RESOURCE LETTER

Resource Letter SPh-1: Solar Physics

Jay M. Pasachoff[a)]
Hopkins Observatory, Williams College, Williamstown, Massachusetts 01267

(Received 2 March 2010; accepted 22 April 2010)

This Resource Letter provides a guide to printed literature, listing selected books and articles and online resources about scientific and cultural references to the Sun and the related topics of solar spectroscopy and space weather. Topics include helioseismology, the chromosphere and corona at solar eclipses, sunspots and other solar activity, and total solar irradiance, as well as instrumental references including spectroheliographs, coelostats, and observatories on the ground and in space. References to general works on heliophysics and plasma physics are minimized.

[DOI: 10.1119/1.3429977]

I. INTRODUCTION

At the turn of the 20th century, much of astronomy was positional and phenomenological. Studies of the Sun played a major role in bringing astronomy to the astrophysical position that it enjoys today. Twenty-first-century solar physics is a vibrant science, with solar telescopes on the ground, including soon the Advanced Technology Solar Telescope being erected in Hawaii on Maui, joining dozens of spacecraft studying the Sun. NASA's Living with a Star program positions the Sun as a major influence on space weather and thus on the Earth. This Resource Letter does not include solar energy as an energy resource.

II. JOURNALS

Solar Physics
The major journal in the field, http://www.springer.com/astronomy/astrophysics+and+astroparticles/journal/11207

Living Reviews in Solar Physics
An online, continuously updatable review journal, http://solarphysics.livingreviews.org/

Astronomy and Astrophysics
The principal European astrophysical journal, a successor to many journals of individual European nations, www.aanda.org/

Astrophysical Journal
This flagship journal of the American Astronomical Society was transferred from the University of Chicago Press to the Institute of Physics (England) in 2009. It was founded in 1895 by solar astronomer George Ellery Hale and a colleague. A rapid communications section is known as *Astrophysical Journal Letters*, apj.aas.org or www.iop.org/EJ/journal/apj

Monthly Notices of the Royal Astronomical Society
www.ras.org.uk or
www.wiley.com/bw/journal.asp?ref=0035-8711&site=1

Nature
Perhaps the most prestigious journal for important new results. Founded in the U.K. by a solar physicist, Norman Lockyer, in the 19th century. Introductory sections include news, www.nature.org

Science
A competitor of *Nature* for prestige in publishing important new results. A journal of the American Association for the Advancement of Science. Introductory sections include news, www.sciencemag.org

Astronomy and Geophysics (A&G)
A popular journal of the Royal Astronomical Society, U.K., www.ras.org.uk; www.wiley.com/bw/journal.asp?ref=1366-8781

Publications of the Astronomical Society of Japan
The Hinode and other Japanese solar spacecraft have led to important articles, http://www.asj.or.jp/pasj/en/index-E.html

Journal of Geophysical Research: Space Physics
Articles about coronal mass ejections, space weather, and heliosphere, http://www.agu.org/journals/ja/

a)Electronic mail: jay.m.pasachoff@williams.edu

Geophysical Research Letters
Articles about coronal mass ejections, space weather, and heliosphere, http://www.agu.org/journals/gl/

Physics Today
A general journal of the American Institute of Physics; http://physicstoday.org

American Scientist
A general journal of Sigma Xi, a scientific-research organization that honors graduating seniors for their research and maintains research support and programs,
http://www.sigmaxi.org

III. CONFERENCE PROCEEDINGS

There are many conference proceedings relevant to solar physics. Here I present a representative list, starting with a selection in reverse chronological order and continuing with all the most recent conference proceedings from the International Astronomical Union and the series from the Astronomical Society of the Pacific. The listings from the European Space Agency and COSPAR (officially, in a never-used name, Committee on Space Research; http://cosparhq.cnes.fr) are less complete.

(1) Solar Polarization 5: In Honor of Jan Olof Stenfo, edited by Svetlana V. Berdyugina, K. N. Nagendra, and Renzo Ramelli (Astron. Soc. Pacific, San Francisco, 2009). (A)

(2) First Results from Hinode, Sarah A. Matthews, John M. Davis, Louise K. Harra (Astron. Soc. Pacific, San Francisco, 2008). (A)

(3) Subsurface and Atmospheric Influences on Solar Activity, R. Howe, R. W. Komm, K. S. Balasubramaniam, and G. J. D. Petrie (Astron. Soc. Pacific, San Francisco, 2008). (A)

(4) Modern Solar Facilities—Advanced Solar Science, edited by F. Kneer, K. G. Puschmann, and A. D. Wittmann (Universitätsverlag Göttingen, Göttingen, Germany, 2007), ⟨http://webdoc.sub.gwdg.de/univerlag/2007/solar_science_book.pdf⟩. (A)

(5) Solar and Stellar Physics Through Eclipses, edited by Osman Demircan, Selim O. Selam, and Berahitdin Albayrak (Astron. Soc. Pacific, San Francisco, 2007). (A)

(6) New Solar Physics with Solar-B Mission, edited by Kazunari Shibata, Shin'ichi Nagata, and Takashi Sakurai (Astron. Soc. Pacific, San Francisco, 2007). (A)

(7) The Physics of Chromospheric Plasmas, edited by Petr Heinzel, Ivan Dorotovic, and Robert J. Rutten (Astron. Soc. Pacific, San Francisco, 2007). (A)

(8) Proceedings of the International Symposium on Solar Physics and Solar Eclipses (SPSE 2006), edited by R. Ramelli, O. Shalabiea, I. Saleh, and J. O. Stenflo (Istituto Ricerche Solari Locarno, Switzerland, 2007). (A)

(9) The Dynamic Sun: Challenges for Theory and Observations, edited by D. Danesy, S. Poedts, A. de Groof, and J. Andries (SP-600, ESA, Leuven, Belgium, 2005). (A)

(10) Coronal and Stellar Mass Ejections, edited by K. Dere, J. Wang, Y. Yan (Cambridge U. P., Cambridge, UK, 2005). (A)

(11) Multi-Wavelength Investigations of Solar Activity, Proceedings of IAU Symposium 233, edited by A. V. Stepanov, E. E. Benevolenskaya, and A. G. Kosovichev (Cambridge U. P., Cambridge, 2004). (A)

(12) Recent Insights into the Physics of the Sun and Heliosphere: Highlights from Soho and Other Space Missions, edited by P. Brekke, B. Fleck, and J. D. Gurman (The Astronomical Society of the Pacific, San Francisco, 2000). (A)

(13) High Resolution Solar Physics: Theory Observations, and Techniques, edited by T. R. Rimmele, K. S. Balasubramaniam, and R. R. Radick (Astronomical Society of the Pacific, San Francisco, 1999). (A)

(14) Whole Sun Month at Solar Minimum, edited by J. G. Luhmann (American Geophysical Union, Washington, DC, 1999) [J. Geophys. Res. 104 (A5), 9673–9910 (1999)]. (A)

(15) Solar Physics with Radio Observations, edited by T. Bastian, N. Gopalswamy, and K. Shibasaki (Nobeyama Radio Observatory, Kiyosato, Japan, 1998). (A)

(16) The SOHO Mission, edited by B. Fleck, V. Domingo, and A. I. Poland (Kluwer Academic, Boston, 1995). (A)

(17) Solar Coronal Structures, edited by V. Rusin, P. Heinzel, and J.-C. Vial (VEDA Publishing House of the Solvak Academy of Sciences, Bratislave, Slovakia 1994). (A)

A. International Astronomical Union solar symposia (http://www.iau.org/science/publications/iau/symposium/)

(18) Physics of Sun and Star Spots, IAU Symposium 273, Ventura, Los Angeles, 2010 (Cambridge U. P., Cambridge, UK, 2011), ⟨http://www.csun.edu/PhysicsAndAstronomy/IAUS273.htm⟩. (A)

(19) Waves & Oscillations in the Solar Atmosphere: Heating & Magneto-Seismology, Symposium 247, Isla de Margarita, Venezuela, 2007, edited by. R. Erdélyi and C. A. Mendoza-Briceño (Cambridge U. P., Cambridge, UK, 2008). (A)

(20) Solar Activity and Its Magnetic Origin, Symposium 233, Cairo, Egypt, 2006, edited by Volker Bothmer and Ahmed Abdel Hady (Cambridge U. P., Cambridge, UK, 2006). (A)

(21) Coronal and Stellar Mass Ejections, Symposium 226, Beijing, China, 2004, edited by K. Dere, J. Wang, and Y. Yan (Cambridge U. P., Cambridge, UK, 2005). (A)

(22) Advanced Solar Polarimetry: Theory, Observation, and Instrumentation, edited by Michael Sigwarth (Astron. Soc. Pacific, San Francisco, CA, 2001). (A)

(23) Recent Insights into the Physics of the Sun and Heliosphere, Symposium 203, Manchester, United Kingdom, 2000, edited by P. Brekke, B. Fleck, and J. Gurman (Astron. Soc. Pacific, San Francisco, CA, 2001). (A)

(24) New Eyes to See Inside the Sun and the Stars: Pushing the Limits of Helio and Astero-Seismology, Symposium 185, Kyoto, Japan, 1997, edited by D. W. Kurtz, J. Christensen-Dalsgaard, and D. Kurtz (Kluwer, Dordrecht, 1998). (A)

IV. TEXTBOOKS AND MONOGRAPHS

A. Current advanced textbooks

(25) Physics of the Solar Corona: An Introduction with Problems and Solutions, M. J. Aschwanden (Praxis, Chichester, UK, 2009), 3rd printing. Comprehensive introduction, definitions, and examples and an overall theoretical interpretation. (A)

(26) **The Solar Corona**, 2nd ed., L. Golub and J. M. Pasachoff (Cambridge U. P., Cambridge, UK, 2009). An advanced textbook providing a survey of current knowledge of the Sun's outer atmosphere, ⟨http://www.williams.edu/astronomy/corona⟩. (A)

(27) **Physics of the Sun: A First Course**, Dermott J. Mullan (Chapman and Hall, London, 2009). (A)

(28) **Fundamentals of Solar Astronomy**, A. Bhatnagar and William C. Livingston (World Scientific, Singapore, 2005). Comprehensive and phenomenological but relatively nonmathematical. (I,A)

(29) **Solar Astrophysics**, 2nd ed., P. Foukal (Wiley-VCH, Weinheim, Germany, 2004). Theoretical in orientation. (A)

(30) **The Dynamic Sun**, edited by B. N. Dwivedi (Cambridge U. Press, Cambridge, UK, 2003). An advanced text that gives a thorough overview and contains comprehensive reference lists.(A)

B. Current general books with solar coverage

(31) **The Cosmos: Astronomy in the New Millennium**, 3rd ed., J. M. Pasachoff and A. Filippenko (Cengage-Brooks/Cole, Boston, MA, 2007). A current survey textbook for college and university students. (E,I)

(32) **A Field Guide to the Stars and Planets**, J. M. Pasachoff (Houghton Mifflin Harcourt, Boston, MA, 2006). Includes observing lists and observing instructions for eclipses. (E,I)

(33) **Foundations of Astronomy**, 11th ed., M. A. Seeds and D. E. Backman (Cengage-Brooks/Cole, Boston, MA, 2011). A current survey textbook for college and university students. (E,I)

(34) **Discovering the Universe**, 8th ed., N. Comins (Freeman, New York, 2009). A current survey textbook for college and university students. (E,I)

(35) **The Cosmic Perspective**, 5th ed., J. Bennett, M. Donahue, N. Schneider, and G. M. Voit (Addison-Wesley, San Francisco, 2008). A current survey textbook for college and university students. (E,I)

(36) **Astronomy: From the Earth to the Universe**, 6th ed., J. M. Pasachoff (Cengage-Brooks/Cole, Boston, MA, 2002). More extensive coverage than *The Cosmos*. (E,I)

C. Current popular solar books

(37) **The Sun, The Earth, and Near-Earth Space: A Guide to the Sun-Earth System**, John A. Eddy (NASA, Washington, DC, 2009), ⟨bookstore.gpo.gov⟩. A well-illustrated contemporary survey of solar science and space weather. (E.I)

(38) **The Sun from Space**, K. R. Lang (Springer, Berlin, 2009). Includes wide coverage of contemporary satellite results. (E,I)

(39) **The Magnetic Universe: The Elusive Traces of an Invisible Force**, J. B. Zirker (Johns Hopkins U. P., Baltimore, MD, 2009). Treats magnetic fields in astronomy in general, not limited to those from the Sun. (E,I)

(40) **The Sun**, David Alexander (Greenwood Guides to the Universe, Santa Barbara, CA, 2009). (I)

(41) **Sun, Earth, and Sky**, 2nd ed., K. R. Lang (Springer, New York, 2006). Wide-ranging survey. (E,I)

(42) **The Sun**, S. Hill and M. Carlowicz (Harry N. Abrams, New York, 2006). (E,I)

(43) **The Sun**, 2nd ed., M. Stix (Springer-Verlag, Berlin, 2004). (I,A)

(44) **Sun Observer's Guide**, Pam Spence (Firefly, Ontario, 2004). (E,I)

(45) **Nearest Star: The Surprising Science of Our Sun**, L. Golub and J. M. Pasachoff (Harvard U. P., Cambridge, 2001). For general readers. (E,I)

(46) **The Complete Idiot's Guide to the Sun**, J. M. Pasachoff (Alpha, New York, 2003). A personal, lighthearted survey, including anecdotes. The book is available as a free download, ⟨www.williams.edu/astronomy/sun⟩. (E,I)

(47) **The Cambridge Encyclopedia of the Sun**, by K. R. Lang. (Cambridge U. P., Cambridge, UK, 2001). Thorough coverage. (I,A)

(48) **Storms from the Sun: The Emerging Science of Space Weather**, M. J. Carlowicz and R. E. Lopez (Joseph Henry, Washington, DC, 2000). Concentrates on space weather. (E,I)

D. Heliophysics

(49) **Heliophysics: Plasma Physics of the Local Cosmos**, Vol. 1, edited by Carolus J. Schrijver and George L. Siscoe (Cambridge U. P., Cambridge, UK, 2009); **Heliophysics: Space Storms and Radiation: Causes and Effects**, Vol. 2, edited by Carolus J. Schrijver and George L. Siscoe (Cambridge U. P., Cambridge, UK, 2010), **Heliophysics: Evolving Solar Activity and the Climates of Space and Earth**, Vol. 3, edited by Carolus J. Schrijver and George L. Siscoe (Cambridge U. P., Cambridge, UK, 2010). (A)

(50) **A Performance Assessment of NASA's Heliophysics Program**, National Research Council (National Acadamies Press, Washington, DC, 2009).

E. Book for the visually impaired

(51) **Touch the Sun**, Noreen Grice (Joseph Henry, Washington, DC, 2005). In Braille with figures embossed so that the visually impaired can feel the shapes, ⟨www.youcandoastronomy.com⟩. (E)

F. Current monographs

(52) **Astronomical Spectrographs and their History**, J. Hearnshaw (Cambridge U. P., Cambridge, UK, 2009). Spectrography has often advanced through the need for solar observations. (A)

(53) **Theoretical Investigations of Mechanisms for Solar Eruptions: Applications of the Catastrophe Theory to Solar Eruptions**, Jun Lin and Terry G. Forbes (VDM Verlag, NY, 2008). (A)

(54) **Magnetic Reconnection: MHD Theory and Applications**, Eric Priest and Terry Forbes (Cambridge U. P., Cambridge, UK, 2007). (A)

(55) **Particle Acceleration and Kinematics in Solar Flares: A Synthesis of Recent Observations and Theoretical Concepts**, M. J. Aschwanden (Kluwer Academic, Boston, MA, 2002). (A)

(56) **Observational Plasma Astrophysics: Five Years of Yohkoh and Beyond**, edited by Tetsuya Watanabe, Takeo Kosugi, and Alphonse C. Sterling (Kluwer, Dordrecht, 1998). (A)

G. Atlases

(57) **Solar Filtergrams of the Lockheed Solar Observatory**, B. Nolan, S. Smith, and H. Ramsey (Lockheed Solar Observatory, Burbank, CA, 1970). (A)

(58) **Center and Limb Solar Spectrum in High Spectral Resolution 225.2 nm to 319.6 nm**, J. L. Kohl, W. H. Parkinson, and R. L Kurucz (Harvard-Smithsonian Center for Astrophysics, Cambridge, UK, 1978). (A)

(59) **The Structure of the Quiet Photosphere and the Low Chromosphere**, edited by C. de Jager (Springer-Verlag, New York, 1968). (A)

(60) **The Radiation of the Solar Photosphere from 2000 Å to 100 μm**, D. Labs and H. Neckel (Springer-Verlag, New York, 1968). (A)

(61) **An Atlas of the Spectrum of the Solar Photosphere from 13,500 to 28,000 cm^{-1} (3570 to 7405 Å)**, L. Wallace, K. Hinkle, and W. Livingston (National Solar Observatory, Tucson, AZ, 1998). (A)

(62) **An Atlas of Sunspot Umbral Spectra in the Visible from 15,000 to 25,500 cm^{-1} (3920 to 6664 Å)**, L. Wallace, K. Hinkle, and W. Livingston (National Solar Observatory, Tucson, AZ, 2000). (A)

(63) **An Atlas of the Photospheric Spectrum from 8900 to 13600 cm^{-1} (7350 to 11230 Å)**, L. Wallace, K. Hinkle, and W. Livingston (National Solar Observatory, Tucson, AZ, 1993). (A)

(64) **Photographic Atlas of the Solar Chromosphere**, A. Ambastha and A. Bhatnagar (Udaipur Solar Observatory, Udaipur, India, 1985). (I,A)

(65) **Selected Spectroheliograms**, Alan Title (California Inst. Technology, Pasadena, CA, 1966). (I,A)

H. Penultimate generation of advanced books

(66) **Astrophysics of the Sun**, H. Zirin (Cambridge U. P., Cambridge, 1988). The insightful originator of the Big Bear Solar Observatory explains solar astrophysics. (A)

(67) **The Solar Chromosphere**, R. J. Bray and R. E. Loughhead (Chapman and Hall, London, 1974). A unique discussion of this solar layer. (A)

(68) **The Solar Granulation**, R. J. Bray and R. E. Loughhead (Chapman and Hall, London, 1967). A unique discussion of this solar phenomenon. (A)

(69) **The Sun**, edited by G. P. Kuiper (University of Chicago Press, Chicago, 1953). The chapters on the solar chromosphere and corona remain standard references. (A)

(70) **A Guide to the Solar Corona**, by D. E. Billings (Academic, New York, 1966). Still a standard reference. (A)

I. Enduring standard solar books

(71) **Our Sun**, rev. ed., D. H. Menzel, (Harvard U. Press, Cambridge, 1959). A delightful survey by the distinguished eclipse veteran and solar physicist, part of the original Harvard Series of popular books on astronomy. (E,I)

(72) **The Sun, Our Star**, R. W. Noyes (Harvard U. P., Cambridge, 1982). A part of the Harvard Series, succeeding Menzel's book. (E,I)

J. History of solar physics

(73) **The Sun Recorded Through History: Scientific Data Extracted from Historical Documents**, J. M. Vaquero (Springer, New York, 2009). Important for assessing the validity of historical data including those relevant to the solar contribution to climate change. (A)

(74) **The Sun Kings: The Unexpected Tragedy of Richard Carrington and the Tale of How Modern Astronomy Began**, S. Clark (Princeton U. P., Princeton, NJ, 2007). A surprisingly exciting biography of an important figure in the history of solar observations. (E,I)

(75) **A Concise History of Solar and Stellar Physics**, J. L. Tassoul and M. Tassoul (Princeton U. P., Princeton, NJ, 2004). (I,A)

(76) **Exploring the Sun: Solar Science Since Galileo**, K. Hufbauer (Johns Hopkins U. P., Baltimore, MD, 1991). Brings solar-physics history to the present era. (I,A)

(77) **Early Solar Physics**, A. J. Meadows (Pergamon, New York, 1970). The standard history of solar physics, including reprints of 19th century and other papers (I,A)

K. The sun as a star

(78) **The Sun as a Star**, R. J. Tayler (Cambridge U. P., New York, 1997). Discusses the Sun as an example of more distant stars. (E,I)

(79) **The Sun and Cool Stars: Activity, Magnetism, Dynamos**, edited by I. Tuominen, D. Moss, and G. Rüdiger (Springer-Verlag, New York, 1990). The Sun in the context of stars like it. (E,I)

L. DVDs

(80) **Colors and Motions of the Sun**, J. M. Pasachoff (Williams College, Williamstown, MA, 2008), a 14-min film including a variety of solar videos from spacecraft and other sources with narration suitable for university students, ⟨http://oit.williams.edu/wit/video/solar.cfm⟩. (I)

(81) **The Universe—Secrets of the Sun**, Episode 1 of the History Channel series (History Channel, NY, 2007), http://shop.history.com/?v=history_show_the-universe, ⟨http://www.imdb.com/title/tt1051155/⟩. (E)

(82) **Solarmax** (Heliograph, Byron Bay, Australia, 2000), DVD version of an IMAX spectacular, ⟨http://www.helio.com.au/solarmax/⟩. (E,I)

(83) **Our Mr. Sun**, A Frank Capra movie for young people from 1956, still a popular introduction; includes Donald Menzel; widely available online, ⟨http://www.imdb.com/title/tt0159620/⟩. (E)

V. HELIOSEISMOLOGY

(84) **Journey from the Center of the Sun**, J. B. Zirker (Princeton U. P., Princeton, NJ, 2001), paperback, 2004; a nontechnical trade book. (E,I)

(85) **Music of the Sun: Story of Helioseismology**, W. J. Chaplin (Oneworld, Oxford, 2006). A nontechnical trade book. (E,I)

(86) **Sunquakes: Probing the Interior of the Sun**, J. B. Zirker (Johns Hopkins U. P., Baltimore, MD, 2003). A nontechnical trade book. (E,I)

(87) "Helioseismology," J. Christensen-Dalsgaard, Rev. Mod. Phys. **74**, 1073–1129 (2002). (A)
(88) "Helioseismology, Asteroseismology, and MHD connections," edited by L. Gizon and Paul Cally, Solar Phys. **251** (1–2), 1–500 (2008). (A)
(89) "Lecture notes on stellar oscillations," J. Christensen-Dalsgaard, ⟨http://www.phys.au.dk/~jcd/oscilnotes/⟩. (A)
(90) "Local helioseismology," L. Gizon and A. C. Birch, ⟨http://solarphysics.livingreviews.org/Articles/lrsp-2005-6/⟩. (A)
(91) "Local helioseismology: Three-dimensional imaging of the solar interior," L. Gizon, A. C. Birch, and H. C. Spruit, Annu. Rev. Astron. Astrophys. (2010) (in press). (A)
(92) "Solar interior rotation and its variation," R. Howe, ⟨http://www.livingreviews.org/lrsp-2009-1⟩. (A)
(93) Overview: ⟨http://soi.stanford.edu/results/heliowhat.html⟩.
(94) Websites and educational resources: ⟨http://solar-center.stanford.edu/heliopage.html⟩.

VI. SOLAR ECLIPSES

A. Main eclipse websites

(95) International Astronomical Union Working Group on Eclipses, ⟨www.eclipses.info⟩.
(96) NASA Website from Fred Espenak, ⟨eclipse.gsfc.nasa.gov/solar.html⟩.
(97) Eclipse Website from Xavier Jubier, http://xjubier.free.fr/en/site_pages/Solar_Eclipses.html.

B. Current eclipse books

(98) **Totality: Eclipses of the Sun**, M. Littmann, F. Espenak, and K. Willcox, 3rd ed. (Oxford U. P., Cambridge, UK, 2008). A survey for the general reader, including both cultural and scientific references. (E,I)
(99) **Total Eclipses: Science, Observations, Myths and Legends**, P. Guillermier and S. Koutchmy (Springer/ Praxis, Chichester, United Kingdom, 1999) [trans. from **Eclipses Totales: Histoire, Découvertes, Observations** (Masson, Paris, 1998)]. Includes both scientific cultural references. (E,I)
(100) **Eclipses: 2005–2017: A Handbook of Solar and Lunar Eclipses and Other Rare Astronomical Events**, W. Held (Floris, Edinburgh, United Kingdom, 2005) [trans. from **Astronomische Sternstuden** (Verlag Freies Geistesleben, Stuttgart, Germany, 2005)]. (E,I)
(101) **Glorious Eclipses: Their Past, Present and Future**, S. Brunier and J.-P. Luminet (Cambridge U. P., Cambridge, 2000) [trans. by S. Dunlop from **Eclipses, les Rendez-Vous Célestes** (Larousse-Bordas/HER, Paris, 1999)]. A coffee-table spectacular. (E,I)
(102) **The Sun in Eclipse**, by M. Maunder and P. Moore (Springer, London, 1998). In a series for amateur astronomers. (E)
(103) **Eclipse**, by D. Steel (National Academy Press, Washington, DC, 2001). A popular survey. (E)
(104) **Total Solar Eclipses and How to Observe Them**, M. Mobberley (Springer, New York, 2007). In an observing series for amateurs, including personal profiles. (E)

C. The scientific value of eclipses

(105) "Solar eclipses as an astrophysical laboratory," J. M. Pasachoff, Nature **459**, 789–795 (2009). A review article describing the important role ground-based eclipse observations continue to play in the space age, as part of Nature's coverage of the International Year of Astronomy. (I,A)
(106) "Scientific observations at total solar eclipses," Jay M. Pasachoff, Research in Astronomy and Astrophysics **9**, 613–634 (2009). A survey of eclipse science and of scientists' plans for observing the 2009 total solar eclipse in China. (I,A)

D. Eclipse predictions and atlases

(107) **Five Millennium Catalog of Solar Eclipses: −1999 to +3000 (2000 BCE to 3000 CE)**, F. Espenak and J. Meeus, Technical Publication TP-2006-214170, NASA, Washington, DC, 2008. Provides information about eclipses over an extended period of time, giving both historical and predictive information, ⟨http://eclipse.gsfc.nasa.gov/SEcat5/SEcatalog.html⟩. (I,A)
(108) **Five Millennium Canon of Solar Eclipses: −1999 to +3000** (2000 BCE to 3000 CE), F. Espenak and J. Meeus, Technical Publication TP-2006-214141, NASA, Washington, DC, 2006, http://eclipse.gsfc.nasa.gov/SEpubs/5MCSE.html. (I,A)
(109) **Annular and Total Solar Eclipses of 2010**, F. Espenak and J. Anderson, TP-2008-214171, NASA, Washington, DC, 2008, http://eclipse.gsfc.nasa.gov/SEpubs/2010/rp.html. (I,A)
(110) **Fifty Year Canon of Solar Eclipses**, F. Espenak, NASA Ref. Pub. 1178, Greenbelt, Maryland, rev. 1987, maps and tables, ⟨http://eclipse.gsfc.nasa.gov/SEpubs/RP1178.html⟩. (I,A)
(111) **Total and Annular Solar Eclipse Paths: 2001–2020**, F. Espenak, 2009, ⟨http://eclipse.gsfc.nasa.gov/SEatlas/SEatlas3/SEatlas2001.GIF⟩.

E. Extent of total, annular, and partial phases

(112) Individual eclipse maps are available through ⟨xjubier.free.fr/en/site_pages/solar_eclipses/5MCSE/xSE_Five_Millennium_Canon.html⟩. The graph can display the extent of partial eclipse at each location. Toggles are the following:

- &Lmt=x (x set to 1 or 0) will display or not the penumbral limits, maximum on horizon and rise/set curves
- &Mag=x (x set to 1 or 0) will display or not the equal magnitude curves
- &Max=x (x set to 1 or 0) will display or not the maximum eclipse curves

F. Eclipses of the decade

(113) Total and Annular Solar Eclipse Paths: 2001–2020, ⟨http://eclipse.gsfc.nasa.gov/SEatlas/SEatlas3/SEatlas2001.GIF⟩.

1. Four partial eclipses of 2011

(114) 4 January 2011 Eastern Europe through India, ⟨http://tinyurl.com/2011Jan04⟩.

(115) 1 June 2011 Greenland, northern Alaska, ⟨http://tinyurl.com/2011Jun01⟩.
(116) 11 July 2011 ocean off Antarctica, ⟨http://tinyurl.com/2011Jul01⟩.
(117) 25 November 2011 New Zealand, Tasmania, ⟨http://tinyurl.com/2011Nov25⟩.

2. Next central eclipses

a. Total solar eclipses.

13–14 November 2012, Northeastern Australia
3 November 2013, Gabon, Congo, Kenya
20 March 2015, Arctic, Svalbard
9 March 2016, Indonesia
21 August 2017, U.S.
2 July 2019, Chile
14 December 2020, Chile and Argentina

b. Annular solar eclipses.

20 May 2012, Western U.S.
10 May 2013, Northeast and Tennant Creek, Cape York, and Australia
29 April 2014, Antarctica
1 September 2016, Gabon, Congo, and Madagascar
26 February 2017, Chile, Argentina, and Angola
26 December 2019, South India, Sri Lanka, and Indonesia (Sumatra and Borneo)

(118) Next U.S. total eclipse. The total solar eclipse of 21 August 2017 will cross the United States from the Pacific Northwest through parts of Idaho, Wyoming, Nebraska, Kansas, Missouri, Tennessee, Georgia, and South Carolina. Totality at the centerline will range from about 2 min through 2 min, 35 s, ⟨http://eclipse.gsfc.nasa.gov/SEgoogle/SEgoogle2001/SE2017Aug21Tgoogle.html⟩.

G. Eclipses as a test of relativity

(119) **Einstein's Jury: The Race to Test Relativity**, J. Crelinsten (Princeton U. P., Princeton, NJ, 2006). Describes in detail the most famous eclipse in scientific history and its well-known ramifications for testing Einstein's general theory of relativity as well as providing lessons in the philosophy of science. (E,I,A)
(120) **Harlan's Globetrotters: The Story of an Eclipse**, D. S. Evans and K. I. Winget (Xlibris Corporation, Philadelphia, 2005). The story of the 1973 eclipse expedition to Africa to test the general theory of relativity, named as a pun on the name of Harlan Smith, the observatory director. (E)
(121) "Solar eclipses as an astrophysical laboratory," J. M. Pasachoff, Nature **459**, 789–795 (2009). This review article includes references to the latest observational verifications of the general theory of relativity from studies of the Sun and other stars. (I, A)

1. Eclipse conference proceedings

(122) **Advances in Solar Research at Eclipses from Ground and from Space**, edited by J.-P. Zahn and M. Stavinschi (Kluwer, Dordrecht, 2000). (A)
(123) **Theoretical and Observational Problems Related to Solar Eclipses**, edited by Z. Mouradian and M. Stavinschi (Kluwer, Dordrecht, 1997). The proceedings of a conference held in Bucharest in 1996, in advance of the 1999 eclipse that was visible there. (A)
(124) **First Results of 1999 Total Eclipse Observations**, edited by D. N. Mishev and K. J. Phillips (Professor Marin Drinov Academic, Sofia, Bulgaria, 2000). About the 1999 total solar eclipse that crossed Europe. (A)
(125) **Solar and Stellar Physics through Eclipses, Proceedings of ASP Conference Series 370**, edited by O. Demircan, S. O. Selam, and B. Albayrak (Astronomical Society of the Pacific, San Francisco, CA, 2007). Eclipses of the Sun and stars. (A)
(126) **The Last Total Solar Eclipse of the Millennium in Turkey**, edited by W.C. Livingston and A. Özgüç (Astronomical Society of the Pacific, San Francisco, CA, 2000), conf. series 205. (A)
(127) **Proceedings of the International Symposium on the Total Solar Eclipse of November 3, 1994**, edited by M. S. Raljevic, F. Zaratti, and J. M. Pasachoff (The National Academy of the Sciences of Bolivia, La Paz, Bolivia, 1995). (A)

2. Eclipse history

(128) **Empire and the Sun: Victorian Solar Eclipse Expeditions**, A. S.-K. Pang (Stanford U. P., Palo Alto, CA, 2002). (E,I)
(129) **Historical Eclipses and Earth's Rotation**, F. R. Stephenson (Cambridge U. P., Cambridge, UK, 1997). Shows the value that eclipses have for assessing Earth's rotation over thousands of years. (I,A)
(130) **UK Solar Eclipses from Year 1 (An Anthology of 3,000 Years of Solar Eclipses)**, S. Williams (Clock Tower, Leighton Buzzard, United Kingdom, 1996). (E,I)

3. Penultimate generation of eclipse books

(131) **The Cambridge Eclipse Photography Guide**, J. M. Pasachoff and M. Covington (Cambridge U. P., Cambridge, UK, 1993). Discusses eclipses of the 1990s and how to observe and photograph them. (E)
(132) **Eclipse**, B. Brewer (Snohomish, Seattle, 1978). (E)
(133) **The Hidden Sun: Solar Eclipses and Astrophotography**, J. Lowenthal (Avon, New York, 1984). (E)
(134) **Total Eclipses of the Sun**, J. B. Zirker (Princeton U. P., Princeton, NJ, 1995). (E,I)
(135) **The Under-Standing of Eclipses**, G. Ottewell (Astronomical Workshop, Greenville, SC, 1991). (E,I)
(136) **Total Solar Eclipse: 2008 and 2009**, Sheridan Williams (Bradt Travel Guides, Buckinghamshire, United Kingdom, 2008). (E)
(137) **Eclipse! The What, Where, When, Why & How Guide to Watching Solar and Lunar Eclipses**, P. S. Harrington (Wiley, New York, 1997). (E)

H. Websites

(138) ⟨http://www.eclipses.info⟩. The Website of the Working Group on Solar Eclipses of the International As-

tronomical Union and the IAU Program Group on Public Education at the Times of Eclipses, with links to maps and other information about observing eclipses; includes many links to other websites.

(139) ⟨http://www.williams.edu/astronomy/eclipse⟩. Eclipse expeditions from Williams College, with links to other sources.

(140) The Solar Eclipse Mailing List. ⟨http://tech.groups.yahoo.com/group/SEML/⟩. An active user group of amateurs and professionals interested in solar eclipses, including both science and viewing. Instant updates or daily summaries are available, or the messages can be read online. Sign up at SEML-subscribe@yahoogroups.com.

(141) TOTALITYNewzine. An online semiannual magazine of eclipse expeditions (TOTALITYNewzine@aol.com), ⟨http://xjubier.free.fr/en/site_pages/Solar_Eclipses.html⟩ or ⟨http://www.eclipse-chasers.com/totality.html⟩.

(142) Interactive Eclipse Paths. ⟨http://xjubier.free.fr/en/site_pages/SolarEclipsesGoogleMaps.html⟩.

(143) Solar eclipse observers' records. ⟨http://www.clock-tower.com⟩.

(144) Solar eclipse observers' statistics. ⟨http://www.eclipse-chasers.com/tsechaserlogsums.php⟩.

VII. THE SOLAR SPECTRUM

(145) **Online laboratories on the solar spectrum and H-alpha imaging.** ⟨www.williams.edu/astronomy/jay/spectrum⟩. An interactive solar spectrum; can be viewed at high-resolution and provides a color orientation, http://bass2000.obspm.fr/solar_spect.php. (I,A)

(146) **Solar Spectrum Atlases from the National Solar Observatory.** Lloyd Wallace and colleagues have prepared a series of atlases from FTS (Fourier transform spectrometer at the National Solar Observatory) archives. These are available in soft-cover for libraries and as ftp files as digital data. Solar identifications are given in the bound atlases. These may be obtained from wcl@noao.edu, fhill@noao.edu, or lwallace@noao.edu; general reference: L. Wallace *et al.*, Astrophys. J., Suppl. **106**, 165 (1996); ⟨http://www2.nso.edu/staff/wcl/atlases.html⟩. (A)

(147) **Calculating the Spectrum**, **Lecture Notes: Introduction to Non-LTE Radiative Transfer and Atmospheric Modeling**, E. H. Avrett, explaining calculations for spectral lines in situations out of local thermodynamic equilibrium; ⟨http://www.cfa.harvard.edu/~avrett⟩. (A)

(148) **Student spectroscopes**, distributed by ⟨http://solar-center.stanford.edu/activities/cots.html⟩. (I)

VIII. SUNSPOTS AND OTHER SOLAR ACTIVITY

Many of the books listed in Secs. III and IV discuss sunspots and solar activity

(149) **The Enigma of Sunspots: A Story of Discovery and Scientific Revolution**, J. Brody (Floris, Edinburgh, Scotland, 2000). Discusses the history and current status of sunspot knowledge and the near-simultaneous and independent discovery of sunspots in the early 1610s by Galileo, Harriot, and Scheiner, and the battle for priority. (E,I)

(150) **Solar Active Region Evolution: Comparing Models with Observations**, edited by K. S. Balasubramaniam and G. W. Simon (Astron. Soc. Pacific, San Francisco, CA, 1994). (A)

A. Latest solar images

The Sun shines every day even though its light does not always come through Earth's atmosphere. Clouds may prevent us on Earth from seeing the Sun, but a spacecraft orbiting high above us always has the Sun in view.

Images are available on the World Wide Web on a daily basis. They come from various ground-based observatories on Earth and from satellites in space. Since it is always daylight somewhere on Earth, we can almost always get a view of the Sun from a ground-based observatory. And space images are quickly made available on the World Wide Web.

Many images that you see are made through filters that pass only a very narrow band of the spectrum. Typically, an H-alpha filter in the visible will pass only 0.5 Å or less out of the spectrum that extends from 3900 Å in the ultraviolet to 6700 Å in the red.

(151) ⟨**www.spaceweather.com**⟩. Shows a white-light view of the Sun every day, a forecast of flares, links to images and a photo gallery, and other information about space weather.

(152) ⟨**www.solarmonitor.org**⟩. Posts links to the major full-disk solar images from spacecraft, including magnetic field, continuum, H-alpha, two coronal EUV lines, and x-rays. A second page ("more instruments") elaborates with farside results from GONG, STEREO pairs of images, and other images.

(153) **NASA's Marshall Space Flight Center**. The sunspot cycle and the butterfly diagram are graphed at http://solarscience.msfc.nasa.gov/SunspotCycle.shtml and ⟨http://www.sidc.oma.be/sunspot-index-graphics/sidc_graphics.php⟩.

(154) **The Solar Influences Data Analysis Center** of the Royal Observatory of Belgium, includes the World Data Center for the sunspot index, ⟨http://www.sidc.oma.be⟩. Graphs of sunspots for the current cycle or back to 1750 are available by choosing "Sunspots" at the left and then choosing "Graphs." Data are also available at http://sidc.oma.be/sunspot-index-graphics/sidc_graphics.php.

(155) **Sunspot drawings since 1947 and daily high-resolution images**, Kandilli Observatory, Turkey (click on the symbol for the English translation), ⟨http://www.koeri.boun.edu.tr/astronomy/⟩.

(156) **AAVSO Solar Observing Program**. The Solar Committee of the American Association of Variable Star Observers keeps an AAVSO American Relative Sunspot Index, ⟨http://www.aavso.org/observing/programs/solar/bulletin.shtml⟩, ⟨http://www.sidc.oma.be/sunspot-index-graphics/sidc_graphics.php⟩.

(157) **Solar Stormwatch**. At solarstormwatch.com, individuals can examine solar images and pick out storms as well as help track them. Volunteers look at images from NASA's STEREO spacecraft as part of the Citizen Science movement, earlier used in Zooniverse (www.zooniverse.org), which started with the Galaxy Zoo identification program.

IX. SOLAR SPACECRAFT

A. Space satellites

(158) Solar Dynamics Observatory, ⟨http://sdo.gsfc.nasa.gov⟩.
(159) Solar and Heliospheric Observatory, ⟨http://sohowww.nascom.nasa.gov/⟩.
(160) SOHO gallery, ⟨http://sohowww.nascom.nasa.gov/gallery⟩.
(161) TRACE (Transition Region and Coronal Explorer), ⟨trace.lmsal.com⟩.
(162) Hinode at NASA's Marshall Space Flight Center, ⟨http://solarb.msfc.nasa.gov⟩.
(163) STEREO (at JHU/APL), ⟨http://stereo.jhuapl.edu⟩.
(164) STEREO (at NASA headquarters), ⟨http://stp.gsfc.nasa.gov/missions/stereo/stereo.htm⟩.
(165) Ulysses Probe Homepage ⟨http://ulysses.jpl.nasa.gov/⟩.
(166) Ramati High Energy Solar Spectroscopic Imager (NASA's Goddard), Education and outreach. ⟨http://hesperia.gsfc.nasa.gov/hessi/outreach.htm⟩.
(167) Ramati High Energy Solar Spectroscopic Imager (NASA's Goddard), Homepage. ⟨http://hesperia.gsfc.nasa.gov/hessi/index.html⟩.
(168) Ramati High Energy Solar Spectroscopic Imager (Berkeley), ⟨http://hessi.ssl.berkeley.edu⟩.
(169) Ramati High Energy Solar Spectroscopic Imager data center, ⟨http://hesperia.gsfc.nasa.gov/rhessidatacenter/⟩.
(170) Imager for Magnetopause-to-Aurora Global Exploration (IMAGE), ⟨http://image.gsfc.nasa.gov⟩.
(171) Thermosphere-Ionosphere-Mesosphere-Energetics and Dynamics (TIMED), ⟨http://www.timed.jhuapl.edu⟩.
(172) GOES Solar X-Ray Imager, ⟨http://www.ngdc.noaa.gov/stp/stp.html⟩ and ⟨http://www.sec.noaa.gov/sxi⟩.
(173) NASA Missions, with links ⟨nasascience.nasa.gov/heliophysics⟩.
(174) NASA's Living with a Star Program, ⟨http://lws.gsfc.nasa.gov⟩.
(175) PROBA2 (Project for Onboard Autonomy-2), an ESA technology-test microsatellite launched in 2009, carries two instruments operated by the Royal Observatory of Belgium, SWAP (Sun Watcher using APS Detectors) and LYRA (Large Yield RAdiometer) for x-ray and extreme-ultraviolet solar irradiance; ⟨http://proba2.sidc.be/index.html/about/⟩ and the instruments.
(176) PROBA2's observations of the 15 January 2010 annular eclipse: ⟨http://proba2.sidc.be/index.html/outreach/documentation/article/proba2-witnesses-an-annular⟩.

B. Future solar satellites and programs

(177) Solar Probe: ⟨http://solarprobe.gsfc.nasa.gov⟩.
(178) Solar Orbiter: Solar Orbiter was chosen in 2010 by the European Space Agency as one of three missions entering the "definition" phase, the final step before a mission is chosen. The spacecraft would come within only 62 solar radii of the solar surface. Its images would include the entire Sun, including the far side and the poles: ⟨http://sci.esa.int/science-e/www/area/index.cfm?fareaid=45⟩.
(179) Synoptic Optical Long-term Investigations of the Sun (SOLIS), a program of the National Solar Observatory; ⟨http://solis.nso.edu⟩.

C. Past spacecraft

(180) Yohkoh Public Outreach Project, ⟨http://www.lmsal.com/YPOP/⟩.
(181) Solar Maximum Mission, ⟨http://solarscience.msfc.nasa.gov/SMM.shtml⟩.
(182) Solar Physics at Marshall Space Flight Center (with links), ⟨http://solarscience.msfc.nasa.gov/⟩.

D. Individual current spacecraft instruments

1. SOHO

The Solar and Heliospheric Observatory (http://sohowww.nascom.nasa.gov/), launched by the European Space Agency with major participation by NASA, has been aloft since 1995. It is located beyond the Moon in the direction of the Sun, where it orbits in a slight halo around the Sun-Earth line so that its radio signals are not overwhelmed by the solar radio radiation. It contains a dozen instruments, including three that often send back hourly images. (1) The *Extreme-Ultraviolet Imaging Spectrograph (EIT)*, from NASA's Goddard Space Flight Center, sends back four types of image to study the chromosphere and corona.

(a) Helium II (that is, ionized helium, given that He I is neutral helium) at 304 Å. It shows gas at temperatures of about 60,000 K.
(b) Iron IX (that is, iron that has lost eight of its electrons) at 171 Å. It is at a temperature of about 1,000,000 K.
(c) Iron XII (that is, iron that has lost eleven of its electrons) at 195 Å. It is at a temperature of about 1,500,000 K.
(d) Iron XV (that is, iron that has lost fourteen of its electrons) at 284 Å. It is at a temperature of about 2,000,000–3,000,000 K.

(2) The *Large Angle and Spectrographic Coronagraph (LASCO)* from the Naval Research Laboratory sends back images using a "coronagraph," a device that blocks out the solar photosphere (the everyday solar surface) to make it possible to see the surrounding corona. Unfortunately, for optical reasons it is not possible for the coronagraph's blocking ("occulting") disk to block out only the photosphere; it has to block out a considerable region surrounding the photosphere as well. The photosphere is drawn in for scale and orientation in the images displayed. The C1 coronagraph is defunct. The C2 coronagraph blocks the innermost half solar radius above the solar disk; its field of view extends from 1.5 solar radii to about 7 solar radii. The C3 coronagraph blocks the innermost 2.5 solar radii above the solar disk; its field of view extends from 3.5 solar radii out to about 33 solar radii. (The Sun's radius is about $700,000$ km$=440,000$ miles at the Sun's distance of $1,500,000$ km$=93,000,000$ miles.) (3) The *Michelson Doppler Imager (MDI) and Solar Oscillations Investigation (SOI)* from Stanford University sends back images of the Sun that match ordinary white light, though they are in a narrow visible-light filter band. The

images can be used to make images that show motions of the Sun to use in helioseismology; they also show the sunspots as they would appear in white light.

(183) SOHO's Website at ⟨http://sohowww.nascom.nasa.gov/⟩ includes links to descriptions of the instruments, to educational matters, and to a gallery of past and present images.
(184) Up-to-date set of eight images from SOHO: ⟨http://sohowww.nascom.nasa.gov/data/realtime/⟩.

2. TRACE

(185) NASA's Transition Region and Coronal Explorer (TRACE) has been aloft since 1998 to make high-resolution observations of the solar corona as well as of the region of transition between the chromosphere and corona. Its field of view covers only part of the Sun at one time, but it shows magnetically controlled loops of gas in the corona at exceedingly high detail. It is a project of the Lockheed Martin Solar and Astrophysics Laboratory, with a telescope built by the Smithsonian Astrophysical Observatory. Its site at http://trace.lmsal.com/POD/NAS2002v2.html shows a wide variety of solar images. The TRACE homepage at ⟨http://trace.lmsal.com/⟩ shows a Picture of the Day as well as providing links to other TRACE imagery.

3. Hinode

A successor to TRACE and to a defunct Japanese x-ray solar satellite known as Yohkoh was launched in 2006. Called Hinode, the Japanese word for "sunrise," after its launch (it had been Solar-B), it carries telescopes built by Lockheed Martin Solar and Astrophysics Laboratory and the Smithsonian Astrophysical Observatory and a spectrographic instrument built at the Mullard Space Science Laboratory in England and at the U.S. Naval Research Laboratory; it is operated in collaboration with the National Astronomy Observatory of Japan and has European Space Agency and Norwegian involvement. The x-ray telescope can image the whole Sun at a time while maintaining the high-resolution of TRACE.

(186) The American Hinode site is ⟨http://solarb.msfc.nasa.gov/⟩.
(187) The Japanese Hinode site is ⟨http://solar-b.nao.ac.jp/index_e.shtml⟩.
(188) The link for daily and archival Hinode XRT (x-ray telescope) images;
⟨http://xrt.cfa.harvard.edu/data/latestimg.php⟩.

4. STEREO

A pair of spacecraft was sent into solar orbit in 2006 to image the Sun simultaneously from two different angles as the spacecraft drift apart. Since it gives a stereoscopic or three-dimensional view, the project is called STEREO, an acronym from Solar Terrestrial Relations Observatories.

(189) See: ⟨http://www.nasa.gov/mission_pages/stereo/main/index.html⟩.
(190) See: ⟨http://stereo.jhuapl.edu/⟩, STEREO 3-D solar images.
(191) http://www.rainbowsymphony.com/sun-3d-anaglyph.html

5. Solar Dynamics Observatory

(192) See: ⟨http://sdo.gsfc.nasa.gov⟩. SDO was launched on 11 February 2010. It carries the following three instruments.
(193) *HMI (Helioseismic and Magnetic Imager)*, extending the Michelson Doppler Imager on SOHO with full-disk coverage at higher spatial resolution, ⟨http://hmi.stanford.edu/⟩.
(194) *AIA (Atmospheric Imaging Assembly)*, with full-disk imaging at 8 wavelengths every 10 s, extending the Extreme-ultraviolet Imaging Telescope on SOHO, ⟨http://aia.lmsal.com/⟩.
(195) *EVE (Extreme Ultraviolet Variability Experiment)*, to measure the solar extreme-ultraviolet (EUT) irradiance, which varies abruptly and which influences Earth's climate, ⟨http://lasp.colorado.edu/eve/⟩.

6. Solar X-ray Imager

(196) GOES (Geostationary Operational Environmental Satellite) Solar X-ray Imager, a solar x-ray imager is on a NASA weather satellite; devices to monitor the total amount of solar energy reaching Earth are on at least three satellites, and other spacecraft also play roles in studying the Sun. After all, the solar panels on earth-resources spacecraft face the Sun all the time, so the add-on cost was relatively small. GOES-13 has sent images since 2006; GOES-14 has sent images since 2009. See: ⟨http://www.swpc.noaa.gov/sxi/⟩.

7. PROBA2

(197) *SWAP (Sun Watcher using APS Detectors)*:
⟨http://proba2.sidc.be/index.html/swap/⟩.
(198) *LYRA (Large Yield RAdiometer)*:
⟨http://proba2.sidc.be/index.html/lyra/⟩.

X. GROUND-BASED OBSERVATORIES

(199) **National Solar Observatory**. It provides live images of solar activity through its digital library and hosts an ftp library of past solar activity. It operates the largest U.S. solar telescope (the McMath-Pierce) on Kitt Peak, Arizona, and the world's best instrumented telescope (the Dunn Solar Telescope) on Sacramento Peak, New Mexico. See: ⟨http://www.nso.edu/⟩.
(200) **Sacramento Peak Observatory/National Solar Observatory**: H-alpha, continuum, helium; ⟨http://nsosp.nso.edu/data/latest_solar_images.html⟩.

(201) ISOON (Improved Solar Observing Optical Network) H-alpha, continuum, helium; ⟨http://nsosp.nso.edu/VIDEOIMG/isoon/latest_h.jpg⟩.

(202) NOAO Image Gallery, ⟨www.noao.edu/image_gallery/⟩.

(203) **Global Oscillation Network Group (GONG)**, ⟨http://gong.nso.edu⟩. The U.S. National Solar Observatory's project called Global Oscillation Network Group adopted the name and the acronym GONG because it is used for helioseismology: To detect how the solar surface is ringing like a bell. Its network of six telescopes around the world has at least one imaging the Sun almost always for years at a time.

(204) The latest images showing sunspots and the magnetic field are available at ⟨http://gong.nso.edu/Daily_Images/⟩.

(205) **Big Bear Solar Observatory: Global H-alpha network**, ⟨http://www.bbso.njit.edu/Research/Halpha/⟩. The site provides links to the Global H-alpha Network, with images from ground-based observatories around the world.

(206) **Swedish Solar Observatory, La Palma**. It arguably provides the highest-resolution solar photospheric images, from the Swedish 1-m Solar Telescope. See: ⟨http://www.solarphysics.kva.se/⟩.

(207) **Ramati High Energy Solar Spectroscopic Imager Data Center**. See especially its Public Outreach pages by clicking on the left and see the latest solar images at ⟨http://www.solarmonitor.org/rhessidatacenter/⟩.

(208) **Solar science described at NASA's Marshall Space Flight Center**, ⟨http://solarscience.msfc.nasa.gov/⟩.

(209) **The sunspot cycle is graphed at** ⟨http://solarscience.msfc.nasa.gov/SunspotCycle.shtml⟩.

A. High-quality amateur solar observations

(210) ⟨www.meade4m.com⟩ from the Meade Instruments Corp.

(211) ⟨www.solarminimum.com⟩, H-alpha movies from Gary Palmer.

(212) **Astronomy Picture of the Day**, http://antwrp.gsfc.nasa.gov/apod/. You can search for sun, corona, eclipse, or other topics.

(213) **High Altitude Observatory**, H-alpha, K-line, helium, Mauna Loa coronagraph images, ⟨http://www.hao.ucar.edu/⟩. It has, at least, daily white light and K-line images.

(214) **Mauna Loa Solar Observatory**, ⟨http://mlso.hao.ucar.edu/cgi-bin/mlso_homepage.cgi⟩.

(215) **San Fernando Observatory**, ⟨www.csun.edu/sfo/⟩. It has, at least, daily white light and K-line images.

(216) **Rome Observatory, Solar-Physics Section**, ⟨http://www.mporzio.astro.it/solare/Lastimages.html⟩.

(217) The archive of images obtained since 1996 is available at ⟨http://www.mporzio.astro.it/solare/calendarioPSPTa.htm⟩.

(218) **Culgoora Solar Observatory (Australia)**, H-alpha low-resolution; ⟨http://www.ips.gov.au/Solar/2/4⟩.

(219) **Kanzelhoehe Solar Observatory (Austria)**, ⟨http://www.solobskh.ac.at/⟩.

(220) Radioheliograph daily images of the Sun; ⟨http://solar.nro.nao.ac.jp/⟩, Nobeyama Radio Observatory, Japan.

B. Mt. Wilson Observatory

The 150 ft solar tower at the Mt. Wilson Observatory has been observing the Sun on every clear day since 1912. It is now run by the Mt. Wilson Institute.

(221) Magnetogram/continuum, ⟨http://www.astro.ucla.edu/~obs/intro.html⟩.

C. Observatoire de Paris

1. BAse de données Solaire Sol

H-alpha prominences, K-line on/off center, radio observations, limb prominences (K_3 is the center of the K-line of ionized calcium; K_{1v} (K_1-violet) is about 1 Å blueward of K_3).

(222) See: ⟨http://bass2000.obspm.fr/home.php?lang=en⟩.

(223) **SOLIS (Synoptic Optical Long-term Investigations of the Sun)**, ⟨http://solis.nso.edu/⟩. Synoptic Optical Long-term Investigations of the Sun at the National Solar Observatory): Photospheric magnetic field; helium (10,830 Å chromosphere); calcium (8542 Å infrared line).

(224) **NASA's Goddard Space Flight Center**. Includes calcium, coronagraph, and helium, as well as SOHO, and links; ⟨http://umbra.nascom.nasa.gov/images/latest.html⟩.

D. Advanced Technology Solar Telescope

The Advanced Technology Solar Telescope is being built on Haleakala, Maui, at an altitude of 3050 m (10,000 ft). The decision was made on the basis of the least atmospheric blurring, the most annual hours of low sky brightness, the lowest dust levels, and the smallest temperature extremes of the 72 sites considered.

(225) See: ⟨atst.nso.edu/⟩ Clicking on "Science" will give a brochure.

The announcement of the approval of the project by the National Science Foundation says that "understanding the role of magnetic fields in the outer regions of the Sun is crucial to understanding the solar dynamo, solar variability, and solar activity, including flares and mass ejections, which can significantly affect life on Earth. ATST research will investigate solar variability and its impact on terrestrial climate; and the conditions responsible for solar flares, coronal mass ejections, and other activities that can impact terrestrial communications and power systems, disrupt satellite communications, and endanger astronauts and air travelers."

> "ATST's 4-meter (13-foot) primary mirror will feed an advanced array of instruments designed to study the Sun in light ranging from near ultraviolet (350 nm) into the far infrared (28,000 nm, or 28 microns). High-order adaptive optics, pioneered by the NSO and its partners at NSO's Dunn Solar Telescope at Sunspot, NM, will correct blurring of solar images caused by Earth's atmosphere and thus allow ATST to observe features in the solar atmosphere with unprecedented sharpness, down

to structures only a few tens of kilometers in size."

(226) Assorted fact sheets at ⟨ftp://ftp.nso.edu/outgoing/users/dooling/fact_sheets/⟩.

(227) Executive Briefing package on ATST at ftp://ftp.nso.edu/outgoing/users/dooling/Brfg/. A DVD on ATST is available on line as a smaller streaming video; ⟨http://atst.nso.edu/node/692⟩.

XI. SPECTROHELIOGRAPHS AND COELOSTATS/HELIOSTATS

An older technique can provide very narrow bands of spectrum, which allows purer isolation of different levels of the Sun's atmosphere, thus allowing more accurate study of motions on the Sun. This technique uses a device called a spectroheliograph. It was used by the great solar scientist George Ellery Hale at the turn of the 20th century; Hale went on to build the two largest telescopes in the world in succession: first the 100 in. telescope on Mt. Wilson and then the 200 in. telescope on Palomar Mountain. (The 200 in. was the largest in the world through about 1995 when the Keck 400 in.—10 m—telescopes went into use.)

In a spectroheliograph, sunlight passes through a narrow slit and makes a spectrum. A second slit then isolates some particular wavelength of the spectrum. Next, the two slits scan together from side to side, meaning that the film or, now, electronic detector behind the second slit builds up an image of the Sun at the precise wavelength that passes through that slit. An advantage of a spectroheliograph is that the wavelength passed can be very narrow and pure, and any wavelength at all can be selected. A disadvantage is that the mechanical scanning is imprecise and takes time, allowing the Sun to change during a scan.

A description of a spectroheliograph, by Raymond N. Smartt, formerly of the National Solar Observatory, is available online through the **McGraw-Hill Encyclopedia of Science and Technology** through their website.

(228) See: ⟨http://www.accessscience.com⟩. (Note that a trial subscription or a full subscription may be necessary.)

1. Coelostats and heliostats

Coelostats and heliostats are tracking mirrors that enable the telescope and any associated instrumentation (spectrograph etc.) to remain fixed. They are used in both major solar observatories and on eclipse expeditions. Heliostats send the solar image down the polar axis and use a motor that rotates once in 24 h. Coelostats reflect the solar image into a secondary mirror that adjusts for the changing solar declination (except for days of eclipses, when they can be set to match that day's declination) and because of the reflection rotate once in 48 h.

(229) L. M. Dougherty, "A note on the principle and nomenclature of heliostats, coelostats and siderostats," J. British Astron. Assoc. 92 (4), 182–187 (1982), ⟨http://adsabs.harvard.edu/abs/1982JBAA…92..182D⟩. (E)

(230) L. M. Dougherty, "Heliostats, siderostats and coelostats," J. British Astron. Assoc. **95** (6), 270–271 (1985), http://articles.adsabs.harvard.edu/full/1985JBAA…95..270D. (E)

(231) J. M. Pasachoff and W. C. Livingston, "Coelostat and heliostat: Alignment and use for eclipse and other field purposes," Appl. Opt. **23**, 2803–2808 (1984). (I,A)

(232) M. Demianski and J. M. Pasachoff, "Coelostat and heliostat: Theory of alignment," Sol. Phys. **93**, 211–217 (1984). (A)

XII. TOTAL SOLAR IRRADIANCE (FORMERLY SOLAR CONSTANT)

(233) World Radiation Center/Physical Meteorological Observatory Davos, under Projects ⟨http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant⟩.

(234) From ACRIMsat, which carries the ACRIM-3 Active Cavity Radiometer Irradiance Monitor (ACRIM), ⟨http://www.acrim.com⟩.

(235) From SORCE/TIM (SOlar Radiation & Climate Experiment/Total Irradiance Monitor), ⟨http://lasp.colorado.edu/sorce/instruments/tim.htm⟩.

(236) From VIRGO (Variability of Solar Radiation and Gravity Oscillations) on SoHO, ⟨http://www.pmodwrc.ch/pmod.php?topic=tsi/virgo/proj_space_virgo⟩.

XIII. SPACE WEATHER

Several of the books listed in Parts II and III cover space-weather topics.

(237) **Space Weather Quarterly: The International Journal of Research and Applications** (International Geopphysical Union): ⟨www.agu.org/journals/spaceweather⟩.

(238) *Space Weather*. www.spaceweather.com. A daily posting that describes the current space weather, including a photograph of the Sun with sunspots, an image of the back side of the Sun, a flare likelihood prediction, and other information and images relevant to space weather. Postings for back days are archived.

(239) *Solar Monitor*, ⟨www.solarmonitor.org⟩. A composite set of ground-based and space full-disk solar images, the most recent from six views on the top-level page, with additional spacecraft images available by clicking.

(240) **NOAA Space Weather Prediction Center**, ⟨http://www.swpc.noaa.gov/⟩.

(241) Lockheed Martin Master List of Solar Web Sites: Space Weather, ⟨http://www.swpc.noaa.gov/Education/index.html⟩.

(242) Magnetosphere, ⟨http://www-spof.gsfc.nasa.gov/Education/Intro.html⟩, an educational website by David P. Stern and Mauricio Peredo.

(243) Auroras, http://www.gi.alaska.edu, from the Geophysical Institute of the University of Alaska, Fairbanks. ⟨http://www.geo.mtu.edu/weather/aurora⟩ from Michigan Tech.

(244) University Corporation for Atmospheric Research, ⟨http://www.windows.ucar.edu/spaceweather⟩.

(245) Space Weather Research Explorer, explanatory pages from the Exploratorium, a science museum in San Francisco, ⟨http://www.exploratorium.edu/spaceweather⟩.

XIV. OTHER ONLINE SOLAR RESOURCES

(246) Lockheed Martin Solar and Astrophysics Laboratory links to ⟨http://www.lmsal.com/solarsites.html⟩.

(247) NASA Goddard Space Flight Center, including calcium, coronagraph, and helium, as well as SOHO, and links, ⟨http://umbra.nascom.nasa.gov/images/latest.html⟩.

(248) Stanford Solar Center, ⟨http://solar-center.stanford.edu⟩.

(249) Stanford Solar Center art-literature-music page, ⟨http://solar-center.stanford.edu/art/⟩.

(250) Solar science described at NASA's Marshall Space Flight Center, ⟨http://solarscience.msfc.nasa.gov/⟩.

(251) Astronomy Picture of the Day, ⟨http://antwrp.gsfc.nasa.gov/apod/⟩. You can search for Sun, corona, eclipse, or other topics.

(252) SOHO Pick of the Week. ⟨http://sohowww.nascom.nasa.gov/pickoftheweek/⟩.

(253) XRT Picture of the Week (from the x-ray telescope on Hinode), ⟨http://xrt.cfa.harvard.edu/xpow/⟩.

(254) NASA's Goddard Space Flight Center Scientific Visualization Studios, ⟨http://svs.gsfc.nasa.gov⟩. Search "Imagery by Keyword" for topics such as sunspots or magnetism, or for spacecraft names.

(255) The ~~Nine~~8 Planets: A Multimedia Tour of the Solar System, Bill Arnett, ⟨http://nineplanets.org/sol⟩.

(256) From Stargazers to Starships, David P. Stern: http://www.phy6.org/stargaze/. Exploratorium resources: http://www.exploratorium.edu/observatory. Multimedia Tour, Michiel Berger: ⟨http://www.astro.uva.nl/demo/od95⟩.

(257) Sun-Earth Day: ⟨http://sunearthday.nasa.gov⟩.

A. Categorized list of books

(258) See Marcus Aschwanden's list of books, arranged by category and year, at ⟨http://www.lmsal.com/~aschwand/publications/index.html⟩.

XV. COLLECTIVE LINKS

(259) From Jay Pasachoff at Williams College http://www.williams.edu/astronomy/jay/solarlinks.

(260) From Lockheed Martin Solar and Astrophysics Laboratory, which operates TRACE and Solar Dynamics Observatory, ⟨http://www.lmsal.com/solarsites.html⟩.

(261) From Markus Aschwanden of Lockheed Martin Solar and Astrophysics Laboratory, whose comprehensive list of the solar literature is arranged by subject and year: ⟨http://www.lmsal.com/~aschwand/⟩.

(262) Clicking on "Missions+Projects" brings you many links: ⟨http://www.lmsal.com/~aschwand/bookmarks_missions.html⟩.

(263) Also, at his next-to-last line, there is a link to "Solar Pictures" that leads you to ⟨http://www.lmsal.com/~aschwand/bookmarks_pictures.html⟩.

(264) Stanford Solar Center links page, ⟨http://solar-center.stanford.edu/about/data.html⟩.

(265) San Fernando Observatory, California State University at Northridge, ⟨http://www.csun.edu/sfo/astrolinks.html⟩.

(266) Solar Physics Division of the American Astronomical Society's links, ⟨http://spd.aas.org/navbar_links.html⟩.

(267) Solar Physics Division's Newsletter for students, ⟨www/msal.com/~zoe/student_news⟩.

XVI. iPHONE/iPAD APP

(268) NASA's STEREO and Tony Phillips, ⟨http://3dsun.org⟩.

XVII. LATEST SPACECRAFT IMAGES

(269) Solar Dynamics Observatory, ⟨http://sdowww.lmsal.com/suntoday⟩.

(270) Helioviewer, with choosable date and time, ⟨http://helioviewer.org⟩.

ACKNOWLEDGMENTS

The author thanks the referees for their useful comments and additions: John W. Leibacher (National Solar Observatory), Stephen L. Keil (National Solar Observatory), Rosemary Wyse (The Johns Hopkins University), Markus Aschwanden (Lockheed Martin Solar and Astrophysics Laboratory), Leon Golub (Smithsonian Astrophysical Observatory), and Deborah K. Scherrer (Stanford Solar Center). The author is grateful for funding for his solar efforts over a long period of time from the Atmospheric and Geospace Sciences Division and the Astronomical Sciences Division of the National Science Foundation, the Heliophysics Division of NASA, and the Committee for Research and Exploration of the National Geographic Society. The author has made use of the NASA-Smithsonian Astrophysics Data System.