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Total Solar Eclipse of 2024 April 8: A Research Expedition to Mexico

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Abstract.

Total solar eclipses provide an opportunity to observe the white-light corona out to several solar radii for a few minutes during totality. In addition to the impressive view, this moment is also ideal for conducting a number of experiments to reveal some still-preserved secrets of the Sun and its connection to our planet. Our team organized a research expedition to observe the latest total solar eclipse on 2024 April 8 in Mexico. In this paper we show our investigation methods and share our preliminary results from the latest research expedition.

Keywords: expedition; eclipse; corona;

Introduction

Total solar eclipses (TSEs) are among the most extraordinary astronomical phenomena observable from Earth, captivating both scientists and the general public alike. This celestial event provides a rare opportunity to study various aspects of solar and terrestrial physics. Historically, total solar eclipses have played a pivotal role in advancing our understanding of the solar corona, the outermost part of solar atmosphere. The fleeting moments of totality, when the bright disk of the Sun is completely covered, allow scientists to observe and analyze the coronal structure and behavior without the overwhelming glare of the solar disk.

On 2024 April 8, a TSE traversed North America, crossing Mexico, the United States, and Canada (Figure 1), granting millions of people the chance to witness one of nature's most spectacular displays. First, it allows for direct observations of the solar corona, providing data on its structure, dynamics, and the processes driving solar wind. Second, the eclipse offers a natural laboratory for studying the effects of sudden changes in solar radiation on the Earth's atmosphere, ionosphere, and even biosphere.

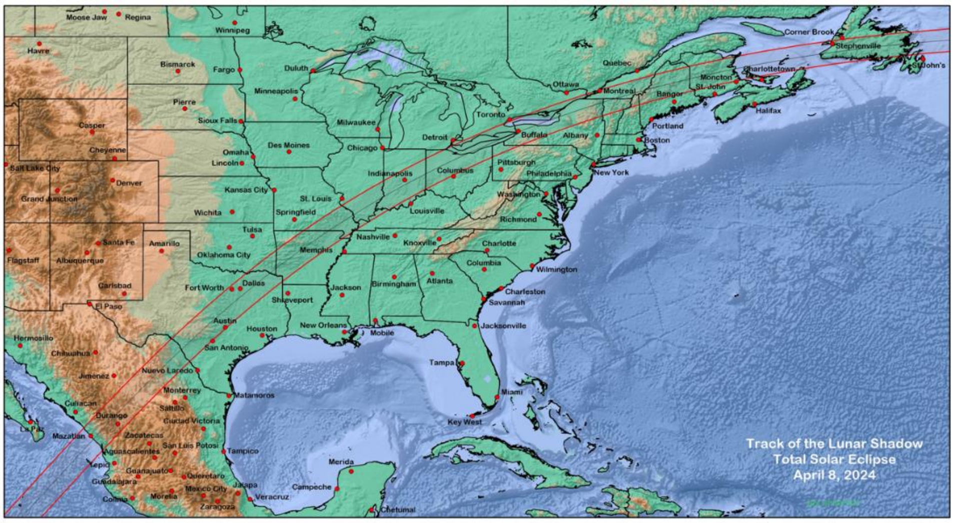


Figure 1. *Topographic map of the track of the eclipse. Source: https://eclipsophile.com/2024tse/*

The maximum duration of the totality was 4 min 28 s (near the Mexican town of Nazas, Durango). Anyway, all preliminary studies regarding the weather conditions confirmed that one of the best places for observations of this eclipse is a bit further from the coast, because of the impact of El Nino on the cloud cover. Using the provided information about the average cloud amount in April along the central axis of the eclipse, our team chose the best observational spot to be located in the surroundings of the town of Monclova (Figure 2).

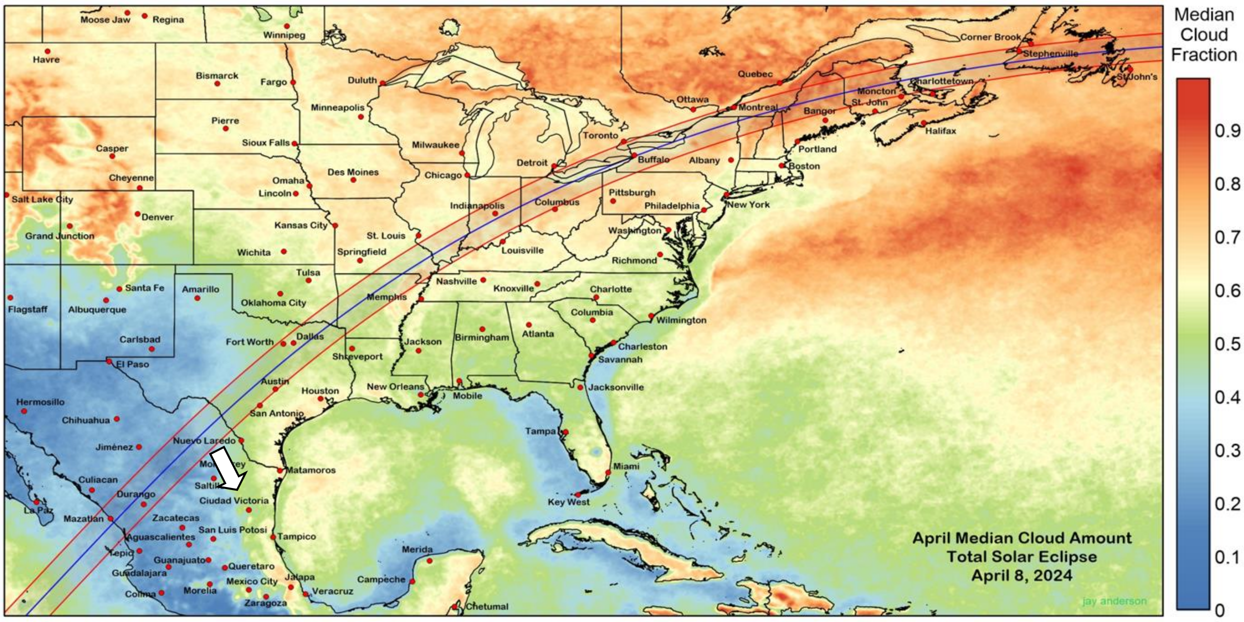


Figure 2. *Average April (2000-2020) cloud cover measured from the Aqua spacecraft (at approximately 13:30 LT). The arrow indicates the approximate position of our team. Data source: NASA. Eclipse track: Fred Espenak (https://eclipsophile.com/2024tse/).*

The chosen spot is outside populated areas, far from city lights and crowds of observers. Its altitude is 650 m. Eclipse details for our location are listed in Table 1.

Table 1. *Eclipse details for the chosen observational area by our team near Monclova (https://www.timeanddate.com/eclipse/solar/2024-april-8).*

Magnitude	Duration [hh:mm:ss]	Duration of the totality [mm:ss]	Maximum [LT]	Sun's altitude at maximum
1.0177	02:41:32	04:08	12:24:59	70°

Experiments

The main task of this research expedition was obtaining a new observational data during the TSE on 2024 April 8 from the territory of Mexico. Unfortunately, the weather conditions prevented the optimal realization of the planned experiments. However, the team's efforts during the TSE were directed to the successful implementation of several main tasks:

2.1. Structure and properties of the white-light solar corona

For this experiment, digital cameras with lenses of different focal lengths were used (Figure 3). Combining different frames taken with different exposures and lenses allows obtaining detailed images revealing the fine structure of the solar corona, both in its inner and outer parts [Espenak, 2000].

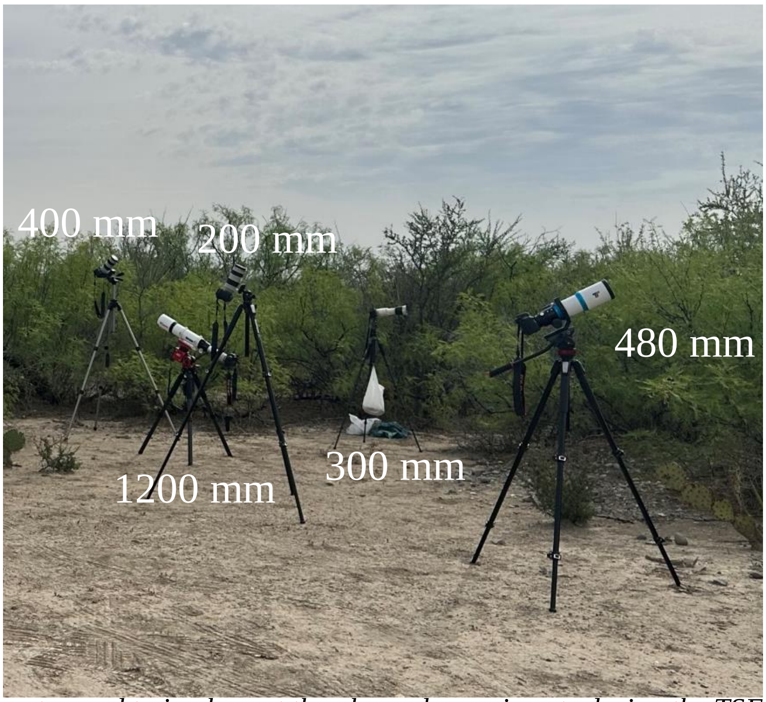


Figure 3. *Instruments, used to implement the planned experiments during the TSE on 2024 April 8 with the focal lengths of different lenses noted.*

Such observations can be used to determine the coronal flattening index (Figure 4) [Ludendorff, 1928] and therefore make a forecast about the maximum monthly sunspot number of the upcoming solar cycle [Pishkalo, 2011]. They can also help to observe the active phenomena in the corona and explore the relations between them. Fiber channels are the places where the quiescent prominences are being formed which we observe on the solar disk as filaments [Martin et al., 1993]. The accompanying coronal structures above them are complicated formations usually located in the base of the coronal streamers. They consist of relatively dark "empty spaces" inside the concentric loop-like structures. The coronal voids are positioned directly over the quiescent prominences and are unstructured and inhomogeneous. Fine, dark fibers are sometimes registered there which can be interpreted as proof of comparatively low-temperature plasma being present.

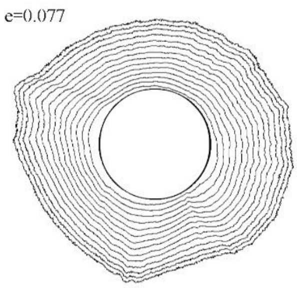


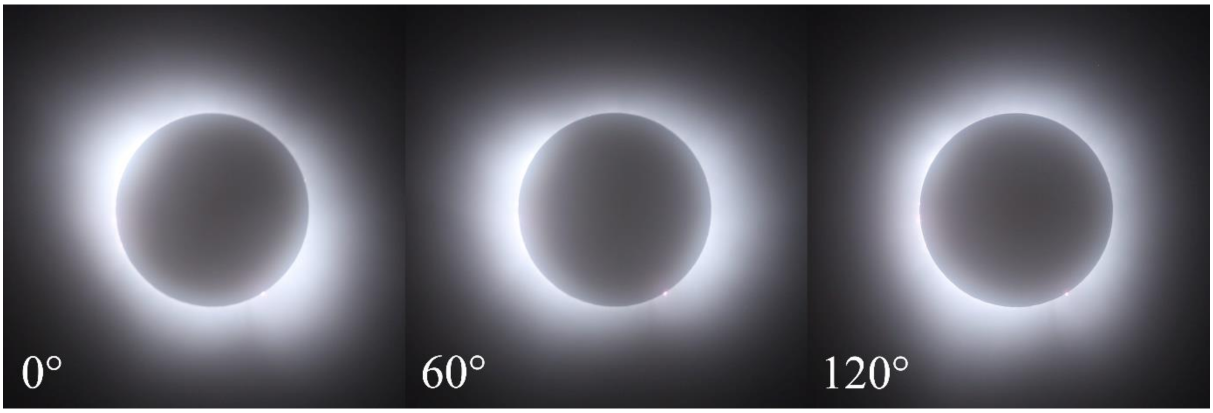
Figure 4. *The flattening of the solar corona and our estimation of the coronal flattening index.*

2.2.Parameters of the polarized solar corona

The intensity of the white-light corona is related to the density of free electrons in it. Polarized-light observations during TSEs hold out possibility for direct definition of the electron density in the corona in order to get a large-scale distribution of the electron concentration. This helps to separate the K and F components of the corona, since at distances less than 3 solar radii from the solar limb, the F-corona (also called dust) is practically unpolarized.

This experiment involved imaging the solar corona with different exposure times with three digital cameras equipped with a polarizing filter – 200, 480, 1200 mm (Figure 3), which allows determination of the degree of polarization in different parts of the corona. The observational data taken with 480 mm lens in 3 positions of the polarizing filter is shown on Figure 5.

Figure 5. *White-light solar corona (from 2024 April 8) captured in three positions of the polarizing*



filter (0º, 60º, 120º) with exposure time 1/5 s and focal length of 480 mm.

2.3. Shadow bands and changes in weather conditions during the eclipse

Noticed for the first time as late as 1820 [Guillermier and Koutchmy, 1999], shadow bands are alternating dark and light streaks that "creep" across the Earth's surface in the seconds before and after the totality. A satisfactory explanation for the observed phenomenon was obtained only at the end of the twentieth century by Codona, who realized that the shadow bands are a consequence of the diffraction of the Sun's rays in the turbulent cells of the atmosphere [Codona, 1986]. However, the influence of the ground atmospheric layer and the meteorological conditions during the observation on the pattern of the shadow bands remains not fully understood to this day.

A Sony Alpha 7 digital video camera and a screen were used to capture and determine the speed and direction of the shadow bands before and after the totality. Along with the video recording, we tracked the change of some basic meteorological parameters such as air temperature and humidity, wind speed and direction with a meteorological sensor and an ultrasonic Gill WindSonic anemometer (with a measurement frequency of four times per second), respectively, which are provided in advance. The purpose of the coordinated measurements is to test our hypothesis about the influence of near-surface atmospheric conditions in the patter of the observed shadow bands.

Conclusions

The expedition to observe the total solar eclipse on 2024 April 8 aimed to capture detailed observations of the solar corona, shadow bands and collect data on atmospheric changes during the rare astronomical event. Unfortunately, despite meticulous planning and the selection of an optimal observation site, the expedition faced significant challenges due to unforeseen poor weather conditions, which ultimately hindered the observations of the eclipse.

We successfully obtained white-light observations of the solar corona despite the thin cloud cover during the totality and recorded the meteorological parameters during the eclipse, but the weather conditions made our task of registering the shadow bands impossible.

While the scientific goals of capturing high-resolution images and comprehensive data sets were only partially achieved, the expedition provided important lessons for future eclipse observations. The experience underscored the importance of flexibility and adaptability in scientific endeavors. The data collected still contributed valuable information that will be useful for ongoing research.

The expedition and the accompanying studies and presentations successfully engaged with different social groups and educational institutions, fostering a greater public interest in astronomy and science. Outreach activities, including educational talks and interactive sessions, were well-received and demonstrated the power of celestial events to inspire curiosity and learning.

In conclusion, while the primary scientific objectives of the total solar eclipse observation expedition were not fully realized due to poor weather conditions, the experience provided significant insights and highlighted the need for enhanced planning and adaptability in field research. The lessons learned from this expedition will inform and improve the strategies for future eclipse observations, ensuring that the scientific community can better navigate and mitigate the unpredictable challenges posed by natural events.

Acknowledgment

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References

Codona, J. L. (1986). The scintillation theory of eclipse shadow bands, A&A, Vol. 164(2), pp. 415–427.

Espenak, F. (2000). Digital Compositing Techniques for Coronal Imaging (Invited review), Last Total Solar Eclipse of the Millennium, ASP Conference Series, Vol. 205. Edited by W. Livingston and A. Özgüç. ISBN: 1-58381-032-3 (2000), p. 101.

Guillermier, P., Koutchmy, S. (1999). Total Eclipses: Science, Observations, Myths and Legends, Springer Publishing, p. 151.

Ludendorff, H. (1928). Sittungsberichte Preuss. Akad. Wiss., Phys.-Math. IClasse Vol. 16, p. 185.

Martin, S. F., Bilimora, R. and Tracadas, P. W. (1993). Magnetic Field Configurations Basic to Filament Channels and Filaments, Bulletin of the American Astronomical Society, Vol. 25, p. 1217.

Pishkalo, M. (2011)., Flattening Index of the Solar Corona and the Solar Cycle, Sol. Phys., Vol. 270, p. 347.