Radio astronomy and interferometry

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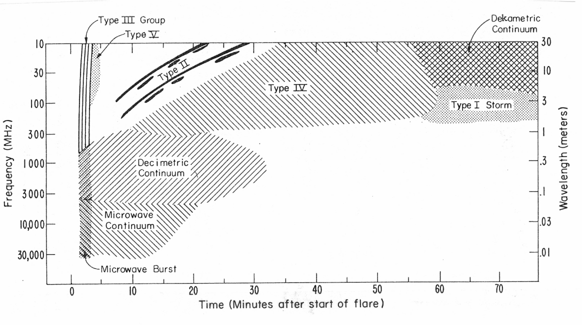
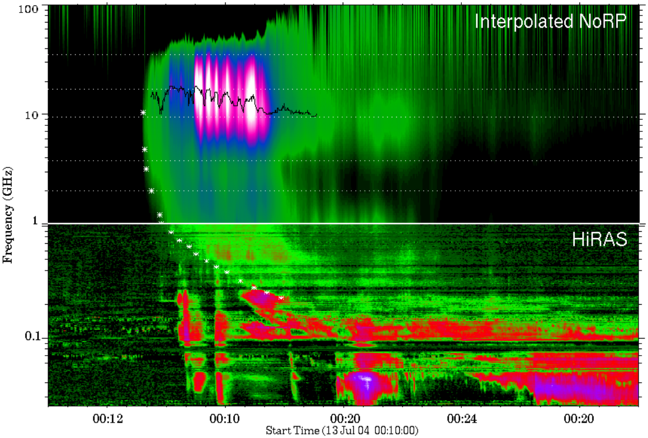
Forth solar lecture 2015



Plasma emission is typically observed at frequencies $<$ 1–2 GHz

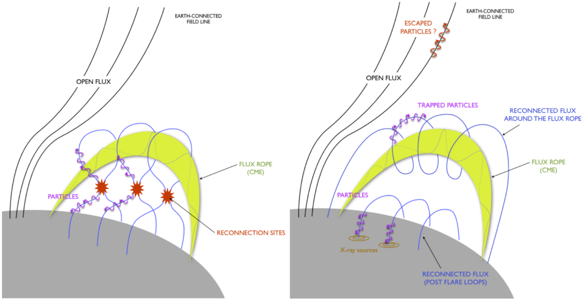
Gyroresonance at 2-10 harmonics (depends on B, narrow continuum near 1–5 GHz)

Gyrosynchrotron at 10–100 harmonics (depends on B, wide continuum up to sub-mm waves)



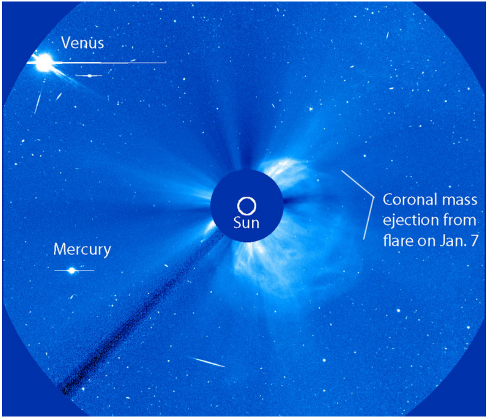
Gyrosynchrotron + plasma emission (from separate sources)

Flare - release of magnetic energy



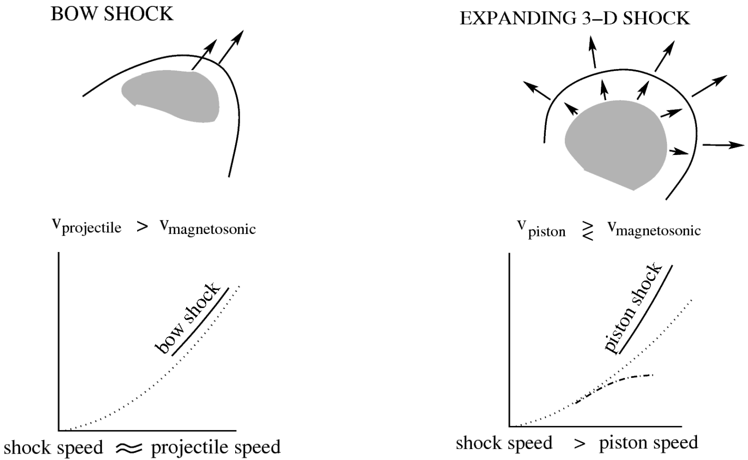
Masson, Sophie et al. Astrophys.J. 771 (2013)

Coronal mass ejection (CME) - ejected mass

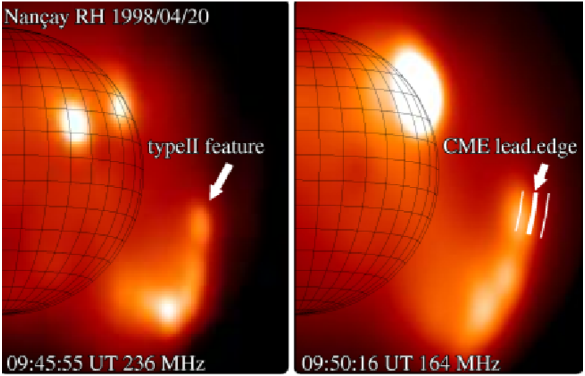


Identification of the leading front? Projection effects?
Remember also lateral expansion.

Driven shocks

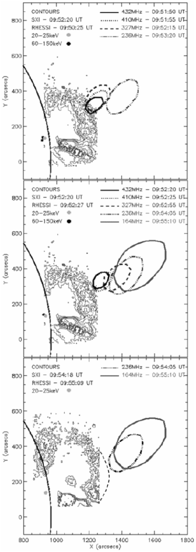


Observations: type II burst driver = CME bow shock



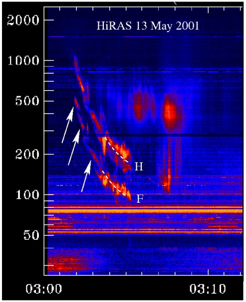
Maia et al. ApJ, 2000

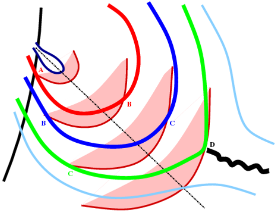
Type II burst driver = rising SXR loop

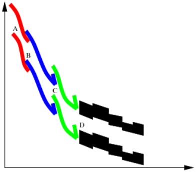


Dauphin et al. 2006

Type II burst source = passage through loops

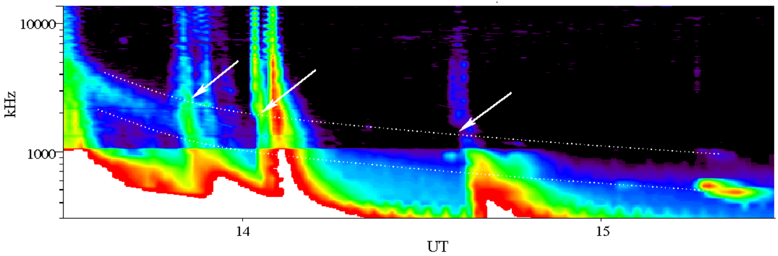






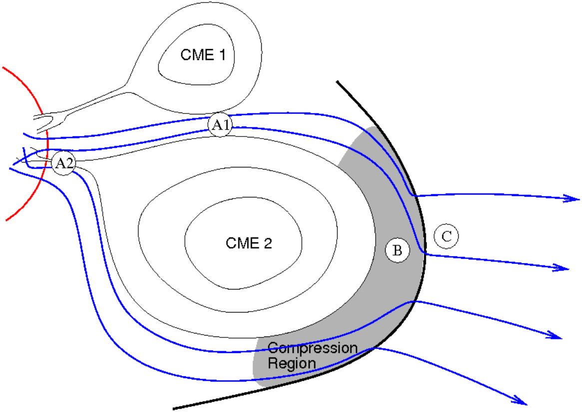
Observations during Japanese daytime, no radio imaging available
Very high frequency start, needed explanation
Different loops have different densities and gaps between loops
(Pohjolainen, Pomoell & Vainio, 2008)

Shocks on the way: tilted type III burst lanes?



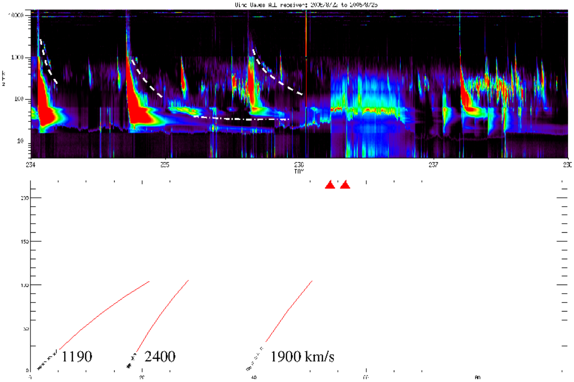
Lehtinen et al., 2008: Electron streams meet a propagating shock

Tilts due to passage through shock fronts



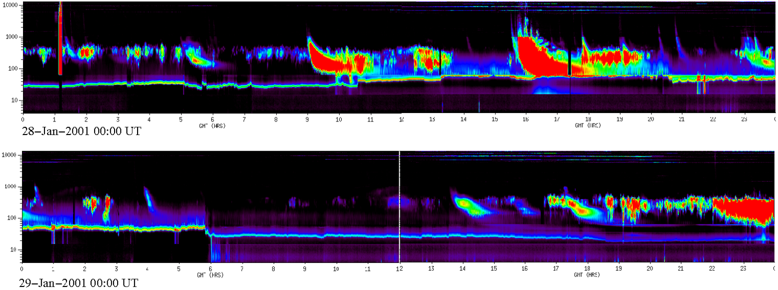
B: compressed high-density region, C: low density and low B

Examples of propagating shocks

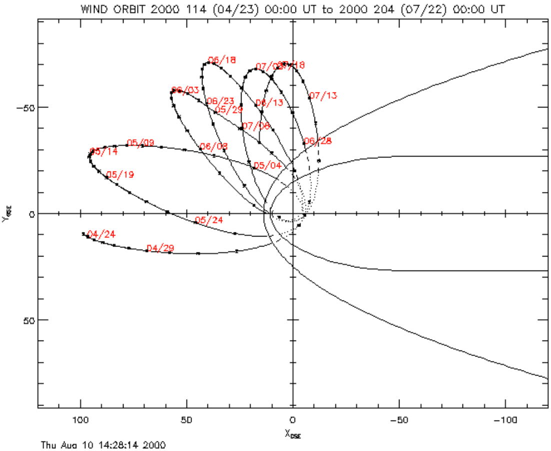


Shock arrival near Earth, fluctuations at local plasma level
Plasma frequency near L1 is 30 – 50 kHz

Other radio emission features

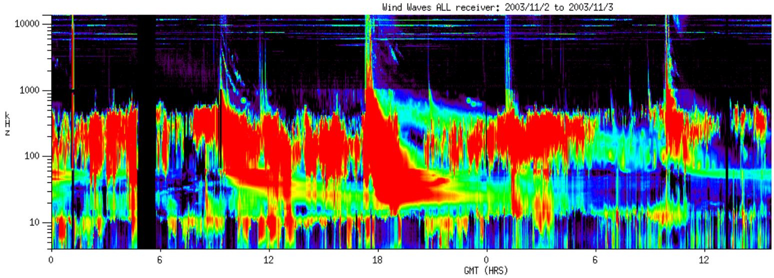


AKR - auroral kilometric radiation appears at 80 – 400 kHz, often in 12 hour episodes, mixed with features that have solar origin



Wind WAVES orbit takes the satellite near Earth where AKR gets stronger

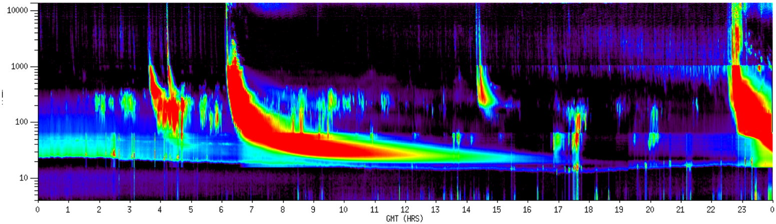
Examples of propagating shocks



Identification of emission lanes may be difficult (type IIIs, AKR...)

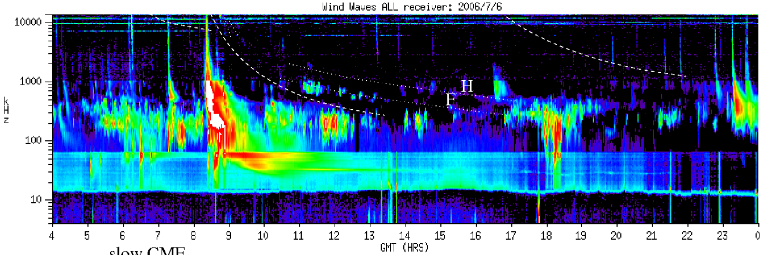
Note also different intensity scale between receivers (RAD1, RAD2, TNR)

Examples of propagating shocks



Solar activity level affects the dynamic spectra in general

IP type II bursts (space observations)



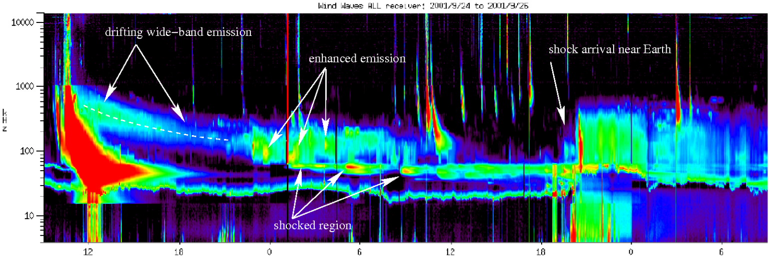
slow CME
start 6 UT
200 km/s

CME start 8:30 UT
910 km/s

CME start 17 UT
330 km/s

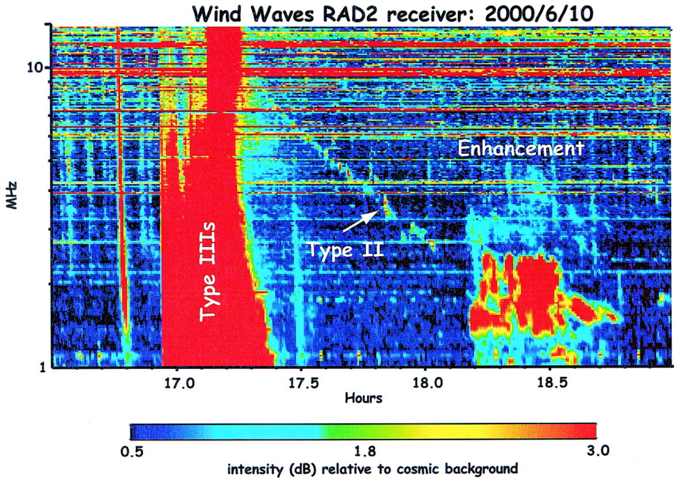
Type II bursts can be patchy, 'blips and blobs' that appear infrequently but still form a lane that can be followed

Many radio features during Sun–Earth propagation



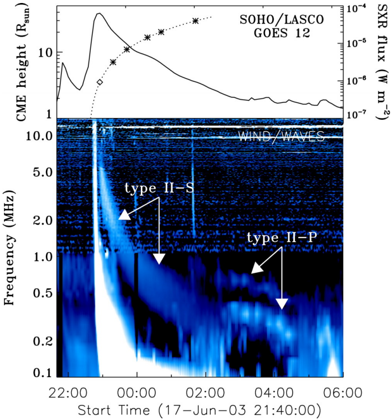
A special type of type II burst: wide-band emission

Features from interacting CMEs?



Gopalswamy et al. ApJ, 2001

Emission is not always plasma emission

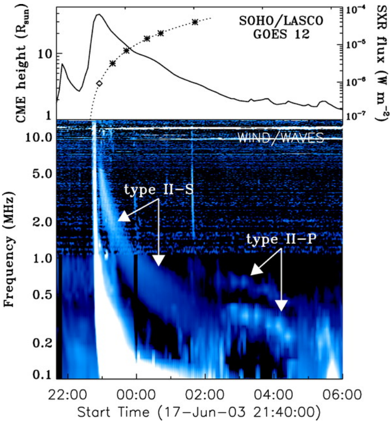


Bastian: plasma vs. synchrotron emission in IP space

Wide-band type II bursts

- Untypically smooth, diffuse, wide-band type II burst (II-S)
- No harmonic emission (seen in the later II-P burst)
- Height-time track does not match with n_e from plasma emission

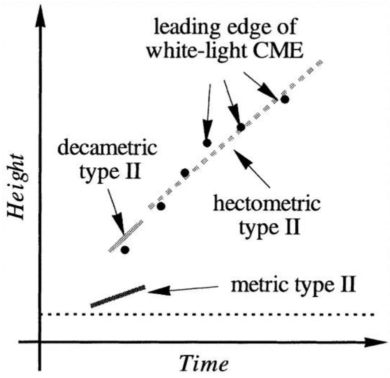
From Bastian T., ApJ 665, 2007



Alternative emission mechanism for wide-band bursts

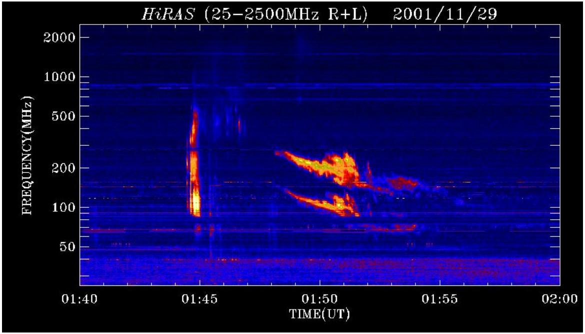
- Electron-cyclotron frequency $f_s \approx 2.8 \times 10^6$ B (Hz)
- Synchrotron emission from power-law electrons with a broad range of pitch angles, broad-band emission centered at: $f \approx f_s \gamma^2 \sin\theta/2$
- Magnetic field varies as $B \approx B_0\ (r/R\odot)^{-\beta}$ within the CME (0.5 – 0.01 G within 3 – 30 $R\odot$)

Things to evaluate on type IIs



- Atmospheric density models -> speed from density change
- Scale height + frequency drift -> may give different speed
- Corona: second harmonic stronger
- IP space: fundamental stronger
- Emission lanes can be band-split
- May not be plasma emission at all

Speed estimates



Type II bursts: fundamental (f) and harmonic (2 x f) bands

ALWAYS MAKE THE MEASUREMENTS USING THE FUNDAMENTAL EMISSION BAND!

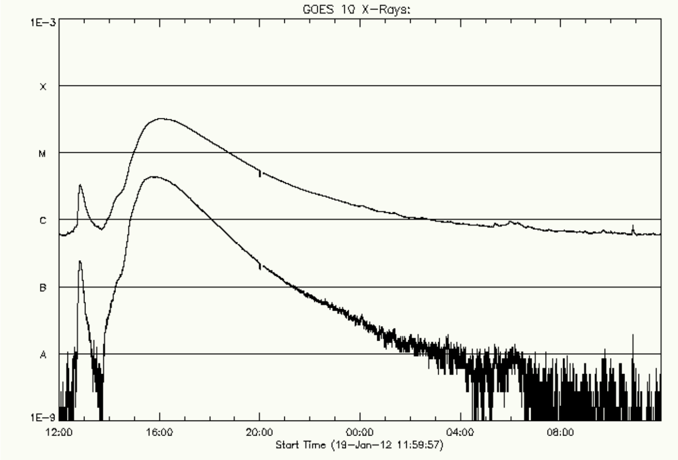
Choosing the density model

Table 1 Heliocentric burst driver height ($R_\odot$) calculated from plasma frequency using different atmospheric density models.

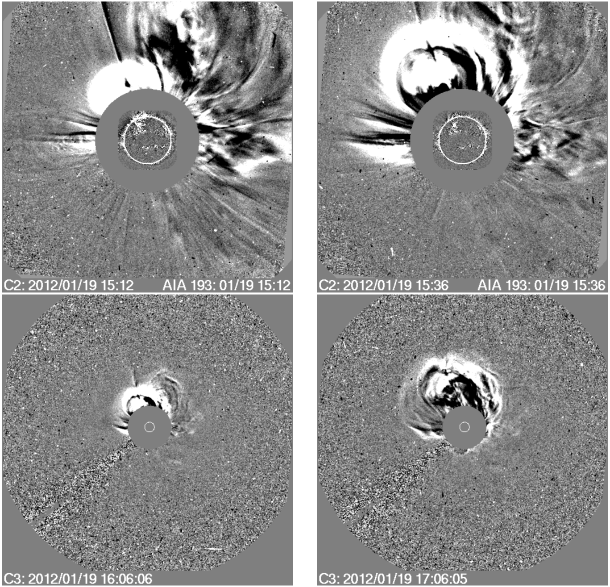
f_p (MHz)	λ (m)	n_e (cm^{-3})	h Saito	h Hybrid	h 2× Newkirk	h 10× Saito	h Leblanc[a]	h IP[a]
500	0.6	3.1×10^9	–	–	–	1.03	–	–
400	0.7	2.0×10^9	–	–	–	1.08	–	–
300	1.0	1.1×10^9	–	1.04	1.05	1.14	–	–
200	1.5	4.9×10^8	–	1.12	1.15	1.26	–	–
100	3.0	1.2×10^8	1.13	1.30	1.37	1.56	–	–
70	4.3	6.0×10^7	1.23	1.45	1.51	1.76	–	–
50	6.0	3.1×10^7	1.34	1.64	1.68	1.99	1.10	–
30	10.0	1.1×10^7	1.58	2.01	2.04	2.40	1.31	–
14	21.4	2.4×10^6	2.07	2.78	2.96	3.33	1.71	–
12	25.0	1.8×10^6	2.19	2.96	3.24	3.57	1.80	–
10	30.0	1.2×10^6	2.36	3.24	3.74	3.97	1.93	–
9	33.3	1.0×10^6	2.44	3.38	4.00	4.17	2.00	–
8	37.5	7.9×10^5	2.56	3.57	4.44	4.47	2.09	–
7	42.9	6.0×10^5	2.72	3.81	5.05	4.86	2.20	–
6	50.0	4.4×10^5	2.90	4.10	6.00	5.38	2.33	–
5	60.0	3.1×10^5	3.13	4.46	7.61	6.06	2.49	–
4	75.0	2.0×10^5	3.49	4.96	11.46	7.09	2.72	1.02
3	100.0	1.1×10^5	4.07	5.75	>30	8.88	3.07	1.37
2	150.0	4.9×10^4	5.18	7.07	$\gg$	12.17	3.69	2.06
1	300.0	1.2×10^4	8.58	10.36	$\gg$	21.30	5.42	4.16

[a] $n_0 = 4.5\ cm^{-3}$ at 1 AU.

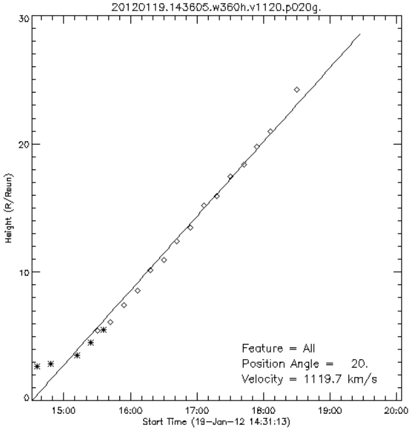
Event to be analysed: January 19, 2012
Event start time approx. 15 UT

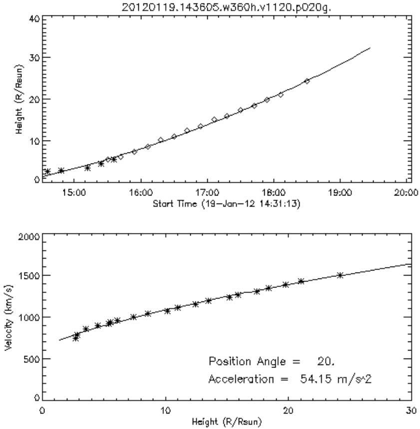


Coronal mass ejection (CME)

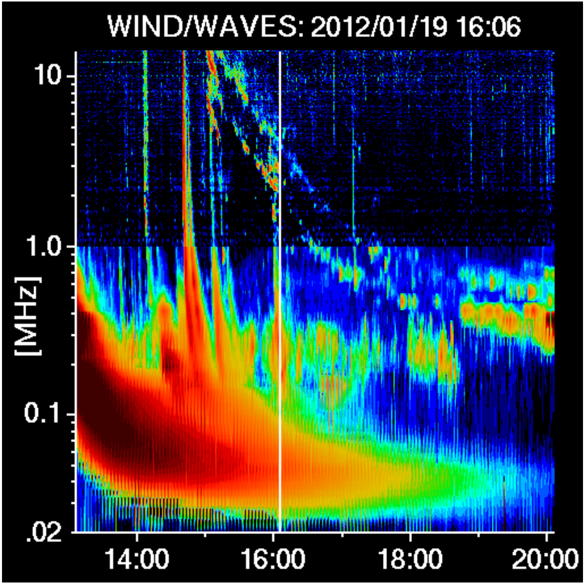


Linear fit and 2nd order fit to CME leading edge

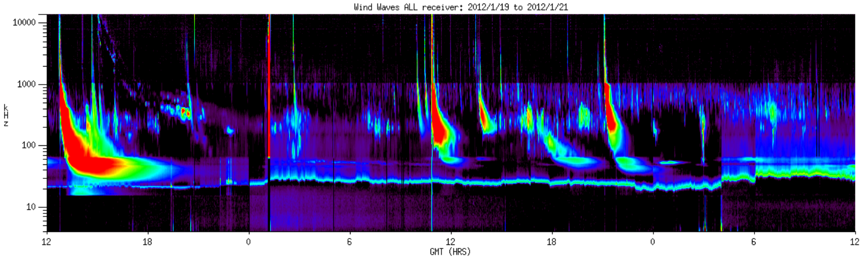




Type II emission = propagating shock waves



Wind WAVES radio dynamic spectrum
19 Jan 2012 12:00 UT – 21 Jan 2012 12:00 UT



Looks like three separate shocks, one shock arrival reported at 04:00 UT 21 January

CESRA Summer School 2015

Community of European Solar Radio Astronomers will arrange a summer shool in Glasgow, Scotland, in August 2015.

The main topic is **solar radio interferometry**

The school is supported by RadioNet3 EU FP7 project (full or partial funding for travel and accommodation costs)