circle of Paris Observatory. Further colour illustrations are integrated into the text (among them a family tree), as well as many in black and white, including a portrait of Reichenbach.

The main part of the book is again the letters, arranged chronologically on 400 pages. They come from 11 different archives, including those in Tartu and Vienna. 259 letters from or to Reichenbach are printed, as well as further correspondence between third parties. Everything is written in German. Among the 27 direct correspondents are well-known names such as Bessel, Gauss, Laplace, Littrow, Schumacher and Struve. There is biographical information about these at the end. In addition, as with Fraunhofer, some documents have also been made accessible to the public for the first time. Rolf Riekher wrote the foreword in January 2019, when he was already 97 years old. It is hard to believe the energy this man still had, even in his old age.

Conclusion

Both volumes are a treasure trove of history of science. Rolf Riekher has once again shown what is possible with an extraordinary combination of expertise, tirelessness, accuracy and expressiveness. The books provide insight into an important period in the development of astronomical instruments that enabled professional users such as Struve and Bessel to make high-precision measurements to decipher the structure of the cosmos. A whole generation of astronomers—mainly active in the field of astrometry—has benefited from the achievements of Fraunhofer and Reichenbach (both died in the same year, by the way).

It is a pity that Riekher's works are only available in German so far. They should be made accessible to a wider audience because of their wealth of new information. The problem is of course the translation of the German-language letters, the character of which must be preserved. This is a difficult task.

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***Cosmology in the Early Modern Age: A Web of Ideas*, by Paolo Bussotti and Brunello Lotti. (Cham, Springer, 2020). Pp. xvii + 328. ISBN 978-3-031-12194-4 (hardback), 160 × 240 mm, US$119.99.**

Both authors of this book on early modern cosmology are at the University of Udine in Italy. Paolo Bussotti is Associate Professor in History of Science and Techniques, and Brunello Lotti is Associate Professor of History of Philosophy.

The authors devote a chapter (typically 30 pages each) to Copernicus, Kepler, Galileo, Descartes, Huygens, Newton and Leibniz. The approach they take in each case can best be explained by considering one element from their study of Copernicus.

The authors reveal that Copernicus had a vexed relationship with Ptolemy:

> Copernicus, the man who dared to challenge and overthrow Ptolemy's system, did not think that Ptolemy … might have carried out wrong observations. Thus, he concluded that the equinoxes trepidate. (p. 17).

While he was not alone in this mistaken view, he did propose "… a new and ingenious theory to explain the trepidation." (p. 17). In this and his study of why the Earth's axis remains parallel to itself, his

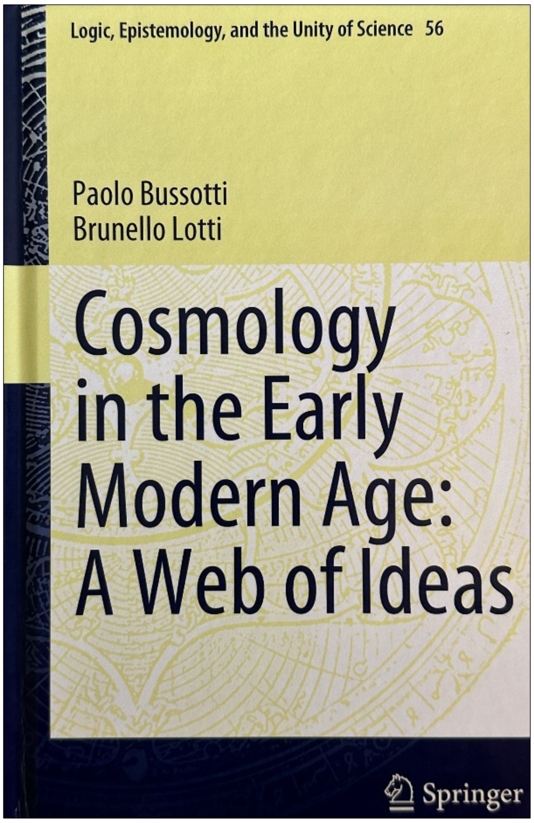
> … procedure was correct from the point of view of a scientific logic. However, knowledge of physics in Copernicus's age was by far insufficient to explain such complex phenomena as those he studied. (p. 18).

This shows us why "… the scientific-psychological presuppositions of a theory have to be considered." (p. 17). It is the application of this psychological method that is one of the two animating principles of the book.

In the case of Copernicus, this is good as far as it goes, but what is lacking is a more regressive analysis. In the 1460s, Georg Puerbach and Johannes Regiomontanus reworked Ptolemy's *Almagest*, and their manuscript was published in 1496 as the *Epitome Almagesti*. Since Copernicus often used this book, which contained foundational proofs for his creation of the heliocentric system, one must ask what were the scientific-psychological presuppositions of those authors, who mined at least some of the 15 earlier medieval commentaries? Why did they feel the need to rework Ptolemy's masterpiece and why did Copernicus place such confidence in it, instead of working only directly with the *Almagest* after it was printed in 1515? Puerbach is not mentioned in the Bussotti–Lotti book, and Regiomontanus is mentioned only in passing. This is not to say that their analysis of Copernicus is incorrect, merely that it could have been given greater depth and nuance, which may have revealed something pertinent.

The second animating principle Bussotti–Lotti employ is a clear delineation between metaphysics and physics. I will give three examples. In his book *De Revolutionibus Orbium Coelestium*, Copernicus writes that

> … the sun is not inappropriately called by some people the lantern of the universe, its mind by others, and its ruler by still others. [Hermes] Thrice Greatest labels it a visible god, and Sophocles' Electra, the all-seeing. (p. 22).



The authors write that anyone who reads the book by Copernicus realises he was "… first and foremost an astronomer, i.e. a geometer; he was not a natural philosopher." They state the passage just quoted is an extremely rare example of

> … an expression of a metaphysical 'world-view' which could be usefully associated to the new astronomical hypothesis and could legitimate it in the eyes of the scholars of his age. (pp. 22–23).

In the case of Leibniz, the authors state

> … though the metaphysical concepttion of the pre-established harmony is not directly mentioned in his planetary theory, it represents the philosophical background of the theory itself. (p. 275).

[The chapter on Leibniz is critically informed by Bussotti's book on his planetary theory, which was reviewed in this journal (Rescher, 2017).]

And for Newton,

> What really matters is to keep firm to the distinction between Newton's science and Newton's philosophical interpretation of his own scientific theories … it is likely that Newton believed that gravity was the manifestation of God's omnipotence in the physical world, but this conviction is irrelevant to the scientific significance of the law of universal gravity. (p. 297).

For Kepler, "… gravity is not a universal disposition of all bodies, but acts only in the case that two bodies are cognate." (p. 43). Therefore, Kepler did not believe gravity determined the motion of the planets around the Sun. While it was left to Newton to provide a gravitational theory, Kepler did make an advance on what the Aristotelians believed, namely that Earth was the *only* centre of gravity. This put him at odds with Galileo, who compared Kepler's 'immediate action at a distance' with the magic and vitalistic attractions of the "… Renaissance thinkers against whom he vindicated his rational-mechanistic natural philosophy." (pp. 45–46). This led Galileo into one of his greatest errors: he criticised "Kepler's idea that the tides depend on the attraction exerted by the Moon on the Earth." (p. 83). But Galileo was not alone in making errors: "… in his deduction of the orbit's ellipticity and of the area law, Kepler analysed only the libratory force." (p. 55). By ignoring the solar motive force, his deductions were incorrect. The authors go into great detail on these and other issues (including a refutation of Alexander Koyré's analysis of Galileo's concept of inertia), making a reading of the Kepler and Galileo chapters full of penetrating analysis that show how they mutually succeeded and failed.

The chapter on Descartes is also masterful. By affirming that

> … the principles of physics coincide with those of geometry … Descartes

> carried on and even pushed to the extreme the mathematization of physics that Galileo and Kepler had initiated.

Unfortunately, he did not actualize this research, and thus "… never managed to explain phenomena through mathematical treatment (p. 143). Both Descartes and Huygens studied light, but for Descartes its speed was infinite. Huygens not only disagreed with Newton's corpuscular theory of light, he correctly established it had a finite speed. But on the subject of gravity, he resorted to analogical reasoning, which is full of pitfalls. From "… the fact that gravity acts on every planet Huygens wrongly inferred that all planets are solid." (p. 186). Further reliance on analogy led him posit the existence of Earth-like forms of life on other planets, and it prompted Bussotti and Lotti to employ a rare exclamation mark:

> To maintain his thesis he supposes that water in the planets is not like our water, but it is still a liquid similar to our water for its use and beauty! (p. 188).

Throughout the book, Bussotti and Lotti pull no punches in disputing the conclusions of other prominent scholars. In addition to Koyré, they dismiss an analysis of Newton's bucket experiment by Robert Rynasiewicz; Robert DiSalle's reading of Newton's absolute motion, again with reference to the water bucket experiment; and Ori Belkind's reading of Newton's argument for absolute space.

There are several typos: "worth" should be "worthy" (p. 17); "critic" should be "critical" (p. 45); "complicate" should be "complicated" (p. 59); "scientists" should be "scientist" (p. 96); "subject" should be "subjects" (p. 117); "resoning" should be "reasoning" (p. 237); and "as as a" should be "as a" (p. 118). The book has no overall Index, which perforce hampers searching for anything. On the other hand, each chapter is fully referenced, and contains many footnotes.

Despite minor quibbles this is a book of great substance. In their critical readings, Bussotti and Lotti do a great service to those who might be misled on critical points of interpretation in their own study of cosmology in the early modern era.

Reference

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With Stars in Their Eyes: The Extraordinary Lives and Enduring Genius of Aden and Marjorie Meinel, by James B. Breckingridge and Alec M. Pridgeon, with an invited chapter by Donald E. Osborn. (Oxford, Oxford University Press, 2022). Pp. xiv + 518. ISBN 9780190915609 (hardback), 235 × 150 mm, US$44.95.

Aden Baker Meinel (1922–2011) with the eventual collaboration of his wife, Marjorie Steele Pettit Meinel (1922–2008), the daughter of Mount Wilson astronomer Edison Pettit, conceived, sometimes developed, and occasionally got to build an enormous variety of devices to improve astronomical observing at visible and infrared wavelengths. This volume tells their story, in considerable and heavily footnoted detail.

A formal timeline (which is not provided but would have been very useful to the reader) would include the observatories on Mount Wilson, Kitt Peak, Mauna Kea, Mount Hamilton, and Mount Palomar, plus the Whipple Observatory and planned facilities in China and elsewhere. Relatively late in their lives, they took an interest in solar energy, before it became fashionable, ending their formal careers at the Jet Propulsion Laboratory, near where they had spent portions of their childhoods in Pasadena, and where their employer was first author Breckenridge of this book.

The Meinels also raised seven children together, one of whom became a Lutheran pastor. They married in September, 1944, spending their honeymoon in the rather spartan Kapteyn Cottage on Mt. Wilson. Aden soon after took off for Europe as part of the ALSOS mission, to find out just what all the Germans had accomplished during World War II at Dachau, Pennemunde, and so forth.

The volume has some gems, for instance, after Aden resigned as Director of the Optical Sciences Center at the University of Arizona (which he had founded) "… the department's student-academic productivity increased noticeably." (p. 288). But my notes also contain more than 150 items called 'oops', 'no', 'something missing', and '???'. Some of the ??? indicate that a reader already needs to know quite a lot about as-