

A STUDY HELIOSPHERIC DISTURBANCE OF SOLAR CYCLE 24 DURING PERIOD FROM 10 MARCH TO 31 MARCH 2015

¹Dharmendra Singh, ²Dr. P.K. Chamadia, ³Dr. C.M. tiwari

¹Research Scholar, Govt. Autonomous P.G. College Satna (M.P.)

dharmendrasingh738@gmail.com

²Professor, Govt. P.G. College, Satna (M.P.)

dr. pramod.chamadia@gmail.com

³A P S University Rewa (M.P.)

cmtiwari_2005@gmail.com

ABSTRACT

The Halo-CMEs and solar flares are important solar ejections which are the cause of storm in Heliosphere. These ejections produce changes in Earth's magnetic field. In this research, we have studied heliospheric disturbance of solar cycle 24 during the period from 10 March to 31 March 2015. We observed that a huge explosion of magnetic field and plasma from the Sun's corona on 15 March 2015 known as halo-CMEs (Coronal mass ejections) and associated solar flares have produced a powerful supergeomagnetic storm on 17 March 2015. We found that Disturbance storm time (Dst) value decreased to its minimum -223 nT and a 3.5% Forbush Decrease (FDs) during the period on 17 March 2015. In the past of astrophysics CMEs are a very recent parameter which is used from the year 1970. In recent investigation by many researchers observed that the solar cycle 24 is weaker than cycles 22 and 23.

Keywords: Heliospheric disturbance, coronal mass ejections, solar cycle 22&23, cycle 24

INTRODUCTION

The solar cycle 24 could produce intense geomagnetic storm and solar energetic particle (SEP) events are associated with solar phenomenon. Earth-directed CMEs are the main factor of generating major geomagnetic storm. Space weather predictions of various agencies are given the disturbance arrival on the Earth. The Earth-directed CMEs that contain a southward magnetic field component is capable to start geomagnetic storms. Gosling et al. (1990) studied the cause of geomagnetic storms have generated that by mostly caused by CMEs phenomena. Hence, best tool of CMEs and shock arrival time at the Earth is desired for prediction of space weather conditions. CME takes the time, arrival to the Earth about minimum in hour and maximum in 1 to 6 days.

Various propagation models of CMEs and shock are using for space weather variation forecast. Gopalswamy et al. (2001) presented a model that space speed of CMEs in interplanetary medium with solar wind decreases

about 1 astronomical unit. A similar CMEs propagation model that considers explicitly the effect of the drag force by the solar wind on the CMEs has been suggested (Vrsnak and Gopalswamy, 2002; Borgazzi et al., 2009). Studies using various methods to track the CMEs propagation have found evidence in support of the drag force model (Byrne et al., 2010; Mostl et al., 2014). Owens and Cargill (2004) predicted a model for arrival of storm towards Earth about 12 hours. Gopalswamy et al. (2001) may be compared to given this model.

LITERATURE REVIEW

Sergey A. Koldobskiy et al. (2022) investigated the pairwise time lags between three global solar and heliospheric indices: sunspot numbers (SSN), representing solar surface magnetic activity, open solar flux (OSF), representing heliospheric magnetic variability, and galactic cosmic-ray (GCR) intensity near Earth. All three indices appear extremely coherent across timescales greater than a few years, with consistent high coherence during the 11-year solar cycle. This is a significant observational restriction for solar and heliospheric physics.

Yuming Wang et al. (2022) investigating the solar surface magnetic field, we find that the source of heliospheric magnetic field—the open magnetic flux on the Sun—already lags behind SSN before it convects into the heliosphere along with the solar wind. The delay during odd cycles is longer than that during sequential even cycles. Thus, we propose that the GCR lag is primarily due to the very late opening of the solar magnetic field with respect to SSN, though solar wind convection and particle transport in the heliosphere also matter. We further investigate the origin of the open flux from different latitudes of the Sun and find that the total open flux is significantly contributed by that from low latitudes, where coronal mass ejections frequently occur and also show an odd–even cyclic pattern. Our findings challenge existing theories, and may serve as the physical basis of long-term forecasts of radiation dose estimates for manned deep-space exploration missions.

Shuai Fu et al. (2021) investigate the fluctuations in Galactic cosmic-ray (GCR) levels during solar cycles 23 and 24, using data from NASA's Advanced Composition Explorer/Cosmic Ray Isotope Spectrometer instrument and ground-based neutron monitors (NMs). Maximum GCR intensity of heavy nuclei at 1 AU during the solar minimum in 2019-2020 transcend existing records, exceeding those recorded in 1997 and 2009 by ~ 25% and ~ 6%, respectively, and are at the greatest levels since the space era. Peak NM count rates, however, are lower than in late 2009. The disparity between GCR intensities and NM count rates has yet to be explained. Furthermore, we discover that the GCR modulation environment during the solar minimum P24/25 differs significantly from previous solar minima in several ways, including remarkably low sunspot numbers, extremely low heliospheric current sheet inclination, rare coronal mass ejections, a weak interplanetary magnetic field, and turbulence. These changes are favourable to lowering the intensity of solar modulation, which provides a credible explanation for the unprecedented GCR intensities in interplanetary space.

Elena Saiz et al. (2013) compile the most significant data collected during the COST Action ES0803. We show that accumulating specific data, such as X-ray solar flares, Type II and/or Type IV radio emission, and solar energetic particle enhancements as inputs to an end-to-end forecasting strategy using an artificial neural network improves predicting outcomes. The geomagnetic reactions at high and low latitudes are examined independently



in the issue of solar wind-magnetosphere-ionosphere interaction. At low latitudes, we give fresh insights into the temporal evolution of the ring current, as shown by Burton's equation, during the storm's main and recovery stages. At high latitudes, the PCC index looks to represent a breakthrough in modelling the connection between the upper atmosphere and the solar wind, with significant forecasting potential. We also discuss the importance of small-scale field-aligned currents in ionosphere Joule heating even under non-disturbed circumstances. Our scientific findings within the scope of COST Action ES0803 range from the short-term development of solar activity, i.e., space weather, to the long-term evolution of relevant solar/heliospheric/magnetospheric parameters, i.e., space climate.

Timothy.A.Howard (2011) created novel approaches for obtaining three-dimensional (3-D) information on coronal mass ejections. Geometry may be applied to white light data from three separate views, which has only been possible since the launch of the STEREO satellite. Heliospheric imaging is another approach that does not necessarily require the many perspective capabilities of STEREO. Heliospheric imagers can use the breakdown in geometrical and Thomson scattering linearity to obtain 3-D information from CME pictures through careful data analysis. In that paper, the author and colleagues highlight the many methodologies that are being developed and utilised to reconstruct the 3-D structure and kinematic history of CMEs.

Gibson et al. (2009) ask, "If the Sun is so silent, why is the Earth ringing?" Two solar minimum periods are compared. Observations from the recent Whole Heliosphere Interval (WHI) solar minimum campaign are compared to the previous cycle's Whole Sun Month (WSM) to show that, while sunspot numbers are a good measure of solar activity, they do not provide enough information to gauge solar and heliospheric magnetic complexity and its effect on the Earth. The current solar minimum is unusually quiet, with sunspot numbers at their lowest in 75 years and the magnetic field strength of the solar wind lower than ever seen. Despite, or maybe because of, a worldwide weakening of the heliospheric magnetic field, enormous near-equatorial coronal holes persisted even as sunspots faded. As a result, powerful, sustained, and recurrent high-speed streams in the solar wind intercepted the Earth in the months preceding the WHI campaign, as opposed to weaker and more irregular streams that occurred around the time of the previous cycle's WSM campaign.

Smith and Marsden (2003) discovered that the slow and intermediate wind and CMEs, as well as their reciprocal interactions, were present from the equator to the south polar cap. Slow and moderate interacting wind occurred in all high helio latitudes in regions inhabited by rapid high latitude wind as solar activity increased. The solar magnetic feature is shown by the source dipole of the heliospheric field, magnetic poles at high latitudes, and heliospheric current sheet close to the solar equator during solar minimum.

Belov et al. (2002) conducted a study of long-term cosmic ray changes in which solar-heliospheric parameters were employed to describe the observed CR modulation in different solar cycles. This work is notable for being based on global solar magnetic field parameters found on the solar-wind source surface. The tilt of the heliospheric current sheet, as well as the mean strength and polarity of the solar magnetic field, are examples of such properties. The direct influence of the polarity of the global solar magnetic field on CR as well as the effect of the polarity on CR modulation, which is related to the change in the tilt of the current sheet, are both considered. The properties of the global solar field have been reconstructed from observations of filaments in the

H line for the era when direct measurements of the solar magnetic field are missing. As a result, the time range of the CR model simulation could be extended all the way to 1953. As a consequence, a semiempirical modulation model has been developed. This model accurately depicts the behaviour of CR with a stiffness of 10 GV during a three-cycle period.

Smith (2000) discovered that around the solar maximum, the polar fields are weak and reversing, but the fields in the active areas, which define the resultant equatorial dipole, are many and powerful. At the lowest phase, Ulysses saw low latitude streamers near the heliospheric current sheet. The streamers become visible at higher latitudes when the Sun accumulates magnetic multipoles during its maximum phase.

G.A. Bazilevskaya (1995) satisfactory relationship is found between the solar activity index that includes both the number of sunspot groups, η , and their mean heliolatitude, ϕ , and the galactic cosmic ray (GCR) intensity over more than three 11-year cycles. The solar activity index, is compared with the tilt of the heliospheric current sheet (HCS).

OBJECTIVES OF THE STUDY

- To study the heliospheric disturbance of solar cycle 24 during period from 10 March to 31 March 2015.
- To observed magnetic field and plasma from the Sun's corona on 15 March 2015 known as halo-CMEs (Coronal mass ejections) and associated solar flares

DISCUSSION OF THE STUDY

Hess and Zhang (2015) presented a drag model that is able gave the arrival of CME ejecta about 1.4 to 3.3 hours at Earth. For this study we have taken hourly data of magnetic field (B), solar wind velocity (v), Disturbance storm time (Dst) data from OMNI web of NASA similarly data of Cosmic ray intensity (in hours) from Moscow ground based neutron monitor having cut-off rigidity ($R_c = 2.42 \text{ GeV}$) and location on the Earth is latitude 55.47N, longitude 37.32E during the period from 10 March to 31 March of year 2015 in days. For CMEs data we have used CME catalog of NASA. Large outflow of magnetic field and plasma from the Sun to interplanetary space produced disturbance in space.

The CMEs is one of the main transient features of the Sun. CMEs just changes into ICMEs when enter in heliospheric space. The figure 1 shows the images of solar output variation from 10 March to 15 March 2015. On 15 March 2015 these Earth-directed CMEs explosions enter into interplanetary space disrupted the space weather. Interplanetary magnetic field (B) and interplanetary force field (VB) shows similar activity and good positive correlation during the same period of time which have shown in figure 2 and 5. Interplanetary field lines change the track of charged particles in heliosphere. Table shows the SOHO/LASCO HALO-CMEs (Coronal mass ejections) their associated solar flare events during period from 10 March to 31 March of year 2015.



Figure 1: Image recorded by (SOHO/LASCO) Coronagraph C2 on March 10 and 15, 2015

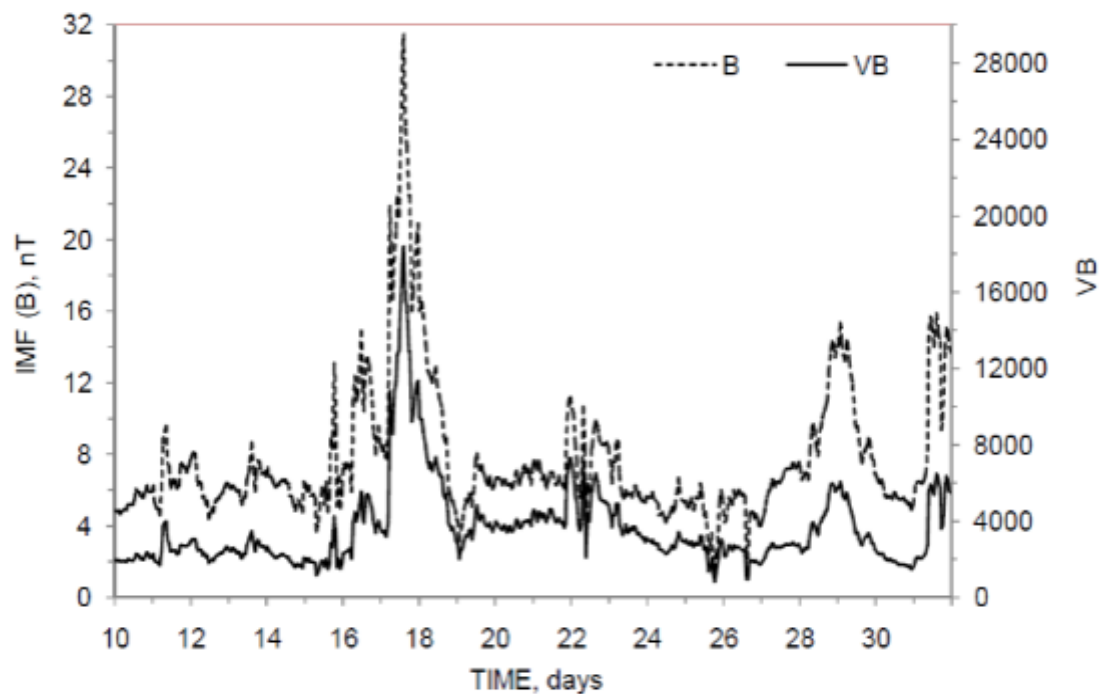
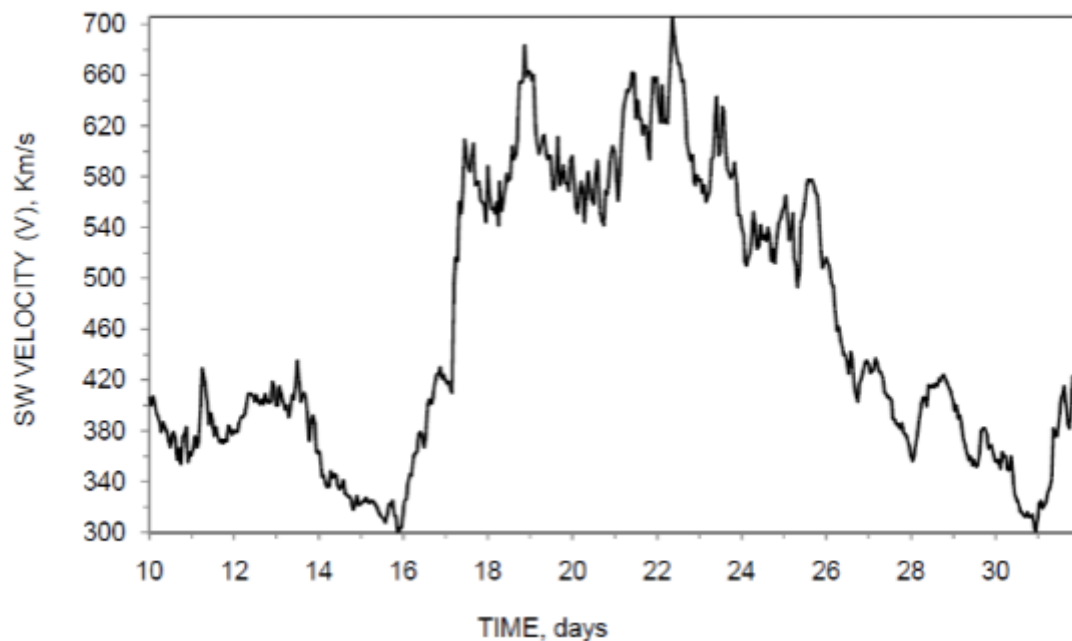


Figure 2: Time profile of IMF (B) and (VB) during the period from 10 March to 31 March 2015

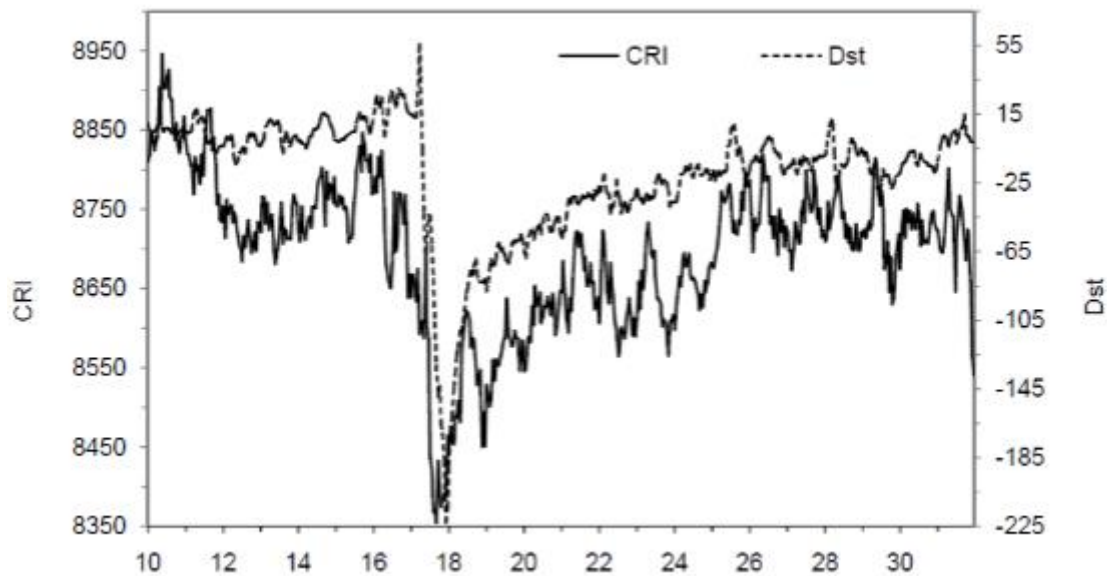


Figures 3: Time profile of solar wind speed (V) during the period from 10 March to 31 March 2015

Solar flares have high energy particles and radiation that are dangerous for human. The magnetic field lines of Earth are protected from the effects of charged particles solar flares and other solar activity which occurred by the Sun also. The most dangerous phenomena of the Sun is x-class flares storm which is very dangerous. The dangerous x-class flares strictly prevented by field line of Earth. The flares storm created a disturbance at Earth surrounding that is ionosphere resulting destroy telecommunication.

Along with energetic ultraviolet radiation, they heat the Earth's outer atmosphere, causing it to expand. This kind disturbance changes the dragging of satellites around Earth. Also, both intense radio emission from flares and these changes in the atmosphere can degrade the precision of global positioning system (GPS) measurements. The small number of very high energy particles that does reach the surface does not significantly increase the level of radiation that people experience every day.

The most disturbing event of this planet on human activity is known as geomagnetic storms are associated with solar flares and plasma. Halo-CMEs sometimes occurred with and sometime are not. The interplanetary magnetic field and interplanetary force play an important role in heliosphere have shown in figure 2. The interplanetary magnetic field and interplanetary force show the similarity during time scale 10-31 March 2015. Therefore it has a good positive correlation as shown in figure 5.



Figures 4: Time profile of Cosmic ray intensity (CRI) and Disturbance storm time (Dst) during the period from 10 March to 31 March 2015

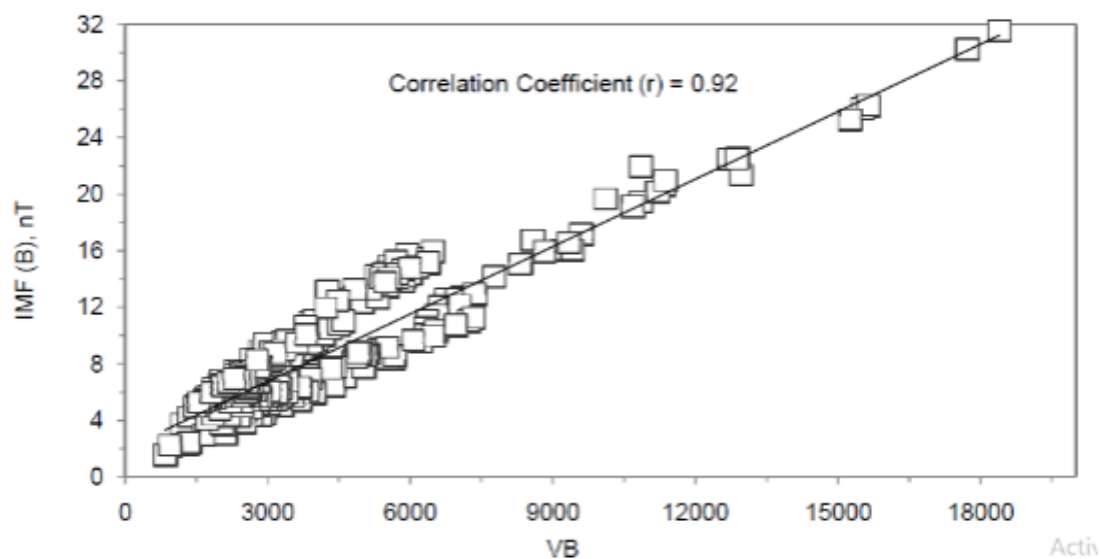


Figure 5: Cross plot between IMF (B) and VB during the period from 10 to 31 March 2015

The expansion of solar ejection in solar space could produce solar wind. The expansion solar wind approximately 450 Km/second in space from the Sun containing more charged particles that are electrons and protons and other particles. The Solar wind propagation movement firstly through the solar coronal holes, which are predominantly occurred near the Sun's pole. In figure 3 shows the flow of solar wind speed during the period from 10-15 March 2015. The effect of solar wind influence on our planet occurred during active region of Sun that is sunspot maxima at this stage solar wind is strong and may produce storm corresponding to flares and CMEs of the Sun.



When these halo-CMEs and their associated solar flares from 15-17 March 2015 reached near the Earth's magnetosphere they modulated the Galactic cosmic rays that coming from interstellar medium. Therefore, nearly 3.5% Forbush decrease occurred during on 17 March 2015. Heliospheric disturbance by the Sun when interact with galactic cosmic rays it modulate the galactic cosmic rays and a remaining partial galactic cosmic rays that are neutron particles reaches on the Earth's magnetosphere. We know that Galactic cosmic rays are charged particles which have 91% of protons and remaining 9% have other elements. On 17 March 2015 same day halo-CMEs and solar flares strike on the Earth's magnetosphere therefore Disturbance storm time (Dst) decreased to its minimum -223 nT and cosmic ray decrease during same period have shown in the figure 4.35. When halo-CMEs and their associated solar flares strikes on Earth's atmosphere on 17 March 2015 it causes temporary disturbances of the planet's magnetic field called geomagnetic storms. These storms could be disturbed our power grids, radiocommunications and GPS navigation etc. So we should worry that an extreme CME on 15 March 2015 could cause a very powerful geomagnetic storm on 17 March 2015, resulting in global catastrophe and endangerable our lives. It means the Sun's violent activity and many unexpected and unpredictable events taking place on its surface suggest that we should prepare for worst.

Date	10 march 2015	15 march 2015	24 march 2015
CMEs Speed (Km/s)	1055	725	1800
CMEs associated solar	M5.7	C9.4	None

Table 1 - List of halo - CMEs and Solar Flares Events during the period from 10 March to 24 March 2015

CONCLUSIONS

In this research we have reached a point to conclude our result. The Cosmic ray modulation and geomagnetic storm are influenced by solar output in form of interplanetary parameters. Solar and interplanetary phenomena are also caused of geomagnetic disturbances such like Ap, Kp and Dst. In this thesis, we have focused mostly effect of variability of interplanetary medium on geomagnetic field parameter and cosmic rays. For this study we have used various neutron monitors geomagnetic field parameters. Finally, on the basis of the observation result and discussion we have formed following conclusions-

- In declining phase of solar cycle 24 huge explosions of magnetic field and plasma on 15 March 2015 of the Sun disturbed geomagnetic field produced largest geomagnetic storm (Dst reached to -223 nT) on 17 March 2015.
- In declining phase of solar cycle 24 huge explosion of magnetic field and plasma on 15 March 2015 at the Sun produced FDs on 17 March 2015.
- The Sun often huge clouds of superheated particles into space known as CMEs. Powerful CMEs that hit Earth can trigger geomagnetic storm, which in turn can disturb radio communication, GPS and power grid and pipelines etc.
- The time profiles of 11-year variation of number halo-CMEs and solar flares are similar to the sunspot variation.
- The time profile of 11-year variation of geomagnetic storms is similar to the sunspot variation.

- We also found that halo-CMEs and solar flares are associated with geomagnetic storms.
- Two important halo-CMEs events are observed during declining phase of solar cycle 24, events of June and March 2015. Dst during these periods goes its minimum ($Dst < -200$ nT).

REFERENCES

1. Gosling, J.T., Bame, S.J., Mc Comas, D.J. and Philips, J.L. (1990). Coronal mass ejections and geomagnetic storm, *J. Geophysics Res. Letter*, 17, 901.
2. Gopalswamy, N., Lara, A., Lepping, R.P., Kaiser, M.L., Berdichevsky, D. and St. Cyr O.C. (2001). Interplanetary acceleration of coronal mass ejections, *J. Geophysics Res. Letter*, 27, 145.
3. Vrsnak, B. and Gopalswamy, N. (2002). Influence aero-dynamic drag on the motion of interplanetary ejection, *Journal Geophysics Res.*, 107, 1019.
4. Borgazzi, A., Lara, A., Echer, E. and Alves, M.V. (2009). Dynamics of coronal mass ejections in the interplanetary medium, *J. Astronomy and Astrophysics*, 498, 885.
5. Byrne, J.P., Maloney, S.A., McAteer, T.J., Refojo, J.M. and Gallagher, P.T. (2010). Propagation of Earth-directed coronal mass ejections in three dimensions, *J. Nature*, 1, 74.
6. Mostl, C., Amla, K., Hall, J.R., Liewer, P.C., De Jong, E.M., Colonnino, R.C., Veronig, A.M., Rollett, T., Temmer, M., Peinhart, V., Davies, J.A., Lugaz, N., Liu, Y.D., Farrugia, C.J., Luhmann, J.G., Vrsnak, B., Harrison, R.A. and Galvin, A.B. (2014). Connecting speeds, Directions and arrival times of 22 coronal mass ejections from the Sun to 1 Astronomical Unit, *Journal Astrophysics*, 787, 119.
7. Owens, M. and Cargill, P. (2004). Predictions of the arrival times of coronal mass ejections at 1- Astronomical Unit, *Ann. Geophysics.*, 22, 661.
8. Gopalswamy, N., Lara, A., Lepping, R.P., Kaiser, M.L., Berdichevsky, D. and St. Cyr O.C. (2001). Interplanetary acceleration of coronal mass ejections, *J. Geophysics Res. Letter*, 27, 145.
9. Sergey A. Koldobskiy et al. (2022) "Time Lag Between Cosmic-Ray and Solar Variability: Sunspot Numbers and Open Solar Magnetic Flux" Published: 22 March 2022 volume 297, Article number: 38.
10. Yuming Wang et al. (2022) "Variation in Cosmic-Ray Intensity Lags Sunspot Number: Implications of Late Opening of Solar Magnetic Field" *The Astrophysical Journal*, Volume 928, Number 2 DOI 10.3847/1538-4357/ac5896.
11. Shuai Fu et al. (2021) "Variations of the Galactic Cosmic Rays in the Recent Solar Cycles", *The Astrophysical Journal Supplement Series*, Volume 254, Number 2, DOI 10.3847/1538-4365/abf936.
12. Elena Saiz et al. (2013) "Geomagnetic response to solar and interplanetary disturbances", *J. Space Weather space Clim.* 3 (2013) A26, DOI: 10.1051/ swsc/2013048.
13. Timothy A. Howard (2011), Three-dimensional reconstruction of coronal mass ejections using heliospheric imager data, *Journal of Atmospheric and Solar Terrestrial Physics.*, 73, 1242–1253.
14. Gibson, et al. (2009) If the Sun is so quiet, why is the Earth ringing? A comparison of two solar minimum intervals, *J. Geophys. Res.*, 2009. vol. 114, p. A09105. doi 10.1029/2009JA014342.



15. J. Smith (2000), The Heliospheric Magnetic Field at Solar Maximum: Ulysses Observations, Space Sci. Rev., 97, 147–160, doi: 10.1023/A:1011854901760
16. Smith, C. W et al. (2003) International Cosmic Ray Conf., 3689–3692.
17. Belov, et al.(2002) Connection of the long-term modulation of cosmic rays with the parameters of the global magnetic field of the Sun, Geomagn. Aeron., 2002, vol. 42, pp. 639–700.
18. G.A. Bazilevskaya (1995) "The relationship between the galactic cosmic ray intensity and the sunspot distribution" Volume 16, Issue 9, 1995, Pages 221-225 [https://doi.org/10.1016/0273-1177\(95\)00339-G](https://doi.org/10.1016/0273-1177(95)00339-G).
19. Hess, P. and Zhang, J. (2015). Predicting CMEs and sheath front arrival at L1 with a Data-Constrained physical model, J. Astrophysics, 812, 144.