**Williams College Expedition Success at Solar Eclipse**

Media contact: Noelle Lemoine, communications assistant; tele: (413) 597-4277;

email: Noelle.Lemoine@williams.edu

online press release: http://communications.williams.edu

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"We had complete and total success under exceptionally clear sky," says Williams College astronomer Jay Pasachoff. "All our experiments, with dozens of telescopes and electronic cameras, collected data during the rare two minutes at which we could see and study the sun's outer atmosphere, the corona." At the current meeting of the Solar Physics Division of the American Astronomical Society, Pasachoff reported on preliminary results from his team's observations in Salem, Oregon, as well as related observations from space and from a radio telescope in California.

"We could see giant streamers coming out of low solar latitudes as well as plumes out of the sun's north and south poles, all held in their beautiful shapes by the sun's magnetic field," he said. "Our high-frequency observations," joint with MIT colleague Michael Person, "used special filters that singled out the specific colors in the red and green that come from million-degree coronal gas, and we have the data recorded. It will take many months now to study, but we have what we came for."

Eight William College undergraduates as well as several recent alumni graduate students and Ph.D.s participated, many programming and operating computer-controlled cameras to record the event.

Pasachoff headed one of the largest organized scientific expeditions to study the sun, and the sun's effects on Earth, at the eclipse. He took advantage of his experience in observing eclipses, and organizing eclipse expeditions, by taking dozens of students and colleagues with him to Salem, Oregon, for the event. "I chose the site because it is in the region with the most favorable cloudiness statistics for August," Pasachoff reports, "while still having the logistical advantages of a city and of campus support. And the statistics paid off, giving us perfect weather to observe the eclipse."

"When I discovered that Willamette University is near the center of totality in the most favorable weather region, and that they were not only glad to provide hospitality on campus but also have an astronomer as their president, we knew that we had found a scientific home-away-from-home. I knew that we could benefit from their site as well as their electricity and computer support, but the additional support they gave us with a machine shop to modify and correct equipment at the last minute was also vital. Back at Williams, we also had an additional piece worked up on an emergency basis by Michael Taylor in the College Science Shop and sent overnight to us in Salem."

Pasachoff viewed his 66th solar eclipse, the most of anyone ever. He serves as Chair of the International Astronomical Union's Working Group on Solar Eclipses, and as such helped coordinate scientific colleagues' visits to the U.S. for eclipse observing from, among other countries, China, Japan, Venezuela, Bulgaria, Greece, Poland, and Slovakia.

Pasachoff's observing team had the advantage of a basic research grant awarded almost three years ago by the Committee on Research and Exploration of the National Geographic Society, which has awarded him 18 research grants dating back to 1970, when he assisted his senior mentor, Prof. Donald Menzel of the Harvard College Observatory, to run a major eclipse expedition to Mexico for that year's eclipse, whose path of totality covered part of the southeastern U.S. as well as Virginia Beach and Nantucket Island, Massachusetts. For the 2017 total solar eclipse, his scientific capabilities then expanded with the award of a major research grant from the Solar Terrestrial Program of the Atmospheric and Geospace Sciences Division of the U.S. National Science Foundation.

With these grants, the Williams College Expedition supported such scientists as Ronald Dantowitz of the Clay Center Observatory of the Dexter Southfield School in Brookline, Massachusetts; Vojtech Rusin of the Astronomical Institute of the Slovak Academy of Sciences in Tatranská Lomnica, Slovakia; John Seiradakis and Aris Voulgaris of the Aristotle University of Thessaloniki, Greece; Marcos Peñaloza-Murillo of the University of the Andes in Merida, Venezuela; and Michael Person of M.I.T.; and had additional collaboration with Amanda Bosh and Stephen Levine of MIT and the Lowell Observatory; and Marek Demianski of the University of Warsaw, Poland. Williams College astrophysics alumni experienced from past eclipse expeditions who participated in the observing include Daniel Seaton of the National Oceanic and Atmospheric Administration (NOAA) and the University of Colorado in Boulder; and graduate students Muzhou Lu of the University of Colorado in Boulder; and Allen Davis of Yale. Graduate student David Sliski of the University of Pennsylvania also made significant contributions to the research effort. They observed from platforms on the Willamette campus that provided electricity and internet to aid in the telescopes' tracking and the electronic-cameras' data-collecting abilities. They were joined in the scientific work by eight Williams College undergraduates, who had already worked all summer in preparing and testing the eclipse equipment: Declan Daly '20 of Seattle; Brendan Rosseau '19 of Glen Ellyn, Illinois; Ross Yu '19 of Huntington Beach, CA; Charles Ide '20 of Natick, Massachusetts; Cielo Perez '19 of Dallas, Texas; Erin Meadors '20 of Albuquerque, New Mexico; Christian Lockwood '20 of Quogue, Long Island, New York; and Connor Marti '20 of Cranford, New Jersey. Aram Friedman of Ansible Technology in Princeton, New Jersey, coordinated wide-field video observations, including a 360° video. Four of the students were supported by Pasachoff's NSF grant; others received funds from the NASA Massachusetts Space Grant Consortium, Sigma Xi (the honorary scientific society), the Clare Booth Luce Foundation, and Williams College, including the Freeman Foote Expeditionary Fund. Former Williams College staff physicist Bryce Babcock also collaborated on the equipment, based on his participation in past expeditions.

Pasachoff worked closely over several months with the NOVA program on PBS, which pushed through a revised final 20 minutes of their hour-long show, "Eclipse Across America," at 9 pm on eclipse night, with a revised version airing two nights later. He also collaborated with the 360° imaging of The New York Times.

The Williams College team's main observations were to study the solar corona, which is a million times fainter than the everyday sun and normally hidden behind the blue sky. "Only at a total solar eclipse, when the blue sky goes away because normal sunlight is hidden by the moon, can we see the corona at all this well. And because the sun's magnetic field changes over the 11-year sunspot cycle and erratically as well, each time we look at the corona--even when we get only a couple of minutes to see it every couple of years somewhere in the world--we have a new sun to study, just as a cardiologist-researcher who looked inside someone's heart in, say, Africa two years ago for a couple of minutes would still have lots to learn by looking at a new patient in the U.S. a couple of years later."

"We are learning about the sun's influence on the Earth," said Pasachoff, "which we now call space weather. Eruptions on the sun can zap and kill satellites in Earth orbit and even cause surges on power lines and blackouts. We want to understand how to predict and monitor solar eruptions that affect us on Earth, and observations during our rare opportunities at total solar eclipses contribute to these goals."

One of the main scientific conundrums that the team tackled is the cause of the heating of the solar corona to millions of degrees. The scientists operated special fast cameras that have negligible dead time between high-quality frames, using the POETS (Portable Occultation, Eclipse, and Transit System) devices that were purchased a dozen years ago jointly by M.I.T.'s occultation-research group and Williams College with a NASA equipment grant. The data were successfully recorded, and will be studied over the next year or two.

In collaboration with NASA's Goddard Space Flight Center (Greenbelt, MD), a combination of space observations at the time of the eclipse with the Williams team's composite images emphasizing coronal structure was released by NASA at:

[https://www.nasa.gov/image-feature/goddard/2017/aug-21-solar-eclipse-from-ground-and-space](https://www.nasa.gov/image-feature/goddard/2017/aug-21-solar-eclipse-from-ground-and-space" \t "_blank) and a version of the combination image with the hot gas on the disk of the sun that was hidden at the eclipse but shown with the Solar Ultraviolet Imager (SUVI) on NOAA's new GOES-16 spacecraft was assembled by NOAA/U-Colorado scientist Daniel Seaton.

Pasachoff also works with atmospheric scientists Peñaloza-Murillo, who had been a Fulbright Fellow at Williams College five years ago, and Michael Thomas Roman of the University of Michigan to understand the effect of the abrupt shutting off of incident sunlight by the onset of totality on Earth's wind, temperature, pressure, and other weather aspects. "One of my granddaughters recorded a temperature drop of at least 12°, as part of her elementary-school project; we have scans from our professional-level weather station to study." In addition, the team made photometric measurements of the sky to study its brightness, in different directions including the zenith, to see how dark the sky will be.

Pasachoff also teamed with radio astronomers to use the Extended Owens Valley Radio Array near Bishop, California; and the National Radio Astronomy Observatory's Very Large Array located 60 miles west of Socorro, New Mexico, to pinpoint emission regions on the solar surface as the moon advanced over them and then continued farther, allowing these magnetic regions to become visible again. The localization of solar activity in this way, once studied in detail, will be the highest ever possible, and will be valuable to compare with space observations in x-rays and the ultraviolet to pin down just where the emission comes from in the fine-resolution magnetic field on the solar surface. Collaborating scientists include Dale Gary and Bin Chen of the Owens Valley Radio Observatory of the New Jersey Institute of Technology; Tim Bastian of the National Radio Astronomy Observatory; and Stephen White of the U.S. Air Force's Research Laboratory in New Mexico.

For PBS's NOVA "Eclipse Across America," aired on public television stations that night, footage from Pasachoff's prior expedition to the most recent previous solar eclipse--a so-called annular ("ring") eclipse that he viewed from Argentinian Patagonia on February 26 this year; and from a subsequent visit to Dantowitz's lab in Brookline, Massachusetts, where eclipse equipment was tested; provided a good bit of the program's background, with twenty minutes of footage from eclipse day added that afternoon. The New York Times's science reporter Dennis Overbye helped coordinate 360° observations also from their site.

At the Solar Physics Division meeting in Portland on Wednesday, Pasachoff also reported on the success of the Megamovie project (http://eclipsemega.movie), in which people across the country--"citizen scientists"--submitted their images and videos to a Google-aided system, to be available to all. Preliminary movies from smart phones and, separately, from regular cameras are already available, and will be continually improving.

Pasachoff also showed images from NASA's pair of spacecraft called STEREO, because they are about halfway around the Earth's orbit and therefore get views of the Sun's back side. The images were supplied by Paulett Liewer of NASA's Jet Propulsion Laboratory (Pasadena, CA). JPL is administered by Caltech, at which Pasachoff has a visiting appointment.

Several other scientists joined Pasachoff at his site to view the fantastic spectacle that is expected, often accompanied by family members. They included David Hathaway, retired NASA expert on the sunspot cycle; Susan McKenna-Lawlor of Maynooth University in Ireland (who mistakenly flew to Portland, Maine, instead of Portland, Oregon, but nevertheless managed to reach Salem, Oregon, in time for the eclipse); Deepto Chakrabarty of MIT; Robert Vanderbei of Princeton; Ruslan Belikov of NASA's Ames Research Center; Edw Ginsberg of the University of Massachusetts at Boston; John Briggs of his private observatory in New Mexico; and Phyllis Lugger of the University of Indiana. Douglas George of Cyanogen Productions Inc. in Toronto, provided a set of electronic cameras; and R.J. Smith of Bisque, Inc., of Colorado, a provider of high-quality tracking telescope mounts and control software, were also part of the expedition. Alan Sliski of Lincoln, Massachusetts, lent his expertise on telescope mounts and on cameras for eclipse use. Williams College alumni with Ph.D. degrees attending included Joey Shapiro Key of the University of Washington at Bothell; Kristen Shapiro Griffin of Northrop Grumman; and with National Science Foundation support: Duane Lee of Vanderbilt University and Marcus Freeman, as well as University of Maryland graduate student in astronomy Amy Steele. Also on site were 10 Japanese astronomers with 40 of their colleagues coordinated between Pasachoff and Hiroki Kurokawa of the Kwasan Observatory, Kyoto University; and nearby-- in Dallas, Oregon--were 25 Chinese astronomers headed by Zhongquan Qu of the Yunnan Observatory, China.

Pasachoff runs a website at http://eclipses.info for the Working Group on Solar Eclipses of the International Astronomical Union, with many links to maps and other resources for the general public as well as for professional astronomers. His website at http://totalsolareclipse.org includes images and other materials from his past eclipse expeditions.

The Solar Physics Division of the American Astronomical Society is meeting in Portland, Oregon, and many of the attendees traveled by bus to the Willamette campus to observe the eclipse, since Portland was outside the zone of totality.

The shadow of the Moon crossing the United States shows well in an animation from NOAA's GOES-16 spacecraft and in a photograph taken by an astronaut on the International Space Station, but shown by Pasachoff in his talk.

At present, two tons of equipment from the Williams College Eclipse Expedition are on a truck--driven by schoolteacher John Nuciforo of Pittsfield, Massachusetts--headed eastward.

Pasachoff participated in the American Astronomical Society's Solar Eclipse 2017 Task Force. With Andrew Fraknoi, he published a Resource Letter on Observing Solar Eclipses in the current issue of the *American Journal of Physics*, available through their website or at http://eclipses.info. He also has articles on eclipses in the August (current) issues of Scientific American and—summarizing 10 years of eclipse research results following his paper in *Nature* in 2009 for the International Year of Astronomy—a new paper in *Nature Astronomy*, "Heliophysics at Total Solar Eclipses," legally shared at http://rdcu.be/uEuz. For younger readers, he also helped prepare issues of two children’s magazines from the Cricket family (*Dig into History* and *Muse*) dedicated to the topic of eclipses. He is giving papers and organizing or co-organizing sessions in advance about the expected research results from the eclipse at the next meetings of the American Geophysical Union (in New Orleans in December); the American Astronomical Society (in suburban DC in January); and the American Association for the Advancement of Science (in Austin in February).

**pictures from the expedition at our expedition website:**

http://totalsolareclipse.org

or directly to:

http://sites.williams.edu/eclipse/2017-usa/

**contact information:**

Prof. Jay Pasachoff, eclipse@williams.edu (useful for scheduling telephone or Skype interviews)

*in Portland, Oregon, Aug 22-26; in LA Aug 28-31; in DC September 1-3.*

**Recent non-technical books (see links at http://solarcorona.com):**

*The Sun* by Leon Golub and Jay M. Pasachoff (Reaktion Press and U Chicago Press, 2017)

*Peterson Field Guide to the Stars and Planets* by Jay M. Pasachoff (Houghton Mifflin Harcourt; 4th edition, 2016 printing with eclipse and Pluto updates)

*Nearest Star: The Surprising Science of Our Sun* by Leon Golub and Jay M. Pasachoff (Cambridge University Press, 2nd edition, 2014).

**websites:**

http://eclipses.info

http://totalsolareclipse.org

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Williams College's Hopkins Observatory is the oldest extant astronomical observatory in the United States.

Founded in 1793, Williams College is the second-oldest institution of higher learning in Massachusetts. The college’s 2,000 students are taught by a faculty noted for the quality of their teaching and research, and the achievement of academic goals includes active participation of students with faculty in their research. Students’ educational experience is enriched by the residential campus environment in Williamstown, Mass., which provides a host of opportunities for interaction with one another and with faculty beyond the classroom. Admission decisions on U.S. applicants are made regardless of a student’s financial ability, and the college provides grants and other assistance to meet the demonstrated needs of all who are admitted.

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*880 Main Street, Hopkins Hall 4th floor P.O. Box 676 Williamstown, MA 01267 USA*[*413.597.4277*](tel:413.597.4277)*413.597.4158*[*communications@williams.edu*](mailto:communications@williams.edu)