. München, C. H. Beck'sche Verlagsbuchhandlung, 1998. xliii, 192 p.

Supplements the 2d ed. (1968) of Max Caspar's *Bibliographia Kepleriana*, edited by Martha List.

Jourdán, Elios R. En busqueda del Mesón de Fierro. Santa Fe, Argentina, 1995. 20, [6] leaves. col. illus., map.

Includes texts of reports of the expeditions undertaken in 1779 by Francisco de Ibarra and in 1783 by Miguel Rubín de Celis.

For more on this prehistoric impact site see "Meteorites and Craters of Campo del Cielo, Argentina," by William A. Cassidy, Luisa M. Villar, Theodore E. Bunch, Truman P. Kohman, and Daniel J. Milton, in *Science*, v. 149, Sept. 3, 1965, p. 1055–1064.

Loza-Balsa, Gregorio. Astronomía y calendario aymara. La Paz, Bolivia, Museo Nacional de Etnografía y Folklore, 1995. 165 p., [2] leaves of fold. plates. illus.

The folded leaves provide a sky chart showing the modern constellations and a translucent overlay with the Aymara constellations.

Nouhuys, Tabitta van. The age of two-faced Janus: the comets of 1577 and 1618 and the decline of the Aristotelian world view in the Netherlands. Leiden, Boston, Brill, 1998. 603 p. (Brill's studies in intellectual history, v. 89)

Contents: ch. 1. Introduction: *Opinio loquitur, ratio respondet*?—A. Preliminaries. ch. 2. Comets after the cessation of dialogue: a historiographical introduction. ch. 3. Comets before the cessation of dialogue. ch. 4. Greek meets Greek: the culmination of dialogue.—B. The Netherlands. ch. 5. Seneca saves Aristotle: cosmology in the Dutch tracts. ch. 6. Cometary concomitants: astrology and teratology in the Dutch tracts. ch. 7. Conclusion: the age of two-faced Janus.

Novikov, Igor′ D. The river of time. Translated from the Russian by Vitaly Kisin. Cambridge, New York, Cambridge University Press, 1998. xxii, 275 p. illus.

Panek, Richard. Seeing and believing: how the telescope opened our eyes and minds to the heavens. New York, Viking, 1998. 198 p.

Prehistoric ritual and religion: essays in honour of Aubrey Burl. Edited by Alex Gibson and Derek Simpson. Thrupp, Stroud, Glos, Sutton Publ., 1998. 242 p. illus., maps, plans.

"H. A. W. Burl: a Bibliography": p. 219–220.

The authors "also assess prehistoric astronomy, the Celtic ritual calendar and the orientation of Stone Age monuments in relation to lunar or solar observations."

See particularly "The Time Lords: Ritual Calendars, Druids and the Sacred Year," by Miranda J. Green (p. 190–202), and "Ritual Astronomy in the Neolithic and Bronze Age British Isles," by Clive L. N. Ruggles (p. 203–208).

Ptak, Roger. Sky stories, ancient and modern. Commack, NY, Nova Science Publishers, 1998. 124 p. illus., facsims.

Real Francia, Pedro J. del. Lexicon Manilianum. Hildesheim, New York, Olms-Weidmann, 1998. 582 p. (Alpha-Omega. Reihe A, Lexika, Indizes, Konkordanzen zur klassischen Philologie, 193)

"Manuscritos y autores de las variantes y conjeturas señaladas": p. iv–v.

Index entries and definitions in Latin; introduction in Spanish.

Remembering Walt Roberts. Boulder, Colo., University Corp. for Atmospheric Research, 1991. 219 p. illus., ports.

Reminiscences of Walter Orr Roberts contributed by many friends and colleagues.

Ristoro, *d'Arezzo*. La composizione del mondo. A cura di Alberto Morino. Parma, Fondazione Pietro Bembo, U. Guanda editore, 1997. xxxiii, 446 p. (Biblioteca di scrittori italiani)

A 13th-century work on geology and astronomy.

Schmid, Karl, *and* Herbert Schmitt. Die astronomische Uhr am Tübinger Rathaus. Mit einem Beitrag von Martin Beutelspacher. Tübingen, Kulturamt der Universitätsstadt Tübingen, 1997. 44 p. col. illus., facsims., ports. (Kleine Tübinger Schriften, Heft 21)

Contents: Schmid, K. Zur Geschichte der Uhr und ihres Erbauers.—Schmitt, H. Zur Technik der Uhr.—Beutelspacher, M. Das alte Zifferblatt der astronomischen Uhr.

Schorn, Ronald A. Planetary astronomy, from ancient times to the third millennium. College Station, Texas A&M University Press, 1998. xxv, 376 p., [8] p. of plates. illus. (part col.), ports.

Sobel, Dava, *and* William J. H. Andrewes. The illustrated Longitude. New York, Walker, 1998. 216 p. illus. (part col.), facsims. (part col.), maps (part col.), ports. (part col.)

Text originally published in 1995.

Soler Gayá, Rafael. Diseño y construcción de relojes de sol y de luna. Prontuario para la construcción de relojes de sol y de luna con la justificación de los métodos y fórmulas. 2. ed. Madrid, Colegio de Ingenieros de Caminos, Canales y Puertos, Demarcación de Baleares, 1997. 448 p. illus. (part col.), maps (part col.) (Colección de ciencias, humanidades e ingeniería, no. 29)

Many dials, old as well as recent, are illustrated, and there is a long list of sundial mottoes in Latin, Spanish, Catalan, French, Italian, Portuguese, and some dialects (p. 117–173).

Taylor, Stuart R. Destiny or chance: our solar system and its place in the cosmos. Cambridge, New York, Cambridge University Press, 1998. xvii, 229 p. illus.

Webster, Roderick, *and* Marjorie Webster. Western astrolabes. With an introd. by Sara Schechner Genuth. Chicago, Adler Planetarium & Astronomy Museum, 1998. 179 p. illus., facsims., ports. (Historic scientific instruments of the Adler Planetarium & Astronomy Museum, v. 1)

Contents: Knappenberger, P. Foreword. History of the Adler Planetarium Collection. Acknowledgments.—Schechner Genuth, S. Introduction. Astrolabes: a cross-cultural and social perspective.—Astrolabes. The astrolabe, a technical introduction. Western astrolabe catalogue.—Quadrants. The astrolabe-quadrant. Astrolabe quadrant catalogue.—Mariner's astrolabes. Mariner's astrolabe catalogue.—Appendices. Star catalogue. Comparison of stars. Concordance. Makers' biographies.

Articles, Including Essays in Books and Papers in Proceedings

Ambrosini, Reto. Sonnenuhren und italienische Zeit im Tessin. Orion, 56. Jahrg., Okt. 1998: 19–24. illus.

"In Italien und im Kanton Tessin war bis zum Ende des 18. / Anfang des 19. Jahrhunderts eine andere Art der Stundenzählung in Gebrauch als nördlich der Alpen. Die Stundenzählung begann mit 24 Uhr beim Sonnenuntergang. Auf diese Weise gezählte Stunden werden italienische Stunden genannt. Dieser Artikel gibt eine kurze Beschreibung solcher Stunden und erklärt, wie eine Sonnenuhr, die italienische Stunden anzeigt, zu lesen ist. Die Konstruktion der italienischen Stundenlinien wird erklärt. Neben einigen historischen Angaben wird der Gebrauch der italienischen Stunden in Italien, im Tessin und in Böhmen beschrieben."

Anderson, Earl R. The seasons of the year in Old English. *In* Anglo-Saxon England. 26. Cambridge, New York, Cambridge University Press, 1997. p. 231–263.

A "historical sketch of seasons-vocabulary."

Armijo Canto, Maruxa. Las estrellas de Dante. *In* Jornadas Medievales, *4th, Mexico City, 1993*. Palabra e imagen en la Edad Media. Actas de las IV Jornadas Medievales. Editores, Aurelio González, Lillian von der Walde, Concepción Company. México, D.F., Universidad Autónoma de México, 1995. (Medievalia, 10) p. 201–209.

Atkins, Keletso E. "Kafir time," wage claims, and other sociocultural antecedents of *togt*, or day labor. *In his* The moon is dead! Give us our money! The cultural origins of an African work ethic, Natal, South Africa, 1843–1900. Portsmouth, NH, Heinemann, 1993. (Social history of Africa) p. 78–99.

The lunar calendar used by the Zulu gave rise to conflicts with European employers over the number of days required to earn a month's wages.

Barker, Peter. Kepler's epistemology. *In* Method and order in Renaissance philosophy of nature; the Aristotle commentary tradition. Edited by Daniel A. Di Liscia, Eckhard Kessler, Charlotte Methuen. Aldershot, Hants, Brookfield, Ashgate, 1997. p. 355–368.

Barocas, Vinicio. The Preston Observatory. 2. Onwards and upwards. Southern stars, v. 38, Sept. 1998: 1–8.

The first part was cited in *JAH*^{2} no. 3.

Bartholomew, Robert E. The Martian panic sixty years later: what have we learned? Skeptical inquirer, v. 22, Nov./Dec. 1998: 40–42.

"The 'War of the Worlds' panic happened sixty years ago, but its lessons are as relevant today as back then."

Bel'kovich, O. I., *and* M. G. Ishmukhametova. Evolîutsiîa meteornogo roîa Perseid za poslednie 130 let po vizual'nym nablîudeniîam. Astronomicheskiĭ vestnik, t. 32, mart/apr. 1998: 182–186. illus.

An English translation, "Evolution of the Perseid Meteor Shower Over Last 130 Years From Visual Observations," appears in *Solar System Research*, v. 32, Mar./Apr. 1998, p. 161–165.

Berkel, Klaas van. Vermeer and the representation of science. *In* The Scholarly world of Vermeer. Zwolle, Waanders, 1996. p. 12–23. illus. (part col.), facsims., ports.

Reflections on Vermeer's painting, *The Astronomer*, a color reproduction of which also appears on the outside front cover of the volume.

Binney, James J., *and* Michael R. Merrifield. Galaxies: an overview. *In their* Galactic astronomy. Princeton, N.J., Princeton University Press, 1998. (Princeton series in astrophysics) p. 1–25. illus.

Contents: 1. Introduction.—2. A brief history of galactic astronomy.

Bollók, János. A *De consulatu suo* asztrológiai vonatkozásai. [The astrological aspects of the *De consulatu suo*] *In* Cicero öröksége. Hereditas Ciceroniana. Tanulmányok a szónok-politikus születésének 2100. évfordulója alkalmából. Studia memoriae Ciceronis MMC annis ante nati dicata. [Hoc volumen redegit Ladislaus Havas] Debrecen, Kossuth Lajos Tudományegyetem, 1995. (Agatha, 1) p. 221–233.

Bònoli, Fabrizio. Astronomia e arte: interconnessioni, problematiche e stimoli. Un esempio: "Astronomia e arte medievale." Giornale di astronomia, v. 24, giugno 1998: 16–32. illus. (part col.)

Buła, Janina. Unglerowska edycja polskiego prognostyku astrologicznego na rok 1531 Mikołaja a Szadka, odnaleziona w zbiorach Biblioteki Czartoryskich. *In* Kraków. Uniwersytet Jagielloński. *Biblioteka*. Biuletyn, r. 47, nr. 1/2, 1997: 41–45. facsims.

Summary in German.

The facsimiles appear on 7 pages of plates preceding the article.

Campion, Nicholas. Sigmund Freud's investigation of astrology. Culture and cosmos, v. 2, spring/summer 1998: 49–53.

Canovas, Rodrigo, Ernesto Livacic, *and* Patricio Lizama. Los meses: referencialidad, alegoría y compromiso cultural en tres descripciones literarias. *In* Jornadas Medievales, *4th, Mexico City, 1993*. Palabra e imagen en la Edad Media. Actas de las IV Jornadas Medievales. Editores, Aurelio González, Lillian von der Walde, Concepción Company. México, D.F., Universidad Autónoma de México, 1995. (Medievalia, 10) p. 187–199.

The three works examined are the *Libro de Alexandre*, the *Libro de buen amor* of Juan Ruiz, and the *Nueva corónica y buen gobierno* of Felipe Guamán Poma de Ayala.

Cernia Slovin, Francesca. Lo scurto e il telescopio. Art e dossier, n. 117, nov. 1996: 27–30. col. illus. (Studi e riscoperte)

"Tra le innumerevoli conseguenze della rivoluzione copernicana, e delle successive acquisizioni scientifiche in materia astronomica, è da annoverare anche un profondo mutamento nei modi di alcune specifiche rappresentazioni pittoriche. Una mutazione che si avverte, però, già in piano Quattrocento, anche se che sarà evidente soprattutto nei soggetti 'celesti' della grande decorazione a fresco delle cupole nei secoli successivi."

Christianson, Gale E. Mastering the universe. Astronomy, v. 27, Feb. 1999: 60–65. col. illus., ports.

"Edwin Hubble gained scientific immortality when he discovered an expanding universe of galaxies."

Clarke, Philip A. The Aboriginal cosmic landscape of southern South Australia. *In* South Australian Museum, *Adelaide*. Records, v. 29, Mar. 1997: 125–145. illus., map.

"Star maps are provided for the Adelaide and Lower Murray areas."

Davoust, Emmanuel. A hundred years of science at the Pic du Midi Observatory. *In* ASP Summer Scientific Symposium Conference, *Chicago, 1997*. Astrophysics from Antarctica. Proceedings of the ASP Summer Scientific Symposium Conference held at Chicago, Illinois, 30 June - 2 July 1997. Edited by Giles Novak and Randall H. Landsberg. San Francisco, Astronomical Society of the Pacific, 1998. (Astronomical Society of the Pacific conference series, v. 141) p. 39–53. illus., ports.

Dyson, John E. Franz Daniel Kahn FRS 1926–1998. Astronomy & geophysics, v. 39, Oct. 1998: 32–33. port.

"Fellow and Councillor of the RAS, distinguished theoretical astrophysicist, gifted teacher and valued colleague."

Edmondson, Frank K. The Ford Foundation and the European Southern Observatory. Journal for the history of astronomy, v. 29, Nov. 1998: 309–326. facsim.

Fang, Lizhi. Searching for three numbers, 1970–1997: an overview of big bang cosmology. *In* Taipei Astrophysics Workshop on Cosmology, *5th, Chung-Li and Taipei, 1997*. Cosmic microwave background and large scale structure of the universe. Proceedings of the 5th Taipei Astrophysics Workshop on Cosmology, held at Chung-Li and Taipei, Taiwan, 18–21 December 1997. Edited by Yong-Ik Byun and Kin-Wang Ng. San Francisco, Astronomical Society of the Pacific, 1998. (Astronomical Society of the Pacific conference series, v. 151) p. 3–12.

Federici Vescovini, Graziella. Biagio Pelacani's astrological history for the year 1405. Culture and cosmos, v. 2, spring/summer 1998: 24–32.

Gallant, Roy A. Saga of the lump: the Pallas meteorite. Sky & telescope, v. 97, Jan. 1999: 50–54. illus. (part col.), col. maps, ports. (part col.)

"Two centuries ago this mass of rock and iron started a chain of events that led to the science of meteoritics."

Gaulke, Karsten, *and* Reimund Torge. Sterne aus Jena: das Projektionsplanetarium I von Carl Zeiss. Kultur & Technik, 22. Jahrg., Nr. 3, 1998: 32–33. illus. (Bilder aus der Technikgeschichte)

Gochermann, Josef, *and* Rolf Chini. Nachruf: Walter Wargau †. 1948–1996. *In* Astronomische Mitteilungen. Nr. 81. Hamburg, 1998. p. 13–14. port.

Gómez Redondo, Fernando. Capítulo IV. La corte letrada de Alfonso X (1256–1284). 4.4. La corte como espacio de la ciencia: las compilaciones astrológicas. *In his* Historia de la prosa medieval castellana. 1. La creación del discurso prosístico: el entramado cortesano. Madrid, Cátedra, 1998. (Crítica y estudios literarios) p. 597–643.

Green, Richard F., David S. De Young, *and* Sidney C. Wolff. Forty years of discovery: Kitt Peak perspective. Nature, v. 395, Oct. 1, 1998, suppl.: A30–A31. col. illus.

Heinicke, Thomas. Neues Weltbild. Klassik-Uhren, 20. Jahrg., Dez. 1997/Jan. 1998: 20–23. col. illus.

"W. J. Blaeu († 1638), berühmter Kartograph und Globenhersteller sowie Mitarbeiter von Tycho Brahe, fertigte in Den Haag ein einmaliges 'Copernikanisches Planetarium,' datiert 1650, das bisher in keinen Fachbuch erwähnt ist. Erst kürzlich wurde es in Waldenburg (Sachsen) wiederentdeckt. Ein Vergleich seines Uhrwerkantriebs mit dem eines früheren Planetariums von Blaeu aus dem Jahr 1620."

Hiscock, Philip. Once in a blue moon. Sky & telescope, v. 97, Mar. 1999: 52–55. col. illus., facsims.

Seeks the origin of the term's use to denote a second full moon in a given month.

Includes a box, "Blue-Moon Mystery Solved?" by Donald W. Olson and Roger W. Sinnott, tracing the usage to the *Maine Farmers' Almanac* for 1937.

Hodge, Paul W. Naming the man in the moon. Astronomy, v. 27, Feb. 1999: 82–85. illus., ports. (part col.)

On the naming of lunar features.

Hoskin, Michael A. Derek Howse (1919–1998). Journal for the history of astronomy, v. 29, Nov. 1998: 398.

Hoskin, Michael A. Olaf Pedersen 1920–1997. Astronomy & geophysics, v. 39, Oct. 1998: 33–34.

"Associate and Fellow of the RAS, authority on the history of science and especially the astronomy of the Middle Ages."

Hulst, Hendrik C. van de. Roaming through astrophysics. *In* Annual review of astronomy and astrophysics. v. 36; 1998. Palo Alto, Calif., Annual Reviews. p. 1–16. port.

The portrait faces p. 1.

Hunger, Hermann. Zur Lesung sumerischer Zahlwörter. *In* Dubsar anta-men: Studien zur Altorientalistik. Festschrift für Willem H. Ph. Römer zur Vollendung seines 70. Lebensjahres, mit Beiträgen von Freunden, Schülern und Kollegen. Unter Mitwirkung von Thomas E. Balke hrsg. von Manfried Dietrich und Oswald Loretz. Münster, Ugarit-Verlag, 1998. (Alter Orient und Altes Testament, Bd. 253) p. 179–183.

ÎUbile V. S. Safronova. Astronomicheski vestnik, t. 32, noîabr′/dek. 1997: 483.

An English translation, "Viktor Safranov's Birthday Anniversary," appears in *Solar System Research*, v. 31, Nov./Dec. 1997, p. 429.

Johns, Adrian. Histories of the heavens: John Flamsteed, Isaac Newton, and the *Historia Cœlestis Britannica*. *In his* The nature of the book: print and knowledge in the making. Chicago, University of Chicago Press, 1998. p. 545–621. facsims., ports.

See also the section "Tycho Brahe, Galileo Galilei, and the Problems of 'Print Culture'" (p. 6–28) in the book's introduction. Additional material relating to the history of astronomy can be found through the index.

Keil, Inge. Der Augsburger Optiker Johann Wiesel und seine Beziehungen zu Herzog August dem Jüngeren von Braunschweig-Lüneburg. *In* Augsburg in der Frühen Neuzeit; Beiträge zu einem Forschungsprogramm. Hrsg. von Jochen Brüning und Friedrich Niewöhner. Berlin, Akademie Verlag, 1995. (Colloquia Augustana, Bd. 1) p. 158–169.

"Johann Wiesel nimmt in der Geschichte der Optik in Deutschland eine nicht unbedeutende

Stellung ein. Wir lernen in ihm einen Handwerker kennen, der im frühen 17. Jahrhundert wohl die erste kommerzielle optische Werkstatt in Deutschland gründete, in der auch die kurz zuvor erfundenen Geräte Fernrohr und Mikroskop gebaut wurden. Durch seine ausgezeichneten Instrumente und die Herstellung der ersten aus zwei und mehr Linsen zusammengesetzten Okulare wurde er in ganz Europa bekannt. Dem Astronomen Riccioli in Bologna, dem wir die heutigen Namen der Mondberge und Krater zu verdanken haben, war bei seinen Mondbeobachtungen ein Fernrohr von Wiesel das liebste ..."

Kibble, Bob. Sundials in London—linking architecture and astronomy. *In* IAU Colloquium, *162d, University College London and the Open University, Milton Keynes, 1996.* New trends in astronomy teaching. IAU Colloquium 162, University College London and the Open University, July 8–12, 1996. Edited by L. Gouguenheim, D. McNally and J. R. Percy. Cambridge, New York, Cambridge University Press, 1998. p. 7–10. illus.

Kropp, William R., Jonas Schultz, *and* Henry W. Sobel. Frederick Reines. Physics today, v. 52, Jan. 1999: 78–80. port.

Lange, Helmut K. H. Adalbert Stifter (23. Oktober 1805–28. Januar 1868). Orion, 56. Jahrg., Okt. 1998: 23–24. port.

Followed by Stifter's "Die Sonnenfinsternis am 8. Juli 1842" (p. 26–29) and a French translation by Laurent Cassagnau, "L'éclipse de soleil du 8 juillet 1942" [sic] (p. 29–32), with illustrations and a map showing the path of the 1842 eclipse and that predicted for Aug. 11, 1999.

Lindgren, Uta. Zeitvorstellungen bei Albertus Magnus und die Genauigkeit astronomischer Zeitbestimmung. *In* Zeitkonzeptionen, Zeiterfahrung, Zeitmessung. Stationen ihres Wandels vom Mittelalter bis zur Moderne. Trude Ehlert (Hrsg.). Paderborn, F. Schöningh, 1997. p. 69–79. illus., facsims.

McCarthy, Dennis D. The Julian and Modified Julian Dates. Journal for the history of astronomy, v. 29, Nov. 1998: 327–330.

McGillion, Frank. The influence of Wilhelm Fliess' cosmobiology on Sigmund Freud. Cosmos and culture, v. 2, spring/summer 1998: 33–48.

Małecki, Rafał. Magiczno-religijna funkcja starożytnych wozów. Archeologia polski, t. 40, zesz. 1/2, 1995: 91–105. illus.

Summary in English.

Discusses the religious aspect of prehistoric wheeled vehicles and their possible connection with a solar cult, and considers the possible astronomical or calendric significance of features in a drawing of such vehicles on a Funnel Beaker Culture pot dating from the middle of the fourth millennium B.C.

Malville, J. McKim, *and* R. N. Swaminathan. People, planets and the sun: Surya *puja* in Tamil Nadu, South India. Culture and cosmos, v. 2, spring/summer 1998: 3–15. illus., plan.

Mark, Hans. A tribute to Victor G. Szebehely. *In* Szebehely, Victor G., *and* Hans Mark. Adventures in celestial mechanics. 2d ed. New York, J. Wiley, 1998. p. v–vi. port.

Markowski, Mieczysław. Mikołaj Kopernik z Torunia—filozof, astronom i ekonomista. *In* Acta mediaevalia. t. 8. Lublin, Red. wydawnictw Katolickiego Uniwersytetu Lubelskiego, 1995. p. 103–116.

Summary in German.

Markowski, Mieczysław. Nicolaus Copernicus' Krakauer Universitätsstudien. *In* Acta mediaevalia. t. 8. Lublin, Red. wydawnictw Katolickiego Uniwersytetu Lubelskiego, 1995. p. 91–102.

Martres, Marie J. Lucien d'Azambuja; ou, Histoire des protubérances solaires à Meudon. Lucien d'Azambuja; or, History of solar prominences at Meudon. *In* IAU Colloquium, *167th, Aussois, France, 1997.* New perspectives on solar prominences. IAU Colloquium 167. Proceedings of a meeting held in Aussois, France, 28 April-4 May 1997. Edited by David Webb, David Rust, and Brigitte Schmieder. San Francisco, Astronomical Society of the Pacific, 1998. (Astronomical Society of the Pacific conference series, v. 150) p. 3–10. port.

The English translation is by Einar A. Tandberg-Hanssen.

Moe, Michael K. Frederick Reines (1918–98). Discoverer of the neutrino. Nature, v. 395, Oct. 15, 1998: 644. port.

Morrison, Leslie V., *and* F. Richard Stephenson. The sands of time and the Earth's rotation. Astronomy & geophysics, v. 39, Oct. 1998: 8–13. col. illus., map.

Neugebauer, Marcia. Pioneers of space physics: a career in the solar wind. Journal of geophysical research, v. 102, Dec. 1, 1997: 26887–26894. group port.

Autobiographical.

Osterbrock, Donald E. Walter Baade, observational astrophysicist. 3: Palomar and Göttingen, 1948–1960. Journal for the history of astronomy, v. 28, Nov. 1997: 283–316; v. 29, Nov. 1998: 345–377. ports.

Pfau, Werner. Nachruf: Martin Schwarzschild †. 1912–1997. *In* Astronomische Gesellschaft. Mitteilungen. Nr. 81. Hamburg, 1998. p. 5–7. port.

Pian, Elena. Alessandro Serpieri e l'astronomia. *In* Alessandro Serpieri, scienziato riminese. Liceo scientifico statale "A. Serpieri," Rimini, 22–23 marzo 1997 [i.e. 1996] A cura della prof.ssa Lidia Maggioli. Rimini, Raffaelli e Luisè editori, 1998. p. 93–96.

Abstract in English.

Renshaw, Steven, *and* Saori Ihara. Tani Jinzan and a Leonid conflagration: a two-fold tragedy of observation and "theory" in Edo-era Japan. Griffith observer, v. 62, Nov. 1998: 14–18, 21.

Riesenfeld, Harald. Haben wir zwei Kulturen? Zur Datierung des Todes Jesu als interdisziplinäre Aufgabe. *In* Wissenschaftstheorie und Wissenschaftspraxis; Reichweiten und Zukunftsperspektiven interdisziplinärer Forschung. Carsten Peter Thiede, Georg Masuch (Hg.). Paderborn, Bonifatius, 1995. p. 179–189.

Examines the question of dating the Crucifixion and the solution proposed by Humphrey and Waddington in 1983. "Die von ihnen durchgeführten Berechnungen des Passahkalenders für die dreissiger Jahre nach Christus, mit Rücksicht auf den Horizont von Jerusalem und mit Beachtung der Schaltjahre, sind eine bedeutsame Hilfe für die Geschichtsforschung. Wo sie sich jedoch an die Auslegung eines alttestamentlichen Zitates im Zusammenhang der Apostelgeschichte machen, zeigen sie, dass sie mit den Methoden der kritischen Auswertung geschichtlicher Quellen nicht vertraut sind."

Rodis-Lewis, Geneviève. Quelques remarques sur la question de la vitesse de la lumière chez Descartes. Revue d'histoire des sciences, t. 51, avril/sept. 1998: 347–354.

Summary in English.

Rodonò, Marcello. L'astronomia sull'Etna. *In* Etna: mito d'Europa. Catania, G. Maimone, 1997. (Universitates saggi) p. 52–54. illus.

Röttel, Karl. "Arithmetica applicirt": Visierkunst, Buchhaltung, Kartographie und Astronomie bei Henricus Grammateus. *In* Heinrich Schreyber aus Erfurt, genannt Grammateus. Festschrift zum 500. Geburtstag. Hrsg. von Manfred Weidauer. München, Institut für Geschichte der Naturwissenschaften, 1996. (Algorismus, Heft 20) p. 67–89. illus., facsims.

Roquette, Peter. Bartel van der Waerden, 2. 2. 1903–12. 1. 1996. *In* Jahrbuch der Heidelberger Akademie der Wissenschaften für 1996. Heidelberg, 1997. p. 138–141. port.

Rowlands, John. Leviathan awakens. Astronomy now, v. 12, Nov. 1998: 23–24. illus. (part col.)

"Lord Rosse's great telescope fell into disuse early this century. Now fully restored, observations can be made by a new generation."

Ruhe, Doris. Eschatologie und Astrologie. Zeitkonzeptionen im *Livre de Sidrac*. *In* Zeitkonzeptionen, Zeiterfahrung, Zeitmessung. Stationen ihres Wandels vom Mittelalter bis zur Moderne. Trude Ehlert (Hrsg.). Paderborn, F. Schöningh, 1997. p. 203–222.

Ruhe, Doris. Boccace astronomien? *In* Gli Zibaldoni di Boccaccio: memoria, scrittura, riscrittura. Atti del Seminario internazionale di Firenze-Certaldo (26–28 aprile 1996). A cura di Michelangelo Picone e Claude Cazalé Bérard. Firenze, F. Cesati editore, 1998. p. 65–79.

"Quelle est donc la position de Boccace face à la théorie des corps célestes et à son application? J'aimerais reprendre le début et y apporter un nouvel éclairage en examinant les textes astrologiques contenus dans les Zibaldoni de Florence."

Russell, David. Island universes from Wright to Hubble. Sky & telescope, v. 97, Jan. 1999: 56–60. illus. (part col.), ports.

Sandage, Allan R. Beginnings of observational cosmology in Hubble's time: historical overview. *In* Space Telescope Science Institute Symposium, *Baltimore, Md., 1997*. The Hubble Deep Field. Proceedings of the Space Telescope Science Institute Symposium, held in Baltimore, Maryland, May 6–9, 1997. Edited by Mario Livio, S. Michael Fall, Piero Madau. Cambridge, New York, Cambridge University Press, 1998. (Space Telescope Science Institute symposium series, 11) p. 1–26. illus.

Sanderson, Richard. The night of raining fire. Sky & telescope, v. 96, Nov. 1998: 30–36. illus. (part col.), ports.

"The great Leonid meteor storm of 1833 terrified the nation and prompted the birth of meteor science."

Schmidtke, Martin. Bessel, Friedrich Wilhelm, Astronom und Mathematiker. * 22. 7. 1784 in Minden, † 17. 3. 1846 in Königsberg. *In his* Königsberg in Preussen: Personen und Ereignisse, 1255–1945, im Bild. Husum, Husum Druck- und Verlagsgesellschaft, 1997. p. 159–160. illus., ports.

Two of the illustrations show the observatory.

Seck, Friedrich. Kepler as author, printer, and publisher. AB bookman's weekly, v. 94, Nov. 21, 1994: 2182, 2184, 2186–2189. illus.

Šolc, Martin. Nachruf: Vladimír Vanýsek †. 1926–1997. *In* Astronomische Gesellschaft. Mitteilungen. Nr. 81. Hamburg, 1998. p. 9–12. port.

Soon, Willie, *and* Steven H. Yaskell. Cycles of the sun. Astronomy now, v. 12, Oct. 1997: 15–16. col. illus., port.

"Edward Maunder noted that the Sun has times of very low sunspot activity. Is the Earth's climate affected by this?"

Steele, John M., *and* F. Richard Stephenson. Eclipse observations made by Regiomontanus and Walther. Journal for the history of astronomy, v. 29, Nov. 1998: 331–344.

Stephenson, F. Richard. Early Chinese observations and modern astronomy. Sky & telescope, v. 97, Feb. 1999: 48–55. illus. (part col.)

"For thousands of years the vigilant gaze of China's ancient and medieval astronomers recorded unusual celestial happenings. Today, these observing logs have proved invaluable to researchers in several fields of study."

Stern, S. Alan. Forging a new solar system. Astronomy, v. 27, Mar. 1999: 40–45. illus. (part col.), ports.

"Few people have entire regions of the solar system named after them, but then few people contributed as much to planetary astronomy as Gerard Kuiper."

Szabó, Árpád. Cicero és a "Somnium Scipionis." [Cicero and the "Somnium Scipionis"] *In* Cicero öröksége. Hereditas Ciceroniana. Tanulmányok a szonok-politikus születésének 2100. évfordulója alkalmából. Studia memoriae Ciceronis MMC annis ante nati dicata. [Hoc volumen redegit Ladislaus Havas] Debrecen, Kossuth Lajos Tudományegyetem, 1995. (Agatha, 1) p. 31–44. illus.

Szebehely, Victor G., *and* Hans Mark. On the shoulders of giants: an historical review. *In their* Adventures in celestial mechanics. 2d ed. New York, J. Wiley, 1998. p. 1–12.

Inclues a "Chronological List of Major Contributors to Celestial Mechanics" (p. 11–12).

Tammann, Gustav A., *and* Lukas Labhardt. A forty-year search for the Hubble constant. *In* Relativistic astrophysics. Harald Riffert, Hans Ruder, Hans-Peter Nollert, Friedrich W. Hehl (eds.). Braunschweig, Vieweg, 1998. p. 238–261. illus.

Tandberg-Hanssen, Einar A. The history of solar prominence research. *In* IAU Colloquium, *167th, Aussois, France, 1997.* New perspectives on solar prominences. IAU Colloquium 167. Proceedings of a meeting held in Aussois, France, 28 April-4 May 1997. Edited by David Webb, David Rust, and Brigitte Schmieder. San Francisco, Astronomical Society of the Pacific, 1998. (Astronomical Society of the Pacific conference series, v. 150) p. 11–19. illus.

Tee, Garry J. Professor and Mrs Aldis: mathematics, feminism and astronomy in Victorian Auckland. Southern stars, v. 38, Sept. 1998: 18–27.

Tiirmaa, Reet. Meteorite craters. *In* Geology and mineral resources of Estonia. Compiled and edited by Anto Raukas and Aada Teedumäe. Tallinn, Estonian Academy Publishers, 1997. p. 378–383. illus., maps.

Trachet, Tim. De afplatter van de aarde. Zenit, 25. jaarg., okt. 1998: 422–426. illus., map, ports.

About Pierre-Louis Moreau de Maupertuis (1698–1759).

Trefil, James. Puzzling out parallax. Astronomy, v. 26, Sept. 1998: 46–51. col. illus.

"Figuring the distance to stars and galaxies challenged both ancient Greeks and modern cosmologists."

Trenary, Carlos. Yaxchilan Lintel 25 as a cometary record. Culture and cosmos, v. 2, spring/summer 1998: 16–23. illus.

Trimble, Virginia. Astrophysical accretion: the approach to the irrationality horizon. *In* October Astrophysics Conference, *8th, College Park, Md., 1997.* Accretion processes in astrophysical systems: some like it hot! Eighth Astrophysics Conference, College Park, MD October 1997. Editors, Stephen S. Holt, Timothy R. Kallman. Woodbury, N.Y., American Institute of Physics, 1998. (AIP conference proceedings, 431) p. 2–14.

Yorka, Sandra B. Planets and poetry: understanding astronomy through its literary connections. Journal of college science teaching, v. 24, May 1995: 404–406. illus.

References cite relevant poems.

Zhurnalu "Astronomicheskiĭ vestnik" — 30 let. Astronomicheskiĭ vestnik, t. 32, îanv./febr. 1998: 3–4.

An English translation, "*Astronomicheskii Vestnik* Reaches Thirty," appears in *Solar System Research*, v. 32, Jan./Feb. 1998, p. 1.

R. S. Freitag
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Reviews

A Creation of His Own: Tappan's Detroit Observatory, by Patricia S Whitesell (Bentley Historical Library, The University of Michigan, Ann Arbor, 1998), xx +236 pp., ISBN 0-472-59006-5, cloth US\$48.00 £37.50, ISBN 0-472-59007-3, paperback, US\$24.95 £18.95, 227 × 152 mm.

This well-illustrated and attractively-designed book highlights the early days of Detroit Observatory of the University of Michigan, an early and important American facility. Doctor Whitesell is not an astronomer, but she has recently supervised an elaborate and painstaking restoration of the building and surviving instruments. Her text outlines much of the interesting enterprise that led to the Observatory's creation, especially regarding Henry Philip Tappan, the first President of the University of Michigan, whose vision was so responsible for the establishment of the facility.

The Detroit Observatory (located in Ann Arbor) is so named because many of the original contributors were associated with the city of Detroit. It was equipped with a 12 5/8-inch aperture refractor with objective by Henry Fitz (1808-1863) and mounting by Jonas H Phelps (1809-1865). The other main instrument was a 6½-inch aperture meridian circle by Pistor and Martins of Berlin. The total cost of the observatory was about \$22 000, of which \$6150 went for the refractor and \$4000 for the meridian circle. (In 1998 US dollars, these figures would be about \$329 000, \$92 000, and \$59 800, respectively.) Both of these instruments survive to this day in substantially unmodified form, though the refractor was somewhat modernized in 1907.

The author uncovered a number of very interesting details regarding these instruments and their makers. The refractor, which is believed to be the largest surviving Fitz that has not been refigured by another optician, was a problematic telescope to manufacture. It was delivered 19 months late in 1855 December. A temporary telescope had been lent to the observatory by Fitz during this delay, but details of this instrument are not given and perhaps do not survive. Unfortunately the mounting of the delivered telescope was considered unsatisfactory by Franz F E Brünnow, the Observatory's first director, and Fitz agreed to provide a new one for an additional \$600. The replacement mounting, actually made by Phelps, arrived in 1857 November, three years after the originally anticipated delivery date. Whitesell found evidence indicating that the objective was also replaced at this time. The technical circumstances of this purported lens exchange would be very interesting to understand, if such information can eventually be found.

Given Phelps' association with the Detroit equatorial, and the rarely-mentioned fact that he was also involved with other important early telescopes, he is something of an unsung hero in the history of American astronomy. Thus it is gratifying to read in this book a number of details about him, particularly regarding his early collaboration with the Gurleys, who went on to become famous makers of surveying instruments.

The author's special interest is history of higher education, so many details of Tappan, his work, family, and associates are included. These details, and others throughout the book, may seem of unimportance to an astronomical specialist, but indeed the information is helpful to understand the context of Detroit Observatory's creation. Thus, for example, we read much of Henry N Walker, a railroad lawyer, who donated the entire cost of the meridian circle. Walker was of course interested in the Observatory's potential for providing accurate time for the railroads. By 1863, a time ball in Detroit was triggered by telegraph signals from the new Ann Arbor facility, and an illustration of this ball is provided in the book.

A particularly interesting chapter relates to the controversial and complex Canadian-born astronomer James Craig Watson (1838-1880), the second director of Detroit Observatory (1864 to 1878). Watson discovered 22 asteroids and was respected as a brilliant mathematician. Often charming but also vain, he generally did not welcome students at the observatory, and he was frequently distracted by personal financial difficulties and investment schemes. After his death, solar astronomer Charles A Young wrote that Watson's "treatment of his wife was simply abominable" and that "there is no need to expose his faults; but they should not be replaced by virtues he did not possess."

The book's 13 short chapters tend to repeat some details, and the chronology jumps around bit, but a benefit is that the chapters tend to stand on their own, and readers are reminded of important facts as they proceed through the text. As with any book of this nature, some technical details would have been clarified if the material had been reviewed by specialists. For example, there is a mention of Fitz and the warmth of his fingers, which "accelerated the flow and figure of the glass" – not the best way to describe the technique of local figuring. (Readers interested in Fitz should note John Lankford's excellent *Sky & Telescope* article, "In Search of Henry Fitz" [September, 1984, issue], which I do not believe is mentioned in this book, though many obscure references are.)

Among trivial things, I appreciated the author's tendency to be very particular regarding the inclusion of middle names and initials. In particular, she refers to Fitz has 'Henry N Fitz, Jr.,' and she carefully distinguishes between Fitz and his much more obscure son, 'Harry,' who also made telescopes at times until his death in 1939. Fitz did not use his middle initial 'N' in signatures on telescopes, and this initial is not mentioned in any prior writings about him that I have seen. As a telescope specialist, I am intrigued with a little detail like this.

Another trivial matter is that while an illustration on page 126 indeed shows an early form of lightweight Clark equatorial, the telescope itself is probably not a 6-inch, as described. But I must admit that another interpretation of this photo is that indeed the telescope is a 6-inch, while the mounting is a larger example of a common Clark design, which, in this expanded form, would be unique among any surviving examples today. The image, like many good points in the book, thus encourages further research for an interested specialist.

The later history of Detroit Observatory, especially regarding the 37½-inch reflector (1906) and its long-running programme of stellar spectroscopy, is not emphasized in this book. There is, however, a very helpful timeline extending into the present era, as well as other appendices including the scientific publications of the first two directors, asteroids and comets discovered at the Observatory, a listing of the all the scientific directors of the facility, important astronomers trained at the facility, etc. An index seems to err on the side of including everything – as I would prefer it!

The recent meticulous restoration of this facility is a credit to the University of Michigan and involved many caring people. Although expensive, the effort set an important example for all of us eager to preserve astronomical history and heritage. I have heard a charming anecdote describing a significant bequest to the University of Michigan to support this restoration, but it does not seem to be included in this book, and I hope it can be publicized later. I look forward to celebrating the more recent bequest to Detroit Observatory at its sesquicentennial in 2004, and I encourage any readers to visit and admire Detroit Observatory, whenever they can.

John W Briggs

Sky Dragons and Celestial Serpents, by Alastair McBeath (Dragon's Head Press, PO Box 3369, London, SW6 6JN, UK, 1998), 72 pp., ISBN 0 9524387 3 9, soft cover, £4.99 plus £0.50 post and packing, 205 × 145mm.

In his popular and influential *Outlines of Astronomy*, first published in 1849, Sir John Herschel grumbled memorably that the constellations:

> ... seem to have been almost purposely named and delineated to cause as much confusion and inconvenience as possible. Innumerable snakes twine through long and contorted areas of the heavens, where no memory can follow them; bears, lions, and fishes, large and small, confuse all nomenclature.

This short book is the story of those 'innumerable snakes'. It gives a comprehensive account of the lore and mythology associated with the serpentine constellations Draco, Cetus, Hydra, and Serpens and also covers the modern, southern hemisphere, Hydrus. The principal myths associated with these constellations in classical antiquity are described as is more recent Romanian folklore. Finding charts and instructions are included for the constellations described and the first chapter gives a general introduction to the constellations and related topics, such as precession. This latter material will probably already be familiar to most astronomers, though it would be useful to mythologists new to the subject. Other celestial phenomena which have draconic lore associated with them, such as comets, meteor showers, and the aurora, are also covered.

The book has two problems worth mentioning. One is that the author overestimates the number of non-zodiacal constellations which originated in ancient Mesopotamia, probably through relying too much on sources published in the first few decades of the twentieth century, when the extant Babylonian astronomical texts were less well understood than they are now. Secondly, having adopted a Mesopotamian origin for the serpentine constellations he then relates them to the Babylonian goddess Tiamat. In Babylonian mythology the sky was formed from half of Tiamat's corpse, but there is no evidence that she was ever represented as a constellation.

The book has extensive lists of references, though it is unfortunate that it went to press slightly too early to mention Roger's recent reviews of the current understanding of the origin of the constellations (*J. Brit. astr. Assoc.*, **108**:9-28, 79-89, 1998). The author is an amateur astronomer and mythologist and the book is produced by a 'small press' publisher specializing in dragon lore. Given the very reasonable price it is well worth buying a copy and enjoying reading the myths associated with the serpentine constellations. However, the thesis that these constellations are related to the Mesopotamian goddess Tiamat should be treated with a healthy dose of scepticism.

Clive Davenhall

Calendars and Constellations of the Ancient World, by Emmeline Plunkett, 1997 (Senate, an imprint of Random House UK Ltd, London), 255 pp., ISBN 1 85958 488 8, soft cover, £1.99,215 × 134mm.

This book is a facsimile edition of *Ancient Calendars and Constellations*, originally published in 1903. It consists of two parts. Part I comprises a series of papers, all of which appeared in the *Proceedings of the Society of Biblical Archaeology*, between 1892 and 1901, apart from one which was published in a set of conference proceedings. Part II is original material.

The book is broadly about the origins of the classical Grecian constellations and also the calendars used by various ancient peoples. A number of such books were published in the decades around 1900, stimulated in part no doubt by the archaeological excavations in Mesopotamia following Botta's discovery of Nineveh in the 1840s, the decipherment of the cuneiform texts found there, and the discovery of unmistakable references to the zodiacal constellations in them. The book examines the archaeological and mythological evidence for knowledge of the zodiacal constellations in the Mesopotamian, Egyptian, Indian, and Chinese civilisations. It also proposes dates for the origins of several ancient calendars according to similarities between images found in mythology and symbolic art and the traditional representations of various constellations, together with the dates when these constellations marked the solstitial and equinoctial points. Part II similarly dates various constellations according to the simple criterion of when precession made them prominent and upright in the sky.

The underlying theme is that the zodiacal constellations had a truly ancient origin in the civilization which preceded the Biblical fall of the Tower of Babel and that they were preserved by the various civilizations that eventually emerged after the races of mankind were "scattered abroad upon the faces of the whole Earth" (Gen. 11:4), though this is not explicitly stated until the end of Part I. In *The Search for the Perfect Language* and *Serendipities*, Umberto Eco has described the search, which exercised scholars for centuries, for the common, perfect, ancestor of all the world's languages, which was spoken before the Tower of Babel fell. There is an echo of this quest in the attempt to show a similar origin and diaspora for the zodiacal constellations.

Much scholarship is displayed, though many of the arguments deployed have been superseded by more recent work and, indeed, some would have been controversial when the book was written (a circumstance which the author does not try to hide). For example, it is not generally accepted that the zodiacal constellations were known to Indian astronomy before the conquests of Alexander. It is surprising to find a reference to the various estimates for the length of time which has elapsed since the Biblical creation, though it is unclear whether this argument is intended to be taken literally, or is merely being used as a literary and rhetorical device.

The style is of its time: courteous and well written. Passages from modern works which were not originally in English are quoted untranslated in the original German or French. The book is not really suitable for anyone new to the topic of the origin of the constellations, and it could be misleading if taken at face value. However, for anyone interested in the development of ideas about the origins of the constellations it is a fascinating and thought-provoking read. The publishers are to be applauded for making this little-known and difficult-to-obtain work available again, particularly given the extremely low price.

Clive Davenhall

From White Dwarfs to Black Holes: The Legacy of S. Chandrasekhar, edited by G Srinivasan (University of Chicago Press, Chicago, 1999), xiii + 240 pp., ISBN 0-226-76996-8, US$40.00 £31.95, cloth.

Subrahmanyan Chandrasekhar, through his brilliance, industry and many students, will be remembered as one of the most powerful and influential mathematical theorists in 20th century astrophysics. His life was a complex web of social privilege, racial discrimination, professional hostility, and spectacular achievement that has already been the subject of biography (K. C. Wali, *Chandra*. Chicago, 1991) and personal commentary (S. Chandrasekhar. *Truth and Beauty*. Chicago: 1987). He was managing editor of *The Astrophysical Journal* from 1952 to 1971, and in that capacity touched the professional lives of a great many astronomers.

Under review here is a collection of essays that reflect the major themes of Chandrasekhar's scientific life. It is well known, as the editor points out, that from 1929 until his death in 1995, Chandrasekhar migrated in a conscious and visible way through a series of major problem areas in theoretical astrophysics, mathematical physics, and relativity, defining their boundaries, rationalizing their operational venues, and establishing the methods by which they could be further studied. In the first six areas, he typically capped his work by publishing a seminal text, usually a compilation of his papers, but in every case an astounding example of the seamlessness of his style.

In his first decade of work, Chandra, as his colleagues and students called him later in life, entered the field of stellar structure, the central thread of theoretical astrophysics, contributing to the theory of white dwarfs. His interests reflected those of his mentors R H Fowler and E A Milne, but he soon found his work the subject of sharp criticism by A S Eddington, who dominated theoretical astrophysics in a manner unknown today. Chandra's work was not to be denied, however, though his perceptions were heavily influenced by the resistance of most astronomers to rigorous mathematical theory. Even those who sympathized with Chandra in the 1930s were unable to assure him that he was a fully accepted colleague in the field. W H McCrea, then an editor of *The Observatory* and rough contemporary to Chandra, wrote to console his passionate and deeply sensitive friend over a rejected paper: "There is always a feeling in the Society that we normally publish too much mathematics, so we sometimes have to decline to publish a paper in which the proportion of mathematics to astronomy seems too great." (McCrea to Chandrasekhar, 14 September 1937. *Chandrasekhar Papers*, University of Chicago)

Such explanations were of little consolation to Chandra, who devoted his enormous energies to the elucidation of mathematical theory and its application to astronomical problems. Although the essays published in this commemorative volume do not adequately reflect this historical context for appreciating Chandra's contributions, they do provide insight into how he influenced each problem area he entered. Most of the chapters provide a bit of biographical background, establishing the relationship the author had with Chandra, and most offer a brief historical introduction to the problem area, its state before Chandra's entry, and its state after his attentions had run their cycle. The bulk of each chapter, however, save one, deals with the contemporary state of the fields of stellar structure and evolution, neutron stars, stellar dynamics, radiative transfer, magnetohydrodynamics, and the theory of black holes. The one chapter that does offer some historical context, by Donald Osterbrock, covers the critical and captivating subject of Chandra as a teacher, reviewing the scientific collaborations and mentoring he provided his many graduate and postdoctoral students.

Typical for a collection of lightly-edited essays, the book lacks an index.

D. H. DeVorkin

The Message of the Angles – Astrometry from 1798 to 1998, proceedings of the international spring meeting of the Astronomische Gesellschaft, held during 11-15 May 1998, edited by P.Brosche, W.R. Dick, O. Schwartz and R. Wielen, *Acta Historica Astronomiae*, **3** (Verlag Harri Deutsch: Thun and Frankfurt am Main, 1999), 276 pp., ISBN 3-8171-1588-1, soft cover, DM 60.30, about £20, 147 × 208 mm.

What can reasonably be considered to be the first international meeting of astronomers, and thus the predecessor of subsequent astronomical conferences, occurred over several months during the summer and autumn of 1798 at the Seeberg Observatory in Gotha, Thuringia, under the auspices of its celebrated director, Franz Xaver von Zach. To commemorate the two hundredth anniversary of this assembly the spring meeting of the Astronomische Gesellschaft was held in Gotha during 1998 May. The present volume is the proceedings of that meeting. In a deliberate reprise of an earlier astronomical tradition the papers are presented in several languages. However, in practice, most are in English, though the reports of the opening ceremonies are in German.

The two main topics of the meeting were astrometry and the history of astronomy. These topics are well-matched: astrometry was long the pre-eminent branch of astronomy and it is a subject where the re-use of historical observations continues to be important in contemporary studies. In addition, astrometry has undergone something of a renaissance in recent years, largely due to the results from the Hipparcos satellite.

The proceedings are divided into four parts: I – the history of astronomy since the enlightenment; II – old and new observations; III – Hipparcos and beyond, and IV – other topics. Each section comprises a few longer papers and a number of shorter ones, typically about a page in length. Many of the papers are informative, useful and interesting, particularly the longer ones. Unsurprisingly, the papers in the historical section concentrate on the original meeting at the Seeberg Observatory and related events and personalities. The second section, about combining historical and contemporary observations, includes contributions on using historical eclipse records to measure changes in the Earth's rate of rotation, various aspects of catalogues in the FK (Fundamental Catalogue) series and on the *Carte du Ciel* project. The third section has papers discussing the effects of the Hipparcos results on the calibration of the distance scale and on knowledge of nearby stars. It also has contributions looking forward to the proposed DIVA and GAIA astrometric satellites. As its name suggests, the final section is something of a mixed bag, but includes, for example, an interesting paper on early studies of the Orion nebula.

English is presumably not the first language of most of the authors, but nonetheless the papers are largely well written and also there are relatively few typographical errors. Any set of conference proceedings is necessarily a collection of disparate papers, rather than a coherent narrative with a developed theme, which some people might find a disincentive for private purchase. However, in the present case, the very reasonable price may mitigate this objection. Also, the volume would be a valuable addition to the library of any department specialising in either the history of astronomy or in astrometry, and, indeed, would be useful in a general astronomical library.

Clive Davenhall

Eclipse, The celestial phenomenon which has changed the course of history, by Duncan Steel Headline Book Publishing, London, 1999), xvi + 368 pp., ISBN 0 7472 7385 5, cloth, AU$34.95, 183 × 130 mm.

I noticed a display of this book in Waterstone's, Eastbourne, UK, whilst staying there during early July this year, the timing of the book being for the eclipse of August 11. The unusual part is that I received a review copy in early August with an embargo date of August 13, two days after the eclipse, perhaps it is just the tyranny of distance.

As suggested in the title, it deals with "... not only solar and lunar eclipses, and related events such as transits and occultations of planets and asteroids, but also the greta influence these events have had upon the advance of civilization." This it does when the reader is taken gently through the four kinds of eclipses, gently, because there is a fifty-page appendix on calculating eclipses. Thus the reader may continue through the book without having to concentrate on mathematics instead of the interwoven historical events. The four kinds of eclipses are solar, lunar, planetary occultations, and transits, with each explained, shown to be useful, and related to an historical event. Although not put into a fifth kind of eclipse, the gravitational lensing by a galaxy is discussed and called an eclipse.

For those more interested in historical events, there are many examples of the use of eclipses both forward and backward. The knowledge that an eclipse was to occur on such a date was used by those with the data to impress, persuade, or defeat those without the knowledge. Many examples of this are given throughout the text. The recording of an eclipse in the past has enabled astronomers to calculate the exact date or year of the related event. A good example of this is the determination of the date of the Crucifixion of Jesus which can be associated with the lunar eclipse of AD 33 April 3 to coincide with the Jewish Passover which is at Full Moon.

The final chapter lists total solar eclipses for the next twenty years and where to view them. Of the forty-eight solar eclipses for the period, thirteen are total, fifteen annular, two hybrid (changing between annular and total along the track), and eighteen are partial. For total lunar eclipses only the first ten of the twenty are listed up to 2008.

The disappointing point about the book is the poor reproductions of the figures which could have been greatly improved with very little increase in price, resulting in a much better publication. The other annoying point which took some time to come to terms with was the use of the Roman I instead of the Arabic 1 mixed up in dates, such as "I987" or "20I2". The book is written in an easy, pleasing style and should make an enjoyable read for both astronomers and others.

John Perdrix

Publications received

Galileo's Planet, Observing Jupiter Before Photography by Thomas Hockey (Institute of Physics Publishing, Bristol, 1999), xvii + 217 pp., ISBN 0 7503 0448 0, cloth, £29.95, US$49.50, 240 × 160 mm.

Seven Wonders of the Cosmos, by Jayant V Narlikar (Cambridge University Press, Cambridge, 1999), x + 324 pp., cloth ISBN 0 521 63087 8 AU$110.00, paper ISBN 0 521 63898 4 AU$34.95, 228 × 152 mm.

Guido Horn d'Arturo e lo specchio a tasselli, edited by Marina Zuccoli e Fabrizio Bònoli 103 pp., paper ISBN 88-491-1292-0, 240 × 172 mm.

Guido Horn d'Arturo: astronomo e uomo di cultura, by Alberto Rossi (Cooperativa Libraria Universitaria Editrice Bologna, Bologna, 1994), 85 pp. paper, 235 × 155 mm.

Author index

Subject index

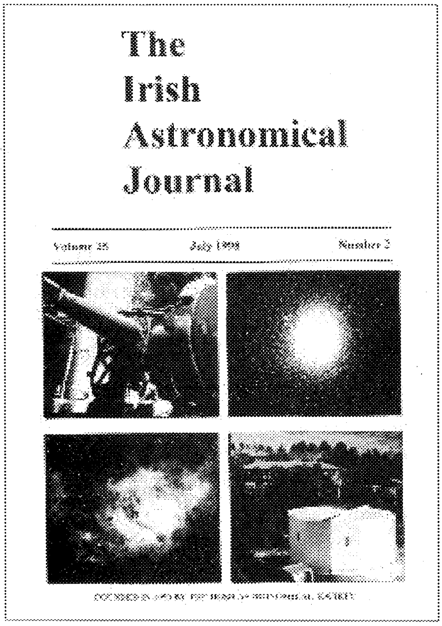
The Irish Astronomical Journal

Founded in 1950

The Irish Astronomical Journal is published as a general review of modern astronomical research papers, articles on space and astronomy and book reviews. The contents will be of interest both to the general reader and the specialist, as well as giving an insight into astronomical problems to scientists in other fields.

The IAJ is published twice a year, in January and July. Subscribers at present include major university and institutional libraries and private individuals worldwide.

The editor will consider for publication papers on all aspects of astronomy: observational, theoretical, technological and historical. Papers on related topics such as geophysics and climatology will also be considered.



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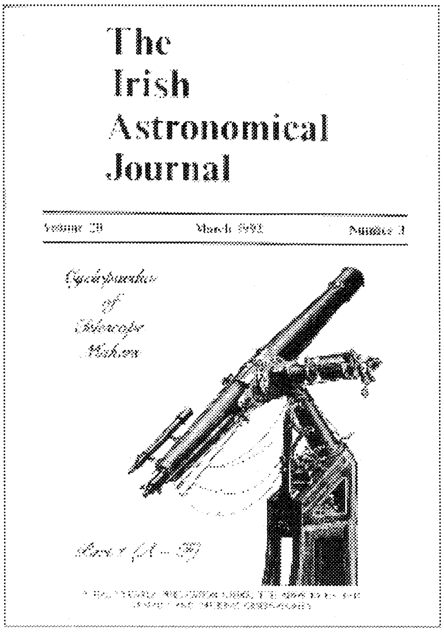

The
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A Cyclopaedia of Telescope Makers was published in the IAJ in seven parts from 1992 to 1997, with 368 illustrations. The *Cyclopaedia* consists of short biographical notes on telescope-makers, telescope-opticians, telescope-engineers, contemporary astronomers and natural philosophers, and retailers of optical scientific instruments of particular influence in their time. It is intended to provide some guidance to those seeking up-to-date information on telescope making, retailing and designing over the last four centuries.

The Editor welcomes communications of all kinds with subscribers worldwide. All correspondence and requests for further information regarding submissions for publication, subscription prices and advertising please contact the editorial office by letter or e-mail or visit the associate website (see below for details).

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Cover illustrations show a series of images of the η Carinae area beginning with a drawing by John Herschel published in 1847, a black and white photograph taken by Ben Gascoigne with the MSSSO 40-inch reflector at Siding Spring, a colour photograph taken by David Malin with the AAO 150-inch at Siding Spring; and a view taken with the Hubble Space Telescope, courtesy J Morse (U. CO), K Davidson (U. MN), and NASA.