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Properties of Solar Activity Phenomena Detected during 2020 December 14 Total Solar Eclipse

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Abstract

During the total solar eclipse on 2020 December 14 a coronal mass ejection has been detected above a prominence on the eastern solar limb. Two active regions at the base and a streamer higher in the corona completed the diversity of activity phenomena on the Sun at that time.

Unfortunately, the expedition that our team planned to Argentina to observe the total solar eclipse failed and we had to use SDO/AIA and SOHO/LASCO data to analyze the parameters of the observed processes and trace the connection between the various manifestations of solar activity.

Introduction

Even in present days the total solar eclipses (TSEs) are still a significant opportunity for detailed explorations of solar corona and the dynamic events taking place in it, because of the ability they provide to capture the different parts of the corona simultaneously. The latest total eclipse was observed on 2020 December 14 from territories in South America. Our team planned an expedition to Argentina [*Tsvetkov et al.*, 2020] that was cancelled because of the international travel restrictions. Nevertheless, the eclipse that happened in a moment of a relatively active Sun, offered a rare opportunity to observe a coronal mass ejection (CME) during the totality.

CMEs originate in regions with closed magnetic field in the lower corona and erupt into the open-field regions of interplanetary space. Both space- and ground-based coronagraphs have been contributing to the study of CMEs with their continuous height coverage. Still they cannot effectively cover the distance range of 1.3 to 2.2 solar radii [*Boe et al.*, 2021] and 74% of CMEs undergo most dramatic acceleration below 1.5 solar radii [*Bein et al.*, 2011].

Other observers successfully captured the phenomenon [*Abramson*, 2021; *Boe et al.*, 2021]. Similar observations are also reported during previous eclipses [*Druckmüller et al.*, 2017; *Filippov et al.*, 2020; *Hanaoka et al.*, 2014; *Koutchmy et al.*, 2002].

Although we could not collect our own data, we use space-based observations from the day of the TSE to investigate the solar activity on the SE solar limb, partially or fully linked with the registered CME, in order to expand our knowledge about the relations between different active processes in the corona.

Space-based observations

The observations of space-based telescopes, shown on Figure 1, reveal part of the detected solar activity phenomena during the eclipse. Taken at 17:30 UT before the end of the full eclipse, the data from SOHO coronagraphs capture a "double-bubble" CME [*Boe et al.*, 2021], while AIA/SDO 304 Å observations demonstrate two active regions (ARs) and one of the two prominences on the south-eastern (SE) limb.

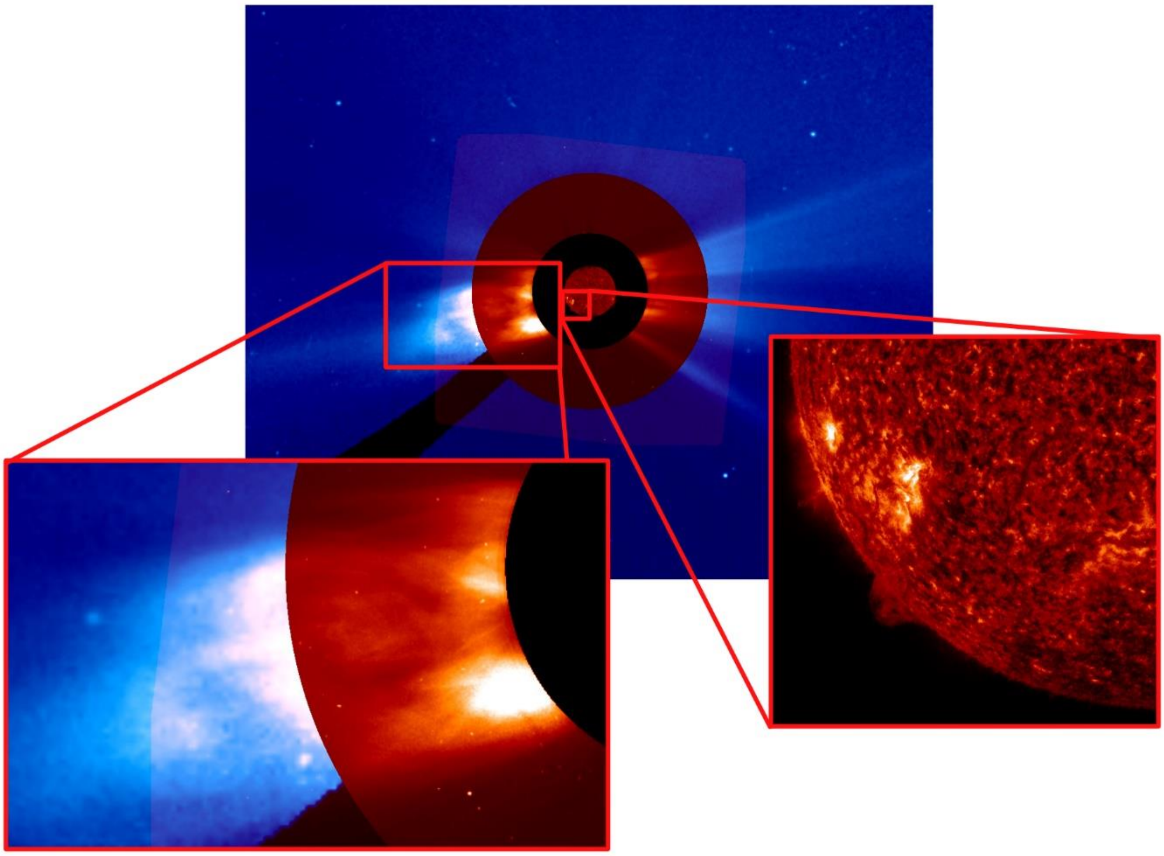


Fig. 1. Combined observations of LASCO/SOHO coronagraphs C2 and C3 with AIA/SDO 304 Å during the total solar eclipse (2020-12-14 17:30 UT).

Properties of the detected solar activity phenomena

a) Timeline of the events

The solar activity included in the current study covers only the phenomena registered at the SE quarter of the Sun on the day of the TSE – between 00:00 and 23:59 UT on 2020 December 14. The timing of the explored events is summarized on Figure 2. The base of the timeline is divided into two-hour intervals, its upper half shows the moments of onset of the eruptive events, while the length of the bars in the lower half demonstrate the duration of each phenomenon.

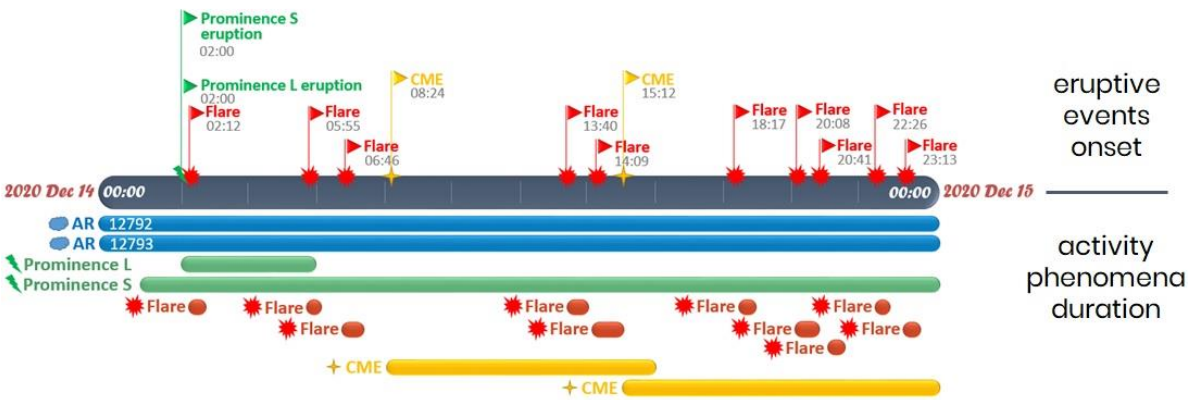


Fig. 2. Timeline of the events observed at the day of the TSE connected with the activity at the SE part of the Sun.

b) Active regions

Two ARs visible on the HMI/SDO magnetograms take place near the SE limb (Figure 3). The AR 12792 is better developed in the day of the TSE and it is the one clearly connected with the observed spectacular CME (hereby stated as CME2).

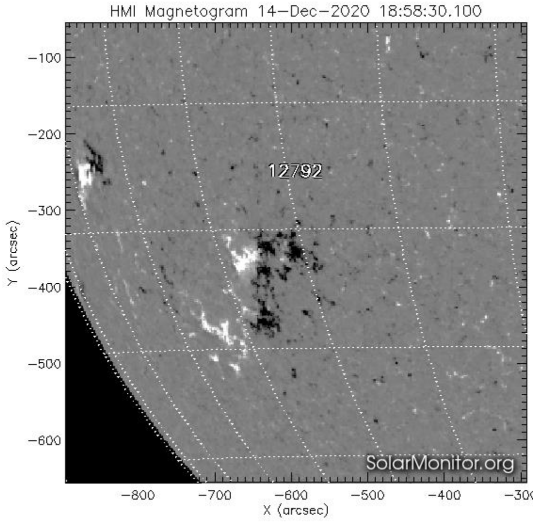


Fig.3. HMI/SDO magnetograms on the day of the eclipse showing the two ARs 12792 and 12793.

Information about the days of emergence, disappearance of the ARs and their properties in the day of the eclipse is presented in Table 1.

Table 1. Details for the two observed ARs according to the NOAA Space Weather Prediction Center.

NOAA	12792	12793
Emergence	13/12/2020	14/12/2020*
Disappearance	25/12/2020	27/12/2020
Position**	S22E52	S16E??
Hale Class**	Beta	Alpha
No. of sunspots**	4	-

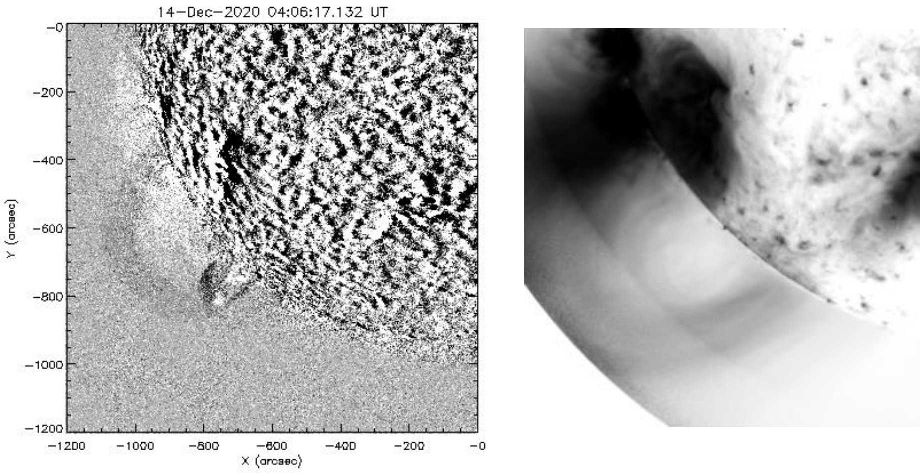
**AR12793 is visible on the magnetograms from Dec 14, but receives officially NOAA No. the next day.*
***On the day of the eclipse (the information about AR12793 latitude is not given for that day).*

c) Prominences and their environment

Two prominences are visible on the SE limb on the day of the eclipse (Figure 4a). The first one (conditionally called "small") emerged before midnight on 2020 Dec 14 and remained a stable inhomogeneous structure even after the eclipse except for the time slot 2:00-9:00 when it erupted.

The other one ("large" prominence) appeared with its symmetric and less dense body, which made it difficult to observe to erupt at about 2:00 reaching higher altitudes (h_{max}) despite the relatively similar developed velocities (v_{max} & v_{avg}).

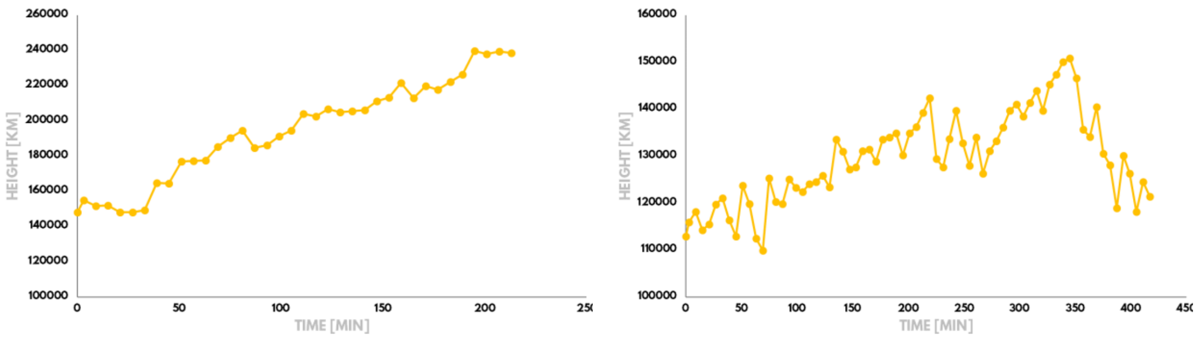
We tracked the position of the highest point of every prominence to build the height-time profiles of the two eruptions (Figure 5). The eruption of the large prominence is shorter and



(a) (b)

Fig.4. AIA/SDO 304 Å image difference reveals the structure of the two prominences (a) while their environment is better displayed on AIA/SDO 211 Å data (b).

does not go through an activation phase. As soon as the prominence becomes visible in AIA 304 Å field of view, it starts rising, reaching almost 240 000 km for less than 3 hours while the smaller prominence reaches 150 000 km for more than 5.5 hours, but finally the eruption turns out to be confined and the prominence material starts falling back down to the Sun. More details are presented in Table 2.



(a) (b)

Fig.5. Height-time profiles of the eruptions of the large prominence (a) and the small prominence (b).

Table 2. Properties of the explored prominences.

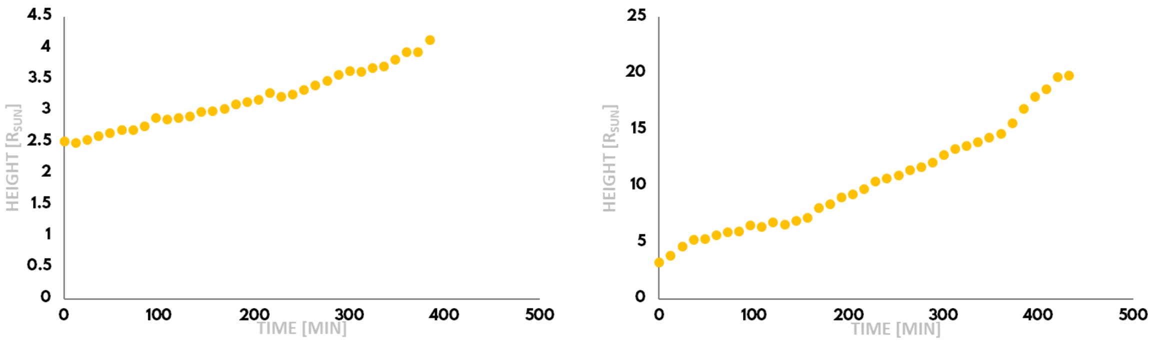
	Large	Small
Visibility [UT]	02-06	00-24
Eruption [UT]	02-06	02-09
Limb	SE	SE
Symmetry	S	A
h_{max} | h_{avg} [10^3 km]	239.5 | 193.7	150.8 | 129.4
v_{max} | v_{avg} [km s^{-1}]	43.2 | 12.7	42.8 | 11.9

At 6:00 UT on the day of the eclipse, a relatively stable equatorial streamer feature that had persisted for several hours is visible [*Boe et al.*, 2021]. Around 13:30 UT, a slow moving front on the northern part of the streamer (near the equator), continues to propagate for a few hours until it is enveloped by the fast CME seen during the eclipse, starting at 15:12 UT. Given its

location, speed and timing, this feature is likely to be the same, or part of the same overall structure, as a slowly erupting arch of the large prominence visible on the 211 Å data a few hours before (Figure 4b).

e) Coronal mass ejections

The two CMEs observed on 2020 Dec 14 could be linked with the active regions discussed above. The second CME that happens in the afternoon of 2020 December 14 (approximately and hour before the totality) is undoubtedly faster and more powerful (Table 3). It reaches almost 20 solar radii height and develops more than 10 times the speed of CME1 while the first CME doesn't even enter the C3 coronagraph FOV. The CME speeds and heights are in agreement with the evaluations of other authors [*Boe et al.*, 2021].



(a) (b)

Fig.6. Height-time profiles of CME1 (a) and CME2 (b).

Table 3. Temporal, spatial and kinematic properties of the explored CMEs. The information for the onset, position angle, angular width and linear speed is taken from SOHO/LASCO CME Catalog [Yashiro et al., 2004].

	1	2
Time [UT]	08:24:05	15:12:10
Central Position Angle [deg]	121	121
Angular Width [deg]	80	88
v [km s^{-1}]	41	437
h_{max} [R_{sun}]	4.14	19.87
h_{avg} [R_{sun}]	3.19	10.42

d) Flares

The two ARs observed on the SE limb on the day of the eclipse demonstrated relatively high flare-productivity – 10 flares are registered by the GOES soft X-ray flare listings (Table 4). Special attention attracts the C4.0 class flare reported at 14:09 during the activation of CME2. The association obtained by GOES flare listing with AR12792 and the given coordinates (S22E48) coincide with the location and timing of the erupting AR that is also linked with CME2.

Table 4. Characteristics of the flares from the SE quarter of the Sun on the day of the TSE as given by the GOES soft X-ray flare listings.

Start [UT]	Peak [UT]	End [UT]	Class	AR
02:12	02:20	02:26	B1.3	12792
05:55	05:59	06:04	B1.4	12793
06:46	06:57	07:03	B1.1	12792
13:40	13:49	13:59	B1.4	12792
14:09	14:37	14:56	C4.0	12792
18:17	18:24	18:32	B2.2	12793
20:08	20:16	20:38	B2.4	12793
20:41	20:44	20:56	B3.5	12793
22:26	22:33	22:37	B2.0	12793
23:13	23:21	23:30	B1.7	12793

Conclusions

The present study summarizes the data from various sources for solar activity observed on the day of the latter total solar eclipse (2020 December 14) on the southeastern limb. Comparison between the spatial and temporal characteristics of various solar activity events in combination with data from different instruments on different wavelengths shows the relations between the active processes in solar atmosphere.

Our measurements and analyses expand the knowledge for different manifestations of solar activity and the connection between them especially when combined with the data of observers that successfully monitored the corona during the eclipse.

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