

Transactions IAU, Volume XXXA

Reports on Astronomy 2015–2018

Piero Benvenuti, ed.

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Report of the Working Group on Solar Eclipses

Honolulu General Assembly through Vienna General Assembly—August 2015 to August 2018
of Division C Education, Outreach and Heritage and Division E Sun and Heliosphere:

Jay M. Pasachoff

Members of the Working Group on Solar Eclipses are:

Jay Pasachoff, Williamstown, Massachusetts, U.S.A.

Iraida Kim, Moscow, Russia

Hiroki Kurokawa, Kyoto, Japan

Jagdev Singh, Bangalore, India

Vojtech Rusin, Tatranská Lomnica, Slovakia

Zhongquan Qu, Yunnan, China

and for technical expertise:

Fred Espenak, Portal, Arizona, U.S.A., <http://EclipseWise.com>

Jay Anderson, Winnipeg, Canada, <http://eclipsophile.com>

Glenn Schneider, Tucson, Arizona, U.S.A.,

<http://nicmosis.as.arizona.edu:8000/UMBRAPHILLIA.html>

Michael Gill, U.K., Solar Eclipse Mailing List eclipsechaser@yahoo.com

Xavier Jubier, Antony, France, <http://xjubier.free.fr>

Michael Zeiler, Albuquerque, New Mexico, U.S.A., <http://eclipse-maps.com> and

<http://GreatAmericanEclipse.com>

Bill Kramer, <https://eclipse-chasers.com>

associates:

Ralph Chou, Mississauga, Canada (prof. emeritus of optometry)

Michael Kentrianakis, U.S.A.; project manager, AAS Eclipse Task Force

The IAU Working Group on Solar Eclipses, during the last triennium, provided links, advice, and endorsements for the solar eclipses, which included

total eclipses:

2016 March 9, Indonesia and Pacific Ocean

2017 August 21, U.S.A.

annular eclipses:

2016 September 1, Africa: Gabon to Madagascar; Réunion; partial phases throughout most of Africa

2017 February 26, Chile and Argentina; Atlantic Ocean; Angola, Zambia and Democratic Republic of the Congo; partial phases in South America, Africa, and Antarctica

partial eclipses:

2015 September 13, Antarctica, southern Africa

2018 February 15, Antarctica; Chile and Argentina

2018 July 13, Antarctica; Tasmania

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2018 August 11, Arctic, including Norway, Russia

*and we are preparing similar advice and activity during the next triennium
(IAU Vienna 2018 to IAU 2021 Busan, Republic of Korea)*

total eclipses:

2019 July 2, Pacific Ocean, Chile, and Argentina

2020 December 14, Pacific Ocean, Chile, Argentina, Atlantic Ocean

annular eclipses:

2019 December 26, Saudi Arabia, Oman; India and Sri Lanka, Indonesia, Malaysia, Singapore;
southernmost Philippines; Guam

2020 June 21, Yemen, Saudi Arabia, Oman; Pakistan, India, China, Taiwan

2021 June 10, Arctic (Canada, Greenland, Russia); partial phases throughout the Eastern U.S.A.,
Europe, and northern Asia

partial eclipses

2019 January 6 Western Asia (China, Russia, Mongolia, Japan, South Korea, North Korea,
U.S.A. (Aleutian Islands of Alaska))

Thumbnail maps are available at

<http://www.eclipsewise.com/eclipse.html#recent>

Detailed Google (zoomable, clickable) maps from Xavier Jubier and Fred Espenak are linked at
their sites and at the IAU Working Group on Solar Eclipses website <http://solareclipses.info>

Xavier Jubier's maps for each can be obtained by substituting the relevant date in the following
map for the 2019 total solar eclipse:

http://xjubier.free.fr/en/site_pages/solar_eclipses/xSE_GoogleMap3.php?Ecl=+20190702&Acc=2&Umb=1&Lmt=1&Mag=1&Max=1&Map=ROADMAP

or a shorter version

http://xjubier.free.fr/xSE_GM?Ecl=+20190702&Acc=2&Umb=1&Lmt=1&Mag=1&Max=1&Map=ROADMAP

We provide information yearly, on behalf of this Working Group, to the 2018 International
Geophysical Calendar: https://www.ngdc.noaa.gov/stp/space-weather/online-publications/igc_calendars/2018/. It is prepared by the International Space Environmental
Service (ISES) Secretary for World Days, Ms. Robyn Fiori, Geomagnetic Laboratory, Natural
Resources Canada, 2617 Anderson Road, Ottawa, Ontario, Canada, K1A 0E7. See also
<http://spaceweather.org>.

For the Great American Eclipse of 21 August 2017, whose path crossed only United States territory, on behalf of the IAU Working Group on Solar Eclipses, we wrote recommendations for visas into the United States or assisted with local arrangements for scientists from China, Japan, Bulgaria, Iran, and elsewhere.

Our IAU Working Group website, <http://eclipses.info>, provides links to the various sites discussed below, meaning that only that simple notation need be cited to give access to the wonderfully informative sites of others.

Espenak's site, <http://eclipsewise.com>, supersedes (with his retirement from NASA) the former "NASA site," which is no longer being updated.

Jubier's site is so useful and popular that in August 2017, the month of the American total solar eclipse, it got 100+ million visitors, including above 10 million daily for two days (eclipse day and an adjacent day).

Anderson's site, <http://eclipsophile.com>, is the definitive source of cloudiness statistics used for pre-eclipse planning and for detailed discussion of the likely weather at the times of eclipses for various locations. Anderson is a meteorologist.

Zeiler's site provided the authoritative set of maps for general use and for publication. Zeiler is a professional map-maker. His website at <http://GreatAmericanEclipse.com> was widely used. Zeiler also provides a trove of historic eclipse maps.

Gill's Solar Eclipse Mailing List is widely used to link professionals and amateurs interested in astronomy. Daily summaries are available as a choice for those who do not want to receive several different mailings almost every day.

Kramer's website includes a list of people who have observed eclipses, with details including how many eclipses observed under what general weather circumstances, and what total time has been spent in totality or annularity. He has calculated that only two small moons of Saturn join Earth's moon in being able to make total solar eclipses: <https://www.eclipse-chasers.com/article/papers/SolarSystemEclipses.shtml>

Chou is the acknowledged expert on eye safety at eclipses.

An extensive and successful effort by an American Astronomical Society Task Force on Solar Eclipses, led by Rick Fienberg (AAS), Angela Speck (U. Missouri), and Shadia Habbal (U. Hawaii), with Project Manager Michael Kentrianakis, included explanations of eye safety and availability of solar filters. <http://eclipse.aas.org>.

A major NASA effort was led by J. Alex Young of NASA's Goddard Space Flight Center. It included web video on eclipse day from several sites across the U.S. NASA provided 11 research grants in an eclipse program, almost evenly divided between solar and ionospheric research.

Much publicity was given after the eclipse to President Donald Trump's glancing skyward at the partial phases without the glasses after gazing, with his wife, skyward through "eclipse glasses": <http://www.cnn.com/2017/08/21/politics/trump-solar-eclipse/index.html>
https://www.washingtonpost.com/news/the-fix/wp/2017/08/21/trump-celebrates-solar-eclipse-by-looking-up-without-special-viewing-glasses/?utm_term=.26d5c5d4d820

A political row followed with Trump providing a meme showing himself "eclipsing" former president Obama: <http://www.cnn.com/videos/politics/2017/08/24/trump-eclipses-obama-tweet-moos-erin-pkg.cnn>

Articles relevant to eclipse preparation and literature included:

Pasachoff, Jay M., and Andrew Fraknoi, 2017, "Resource Letter OSE-1 on Observing Solar Eclipses," *American Journal of Physics* **85**(7), 485-494, July.

Pasachoff, Jay M., 2017, "The Great Solar Eclipse of 2017," *Scientific American*, **317**, #2, 54-61, August.

Pasachoff, Jay M., 2017, "Heliophysics at Total Solar Eclipses," *Nature Astronomy* **1**, article number 0190 (August). <https://www.nature.com/articles/s41550-017-0190> <http://rdcu.be/uEuz>

Another public-education report was

Pasachoff, Jay M., "Getting Ready for the Eclipse," National Geographic Society Education Blog.

<http://blog.education.nationalgeographic.com/2017/06/29/getting-ready-for-the-eclipse/>

Eclipse-related books were published at many levels. A children's book, *When the Sun Goes Dark* by Andrew Fraknoi and Dennis Schatz (National Science Teachers Association, 2017) is an illustrated book for children 9-14. Another children's book (ages 8-12), *Earth, Moon and Sun*, was written by Leon Golub and illustrated by Sibyl S. Senters (CreateSpace, 2016), includes not only a trip to see the eclipse but also to an Observatory and shows its readers how to figure out that the Moon goes around the Earth and the Earth and Moon go around the Sun.

Andrew Fraknoi worked with foundations to distribute over 2 million pairs of "eclipse glasses," largely through public libraries. His report: "2.1 million pairs of eclipse glasses were distributed free through public libraries in the U.S. for the solar eclipse event on August 21, 2017. 7,100 organizations, including public library branches, bookmobiles, tribal libraries, library consortia, and state libraries, received a package of free safe-viewing glasses, plus a 24-page information booklet on how best to do public outreach programs about the eclipse. The project was supported, in part, by the Gordon and Betty Moore Foundation, with additional help from

Google, NASA, and the National Science Foundation (NSF). This was the single largest distribution of free glasses in the entire country and reached more people with glasses and information than any other educational effort for the 2017 eclipse. It is projected that this library eclipse project allowed 6 million people to observe the event safely.

“The eclipse-glasses project was conceived by three astronomers, Andrew Fraknoi (Foothill College, Los Altos Hills, California), Dennis Schatz (Pacific Science Center, Seattle, WA), and Douglas Duncan (University of Colorado, Boulder, Colorado). Together they brought the idea to Paul Dusenbery, Director of the Space Science Institute’s National Center for Interactive Learning (NCIL), located in Boulder, Colorado. NCIL already managed the STAR Library Network (*STAR Net*) to help libraries with STEM programming (with support from NASA, NSF, and others). This network then expanded considerably once the availability of free glasses was announced.

“More detailed information about the library eclipse program is available at: www.starnetlibraries.org/2017eclipse/.”

Jubier provided a free smartphone app (iOS and Android):

<http://www.bigkidscience.com/eclipse/>.

Moreover over 100,000 eclipse glasses were distributed free to schools and kids. This initiative was part of a STEM educational program and there are plans to do the same in South America in 2019 and 2020. The smartphone app has been translated to Spanish. More on the home webpage <http://www.bigkidscience.com/>

Many of us participated in public outreach. For example, Zhongquan Qu, who was with about 30 colleagues in Dallas, Oregon (about 50 km west of Salem), was invited to give a lecture two days before totality on the life of the sun and the Chinese team’s observational plan for the 2017 grand American solar total eclipse. He also answered the questions raised by the audience. Bill Kramer gave a wide variety of interviews for TV/radio/web/schools. Vojtech Rusin provided information about the Great American Eclipse in Slovakian:

<http://vedanadosah.cvtisr.sk/uplne-zatmenie-slnka-1>

<http://vedanadosah.cvtisr.sk/uplne-zatmenie-slnka-2>

http://www.sav.sk/index.php?lang=sk&doc=services-news&source_no=20&news_no=7057

Aj tatranské „čierne“ Slnko je v Nature

Translation: The Tatra "Black" Sun is also in nature

http://www.sav.sk/index.php?lang=sk&doc=services-news&source_no=20&news_no=7087

Biela koróna a “čierne” Slnko z Ameriky

Translation: The white light corona and "Black" Sun on America

Many new books about eclipses, historic and current, were released. Reviews included:

Pasachoff, 2016, books review of *Sun Moon Earth: The History of Solar Eclipses from Omens of Doom to Einstein and Exoplanets* by Tyler Nordgren; *In the Shadow of the Moon: The Science, Magic, and Mystery of Solar Eclipses* by Anthony Aveni; and *American Eclipse: A Nation’s Epic Race to Catch the Shadow of the Moon and Win the Glory of the World* by David Baron, *Phi Beta Kappa (PBK) Key Reporter*.

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<http://www.keyreporter.org/BookReviews/LifeOfTheMind/Details/2109.html>

Pasachoff, 2017, "Total eclipse: American spectacle this time," review of *In the Shadow of the Moon: The Science, Magic, and Mystery of Solar Eclipses* by Anthony Aveni; *American Eclipse: A Nation's Epic Race to Catch the Shadow of the Moon and Win the Glory of the World* by David Baron; Frank Close, *Eclipse: Journeys to the Dark Side of the Moon*; and *Mask of the Sun: The Science, History, and Forgotten Lore of Eclipses* by John Dvorak, in *Nature* **545**, 409-10 (May 25).

With or near me in Salem, Oregon, for nearly two minutes of totality were Working Group members (and their teams) Kurokawa, Qu, Rusin, and Chou.

An hour-long Public Television (PBS) show, *NOVA*: "Eclipse Over America," was devoted to the eclipse and aired that night, <https://nova.wistia.com/medias/py80aesc2x>, with an international version now being distributed. A one-week pre-eclipse eye-safety post by Chou, linked to the PBS video, received 5.1 million views: <https://www.facebook.com/NOVApbs/videos/10154808533022196/>

Mark Bender's "Eclipse Across America" pre-eclipse series of videos is available on Curiosity Stream: <https://curiositystream.com/eclipse/>.

Jarita Holbrook issued her movie "Black Suns: An Astrophysical Adventure," about African-American astronomers at the 2012 annular and total eclipses; it won the 2017 Jury Award at The Art of Brooklyn Film Festival and is being released for general purchase in 2018. <http://www.bridgingstories.com/projects/black-sun/>

Citizen science included the MegaMovie project at Space Sciences Laboratory of the University of California, Berkeley. <http://EclipseMega.movie>; as of this writing the website movie had about 50,000 images from about 12,000 individuals. Another project used about 68 identical telescopes spaced across the Continental United States, headed by Mark Penn of the National Solar Observatory: Citizen CATE (Continental-America Telescopic Eclipse): <https://eclipse2017.nso.edu/citizen-cate/>

Post-American-eclipse, we have arranged for special eclipse sessions at the American Geophysical Union (December 2017), the American Astronomical Society (January 2018; sessions 220 (oral) and 242 posters): Results from the August 21, 2017, Total Solar Eclipse), and the American Association for the Advancement of Science (February 2018) meetings. <https://agu.confex.com/agu/fm17/preliminaryview.cgi/Session22332>
<https://agu.confex.com/agu/fm17/preliminaryview.cgi/Session22307>
<https://aaas.confex.com/aaas/2018/meetingapp.cgi/Session/17655>

For the February 2017 annular eclipse, Beatriz Garcia (President of the IAU Commission C1 on Education and Development), Néstor Camino, Mariana Orellana, and others arranged an eclipse

workshop in Esquel, Argentina. <http://sion.frm.utn.edu.ar/WDEAII/> (Workshop de Difusion y Educacion en Astronomia) and http://xjubier.free.fr/en/site_pages/solar_eclipses/ASE_20170226_pg02_Esquel_WDEAII_Workshop.html

Astronomers Without Borders, headed by Mike Simmons in the U.S.A., arranged to provide eclipse glasses. See <http://astronomerswithoutborders.org>. He is now collecting leftover or used glasses from the 2017 USA eclipse to distribute in South America for the 2019 solar eclipse, which will be partial throughout most of the continent.

A summary of eclipse efforts also appeared: Jay M. Pasachoff, “The American Eclipse of 2017,” Newsletter #86 of the Commission (C1) on Astronomy Education and Development of the International Astronomical Union, pp. 14-15. http://iaucc1.frm.utn.edu.ar/?page_id=214

An art-and-artifacts about eclipses was mounted during the summer of 2017 at Art Center College of Design in Pasadena, CA:

<http://www.artcenter.edu/connect/events/eclipse.html>

<http://williamsongallery.net/eclipse/>

It included three Howard Russell Butler oil paintings of the 1918/1923/1025 total solar eclipses; a new Russell Crotty eclipse image; artifacts brought by Tony Misch of items used at Lick Observatory eclipse expeditions early in the 20th century, and more.

A video from a Japanese meteorological satellite of the 2016 umbra appears at <https://www.nytimes.com/2017/07/19/science/what-a-total-solar-eclipse-looks-like-from-space.html>

A video from NASA’s DSCOVR satellite of the 2017 umbra appears at <https://www.nasa.gov/image-feature/goddard/2017/nasas-epic-view-of-2017-eclipse-across-america>

NASA’s Earth Polychromatic Imaging Camera (EPIC) captured 12 natural color images of the moon’s shadow crossing over North America. EPIC is aboard NOAA’s Deep Space Climate Observatory (DSCOVR).

Acknowledgments:

The eclipse work of J.M.P., his students, and his research colleagues at the 2017 eclipse was supported in large part by grants from the Solar Terrestrial Program of the Atmospheric and Geospace Sciences of the U.S. National Science Foundation and from the Committee for Research and Exploration of the National Geographic Society.