

Statistical Observation of Coronal Mass Ejections and Solar flares**¹Preetam Singh Gour, ²Devangana S. Chaturvedi**¹Jaipur National University, Jaipur, Rajasthan, India²Scholar of M.Sc. (Physics), Jaipur National University, Jaipur, Rajasthan, IndiaEmail- devanganachaturvedi21@gmail.com, singhpreetamsingh@gmail.com**Abstract**

The sun's atmosphere is frequently disrupted by coronal mass ejections (CMEs) coupled with different solar phenomena like geomagnetic storms, solar energetic particle and solar flare. CMEs play the important role in the root cause of weather in earth's space environment among all solar phenomena's. CMEs are considered as the major natural hazardous phenomena at the surface of sun because this event can cause several other phenomena like solar flare and many more. In this manuscript coronal mass ejection (CMEs) and solar flare events have been taken over a large time span from 1998 to 2013. There were thousands of CMEs and solar flares which were observed but under some condition that is linear speed of CMEs should be equal or greater than 500Km/Sec. On this basis numbers of selected CMEs were 357 which were associated with different types of solar flares. In order to find out the correlation between coronal mass ejections with different categories of solar flares statically, we have found that CMEs event was not recorded for A-class flares. Whereas 45, 132, 113 and 67 CMEs events were observed for B, C, M and X-class solar flares respectively. We apply the statistical model and found that coronal mass ejections (CMEs) and solar flares are correlated to each other with very strong positive correlation coefficient ($r = 0.79$) for X-class flare and strong positive correlation coefficient ($r = 0.4$) for C-class flare and no relation for B-class flares and M-class flare.

Keywords: - coronal mass ejections, Solar flares, solar magnetic cycle.**1- INTRODUCTION**

The sun is the most dominant object in solar system constitutes approximately 99.8% of total mass of the system. Most of the mass is in form of plasma. To the normal observer, the sun is constant but for a keen observer, sun is not constant. There are lots of solar phenomena which occur every minute inside sun - Solar flare and coronal mass ejection are two of them. Speed of CMEs can reach several hundreds to a few thousands kilometer per second. Solar flare can be detectable in Electromagnetic radiation ranging from radio to gamma waves. These processes occur over tens of minute to several hours. Both the phenomena have adverse effect on space weather, earth's atmosphere and

technologically by erupting the radio communication. Solar flare is an solar atmospheric activity due to sun's magnetic field first discovered or observed by [R.C. Carrington, 1860] and [R. Hodgman, 1856] on 1st September 1859 in optical light. An X-ray solar flare is a sudden flash of increased brightness on any star like sun. Coronal mass ejection is a significant release of plasma and accompanying magnetic field from the solar corona. Firstly CMEs were considered to be initiated by large solar flare Lin and Hudson, 1976]. It has been found that CMEs associated with large X-ray flares are likely to be fast and wide [Gosling et al., 1976]. The relation between coronal mass ejection (CME) and solar flare

during the 23rd solar cycle was found that the best time interval between then [detection time of the CME and the start time of its associated solar flare lies between ± 1 h. M. Youssef noticed that the energy of CME are more correlated to the X-ray flux of their associated flares during the period of high solar activity. In addition to that it is found that CMEs association rate is dominant for X-type flares [M. Youssef, 2012]. The probability of CME- flare association increases with flare duration [sheeley et al., 1983]. There are three ideas about the relationship between solar flare and CME- (1) flares produce CMEs [Dryer, 1996], (2) flares are byproduct of CMEs [Hundhausen, 1999], (3) flares and CMEs are part of the same magnetic eruption phenomena[Harrison1995][Zhang et al.,2001]. One of the result derived earlier was flare associated CMEs are faster than other CMEs [Mac Queen and Fisher, 1983].Among the 104 X-class flares that occurred during the period of 1996 to 2004, [Yuming Wang et al., 2007] found that 10% of solar flare is not associated with coronal mass ejection whereas 90% are associated with each other. There is very significant association between flare activity and CME onsets. The flares and CME are intimately coupled, yet the characteristics of the two do not have any clear relationship. Our conclusion from this is that the flare and CME do not drive one another, but are the result of same activity in the solar corona. The magnetic activities which lead to the flare event in one part of the magnetic structure, lead to an eruption of a larger scale component of the structure. In this way, the duration, intensity, location and timing of the flare need only be loosely linked to the location, velocity of ascent and timing of the CME [Yuming Wang et al., 2007]. It is found that solar flare without CMEs exist

[Yashiro et. al.2006].There is often confusion about the difference between solar flares and coronal mass ejections (CMEs). Both solar flares and CMEs are energetic events which occur on the Sun. These events are both associated with high energy particles. In the case of a CME, coronal material is ejected into space at high speeds, sometimes in the direction of Earth. Both flares and CMEs depend on magnetic fields on the Sun. The most obvious difference between a solar flare and a CME is the spatial scale on which they occur. Flares are local events as compared to CMEs which are much large eruption of the corona. Solar flares and coronal mass ejections often occur together, but each can also take in absence of the other. Solar flares and coronal mass ejections often occur together, but each can also take place in the absence of each other.

2- DATA COLLECTION

During the rising phase of solar cycles 23 and 24 that is from 1996 to 2013, more than thousands CMEs were observed by SOHO/LASCO (Solar and Heliospheric observatory/large angle spectrometric coronagraph) spacecraft LASCO has three telescope C1, C2, C3. Linear speed of CMEs should be equal or greater than 500km/sec. The CME data was collected from the SOHO/LASCO online catalogue of CMEs (http://cdaw.gsfc.nasa.gov/CME_list/index.html). X-ray solar flare data was collected from online catalogue of GOES (geostationary environmental satellite) (<http://www.ngdc.noaa.gov.stp./space-weather/solar-data/solar-features/solar-flares/x-rays/goes/xrs/>).Hence, the data was taken from these online catalogues for the further calculation that is for the calculation of correlation coefficient between solar flare and CME's.

**Table1- Complied data of coronal mass ejections and solar flares
1998**

Solar Flares				Coronal Mass Ejections			
Date	Time	type	intensity	Date	Time	speed	Type
25-Jan	14:29	C	11	25/1/1998	15:26:34	693	Halo
29-Mar	6:35	B	34	29/3/1998	3:48:28	1397	Halo
31-Mar	5:32	C	14	31/3/1998	6:12:02	1992	Halo
23-Apr	5:35	X	12	23/4/1998	5:55:22	1691	Halo
27-Apr	8:55	X	10	27/4/1998	8:56:06	1385	Halo
29-Apr	16:06	M	68	29/4/1998	16:58:54	1374	halo
01-May	22:36	M	12	05-01-98	23:40:09	585	halo
02-May	4:48	C	54	05-02-98	5:31:56	542	halo
02-May	13:31	X	11	05-02-98	14:06:12	938	halo
07-Jun	11:07	B	52	06-07-98	9:32:08	749	halo
20-Jun	20:25	B	50	20/6/1998	18:20:37	964	halo
25-Oct	13:51	C	22	25/10/1998	12:54:06	839	halo
04-Nov	7:13	C	16	11-04-98	7:54:06	523	halo
05-Nov	19:00	M	84	11-05-98	20:44:02	1118	halo
07-Nov	11:02	M	24	11-07-98	11:54:05	632	halo
24-Nov	2:07	X	10	24/11/1998	2:30:05	1798	halo
26-Nov	4:37	C	18	26/11/1998	3:54:05	1505	halo
18-Dec	17:13	M	80	18/12/1998	18:09:47	1749	halo
1999							
24-Apr	12:26	B	52	24/4/1999	13:31:15	1495	halo
03-May	5:36	M	44	05-03-99	6:06:05	1584	halo
10-May	5:22	M	25	05-10-99	5:50:05	920	halo
27-May	11:36	C	45	27/5/1999	11:06:05	1691	halo
01-Jun	18:53	C	12	06-01-99	19:37:35	1772	halo
04-Jun	2:46	C	0:00	06-04-99	0:50:06	803	halo
22-Jun	17:37	M	17	06-08-99	21:50:05	726	halo
23-Jun	6:49	M	17	22/6/1999	18:54:05	1133	halo
24-Jun	12:04	C	41	23/6/1999	7:31:24	1006	halo
26-Jun	7:14	C	70	24/6/1999	13:31:24	975	halo
28-Jun	12:13	C	16	26/6/1999	7:31:25	558	halo
29-Jun	6:24	C	30	28-06-99	12:06:07	560	halo
29-Jun	19:07	M	16	29/6/1999	7:31:26	634	halo
06-Jul	20:18	C	21	28/6/1999	12:06:07	560	halo
25-Jul	13:08	M	24	29/6/1999	7:31:26	634	halo
20-Sep	5:46	C	28	29/6/1999	19:54:07	560	halo
14-Oct	8:54	X	18	07-06-99	17:06:05	899	halo
06-Dec	9:40	C	12	25/7/1999	13:31:21	1389	halo
20-Dec	19:50	C	15	20/9/1999	6:05:05	604	halo
22-Dec	1:50	M	18	14/10/1999	9:26:05	1250	halo

22-Dec	18:52	M	53	12-06-99	9:30:08	653	halo
				12-12-99	8:30:05	720	halo
				20/12/1999	18:06:05	1237	halo
				22/12/1999	2:30:05	570	halo
				22/12/1999	19:31:22	605	halo
2000							
18-Jan	17:07	M	39	18/1/2000	17:54:05	739	halo
28-Jan	19:45	C	47	27/1/2000	19:31:17	828	halo
03-Feb	12:01	C	12	28/1/2000	20:12:41	1177	halo
08-Feb	8:42	M	13	02-03-00	12:30:05	735	halo
09-Feb	19:15	C	74	02-08-00	9:30:05	1079	halo
10-Feb	1:40	C	73	02-09-00	19:54:17	910	halo
11-Feb	12:25	C	23	02-10-00	2:30:05	944	halo
12-Feb	3:51	M	17	02-11-00	13:31:25	521	halo
17-Feb	20:17	M	13	02-12-00	4:31:20	1107	halo
29-Mar	11:14	C	18	17/2/2000	21:30:08	728	halo
04-Apr	15:12	C	97	03-01-00	30-03-05	529	halo
23-Apr	13:14	C	27	29/3/2000	10:54:30	949	halo
03-May	2:14	B	88	04-04-00	16:32:37	1188	halo
05-May	15:19	M	15	23/4/2000	12:54:05	1187	halo
12-May	23:23	M	10	05-03-00	2:06:05	693	halo
22-May	1:20	C	63	05-05-00	15:50:05	1594	halo
06-Jun	14:58	X	23	05-07-00	20:50:07	1781	halo
07-Jun	15:34	X	12	05-12-00	23:26:05	2604	halo
10-Jun	16:40	M	52	22/5/2000	1:50:05	649	halo
11-Jul	12:12	X	1	06-06-00	15:54:05	1119	halo
14-Jul	10:03	X	57	06-07-00	16:30:05	842	halo
25-Jul	2:43	M	80	06-10-00	17:08:05	1108	halo
12-Sep	11:31	M	10	07-11-00	13:27:23	1078	halo
12-Sep	5:36	B	98	14/7/2000	10:54:07	1674	halo
16-Sep	4:06	M	59	25/7/2000	3:30:05	528	halo
25-Sep	2:05	M	18	27/7/2000	19:54:06	905	halo
02-Oct	2:48	C	41	08-09-00	16:30:05	702	halo
02-Oct	19:57	C	84	09-12-00	11:54:05	1550	halo
16-Oct	6:40	M	25	09-12-00	17:30:05	1053	halo
24-Oct	8:04	C	23	16/9/2000	5:18:14	1215	halo
25-Oct	8:45	C	40	25/9/2000	2:50:05	587	halo
15-Nov	22:15	C	30	10-02-00	3:50:05	525	halo
24-Nov	4:55	X	20	10-02-00	20:26:05	569	halo
24-Nov	14:51	X	23	10-10-00	0:26:05	506	halo
24-Nov	21:42	X	18	16/10/2000	7:27:21	1336	halo
25-Nov	0:59	M	82	24/10/2000	8:26:05	800	halo
25-Nov	9:06	M	35	25/10/2000	8:26:05	770	halo
25-Nov	18:33	X	19	11-01-00	16:28:08	801	halo

26-Nov	16:34	X	40	15/11/2000	23:54:05	826	halo
13-Dec	16:58	C	11	24/11/2000	5:30:05	1289	halo
14-Dec	18:24	C	14	24/11/2000	15:30:05	1245	halo
18-Dec	11:03	C	70	24/11/2000	22:06:05	1005	halo
28-Dec	13:20	C	27	25/11/2000	1:31:58	2519	halo
				25/11/2000	9:30:17	675	halo
				25/11/2000	19:31:57	671	halo
				26/11/2000	17:06:05	725	halo
				13/12/2000	16:26:05	1067	halo
				14/12/2000	17:06:05	725	halo
				18/12/2000	11:50:05	510	halo
				28/12/2000	12:06:05	930	halo
2001							
05-Jan	18:23	C	68	01-05-01	17:06:05	828	halo
20-Jan	18:33	M	12	01-10-01	54:05:00	832	halo
20-Jan	21:06	M	77	20/1/2001	19:31:50	839	halo
28-Jan	15:40	M	15	20/1/2001	21:30:08	1507	halo
10-Feb	5:31	C	14	28/1/2001	15:54:05	916	halo
11-Feb	0:57	C	65	02-10-01	5:54:05	956	halo
15-Feb	13:08	B	88	02-11-01	1:31:48	1183	halo
18-Mar	4:21	B	58	15/2/2001	13:54:05	625	halo
24-Mar	19:35	M	17	18/3/2001	2:26:05	752	halo
25-Mar	16:25	C	90	24/3/2001	20:50:05	906	halo
28-Mar	11:21	M	43	25/3/2001	17:06:05	677	halo
29-Mar	9:57	X	17	28/3/2001	12:50:05	519	halo
01-Apr	10:55	M	55	29/3/2001	10:26:05	942	halo
05-Apr	16:57	M	51	04-01-01	11:26:06	1475	halo
06-Apr	19:10	X	56	04-05-01	17:06:05	1390	halo
09-Apr	15:20	M	79	04-06-01	19:30:02	1270	halo
10-Apr	5:06	X	23	04-09-01	15:54:02	1192	halo
11-Apr	12:56	M	23	04-10-01	5:30:00	2411	halo
12-Apr	9:39	X	20	04-11-01	13:31:48	1103	halo
18-Apr	2:11	C	22	04-12-01	10:31:29	1184	halo
26-Apr	11:26	M	78	18/4/2001	2:30:05	2465	halo
15-Jun	16:15	C	22	26/4/2001	12:30:05	1006	halo
20-Jun	19:01	C	23	15/6/2001	15:56:27	1701	halo
24-Jun	7:22	C	31	20/6/2001	19:54:05	1407	halo
25-Aug	16:43	X	0:00	24/6/2001	7:31:52	1094	halo
11-Sep	14:01	C	32	15/8/2001	23:54:05	1575	halo
24-Sep	9:32	X	26	19/8/2001	6:06:05	556	halo
28-Sep	8:10	M	33	25/8/2001	16:50:05	1433	halo
01-Oct	4:41	M	91	09-11-01	14:54:05	791	halo
05-Oct	11:31	C	19	24/9/2001	10:30:59	2402	halo
09-Oct	10:46	M	14	28/9/2001	8:54:34	846	halo

19-Oct	16:13	X	16	10-01-01	5:30:05	1405	halo
22-Oct	14:27	M	67	10-05-01	10:30:27	1537	halo
25-Oct	14:42	X	13	10-09-01	11:30:05	973	halo
04-Nov	16:03	X	10	19/10/2001	16:50:05	901	halo
17-Nov	4:49	M	28	20/10/2001	2:26:05	764	halo
21-Nov	12:07	C	47	22/10/2001	15:06:05	1336	halo
22-Nov	22:32	M	99	25/10/2001	15:25:05	1092	halo
28-Nov	19:42	C	17	11-04-01	16:35:06	1810	halo
13-Dec	14:20	X	62	17/11/2001	5:30:06	1397	halo
14-Dec	8:40	M	35	18/11/2002	21:30:08	888	halo
25-Dec	11:30	C	54	21/11/2001	14:06:05	518	halo
28-Dec	20:02	X	34	22/11/2001	23:30:05	1437	halo
				28/11/2001	17:30:06	500	halo
				13/12/2001	14:54:06	864	halo
				14/12/2001	9:06:06	1506	halo
				25/12/2001	11:30:05	1773	halo
				28/12/2001	20:30:05	2216	halo
				13/12/2001	14:54:06	864	halo
				14/12/2001	9:06:06	1506	halo
				25/12/2001	11:30:05	1773	halo
				28/12/2001	20:30:05	2216	halo
2002							
04-Jan	9:24	C	37	01-01-02	18:30:33	900	halo
08-Jan	18:14	C	96	01-04-02	9:30:05	896	halo
14-Jan	5:29	M	44	01-08-02	17:54:05	1794	halo
20-Feb	5:52	M	51	14/1/2002	5:35:07	1492	halo
10-Mar	22:21	M	23	27/1/2002	12:30:05	1136	halo
11-Mar	22:48	C	30	16/2/2002	6:30:05	1209	halo
14-Mar	16:44	C	49	20/2/2002	6:30:05	952	halo
15-Mar	22:09	M	22	03-10-02	23:06:55	1492	halo
18-Mar	2:16	M	10	03-11-02	23:30:05	950	halo
20-Mar	15:44	C	40	14/3/2002	17:06:06	907	halo
22-Mar	10:12	M	16	15/3/2002	23:06:06	957	halo
15-Apr	3:05	M	12	18/3/2002	2:54:06	989	halo
17-Apr	7:46	M	26	20/3/2002	17:54:05	603	halo
21-Apr	0:43	X	15	22/3/2002	11:06:05	1750	halo
06-May	13:29	C	17	15/4/2002	3:50:05	720	halo
07-May	3:37	M	14	17/4/2002	8:26:05	1240	halo
08-May	12:58	C	42	21/4/2002	1:27:20	2393	halo
16-May	0:11	C	45	05-06-02	13:50:05	627	halo
22-May	3:18	C	50	05-07-02	4:06:05	720	halo
28-May	16:29	C	36	05-08-02	13:50:05	614	halo
09-July	15:11	C	12	16/5/2002	0:50:05	600	halo
15-July	19:59	X	30	22/5/2002	3:50:05	1557	halo

16-July	13:31	C	85	28/5/2002	16:26:05	1244	halo
18-July	8:15	C	16	06-05-02	12:43:35	991	halo
18-July	19:52	C	21	07-09-02	19:31:48	1076	halo
19-July	16:46	C	39	15/7/2002	20:30:05	1151	halo
20-July	21:04	X	33	16/7/2002	16:02:58	1636	halo
23-July	0:18	X	48	18/7/2002	8:06:08	1099	halo
26-July	22:03	M	53	18/7/2002	19:31:47	2191	halo
16-Aug	11:32	M	52	19/7/2002	16:30:05	2047	halo
22-Aug	1:47	M	54	20/7/2002	22:06:09	1941	halo
24-Aug	0:49	X	31	23/7/2002	0:42:05	2285	halo
05-Sep	16:18	C	52	26/7/2002	22:06:10	818	halo
06-Sep	12:16	C	20	16/8/2002	12:30:05	1585	halo
14-Oct	14:19	C	13	22/8/2002	2:06:06	998	halo
18-Oct	19:14	C	41	24/8/2002	1:27:19	1913	halo
25-Oct	9:15	B	94	09-05-02	16:54:06	1748	halo
25-Oct	16:33	C	16	09-06-02	13:31:49	909	halo
26-Oct	3:19	C	28	14/10/2002	14:54:05	1694	halo
27-Oct	21:53	C	43	18/10/2002	18:54:05	640	halo
09-Nov	13:08	M	46	25/10/2002	10:06:05	629	halo
16-Nov	6:32	C	19	25/10/2002	15:06:05	870	halo
24-Nov	20:14	C	64	26/10/2002	7:27:15	846	halo
02-Dec	16:42	B	77	27/10/2002	23:18:13	2115	halo
08-Dec	23:18	C	25	11-09-02	13:31:45	1838	halo
19-Dec	21:34	M	27	16/11/2002	7:12:05	1185	halo
				24/11/2002	20:30:05	1077	halo
				12-02-02	17:54:05	867	halo
				12-08-02	23:54:05	1339	halo
				19/12/2002	23:06:05	1092	halo
2003							
18-Mar	11:51	X	15	18-03-03	13:54:05	1042	halo
19-Mar	2:30	C	34	19/3/2003	2:30:05	1342	halo
27-May	5:06	M	16	27/5/2003	6:50:05	509	halo
27-May	22:56	X	13	27/5/2003	23:50:05	964	halo
28-May	0:17	X	36	28/5/2003	0:50:05	1366	halo
29-May	0:51	X	12	29/5/2003	1:27:12	1237	halo
31-May	2:13	M	93	31/5/2003	2:30:19	1835	halo
10-Jun	8:34	M	27	06-10-03	6:30:05	525	halo
15-Jun	23:25	X	13	15/6/2003	23:54:05	2053	halo
17-Jun	22:27	M	68	17/6/2003	23:18:14	1813	halo
03-Aug	2:20	C	25	08-03-03	0:30:05	699	halo
18-Oct	14:48	C	33	21/9/2003	8:30:05	554	halo
21-Oct	3:19	C	79	21/9/2003	20:59:17	646	halo
28-Oct	9:51	X	172	18/10/2003	15:30:21	627	halo
29-Oct	20:37	X	100	21/10/2003	3:54:05	1484	halo

02-Nov	17:03	X	83	28/10/2003	11:30:05	2459	halo
04-Nov	19:29	X	280	29/10/2003	20:54:05	2029	halo
04-Nov	11:15	C	57	11-02-03	9:30:05	2036	halo
06-Nov	17:24	B	58	11-02-03	17:30:05	2598	halo
07-Nov	15:17	B	47	11-04-03	12:06:06	1208	halo
09-Nov	0:18	B	38	11-04-03	19:54:05	2657	halo
11-Nov	13:21	M	16	11-06-03	17:30:05	1523	halo
12-Nov	9:28	C	18	11-07-03	15:54:05	2237	halo
18-Nov	8:12	M	39	11-09-03	6:30:05	2008	halo
20-Nov	7:25	C	38	11-11-03	2:30:07	1359	halo
				11-11-03	13:54:05	1315	halo
				11-12-03	10:54:06	1197	halo
				18/11/2003	8:50:05	1660	halo
				20/11/2003	8:06:05	669	halo
2004							
21-Jan	4:02	C	12	20/1/2004	0:06:05	965	halo
06-Apr	12:08	M	13	21/1/2004	4:54:05	762	halo
08-Apr	8:13	B	66	26/1/2004	15:30:05	879	halo
23-May	10:19	B	34	04-06-04	13:31:43	1368	halo
07-Jun	2:36	B	50	04-08-04	10:30:19	1068	halo
13-July	8:40	M	54	04-11-04	11:54:05	1132	halo
20-July	12:22	M	86	23/5/2004	11:06:06	988	halo
23-July	16:03	C	10	06-07-04	0:50:05	723	halo
25-July	14:19	M	11	07-02-04	5:00:05	892	halo
29-July	11:42	C	21	07-05-04	23:06:05	1444	halo
08-Aug	9:50	B	38	07-06-04	20:06:06	1307	halo
12-Sep	0:04	M	48	13/7/2004	9:30:05	747	halo
30-Oct	16:18	M	59	20/7/2004	13:31:52	710	halo
03-Nov	16:53	C	38	23/7/2004	16:06:06	824	halo
04-Nov	8:45	C	63	25/7/2004	14:54:05	1333	halo
06-Nov	1:40	M	36	29/7/2004	12:06:05	1180	halo
07-Nov	15:42	X	20	08-08-04	8:54:05	1004	halo
09-Nov	16:59	M	89	09-03-04	0:30:05	751	halo
10-Nov	1:59	X	25	09-03-04	10:30:18	737	halo
08-Dec	19:34	C	25	09-04-04	6:54:05	1067	halo
30-Dec	21:30	B	28	09-12-04	0:36:06	1328	halo
				30/10/2004	16:54:05	690	halo
				11-03-04	16:06:05	1068	halo
				11-04-04	9:54:05	653	halo
				11-06-04	1:31:51	818	halo
				11-07-04	16:54:05	1759	halo
				11-09-04	17:26:06	2000	halo
				11-10-04	2:26:05	3387	halo
				12-03-04	0:26:05	1216	halo

				12-08-04	20:26:05	611	halo
				15/12/2004	17:36:05	621	halo
				30/12/2004	22:30:05	1035	halo
2005							
01-Jan	0:01	X	17	01-05-05	15:30:06	735	halo
15-Jan	5:54	M	86	15/1/2005	6:30:05	2049	halo
15-Jan	22:25	X	26	15/1/2005	23:05:50	2861	halo
19-Jan	8:03	X	13	17/1/2005	9:30:05	2094	halo
20-Jan	6:36	X	71	17/1/2005	9:54:05	2547	halo
19-Apr	21:41	B	80	19/1/2005	8:29:39	2020	halo
01-May	0:34	B	53	20/1/2005	6:54:05	882	halo
02-May	5:18	B	95	02-01-05	11:06:07	1380	halo
05-May	20:09	C	78	17/2/2005	0:06:05	1135	halo
06-May	16:03	C	85	19/4/2005	22:06:05	834	halo
10-May	16:06	C	11	05-01-05	0:50:05	634	halo
11-May	19:22	M	11	05-02-05	5:26:06	689	halo
13-May	16:13	M	80	05-05-05	20:30:05	1180	halo
26-May	13:10	B	75	05-06-05	17:28:31	1128	halo
03-Jun	11:51	M	10	05-10-05	16:06:05	609	halo
14-Jun	6:54	C	42	05-11-05	20:13:08	550	halo
28-Jun	15:34	B	17	13/5/2005	17:12:05	1689	halo
05-Jul	14:52	C	13	26/5/2005	15:06:05	586	halo
07-Jul	16:07	M	49	06-03-05	12:32:10	1679	halo
14-Jul	10:16	X	12	14/6/2005	7:24:05	791	halo
17-Jul	10:25	B	11	25/6/2005	8:06:05	852	halo
26-Jul	4:49	B	18	28/6/2005	17:06:05	1303	halo
27-Jul	4:33	M	37	07-05-05	15:30:05	772	halo
30-Jul	6:17	X	13	07-07-05	17:06:07	683	halo
22-Aug	0:44	M	26	14/7/2005	10:54:05	2115	halo
22-Aug	16:46	M	56	17/7/2005	11:30:05	1527	halo
23-Aug	14:19	M	27	21/7/2005	3:54:05	925	halo
29-Aug	10:59	B	82	22/7/2005	23:54:05	527	halo
31-Aug	10:26	C	20	24/7/2005	11:30:07	1258	halo
31-Aug	22:58	B	21	24/7/2005	13:54:05	2528	halo
02-Sep	11:23	B	19	24/7/2005	22:30:05	1234	halo
03-Sep	4:05	B	61	25/7/2005	11:06:05	1660	halo
05-Sep	8:53	C	27	26/7/2005	4:54:29	1458	halo
09-Sep	9:42	X	36	27/7/2005	4:54:05	1787	halo
10-Sep	21:30	X	21	30/7/2005	6:50:28	1968	halo
11-Sep	12:44	M	30	22/8/2005	1:31:48	1194	halo
13-Sep	19:19	X	15	22/8/2005	17:30:05	2378	halo
				23/8/2005	14:54:05	1929	halo
				29/8/2005	10:54:05	1600	halo

				31/8/2005	11:30:05	825	halo
				31/8/2005	22:30:05	1808	halo
				09-02-05	0:30:05	1384	halo
				09-03-05	3:12:05	1672	halo
				09-05-05	9:48:05	2326	halo
				09-09-05	19:48:05	2257	halo
				09-10-05	21:52:07	1893	halo
				09-11-05	13:00:53	1922	halo
				13/9/2005	20:00:05	1866	halo
				12-07-05	19:12:05	673	halo
2006							
30-Apr	9:13	C	18	30/4/2006	9:54:04	544	halo
07-Jun	8:50	B	53	07-06-06	8:54:04	911	halo
16-Aug	8:12	B	34	16/8/2006	7:31:43	563	halo
16-Aug	14:37	C	36	16/8/2006	16:30:04	888	halo
06-Nov	17:43	C	88	11-06-06	17:54:04	1994	halo
13-Dec	2:14	X	34	13/12/2006	2:54:04	1774	halo
14-Dec	21:07	X	15	14/12/2006	22:30:04	1042	halo
2007							
no data				19-01-07	4:30:04	562	halo
				25/1/2007	6:54:04	1367	halo
				30/7/2007	4:54:04	563	halo
2008							
no data							
2009							
no data							
2010							
12-Feb	12:42	B	89	02-12-10	13:42:04	509	halo
04-Mar	8:01	B	20	04-03-10	10:33:58	668	halo
01-Aug	16:06	B	45	08-01-10	13:42:05	850	halo
07-Aug	17:55	M	10	08-07-10	18:36:06	871	halo
14-Aug	9:38	C	44	14/8/2010	10:12:05	1205	halo
31-Aug	21:50	B	14	31/8/2010	21:17:21	1304	halo
14-Dec	15:03	C	23	14/12/2010	15:36:05	835	halo
2011							
15-Feb	1:44	X	22	15/2/2011	2:24:05	669	halo
07-Mar	19:43	M	37	03-07-11	20:00:05	2125	halo
02-May	7:13	B	47	21/3/2011	2:24:05	1341	halo
13-Jun	6:12	B	97	26/3/2011	6:24:05	699	halo

21-Jun	1:22	C	77	05-02-11	8:12:06	976	halo
03-Aug	13:17	M	60	06-04-11	6:48:06	1407	halo
04-Aug	3:45	M	93	06-04-11	22:05:02	2425	halo
06-Sep	22:12	X	21	06-07-11	6:49:12	1255	halo
06-Sep	3:19	M	25	06-07-11	19:16:26	738	halo
22-Sep	10:29	X	14	13/6/2011	4:24:06	957	halo
24-Sep	19:09	M	30	21/6/2011	3:16:10	719	halo
24-Sep	12:33	M	71	08-03-11	14:00:07	610	halo
22-Oct	10:01	M	13	08-04-11	4:12:05	1315	halo
03-Nov	23:28	M	21	08-09-11	8:12:06	1610	halo
04-Nov	0:26	C	54	09-06-11	2:24:05	782	halo
09-Nov	13:04	M	11	09-06-11	23:05:57	675	halo
13-Nov	20:12	C	11	22/9/2011	10:48:06	1905	halo
20-Nov	22:59	C	21	24/9/2011	12:48:07	1915	halo
26-Nov	8:01	C	15	24/9/2011	19:36:06	972	halo
07-Dec	9:06	B	88	10-01-11	20:48:05	1238	halo
21-Dec	2:57	C	31	10-04-11	13:25:51	1101	halo
				22/10/2011	1:25:53	593	halo
				22/10/2011	10:24:05	1005	halo
				27/10/2011	12:00:06	570	halo
				11-03-11	23:30:05	991	halo
				11-04-11	1:25:29	756	halo
				11-09-11	13:36:05	907	halo
				13/11/2011	18:36:05	596	halo
				17/11/2011	20:36:05	1041	halo
				20/11/2011	23:12:06	641	halo
				26/11/2011	7:12:06	933	halo
				12-07-11	9:36:05	713	halo
				21/12/2011	3:12:10	1064	halo
2012							
02-Jan	14:31	C	24	01-02-12	15:12:40	1138	halo
12-Jan	7:54	C	25	01-12-12	8:24:05	814	halo
19-Jan	13:44	M	32	16/1/2012	3:12:10	1060	halo
26-Jan	3:58	C	64	19/1/2012	14:36:05	1120	halo
27-Jan	17:37	X	17	23/1/2012	4:00:05	2175	halo
09-Feb	22:01	B	75	26/1/2012	4:36:05	1194	halo
10-Feb	23:21	B	84	27/1/2012	18:27:52	2508	halo
04-Mar	10:29	M	20	02-09-12	21:17:36	659	halo
05-Mar	2:30	X	11	02-10-12	20:00:05	533	halo
07-Mar	0:02	X	54	16/2/2012	6:36:05	538	halo
07-Mar	1:05	X	13	23/2/2012	8:12:06	505	halo
09-Mar	3:22	M	63	03-04-12	11:00:07	1306	halo
10-Mar	17:15	M	84	03-05-12	4:00:05	1531	halo

13-Mar	17:12	M	79	03-07-12	0:24:06	2648	halo
18-Mar	2:28	C	19	03-07-12	1:30:24	1825	halo
21-Mar	6:32	B	95	03-09-12	4:26:09	950	halo
05-May	20:49	C	15	03-10-12	18:00:05	1296	halo
07-May	16:59	C	24	13/3/2012	17:36:05	1884	halo
31-Aug	19:45	C	84	18/3/2012	0:24:05	1210	halo
19-Sep	10:27	B	39	21/3/2012	7:36:05	1178	halo
16-Nov	6:41	C	14	24/3/2012	0:24:05	1152	halo
20-Nov	12:36	M	17	26/3/2012	23:12:05	1390	halo
21-Nov	6:45	M	14	28/3/2012	1:36:07	1033	halo
21-Nov	15:10	M	35	04-07-12	16:48:05	765	halo
23-Nov	12:06	C	12	25/8/2012	16:36:05	636	halo
23-Nov	23:36	C	10	31/8/2012	20:00:05	1442	halo
27-Nov	2:10	C	59	09-02-12	4:00:06	538	halo
12-Dec	18:35	B	79	09-08-12	10:00:06	734	halo
				19/9/2012	11:36:06	616	halo
				20/9/2012	5:48:06	633	halo
				20/9/2012	15:12:10	1202	halo
				21/9/2012	6:24:05	639	halo
				27/9/2012	10:12:05	1219	halo
				28/9/2012	0:12:05	947	halo
				28/9/2012	10:36:05	768	halo
				29/9/2012	0:12:05	755	halo
				14/10/2012	0:48:05	987	halo
				11-08-12	2:36:06	855	halo
				11-08-12	11:00:08	972	halo
				16/11/2012	0:48:06	667	halo
				16/11/2012	7:24:14	775	halo
				20/11/2012	12:00:07	619	halo
				21/11/2012	4:24:07	920	halo
				21/11/2012	16:00:05	529	halo
				23/11/2012	13:48:06	519	halo
				23/11/2012	23:24:05	1186	halo
				27/11/2012	2:36:05	844	halo
				12-02-12	16:36:05	678	halo
2013							
05-Mar	1:51	B	52	26/2/2013	9:12:08	978	halo
15-Mar	5:46	M	11	03-05-13	3:48:05	1316	halo
11-Apr	6:55	M	65	15/3/2013	7:12:05	1063	halo
21-Apr	7:30	C	13	04-11-13	7:24:06	861	halo
24-Apr	0:17	C	14	21/4/2013	7:24:07	919	halo
24-Apr	22:39	C	16	24/4/2013	0:48:05	699	halo
13-May	1:53	X	17	24/4/2013	22:12:06	594	halo

13-May	15:48	X	28	05-01-13	3:12:08	762	halo
14-May	0:00	X	32	13/5/2013	2:00:05	1270	halo
15-May	1:25	X	12	13/5/2013	16:07:55	1850	halo
17-May	8:43	M	32	14/5/2013	1:25:51	2625	halo
22-May	13:08	M	50	15/5/2013	1:48:05	1366	halo
13-Jun	4:28	B	45	17/5/2013	9:12:10	1346	halo
28-Jun	1:36	C	44	22/5/2013	13:25:50	1466	halo
17-Aug	18:49	M	14	13/6/2013	4:24:07	763	halo
19-Aug	21:58	C	10	24/6/2013	4:00:05	709	halo
20-Aug	9:57	C	16	28/6/2013	2:00:05	1037	halo
30-Aug	2:04	C	83	22/7/2013	6:24:05	1004	halo
04-Sep	12:12	B	73	17/8/2013	19:12:06	1202	halo
24-Sep	22:50	C	11	19/8/2013	23:12	877	halo
07-Dec	7:17	M	12	29/10/2013	22:00:06	1001	halo
13-Dec	22:55	C	12	11-02-13	4:48:05	828	halo
28-Dec	17:53	C	93	11-04-13	5:12:05	1040	halo
				11-07-13	0:00:06	1033	halo
				11-07-13	10:36:05	1405	halo
				11-10-13	17:00:06	532	halo
				19/12/2013	10:36:05	740	halo
				12-07-13	7:36:05	1085	halo
				13/12/2012	21:24:05	518	halo
				26/12/2013	3:24:05	1336	halo
				28/12/2013	17:36:06	1118	halo

3- RESULT ANALYSIS AND DISCUSSION

We study the linear relationship between the intensity of X-ray solar flares and speed of coronal mass ejection (CME). There are thousands of CMEs associated with solar flare in the period 1998 to 2013. The relation between coronal mass ejection and intensity of solar flares which is calculated here is during 23rd solar magnetic cycle (1998 to 2013). We have selected those CMEs events whose velocity will be equal or greater than 500km/sec. we have no observed CMEs events for 2008 & 2009. For this time span (1998-2013) we have found 357 coronal mass ejections (CMEs) events which were associated with different categories of x-ray solar flares (A, B, C, M, & X). On further categorization 45, 132, 113 and 67 CMEs events were observed for B, C, M and X-class solar flares respectively but

for A-class flare no CMEs were observed. The relation between flares and CMEs are positive as well as negative. There are total five types of solar flares A, B, C, M, & X. when speed of CMEs are correlated by intensity of solar flares via correlation coefficient whose value vary from -1 to +1. The value of r shows an important result Correlation coefficients [Karl Pearson, 1896] are used in statistics to measure how strong a relationship is between two variables. A correlation coefficient of 1 means that for every positive increase in one variable, there is a positive increase of a fixed proportion in the other. A correlation coefficient of -1 means that for every positive increase in one variable, there is a negative decrease of a fixed proportion in the other. Zero means that for every increase, there isn't a positive or negative increase. The two just aren't related.

Speeds of CME's are taken above 500km/sec and intensity of different types

of solar flares is taken and correlated separately with CMEs.

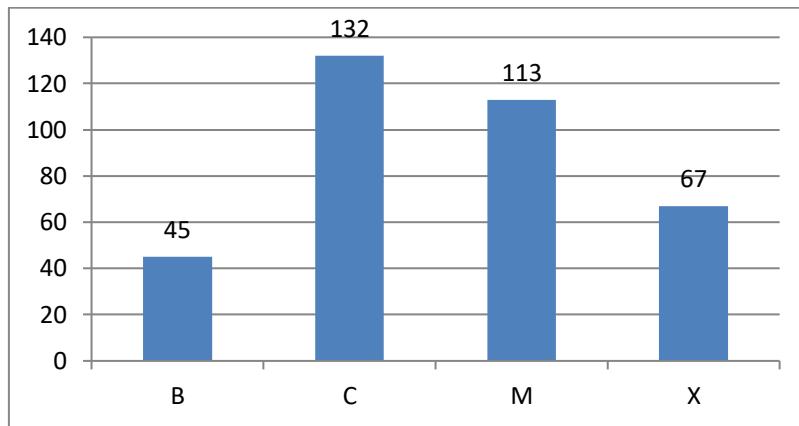


Figure-1: Bar graph number of solar flare vs type of flare

Graph shown above is a bar graph where y- axis shows the number of counts that is number of solar flares found in the period of 1998 to 2013. Numbers of flare are 45,132,113 and 67 for B-class, C-class, M-class and X-class respectively. C- Class flare found maximum in this period that is 132 CMEs events are associated with this.

Some of the conclusion drawn from theoretical, experimental and mathematical data's (above or equal to 500 km/sec) is such as-

- A class solar flare were found so rarely and those who found do not relate with coronal mass ejections for the velocity $>500\text{km/sec}$. so in this observation class A are kind of excluded or we can say A class solar flare have no relation between flare intensity and speed.
- B class solar flare shows no relation. So, the probability of their dependence is low we can't say that there is any relation between intensity and speed one of the phenomena occur then there is no possibility second one will also occur. There is no relation the value is low that is approx. 0.003 so there is no relation. In figure-2 X-axis shows speed of coronal mass ejection and Y- axis shows intensity of solar flare.

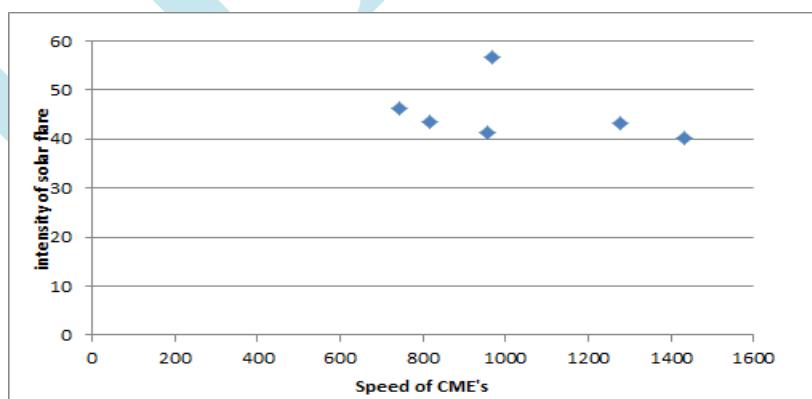


Figure-2: Scatter plot for B-class solar flare with correlation coefficient 0.003

- C class solar flare shows strong positive correlation means there is a relation between solar flare type C and CMEs speed above and equal to 500km/sec. They are dependent on each other or we can say there is strong probability of occurrences of them together. The value of correlation coefficient is 0.40. In the scatter plot (Figure-

3) X- Axis shows speed of coronal mass ejection and Y-axis shows intensity of solar flare.

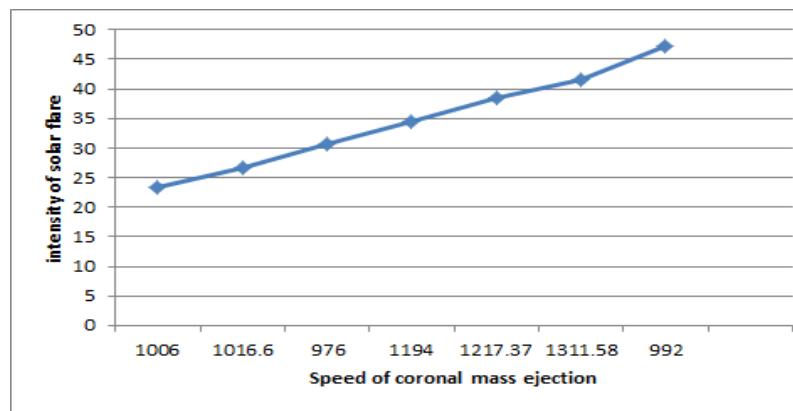


Figure-3: Scatter plot for C-class flare with correlation coefficient 0.40

- M class solar flare shows no relation between which means solar flare and speed of CME's shows no relationship or we can say there is no relation between these factors. The value of correlation coefficient 0.0074. In the scatter plot (Figure-4) X- Axis shows speed of coronal mass ejection and Y- axis shows intensity of solar flare.

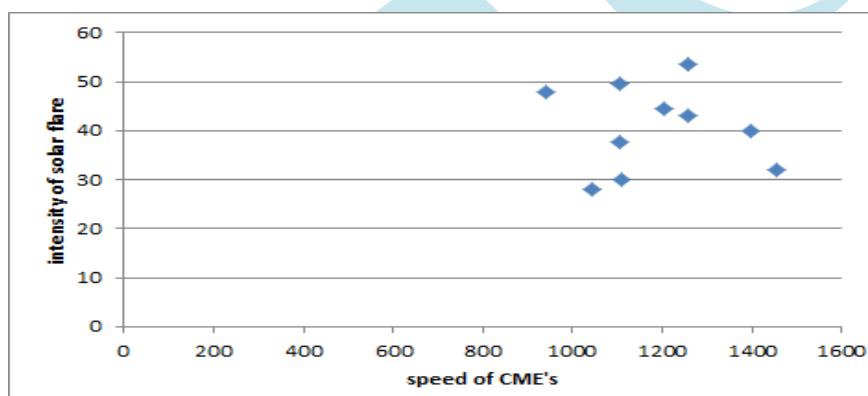


Figure-4: Scatter plot for M-class flare with correlation coefficient 0.0074

- X class solar flare shows strong positive correlation which means they are dependent or we can conclude occurrences of these flares with CMEs speed above or equal to 500km/sec. the value of correlation coefficient between these two events is 0.79.

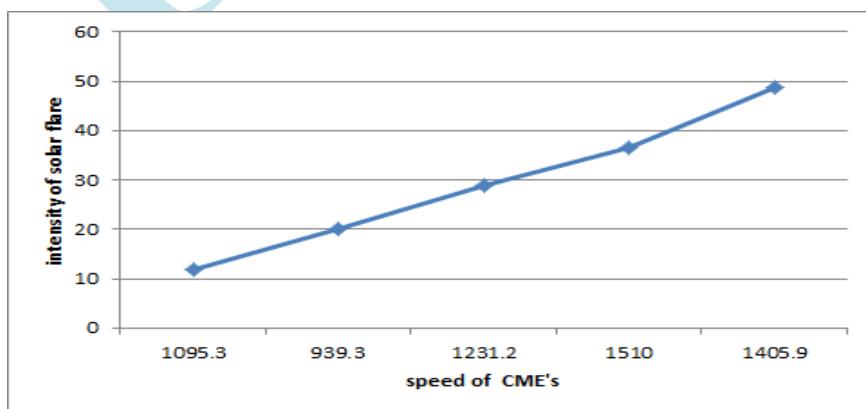


Figure-5: Scatter plot for X-class flare with correlation coefficient 0.79

The study of graph of these flares and the parameters are flare intensity versus speed of coronal mass ejection per year. These are the scatter plot of different type of solar flare. Different type of flare shows different relationship and the correlation coefficient are different for different type of flares.

ACKNOWLEDGEMENT

I am very thanking full to the SOHO/LASCO, NOAA and solar geophysical data report for making the data freely available. I am very thankful to my guide Dr. Preetam Singh Gour for his valuable guidance and encouragement throughout the writing of this paper.

4- REFERENCES

- i. Carrington R.C. (1860). Monthly notices of the royal astronomical society, 20, p.13, (1860)
- ii. Watari, S., Smith, Z., Garcia, H.A., Detman, T., Dryer, M. (1996). Coronal change at the south-west limb observed by Yohkoh on 9 November 1991, and the subsequent interplanetary shock at Pioneer Venus Orbiter, *Sol Phys*, 167, 357–369. <https://doi.org/10.1007/BF00146345>
- iii. Gosling, J.T., Asbridge, J.R., Bame, S.J., Feldman, W.C. (1976). Solar wind speed variations: 1962-1974, *J. Geophys. Res.*, 81, 5061-5070.
- iv. Harrison, R.A. (1995). The nature of solar flares associated with coronal mass ejection, *Astron. Astrophys.*, 304, 585-594.
- v. Pearson, K. (1896). Mathematical contributions to the theory of evolution-iii. Regression, Heredity and Panmixia, *The royal society*, 187, 254-318.
- vi. Lin, R.P., Hudson, H.S. (1976). Non-thermal processes in large solar flares. *Sol Phys.*, 50, 153–178. <https://doi.org/10.1007/BF00206199>
- vii. MacQueen, R.M., Fisher, R.R. (1983). The kinematics of solar inner coronal transients. *Sol Phys.*, 89, 89–102.
- viii. Youssef, M. (2012). On the relation between the CMEs and solar flares, *NRIAG J. Astron. Geophys.*, 1, 172-178. <https://doi.org/10.1016/j.nrjag.2012.12.014>
- ix. Hodgson, R. (1859). On curious appearance seen in the sun, *Mon. Not. r. Astr.Soc.*, 20, 15-16. [10.1093/mnras/20.1.15](https://doi.org/10.1093/mnras/20.1.15)
- x. Sheeley, N. R., Jr., Howard, R. A., Koomen, M. J., Michels, D. J. (1983). Association between coronal mass ejections and soft X-ray events, *The Astrophysical journal*, 272, 349-354.
- xi. Yashiro, S., Akiyama, S., Gopalswamy, N., Howard, R.A. (2006). Different Power-Law Indices in the Frequency Distributions of Flares with and without Coronal Mass Ejections, *The Astrophysical J. Lettr.*, 650, L143-L146.
- xii. Wang, Y., Zhang, J. (2007). a comparative study between eruptive X-class flares associated with coronal mass ejections and confined X- class flares, *the astrophysical journal*, 665, 1428-1438.
- xiii. Wang, J., Zhang, J., Wang, T., Zhang, C., Liu, Y., Nitta, N., Slater, G.L. (2001). Flare –CME events associated with a super active region, *Recent insights into the physics of the sun and heliosphere: highlights from SOHO and other space missions, Proceedings of IAU Symposium 203, Astronomical Society of the Pacific*, 331.
- xiv. Strong, K.T., Saba, J.L.R., Haisch, B.M., Schmelz, J.T. (Eds.). (1999). The many faces of the sun: A summary of the results from NASA's solar maximum mission, Springer, New York.
- xv. Hundhausen, A., (1999). Coronal mass ejections in: Strong, K.T., Saba, J.L.R., Haisch, B.M., Schmelz, J.T. (Eds.), *The many faces of the sun: A summary of the results from NASA's solar maximum mission*, Springer, New York, 143-200.