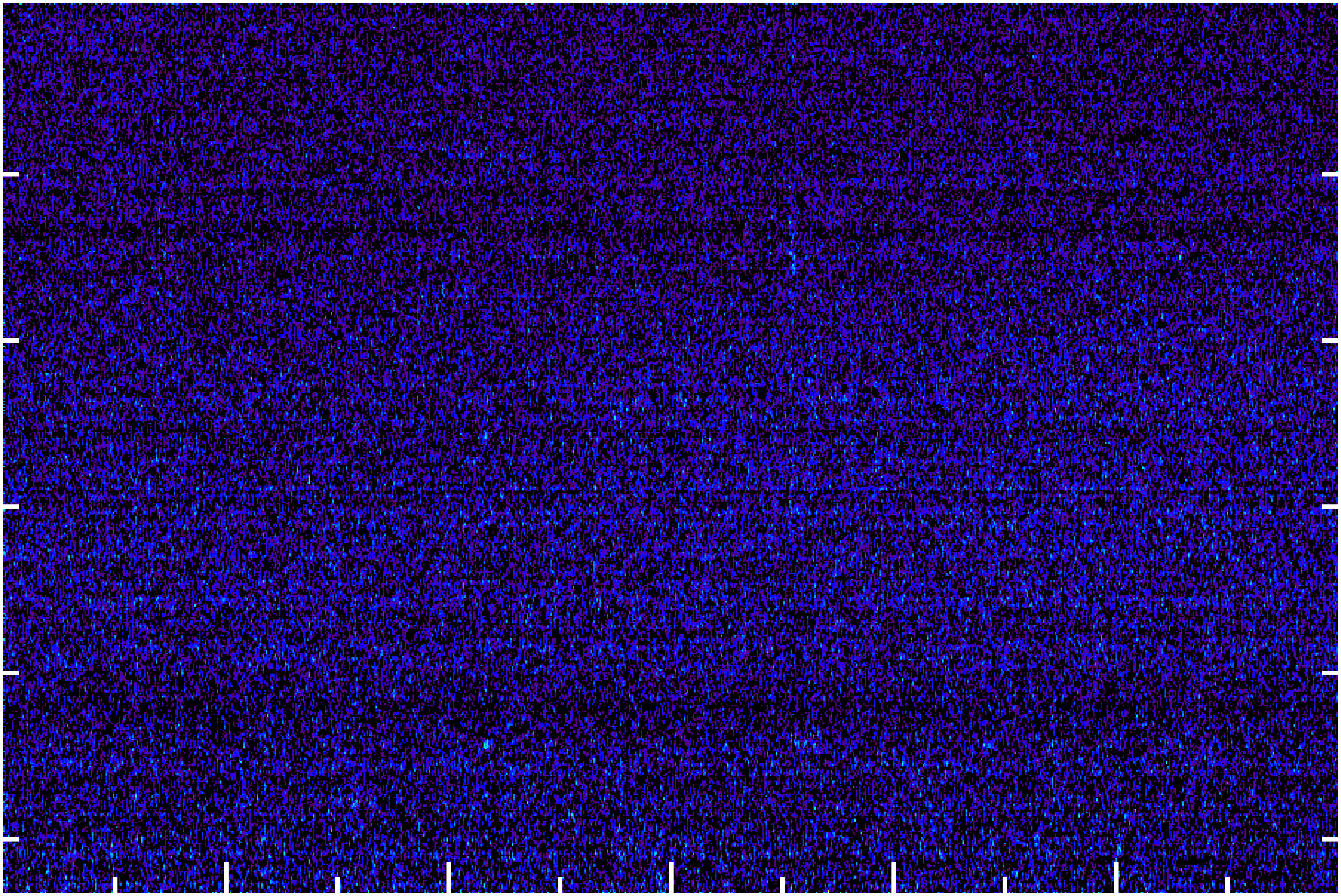
Solar Radio Bursts from the Ground

- Introduce new facility relevant for SHINE community: GBSRBS
- Quick review of solar radio bursts
- Revisit the CME/Type II discussion

Green Bank
Solar Radio Burst Spectrometer

Quiet dynamic spectrum: 1 hour, 18-70 MHz



GBSRBS

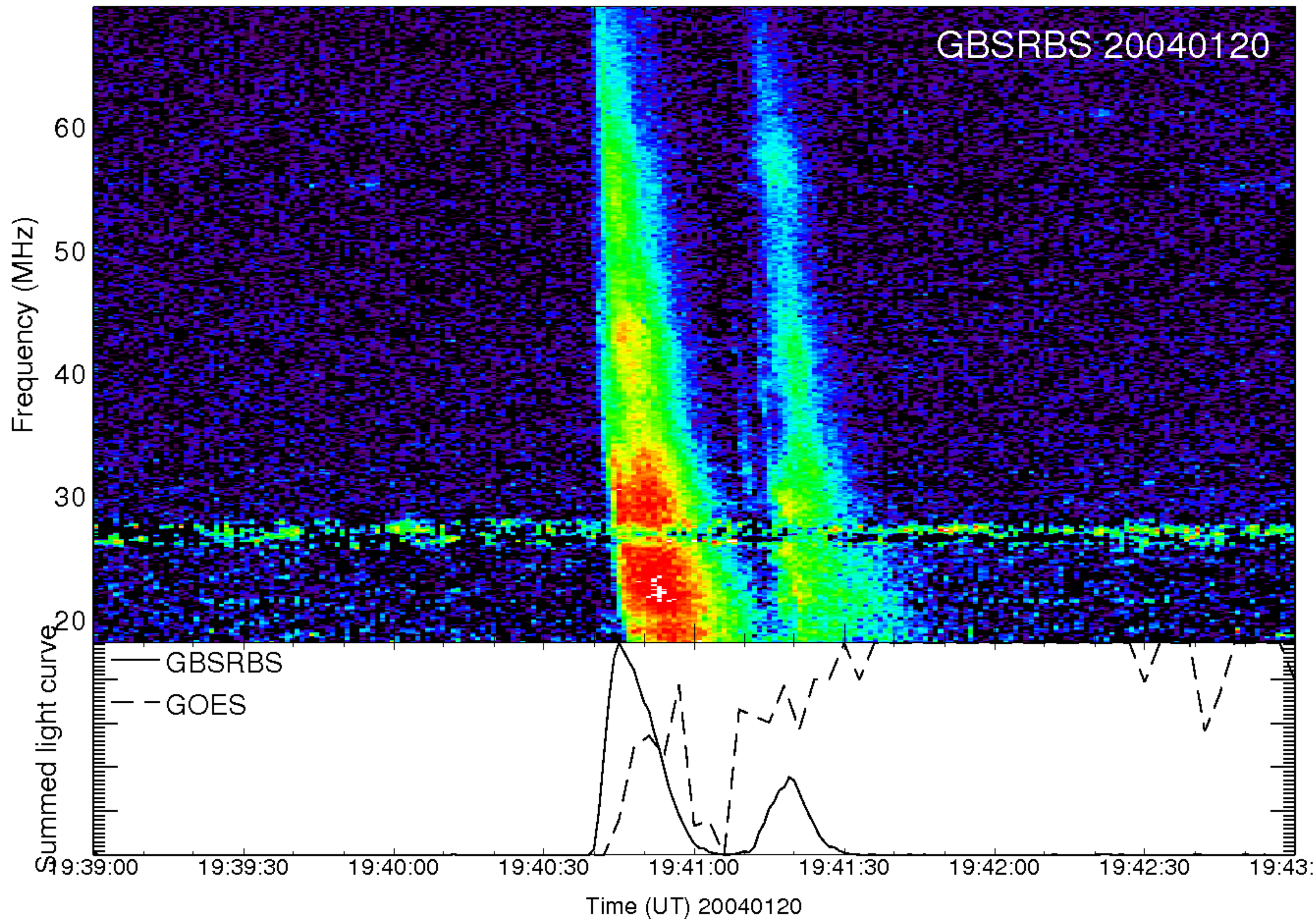
- Construction funded by National Science Foundation: PI Tim Bastian, engineer is Rich Bradley
- Aim to make quality dynamic spectra in western hemisphere time zone publicly available
- Takes advantage of the Radio Quiet Zone around the Green Bank Observatory in West Virginia
- Initially operates from 18-70 MHz; presently debugging 300-1000 MHz system; 70-300 later
- 1 second time resolution, excellent frequency resolution (similar to Erickson system)
- Web site makes all data available publicly (when RAID comes back up):

  http://www.nrao.edu/astrores/gbsrbs

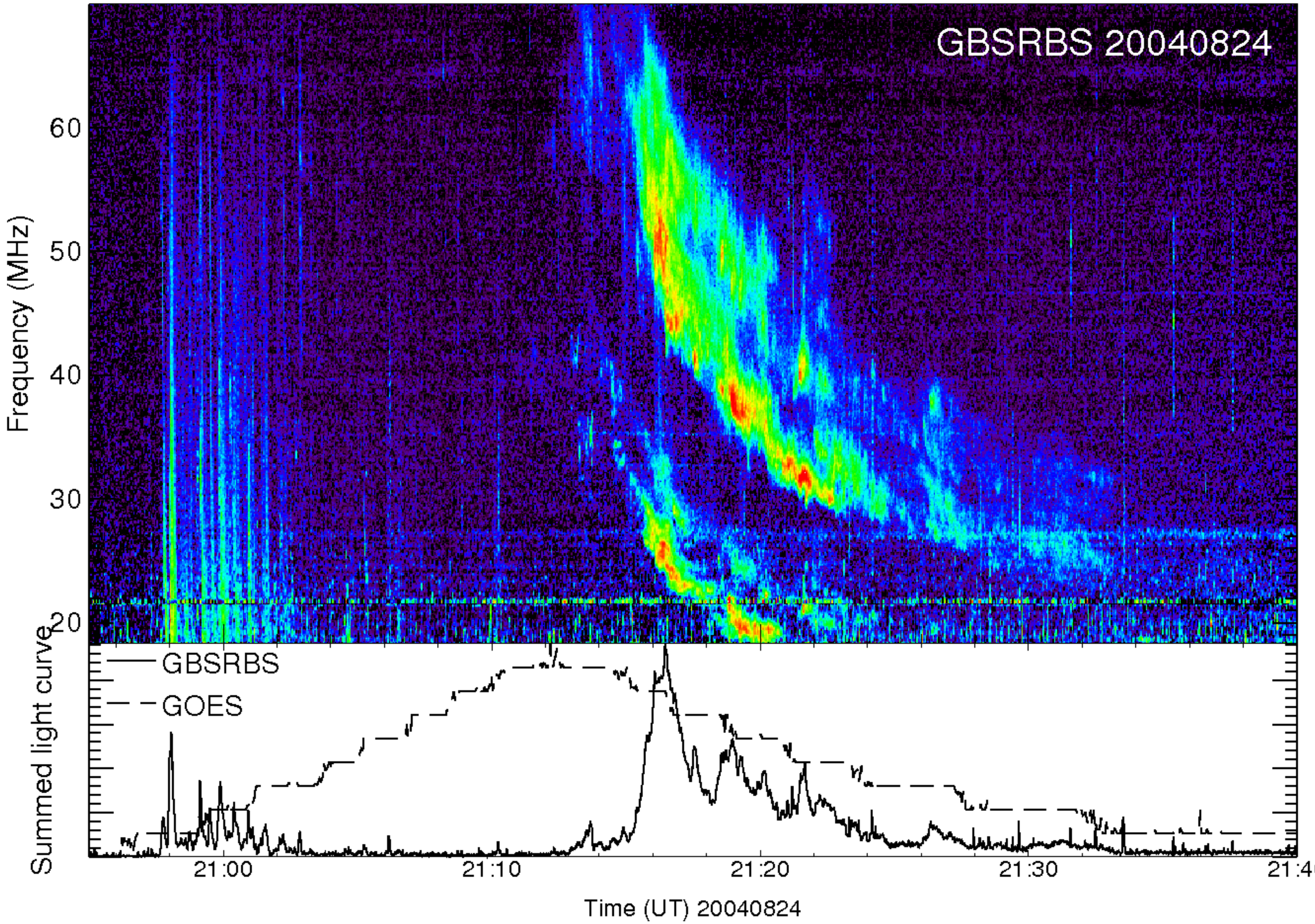
Solar Radio Bursts for the non-Expert

- There are five types of burst: Types I-V
- Rule #1: Never mention Type I bursts
- Rule #5: Never mention Type V bursts
- Nearly everything is at the plasma frequency $f_p=9000n_e^{0.5}$, or at $2f_p$, so frequency => density and frequency drift rate reflects speed across coronal density gradient

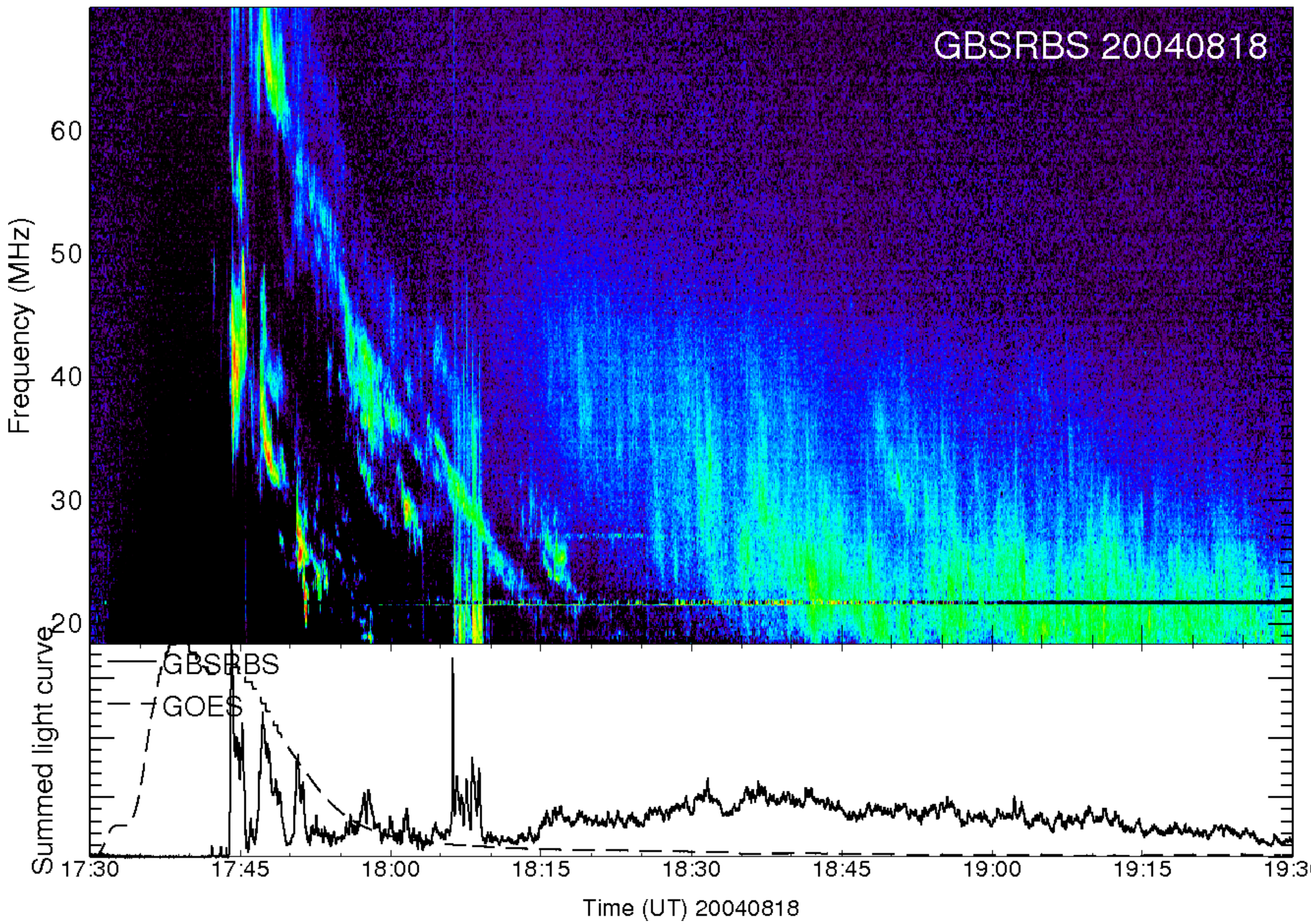
Type III burst: fast-drift electron beam (4 mins)



Type III's followed by Type II (45 mins)



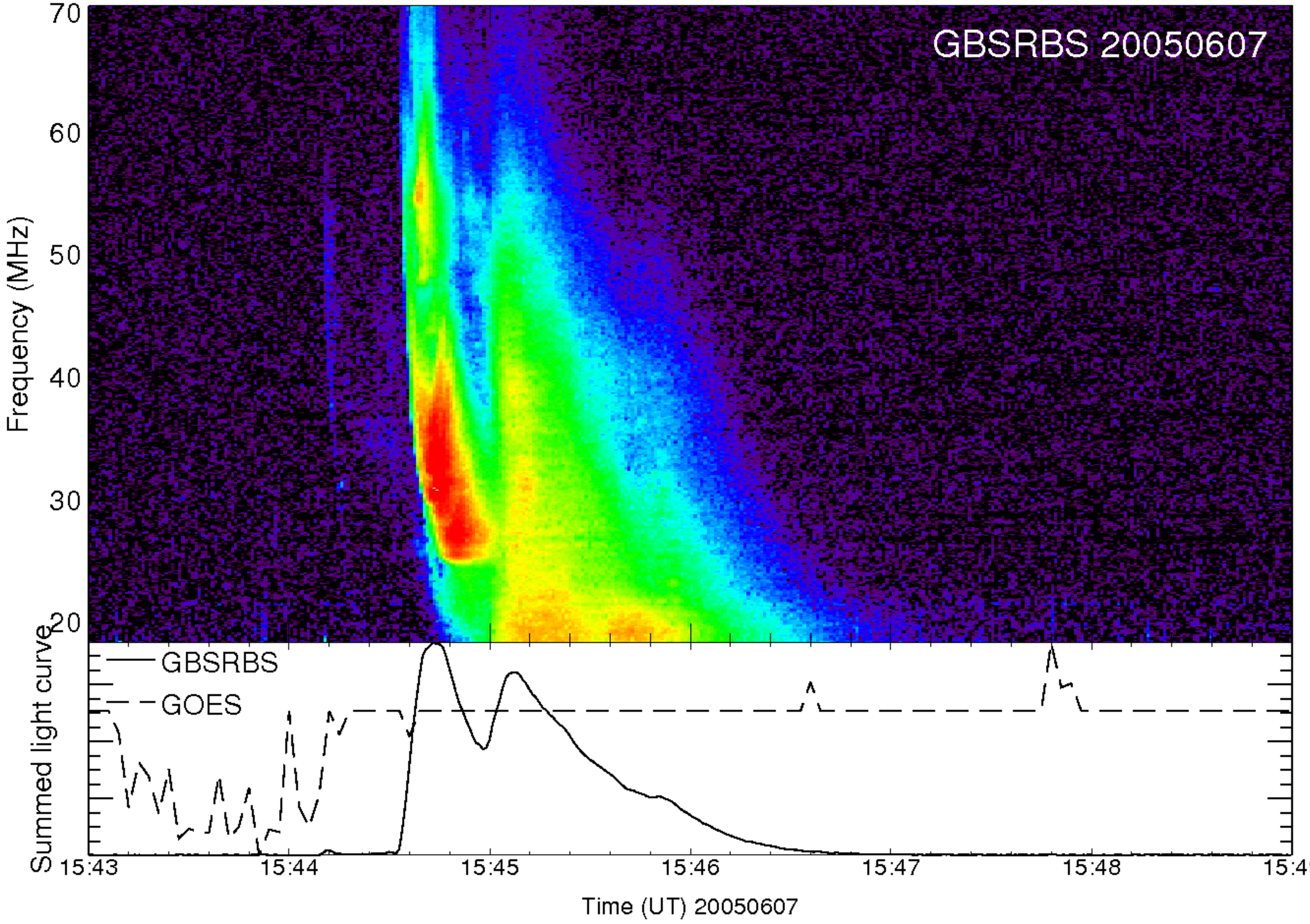
Type II followed by Type IV (2 hours)



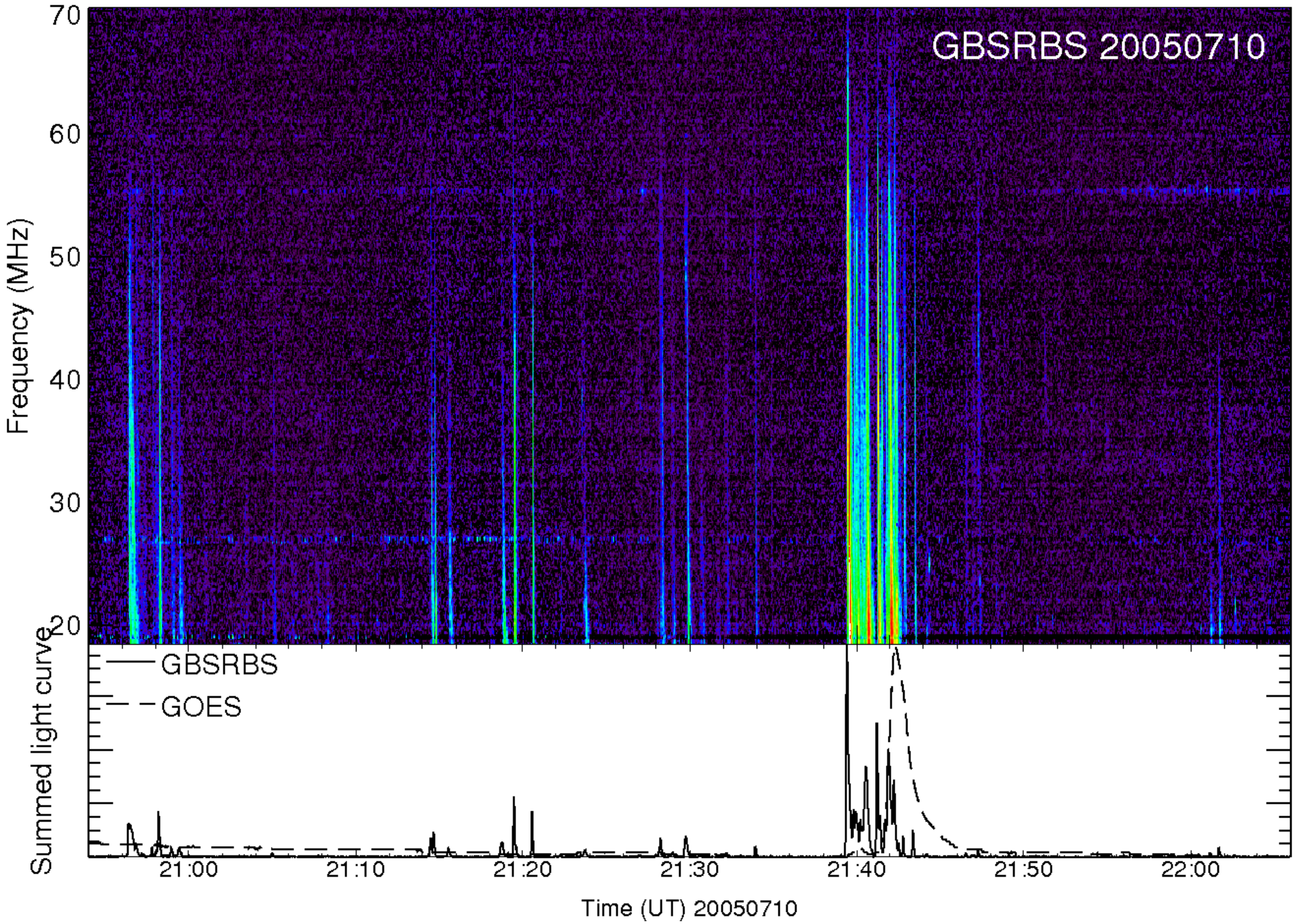
Solar Radio Bursts

- Type III bursts: fast frequency drift rate, due to electron beams on open field lines, bump on tail instability, locally narrowband
- Type II bursts: slower frequency drift rate, speeds of order Alfven speed, typically see split bands at f_p and $2f_p$ simultaneously: shocks!
- Type IV bursts: broadband, start in extended phase of flares, often show vertical structure on spectra that could be modulations or fast-drift: mechanism unclear

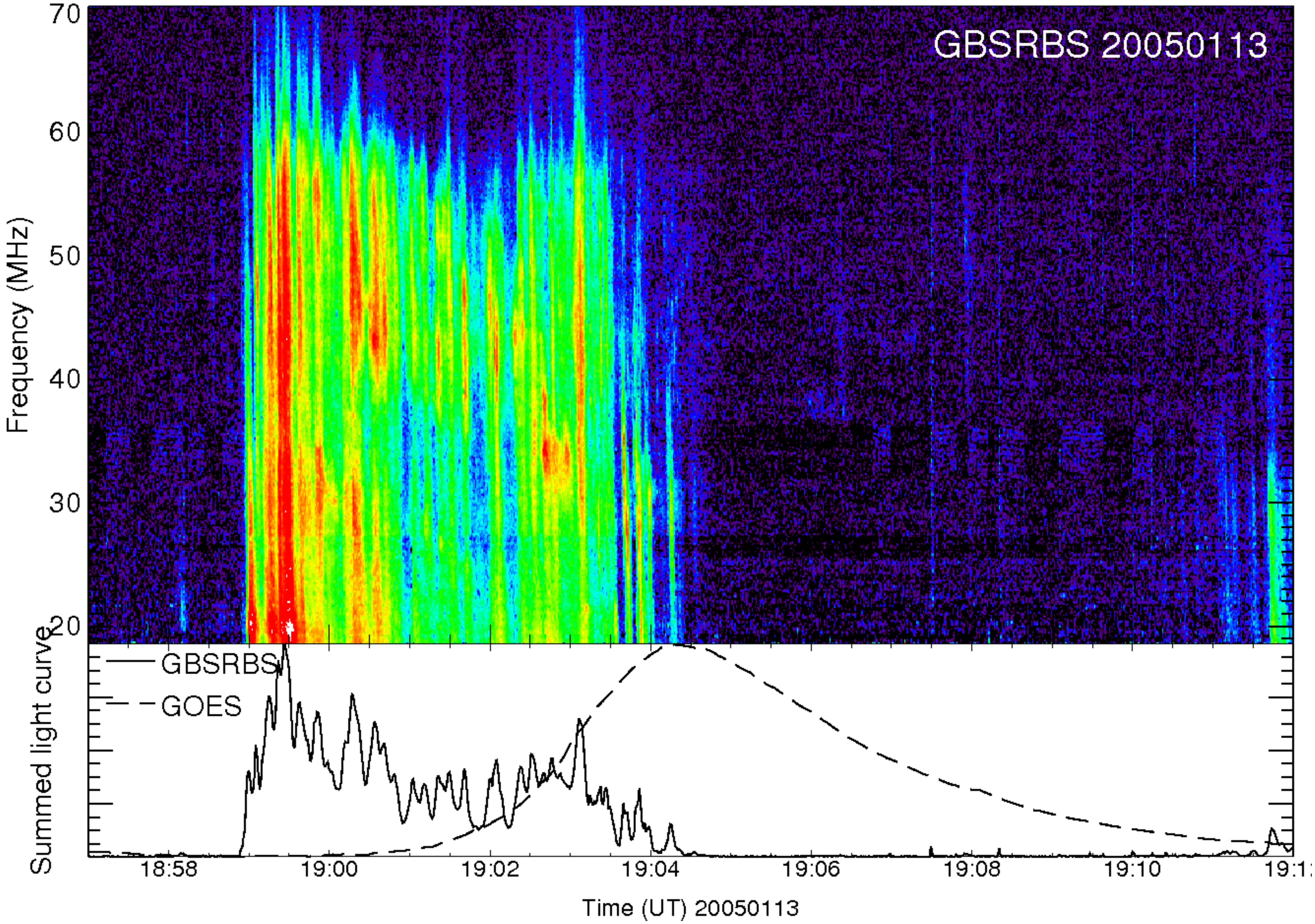
Type V: extended phase of Type III (6 mins)



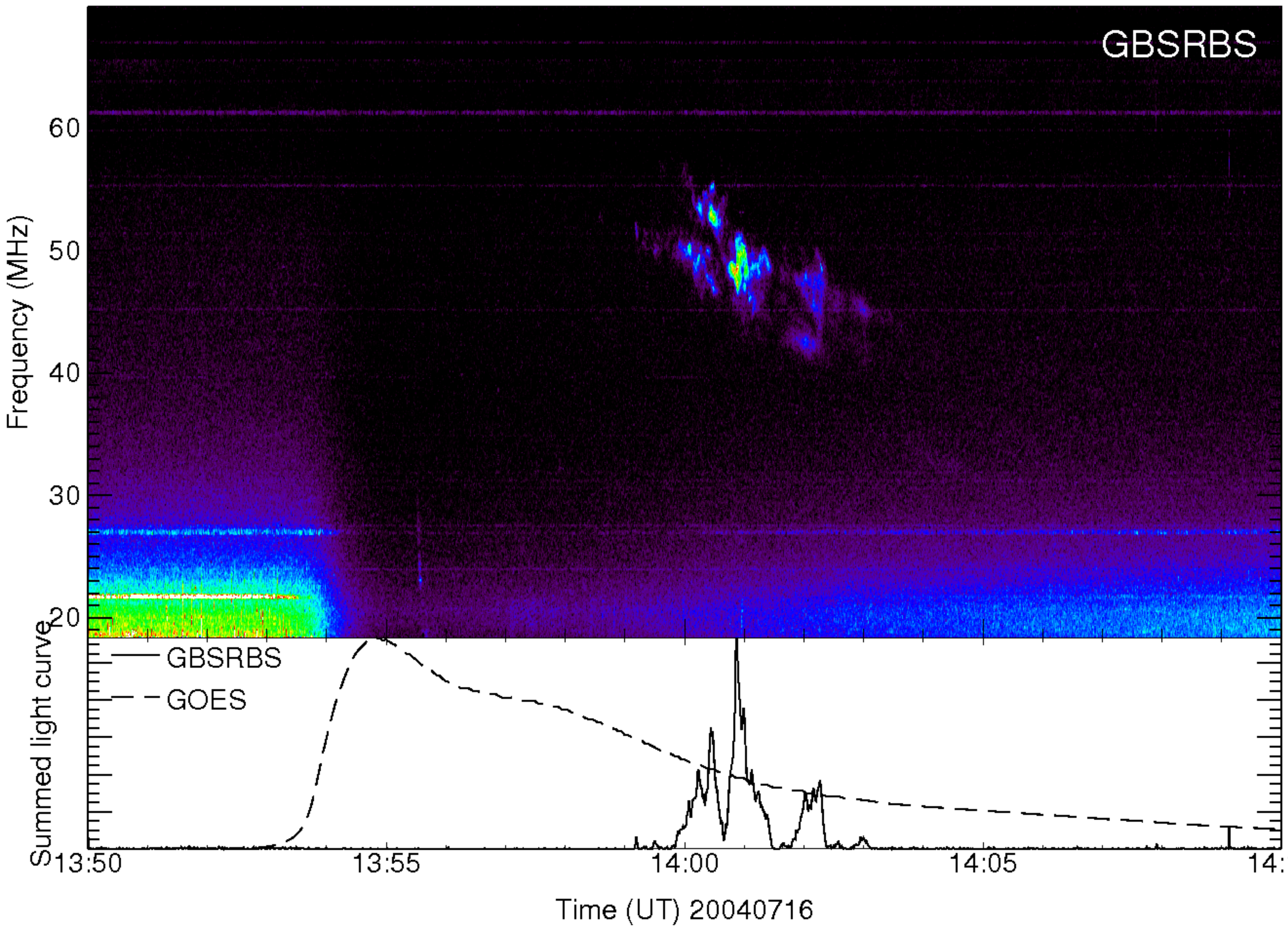
Type IIIs can occur all the time (75 mins)



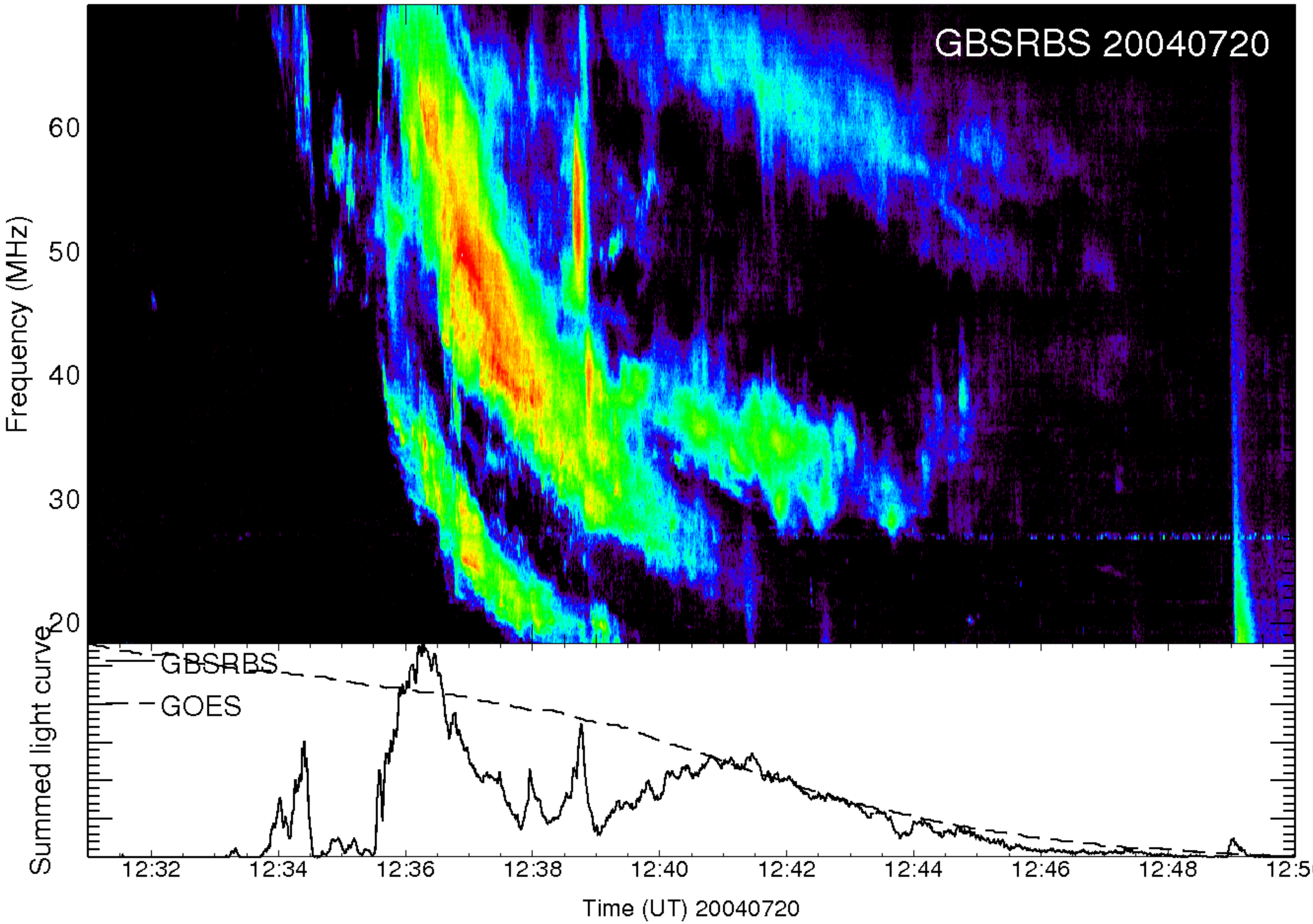
Type III cluster in rise phase (13 mins)



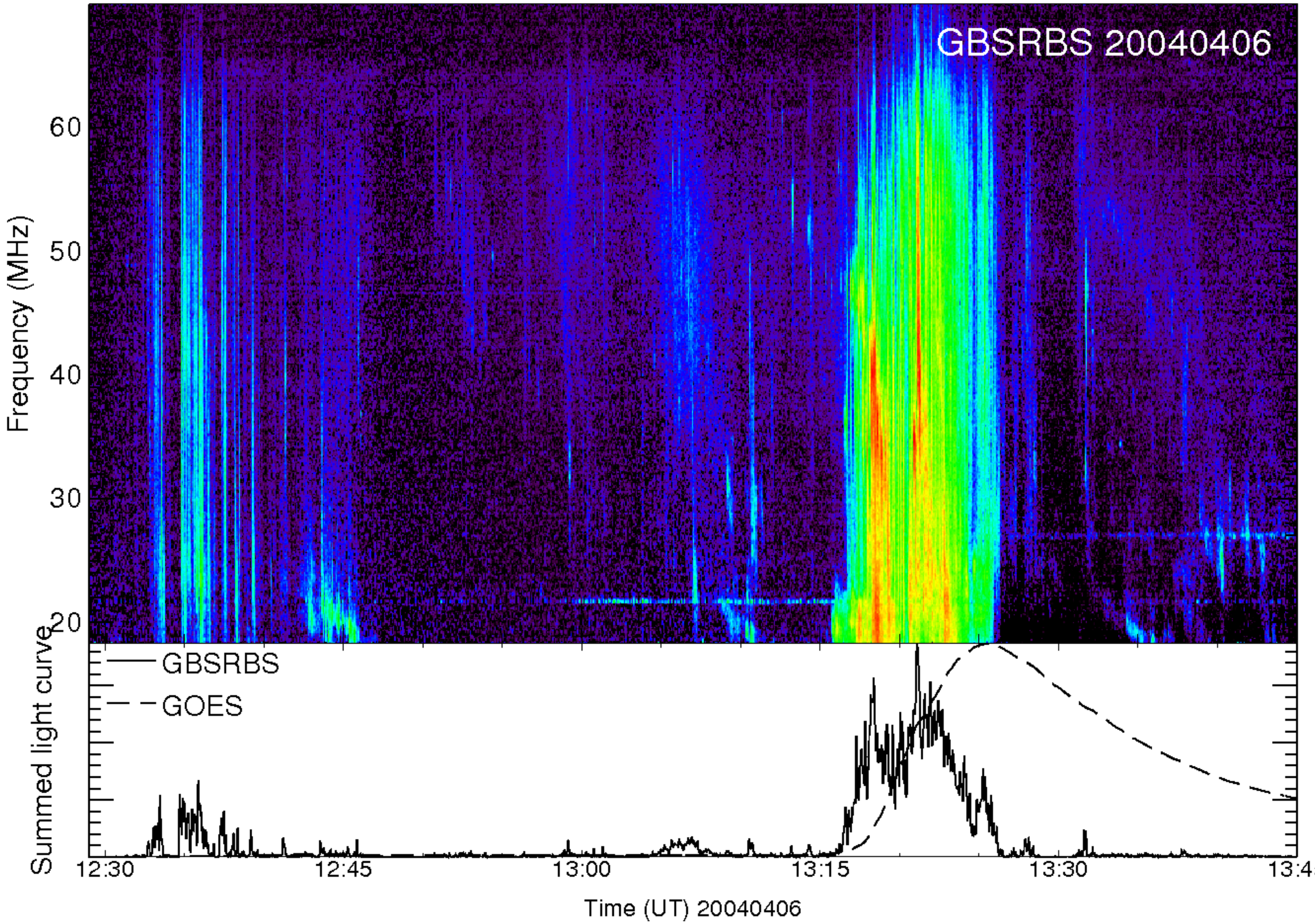
Short wave fadeout followed by Type II (20 mins)



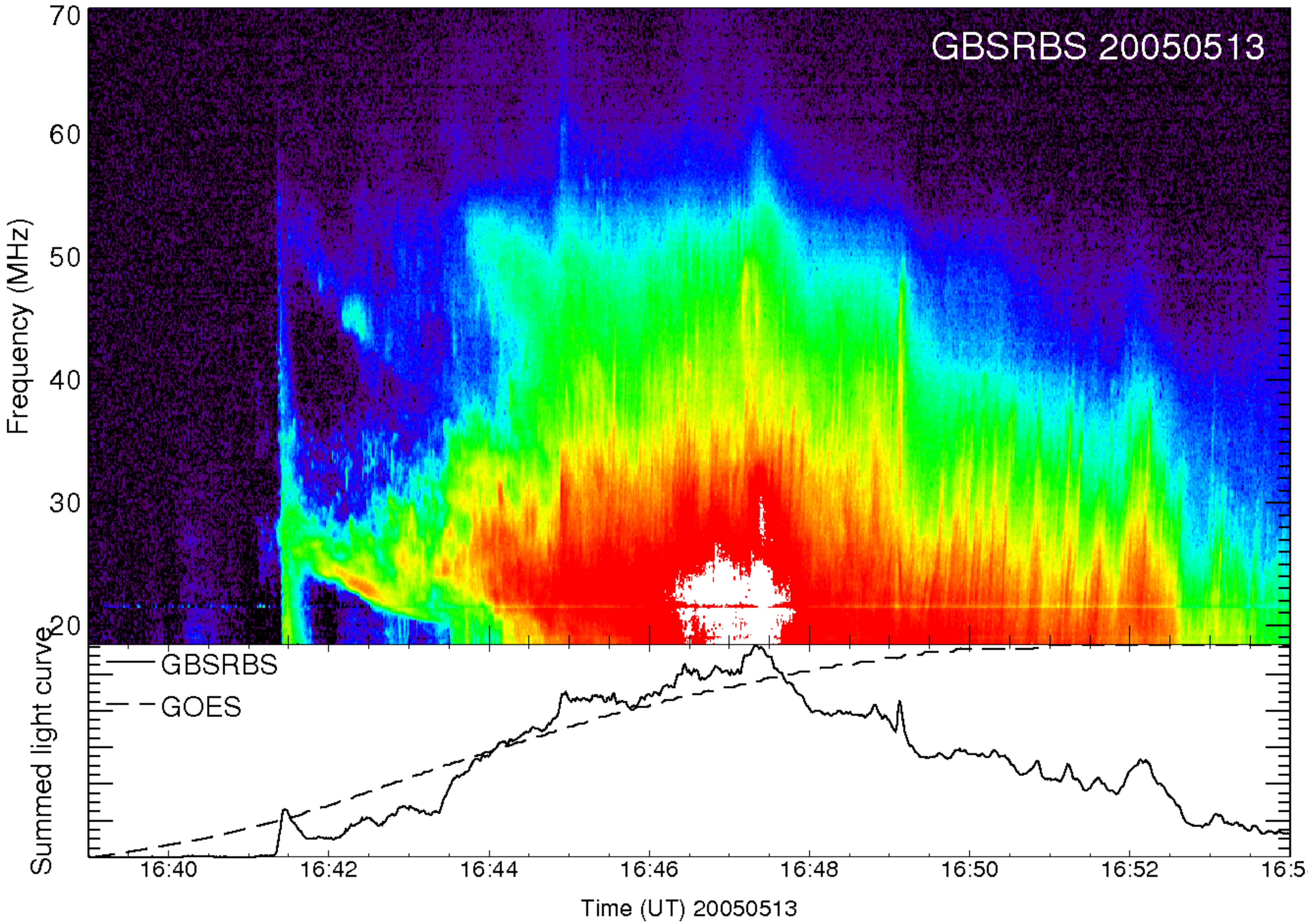
Pair of Type IIs in one event (19 mins)



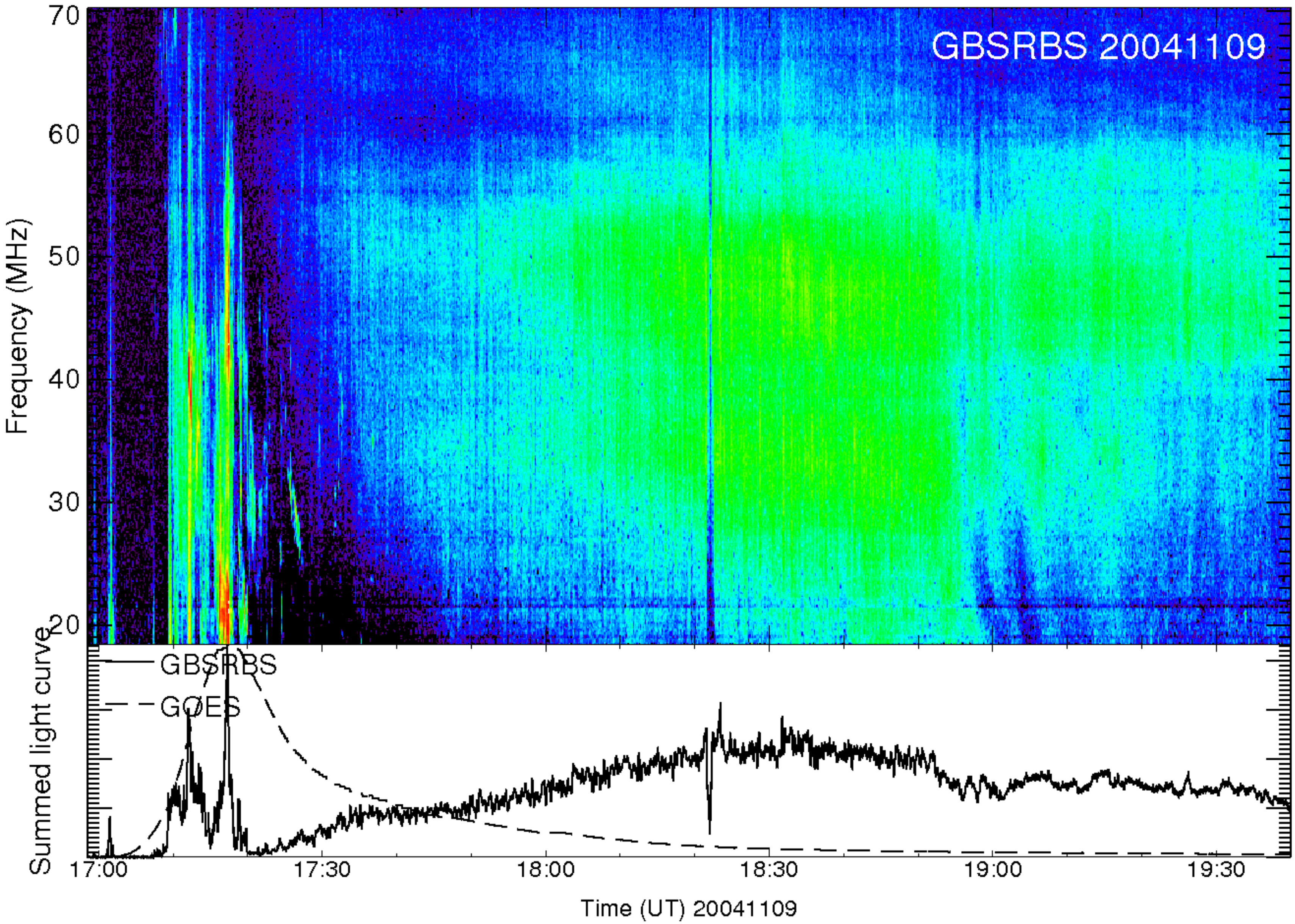
Complex burst with many phenomena (70 mins)



Bright low frequency burst: II or not? (15 mins)



Type III's, followed by Type IV (2.7 hours)



Type IIs and CMEs

- Long controversy over the relationship between Type II radio bursts and CMEs.
- No disagreement that Type IIs are shocks: what drives shock?
- CME is a natural driver.
- Alternative is a blast wave from a flare

Type IIs and CMEs

- Type IIs are flare phenomena: always follows the flare impulsive onset and there is no compelling example of a II without a flare

- But if flares with IIs also have CMEs, then IIs can still be CME-driven

- Doubts about blast waves from flares: used to be thought that Hα Moreton waves were evidence

Problems with Blast Waves

Cliver, Webb et al.:

- Type IIs can occur with all flare sizes: why no correlation with flare size if blast wave?
- High correlation between Type IIs and CMEs
- Some Type IIs seem to occur without CMES: argue they are present but not seen
- Type II speeds are similar to CME speeds
- Hα Moreton waves could be CME-related not flare-related
- CMEs can drive Type IIs in the solar wind: why not in the corona as well?

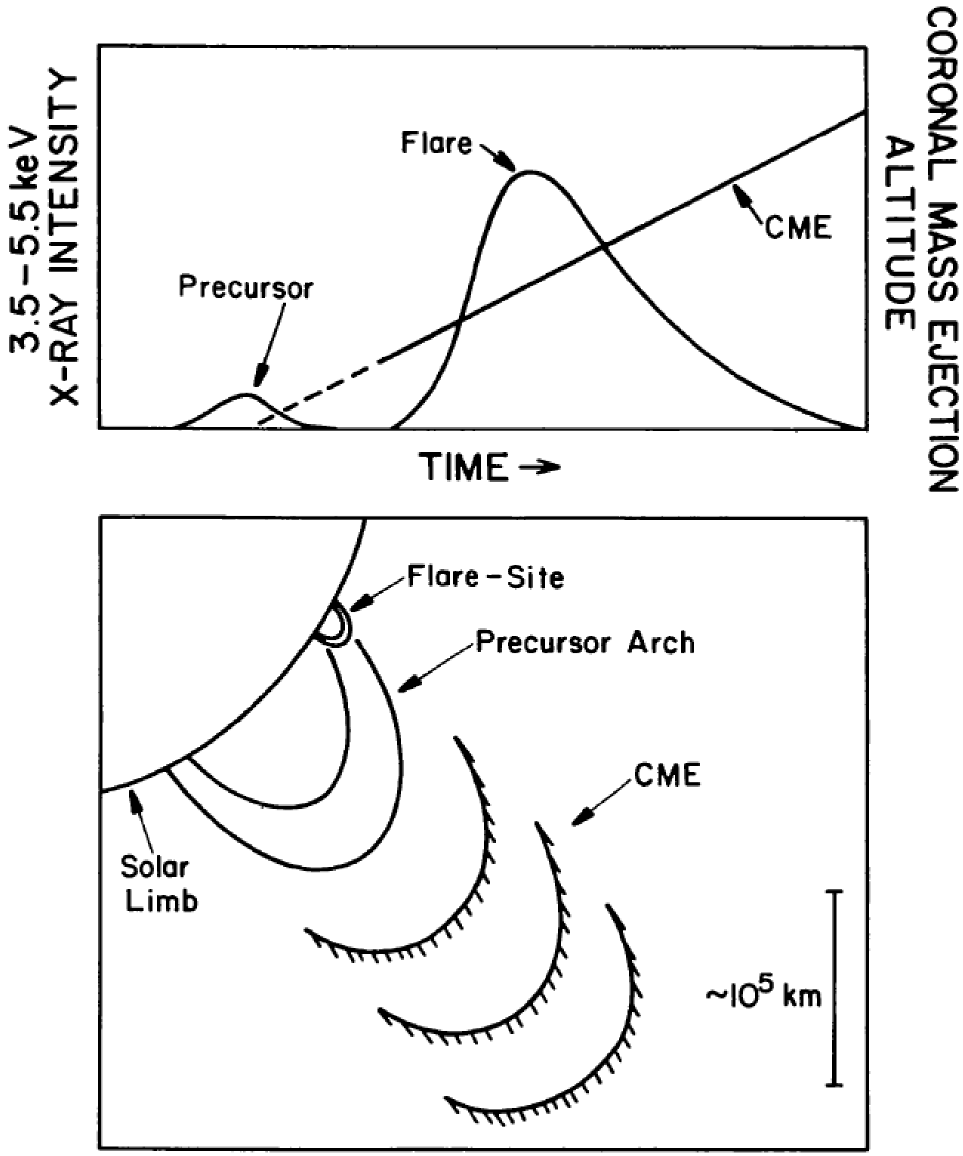


Fig. 6. A coronal arch of scale-length several times 10^5 km brightens in soft X-rays (precursor). At this time a Coronal Mass Ejection (CME) is launched and it appears to propagate directly from the arch. Some tens of minutes later a flare occurs in one foot of the arch

"Solar flare myth"

Harrison 1986:
"The launch of a coronal mass ejection appears to be a pre-flare phenomenon."

If CME underway when flare starts, why no Type IIs before flares?

Type IIs and CMEs

- Jie Zhang et al 2001: LASCO C1 shows that CMEs accelerate impulsively in conjunction with flare impulsive phase, not before

- If CME does not reach super-Alfvenic speeds before flare starts, then do not expect to see Type IIs before flare, and that objection vanishes (e.g., Cliver et al 2005)

Date	Time	Obs		Flare	(loc)	CME	(km/s)	
2004 01 19	2003-2013	PAL	GB	C8	S16W05	No	NW	
2004 06 02	2310 2315	PAL	GB		over W	1100	W	
2004 06 03	1624-1640	SVI	GB	-	over W	1200	SW	
2004 06 26	2112-2118		GB	B4	S10W87			No LASCO
2004 07 16	1359-1404	HOL	GB	X4	S10E35	No		
2004 07 20	1235 1248	SVI	GB	M9	N10E35	700	N	
2004 07 20	2107-2116	PAL		C8	N04E30	470	SE	Not a II
2004 07 23	1600-1608	SVI	GB	C1	N05W04	820	WH	Flare ID wrong
2004 07 25	1521-1526	SVI		-		No		Not a II
2004 08 18	1742-0000	PAL	GB	X2	S13W88	570	W	
2004 08 24	1353-1354		CB	B8	S06E81	800	E	
2004 08 24	2110-2134	CUL	GB	B5	N17W57	600	W	
2004 09 08	1405-1411	SAG		-		No		Not a II
2004 09 19	1656-1713	SAG	GB	M2	N03W58			No LASCO
2004 10 30	1629-1635	SAG	CB	M6	N12W27	690	WH	
2004 11 03	1541-1556	SAG	GB	M5	N08E39	1070	E	
2004 11 07	1559-1616	SAG	GB	X2	N09W17	1760	WH	
2004 11 09	1724-1727	SAG	GB	M9	N07W51	1720	WH	
2004 12 08	1945 2004	PAL	GB	C3	N07W03	610	H	
2004 12 29	1626-1632	SAG	GB	M2	N03E64	770	E	
2004 12 31	1518-1522		GB	C7	N03E38	800	E	
2005 01 14	1247-1252	SVI		C5	S06E04	No		Not GB: > 65 MHz
2005 01 15	1422 1430		GB	M3	S08W11	500	W	
2005 04 17	2109-2120		GB	C5	S11E76	Yes	E	
2005 04 19	2150-2202	PAL	GB	B8	S12E57	740	E	
2005 05 02	2235-2255		GB	C8	S08E89	930	E	Reported then lost
2005 05 06	1648-1658	SAG	GB	C9	S07E28	1100	SE	
2005 05 11	1937-1945	PAL	CB	M1	S11W51	470	SW	
2005 05 13	1641-1652	SVI	GB	M8	N11E11	1020	H	
2005 05 14	2046-2059	PAL	GB	C3	S08W89	650	W	
2005 05 15	2236-2252		GB	M4	S16E14	No		
2005 05 31	1445 1506	SAG	GB	C2	N12W22	slow	NW	
2005 06 03	1205-1217	SAG	GB	M1	N15E89	1660	E	
2005 06 14	1548-1555		GB	C7	N11W60	900	W	
2005 06 16	2010-2016	SAG	GB	M4	N08W89			No LASCO

Type IIs reported during GBSRBS obs:

18 months

27 from SGD: 3 false (structure in Type IV), 1 stops at 70 MHz

31 from GB: 8 not in SGD (low frequency only, faint, or lazy)

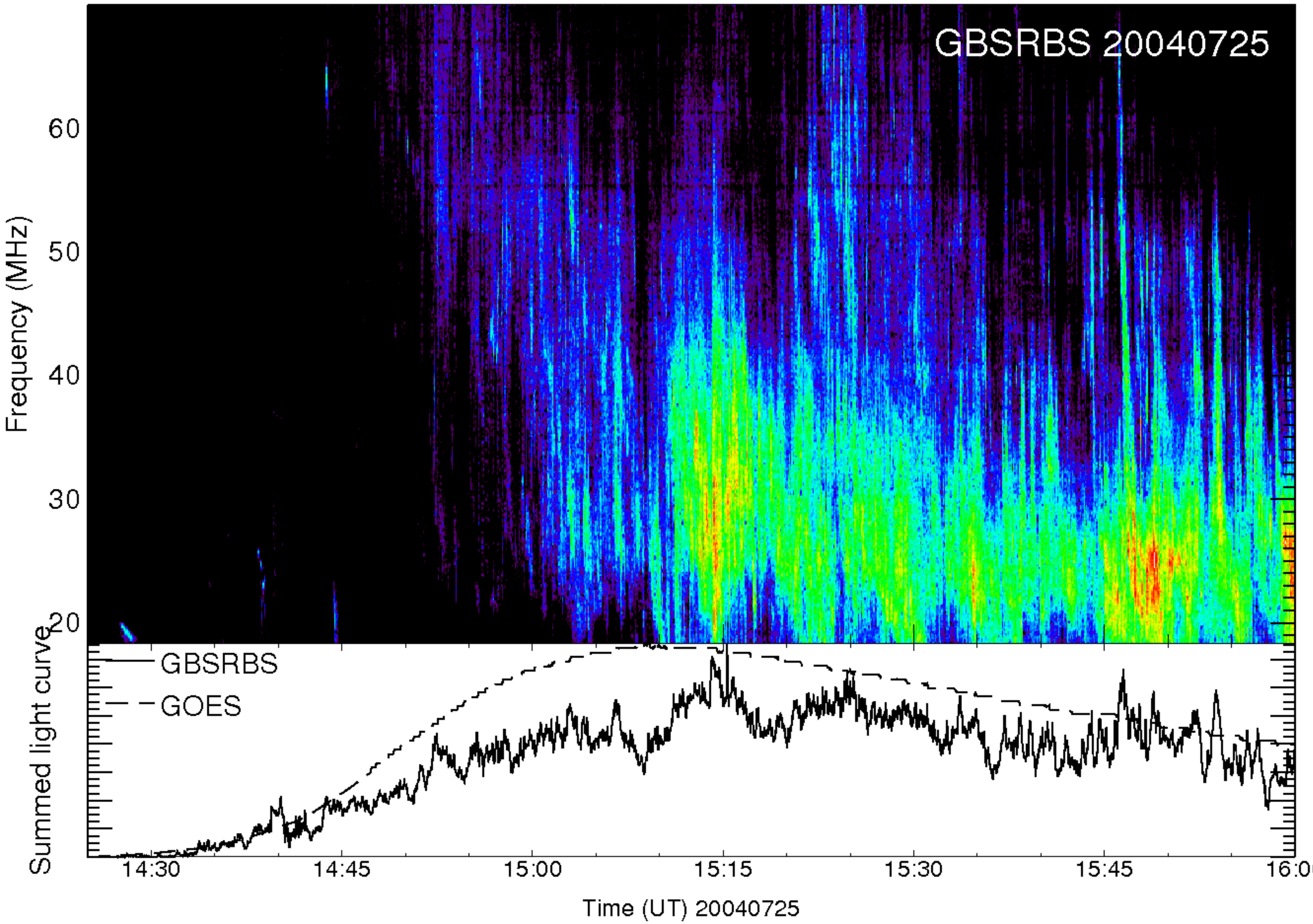
4 of 35 have no detectable CME

All have flares (2 over limb, fast CMEs).

Wide range of flare sizes

Wide range of CME speeds

Type II in SGD (20-25) : structure in IV (1.5 hrs)



Type IIs and CMEs

- SGD Type IIs from 1994-2003:
  - 70% of X flares (63/90)
  - 21% of M flares (262/1229)
  - 3% of C flares (300/11893)
  - 0.5% of B flares (29/6307)

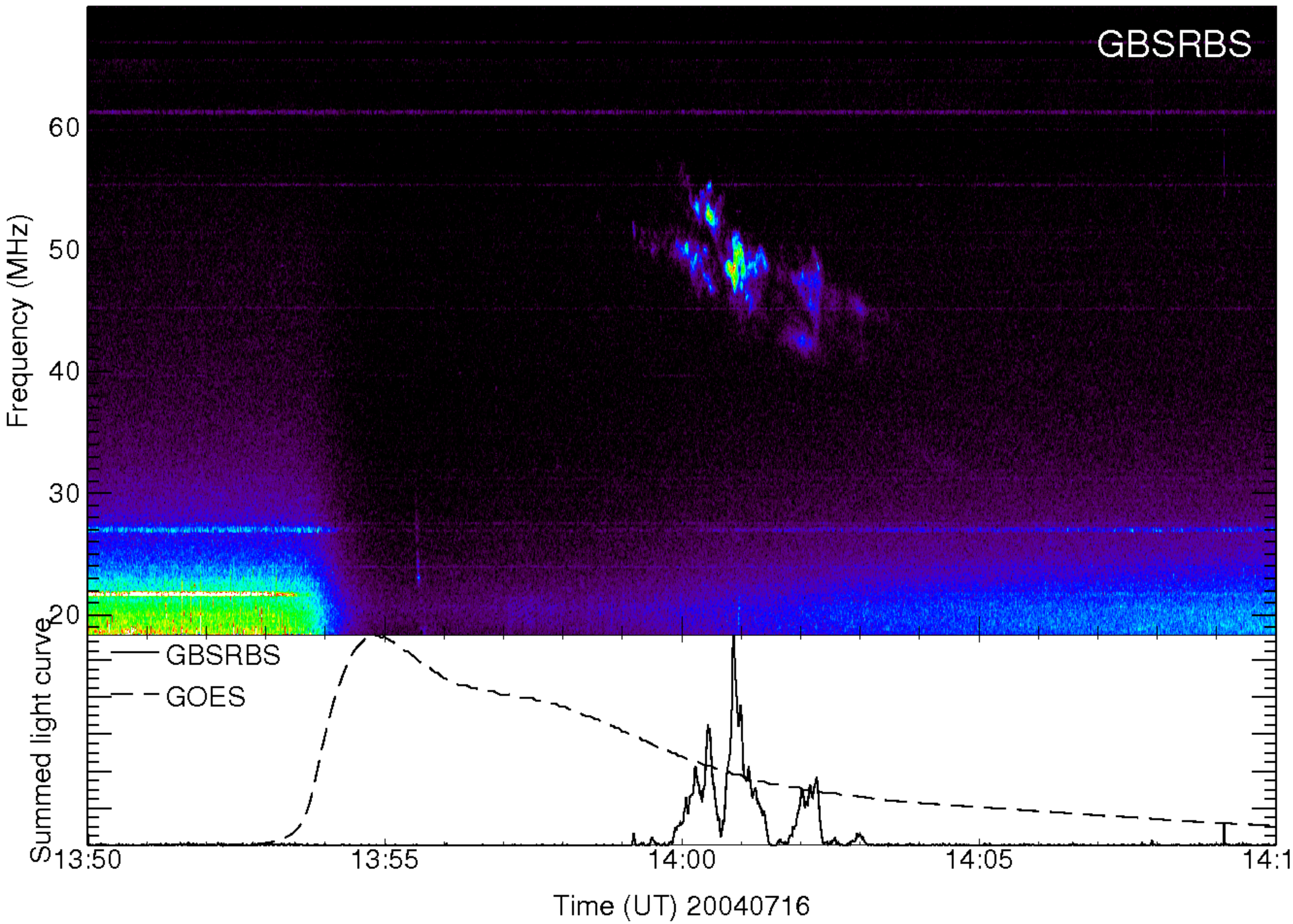
- CMEs faster than 1000 km/s in 2004:
  - 36% have Type IIs (18/50 but rubbery)
  - Up to 1700 km/s without a II

Type IIs and CMEs

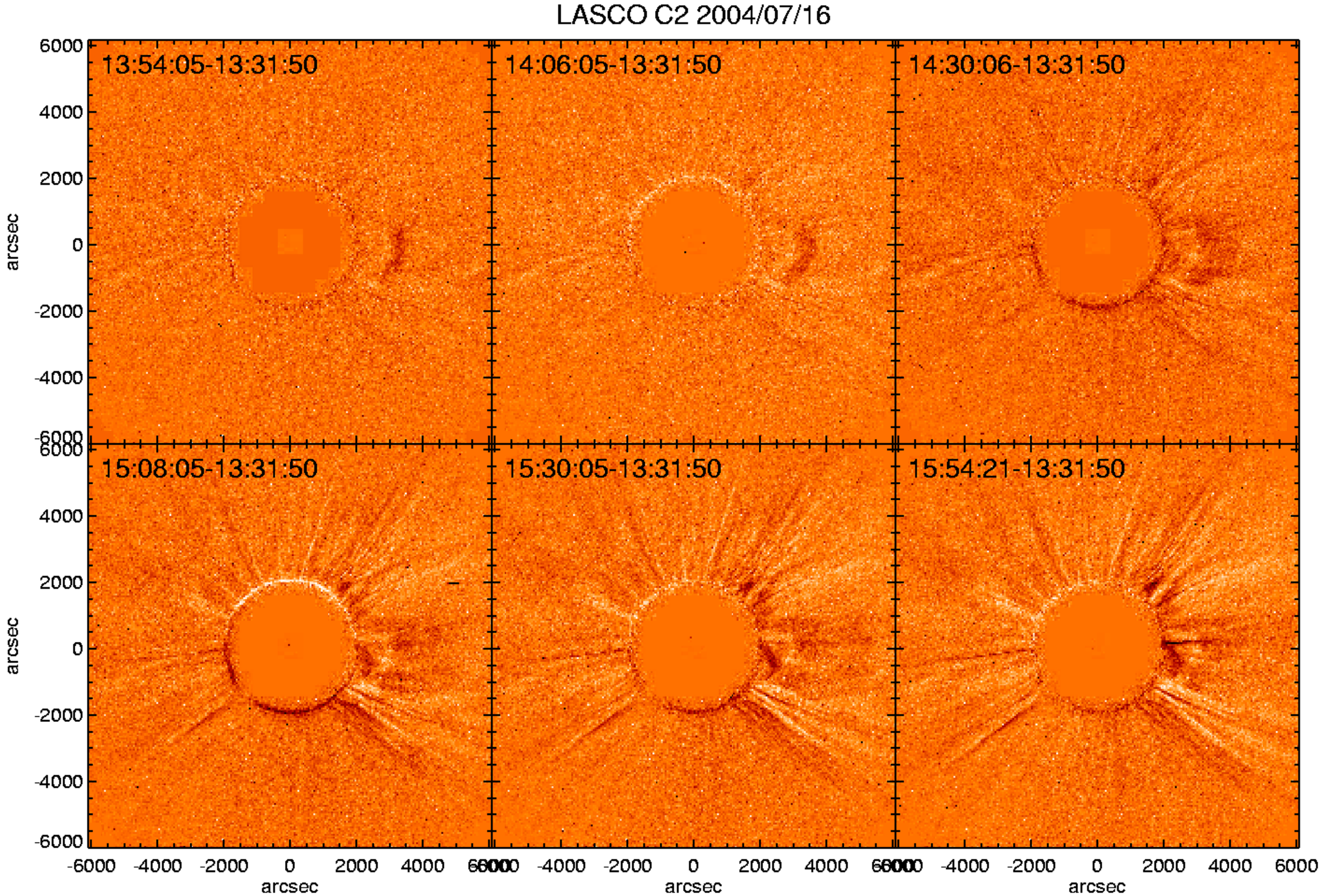
- Type IIs during GBSRBS observations:
  - 32 events
  - 3 have no LASCO data
  - 26 have CMEs: 26/29 = 90%
  - 3 have no detectable CME (X4)

- Type IIs from Hiraiso, Japan, in 1999:
  - 5 out of 28 have no CMEs (1 limb)
  - Only 2 CMEs with speeds > 1000 km/s
  - 13/34 1999 CME's > 1000 km/s have IIs

Short wave fadeout followed by Type II (20 mins)



X4 flare (E35) with a Type II but no CME



Are Type II Radio Bursts Driven by CMEs?

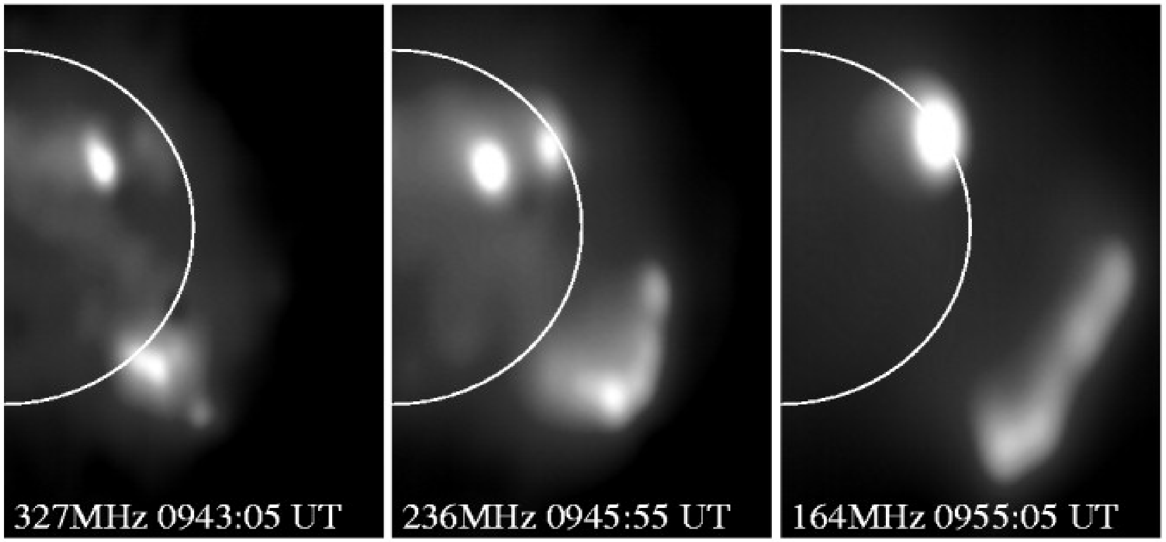
Pros:

- What else can drive a shock?
- Good association between CMEs and Type IIs
- No correlation between flare size and presence of Type II
- There is some correlation between CME speed and Type II
- CMEs drive IP Type IIs, why not coronal

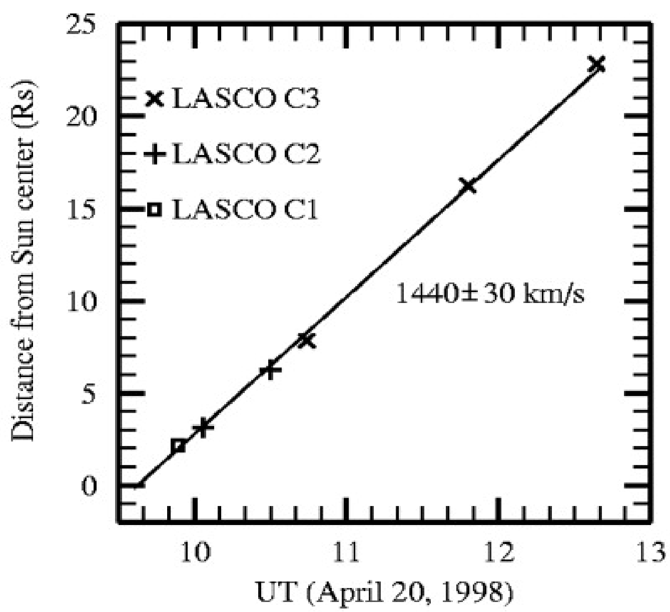
Cons:

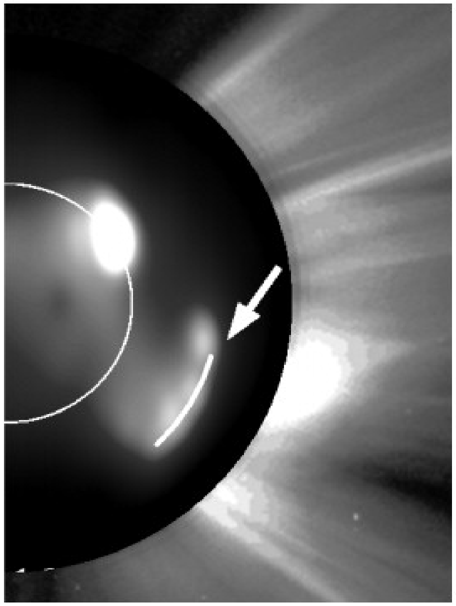
- Type IIs never occur without a flare
- Type IIs never occur before the flare
- Type IIs do occur without CMEs
- Type IIs are never seen before the associated flare
- When simultaneous images are available, the Type II seems to be lower than the CME: this old result still seems to be true with modern data (Klein et al. 1999; see next)

Type II located at CME front



Nancay observations of a CME with a Type II at the leading edge (Maia et al. 2000). However most Nancay data show the Type II behind the CME front, eg at erupting SXR loops (Klein et al 1999).

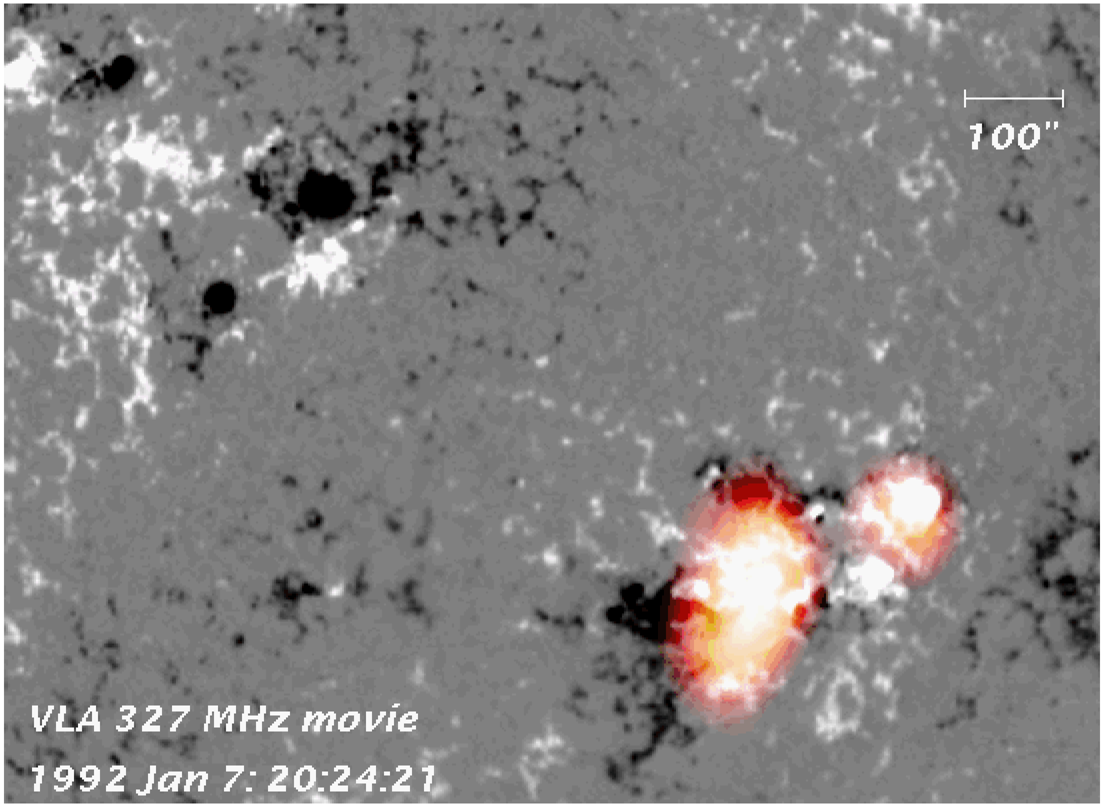




Implications of the Type II/CME Relationship

- If flare-associated CMEs begin to accelerate in the impulsive phase of the flare as argued by Zhang et al., then the timing objection to driving Type IIs with CMEs vanishes.
- Flares occur without Type IIs, CMEs (including fast ones) occur without Type IIs, Type IIs (apparently) occur without CMEs, but Type IIs never occur without flares: Type IIs are a flare phenomenon.
- The usual appearance of II after the impulsive phase probably due to variation of Alfven speed in corona (Gopal). Inferred height at onset of emission ~ 1 solar radius.
- This does not prove the blast wave idea.

High Speed Flare Disturbance: 26000 km/s



Summary

- If you have an event in western hemisphere daylight, check the GBSRBS web site
- For SHINE-related issues the main interest is in Type IIIs as diagnostics of open field lines, Type IIs for shocks and possibly CMEs and/or acceleration.
- Type IIs are definitely a flare phenomenon: they also have a very high correlation with CMEs, but not 100%, so it is hard to imagine that the Type II shocks are driven by CMEs.
- Flares are very good at launching travelling disturbances

http://www.nrao.edu/astrores/gbsrbs