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Preliminary Report on the 14 December 2020 Total Solar Eclipse Observations

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Abstract. I summarize preliminary scientific observations from sites in Chile and Argentina from which the totality was observed on 14 June 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 south 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 holes in the clouds might have led to observational success.

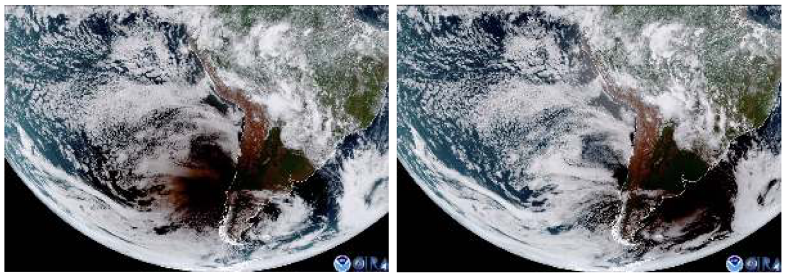

Figure 1. Two GOES-16 Advanced Baseline Imager (ABI) composite images showing the umbra as it approaches and covers part of Chile and Argentina. The Rayleigh-corrected imagery combines the two visible bands (centered at 0.47 and 0.62 μm), along with information from the 'vegetation' band (centered at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

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 (Table 1).

2. Observational Goals (table 1)

• 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

• With Marcos Pealoza-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 2017 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.

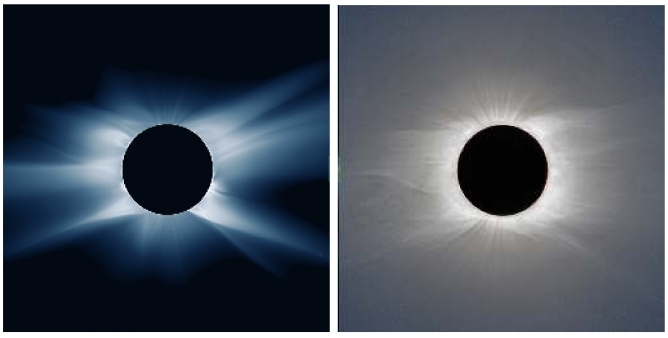

Figure 2. (left) Predictive Science Inc's posted computer model as of days before the eclipse. (right) A composite image based on observations from Andreas Möller of Germany from Piedra del Águila, Argentina, and composited within hours after the eclipse by Wendy Carlos working with me.

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 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`.

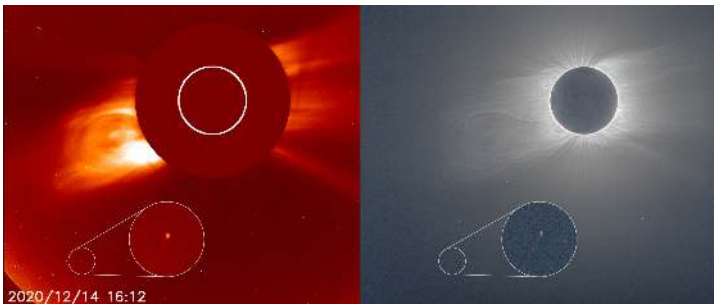

Figure 3. Two comets show on the images made through a hole in the widespread clouds at Piedra del Águila by Andreas Möller, with the composite image made in my collaboration with Vojtech Rušin and Roman Vaňúr of the Slovak Astronomical Institute, Tatranská Lomnica, Slovakia. In the SoHO image, colored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

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`

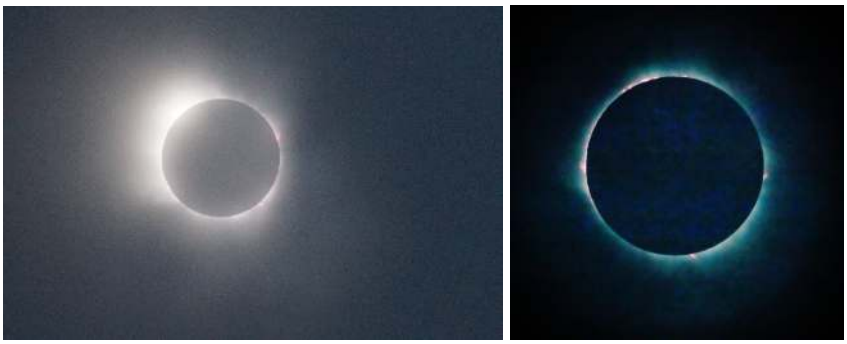

Figure 4. (left) The corona from Gorbea, Chile. (Patricio Rojo, U. Chile, Santiago), (right) Prominences from El Condor near Las Grutas, Argentina (Verónica Espino, Planetario Galileo Galilei, Buenos Aires).

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 from highly ionized iron, which revealed that the corona is millions of kelvins hot. U.S. observer Robert Slobins, who has been observing "slitless spectra"with the narrow band of chromosphere or corona near the limb acting as its own slitcoached Córdoba Observatory astronomer Diego Guerrero on how to set up the equipment and even directed him, 200 km long-distance, from Las

Grutas westward to a favorable low-cloud location at Ministro Ramos Mexa. The coronal red line from 9-times-ionized iron, barely visible, 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.

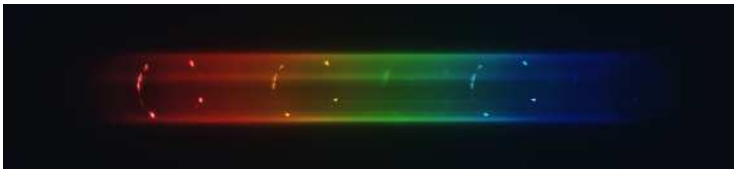

Figure 5. A slitless spectrum, showing coronal lines from highly ionized iron in the red and in the green with brighter chromospheric and prominence lines, including H-alpha in the red and the yellow line from which helium was discovered about 150 years ago. (credit: Diego Guerrero (Córdoba Observatory,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

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

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