



# CORONAL MASS EJECTION, SOLAR FLARE AND INTERPLANETARY SHOCK CAUSED GEOMAGNETIC STORMS DURING MAXIMA PHASE OF SOLAR CYCLE 24

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**Abstract:** - We analyse study about maxima phase of solar cycle 24, which is the mostly recently completed solar cycle, it starts at December 2008 to December 2019 duration of solar cycle is 11 year, max sunspot activity max count month at April 2014 and max count value 81.8. we discuss about Coronal mass ejections (CMEs) and Solar flare (SF), how can generate and disturbance create Earth magnetosphere? Solar flare is energetic X-ray or Solar energetic particles (SEPs) and CME contain large amount of plasma. Another solar parameter Interplanetary Shocks (IP) which can disturbed Earth's magnetic field. In this solar cycle  $Dst \leq -30nT$  according 27 geomagnetic storms value observed, this value associated with CMEs, SF and IP shocks, 77.77% association rate between CME and geomagnetic storm, where partial halo CME (51.85%) and halo CME (25.92%), solar flare association rate is 84.61% and M-class (22.22%). C-class (37.03%) and X-class (18.51%) respectively but remaining 22.22% CMEs and SF not belongs to Dst index. We examine IP shock only Fast Forward (FF) type, table 2 contain based on IP shock upstream and downstream values contain shocks parameter (velocity, density and magnetic field) create graphical analysis.

**Keywords:** - Coronal mass ejection (CME), Solar flare (SF), Solar energetic particle (SEP), Interplanetary (IP), Fast forward (FF)

## 1. INTRODUCTION: -

The scientific community has shown interest in studying the circumstance at the sun that can affect the performance of space born and ground based technical system that have the potential to impact human health and life, specifically the study of space weather (Schwenn, R., 2006). Sun is source of energy in our galaxy all activity related to the sun affects space weather program (Gopalswamy, N., 2022). Sun's most potential events such as solar flares, which cause sudden changes in the Earth's atmosphere, solar energetic particle or SEP's which can harm satellite equipment's and endanger astronaut's and coronal mass ejection or CME's which cause geomagnetic storms among other effects (Gosling, J. T. et. al., 1990 and Schwenn, R. et. al., 2005).

Since shock waves may accelerated particle (such as proton ions and electrons) to near relativistic energies their creation in corona is significant in this respect (Jones, F. C. et. al., 1991). They are generated as piston driven as shocks in advance of rapid coronal mass ejection (CME's) or as vltast waves as a result of the massive flare introduced pressure pulse. They can be found in the corona using ultraviolet spectra white light pictures and radio dynamic spectra (Billings, D. E., 2013).

A directed plasma flows kinetic and magnetic energy is partially converted to plasma heating in the shock which is discontinuity with a transmitted mass flow that decelerates from a super to sub-Alfven dissipative structure. However, particle collision is not the mechanism by which the dissipation occurs. These are two types of collision less shocks super and sub crutial (Malkov, M. A. et. al., 2001).

According to the Rankine Hugoniot relationship resistivity in super crutial shocks is unable to supply all of the dissipation required for a shock transition in contrast to sub-crutial shock therefore the dissipation needs for sub-crutial shocks production is provided by other processes like-as wave particle interactions (Lembege, B., 1992). The area able to effectively accelerate SEP's to high energy because of this, the angle between the magnetic field affects the SEP acceleration efficiency (Xie, H. et. al., 2017). Indeed, the creation of both quassi-parallel fronts is probably induced by the extension of the CME fronts. Our analysis, based on the maximum phase of solar cycle 24 is complete after 23 months, during the recorded sunspot maximum count no. 81.8 and minimum count no. 2.2 and their type behavior of solar parameters coronal mass ejection, solar flare and interplanetary shock, correlate to geomagnetic storm.

## 2. EXPERIMENTAL DATA: -

This study examines magnetic disturbance related geomagnetic storms using solar features solar flare (SF), Coronal mass ejections (CMEs), interplanetary shocks and geomagnetic disturbance Dst index data in solar cycle 24 maximum phase. This study will use data from the SOHO Large angle spectrometric coronagraph (SOHO/LASCO) and extreme ultraviolet imaging telescope (SOHO/EIT) to determine the type of CME appearance date, time and speed also.

Hourly data of the Dst index is obtained from the omni web data (<https://omniweb.gsfc.nasa.gov/form/dxi.html>). X-ray solar flare data other solar data the U.S. department of commerce's solar geophysical data report the NOAA monthly issue and solar data (<https://www.ngdc.noaa.gov/stp/solardataservice.html>) are all used.

WIND and ACE spacecraft issue data of year universal time, type of shock and individual event detail are used to obtain Interplanetary Shock data from Center for Astrophysics Interplanetary Shock Database (<https://lweb.harvard.edu/shocks/>), which summarizes data annually.

**Table 1 Association of Geomagnetic storm, Coronal mass ejection, Solar flare and IP Shock data**

S. No.	GM Storm Onset Time			CME Appearance		CME		Solar Flare	Shock	
	Year	Day	HR	Date	Time	Type	Speed		Time	Type
1	2014	1	12	31-12-2013	10:36:05	Partial Halo	1101	M	NA	NA
2	2014	39	5	04-02-2014	16:36:06	Partial Halo	368	M	16:16	FF
3	2014	49	14	15-02-2014	02:24:05	Partial Halo	362	C	03:09	FF
4	2014	54	10	21-02-2014	16:00:05	Halo	1252	C	15:50	FF
5	2014	58	17	25-02-2014	01:25:50	Halo	2147	X	NA	NA
6	2014	71	21	09-03-2014	03:12:10	Partial Halo	713	M	NA	NA
7	2014	101	14	08-04-2014	23:12:12	Halo	514	C	NA	NA
8	2014	119	23	NA	NA	NA	NA	NA	NA	NA
9	2014	123	20	NA	NA	NA	NA	NA	16:37	FF
10	2014	128	0	06-05-2014	17:36:05	Partial Halo	859	M	21:19	FF
11	2014	239	5	24-08-2014	12:36:05	Halo	551	M	NA	NA
12	2014	255	21	10-10-2014	16:12:05	Partial Halo	782	C	NA	NA
13	2014	266	9	NA	NA	NA	NA	NA	NA	NA
14	2014	272	5	26-09-2014	04:28:16	Halo	1469	C	NA	NA
15	2014	281	10	NA	NA	NA	NA	NA	NA	NA
16	2014	291	13	17-10-2014	09:24:19	Halo	1053	C	NA	NA
17	2014	300	15	25-10-2014	21:36:05	Partial Halo	663	X	NA	NA
18	2014	308	8	01-11-2014	05:00:05	Partial Halo	1666	C	NA	NA
19	2014	314	7	07-11-2014	18:08:34	Partial Halo	795	X	NA	NA
20	2014	315	15	08-11-2014	16:36:05	Partial Halo	426	C	NA	NA
21	2014	318	14	11-11-2014	04:36:05	Partial Halo	839	C	NA	NA
22	2014	323	15	NA	NA	NA	NA	NA	NA	NA
23	2014	340	20	NA	NA	NA	NA	NA	NA	NA
24	2014	346	5	10-12-2014	18:00:06	Partial Halo	1361	C	NA	NA
25	2014	355	2	19-12-2014	01:04:42	Halo	1331	X	NA	NA
26	2014	357	18	20-12-2014	01:25:57	Partial Halo	830	X	NA	NA
27	2014	363	4	26-12-2014	05:48:05	Partial Halo	1097	M	NA	NA

### 3. DATA ANALYSIS: -

#### 3.1 Association of geomagnetic storm and Coronal mass ejection

In this section we have reviewed geomagnetic storms associated with coronal mass ejection observed duration of 1 January 2014 to 31 December 2014, which has maxima of solar cycle 24. During in this observation 27 geomagnetic storms with  $Dst \leq -30nT$  were recorded. The association rate of geomagnetic storm 21 out of 27 (77.77%) for both halo and partial halo coronal mass ejection (CMEs) has been determined. The association rates for partial halo and halo CME have been found to be 51.85% and 25.92%, there are 22.22% CME data not associated with geomagnetic storm respectively.

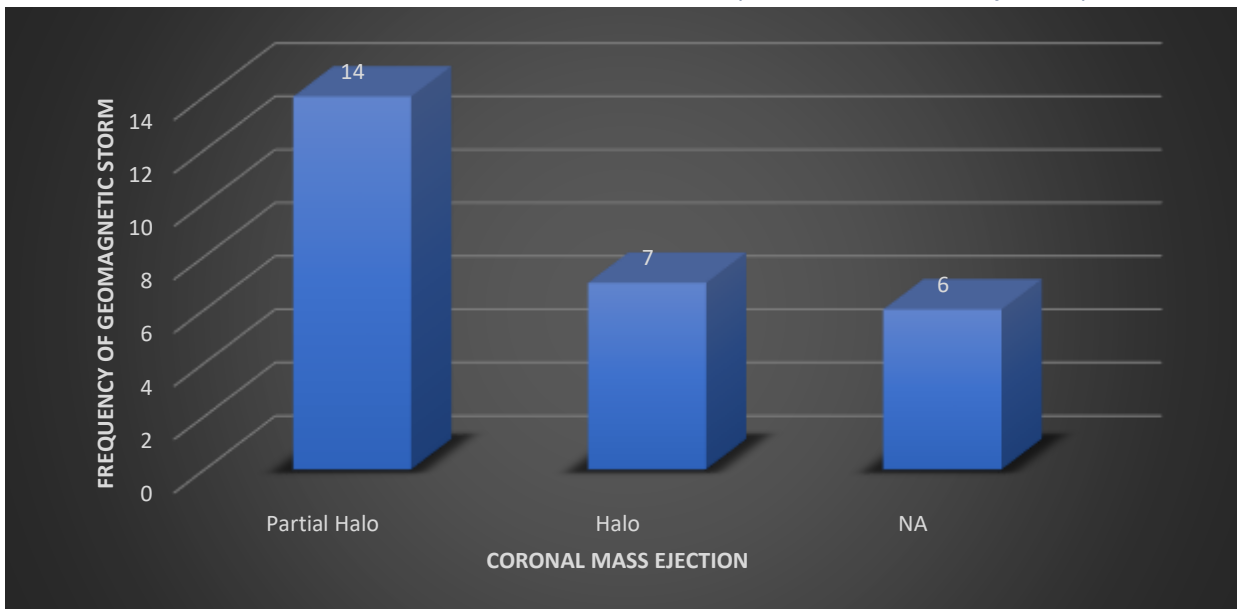


Figure-1 Bar diagram of coronal mass ejection and frequency of associated geomagnetic storms during of solar cycle 24

### 3.2 Analysis of X-ray Solar flare during maxima phase solar cycle 24

Solar flare are extreme solar events that cause massive disruptions to solar wind plasma and geomagnetic storms in geomagnetic fields. Many researchers have examined geomagnetic storms in conjunction with solar flares and in this study, we have identified 27 geomagnetic storms which 22 out of 27 (84.61%) are found to be associated with x-ray solar flares of various categories. The association rates of M-Class, C-Class, and X-class x-ray solar flares are 22.22%, 37.03% and 18.51% but 22.22% solar flare are not associated respectively. It is also observed that majority of the geomagnetic storms are associated with C-class solar flares.

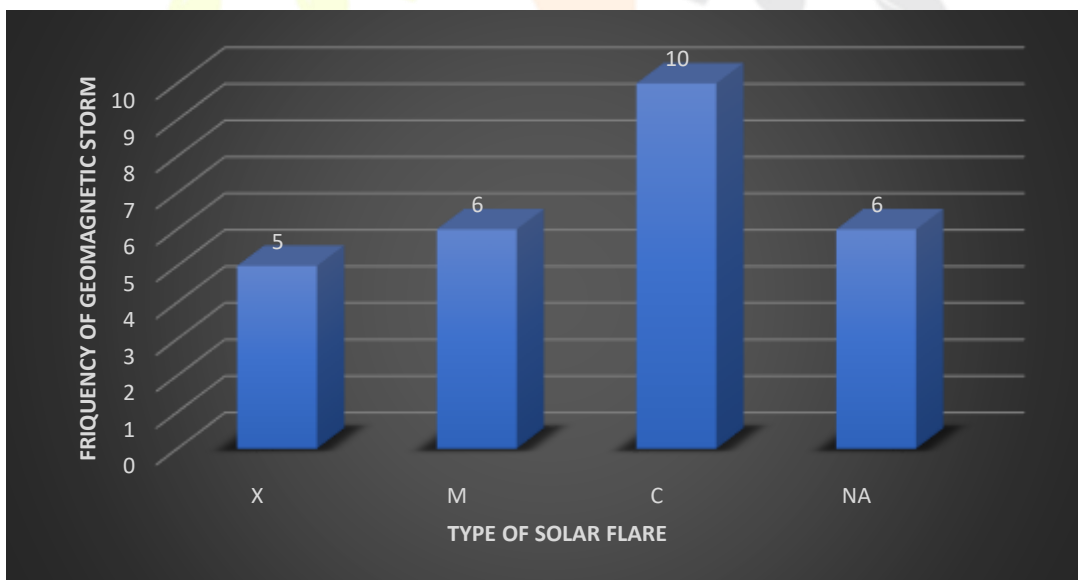


Figure-2 Bar diagram of geomagnetic storms and type of solar flare during maxima phase of solar cycle 24

### 3.3 Analysis of Interplanetary shock during solar cycle 24: -

In this section, an interplanetary shocks database is presented using the wind shock analysis method. The table contains five shock-based data points, but only four shock data points are available for graphical analysis, which are associated with the geomagnetic storm onset time value. Several solar wind parameters are tracked over time using moving averages and the detection algorithm continuously determiners a quality factor Q based on these changes responding to o anordinary IP shock scale. The quality factor can be described as follows

$$\Delta V = \frac{2|V_2 - V_1|}{V_2 + V_1}, \quad \Delta B = \frac{2|B_2 - B_1|}{B_2 + B_1}, \quad \Delta W = \frac{2|W_2 - W_1|}{W_2 + W_1}, \quad \Delta N = \frac{2|N_2 - N_1|}{N_2 + N_1}$$

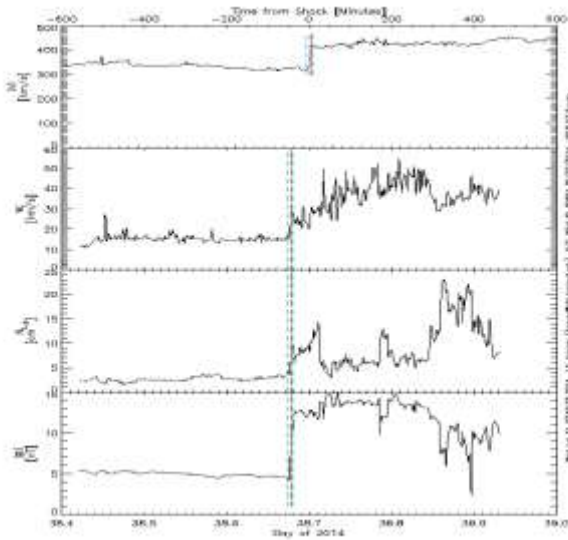


Fig. 3 (a) IP shock 16:16 UT

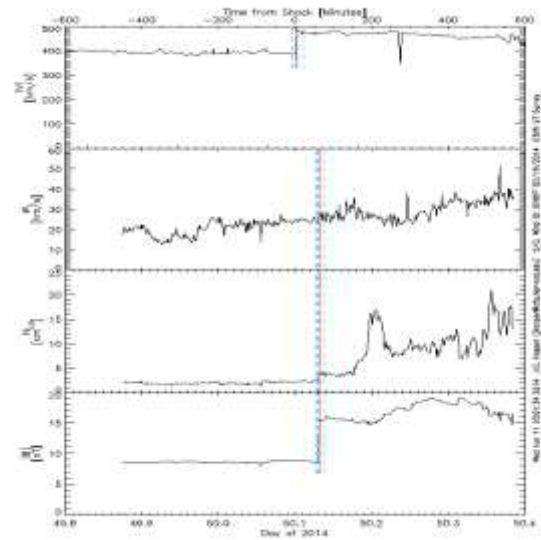


Fig. 3 (b) IP shock 03:09 UT

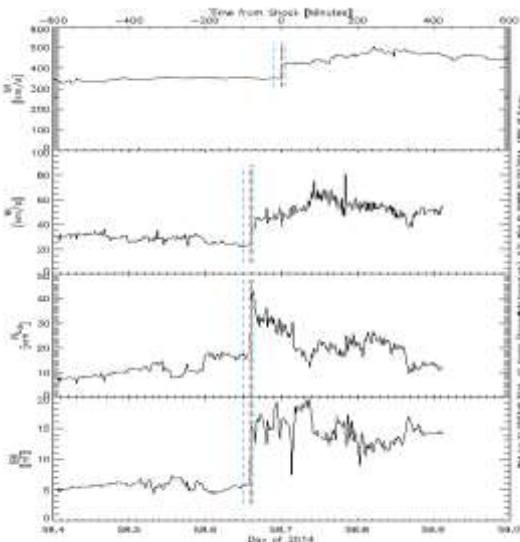


Fig. 3 (c) IP shock 15:50 UT

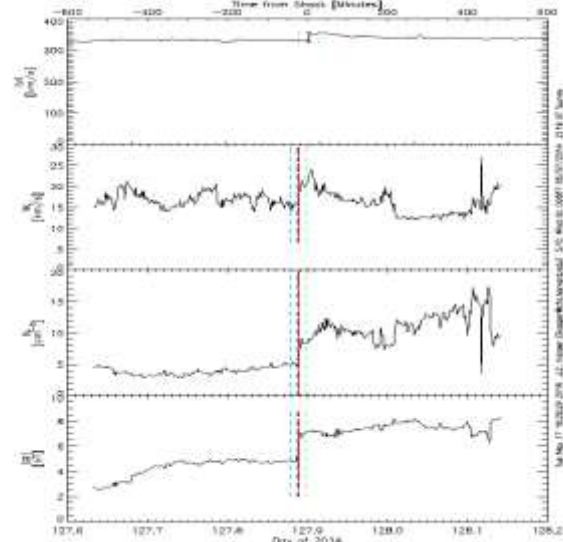


Fig. 3 (d) IP shock 21:19 UT

**Figure 3. Compare four different graph show IP (FF) shock based parameter**

Includes selecting an appropriate Galilean frame where the discontinuity is time stationary and where spacecraft observations (or time series) of density, velocity and magnetic field across a shock are obtained. It is possible to define viable quantities like the normal mass flux, the upstream and downstream asymptotic magnetofluid states, tangential stress, the normal component of the magnetic field and the normal component of the magnetic field and the tangential electric field.

**Table-2 Result analysis Interplanetary Fast Forward (FF) Shock**

S. No.	Shock appearance time (UT)	Upstream Value								
		V([km/s])			W(km/s)		Ni [n/cc]	B [nT]		
		Vx	Vy	Vz	Wi	We		Bx	By	Bz
1	16:16	-325.8 ± 7.7	-4.4 ± 5.4	-46.9 ± 2.1	15.8 ± 0.6	501.2 ± 18.5	3.8 ± 0.3	-1.4 ± 0.4	2.2 ± 0.2	3.4 ± 0.6
2	03:09	-387.8 ± 3.1	-1.6 ± 5.0	4.6 ± 1.2	23.5 ± 0.4	743.5 ± 11.3	2.4 ± 0.0	3.5 ± 0.1	-3.1 ± 0.3	-7.1 ± 0.1
3	15:50	-308.8 ± 1.1	-12.5 ± 2.1	-9.9 ± 1.3	15.4 ± 1.5	486.3 ± 48.4	13.9 ± 0.4	-1.2 ± 0.3	-2.1 ± 0.6	1.9 ± 0.3
4	21:19	-330.7 ± 0.8	7.5 ± 0.9	-5.4 ± 0.9	15.3 ± 0.6	482.9 ± 19.9	5.1 ± 0.2	1.7 ± 0.0	2.3 ± 0.2	-3.8 ± 0.2

S. No.	Shock appearance time (UT)	Downstream Value								
		V([km/s])			W(km/s)		Ni [n/cc]	B [nT]		
		Vx	Vy	Vz	Wi	We		Bx	By	Bz
1	16:16	-404.4 ± 3.6	-39.2 ± 11.3	-65.4 ± 13.3	27.1 ± 2.7	857.5 ± 85.0	8.8 ± 1.4	-4.6 ± 0.5	7.6 ± 3.0	4.9 ± 4.8
2	03:09	-474.3 ± 6.6	1.6 ± 9.7	-34.6 ± 5.7	26.6 ± 1.4	840.4 ± 45.2	3.9 ± 0.2	5.8 ± 0.4	-3.5 ± 4.0	-13.4 ± 1.0
3	15:50	-331.1 ± 2.0	-11.1 ± 3.0	-33.1 ± 1.0	20.9 ± 2.8	661.5 ± 87.8	23.6 ± 1.8	-2.0 ± 0.8	-4.8 ± 1.0	2.4 ± 1.0
4	21:19	-351.7 ± 1.1	16.3 ± 1.7	-5.2 ± 2.0	20.3 ± 0.8	641.8 ± 25.1	8.3 ± 0.6	1.4 ± 0.1	3.4 ± 0.8	-5.8 ± 0.3

There are four fundamental techniques for determining the shock normal of a single spacecraft. These include Lepping and Argentiero’s (LA) least squares method, magnetic coplanarity (MC), velocity coplanarity (VC), and Abraham-Shraener’s (AS) mixed data methods, equations for conservation. Each of these approaches makes use of a portion of the Rankine Hugoniot (RH) conservation of mass flux, normal component of the magnetic field tangential component of the momentum flux and all of the electric field’s tangential components have been received in this subset.

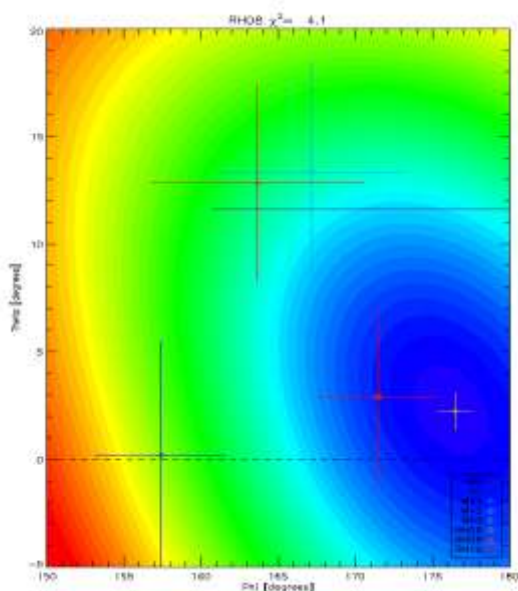


Fig. 4 (a) IP shock 16:16 UT

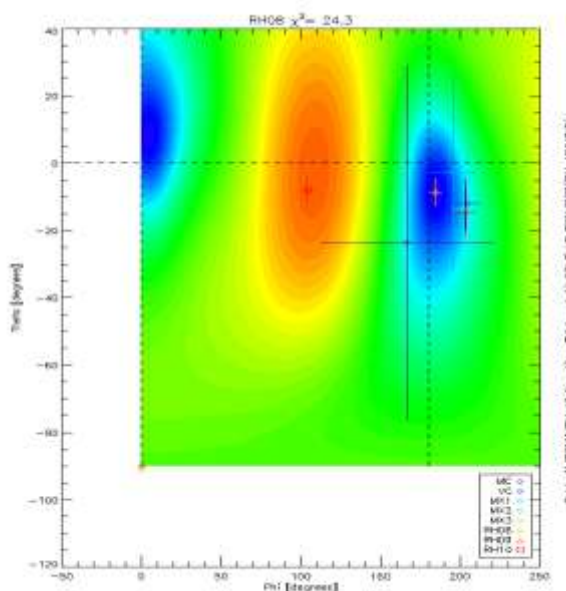


Fig. 4 (b) IP shock 03:09 UT

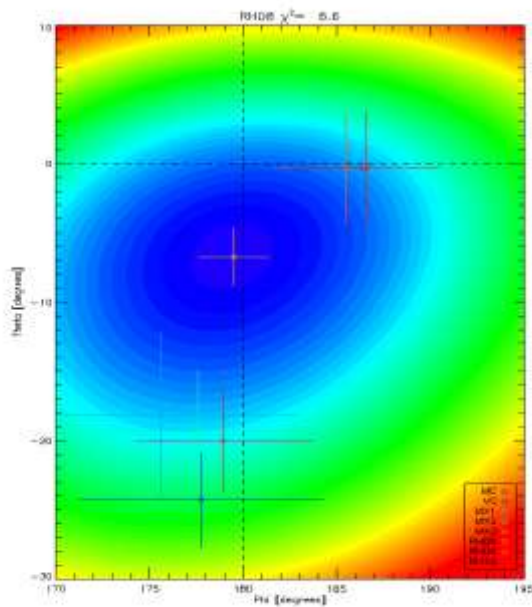


Fig. 4 (c) IP shock 15:50 UT

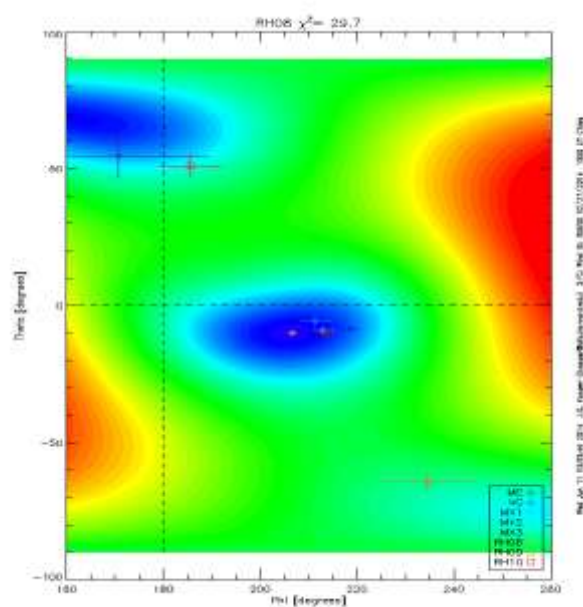


Fig. 4 (d) IP shock 21:19 UT

#### Figure-4 Compare four different bow shape quasi-parallel and quasi-perpendicular IPshock

Figure 4 show detailed plots of the plasma density in a heliocentric (R, T, N) coordinate system for a quasi-parallel and quasi-perpendicular interplanetary shock respectively along with the magnitude and components of the magnetic field and plasma bulk velocity. Figure also display a comparable plot for a planetary quasi-perpendicular bow shock in a geocentric solar ecliptic (GSE) coordinate system. The vertical lines represent the intervals chosen for the shock geometrical analysis.

#### 4. RESULT: -

1. The correlation between geomagnetic storms and coronal mass ejection rates in 77.77%. if partial halo CME is greater than halo CME the correlation rates are 51.85% for partial halo CME and 22.22% for halo CME.
2. X-ray solar flare events are 8.61% associated with geomagnetic storm, there are M- class, C-class and X-class solar flare recorded their association values are 22.22%, 37.03% and 18.05% respectively.
3. Interplanetary shocks database mostly impacts to geomagnetic storm this duration five IP shocks are observed, where only four shocks associated with geomagnetic storms. IP shocks plasma database upstream and downstream value study about shock parameter velocity, density and magnetic field intensity.

#### 5. CONCLUSION: -

In this article we study about solar maxima of solar cycle 24 observed data during 1 January 2014 to 31 December 2014, we found 27 geomagnetic storm ( $Dst \leq -30nT$ ) value, solar parameter coronal mass ejection, solar flare and interplanetary shock data which associated with Dst index value.

1. CMEs contains are massive energetic plasma where partial halo CME are more impactful than Halo CME, so we conclude that the partial halo CMEs are mainly caused of near-Earth magnetosphere.
2. X-ray solar flare their different states are found in this duration where M-class solar flare more associated than other solar flare so we conclude C-class X-ray solar flare affect geomagnetic disturbances.
3. We observed fast-forward (FF) type IP shocks which propagate outward from the Sun, these shocks are common cause of geomagnetic disturbance. This shock increased plasma parameters, enhanced magnetic field and impacts Earths magnetosphere.

## 6. ACKNOWLEDGEMENT: -

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