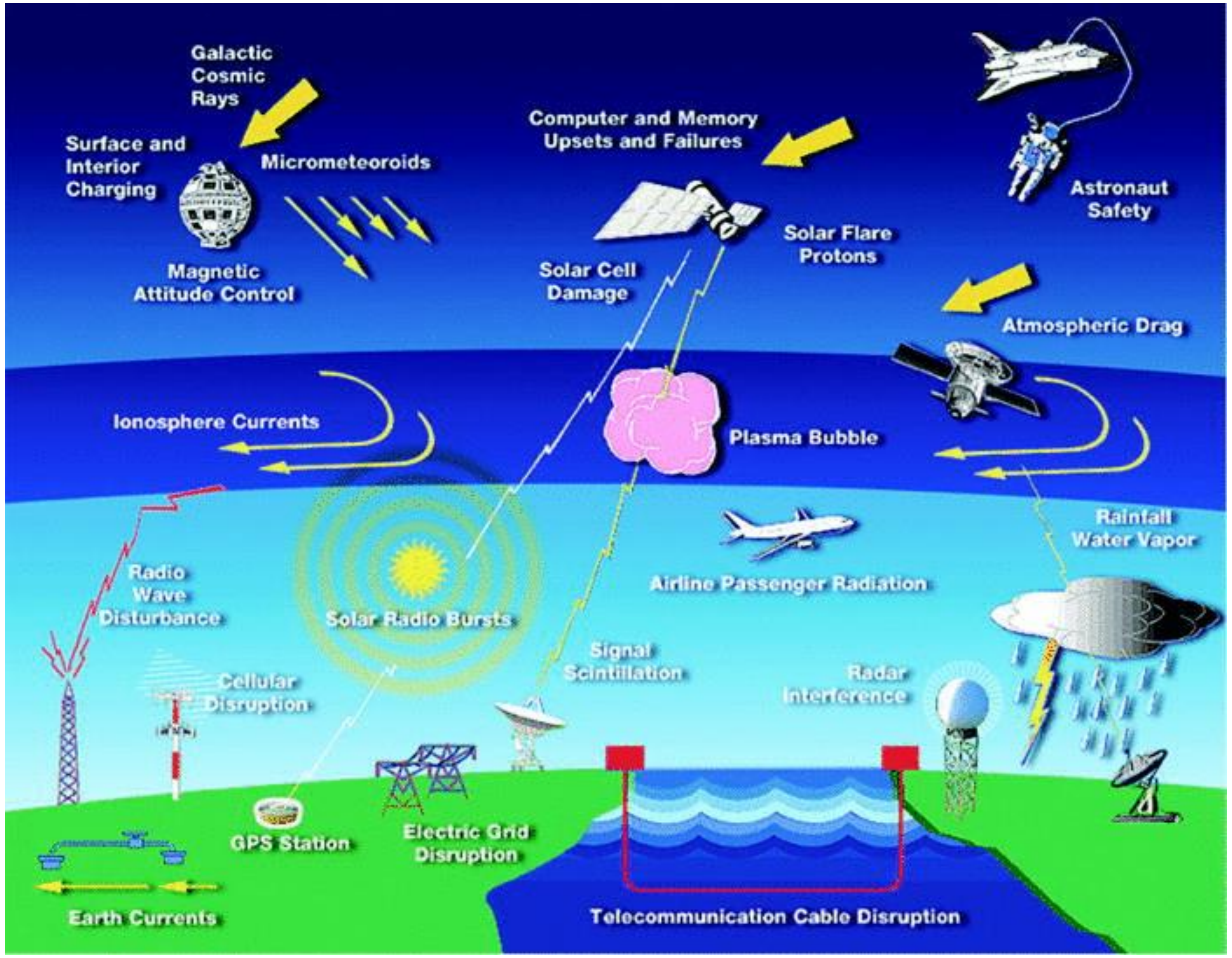
Criteria for identification of geoeffective solar events

Katya Georgieva, Simeon Asenovski, Boian Kirov

Space Research and Technology Institute

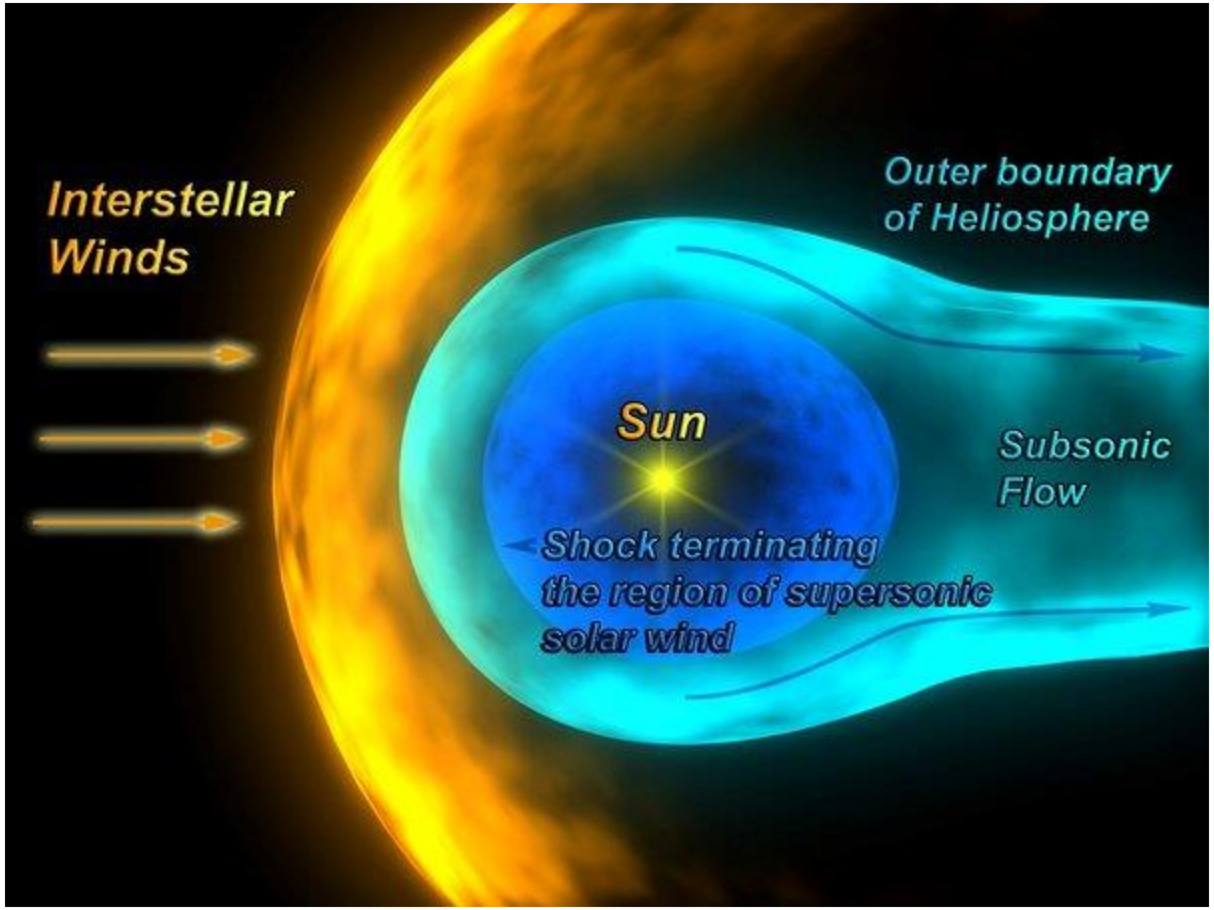
Bulgarian Academy of Sciences

"Space weather" is defined as conditions in the interplanetary and near-Earth space that can affect the performance and reliability of space-borne and ground-based technology, as well as human life and physiological conditions.



D.Baker et al. American Journal of Physics 84, 166 (2016)

Space weather agents
background solar wind

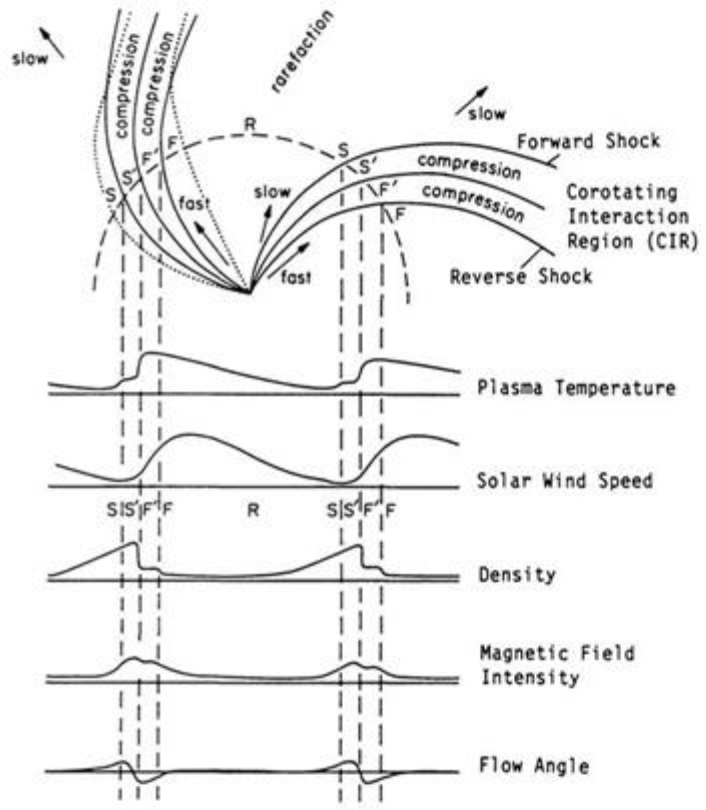


The solar corona is not in hydrostatic equilibrium and is constantly expanding

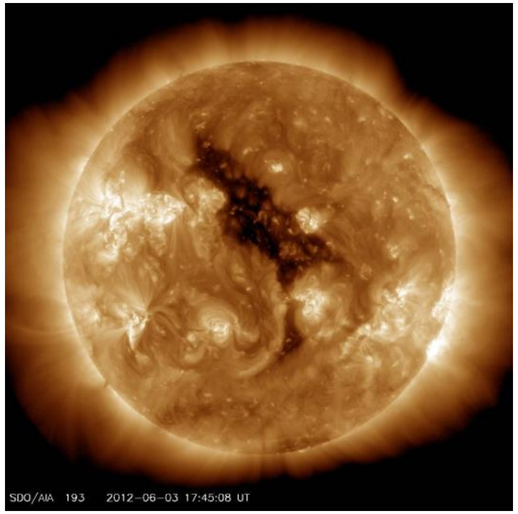
The Earth together with the whole Solar system is within this expanding coronal plasma with embedded solar magnetic fields called SOLAR WIND

The solar wind is in itself a space weather agent leading to solar activity even in the absence of other space weather agents

Space weather agents
high speed solar wind streams



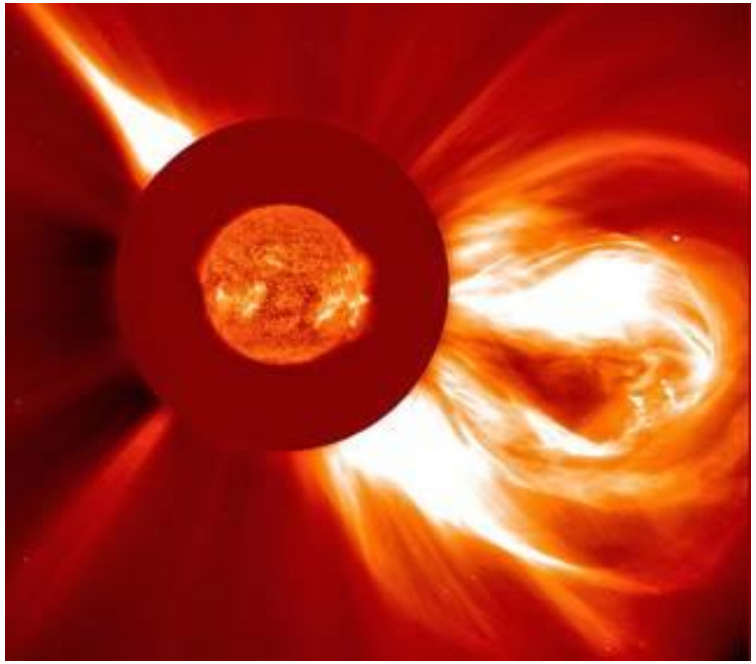
Richardson et al. 1993, after Belcher & Davis 1971

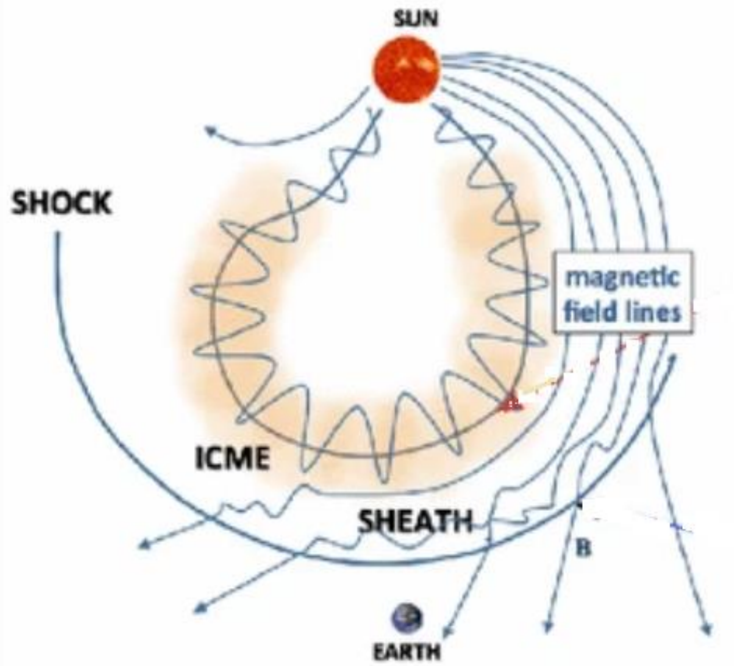


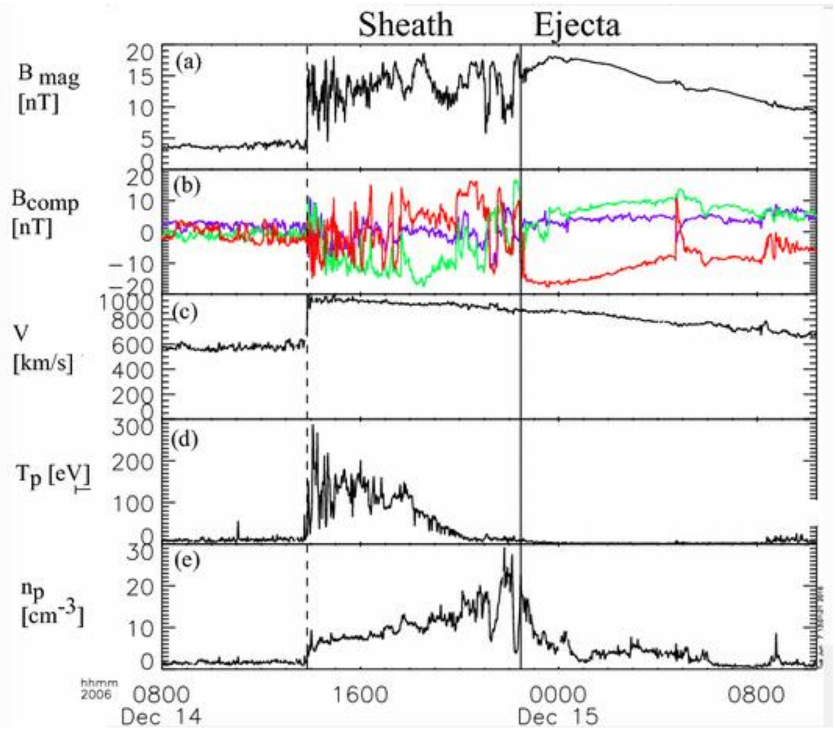
From solar coronal holes – regions of unipolar magnetic fields with low temperature (=dark)

Flow along open magnetic field lines = freely extending into the interplanetary space (=faster than the ambient solar wind)

Space weather agents
coronal mass ejections







Strong magnetic field
Low temperature
Low plasma betta
Decreasing density (expansion)

Earlier classifications and catalogs

ftp://ftp.ili.rssi.ru/pub/omni/catalog

Set of criteria

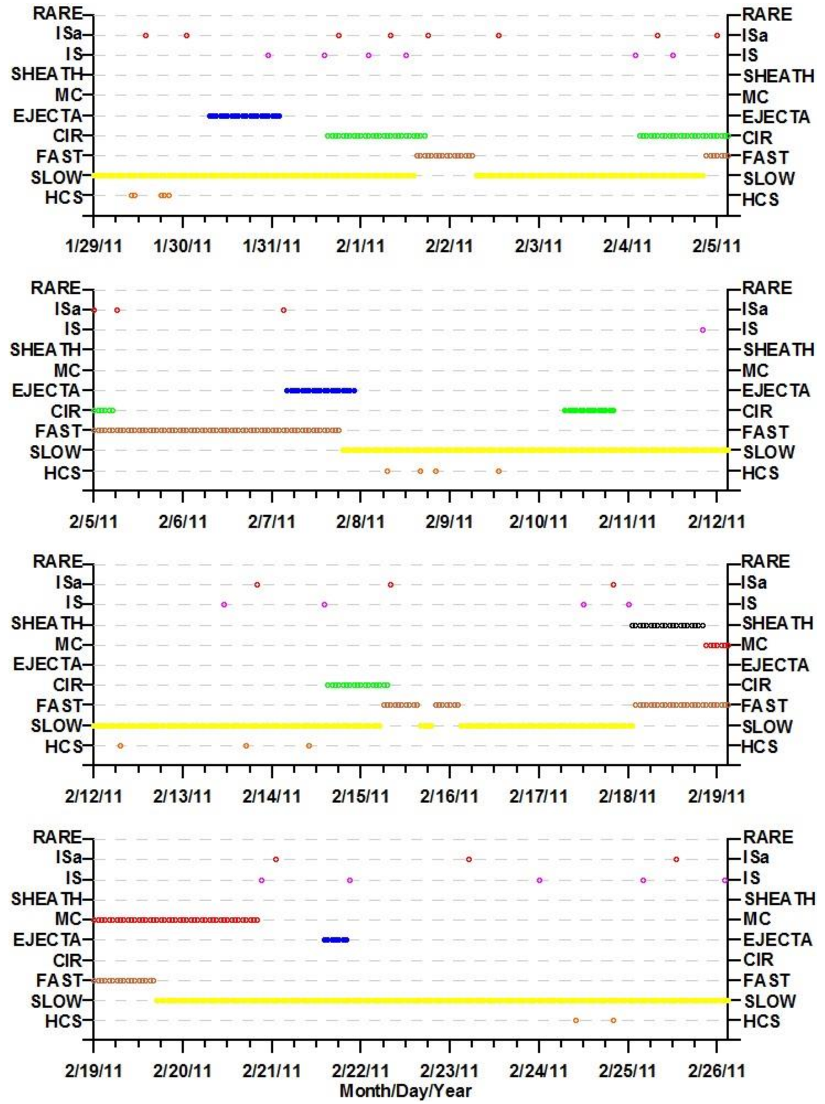
Yermolaev et al, Catalog of Large-Scale Solar Wind Phenomena during 1976-2000, Cosmic Research, 2009, Vol. 47, No. 2, pp. 81-94

Table 1. The set of criteria used for identification of various types of solar wind streams

no.	SW type	P	N, W	V, W	B, W	T/T_{exp}, W	NkT, W	β, W	$DV6$, W	DN, W	DB, W	B_X, W	B_Y, W	T, W
1	HCS	5	>7	<500				>0.7				*	*	
			0.5	0.5				0.5				**2.5**	**2.5**	
2	SLOW	3	>3	**<450**				<1						
			0.5	**2.0**				0.5						
3	FAST	3	<20	**≥450**				<1						
			0.5	**2.0**				0.5						
4	CIR	5	>3		>5	>1	>0.007	>1						
			0.5		0.5	**3.0**	0.5	0.5						
5	EJECTA	4	<10			**<0.5**	<0.01	<0.5						
			0.5			**4.0**	1.0	1.0						
6	MC	5	<10		**>10**	**<0.5**	<0.01	<0.5						
			0.5		**3.0**	**3.0**	1.0	1.0						
7	RARE	4	**≤1**	<500		<1	<0.01							
			2.5	0.5		0.5	0.5							
8	IS	4							>50	>2	>2			**a
									1.0	1.0	1.0			1.0
9	ISA	4							<–50	<–2	<–2			**b
									1.0	1.0	1.0			1.0

Note: 1. HCS and IS (ISA) are boundaries rather than extended regions, therefore, for HCS * one should check reversals of B_X and B_Y components of the IMF relative to their preceding values, and for IS ** a and ISA ** b the increments of temperature $\Delta T > 0$ and $\Delta T < 0$, respectively, should be checked.
2. For SHEATH the same criteria as for CIR were used.

Yermolaev et al. (2009)



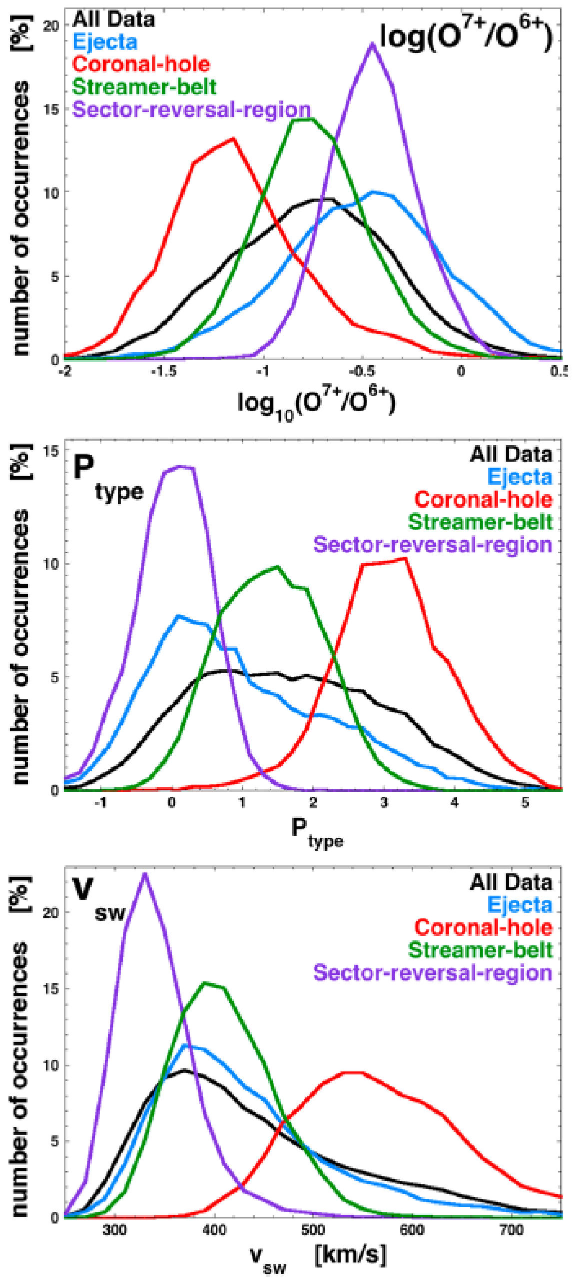
Earlier classifications and catalogs

Table 5. Mean Values for Various Plasma Parameters in the Four Types of Solar Wind Plasma at 1 AU[a]

	Ejecta	Coronal-Hole-Origin Plasma	Streamer-Belt-Origin Plasma	Sector-Reversal-Region Plasma	All Solar Wind
Plasma age (h)	100	75	103	123	100
n_p (cm^{-3})	6.8	3.5	6.3	12.0	6.8
T_p (eV)	7.7	18.4	8.2	3.0	9.7
B (nT)	11.0	6.1	5.7	4.6	6.3
v_{sw} (km/s)	434	567	409	342	438
$\mathrm{Log}_{10}(O^{7+}/O^{6+})$	-0.495	-1.13	-0.754	-0.446	-0.766
$\mathrm{Log}_{10}(C^{6+}/C^{5+})$	0.053	-0.263	0.038	-0.067	-0.059
Fe/O	0.11	0.058	0.076	0.090	0.077
$\mathrm{Log}_{10}(S_\alpha)$	2.1	2.7	2.1	1.4	2.1
P_{type}	0.95	3.1	1.4	0.029	1.7
α/p	0.051	0.042	0.040	0.024	0.038
$\delta B/B$	0.24	0.46	0.40	0.38	0.39
M_A	4.4	8.3	8.6	13.1	8.8
P_{ram} (nPa)	2.6	2.2	2.1	2.7	2.3
Kp	2.7	2.9	1.8	1.3	2.2
β_p	0.13	0.75	0.74	0.98	0.71
v_A (km/s)	110	73	51	31	61
c/ω_{pi} (km)	114	133	99	73	104
r_{gi} (km)	24	75	55	43	54

[a]For O^{7+}/O^{6+}, C^{6+}/C^{5+}, Fe/O, S_α, and P_{type}, the 1998–2011 ACE data set was used; for all other quantities, the 1963–2012 OMNI2 data set was used. For logarithmic quantities, the mean value of the logarithm is given. The quantity c/ω_{pi} is the ion-inertial length and r_{gi} is the thermal ion gyroradius.

Xu and Borovsky (2006)



Earlier classifications and catalogs

https://izw1.caltech.edu/ACE/ASC/DATA/level3/icmetable2.htm

Near-Earth Interplanetary Coronal Mass Ejections Since January 1996

Compiled by Ian Richardson (1, 2) and Hilary Cane (3),

(1) Heliospheric Physics Laboratory, Code 672, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA,

(2) Partnership for Heliophysics and Space Environment Research (PHaSER) and The Department of Astronomy, University of Maryland, College Park;

(3) University of Tasmania, Australia.

Revised October 27, 2022*

ote added May 18, 2016: The dates in the table have been reformatted so that the year is now included for every time. Previously, the year was indicated only at the start of the list of events in that year, and only month and day were ıdicated in the event times. This change should make it easier to convert the list into another format, such as text or a spreadsheet. Currently, we don't maintain text or spreadsheet versions of the list, but these can be made by, for example, ownloading and opening the file in a spreadsheet program such as Excel. Each box in the list should appear as a spreadsheet cell. Note that the contents of each box in the list are not necessarily uniform, so some editing (e.g., removing letters om some times in the first column) may be required. The list can then be saved in the desired format. A text version can also be made by converting the file to pdf and extracting the text from the pdf version.

Disturbance Y/M/D (UT) (a)	ICME Plasma/Field Start, End Y/M/D (UT) (b)		Comp. Start, End (Hrs wrt. Plasma/ Field) (c)		MC Start, End (Hrs wrt. Plasma/ Field) (d)		BDE? (e)	BIF? (f)	Qual. (g)	dV (km/s) (h)	V_ICME (km/s) (i)	V_max (km/s) (j)	B (nT) (k)	MC? (l)	Dst (nT) (m)	V_transit (km/s) (n)	LASCO CME Y/M/D (UT) (o)
1996/05/27 1500	1996/05/27 1500	1996/05/29 0300	...	...	0	+4	N	...	2	0	370	400	9	2	-33	...	
1996/07/01 1320	1996/07/01 1800	1996/07/02 1100	...	...	0	0	N	...	3	40	360	370	11	2	-20	...	
1996/08/07 0600	1996/08/07 1200	1996/08/08 1000	...	...	0	0	N	...	2	10	350	380	7	2	-23	...	
1996/12/23 1600	1996/12/23 1700	1996/12/25 1100	...	...	+10	0	N	...	2	20	360	420	10	2	-18	435	1996/12/19 1630 H

Earlier classifications and catalogs

http://www.geodin.ro/varsiti/

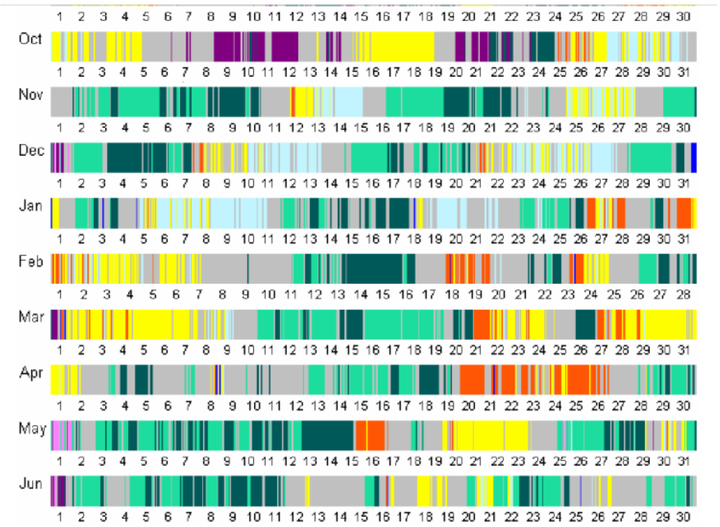
Catalog of high speed streams

No. crt.	Year	Month	Day	3-h	V0 (km/s)	V1 (km/s)	Δt1	Vmax (km/s)	Dur (days)	ΔV1 (km/s)	ΔVM (km/s)	I	Source	IMF	Dst_min (nT)	Dst_date (mm:dd:hh)	Bz_min (nT)	Bz_date (mm:dd:hh)	SSC_date (mm:dd:hh)	Energy estimate ΔWε (J)	Energy estimate ΔW (J)	SYM-H_min (nT)	SYM-H_date (mm:dd:hh:min)
1	2014	1	1	3	371.7	620	13	620	5.2	248.3	248.3	1291.16	CH598	+	-39	01:01:15	-8.3	01:01:13				-39	01:01:15:29
															-31	01:03:19	-3.3	02:01:16				-33	01:03:19:32
2	2014	1	11	6	371.3	673.3	10	877.3	5.6	302	506	2833.6	CH*	-									
3	2014	1	20	1	285	459	15	559.3	8.1	174	274.3	2221.83	CH600	+									
4	2014	1	28	2	312.7	483.7	11	483.7	3.8	171	171	649.8	CH601	+									
5	2014	2	9	4	382	542.3	12	542.3	3.7	160.3	160.3	593.11	CH602	-									
6	2014	2	27	4	335.7	471	3	471	4.6	135.3	135.3	622.38	CME, CH605	-	-97	02:27:23	-12	02:27:21	02:27:16	4.09E+15	1.35E+17	-101	02:27:23:24
															-52	03:01:08	-2.8	03:01:06		2.22E+15	3.55E+16	-51	03:01:08:10
7	2014	3	4	1	336	450	15	484.3	5.6	114	148.3	830.48	CH606	+									
8	2014	3	12	5	268.3	469	11	493	5.2	200.7	224.7	1168.44	CH607	+	-43	03:13:04	-8.3	03:13:00				-42	03:13:03:52
9	2014	3	21	1	317.7	497	14	498.3	4	179.3	180.6	722.4	CH608	+									
10	2014	4	7	2	339.3	442.7	7	467.7	5.4	103.4	128.4	693.36	CH*	+	-87	04:12:09	-8.9	04:12:06		1.79E+16	7.31E+17	-90	04:12:09:53
11	2014	5	22	3	307	503.7	11	503.7	4.9	196.7	196.7	963.83	CH*	-									
12	2014	6	10	2	410.3	596.7	10	596.7	2.6	186.4	186.4	484.64	CH622	+									
13	2014	6	17	3	344.7	449.7	13	457	6.4	105	112.3	718.72	CH*	-									
14	2014	7	14	3	329.7	475.7	12	475.7	3.9	146	146	569.4	CH*	-									
15	2014	8	10	3	312.3	452	13	494.7	5.9	139.7	182.4	1076.16	CH631	-									
16	2014	8	28	3	318.3	441.3	10	451.7	14.6	123	133.4	1947.64	CH*	+	-79	08:27:18	-13.1	08:27:14		5.60E+15	3.43E+17	-90	08:27:18:18
															-52	08:28:17	-8.8	08:28:15		6.77E+13	5.63E+15	-57	08:28:16:37
17	2014	9	18	8	354.3	487	7	558.3	11	132.7	204	2244	CH*	+									
18	2014	10	19	7	379	514.3	6	643.7	6	135.3	264.7	1588.2	CH639	+	-51	10:20:17	-5.9	10:20:16		2.84E+16	5.45E+17	-57	10:20:17:10
															-46	10:22:02	-1.8	10:22:02				-45	10:22:02:06
19	2014	10	30	5	333.7	443.3	10	514	4.6	109.6	180.3	829.38	CH641	-									
20	2014	11	4	2	410	539.3	13	539.3	7	129.3	129.3	905.1	CH*	-	-44	11:04:10	-8.5	11:04:09				-46	11:04:10:34
21	2014	11	11	2	451.3	598	10	598	2.9	146.7	146.7	425.43	CH*	-	-65	11:10:17	-5.4	11:10:16	11:10:02	3.65E+16	-	-63	11:10:17:07

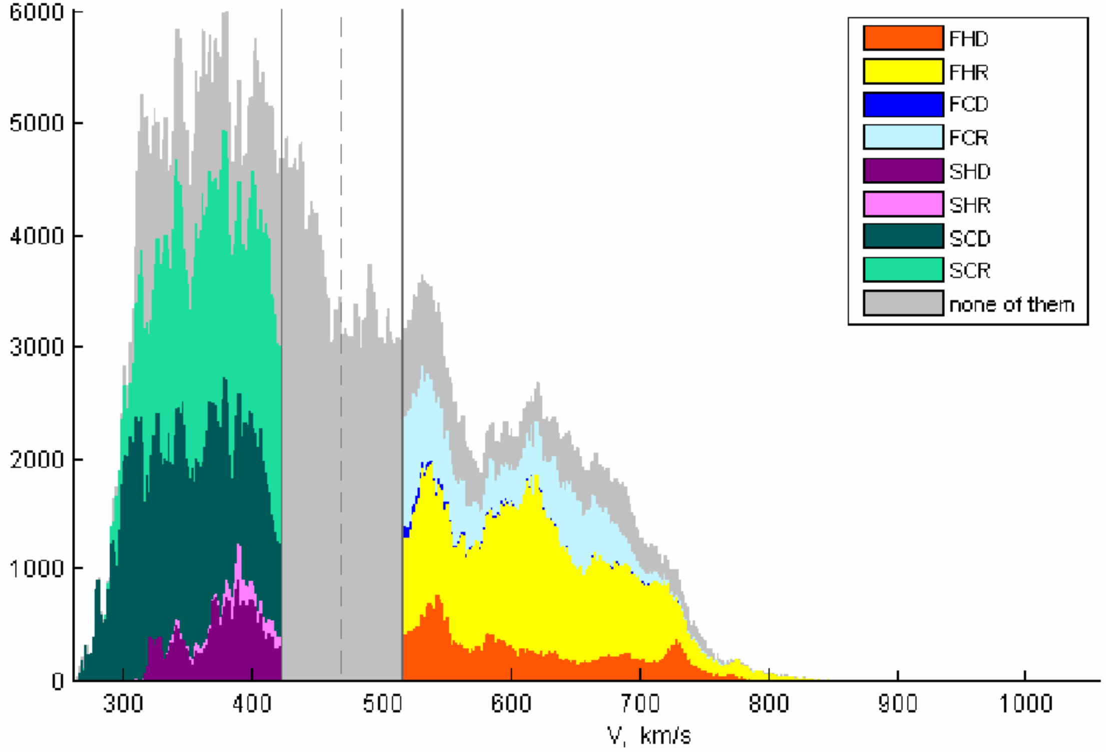
Maris and Maris (2005)

9 types of solar wind

fast-hot-dense (FHD)
fast-hot-rarefied (FHR)
fast-cold-dense (FCD)
fast-cold-rarefied (FCR)
slow-hot-dense (SHD)
slow-hot-rarefied (SHR)
slow-cold-dense (SCD)
slow-cold-rarefied (SCR)
zero

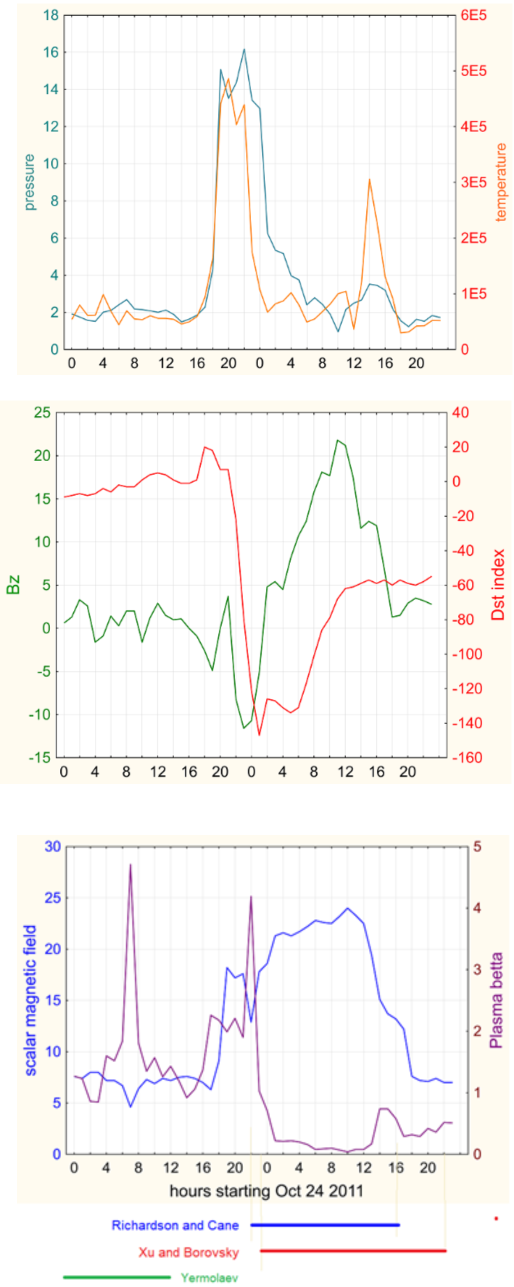


Earlier classifications and catalogs



Veselovsky et al. (2021)

Difference between catalogs due to different criteria



Our criteria for CMEs

Proton temperature $T_p < 0.5T_{exp}$

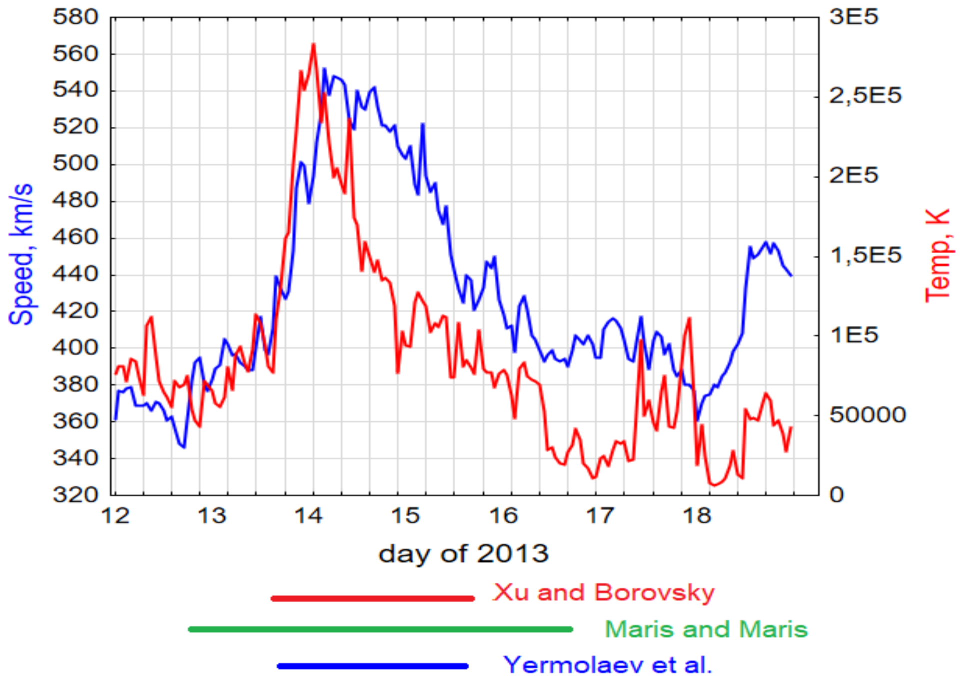
$T_{exp} = 3(0.0106V_{sw} - 0.287)$ if $V_{sw} < 500$ km/s

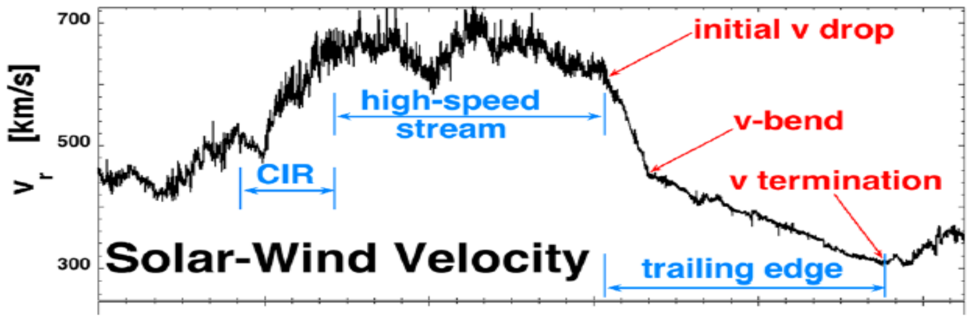
$T_{exp} = (0.77V_{sw} - 265)$ if $V_{sw} > 500$ km/s

Magnetic field magnitude $B \geq 10$ nT

Plasma Beta ≤ 0.8 for at least 5 hours.

Difference between catalogs due to different criteria





Our criteria for HSS

increase of the solar wind velocity by at least 100 km/s in no more than one day to at least 500 km/s for at least 5 hours

accompanied by high temperature ($T_p > T_{exp}$) and low density

HSS lasts until V starts increasing and keeps increasings for at least 5 hours

All solar wind which is not CME or HSS is considered **background solar wind**

Acknowledgements
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Thanks for your attention!