Preface

Our Sun is a fairly ordinary star, a bit brighter than most but not exceptionally so. There are many stars much bigger and brighter, while most stars are smaller and fainter. The Sun is not an especially variable or active star, and it has no enormous chemical or magnetic peculiarities. It is not a very young star, nor is it old and nearing the end of its life. It is, in short, truly exceptional in only one way: it is very close to the Earth – in fact, at just the right distance to make life as we know it possible.

Most of us do not worship the Sun as did many in ancient civilizations, but we certainly should not take for granted the light and heat that it provides. Left to itself, the Earth would be a fantastically frigid rock at near absolute-zero temperature. If the Sun had been slightly more massive, its high temperature would have made the Earth's surface hot enough to melt lead. A smaller Sun would have left the Earth unbearably cold and possibly subject to high levels of radiation, since smaller stars tend to have higher levels of activity, giving off devastating ultraviolet and x-rays. Distance also matters. Had the Earth been closer, we might be as infernally hot as Venus; farther away and we might have been as cold and arid as Mars. We are in the position of Goldilocks, living at just the right distance from a just-right star.

Does this mean that the planet Earth is unique and that we live in a providential "best of all possible worlds?" There are dangers with this way of thinking, flattering as it is to human sensibilities, because it may foster a certain complacency, a feeling that things could not be otherwise. Since indeed other planets in our Solar System do not so far appear to support life, this implies that life requires some fairly unlikely conditions in order to flourish. On the other hand, granted that the probability of finding Earth–like conditions is small, the number of planets in the Universe is very large (probably billions in our Galaxy alone). This obviously increases the statistical likelihood of habitable planets. On this view, the earth is not so much providentially unique as merely *rare*.

This in turn implies certain responsibilities for its inhabitants. Since life as we know it appears to be possible within only a narrow range of conditions, it would be prudent to know as much as we can about the star that provides the bedrock conditions on which our existence is founded. Moreover our new-found ability to alter the Earth's state on a global scale brings this need into sharp focus. For example, it is not enough for the Earth to be at the right distance from the Sun, and reflect back the right percentage of the solar light it receives. The Earth's atmosphere is also of major importance in determining the global temperature. Without it, the Earth would be colder by about 33°C (roughly 60°F), and therefore a frozen lump of ice. Right now, we are making small but significant changes to the composition of our atmosphere that are beginning to be large enough to produce major unpleasant effects. Do the natural variations in the Sun's brightness enhance or diminish these man-made effects? How do changes in solar activity affect the formation of ozone and atmospheric circulation and weather patterns?

This book explores the Sun in a comprehensive way for the non-scientific reader who wants to gain a general idea of the range and significance of solar physics. We explain what is known about the Sun and how this knowledge is acquired, discuss the origin of the Sun's light and heat, and explore how the Sun evolved and what it will become. We pay special attention to cutting-edge research on the Sun's outer atmosphere – the part that we can see – and the effects of this atmosphere on the Earth and the space around Earth. Unlike other stars, which are mere points in the sky, the Sun is so close that we can see its surface. We see sunspots form and gigantic explosive events erupt out toward the Earth. Thanks to careful measurements of the Sun's surface motions, we have recently even learned to "see" inside the Sun.

A quick tour of the contents of this book may convey our intention of being both informative and analytical:

Chapter 1. The Sun and its satellites: basic facts about the Sun and a few insignificant specks in its neighborhood.
Chapter 2. From gas to light: how a cloud of gas and dust turns into a 380,000,000,000,000,000,000 megawatt furnace.
Chapter 3. What we see: what our eyes, with a bit of help, tell us about the Sun.
Chapter 4. What we don't see: the colors we can't see and how we look inside the Sun.
Chapter 5. Eclipses: studying the Sun by covering it up.
Chapter 6. Space missions: what it's like beyond our atmosphere.
Chapter 7. The long haul: climate and the Sun.
Chapter 8. Space weather: the dangers lurking above our thin atmosphere.

The chapters may be read in any order, as they are largely self-contained. The first three chapters are similar to what is found in a standard astronomy book, although up-to-date and with emphasis on the subjects to be discussed in the rest of the book. Chapters 4–8 make up the main body, starting with our new ability to study the previously invisible parts of the Sun, followed by discussions of eclipse expeditions and space research from a personal perspective, as experienced by the authors. Chapter 7 deals with the relationship between the Sun and the Earth's climate, including the difficult issue of global warming. The last chapter concerns the shorter-term variations in the space around the Earth, which are now being called "space weather," and the reasons why we should be concerned about it.

Our book continues a fine tradition of descriptive books about the sun for general audiences. We are proud to be following in the footsteps of Donald H. Menzel's *Our Sun*, with its first edition in 1949 and its second edition in 1959. We are also proud to be in the tradition of Robert W. Noyes's *The Sun, Our Star* (1982). There is much that is new on and under the Sun in the intervening years, and it is a pleasure to be able to describe it here. One of us (JMP) got his start in solar astronomy from both the distinguished scientists who were just listed. Donald Menzel took him, as a Harvard first-year student, to a total solar eclipse, which they saw from an airplane over the Massachusetts coast, and introduced him to the changing solar surface as part of a freshman seminar. Robert Noyes took him, as a graduate student, to his first professional observing experiences by inviting him to spend a summer working with him and with Jacques M. Beckers at the Sacramento Peak Observatory, Sunspot, New Mexico. That work developed into his thesis on the solar chromosphere, with Noyes as advisor. Subsequently, as the Donald H. Menzel Postdoctoral Fellow at the Harvard College Observatory, he worked with Professor Menzel in running a Harvard-Smithsonian expedition to the 1970 total solar eclipse in Mexico. He also collaborated with Dr. Menzel on eclipse expeditions to Prince Edward Island, Canada, in 1972, and to Kenya in 1973. It could not have been foreseen that Dr. Menzel's Harvard freshman seminar would begin JMP on his current set of 58 solar eclipse expeditions that have taken him around the world.

This book attempts to render all technical material in ordinary English. In other words, our text contains few, if any, equations. The book closest to the present volume is Ken Lang's excellent *Sun, Earth and Sky*. The main difference between the two is that we approach the story from a different point of view. Rather than present science as a series of prestigious accomplishments, we invite the reader into an open-ended process of discovery. We try to show what motivates the questions that are being framed in solar physics, and how instrumental developments and theoretical creativity work together in a dynamic way to gain better insight into the Sun. Our aim is to introduce a wide and diverse audience to the substance and importance of solar physics without straining the reader's patience. If we succeed in doing this, our efforts will be amply rewarded.

Although we primarily address non-scientists, we hope that technophiles may also find the discussions worthwhile, as we devote considerable attention to instrumentation. For those who want to pursue some of our topics in a more technical fashion and who have access to the World Wide Web or the Internet, the following are Websites specializing in solar or solar-terrestrial matters:

- The Solar Data Analysis Center at NASA:
  http://umbra.nascom.nasa.gov/images/latest.html
- Solar Monitor
  http://www.solarmonitor.org
- The Space Weather Prediction Center
  http://www.swpc.noaa.gov

- The Sun Today
  http://sdowww.lmsal.com
- National Solar Observatory
  http://www.nso.edu
- Today's Space Weather
  http://www.spaceweather.com
- Solar eclipse website from JMP for the International Astronomical Union
  http://www.eclipses.info
- Eclipse maps
  http://sites.williams.edu/iau-eclipses/reference-materials/#maps

Finally, despite our best efforts, there will inevitably be typos and errors. We apologize for this in advance, and plan to maintain an errata page with an updated list of corrections, located at:

- http://www.williams.edu/Astronomy/sun.html

We encourage readers to send us typographical or other errors they find at:
lgolub@cfa.harvard.edu or eclipse@williams.edu.