***Time and Time Again: Determination of Longitude at Sea in the 17th Century*, by Richard de Grijs. (Bristol, IOP Publishing, 2017). Pp. xvi + 351. ISBN 978-0-7503-1195-3 (hardback), 186 × 263 mm, $US $159.**

Professor Richard de Grijs is well-known to this reviewer through our association in Division C of the IAU and the succession of papers that he has recently submitted for publication in this journal (see de Grijs, 2020a; 2020b; 2020c; 2020d). Although he has built a distinguished career in astrophysics and academia, this is his first book in the history of astronomy field. I sincerely hope that it will not be his last.

The back cover 'blurb' tells us that

> Determination of one's longitude at sea has perplexed sailors [as it did astronomers] for centuries. The significant uptake of world trade in the 17th and 18th centuries rendered the increasingly urgent need to solve the 'longitude problem' …

In 367 pages and seven chapters *Time and Time Again* … tells us about how longitude was determined at sea during the seventeenth century, yet it does far more than this as the following account will reveal.

Chapter 1, "Changing Times", provides a geographical and cultural context for longitude determination by exploring the 'Dutch Golden Age'. As de Grijs says in his Preface,

> The 17th Century is regarded as the 'Golden Age' in the history of the Netherlands. The open, tolerant, and transparent conditions in the 17th Century Dutch Republic allowed the nation to play a pivotal role in the international network of humanists, scholars, and 'natural philosophers', before and during the

> 'Scientific Revolution.' Intellectuals from all over Europe visited the liberal country on the North Sea, which was then considered the 'storehouse of the intellectual world.' (page xi).

At this time, the Vereenigde Oostindische Compagnie (Dutch East India Company) monopolized trade in spices, timber and other lucrative products and the need for accurate maps, charts and navigational tools was paramount.

De Grijs then discusses "The rise of the scientist" and "Scholarly communication and scientific networks in the 17th century", and the "Birth of the learned societies and their scientific journals", before typifying the seventeenth century as the "… modern pinnacle of human ingenuity". I found much of interest in this chapter, including the concept of 'natural philosopher' *in lieu* of 'scientist'—a term dear to my astrophysics colleagues in Cambridge and Cape Town, Professors Gerry Gilmore and Brian Warner. We are also reminded that during the seventeenth century

> Writing, editing and publishing books was slow and expensive—then as now—while their readership was often limited, and printing a book carried a financial risk. (page 1-8).

And, until the rise of academic journals, some researchers resorted to including anagrams in their correspondence in order to announce their discoveries. This was possible in an era that saw the spread of 'correspondence networks' across Europe.

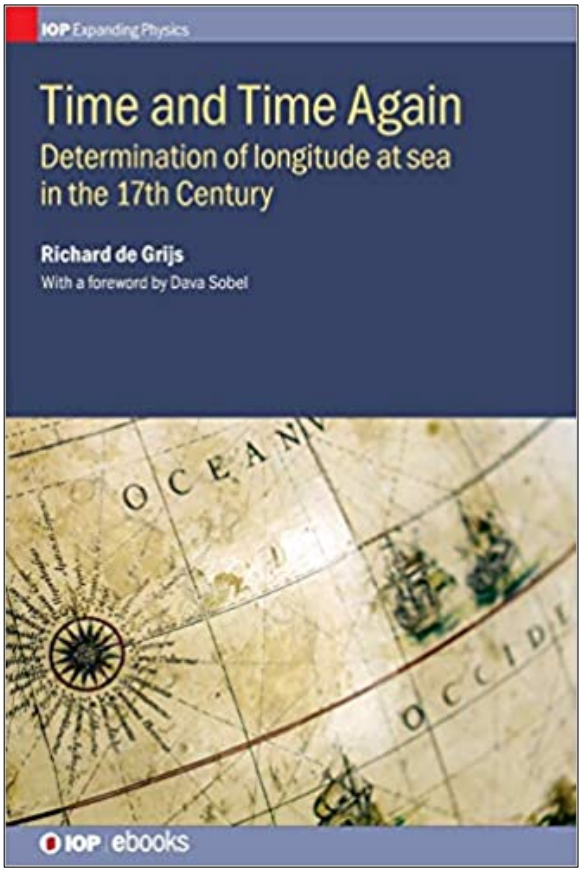
At this time "… the Italian city states, including Naples, Rome and Florence, had long also been major centres of scientific enquiry." (page 1-13), as described, for example, by Gargano (2019) and Molaro (2017) in recent papers in this journal. Meanwhile, in England, what role did French scholars play in the formation of the Royal Society (of London)? Scientific societies mushroomed at this time, and their journals became major outlets for research results.

Chapter 2, de Grijs (page 1-23) tells us,

> … is, in essence, a brief history of cartography. Its aim is to establish the context of the time [excuse the pun!]. The development of global coordinate grids originated in Greek antiquity, although the idea took independent root in the Islamic world and East Asia. Establishing an absolute reference grid requires accurate determination of longitudes and latitudes.

In this chapter, de Grijs 'spreads his cultural and chronological wings', discussing not only Greek mathematical geography and Ptolemy's map projections and Islamic cartography and mapmaking, but even Polynesian navigation, and 'East Asian navigation and cartography'. The chapter ends with the navigational techniques used by Christopher Columbus (1451–1506) on his "... fabled voyages across the Atlantic to 'discover' the Americas." (page 2-40) and then Section 2.3.3 on "Piracy and the Portuguese/ Spanish conquest of the New World". Navigation in the expansive Pacific Ocean "… was a particularly pressing problem … [as] it was, in essence, a closed book to European navigators …" (p. 2-54), and accurate maps of the region were desperately needed. This was accentuated by territorial rivalry between Portugal and Spain, and was not fully resolved with the demarcation line agreed to at the Treaty of Zaragoza in 1529.

Chapter 3 is titled "Early insights inspired by Galileo Galilei" (1564–1643), and after discussing his invention of the pendulum and pendulum



clock design, turns to Christiaan Huygens (1629–1695) and his own development of the pendulum clock. De Grijs (page 1-23) believes that these innovations "… set the tone for the Scientific Revolution." These horological achievements were then tied in with the urgent need to accurately determine longitude at sea, which led various sea-faring nations to offer lucrative 'longitude prizes'. As de Grijs recounts, these inspired

> … significant efforts by the educated elite [which] revealed not only new laws of physics, but also deeply entrenched positions and personal struggles, once again showing that scientists and scholars throughout history

> have always been just as humanly fallible as we are today. (pages 1-23–1-24).

Chapter 4 outlines the development of a practical timepiece for use at sea during the first half of the seventeenth century, with emphasis on (but not restricted solely to) the achievements of Britain's Robert Hooke (1635–1703) and Scotland's Alexander Bruce (1629–1681). This 72-page chapter contains numerous drawings and quotations (some of them lengthy), and an assortment of equations. Chapter 4 is, without doubt, the most technical of the whole book, and it will appeal most to those with a particular passion for the technological niceties of horology. At the end of the chapter there are 183 notes and references for those wishing to pursue this topic further.

After the publication of Huygens' *Horologium Oscillatorium* in 1673 there was further experimentation with clock design, mainly in England and France, and this is discussed in Chapter 5 (which runs to 65 pages). Consequently,

> Scientists, scholars, and clock-makers on both sides of the English Channel continued to compete, both scientifically and in their pursuits of the commercialization of their designs. Long-range sea-trials from the northern Dutch Republic to the Cape of Good Hope offered significant promise of breakthroughs in clock design and performance … (page 1-24).

As the principal figure in seventeenth century clock design, Huygens not only dominates Chapter 5 but also features in Chapter 6, where his disagreements with Isaac Newton (1643–1727) are aired, before we explore how Newton tried to use astronomy to solve the 'longitude problem' and the role played in this by Astronomer Royal, John Flamstead (1646–1719). Rounding out this chapter is a review of attempts to solve the 'longitude problem' that did not involve time-pieces. Thus, we learn about whether terrestrial magnetism, or even alchemy, could provide a viable solution (... they could not!).

Time and Time again … ends with a final un-numbered chapter titled simply "Epilogue. Zero longitude" which in 25 pages takes us far beyond the seventeenth century, to explore (in Section E.1) how it was that Greenwich in England was assigned zero longitude in 1884, after many locations had served to mark this for different nations long prior to this date (see the list on pages 7-1 and 7-2). Even England at one time had three: Lizard Point (Cornwall), St. Paul's Cathedral (London) and the Royal Observatory at Greenwich. But, as de Grijs reminds us, notwithstanding the 1884 conference decision "Full implementation of all the resolutions passed … would not occur until 1925 …" (page 7-8). Before returning to the Greenwich Meridian and the Airy Transit Circle in Sections E.3 and E.4, respectively, de Grijs introduces Section E.2, which briefly describes "Prime meridians from Greek Antiquity until the Enlightenment". This Chapter ends with two pages of References, which close off the whole book.

Time and Time Again ... is a scholarly work, as we might expect from someone with an impressive track record in research. It is packed with detail (including many quotations taken directly from archival sources), is copiously illustrated, and each chapter ends with Notes and References for those who may want more. It even has a Foreword by Dava Sobel. What it lacks, however, is an Index. Nonetheless, it is an indispensable text for anyone interested in seventeenth century nautical astronomy, or the perplexing 'longitude problem'. In the front section of his book Richard de Grijs dedicates this volume to his parents and hopes that

> … *this manuscript will finally put to rest a standing joke in the family triggered by my exasperated exclamation as a high-school pupil that* 'History is merely excess baggage, surplus to requirements.' (his italics).

We are delighted that Richard had finally developed a passion for 'excess baggage'!

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