The Sun Today

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Cover illustration:
The Daniel K. Inouye (Advanced Technology) Solar Telescope has a 4 m diameter primary mirror. It is sited on the summit of Haleakala ('House of the Sun') on the Hawaiian island of Maui. Viewed against the Milky Way galaxy. Photo by Scott Lacasse

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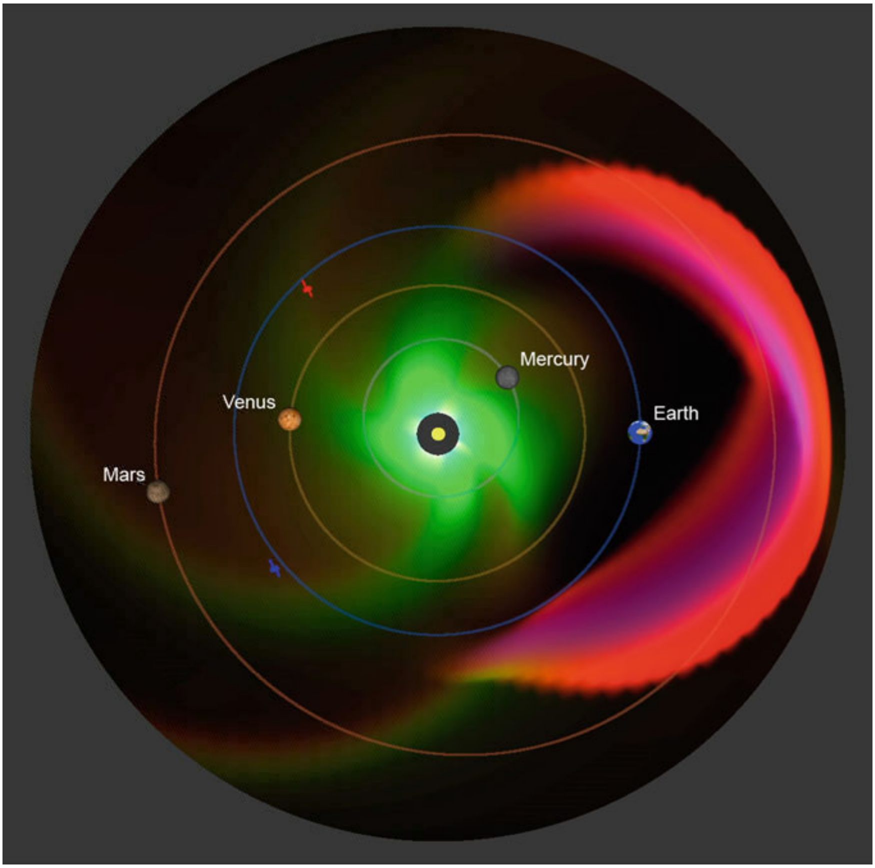
For Ennio



Frame from NASA movie of a model for the track of a fast coronal mass ejection of March 15, 2013 when it has crossed the inner solar system. Courtesy of Goddard Media Studios, NASA

Preface

The world's a scene of changes; and to be
Constant, in Nature were inconstancy.
Abraham Cowley (1618–1667)

By now, thanks to reports on TV and in magazines, we are all aware that the Sun is a moody creature subject to tantrums and unpredictable sulks, and warnings about the damage one of its explosions could cause our satellites and power supplies sound increasingly urgent. On the other hand, the possible role of the Sun in global warming and in precipitating droughts and famines tends to be eclipsed, for reasons good and bad, by explanations which highlight human folly. Add to the mix conflicting reports about the benefits and potential harm of exposure to the Sun's rays and we are left with a poor grasp of what we could call the solar factor.

Three of my Springer books have touched on the history of the Sun. The present book focuses on its current nature; a set of stills from an array of films. If to a moviegoer 'A stopped frame outside of a movie isn't anything, not even a photograph'[1], to a student of nature it is just as helpful as were Muybridge's images of galloping horses: witness the solar storm snatched from a NASA movie (Frontispiece). Even so, some flexibility is needed to capture a mood, especially as the Sun of today embodies events that occurred elsewhere in the solar system aeons ago. Perhaps it is better to think of this book as more like a TV interview, where some reminiscence is expected but the central character remains in view.

Previous studies of the Sun's activity and its interaction with us on Earth include both highly technical accounts and treatments aimed at the non-scientific reader[2]. My book is neither fish nor fowl (I'd call it a monograph if it were not so weedy[3]): it summarises what we have learnt from recent satellite missions, observation from the Earth, and the fruits of theory and computer modelling, and it also proposes a novel mechanism for heating the corona to 2 million K and for structuring the solar atmosphere. But its intended audience is ill-defined. To echo John Bahcall[4], the book aims to 'share the fun of figuring out some of nature's puzzles'; and surely half the fun is learning new stuff: popular science which excessively dilutes the science cheats the reader just as the language of the Reader's Digest Condensed Books series evaporated away some of the books' literary qualities while safeguarding their narratives. At all events, the text of The Sun Today is self-contained but extensive reference lists will enable the reader to follow up points of interest in the library or on the Internet and they allow me to give credit for the many ideas and data I cite.

Loren W. Acton, Edward Hanna, John Marshall and Gary J. Rottman generously commented on the text. I am again indebted to the space agencies, and above all NASA, for access to the fruits of their missions, to Michael Woolfson, Judith Lean, Ken Phillips and Leo Vita-Finzi for stimulating discussions, to Petra van Steenbergen and Hermine Vloemans at Springer for support, to Simon Tapper for help with the figures, and to Scott Lacasse for the cover image.

London, UK
September 2018

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References

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2. Examples: A Bhatnagar & W Livingston *Fundamentals of solar astronomy* (2005); H Friedman *Sun and Earth* (1985); L Golub & J M Pasachoff *Nearest star* (2nd ed 2014); K R Lang *The Sun from space* (2000); D J Mullan *Physics of the Sun* (2010); K J H Phillips *Guide to the Sun* (1992); C P Sonnett et al. (eds) *The Sun in time* (1991); M Stix *The Sun* (2nd ed 2002); O R White (ed) *The solar output and its variation* (1977); H Zirin *Astrophysics of the Sun* (1988).
3. The Minigraph: the future of the monograph? stunlaw.blogspot.com/2013/08
4. J N Bahcall (1989) *Neutrino Astrophysics*. Cambridge Univ. Press, Cambridge

Abbreviations

AU = Astronomical unit = Average distance from Earth to Sun = $\sim 150 \times 10^6$ km.
ly = Light year = $\sim 9.5 \times 10^{12}$ km.
pc = Parsec = ~ 3.26 ly = 3×10^{13} km.
$M_\odot$ $L_\odot$ $R_\odot$ = Solar mass, solar luminosity, solar radius.
Gyr = 10^9 yr Myr = 10^6 yr.

Some of the numerous acronyms that infect the subject are spelled out in the text or in the index.

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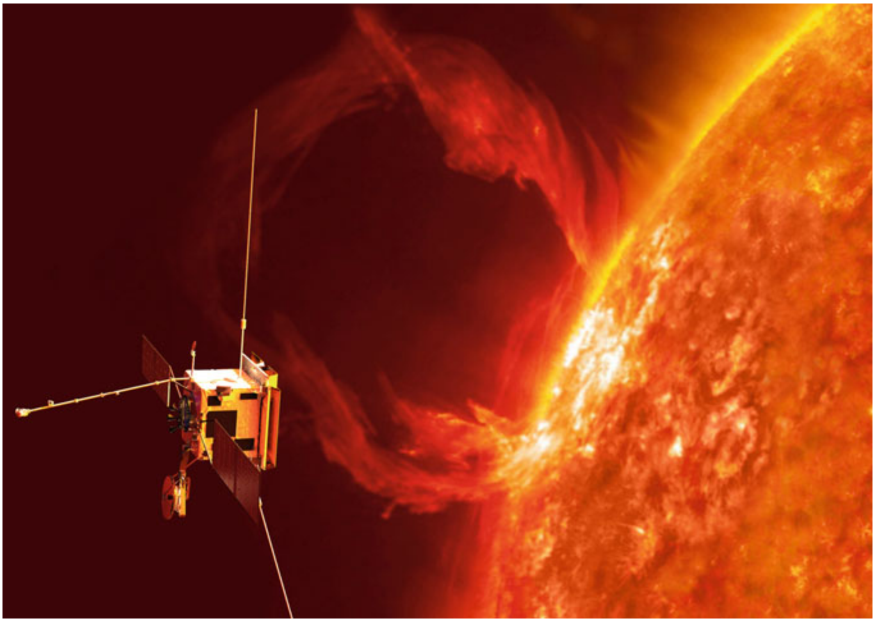

ESA's next-generation Sun explorer, Solar Orbiter, will be launched in 2020. It will investigate the connections and the coupling between the Sun and the heliosphere. Image credit ESA/AOES

Chapter 1
A Commonplace Star

Abstract In 1911 the Sun shed its unique role in humanity's universe and joined the ranks of several million G2V yellow dwarf stars; whatever the resulting loss of prestige by association, humanity has thereby gained greatly in its understanding of solar history and probable future by analogy with kindred stars and the calibration of models of solar evolution. The Sun's composition and inner workings were revealed by spectroscopy and nuclear physics; advances in solar physics and chemistry illuminate other stars, solar systems and galaxies, to the benefit of our cosmic understanding. Numerous devices now monitor the Sun, their development prompted by necessity as well as curiosity.

The Sun gained the status of star whenever astronomers accepted a multiplicity of solar systems. Democritus (~460–370 BC), for example, referred to innumerable other worlds some of which had no sun and moon and others more than one, and Aristarchus of Samos (~310–230 BC) suggested that the stars were distant suns[18]. The motion bubbled to the surface from time to time thereafter even though it must have seemed a confusing if not heretical diversion from the business of understanding our immediate planetary environment. In the 16th century it was voiced by Bruno, in the 17th by Descartes and von Guericke, and in the 18th by William Herschel and Immanuel Kant, whose nebular hypothesis (1755) envisaged a stage when multiple suns revolved around a galactic centre.

Readers familiar with the achievements of modern astronomy may already feel impatient with a historical digression, but the roots of the subject are intriguingly hardy. The main categories of stars are still based on the classification of Hipparchus (~130 BC); the droll dwarf-giant notation that was introduced over a century ago has survived[7, 25]; and even the stellar temperature calibration introduced by Annie Jump Cannon in 1918–1924 remains largely in place. Today's solar astronomy tolerates such archaisms, like poultices in a transplant clinic, while it promotes and exploits great advances in hardware and ideas.

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