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Corona Mass Ejection in Solar Cycle 24 and 25

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Abstract: *Solar magnetic fields are responsible for the activity of the Sun and it is important to understand the physical processes responsible for the generation of magnetic field and its interaction with the atmosphere. The Sunspots and flares are time-varying events observable in the main sequence stars like Sun. We analyse the interplanetary space solar wind and the structure of Interplanetary Coronal Mass Ejection (ICME) as it passed through the Earth resulting in a strong Forbush decrease. We also present the analysis of linear speed of the CMEs at different angular widths.*

Keywords: *Coronal Mass Ejection, sunspot, Solar wind*

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1. Introduction

The Sun is a big sphere of electrically charged hot plasma that generate powerful magnetic field around it. The varying magnetic activity in the Sun is well known and established now. The variation is generated by an internal dynamo having cyclic period of ≈ 11 years (known as solar cycle) as is revealed by multi-wavelength synoptic observations from different layers in the Sun's atmosphere [1]. These observations include the broadband visible wavelength observations of Sun's activity in the form of dark sunspots made for the first time in the year 1844 [2], further confirmed using polarimetric observations [3], coronal X-ray emission [4] and chromospheric emission in several atomic lines [5]. The magnetic of the sun flips during each solar cycle in every eleven years. After eleven year the north and South Pole of the Sun switches places. The solar cycle affects the activity on the surface of the sun. As the magnetic field changes, the activity on the surface of Sun also changes. The solar activity gives rise to the Sunspots, solar flares, coronal mass ejection, solar wind and Forbush decreases. The basic questions about the solar activity are (i) why do Sunspots appear at low latitudes (below about ±40˚? (ii) why the propagation of the activity belt is towards the equator? We analyse all aspects of solar activity in the present work.

2. Solar Cycle

The solar cycle shows change in magnetic field of Sun after a cycle of approximately 11 years. It is also referred to as solar magnetic activity cycle. Solar cycle has been observed for centuries by noting the appearance change in the sun. The solar activity during solar cycle governs the environment of the solar system planets. The climate fluctuations in the atmosphere of earth and space weather are created due to solar activity. The first solar cycle is believed to be started in 1755. Rudolf Wolf proposed the numbering of cycles in the mid-19th century. The present solar cycle number 25 that started in December, 2019 and is expected to last by 2030.

3. Sun Spots

The sunspots are manifestations of magnetically distributed conditions at the sun's visible surface. These are the areas of particularly strong magnetic forces on the surface of sun. They are somewhat cooler and thus darker than their surroundings, being about 3800K hot. Due to this and their size (about 1000 to 100000 km in diameter), they can be observed visually from the earth. They grow

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over a few days and last for several days to a few months. The sunspot number and solar activity is at maximum in the middle of solar cycle when the sun's internal magnetic field is most chaotic. The sun emits more energy when there are more Sunspots as compared to the fewer Sunspots and during solar maximum the most.

4. Solar Flares

A solar flare is a violent explosion in the Sun's atmosphere with an energy equivalent to tens of millions of Hydrogen bombs. The large amount of energy is ≈ 10^{27} - 10^{32} ergs that takes place in few seconds to several tens of minutes. Solar flares take place in the solar corona and chromospheres, heating the gas to very high temperature and accelerating the particles such as protons, electrons and heavier ions to very high speed comparable to the speed of light. Thus, they produce electromagnetic radiations across the spectrum at all wavelengths ranging from long wave radio signals to the shortest wavelength gamma rays. Solar flares were first observed on the Sun in 1859 by English Astronomer Richard Carrington.

The frequency of solar flare and that of solar cycle is nearly same. When solar cycle is at its maximum, the active regions on the surface of Sun are large and later many solar flares are observed. There is decrease in number of activity as the Sun approaches the minimum part of its cycle. The most powerful solar flare was believed to have occurred in September, 1859. It was seen by Richard Carrington and left a trace in Greenland ice in the form of Nitrates and Beryllium. The solar flare is also known as Carrington event.

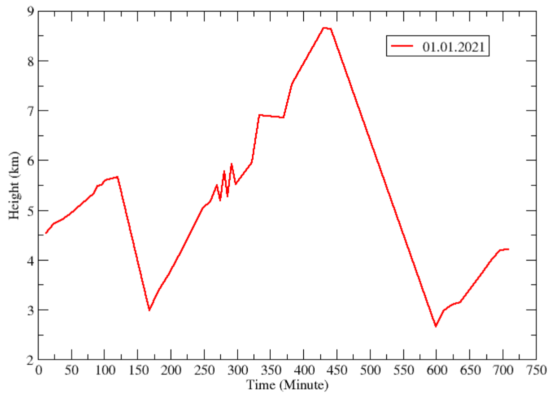

Fig. 1.: Height of solar flare with time.

The Fig. 1 shows the solar flare as function of time for the month of January, 2021. The gaps in the curves (sudden fall and rise in curve) show no activity during the time in twenty four hours.

5. Coronal Mass Ejection

A Coronal Mass Ejection (CME) is a solar event which involves a burst of Plasma consisting primarily of electrons and protons in addition to small quantities of heavier elements such as Helium, Oxygen and Iron [6, 7]. When these CMEs reach the earth, they often disrupt the earth's Magnetosphere, compressing it on the dayside and extending the night side tail [8]. The Sun produces about three CMEs everyday near

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solar Maxima where as there is about one CME every five days near solar minima.

Although, both the eruptions i.e. solar flayers and CMEs involve gigantic explosions of energy, but both are entirely different. The two phenomena sometimes occur simultaneously and the strong solar flares are always correlated with CME. The solar flares travel with the speed of light and it takes 8 minutes for the light from solar flare to reach earth, whereas CMEs travelling over a millions of kilometres per hour takes up to three days for Plasma light to reach the earth. Also, the solar flares appear as a bright light whereas CMEs appear as an enormous collection of gas swelling into space.

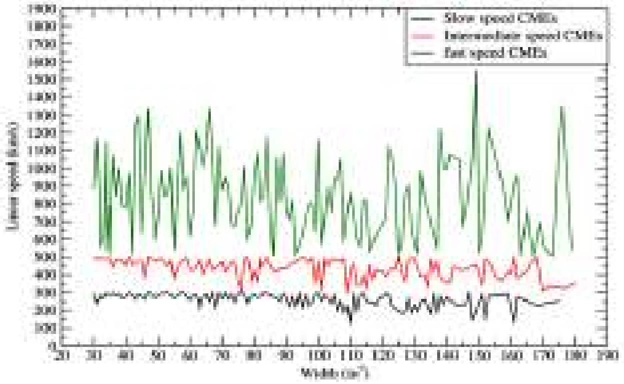

Fig. 2.: The speed of CMEs of 25th solar cycle (with maximum linear speed)

The energy emitting from solar Flare can disturb the atmosphere through which radio waves travel causing degradation and brief lack outs in navigation and communication signals. CMEs on reacting Oxygen and Nitrogen of Earth's atmosphere cause the creation of Aurora, also known as Northern and Southern Lights. Extreme eruptions can affect electrical grids on earth. In the present work we plot the data for 25th solar cycle finalised in the Coordinated Data Analysis Workshop (CDAW) from the Large Angle and Spectrometric Coronagraph (LASCO) on board the Solar and Heliospheric Observatory (SOHO), [9]. The observed data of speed of CMEs as a function of angular width for 25th solar cycle, is shown in Fig. 2. In the plot we show all the events for three speed ranges i.e. slow speed, intermediate and fast speed with maximum linear speed (minimum linear speed not shown here). The black, red and green lines respectively show the slow, intermediate and fast speeds of CMEs. It is clear from the figure that most of the fast CMEs are ejected with very high linear speed.

6. Solar wind

The Solar wind is a stream of charged particles released from corona of the Sun. It streams plasma and other particles from the Sun out into space. The other particles in the Solar wind are protons (95%) with small amount of ionized Helium and some traces of heavier ions. Eugene Parker, a physicist from Chicago first proposed the Solar wind in 1957 by viewing solar wind in the halo around the Sun during an eclipse. The research on solar wind has revealed that there are no electromagnetic waves close to the Sun, but the electrostatic wave. The electrons show the effect of an electric field created in part by the pull of Sun's gravity, similar to what happens

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at the earth's poles when a polar wind is accelerated. The solar wind can disturb earth's magnetic field impact, communication and GPS signals, make satellites malfunction, cause power outages on earth at Northern latitudes and can also be harmful to astronauts travelling in space.

7. Forbush Decrease

A sudden decrease in cosmic ray intensity followed by a gradual recovery lasting for several days is called Forbush decrease. Such a phenomenon is a result of energetic particles in a distributed interplanetary magnetic field associated with magneto-hydrodynamic shock wave caused by solar flares [10].

The decreases in intensity were first observed by Scott Forbush, an American physicist in 193, using ionization chamber. The magnitude of Forbush decrease depends on the size of CME, the strength of magnetic field in the CME and the proximity of CME to the earth. The occurrence of Forbush decrease events vary according to the solar cycle. A large number of them are found during the maximum solar activity period. Solar wind velocity becomes high during the period of Forbush decreases.

Over the last five decades the Sun was unusually active in four cycles only, but the solar cycle-24 was very weak with lesser number of Sunspots. The first Forbush decrease of solar cycle-24 was observed in 2011 by Solar Terrestrial Relations Observatory (STEREO) mission [9]. The 25th solar cycle has started in December 2019 and the activity is very low. In the whole year, 2019 the number of Sunspots was very low and no Sunspots were observed for 281 days in the year 2019. The initial stage of cycle-25 is also very weak and very similar to the solar cycle-24. As per NASA, the maximum of solar activity of the cycle-25 is expected to be seen in the year 2025 around the month of July, when there will be a sharp rise in number of Sunspots to more than 100.

8. Conclusion

In conclusion, we analyse the evolution of solar activity and the activity through solar cycles predicts an idea of the frequency of space weather storms of all types from radio blackouts to geomagnetic storms and solar radiation storms. Enhanced observations of the Sun from new satellites to be launched by National Oceanic and Atmospheric Administration (NOAA) space weather L-I observatory will help improve space weather forecasting by providing imagery of CMEs and monitor all solar activities in finer details.

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