Scientific Committee on Solar-Terrestrial Physics

Long-term Preservation of Solar Terrestrial Data

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"…many of the most significant discoveries in science will be found not in but between the rigid boundaries of the disciplines: the terra incognita where much remains to be learned." J. A. Eddy

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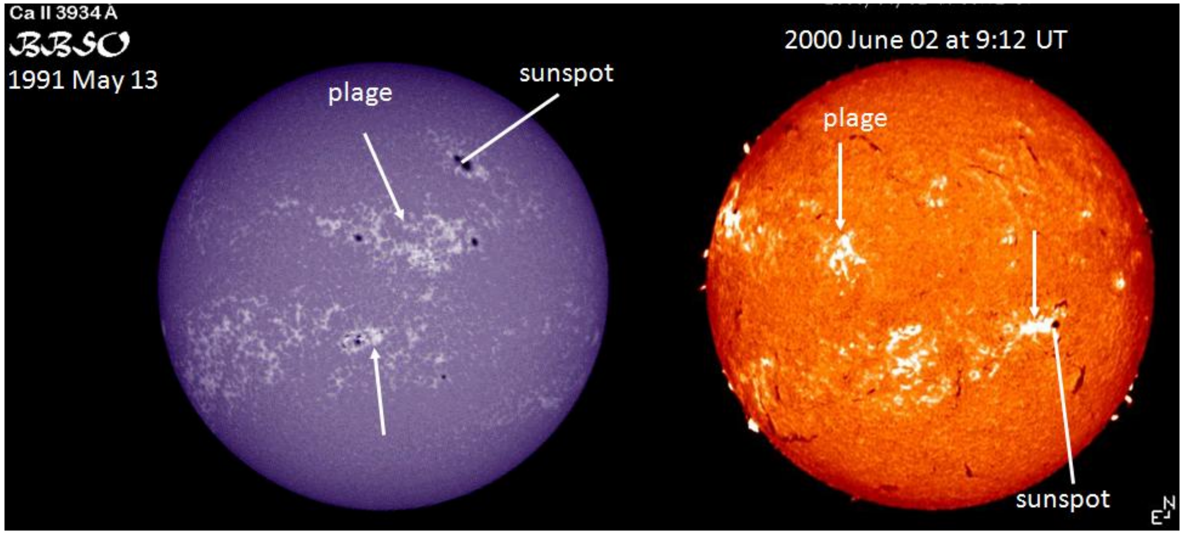
Long-term Variability Impacting Earth…

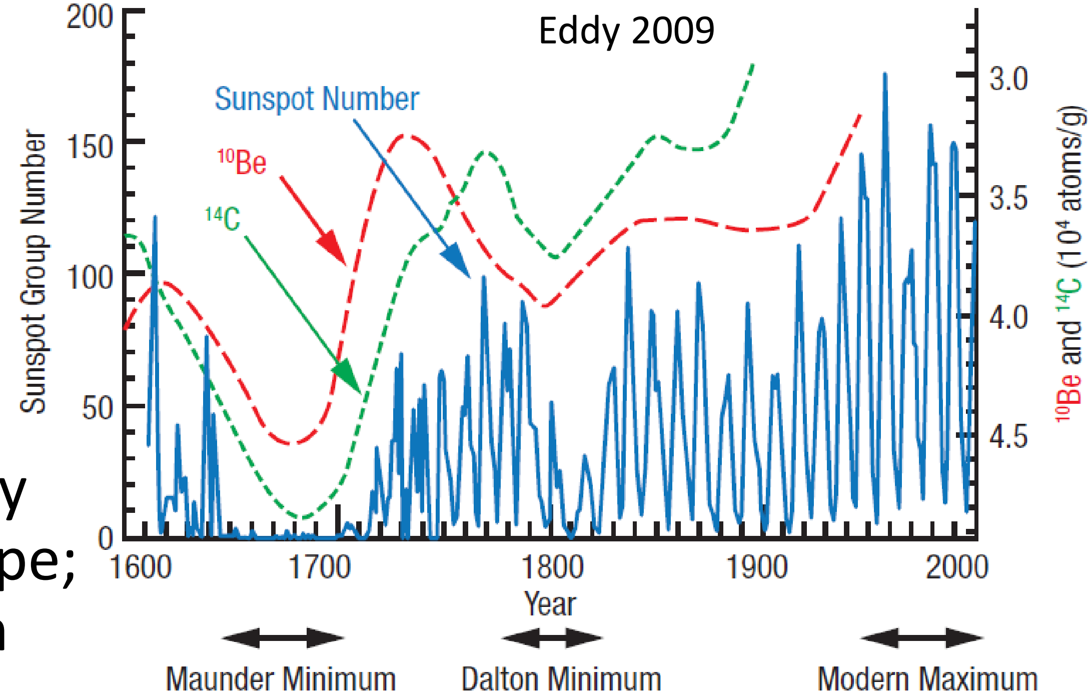
Friedrich Wilhelm Herschel
(1738 – 1822)
Discoverer of Uranus, two moons of Uranus (Titania, Oberon), two moons of Saturn (Enceladus, Mimas), infrared radiation, published catalogs of 1000s of nebulae, …

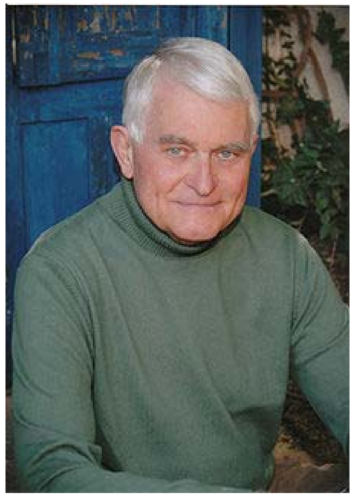
- In 1801 Herschel reported to the Royal Society that five prolonged periods of few sunspots correlated with high wheat prices in England
- Herschel inferred that less number of sunspots indicated less heat and light from the Sun so the wheat production was low and the wheat was costly
- Herschel was ridiculed for this report, but now we know that when there are more sunspots, the Sun emits more radiation because of the brighter regions appearing around sunspots
- Also this is a discovery of periodic sunspot activity, recognized half a century later in 1843 by S. H. Schwabe



The Maunder Minimum & Variable Solar Activity

- Established the connection between prolonged periods of low sunspot activity (1645-1715) to very cold winters in Europe; named the period as Maunder minimum (Eddy, 1976)
- Named another period of low sunspot activity (1460-1550) as Spörer Minimum
- Spörer was the first to recognize the 1645-1715 period of low sunspot activity





J. A. Eddy (1931 – 2009)

CME in Old Eclipse Pictures: 1860 July 18

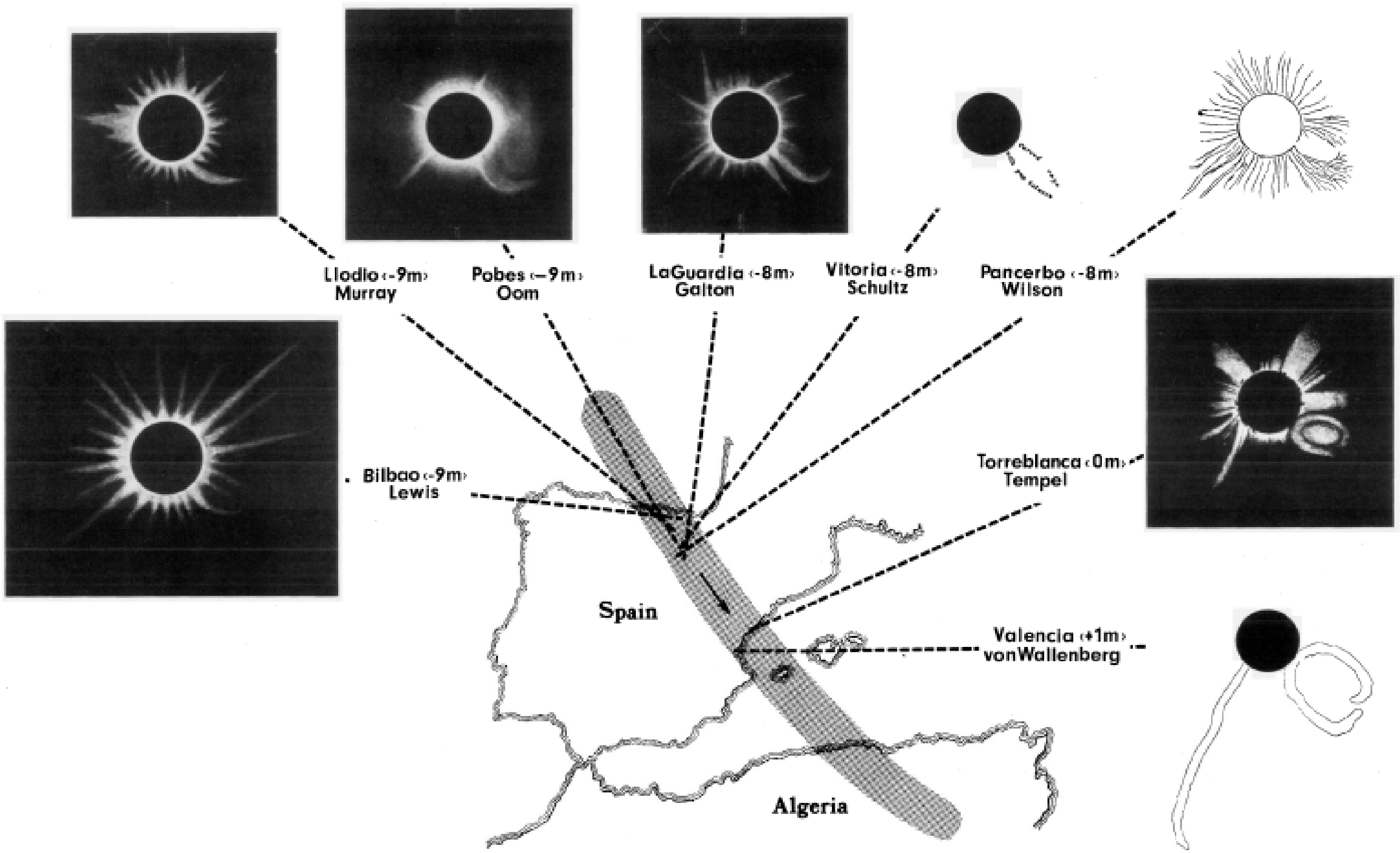
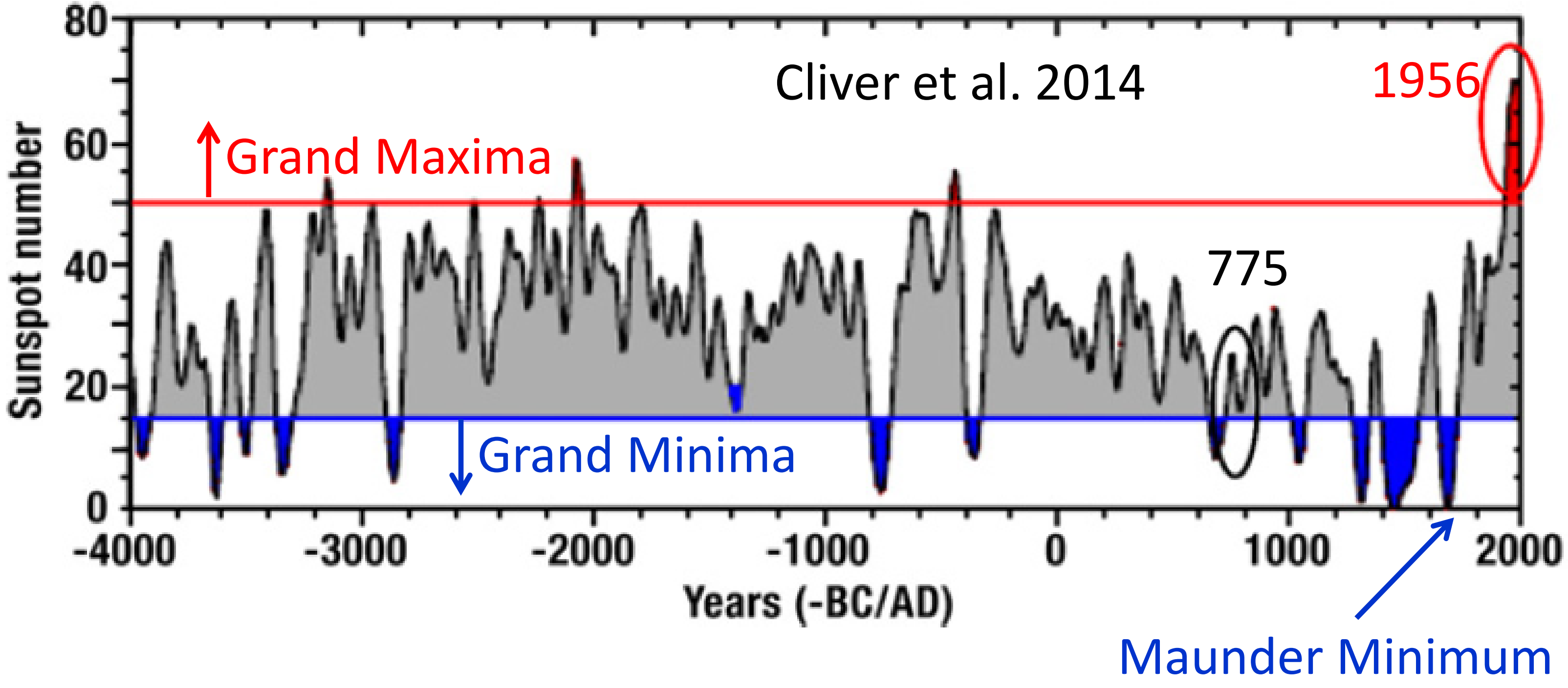


Fig. 4. Selected drawings of the corona (from Ranyard, 1879), made by different observers along the path of totality in Spain during the 1860 eclipse. Times are relative to mid-totality at Tempel's station at Torreblanca

Eddy, 1974 estimated the CME speed to be 200-500 km/s

Solar Activity Reconstruction over Longer Period



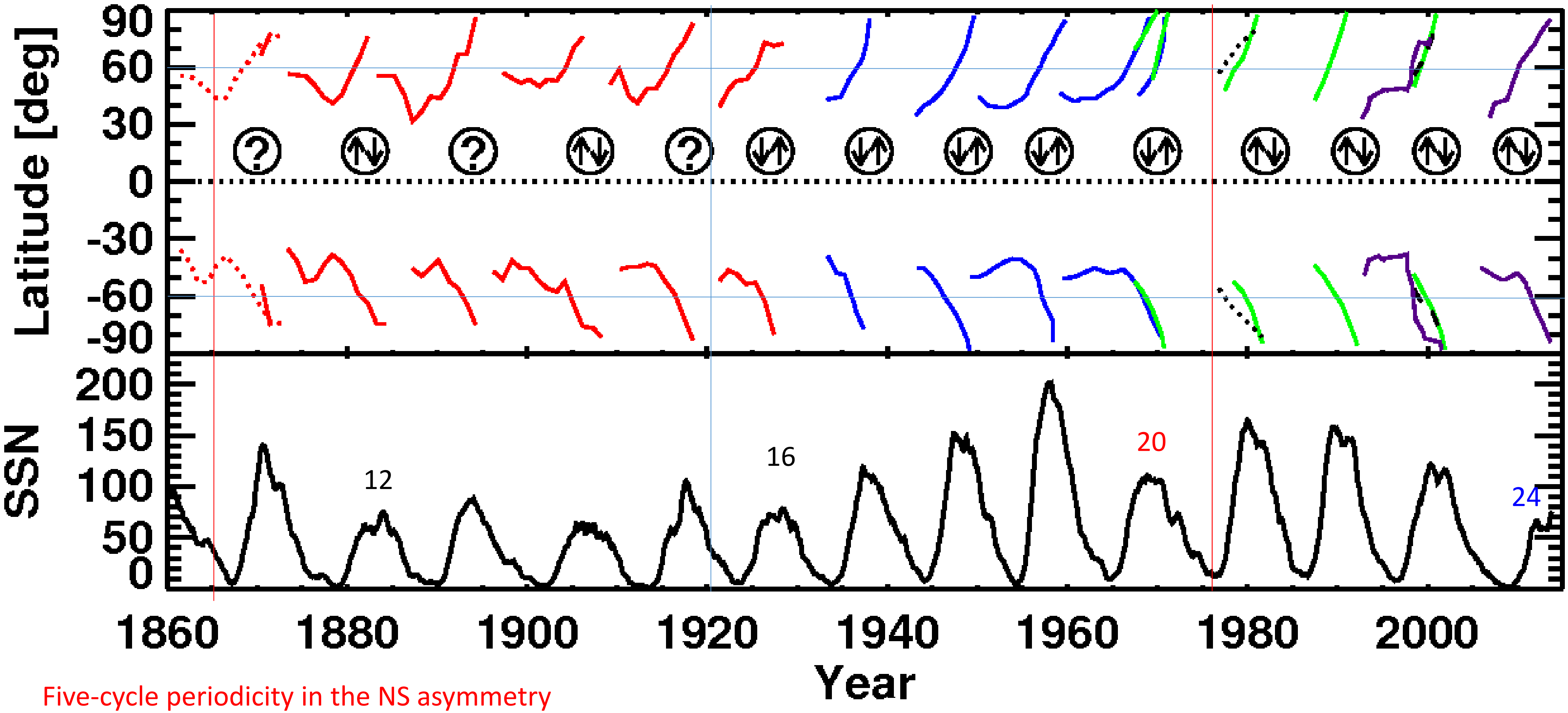
AD 775 ^{14}C Increase

- Miyake et al. (2012) found increase in ^{14}C in tree rings from 2 Japanese trees
- Confirmed using tree rings from other parts of the world
- Solar? SN? GRB?

Usoskin et al. 2013 (23 Feb 1956); Jull et al. 2014 (19 Oct 1989) – Solar particle events

Neuhaeuser & Neuhaeuser 2015 - Due to solar activity variation

Long-term Variation in Asymmetry from Rush to the poles of filaments

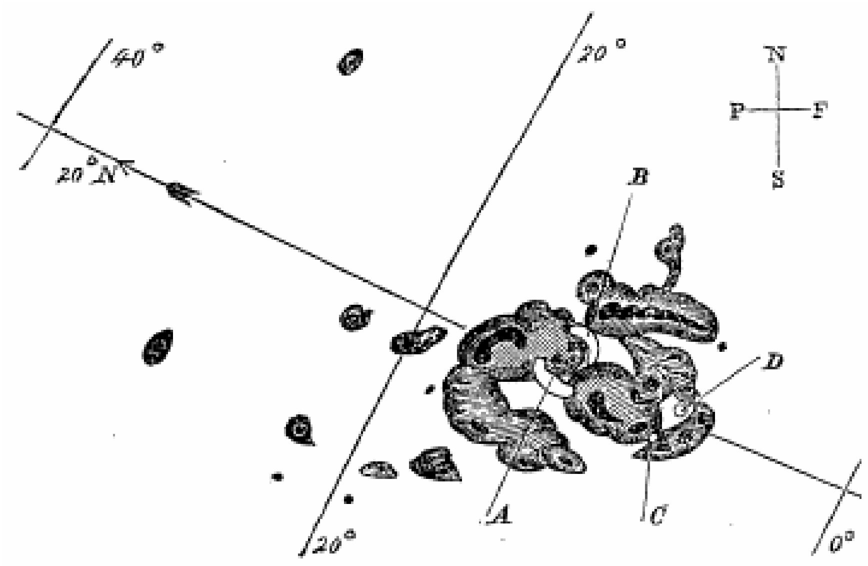


Five-cycle periodicity in the NS asymmetry

The Historical Carrington Event

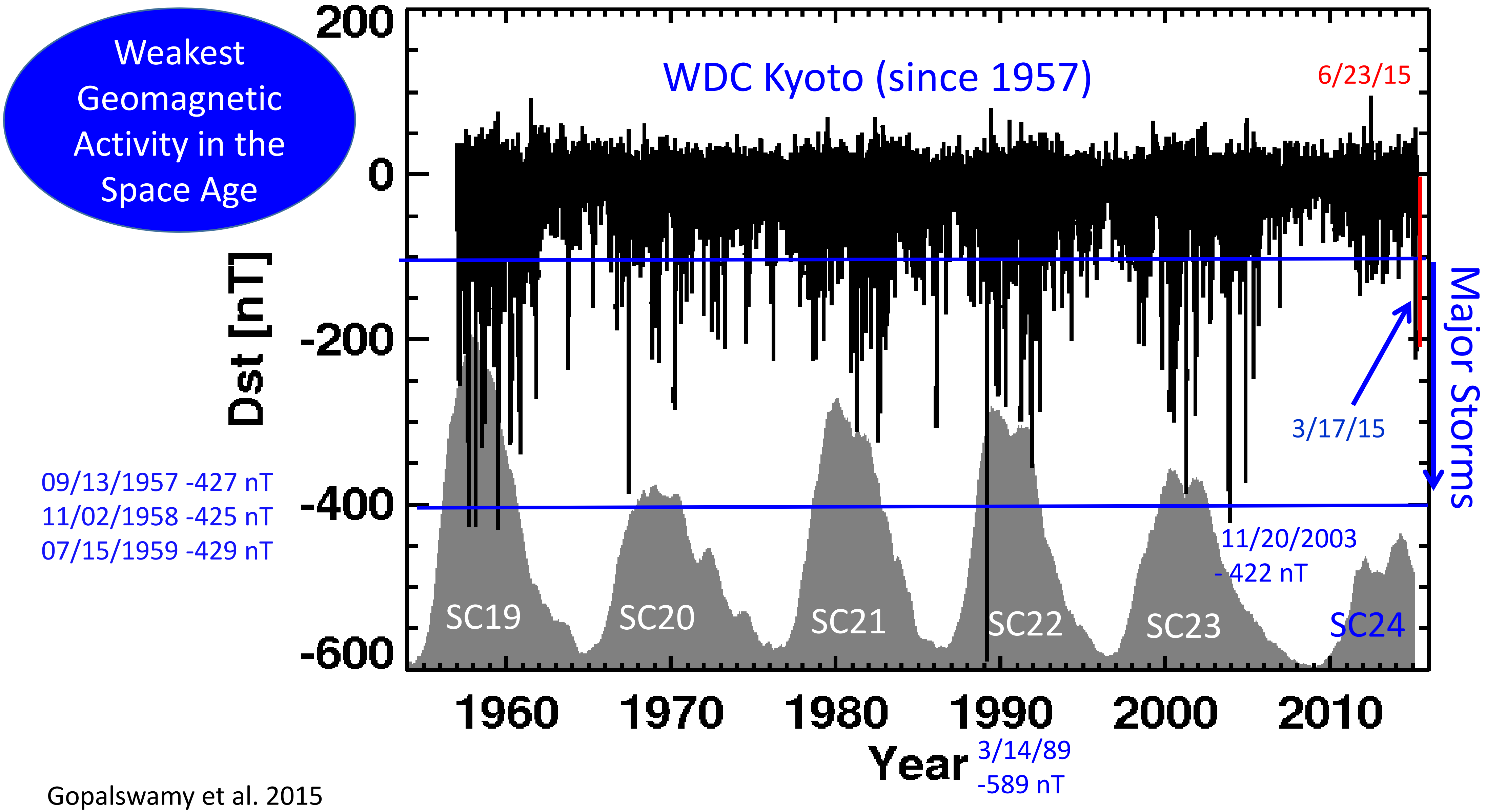
The Discovery of a Solar Flare

- Sudden brightening on the Sun amidst a sunspot group on September 1, 1859
- Independently observed by R. C. Carrington and R. Hodgson
- Magnetic storm commenced early on September 2, about 17.5 hours later
- Dst estimated from -1760 nT (Tsurutani et al. 2003) to -850 nT (Siscoe et al. 2006) – from the historical Alibag magnetometer data in India



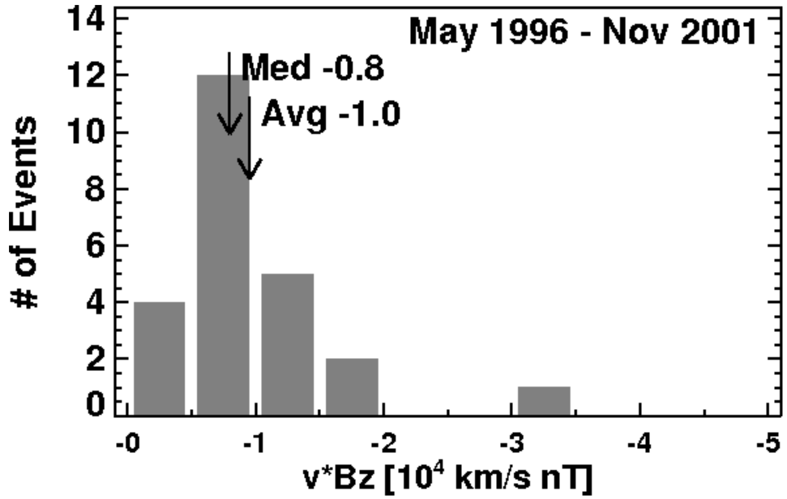
Drawing by Carrington

Benchmark to compare other storms



Gopalswamy et al. 2015

Weak activity – Weak Heliosphere- CME Expansion – Magnetic Dilution

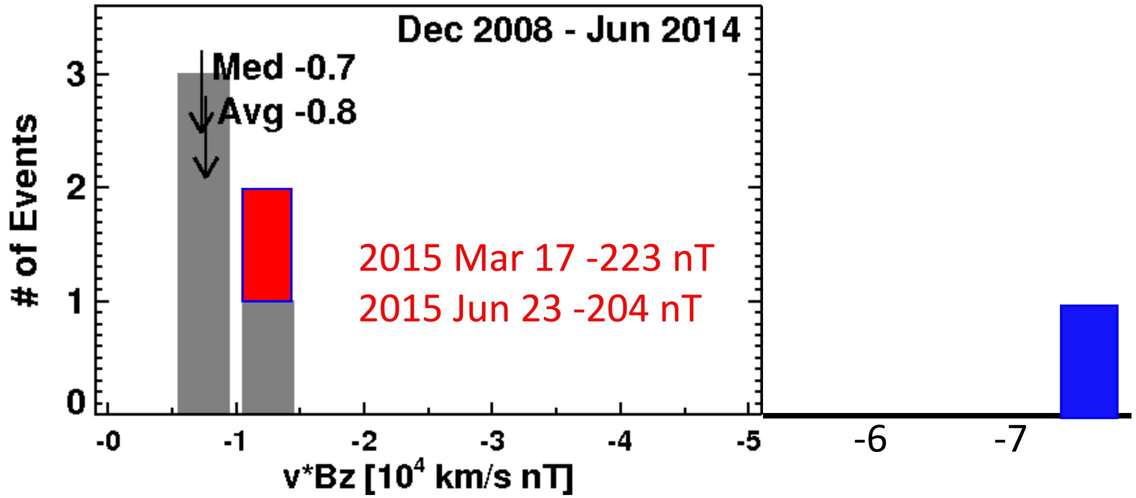


2012 July 23 Extreme Event

V = 1500 km/s

Bz = -52 nT

VBz = -7.8×10^4 km/s nT



Cycle 24

- Sunspot number down by 40% (vs. SC 23)
- Very few major geomagnetic storms
- Very few high-energy SEP events
- Discordance between sunspot number and CME rate

2012 July 23 Extreme Event: Carringtonesque?

Dst = – 0.01VB_z – 32 nT

Expected storm strength

V = 1500 nT

Bz = -52 nT

Dst = - 812 nT

(Liu et al. 2014 : -1150 to -600 nT)

Carrington Dst: -850 nT to -900 nT

(Siscoe et al. 2006; Cliver & Dietrich 2013)

→ VBz = 8.7x10^4 km/s•nT

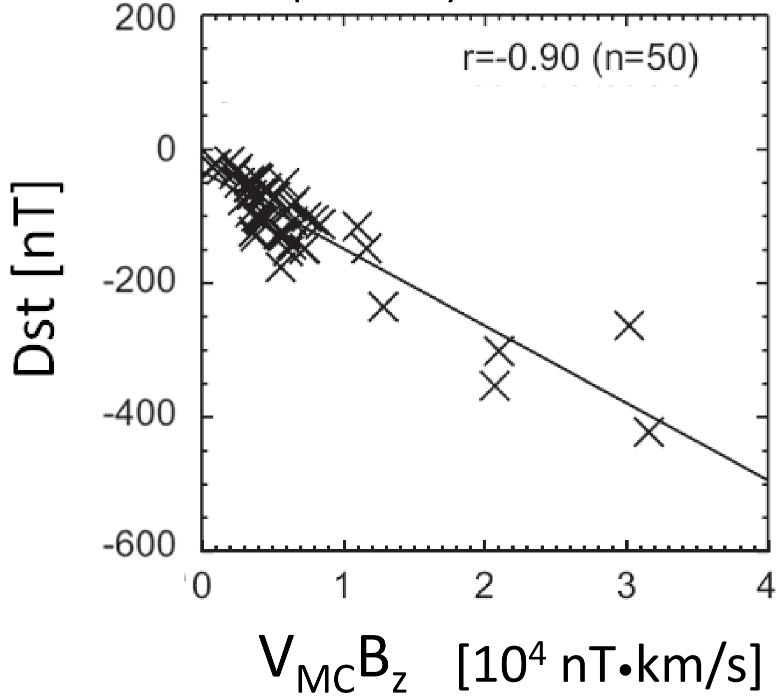
V=1700 km/s → Bz = -51 nT

Tsurutani et al. 2003: -1760 nT

VBz = 1.7x10^5 km/s•nT

V = 1700 km/s → Bz = -100 nT

Gopalswamy 2008



Historical Fast Transient Events

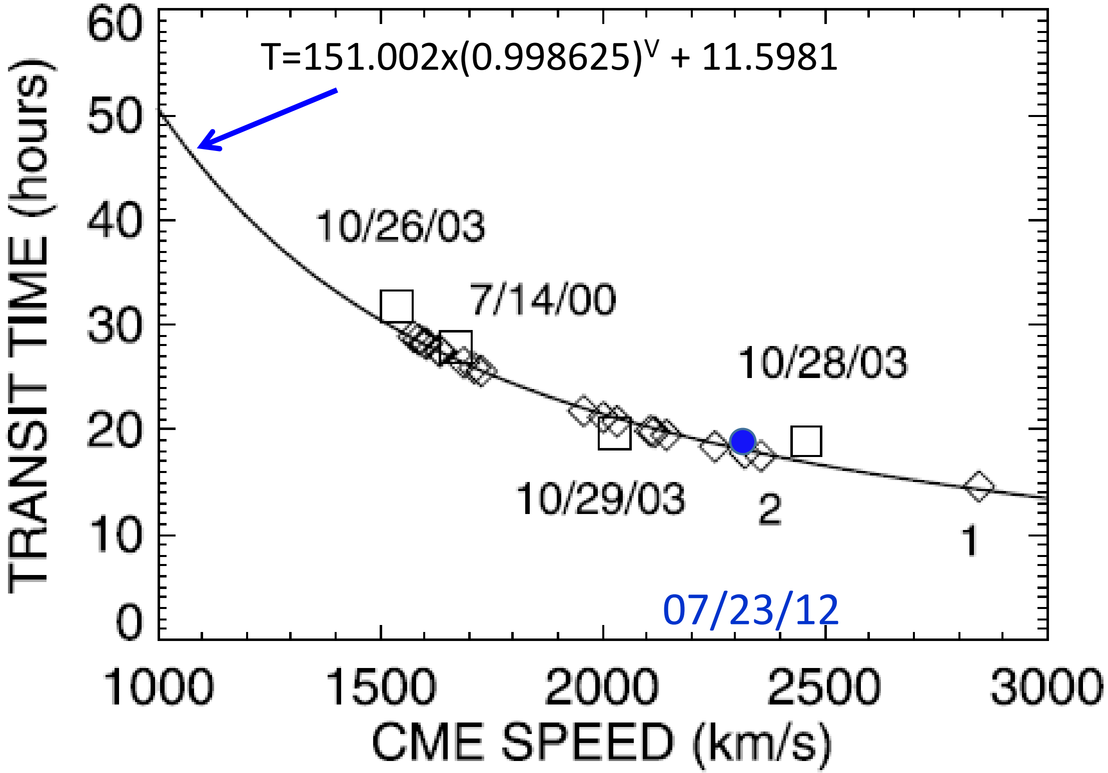
- 15 events with Transit time <24 h
- 2012 July 23 event is added to this list

Table 3. Historical Fast Transit Shocks Compared With Those of the October–November 2003 Period

Number	Flare Date	UT	Location	Area	SC Date	SC UT	T	V_{inf}	Ref.[h]
01	1 Sep 1859	1118	N20W12	2300	2 Sep	0448	17.5	2356	N
02	15 Jul 1892	1700	S31E32	829	16 Jul	1230[c]	19.5	2144	H,N
03	10 Sep 1908	0536	S21W22	494	11 Sep	0947	28.2	1605	H
04	24 Sep 1909	1006	S05W08	605	25 Sep	1143	25.6	1728	H,N
05	10 Nov 1916	1542	N24E18[c]	142	11 Nov	1912	27.5	1636	N
06	14 Feb 1917	1606	S23E44[c]	110	15 Feb	1200	19.9	2108	N
07	25 Jan 1926	2000	N21W17	3285	26 Jan	1648[f]	20.8	2033	N
08	31 Jul 1937	1642	N24E67[d]	634	1 Aug	2136	28.9	1575	N
09	16 Jan 1938	0040	N17E31	3179	16 Jan	2235	21.8	1958	CS,N,Ca
10	15 Apr 1938	0830	N27W12	1098	16 Apr	0542	21.2	2002	Cb
11	28 Feb 1941	0930[a]	N12W14	683	1 Mar	0354	18.4	2253	CS,Ca,N1
12	17 Sep 1941	0836	N11W09	1896	18 Sep	0448	19.8	2117	N,CS,Ca
13	28 Feb 1942	1242	N07E03	1865	1 Mar	0812	19.5	2144	N, Ca
14	6 Feb 1946	1628	N27W19	4799	7 Feb	1018	17.8	2320	Ca,Cb
15	25 Jul 1946	1504	N21E16	4279	26 Jul	1842	27.6	1631	Cb,NGDC
16	20 Jan 1957	1100	S30W18	557	21 Jan	1254	25.9	1712	Cb,NGDC
17	9 Feb 1958	2108	S12w14	756	11 Feb	0124	28.3	1600	Cb,NGDC
18	10 May 1959	2102	N18E47	1552	11 May	2324	26.4	1688	Cb,NGDC
19	14 Jul 1959	0325	N17E04	1314	15 Jul	0800	28.6	1587	Cb,NGDC
20	16 Jul 1959	2114	N16W31	1981	17 Jul	1642	19.5	2144	Cb,NGDC
21	12 Nov 1960	1315	N28W01	1740	13 Nov	1023	21.2	2002	CS,Ca,E
22	4 Aug 1972	0620	N04E08	1140	4 Aug	2054	14.6	2847	Ca,Cb
23	14 Jul 2000	1024[b]	N22W07	490	15 Jul	1417	27.9	1670[g]	G,NGDC
24	26 Oct 2003	1741[b]	N04W43	1420	28 Oct	0130	31.8	1537[g]	T,NGDC
25	28 Oct 2003	1106[b]	S20E02	2110	29 Oct	0600	18.9	2459[g]	T,NGDC
26	29 Oct 2003	2041[b]	S19W09	2680	30 Oct	1620	19.7	2029[g]	T,NGDC
27	23 Jul 2012	0210	S17W141				18.6	2330	

Cliver et al., 1990; Gopalswamy et al., 2005;2014

Transit Time (Flare Onset to Sudden Commencement)



$a = -0.0054\ (u-u_c)$

$u_c = 406$ km/s

u= 2330 km/s gives

a = -14 m/s^2 (formula)

a = 12.4 m/s^2 (observed)

T = 17.7 h (formula)

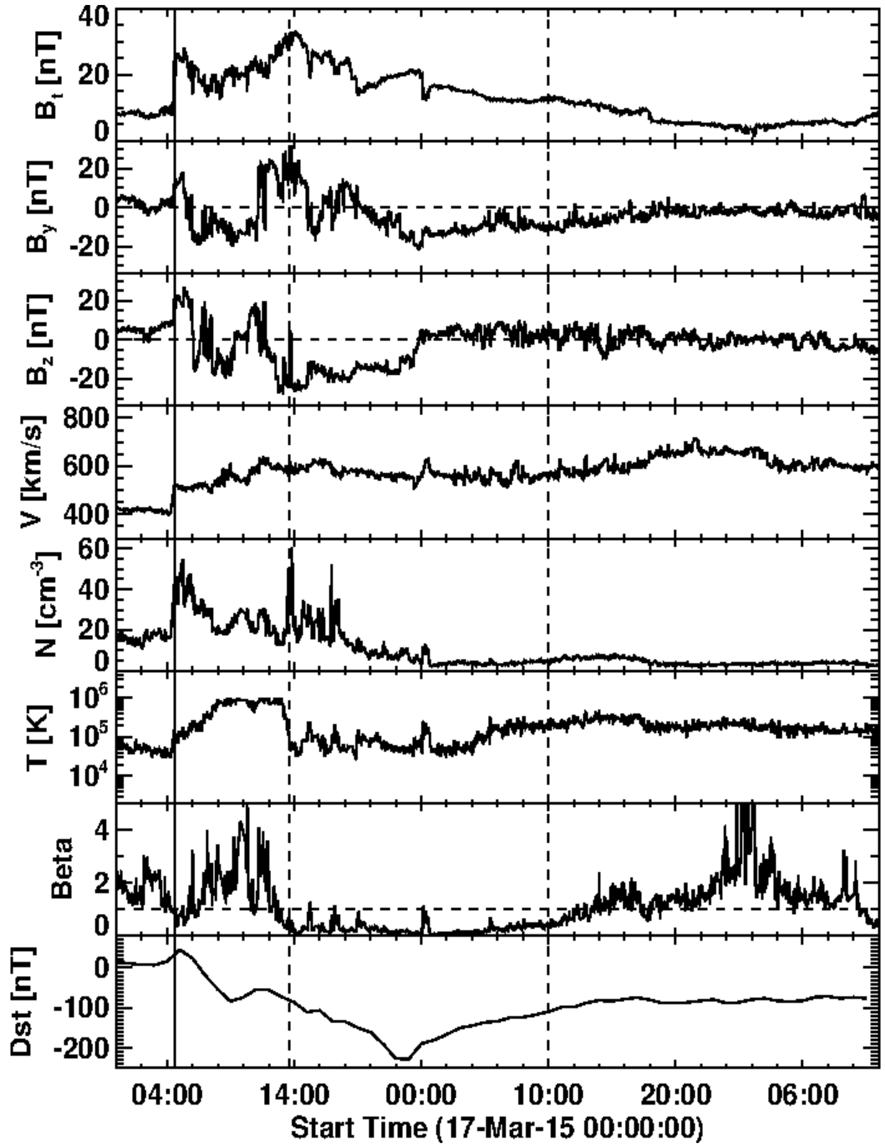
vs. 18.6 h observed

The transit time of 2012 July 23 CME is close to the Carrington event

2015 March 17 Storm

- March 15, 2015 CME with a speed of ~1120 km/s (S18W39); Earthward speed ~1025 km/s
- The magnetic cloud arrived at L1 with a speed of ~600 km/s and a Bz of -25 nT, giving VBz = -1.5×10^4 nT•km/s
- Observed Dst = -223 nT
- Dst = -0.017VBz +16 nT → -239 nT
- If there were no expansion, VBz → VBz/0.6 and the Dst would be -409 nT

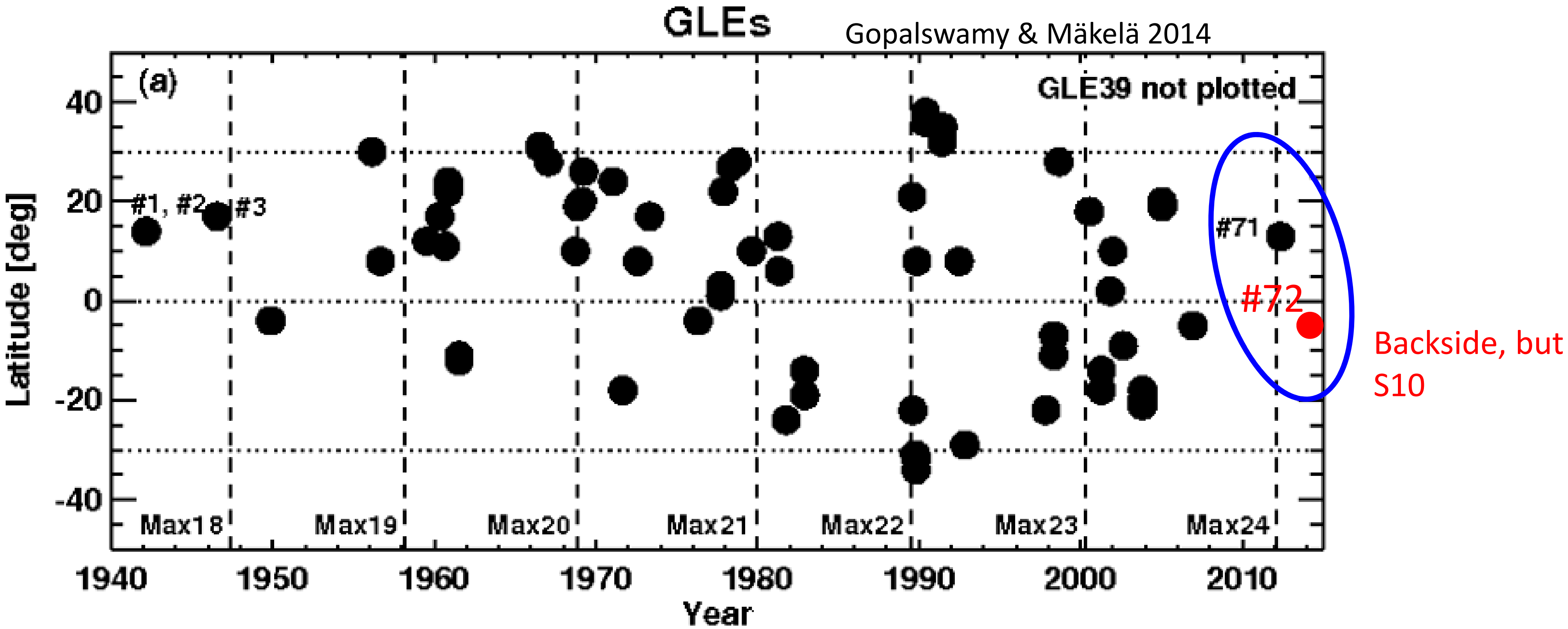
Gopalswamy et al. 2015



Dearth of GLEs in Cycle 24

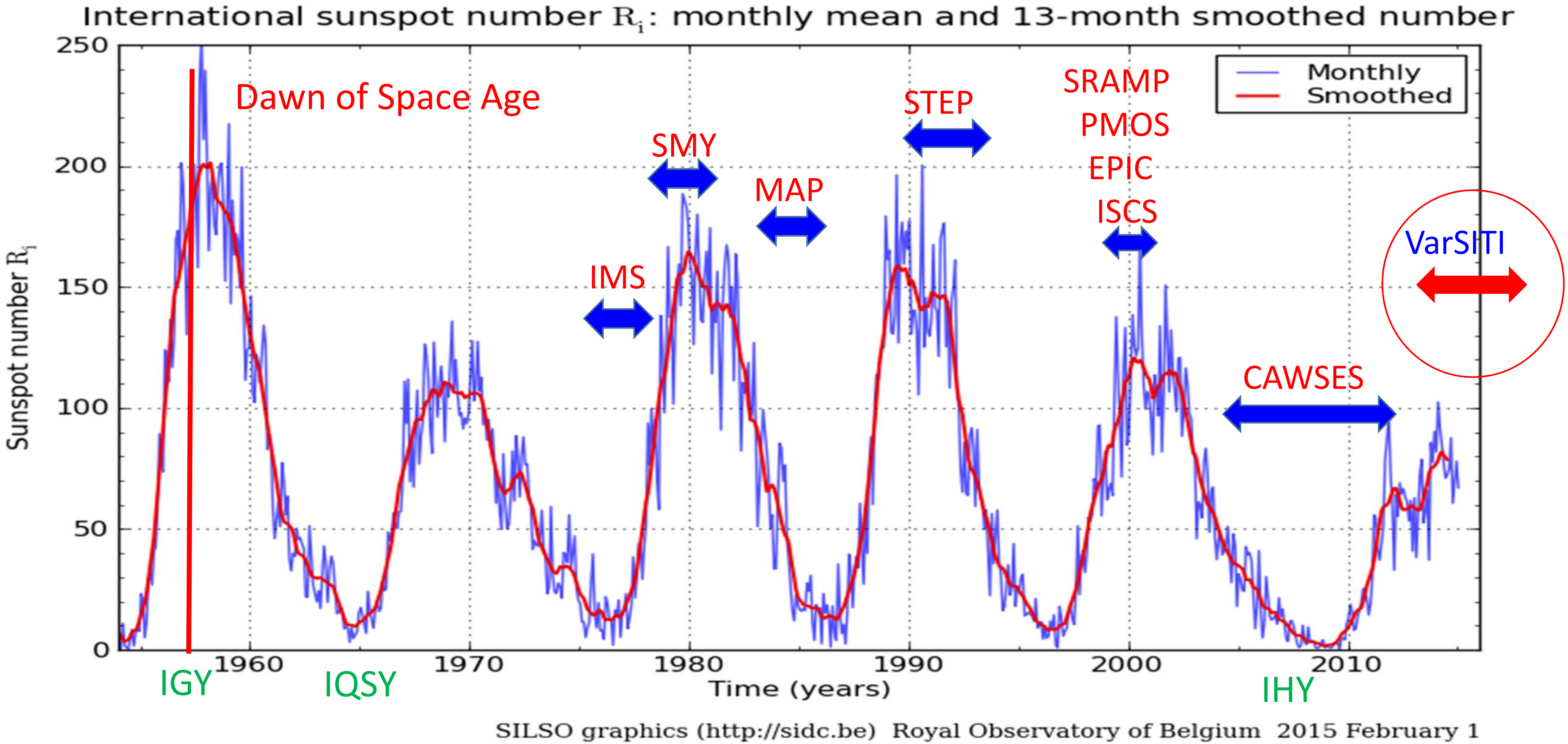
Latitudinal connectivity?
Change in the state of the heliosphere?
CME speed?

Gopalswamy & Mäkelä 2014



About 15% of SEP events have GLEs (Shea and Smart 2008). In cycle 24, only 5%

Solar Variability and SCOSTEP Scientific Programs



Summary

- Historical data often helps making new discoveries – e.g. the Carrington superstorm, AD 775 ^{14}C event
- Data collected from natural archives and instrumental observations need to be preserved
- Historical data have established benchmarks for various phenomena
- Historical data provide broader parameter space to test theories/ideas