# PREFACE

I am neither a specialist in solar physics and astronomy nor a historian of science. My field of expertise is particle astrophysics—more specifically, the study of ultra-high-energy cosmic rays, which include the highest energy subatomic particles in the universe. These extreme energy events are very rare and are difficult to capture. They are most likely produced in distant galaxies that harbor supermassive black holes at their centers. Studying these particles requires the construction of enormous arrays of detectors spread over hundreds of square kilometers and the development of very sensitive telescopes to detect the faint fluorescence produced by the particles. The two main observatories are the Telescope Array located in the western desert of Utah and the Pierre Auger Observatory near Malargüe, Argentina. There is a kind of "background hum" in these detectors—a steady rain of much lower energy particles, many of which come from our Sun, this relatively docile beast in our cosmic backyard. It emits low-energy particles copiously, but from my perspective, these just added to the noise we had to dig through to get to the interesting events.

I changed my mind about the Sun while on a short sabbatical leave from the University of Utah, spending time at the

University of Adelaide in Australia. Adelaide, a beautiful city on a bay with a Mediterranean feel to it, has a university known for its astronomical and cosmic ray research as well as a fine wine collection in the very pleasant open-air faculty club. It looked as though it would be a relaxing few months.

A few weeks after arriving, I happened to wander into the university library stacks and randomly pulled out a few books in the astronomy section. These turned out to be on the Sun—an area of astronomy I was not very familiar with. For the rest of my sabbatical, from morning till night, I found myself hooked and immersed in the science and the history of the science of the Sun—the phenomenon of sunspots in particular. I had had some vague ideas about these solar blemishes, but the more I read, the more fascinated I became. The Sun turned out to be a huge laboratory for the study of magnetic effects in a super-hot plasma gas. This laboratory was spinning on its axis, and it had a beat to it—a kind of clock, if you will. The clock manifested itself in the appearance of sunspots, growing and waning in number every eleven years or so.

But that was not the end of the story. A sweeping wind of particles, pulsing with the same beat as the sunspots, impacted Earth and the other planets of the solar system. On occasion, enormous storms on the Sun would send hurricanes of these particles toward Earth, wreaking havoc with compasses, communication satellites, even the power grid, and increasing radiation to dangerous levels. Why would a giant rotating ball of hot gas behave this way?

I began to think that this story could be a great unifying idea for an introductory science course—one dedicated to nonscientists. As a graduate of the University of Chicago in the 1960s, I had fond memories of the general education courses we were all required to take (this was still the legacy of the Hutchins

Great Books era)—in particular, Karl (Jock) Weintraub's section of the History of Western Civilization. To be putting together science, the history of ideas, and a little philosophy seemed both nostalgic and bracing after decades of doing pure science. There were so many stories and philosophical issues in the history of our understanding of the Sun. Appreciation of the reality of sunspots turned out to be entangled with major cultural shifts: the ancient Greeks and Chinese, the rise and dominance of Islam, the power of the Catholic Church, and the beginnings of a truly empirical science all played a role. Tracking the story of sunspots in different cultures through history could be a way of bringing together seemingly disparate areas—science, philosophy and religion, and the rise and fall of cultures and civilizations. And there was a whole panoply of personalities, some famous and others less well known.

In the following year I developed the curriculum for Liberal Education 141: The Clock in the Sun. I wrote extensive course notes, since no appropriate textbook existed. I taught the course for a number of years, learning to adapt to the new generation of undergraduates, who were not just younger versions of myself. Years later, after retiring from the University of Utah and coming across my course notes, I realized that they could be turned into a real book, aimed at the general reader with an interest in science and its history. I was very pleased that Columbia University Press was interested in my initial proposal. This was a particularly welcome association because my first real scientific job was a postdoctoral appointment at Columbia University's Nevis Laboratories. I was an assistant professor in the physics department from 1975 until I left for the University of Utah in 1981. My time at Columbia laid the foundation for my future work in particle and astroparticle physics, so it seems fitting to close my career with this publication at this press.

The book is organized chronologically but not pedantically so. The first five chapters, covering solar science in medieval China, Europe, and the Islamic empire, follow a historical order. This material does not require much prior knowledge of physics or astronomy. The emphasis here is on how cultural influences affected the development of ideas about the Sun. In some instances, these influences made it virtually impossible to reach correct conclusions. A secondary theme is the porous nature of the boundaries between what seem at first sight isolated, antithetical cultures. The movement of information and scientific ideas from culture to culture and their modification as they traveled across the ancient world can be readily seen in the microcosm of ideas about the Sun. In recent years there has been a growing realization of the importance of astronomy in the Muslim empire, not just as a transmission and preservation of Greek scientific ideas but as highly original in itself. Arab astronomers even played a role in the development of astronomy in ancient China.

With the arrival of the Renaissance and the towering figure of Galileo, we reach the beginnings of the modern scientific worldview. With detailed telescopic observations, the study of sunspots becomes more quantitative, culminating in the discovery of the solar cycle. Different aspects of solar science now begin to develop an independent history. The science of sunspots also needs to be spelled out in much more detail, and individual chapters become more thematic, dedicated to particular aspects of solar astronomy. I have tried, as much as possible, to keep to a historical chronology within each thematic chapter, but inevitably there are time jumps and repetitions, for which I beg the reader's patience.

The discovery of the solar cycle coincided in time with the realization that there was another tide in the affairs of men—the business cycle. Because both cycles seemed to have the same period, rampant speculation on whether and how they could be related ensued. Several chapters are devoted to ideas about the possible relationship between solar activity and economic cycles, whether mediated by the supposed solar effect on weather or by other factors. While most of these ideas turned out to be dead ends, they did lay the foundation for ideas about the possible effect of solar variations on climate change.

I would like to thank the physics department of the University of Adelaide for their hospitality during my sabbatical. Particular thanks go to Bruce Dawson and Roger Clay for making our family feel very much at home. This visit began the nearly two-decade gestation period for this book—it would not exist otherwise. I would also like to thank my Utah students who sat through that sometimes-rough experiment. Their questions and enthusiasms helped me focus and refine the material you are about to read. The librarians at the Stanford rare book room and the University of California, Berkeley libraries were extremely helpful in pointing me in the right direction in my historical research. I would like to thank Miranda Martin, my editor at Columbia University Press, for her support and encouragement for this project through some difficult Covid times. Jamie Zvirzdin contributed valuable writing advice as well as detailed editing. Julie Callahan did a wonderful job at cleaning up many of the illustrations. Finally, heartfelt thanks to Susan Sokolsky for her careful reading, editing, and perceptive comments, which produced a much clearer and more coherent narrative.

# THE CLOCK
# IN THE SUN