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Imaging and Spectra of the Chromosphere and Corona at the 2013 Total Eclipse in Gabon

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Introduction

The expedition organized by Williams College observed the white-light corona and the coronal spectrum during the total solar eclipse on November 3, 2013, from the national park La Lopé, central Gabon, Africa. These observations fell during the second peak of solar maximum of Cycle 24.

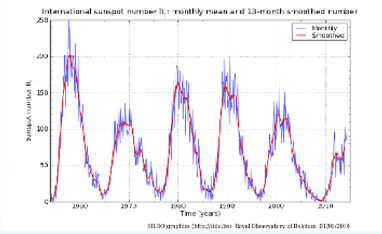


Fig. 1. Sunspot number over the last several solar cycles, showing the extended period of reduced activity preceding Cycle 24. Courtesy of Royal Obs. Belgium.

The unusual behavior of this solar cycle is well-known among solar astronomers, but its cause remains mysterious. An extended period of low activity preceded the onset of the Cycle 24 solar maximum, which when combined with other evidence (e.g., that of Altrock 2011 and Penn & Livingston 2011) may suggest that Cycle 25 may have an extremely reduced solar maximum. Our observations of this eclipse aim to study the solar maximum corona at this peculiar time in the Sun's activity cycle.

The path of totality first made landfall in Gabon; the duration of totality at our site was 59 seconds. Observations were made from the villages Mkongo I and II with a variety of Nikon and Canon DSLRs, and with a custom-built slitless spectrograph. Individual images from multiple cameras were combined to allow the inner, middle, and outer corona to appear together in a single composite image, despite the white-light corona's extreme dynamic range.

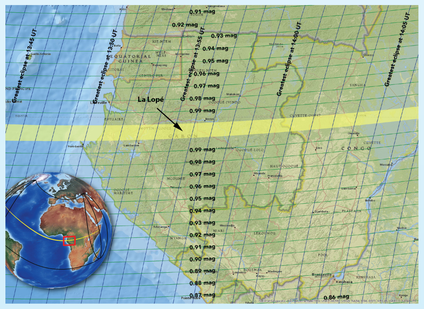


Fig. 2. Path of totality, with our observation sites indicated. Courtesy of Michael Zeiler.

Coronal Features

Although this secondary maximum was (in terms of Wolf's number) rather low when compared with preceding cycles, the while-light corona exhibited an almost typical maximum type, with flattening index amounting to only 0.01. Even a passing look at the processed images indicates that the fine structure of the white-light corona is rather intricate as a result of the complexity of its underlying magnetic fields. One clearly sees a prevailing number of plumes, both straight and curved, whose bases near the solar limb are not big enough when compared with those of typical helmet-streamers. As the latter are usually located above the neutral line of large-scale magnetic fields, from our observed set this criterion seems to be met just by one helmet steamer/plume, that located at the southern hemisphere. Its base region, located at PA 138–173°, features a small prominence, a coronal void and a set of concentric dark and light arcs; the width of the base falls well within the observed span summarized in a recent work of Rušin et al. (2013). Another readily discernible group of features is a triple of dark voids, located close to the limb at PA 45–50°, PA 87–91°, and PA 219–322°.

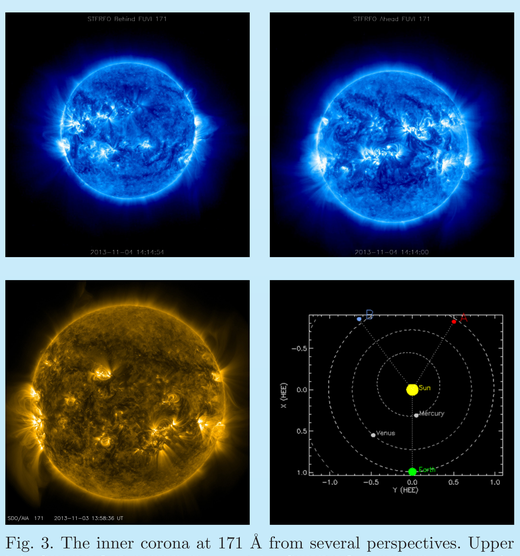


Fig. 3. The inner corona at 171 Å from several perspectives. Upper left: STEREO-B/EUVI. Upper right: STEREO-A/EUVI. Lower left: SDO/AIA. Lower right: the relative positions of the three spacecraft, with SDO in Earth orbit.

Spectrum

A slitless flash spectrum reveals the spectral features of the chromosphere (the Balmer and helium lines) and corona (the forbidden iron lines). The spectrum clearly shows that the coronal green line is brighter than the coronal red line, indicating the relatively high temperature of the corona over the solar cycle. We intend to carry out analysis for the 2012 and 2013 eclipse similar to those for the 2010 eclipse described in Voulgaris et al. (2012).

Abstract

We successfully observed the 3 November 2013 eclipse's 59 s of totality in clear sky from the centerline of totality where it exited La Lopé National Park in Gabon, close to the maximum totality available on land. Our wide-field imaging showed two CMEs and an erupting prominence. We compare our images with those obtained elsewhere in totality to assess motion and dynamics. Our imaging observations are also compared with near-simultaneous observations from SDO/AIA, SDO/HMI, Hinode/XRT, SOHO/LASCO, SOHO/EIT, PROBA2/SWAP, and STEREO/SECCHI. We also have spectra with chromospheric and coronal emission lines, which continue to show overall warming of the corona in 2012 and 2013 through studies we have made over the solar cycle that include the ratio of intensities of the coronal red (Fe X 637.4 nm) and green (Fe XIV 530.3 nm) forbidden lines.

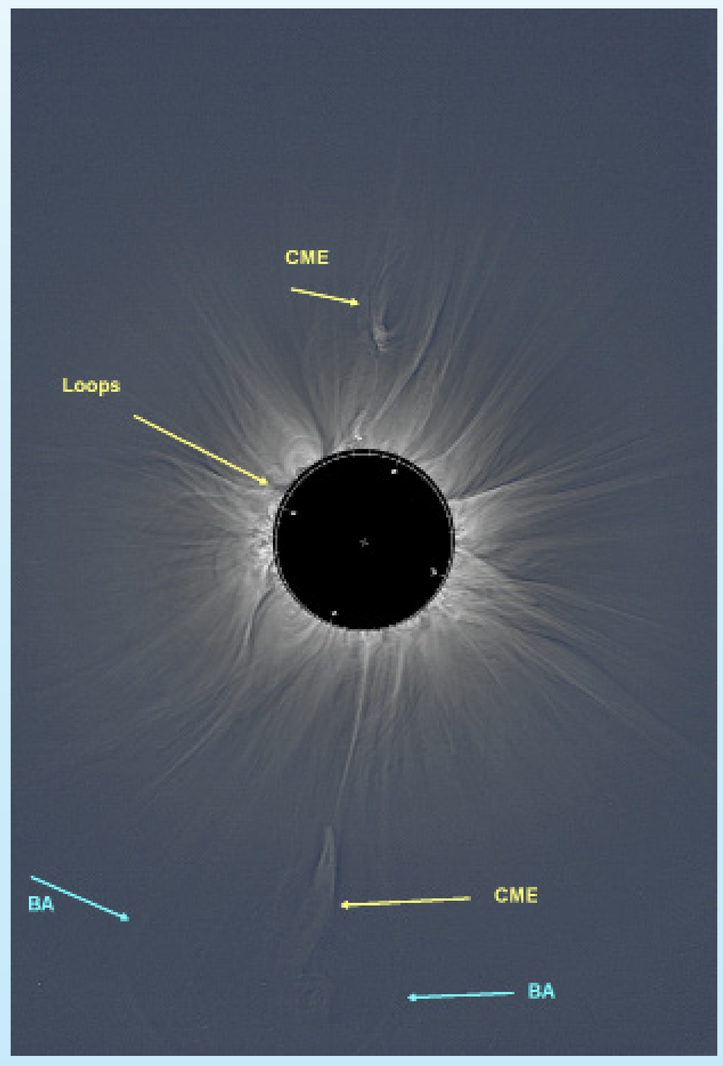
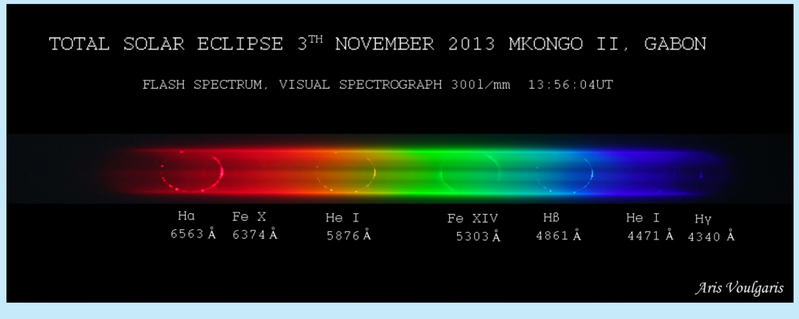


Fig. 4 (above). Composite image created by Miloslav Druckmüller from hundreds of individual images and calibration frames from three cameras: Nikon D3X, Nikon D90, and Canon EOS 70D. CME: coronal mass ejection. BA: bright arcade. The labeled features are discussed in the text.

Fig. 5 (below). Flash spectrum obtained during totality by Aristeidis Voulgaris. Emission lines are indicated. Of particular interest are the Fe X 6374 Å and Fe XIV 5303 Å lines (the coronal "red line" and "green line," respectively).



Coronal Activity

Two coronal mass ejections (CMEs) are visible, both apparently located outside active regions. The first one is located at PA 19°, at a height of about 2.70 $R_\odot$ (its lowest bright edge seen at 2.18 $R_\odot$). This CME was likely connected with an eruptive prominence whose one leg was rooted at PA 30° and which showed some dynamics at 1.20 $R_\odot$ above the solar limb. The projected speed of this CME as derived from SOHO/LASCO 2 observations is estimated to be 140 km/s (at 23:54 UT it was observed with LASCO 3 at the height of around 11 $R_\odot$).

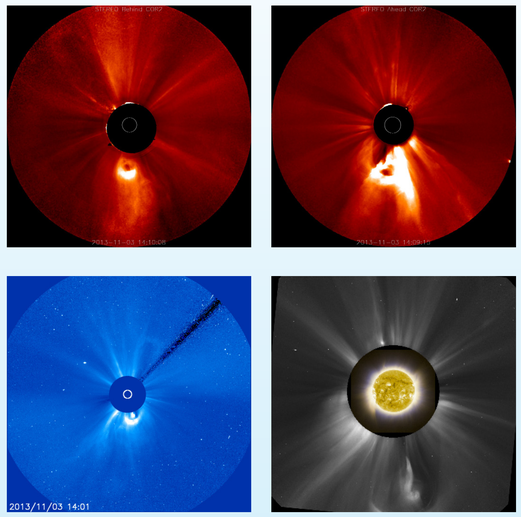


Fig. 6. Spacecraft images coinciding with totality at La Lopé. Upper left: STEREO-B/SECCHI. Upper right: STEREO-A/SECCHI. Lower left: SOHO/LASCO 3. Lower right: composite of PROBA2/SWAP (in EUV) in the center, a white-light eclipse image around it, and SOHO/LASCO 2 providing the outermost image.

The other CME, whose center was located at PA 196°, was of a prolonged shape extending from 2.27 $R_\odot$ to 5.45 $R_\odot$. This CME could well be linked with a plume whose base was located at PA 205° and which featured a bright emanation towards the CME. The projected speed of this CME, as derived from SOHO/LASCO 2 between 13:56 and 15:00 observations, is estimated to be around 175 km/s (for the brightest part of the CME). This southern CME is also surrounded by a bright arcade whose legs are most likely rooted at PA 185° and PA 240°. As the time difference between our observations and those carried out by Constantinos Emmanoulidis at the site in Lambarene (Druckmüller, private communication) was rather small, comparing images from the two sites shows no change in the shape of the two CMEs or in the arcade. However, SOHO-derived projected radial speed for this arcade between 08:00 and 13:56 was estimated to be around 120 km/s. SOHO/LASCO 3 observations of this complex showed them at 23:54 at a height of 26 $R_\odot$ (the arcade; the prominence part was slowly lower – at 18 $R_\odot$). We will soon make comparisons with East African sites' results.

Finally, we mention a pair of loops interconnecting two active regions on both hemispheres. Their feet are rooted at PA 75° (northern hemisphere) and PA 104° (southern one). These loops were also observed in EUV by SOHO and SDO during this eclipse. A role of the transequatorial loops (TELs) could play a very important role for three major solar phenomena: dynamo, reconnection, and eruption as discussed by Pevtsov (2004). Some other statistical TELs properties have been discussed by Chen et al. (2007).

Acknowledgments

We thank Xavier Jubier for creating and maintaining the software, *Solar Eclipse Maestro*, that was used to operate several of our cameras. We also thank Miloslav Druckmüller for his hard work in creating the composite image seen here.

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