substitute for thought in Physics." (page 219).

Lightspeed provides a good summary of the scientists and historical advances involved in determining the speed of light. Readers with some background knowledge of optics, electricity and magnetism will have an easier time digesting all of the information Spence has included such as light ray diagrams. In addition, Spence gives descriptions of many of the instruments that were developed in order to investigate the behavior of light. Ingenious designs of instruments that could make precise measurements were needed to fine tune the mechanical methods required for speed of light measurements such as the extensive use of rotating mirrors.

Spence delves into lives of some of the lesser known scientists, several almost forgotten today, giving credit to those who did important research but have historically not been given the credit they deserved. Quite a few specific suggestions of books and research papers are given for those wishing to dig more deeply into specific topics or learn more about the contributions of specific scientists. For example, Spence points out that while Michael Faraday was an excellent experimentalist who contributed much to the study of electromagnetism using clear and simple language, it was James Clerk Maxwell who summarized Faraday's work in a set of equations that are now the basis of modern electromagnetic theory. Maxwell also demonstrated that magnetic and electric fields travel as waves at the speed of light.

Spence brings to light many insufficiently appreciated achievements such as those of Oliver Heaviside, who rewrote Maxwell's equations in the late 1800s in the form used today. In doing so, Spence nicely paints a detailed picture of the way that scientists build on the knowledge gained from previous observations and experiments to keep adding to the total body of knowledge. He also shows that the process is often not linear and can take many years to complete. When discussing radio and telecommunications, he notes the contributions Heinrich Hertz made and points out that "Modern attempts to reproduce his work have shown how difficult it must have been." (page 170).

The only real problem with reading *Lightspeed* is that Spence packs so many details concerning specific scientists, experiments, instruments, and equations in each chapter that it can overwhelm anyone not already familiar with the topics covered. The background history is fun, but plowing through all the experimental and biographical details may cause some to not continue reading to the end. No matter how far one reads, though, be sure not to miss the explanation in Appendix 5 of "… how to measure the speed of light with a Microwave oven and pizza dough …" on page 229.

Dr Jana Ruth Ford
Department of Physics & Astronomy,
Middle Tennessee State University,
Murfreesboro, TN, USA
E-mail: jford@mtsu.edu

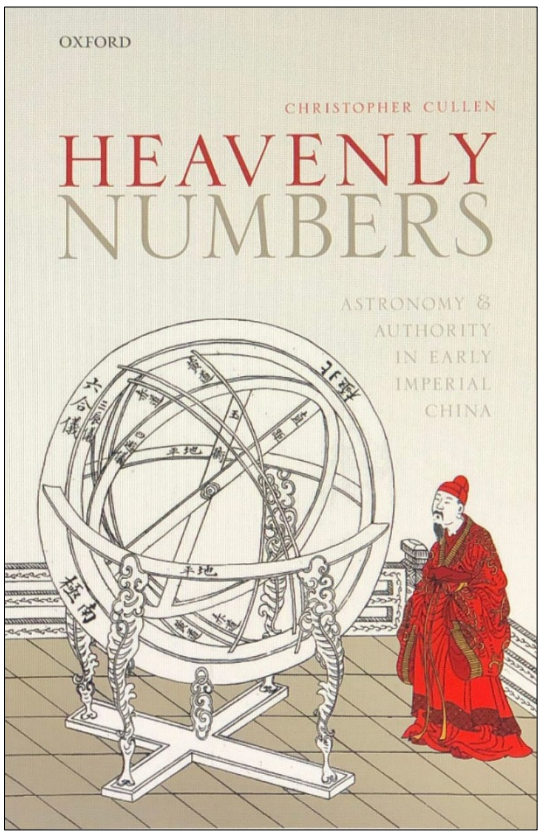
***Heavenly Numbers: Astronomy and Authority in Early Imperial China*, by Christopher Cullen. (Oxford, Oxford University Press, 2017). Pp. xiv + 426. ISBN 9780198733119 (hardback), 234 × 156 mm, £78.**

Heavenly Numbers: Astronomy and Authority in Early Imperial China by Christopher Cullen provides an overview of the role of astronomers and astronomy in early imperial China at court and everyday life. Cullen describes China as a "… distinctly astronomical empire …" (page 19), in which rulers claimed legitimacy, in part, by demonstrating their comprehension of cosmic patterns. *Heavenly Numbers* serves, to an extent, as a companion volume to Cullen's 2016 monograph, *The Foundations of Celestial Reckoning*, in which he translates three Han astronomical systems (*li* 曆). While *Foundations* is directed at specialists of early Chinese history and contains translations of highly technical texts, *Heavenly Numbers* is written for a broader audience, speaking both to historians of non-Chinese astronomy, as well as to historians of early China who have some interest in astronomy and astronomers in the early imperial period. It is largely successful in this endeavour; enough basic astronomical information is presented to accommodate Han specialists without any technical background, and sufficient cultural history is provided for historians of astronomy who are not familiar with the early imperial context. The book also includes technical discussions of Han astronomical systems, usually presented in boxes inset in the text, for those who wish to have a more detailed understanding of the constants and calculations employed by Han astronomers.

Cullen centres his narrative on individual astronomers and their work during the Western and Eastern Han periods (206 BCE–220 CE). During this period, a narrative was created wherein sage rulers of antiquity observed the heavens and established calendars for the people. This narrative contributed to Han legitimacy, and established the importance of astronomy and astronomers at Court. It was during this early period, Cullen argues, that the foundations for astronomical debate at Court were laid, as was the precedent of rulers establishing astronomical syst-

ems. These systems would be used by Court astronomers to create annual civil calendars and to calculate lunar phases, eclipses, and other astronomical phenomena. *Heavenly Numbers* tells the story of these astronomers.

In addition to being an astronomical Empire, as Cullen notes, the Han was also an archival Empire, providing historians of astronomy with a huge archive of sources which include technical documents, calendars, and records of debates over astronomical principles. This archive is unique in the ancient world; for no other ancient civilization are we able to trace the evolution of astronomical thinking in such detail (page 7). The richness of the Han sources allows Cullen to



place developments in astronomical thought in their cultural context, showing how Han astronomy was itself strongly influenced by, and needed to align itself with, Han philosophical thought. The development of the 'Han paradigm', which came to influence later imperial astronomy (page 19), is traced through the work of various astronomers: some were employed by the Court, others studied the sky independently.

Chapter Two presents the cultural and historical role of astronomy in state authority, describing the development of the narrative of sage rulers of antiquity observing the heavens and creating calendars for the people. The chapter then outlines some of the basic principles of astronomical systems and calendars, as well as the sources in which these records are preserved. Chapters Three through Eight look, chronologically, at the work of different astronomers, examining how their principles developed, the systems they created for the state, the methods of observation they employed, and the astronomical debates they engaged in at Court. The Epilogue (Chapter Nine) summarizes some of the main points, and briefly discusses the legacy of the Han paradigm in later imperial China.

Several of the topics in the book are the subject of Cullen's many other books, chapters, and research papers, but here they are woven together into a narrative that presents a broad overview of early Chinese astronomy which is much more accessible to the non-specialist. Cullen employs a variety of sources, including texts from the received tradition (many of which he has translated in full in other publications), newly excavated or 'discovered' (a euphemism for looted) documents, as well as archaeological artefacts, such as the *shi* 栻 ('[cosmic] models', page 202). The translations are accompanied by Chinese graphs, and the book contains many images, including those of bamboo manuscripts, drawings and prints of astronomical equipment, and pages from Chinese texts. While Han specialists might not find page reproductions of Qing-era compilations (for example, from the *Si ku quan shu*) particularly relevant, they do provide the non-Han specialist with an idea of what these astronomical texts might have looked like.

Throughout the book, when relevant, Cullen makes comparisons with astronomers and astronomical knowledge from other civilizations. He is careful not to fall into the value trap of proclaiming one society more advanced than the other. Rather, comparisons are made to highlight the uniqueness of the Chinese case, and to emphasize the importance of the cultural background in which these astronomers worked. Comparisons with ancient Mediterranean or Mesopotamia highlight the cultural differences of these civilizations and their astronomers' attempts to understand the cosmos, but for the most part, Cullen tries, wherever possible, to let the Chinese astronomers speak for themselves. Descriptions are also included of his own attempts to re-create some of the experiments of the Han astronomers, relating his experiments in using a Clepsydra on his balcony at Cambridge in the 1970s, or checking the observational data recorded in Han sources with modern software

As a work of cultural history, *Heavenly Numbers* is at times overly technical, which may dissuade readers who balk at the sight of

mathematical equations and astronomical diagrams. However, alongside the technical details, Cullen explains the context of the technical developments, allowing readers to understand their importance. *Heavenly Numbers* is an accessible introduction to the world of early Chinese astronomy, for Han specialists, and I would imagine that historians of astronomy of other cultures will find it a good introduction to the very rich astronomical culture of early China.

Reference

Cullen, C. 2016. *The Foundations of Celestial Reckoning: Three Ancient Chinese Astronomical Systems*. New York, Routledge.

Dr Rebecca Robinson
Research Assistant Professor,
Department of History, Hong Kong Baptist University, Hong Kong.
E-mail: rrobinson@hkbu.edu.hk

Wordsworth, Coleridge, and 'The Language of the Heavens', by Thomas Owens. (Oxford, Oxford University Press, 2019). Pp. xiv + 207. ISBN 978-0-19-884086-2 (hardback), 155 × 240 mm, US$85.

In this important book, Thomas Owens (University College London) brilliantly accomplishes what I most admire in a book of historical astronomy: overturning prevalent critical consensus. In this case the consensus is that the poets William Wordsworth and Samuel Taylor Coleridge did not have the access, interest, or capacity to understand contemporary developments in astronomy and mathematics. The disparagement of English poets in this regard is nothing new—John Milton was accused by scholars of similar ignorance for centuries, a canard only recently proven false (Cunningham, 2016). Milton's legacy reappears many times in this book; Coleridge himself regarded one of Wordsworth's 1802 poems as having been written "… in the spirit of the best of Milton's sonnets." (page 83).

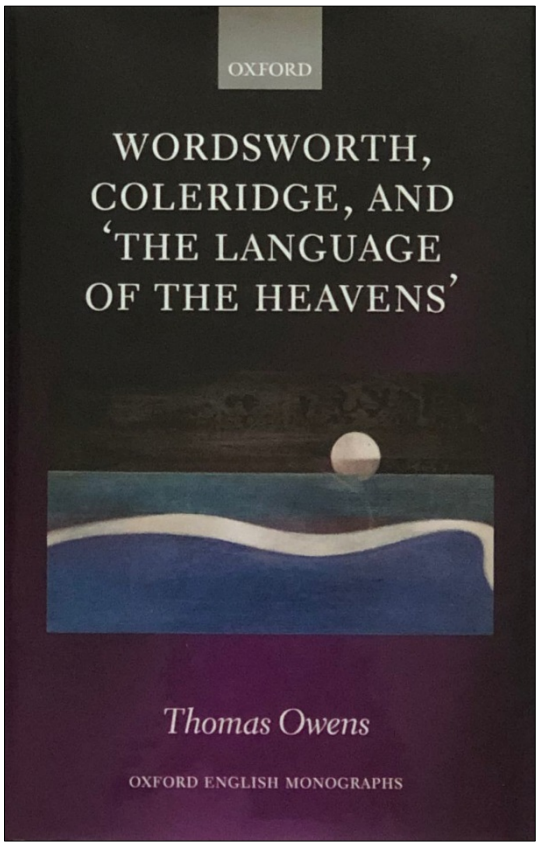
That, perhaps, is not surprising, but the legacy of Johannes Kepler certainly is. In his Lectures of 1818 and 1819, "Coleridge singled out Kepler as marking the beginning of 'truly scientific astronomy'…" (page 168), and he

> … found it impossible not to admire the celestial harmony he found in Kepler which relied on a congruence between geometrical and physical phenomena. (page 19).

In an 1819 lecture, Coleridge rightly declared astronomy "… will for ever remain the greatest monument of human greatness." (page 168). Of course Coleridge was a poet, so his misuse of the contemporary discoveries of William Herschel—while astonishing in its application—is not startling. Consider his pairing of sunspots (which Herschel wrote about in 1801) with infrared radiation (which Herschel discovered in 1800). "Coleridge affirmed," writes Owens,

> … in double Herschelian terms that the Church of England was 'the *most* Apostolic church … and that the imperfections in its Liturgy are spots indeed, but spots on the sun which impede neither its Light nor its Heat.' (page 155).

Owens goes beyond mere poetic analysis here by providing the historical background, noting the pairing:



> … made for a particularly apposite union considering that Herschel chanced upon the discovery of infra-red whilst testing his coloured filters for the Sun in order to observe its spots in the first place. (page 156).

On astronomy and physics more generally, Owens elucidates the "… somewhat ironic …" fact that "… Coleridge's religious teachings are bookended not by Herschel but by Newton." (page 148). He begins by quoting from a 1796 passage in which Newton was used by Coleridge as a conduit for satire in describing the Church Establishment in terms of the "Laws of the Planetary System" (page 148). But by 1830, the poet had changed his mind, realizing "… that centripetal and centrifugal forces gave him a cosmic analogy …" to bolster his views (page 149). Owens draws