Session 2: Citizen Science and Solar Eclipses

https://doi.org/10.1017/S1743921321000843 Published online by Cambridge University Press

https://doi.org/10.1017/S1743921321000843 Published online by Cambridge University Press

Education and Heritage in the era of Big Data in Astronomy
Proceedings IAU Symposium No. 367, 2020
R. M. Ros, B. Garcia, S. R. Gullberg, J. Moldon & P. Rojo, eds.
doi:

Introduction

Session 2 was for "Citizen Science and Solar Eclipses" and the section of the Proceedings opens accordingly with "Preliminary Report on the 14 December 2020 Total Solar Eclipse Observations," a paper by Jay Pasachoff that was presented at a public talk during the symposium. The symposium was timed to coincide with this solar eclipse to include an excursion for viewing. This unfortunately did not happen due to the global Covid-19 pandemic. Jay and his research team were able to secure permission to enter Chile and traveled to Temuco for their observations in study of the solar corona. Jay outlines their research objectives and comparisons of predictions and observations were posted by NASA's Goddard Space Flight Center. Regrettably clouds obscured the viewing of totality from many locations.

After the presentation Margarita Metaxa asked:

What is the difference between the inner and outer corona?

and Jay answered:

In the lower solar corona, there are helmet streamers. They consist of closed magnetic loop-like arcades connecting to the solar surface. Farther out in the solar corona, the streamers extend to a radial stalk connecting to the out-flowing solar wind. These structures, with photospheric light scattered off coronal electrons, are part of the K-corona (kontinuierlich-corona); they have polarization and no absorption lines. Even farther out is the F-corona (Fraunhofer corona). with photospheric light scattered by dust largely near the orbit of Mercury. The F-corona shows absorption lines and is basically unpolarized. The standard "separation of the F- and K-coronas" uses the depth of Fraunhofer lines or the percentage of continuum polarization.

Nestor Camino asked:

In the eclipse of 2020, will any group reproduce Edington's experience?

Jay replied:

No group carried out the Eddington experiment-to test Einstein's general theory of relativity by detecting displacement of star images near the eclipsed Sun-at the 2020 eclipse, but there is already at least one group preparing such measurements for 2024. The Eddington experiment, once a professional type of observation but now able to be performed by advanced amateur astronomers, was carried out most recently at the 2017 eclipse in the United States.

The following article is one by Alcides Ortega and Nelson Falcón that is called "Astronomical Society of the University of Carabobo: Scientific enculturation agent in Valencia City (Venezuela)." Alcides give a great overview of the Astronomical Society of the University of Carabobo (SAUC) and the value it has added by motivating cultural appropriation and scientific enculturation while embracing aspects of diversity. The many activities and goals of SAUC are described and the description highlights the motivating power of astronomy to the public.

© The Author(s), 2021. Published by Cambridge University Press on behalf of International Astronomical Union

https://doi.org/10.1017/S1743921321000843 Published online by Cambridge University Press

The next article is one by Emmanuel Rollinde called "Modeling astronomy education, the case of F-HOU tools: SalsaJ and Human Orrery." Here the author introduces these two means of using astronomy to motivate interdisciplinary science education. Such A Lovely Software for Astronomy in Java (SalsaJ) is software that allows students to replicate data analysis made by astronomers and the author gives good example of its use and value. Next, he shows the effectiveness of using a "human Orrery" that lets students enact planetary movements as a group in a manner that helps them experience the proper relative speeds.

Following the talk Breezy Ocana Flaquer asked:

You showed the students can calculate the velocity of the stars in the center of the milky way, for that do you need to download some data, i assume, if so, from where?

and Emmanuel replied:

The data are the images of the stars around the center of the galaxy. Students have to pick up one of the stars that makes a full loop (this is the tricky part...). Then they plot the location of this star and recover the ellipse. They do not calculate the velocity of the star. Data are available on the GHOU web site handsonuniverse.org/france (it is under construction and should be ready early 2021...) but you may send us a mail if you need data soon...

Next, Cynthia Quinteros said:

May I ask you the link to the publication on the use of SalsaJ? Is there, by any chance, any partial reproduction of that work in English? Many thanks in advance!

and Emmanuel responded with:

SalsaJ publication : https://arxiv.org/pdf/1202.2764.pdf in French : https://hal.archives-ouvertes.fr/hal-02303711/document the francophone conference : https://astroedu-fr.sciencesconf.org/

The final article presented with "Citizen Science and Solar Eclipses" is "A dialogue between Vygotsky's learning theory and peer instruction in astronomy classes," written by Jamili De Paula, Denise Ferraz, and Newton Figueiredo. The authors discuss what was learned from the analysis of polls about peer instruction following a 2018 Brazilian undergraduate astronomy course regarding astrometry and celestial mechanics. The peer instruction methodology used was explained and the questionnaire/polls were described. The authors conclude by highlighting the observed value that was added to the learning of the students using this method of instruction.

After the talk Rade Marjanović asked:

In your opinion is it possible to use the peer instruction method in senior years of elementary school, in particular in classes of physics (with a dash of astronomy, since I am astronomer ?

and Newton answered:

Yes, it is possible and some of my students are actually doing that with very good results.

As evidenced by these opening-day articles presented in the proceedings, IAUS 367 Education and Heritage in the Era of Big Data in Astronomy was off to a great start.

https://doi.org/10.1017/S1743921321000843 Published online by Cambridge University Press

Education and Heritage in the era of Big Data in Astronomy
Proceedings IAU Symposium No. 367, 2020
R. M. Ros, B. Garcia, S. R. Gullberg, J. Moldon & P. Rojo, eds.
doi:10.1017/S1743921321000843

Preliminary Report on the 14 December 2020 Total Solar Eclipse Observations

Jay M. Pasachoff

Williams College–Hopkins Observatory, Williamstown, MA 01267, USA
Chair, International Astronomical Union Working Group on Solar Eclipses
email: eclipse@williams.edu

Abstract. This paper summarizes preliminary scientific observations from sites in Chile and Argentina from which the totality was observed on 14 December 2020 at the minimum of the solar-activity/sunspot cycle.

Keywords. Sun eclipse

1. Introduction

The prediction of the 14 December 2020 total solar eclipse's path across Patagonia dovetailed nicely with the plans for IAU Symposium 367 in San Carlos de Bariloche, with the participants being bused on eclipse day north for an hour or so to totality. Though the worldwide COVID-19 protocols led to the symposium being changed to virtual, the location where the meeting participants would have gone was near where cleared skies would have led to observational sucess. These included Piedra del Águila, north of the original meeting site at Bariloche.

My team's planning for the years before the eclipse was based on the Atlantic Coast of Argentina, in Las Grutas, but COVID-related travel shutdowns led to the cancellation of many groups' tours and of travel plans even for scientific teams. The presentation of lists of research groups to the Argentinian government some two months before totality did not promptly allow our admission to Argentina, and my own team wound up working through the American Embassy in Chile to get permission to enter. The existence of a major airport, Temuco (ZCO), within totality in Chile was a major advantage to deciding where my scientific team should go. Our main goals were related to the study of the solar corona.

2. Observational Goals

- Study how the magnetic field, changing over the 11-year sunspot cycle, constrains the coronal streamers and polar plumes
- Assess how coronal mass ejections (different at each eclipse) propagates through space, making "space weather" that impinges on Earth
- Measure the intensities and distributions of hot coronal gas at different temperatures (highly ionized iron: Fe XIV, Fe X, new: Ar X=argon^{+9}
- Carry out >1 Hz measurements to assess one of the proposed methods of coronal heating
- Measure velocities of moving gas and changing coronal magnetic field

© The Author(s), 2021. Published by Cambridge University Press on behalf of International Astronomical Union

https://doi.org/10.1017/S1743921321000843 Published online by Cambridge University Press

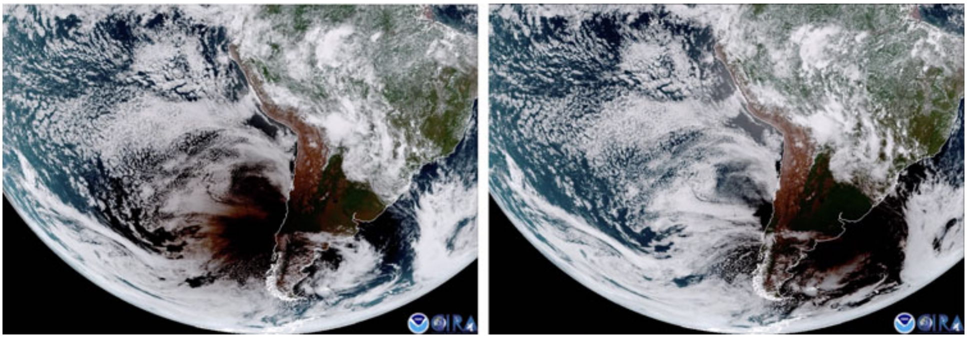

Figure 1. Two GOES-16 Advanced Baseline Imager (ABI) composite images showing the umbra as it approaches and covers part of Chile and Argentina. The Rayleigh-corrected imagery combines the two visible bands (centered at 0.47 and 0.62 μm), along with information from the 'vegetation' band (centered at 0.86 μm). (Tim J. Schmit, NOAA/NESDIS Center for SaTellite Applications and Research (STAR)).

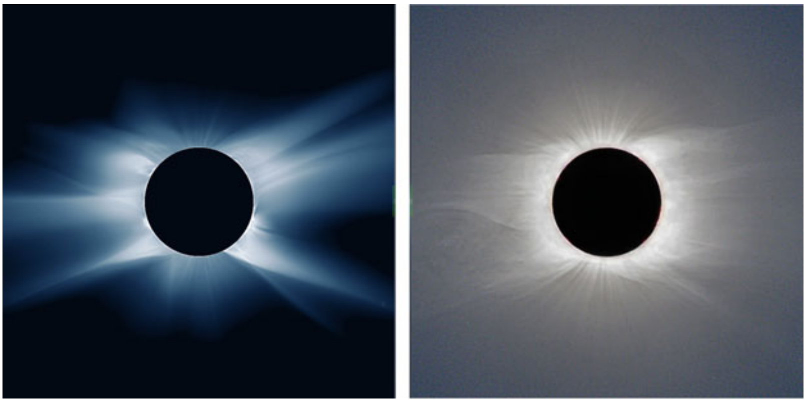

Figure 2. (left) Predictive Science Inc's posted computer model as of days before the eclipse. (right) A composite image based on observations from Andreas Möller of Germany from Piedra del Águila, Argentina, and composited within hours after the eclipse by Wendy Carlos working with me.

• With Marcos Peñaloza-Murillo, again measure the effect of the abrupt extinguishing of solar heating on terrestrial atmospheric temperature and pressure, potentially causing atmospheric gravity waves

3. Contents

As we had done at the preceding eclipses, including 2018 in the United States (Mikić, *et al.* 2018) and 2019 in Chile (Pasachoff, *et al.* 2020), we planned to compare our observations of the coronal streamers and other aspects of coronal configurations with the shapes predicted by a group from Predictive Science Inc of San Diego, California, based on the preceding months' of observations of the photospheric magnetic field with NASA's Solar Dynamics Observatory. Of course, the far side of the Sun hadn't been observed from two to four weeks before totality, so deviations between the predictions and the observations (Fig. 2) could stem from such time delays in magnetic-field measurements in addition to needed improvements in the computer model.

Though most sites in Chile were under clouds, including the one where my team had set up, near Pucón and the Villarrica volcano's ski area, there were a few regions at

https://doi.org/10.1017/S1743921321000843 Published online by Cambridge University Press

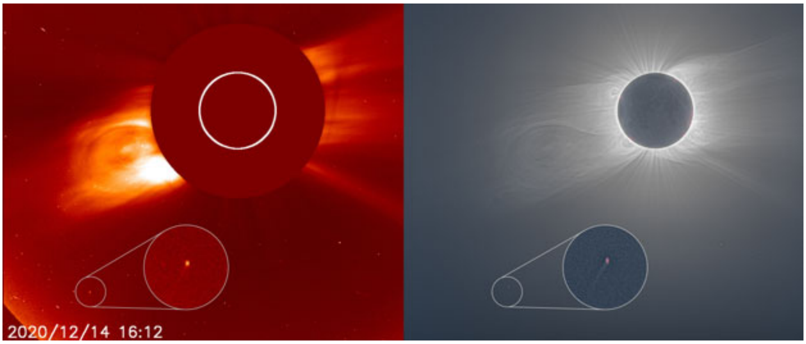

Figure 3. Two comets show on the images made through a hole in the widespread clouds at Piedra del Águila by Andreas Möller, with the composite image made in my collaboration with Vojtech Rušin and Roman Vaňúr of the Slovak Astronomical Institute, Tatranská Lomnica, Slovakia. In the SoHO image, colored red, a white circle shows the actual size of the solar disk, which is hidden behind the NRL C2 coronagraph's occulting disk.

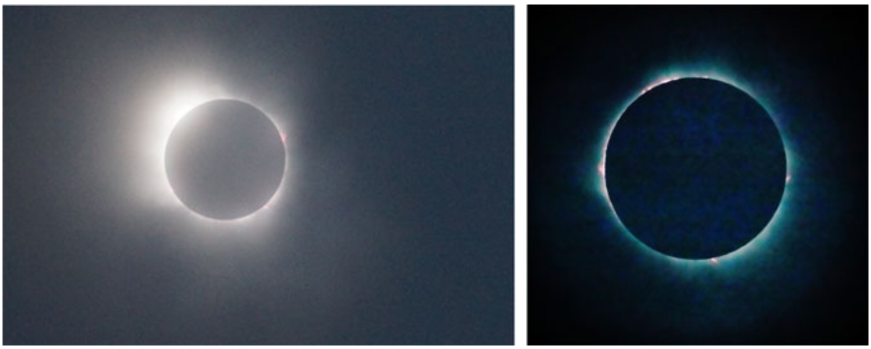

Figure 4. (left) The corona from Gorbea, Chile. (Patricio Rojo, U. Chile, Santiago), (right) Prominences from El Condor near Las Grutas, Argentina (Verónica Espino, Planetario Galileo Galilei, Buenos Aires).

which clouds parted for at least a fraction of totality, including Piedra del Águila, south of the original meeting site at Bariloche and therefore close to where the Symposium participants might have been bused on eclipse day.

Our comparison of the predictions and our observations were posted the next day by NASA's Goddard Space Flight Center: https://www.nasa.gov/feature/goddard/2020/scientists-use-nasa-data-predict-appearance-corona-dec-14-total-solar-eclipse.

A citizen-scientist the day before the eclipse had located a sungrazer comet on an image from the European Space Agency's Solar and Heliospheric Observatory (SoHO); the U.S. Naval Research Laboratory's "C2" coronagraph observed it, and with prodding from me Karl Battams there gave it number SOHO-4108, jumping ahead of a couple of thousand unnumbered SoHO comets. It was reported officially on Minor Planet Electronic Circular 2020-Y19, 2020, COMET C/2020 X3 (SOHO), https://minorplanetcenter.net/mpec/K20/K20Y19.html. We discussed the comet images from SOHO and on a composite of several dozen of Andreas Möller's images from Piedra del Águila made for Vojtech Rušin and me by Roman Vaňúr (Fig. 3). https://www.nasa.gov/feature/goddard/2020/recently-discovered-comet-seen-during-2020-total-solar-eclipse-SOHO

https://doi.org/10.1017/S1743921321000843 Published online by Cambridge University Press

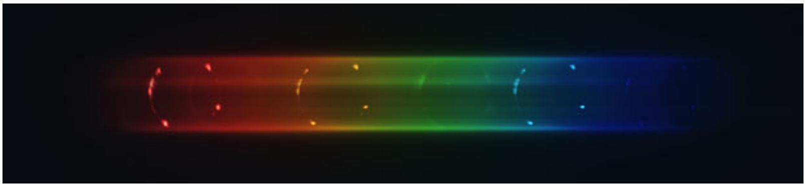

Figure 5. A slitless spectrum, showing coronal lines from highly ionized iron in the red and in the green with brighter chromospheric and prominence lines, including H-alpha in the red and the yellow line from which helium was discovered about 150 years ago. (credit: Diego Guerrero (Córdoba, Argentina) and Robert B. Slobins (flashspectrum.com), Tallahassee, Florida).

Across the band of totality, several other scientists were able to image the corona through clouds. Patricio Rojo of the University of Chile imaged the corona from Gorbea in western Chile (Fig. 4a). Verónica Espino of the Planetario Galileo Galilei imaged the prominences from El Condor near a cloudier Las Grutas from eastern Argentina (Fig. 4b).

Coronal spectra show especially two emission lines in the visible range from highly ionized iron, revealing that the corona is millions of kelvins hot. U.S. amateur astronomer Robert Slobins, who has been observing and recording "slitless spectra" –with the narrow band of chromosphere or corona near the limb acting as its own slit– since 1984, coached Córdoba, Argentina, amateur astronomer Diego Guerrero on setting up the equipment and even directed him, 200 km long-distance, from Las Grutas to a favorable location at Ministro Ramos Mexía. The coronal red line from 9-times-ionized iron, barely visible in this reproduction (Fig. 5), should be revealed after calibration to be stronger than the green line from 13-times-ionized iron at this minimum stage of the sunspot cycle.

In spite of the clouds, our meteorological station at Pucón, run there by Michael Roman (U. Leicester, UK) and Theo Boris (Collegiate School, New York City) provided temperature, pressure, wind, and insolation measurements for the eclipse day ± 1. A team including a dozen undergraduates and faculty sponsored by the Montana Space Grant Consortium, led by Jennifer Fowler, launched weather balloons as high as 32 km on eclipse day ± 1 and detected eclipse-driven gravity waves emanating from the path of totality. They flew radiosondes measuring temperature, pressure, relative humidity, and wind speed and direction.

A team led by dual-citizen Demián Gómez of The Ohio State University made ionospheric measurements from Argentina.

Though COVID-related restrictions led to difficulties in location and kept most tourists away from the eclipse path, and kept us from bringing our coronal-oscillation experiment meant to verify specific theories of coronal heating (with institutional restrictions on my own travel and that of my astrophysics-major students as well as that of Michael Person from MIT), enough observations were made to provide scientific advancement as a result of the 14 December total solar eclipse.

4. Acknowledgments

Our expedition to Chile and subsequent data reduction received major support from grant AGS-903500 from the Solar Terrestrial Program, Atmospheric and Geospace Sciences Division, U.S. National Science Foundation. Christian Lockwood (Williams College '20) was supported by a grant from the Sigma Xi Honorary Scientific Society. Predictive Science Inc. was supported by the US Air Force Office of Scientific Research, NASA, and NSF. V. Rušin is supported by the project VEGA 2/0048/20 (Slovak Academy of Sciences).

https://doi.org/10.1017/S1743921321000843 Published online by Cambridge University Press

References

Mikic, Z., Cooper, D., Jon, A. L., Ronald, M. C., Duncan, M., Lisa, U., Pete, R., Roberto, L., Tibor, T., Viacheslav, T., Janvier, W., Miloslav, D., Jay, M. P., & Wendy, C., 2018, "Predicting the Corona for the 21 August 2017 Total Solar Eclipse," *Nature Astronomy* 2, pp. 913–921, https://doi.org/10.1038/s41550-018-0562-5; https://rdcu.be/5iVS

Pasachoff, J.M. et al. 2020, *Early Results from the Solar-Minimum 2019 Total Solar Eclipse*, for IAU Symposium 354, "Solar and Stellar Magnetic Fields: Origins and Manifestations", Copiapo, Chile, July 2019, pp. 3-14 (Cambridge University Press).

Peñaloza-Murillo, M.A. et al. 2020, Air temperature and humidity during the solar eclipses of 26 December 2019 and of 21 June 2020 in Saudi Arabia and in other eclipses with similar environments, in preparation Arxiv, http://arxiv.org/abs/2011.11460

https://doi.org/10.1017/S1743921321000843 Published online by Cambridge University Press