Multi-Wavelength Study of an Intense Solar Flare Associated with a Halo CME on 25th February, 2014

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ABSTRACT:

Sun emits electromagnetic radiations ranging from few KHz to gamma during spectacular solar energetic events such as solar flares, coronal mass ejection (CME), prominence eruption, filament eruption etc. It is observed that solar flares are often associated with coronal mass ejections.

There are several ground based as well as space based observatories to monitor solar activity continuously in different wave bands. In our present study we have analyzed a solar event occur on 25th February, 2014 at 00:59 UT in South-West region of the sun, which was characterized as X class flare as observed by GOES X-ray observations. This energetic solar flare was associated with a halo CME as observed by LASCO white light observations. The analysis of the observed flare and CME data reveal that the flare emits strong electromagnetic radiations in different wave bands observed by EIT, TRACE, etc. The white light CME observation shows that the CME was initially accelerated in C_2 field of view and then decelerate, which again accelerate. The analysis of the CME propagation reveal that the CME suffers viscous drag as was driven by the impulsive flare energy in the lower atmosphere of the Sun. The internal magnetic energy stored in the CME as resulted from the shearing of the magnetic loops, which provides the necessary kinetic energy to the CME. As the CME material diffuses in the IP medium CME accelerates. The rate of diffusion is proportional to the acceleration of the CME. The analysis also reveal that the CME reaches the Earth atmosphere on 28th February, 2014 and result a moderate Dst in the Earth atmosphere.

Key words: Solar Flare, CME, Dst, Coronagraph, magnetic loops

1. Introduction:

Sun is our nearest star and several spectacular energetic events such as Solar flare, CME, Prominence eruption etc. occur in the sun. Being a nearest star it is easier to observe the various phenomena occurred on Sun with greater accuracy and distinct observations. Since we are the inhabitant of solar system and life of all the living beings entirely depends on the existence and the activity of the sun, hence it is important to understand the dynamics and the physical processes associated with these energetic events so as to formulate a general understanding of the events occurred in the other stars.

Solar flares and Coronal mass ejections (CMEs) are known to be the two most energetic phenomena that occur in the atmosphere of the Sun, and have profound effects on the physical environment in the geo-space environment and human technological systems. It has been suggested based on observations that, CMEs and flares are the two different phenomena of the same energy release process in the lower corona and upper corona (e.g., Harrison 1995; Zhang et al.2001; Harrison 2003). They do not drive one another but are closely related.

In this present analysis we have studied the multi wavelength study of an intense solar flare, associated with a halo CME occurred on 25th February, 2014 of solar cycle 24. The eruption consisting of a halo CME and an X-4.9 Solar flare that occurred in the active NOAA region AR 1990. Solar flare and Coronal Mass Ejections (CMEs) are prominent signatures of the explosive release of energy stored in the coronal magnetic field. Multi wavelength observations with increasing sensitivity and temporal resolution give a great deal of insight into the physics of solar flares/CMEs. Now it has widely been accepted that the magnetic reconnection is a key process of energy release in the solar atmosphere. It is observed that because of the initiation of the CME, a moderate Geomagnetic Storm G2 was occurred during the event. Intense geomagnetic storms occur when the southward field in the interplanetary CMEs (ICMEs) reconnects with the Earth's magnetic field (Tsurutani et al., 1988; Gonzalez et al., 1994). Intense storms can also occur when the sheath Region between the ICME and the shock has southward component of the magnetic field. It has been found that nearly 90% of intense storms (Dst-100nT) result from Earth-directed halo CMEs (Zhang et al., 2007; Joshi et al., 2011).

2. DATA ANALYSIS

2.1. Observation of Solar flare:

Table 2.1.1. Characteristics of Solar Flare

Date	Time	Class Intensity (watt/m^2)	Associated phenomena	Location
25/02/2014	00:49 UT	X 4.9	1. A Halo CME 2. Type III, II Radio Burst	S12-E82

2.1.1. Goes GOES X-ray flux intensity:

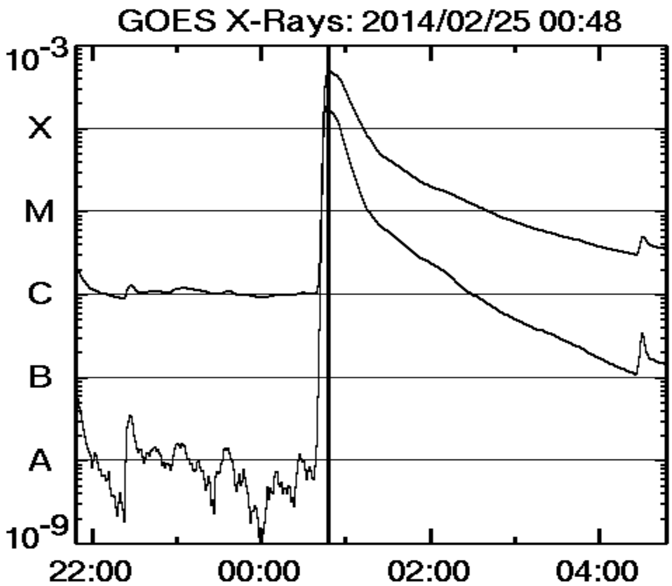

Fig. 2.1: GOES X-ray flux intensity at 1-8 A and 0.5 4 A during the flare on 25th Feb, 2014

The analysis of the X-Ray emission plot of the GOES observation reveals that the emission was peaked at 00.49UT and the impulsive phase is shorter than the decay phase of the solar flare. The longer decay phase indicates the secondary emission of X-Ray.

2.2. X 4.9 Solar Flare observed at different Wave Bands:

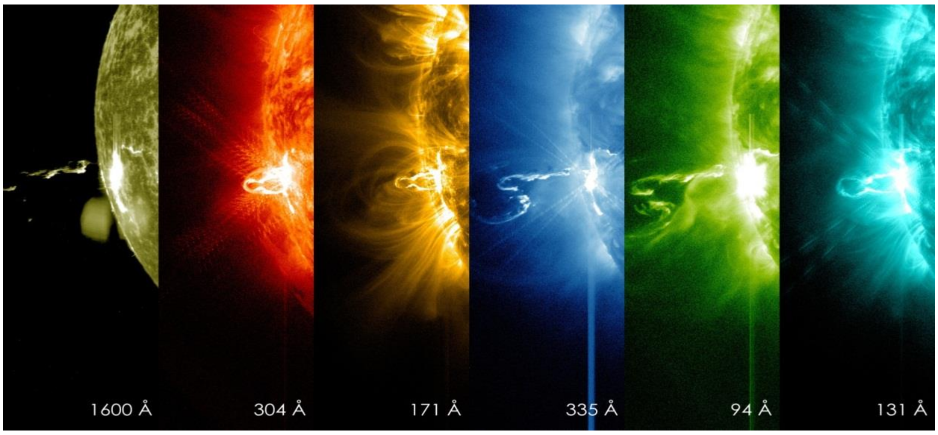

Fig 2.2. X 4.9 solar flare observed at different wavelengths by Solar Dynamic Observatory (SDO).

Figure shows the observations of the solar flare X4.9 at different wavelengths by the Solar Dynamic Observatory (SDO). The first frame of the image was observed at the wavelength 1600Ǎ. This emission shows the emission from the upper photosphere and transition region. Again, second image shows the emission at wavelength 304 Ǎ from the Chromospheric region. Further, third image at 171Ǎ shows the emission from the solar corona. Similarly, fourth image shows hotter, magnetically active regions in the corona. And fifth and sixth images at the wavelength 94Ǎ and 131Ǎ respectively occur from the region of the corona during a solar flare and hottest material in a flare. These images reveal the progression of the solar flare at different height of the Sun and can track the initiation of the associated CME as well as physical behavior of the flaring region.

2.3. Observation of CME:

Table 2.1.2. Characteristics of CME

Date	Time	Central PA (deg)	Angular Width (deg)	Linear Speed (km/s)	Speed at final height (km/s)	Speed at 20 R_S (km/s)	Acceleration (m/s^2)	MPA (deg)
25.2.2014	01:25:50 UT	Halo	360	2147	1809	2069	-158.1	73

2.3.1. SOHO/LASCO White light images of the CME evolution:

Fig 2.3 shows the white light observation of Halo CME on 25th February, 2014 overlaid with SOHO/EIT. The central image is the EIT observation of the solar flare at the wavelength 131Ǎ and the rest of the images are LASCO image of the halo CME. The EIT image shows a bright flare region overlaid by white light image of the CME.

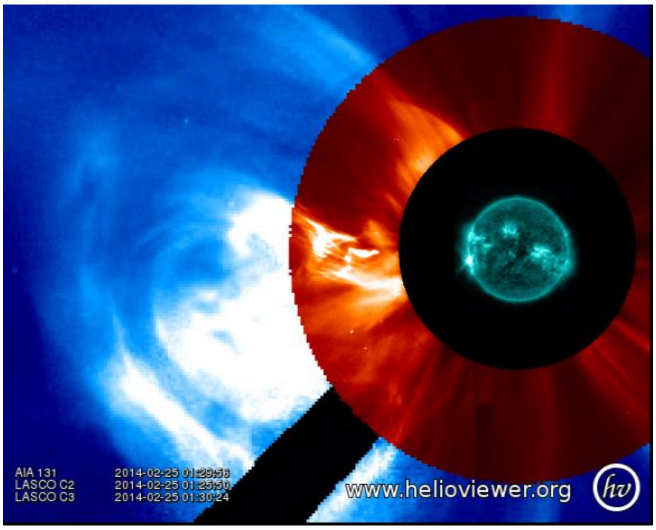

Fig. 2.3: White Light observation of CME overlaid with EIT images of the solar flare on 25th Feb, 2014

SOHO/LASCO white light observation of the Halo CME are well correlated with the SOHO/EIT images during its initiation. The evolution of CME shows the coronal magnetic loops structure. It is evident from the images that the upper Chromospheric evolution of the solar flare is associated with halo CME.

2.3.2. Height-Time plot of a CME:

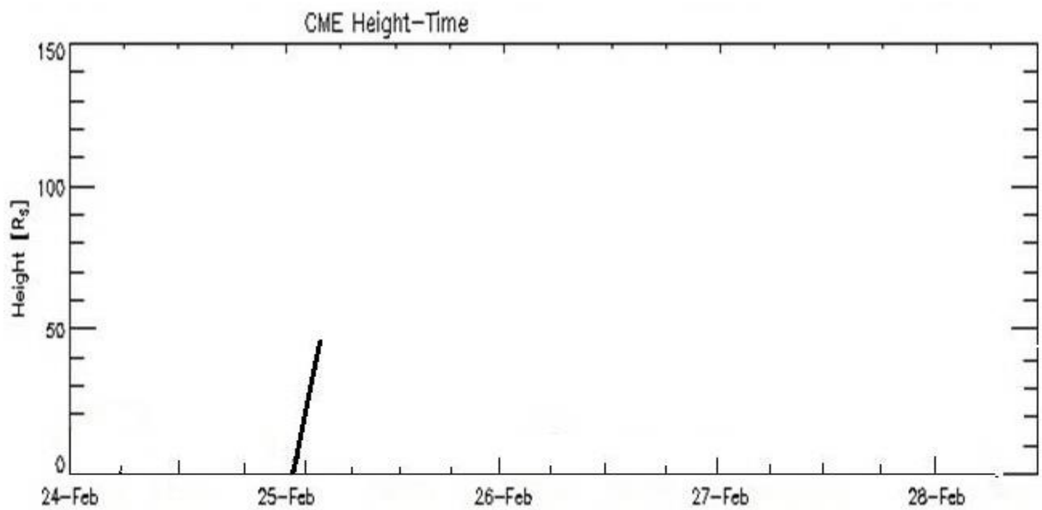

Fig 2.4. Height time plot of the CME shows very high acceleration at the lower corona of the sun.

Fig 2.4 shows the Height-Time plot of the CME. The velocity and acceleration of the CME can easily be derived from the slope of the height time plot of the CME.

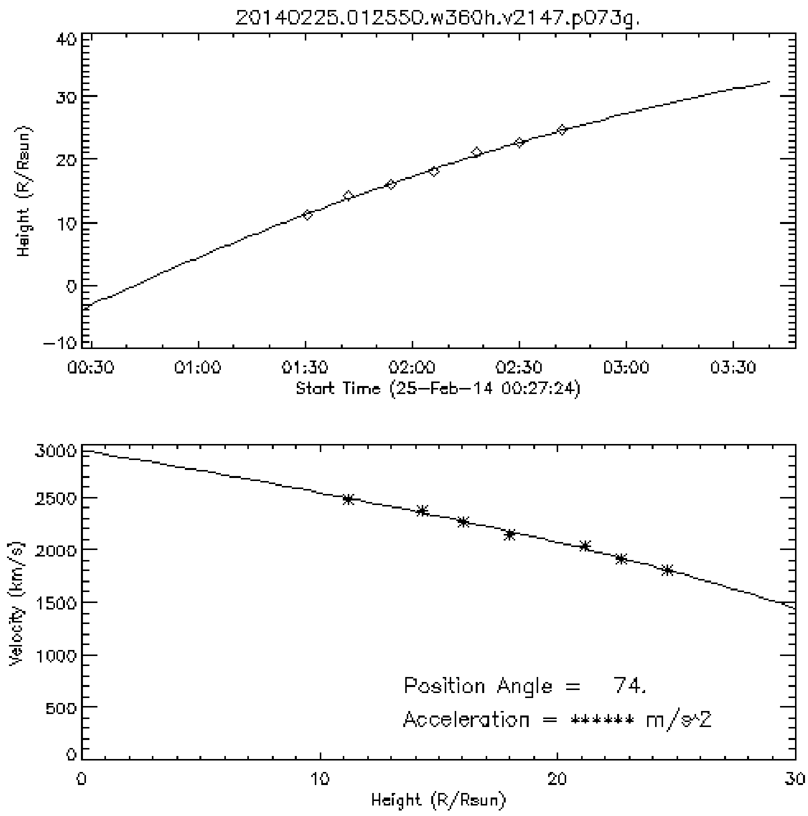

Fig 2.5. Height time plot of the CME at different solar radii(top) and CME velocity with increasing height shows deceleration.

Figure shows that the CME was accelerated with a very high acceleration and after few solar radii the velocity decreases.

2.4. Observation of radio burst during solar flare and CME:

It is often observed that the radio burst are associated with the solar flare and coronal mass ejection, which are used as the precursor of the solar flare and CME. Radio type III burst are emitted during the impulsive phase of the solar flare and interplanetary type II radio burst are associated with the shock produced as a result of the CME propagation. Further, these IP radio burst can also create hazards to the artificial satellite communication as is observed in this analysis.

Table 2.1.3: Associated radio burst

Date	Begin time	Peak time	End time	Peak Flux/Estimated Velocity (km/sec)	Type of radio burst
25/02/2014	00:42 UT	00:45 UT	O1:07 UT	3700 sfu	Type III or 10cm radio burst
	00:45 UT			1972	Type II
	1355 UT			NOAA Scale S-1	HF radio propagation was effected

2.5. Dst resulted for flare Halo CME:

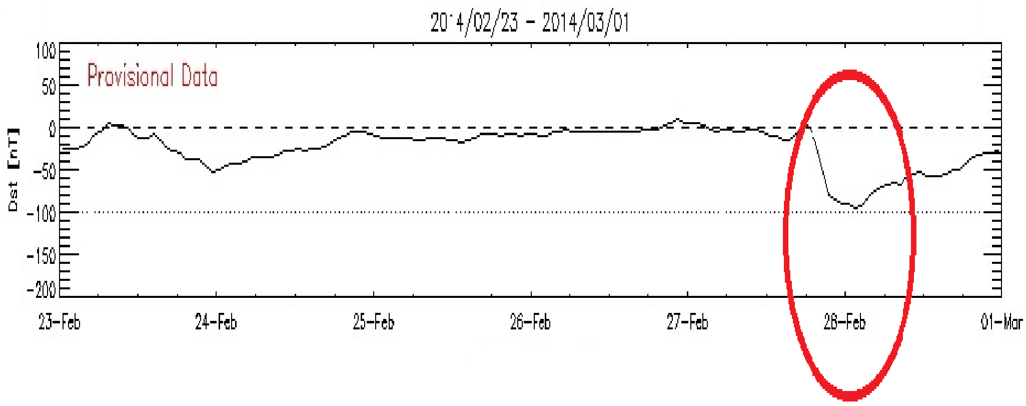

Fig 2.6. In this figure we have seen that there is a DST of around -100nT and occurred at 28th Feb, 2014 at around 24 UT.

Fig 2.6 we have seen that there is a Dst of around -100nT and occurred on 28th February, 2014 at around 24UT. Since the CME occurred in a region of S12E82, hence it takes longer time to hit the Earth's magnetosphere and in the present analysis the CME reaches on 28th February.

CME causes Dst when it interact with the Earth's magnetosphere and as a result of the interaction of the magnetic field associated with the CME and the magnetic field of Earth's magnetosphere decreases. And Solar wind particles can easily enter into the Earth's atmosphere and create several distinguished hazards such as i) It can change the orbit of the satellite ii) Radio blackout in the satellite as well as on the Earth's surface.

3. Conclusions:

From this analysis we are reporting that the intense Solar flare X4.9 occurred on 25th February, 2014 at 00:49 UT, which was associated with a halo CME, Type III, Type II radio emission, 10cm radio burst, Proton event 10 MeV Integral Flux exceeded 10sfu, a moderate Geomagnetic Storm G2 and a minor S1 radiation storm were occurred. The speed of the associated halo CME in the C2 field of view was 2147km/sec. When it approaches to a maximum height of C2, the speed of the CME decreases to 1809km/sec, i.e., the CME is decelerated and at the C3 field of view the speed of the CME is found to be 2069km/sec. The present analysis reveal that when the CME was propagating through IP medium it suffers viscous drag, and hence the velocity of the CME decreases at the upper height of C2 field of view. At C3 field of view the CME was driven by internal magnetic energy which is interconverted to kinetic energy of the CME and hence the speed of the CME increases again. Again, as the CME is propagating through the IP medium the plasma materials confined in the magnetic loop diffuses to IP medium, hence mass of the CME decreases as a result the CME speed increases. Again, the multi-wavelength study can be used as an important tool to understand the dynamics and the evolution of the flare and associated CME. Moreover, the observation of the radio burst reveal the energy associated with the solar flare during its various stages of eruption of the flares and the CME. Type II radio burst are associated with the shock resulted from the high speed CME and the duration of the radio burst reveal the maintainability of the magnetic energy as possessed by the CME in the IP medium.

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