Observation of periodic radio bursts associated with EUV enhancements

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Goddard, C. R et. al, A&A, 2016

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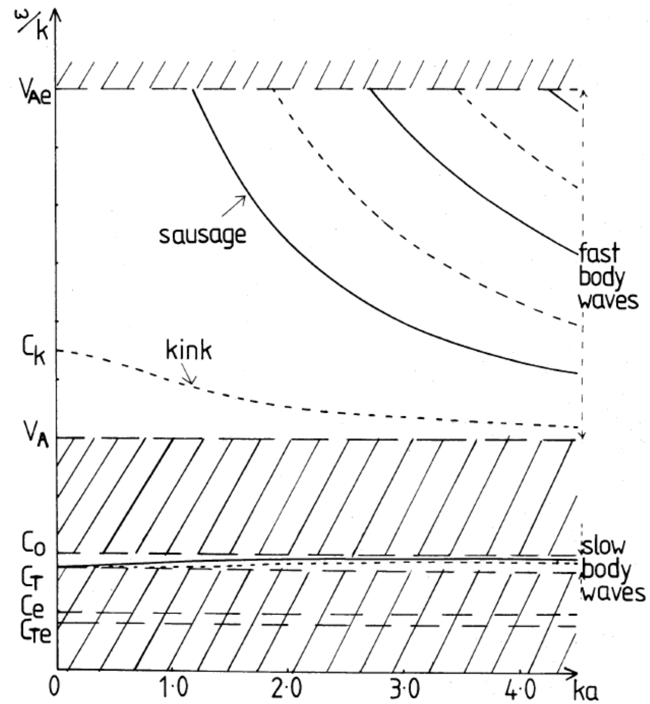
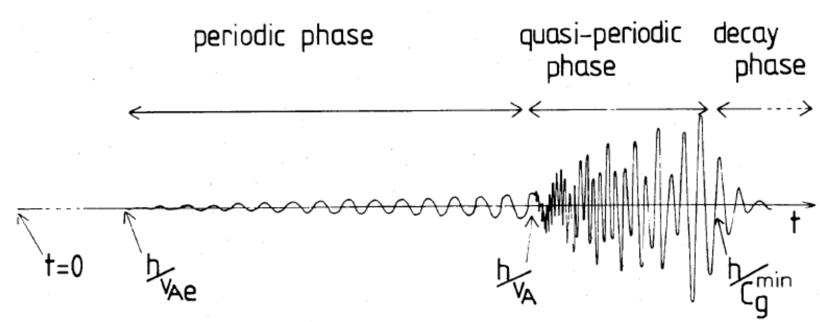
Fast dispersive wave trains

- Dispersive evolution of fast magneto-acoustic waves guided by coronal structures creates quasi-periodic fast wave trains.

- The wave train forms a certain distance from the source, depending on the wave guide width and the wavelength.

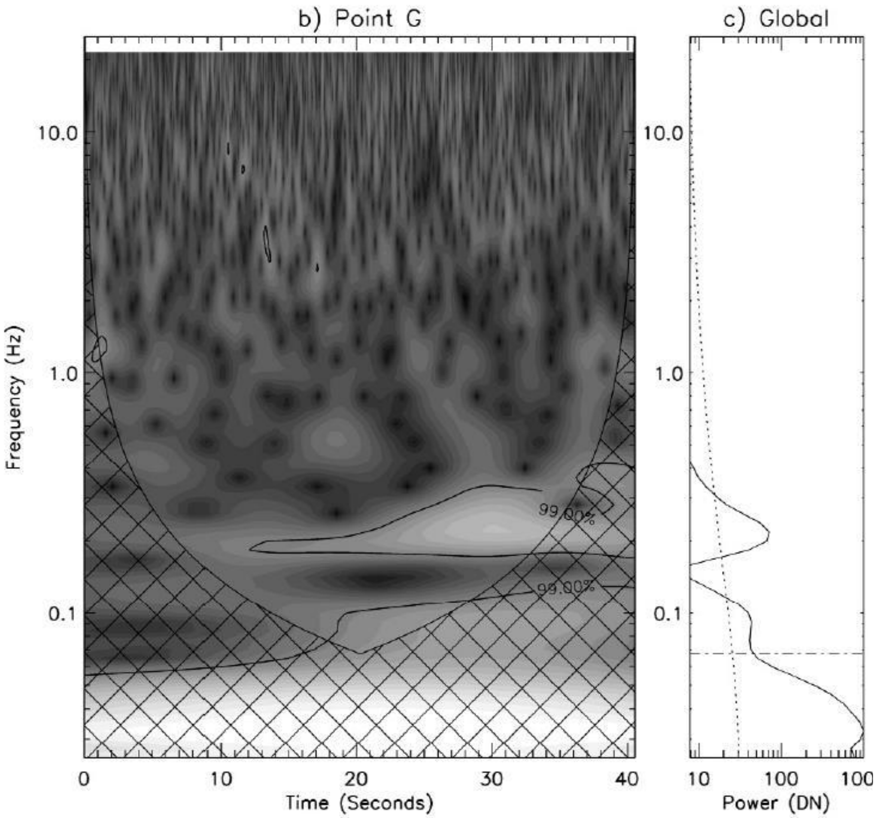
- Detections show typical speeds of 500 –2000 km s^{-1} and periods of 30 –200 s.





Figures: Roberts, B., Edwin, P. M., & Benz, A. O. 1984, ApJ, 279, 857

Fast dispersive wave trains



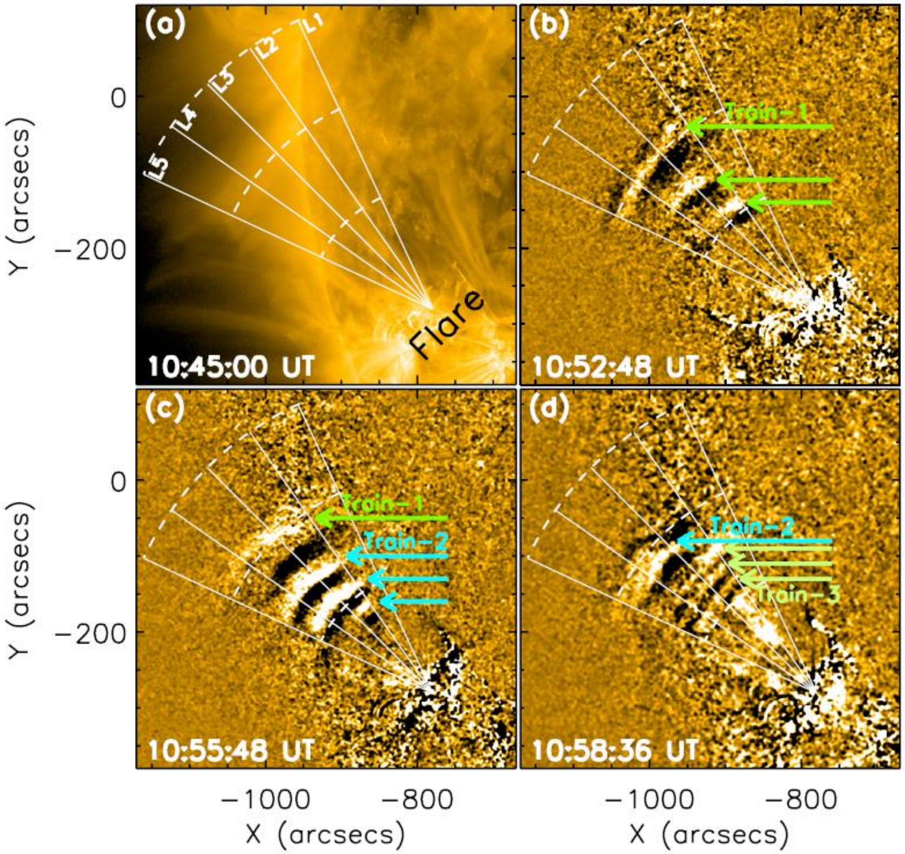


Figure 1 : Katsiyannis, et al. 2003, A&A, 406,709
Figure 2 : Yuan, D., Shen, Y., Liu, Y., et al. 2013, A&A, 554, A144

Type II radio bursts

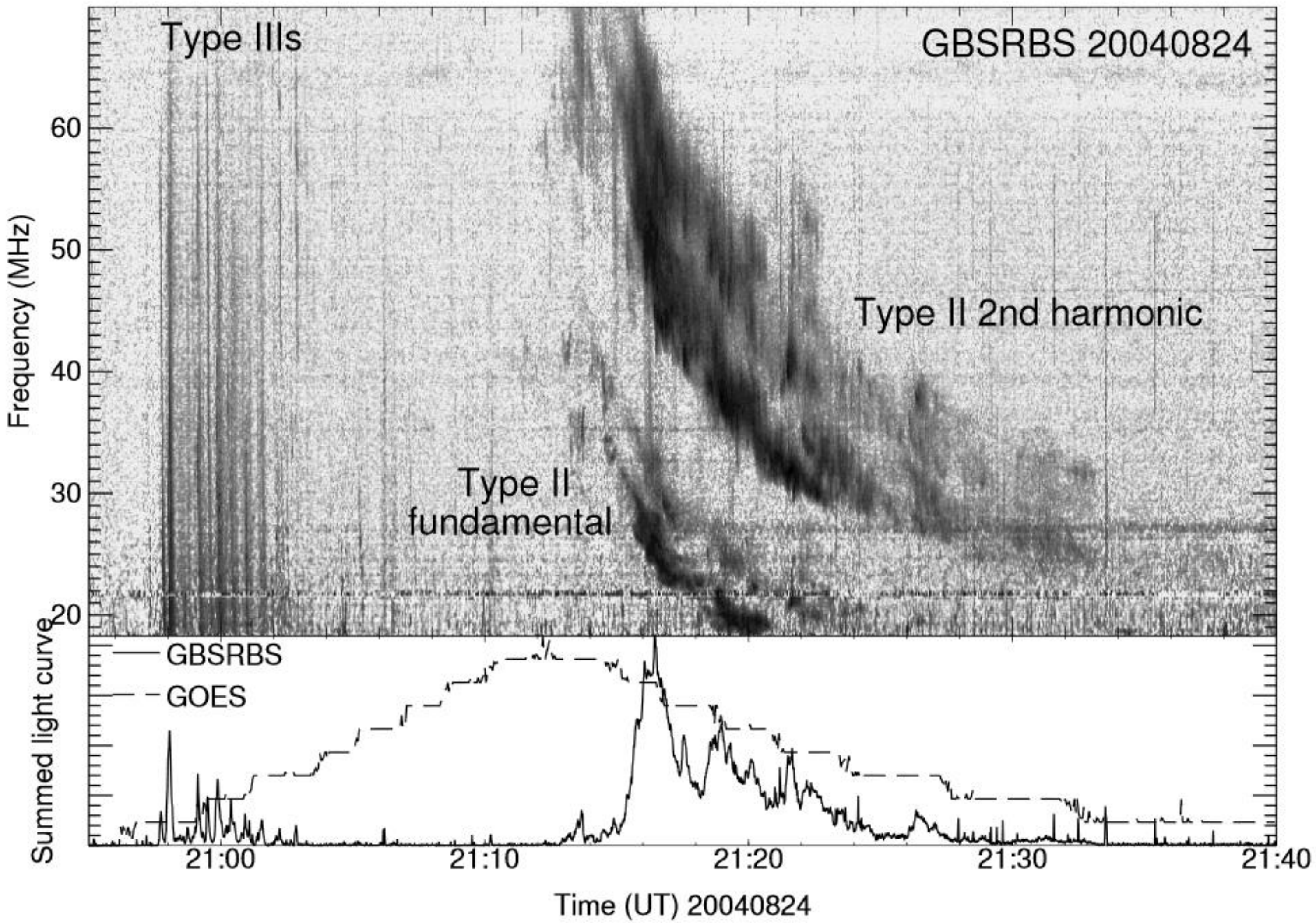
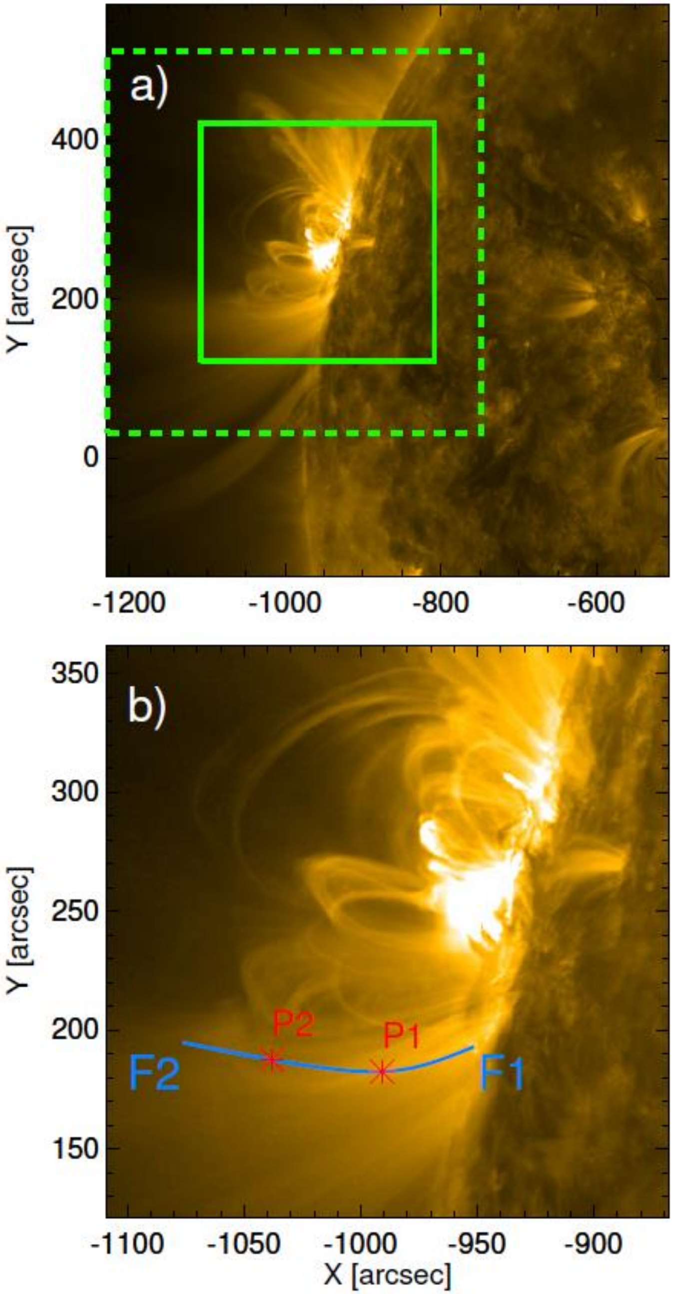


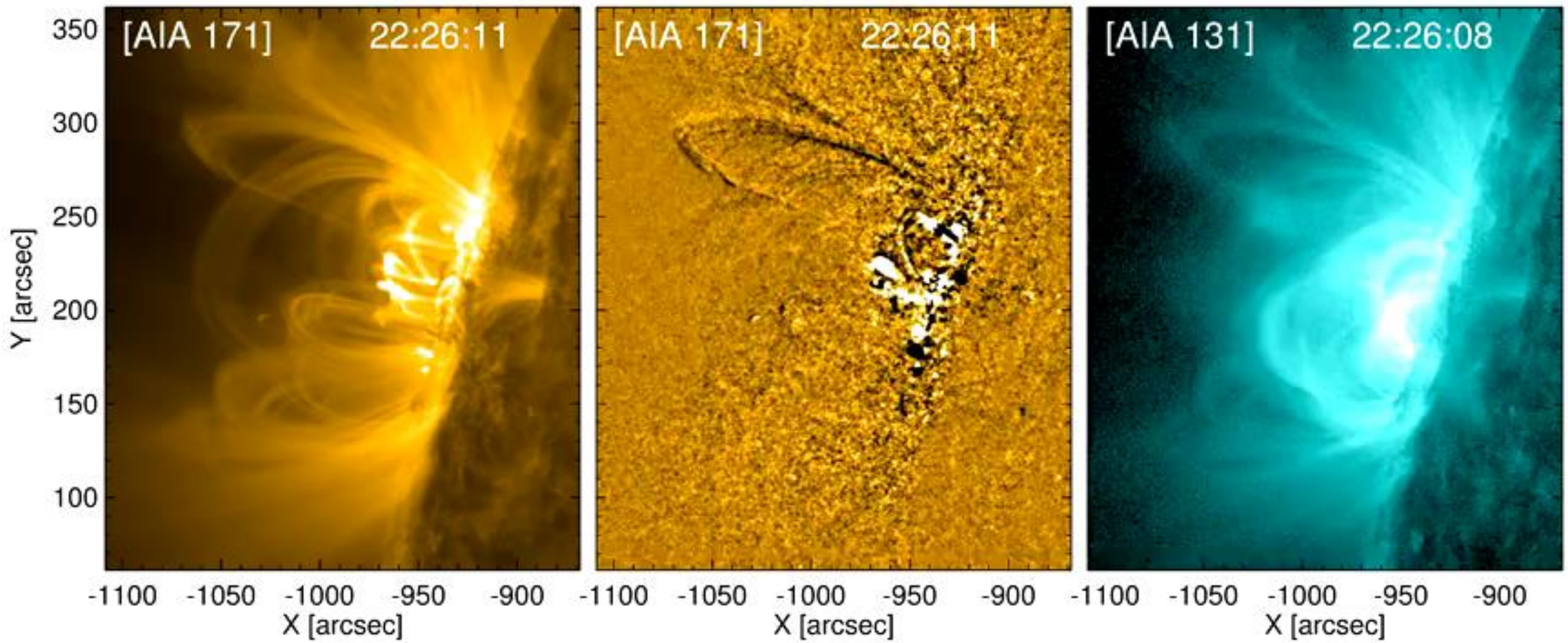
Figure: Solar Radio Bursts and Space Weather, Stephen M. White

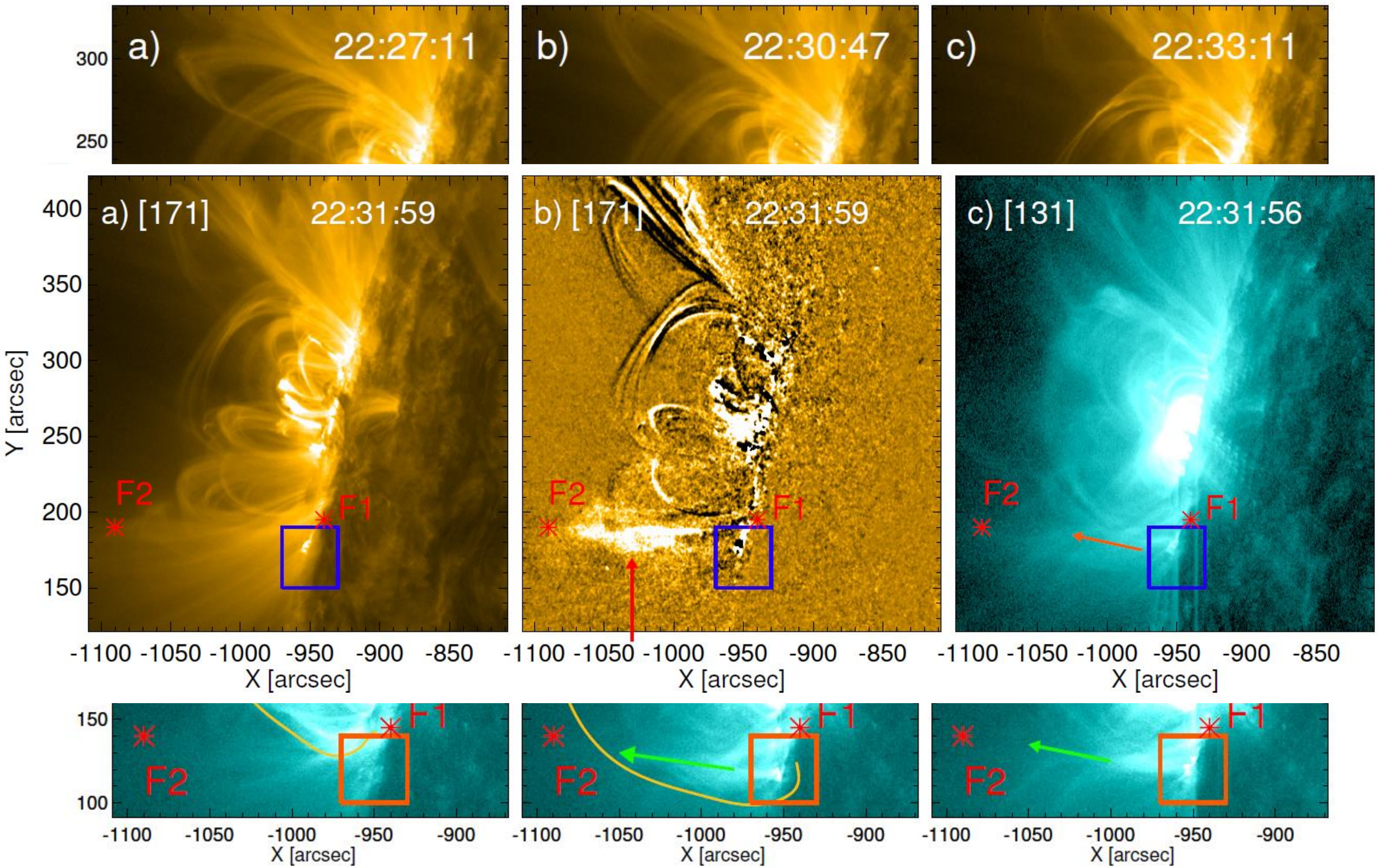
Flare Details

- M6.5 class flaring event, 03/11/14.
- Rapidly propagating intensity fluctuations visible at 171 Å (nothing in other channels).
- CME interaction with the background structures observed at 131 Å, reconnection occurs.
- Correlation of start times of guided enhancements with CME interaction.



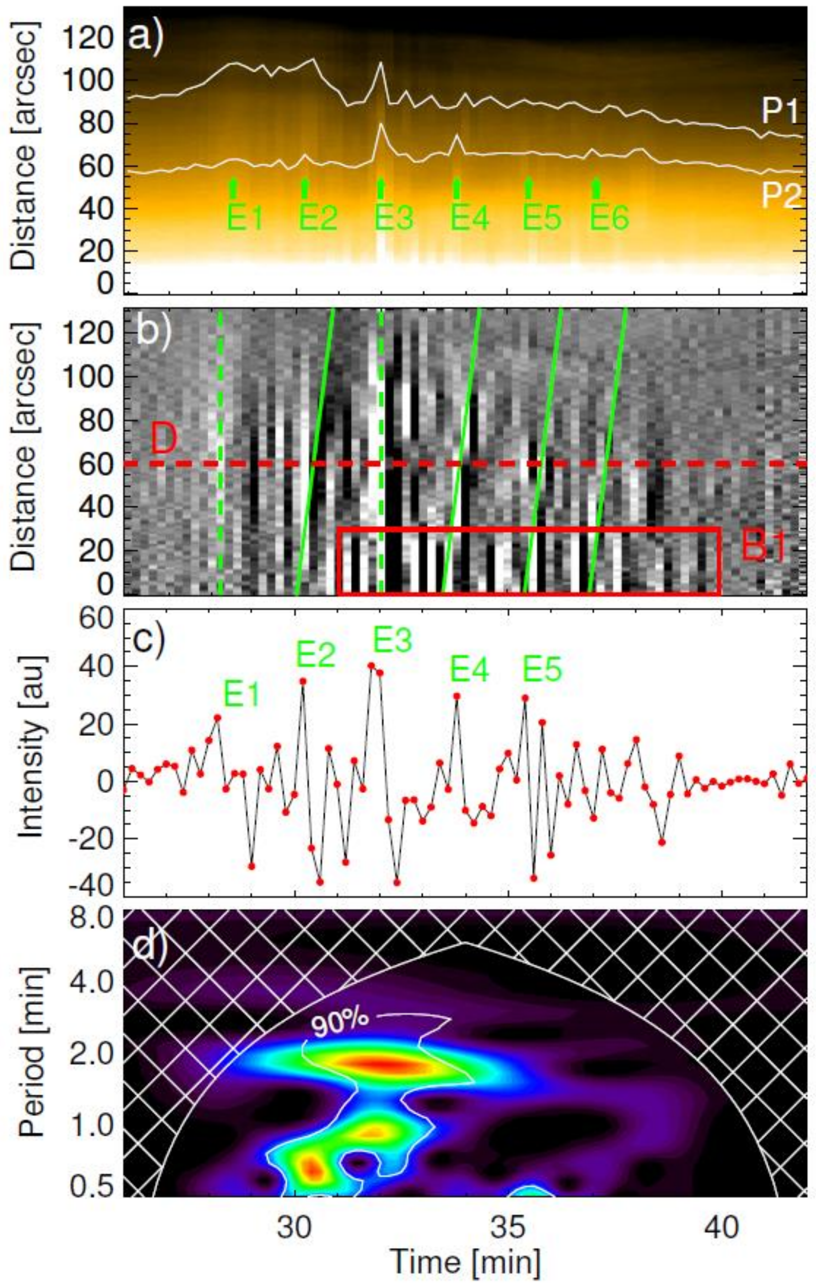
AIA - 171, 171 RDI, 131 Å




a)
22:27:11
b)
22:30:47
c)
22:33:11
a) [171]
22:31:59
b) [171]
22:31:59
c) [131]
22:31:56
F2
F1
Y [arcsec]
X [arcsec]

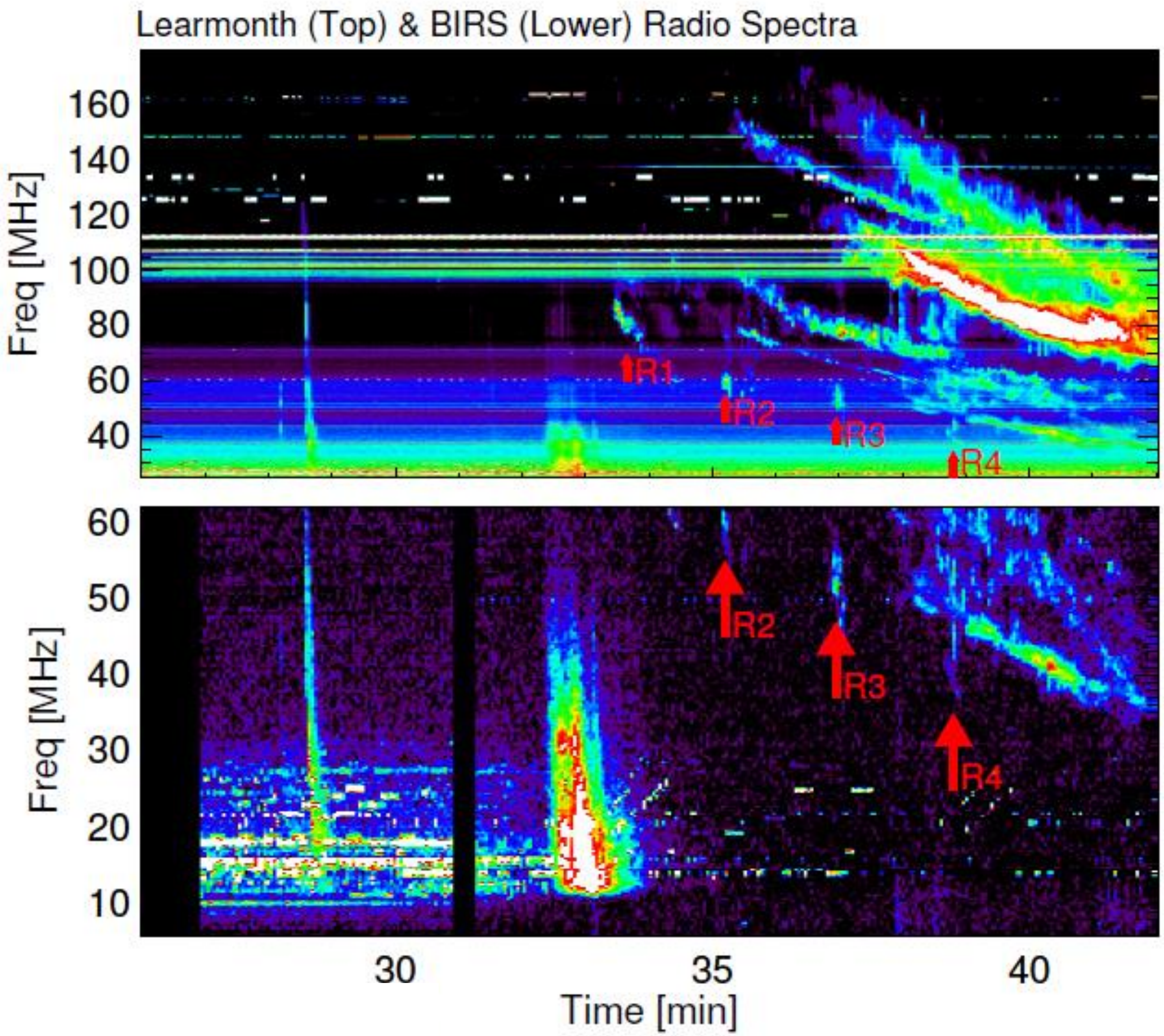
Time Distance map

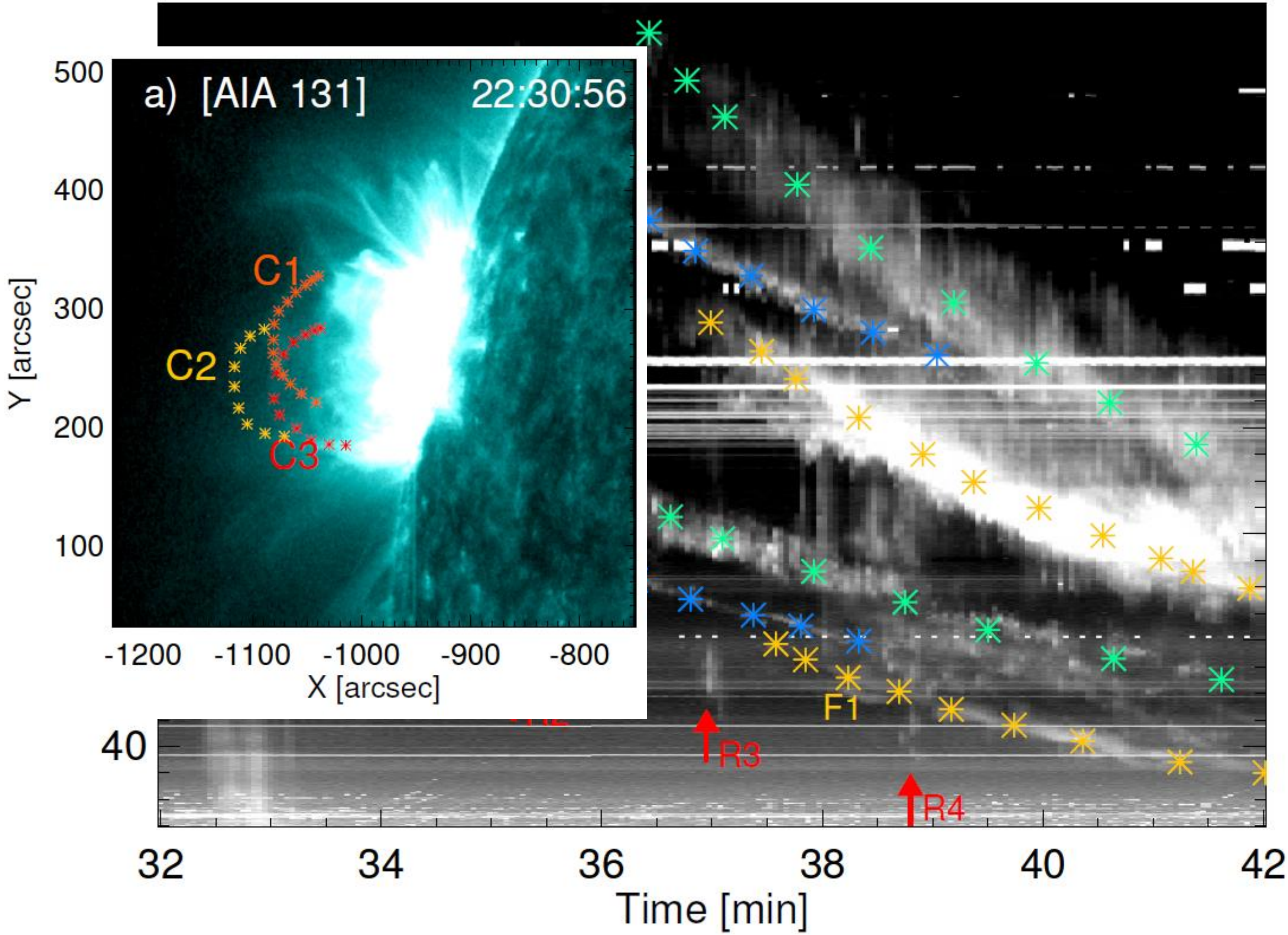
- Intensity perturbations propagate along a funnel structure away from the active region.
- RDI TD map reveals some propagating features with phase speeds of ~1200 km s^{-1}.
- Propagation of some enhancements is not observed.
- Contribution of several different propagations/oscillations?
- Periodicity of ~1.8 min from wavelet and P=1.7±0.2 min from the TD map enhancements.



Radio spectra

- Periodic features seen following the Type III burst in both spectra.
- Features occur before type II burst associated with the CME.
- Type II burst has multiple harmonic and fundamental lanes.
- Decreasing frequency trend is parallel to the type II burst.





a) [AIA 131]
22:30:56
C1
C2
C3
Y [arcsec]
X [arcsec]
500
400
300
200
100
-1200
-1100
-1000
-900
-800
40
R3
R4
F1
32
34
36
38
40
42
Time [min]

Radio periodicity : $\Delta t = 1.72 \pm 0.12$ min

Frequencies : F=83, 59, 54, 42 MHz

$$F = 9\sqrt{n_e}$$

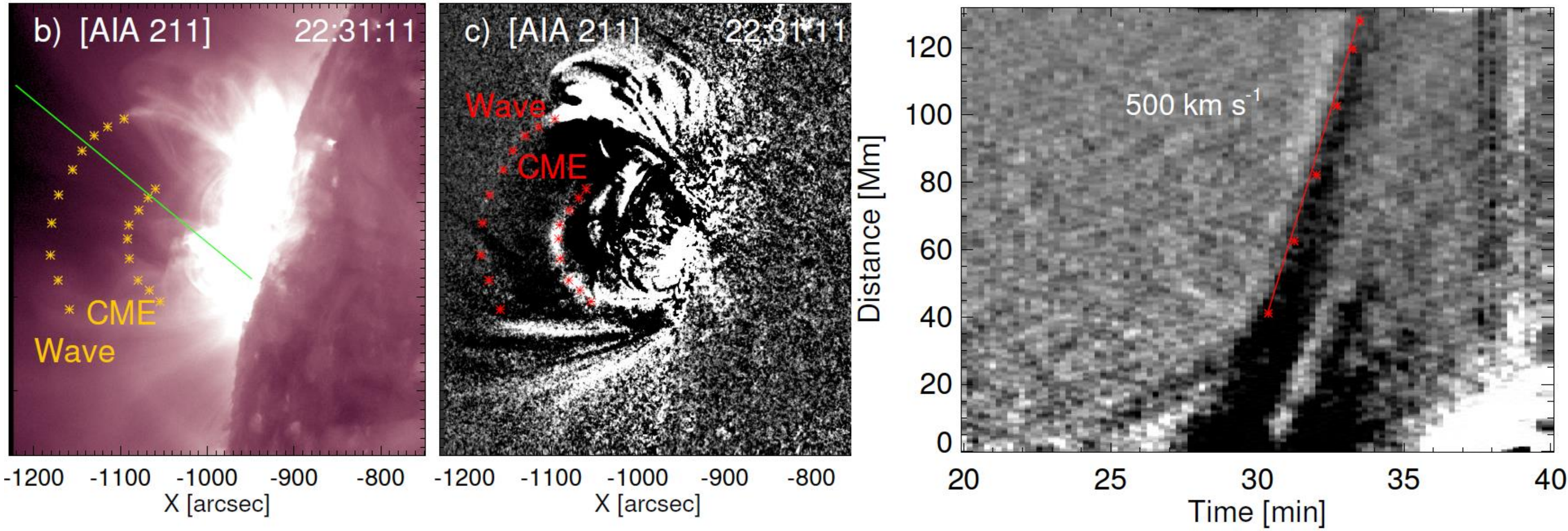
Densities : n_e = 8.47, 4.34, 3.56, 2.12 x10^7 cm^{-3}

$$n_e = n_{e0} * 10^{4.32(R/R_{sun})}$$

Heights : Z=209, 288, 334, 418 Mm. (very approximate)

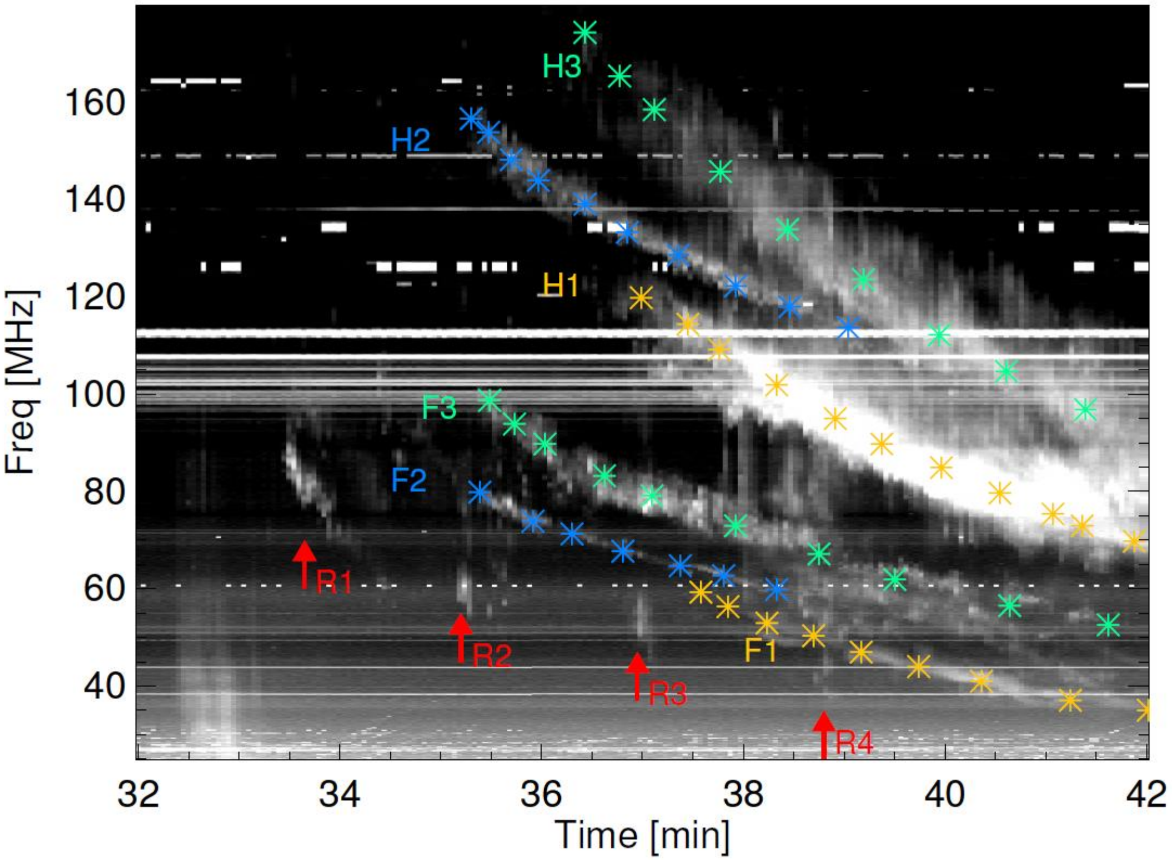
Emission location velocity : plot z vrs Δt, v_{em}= 630 km s^{-1}

CME as emission location



- Height of leading edge at: Z_{TR1}= 260 Mm, Velocity v=500 km s^{-1}
- Using the velocity, obtain: Z_{cme}= 260, 310, 366, 425 Mm
- Radio gave: Z=209, 288, 334, 418 Mm, v=630 km s^{-1}

Additional information



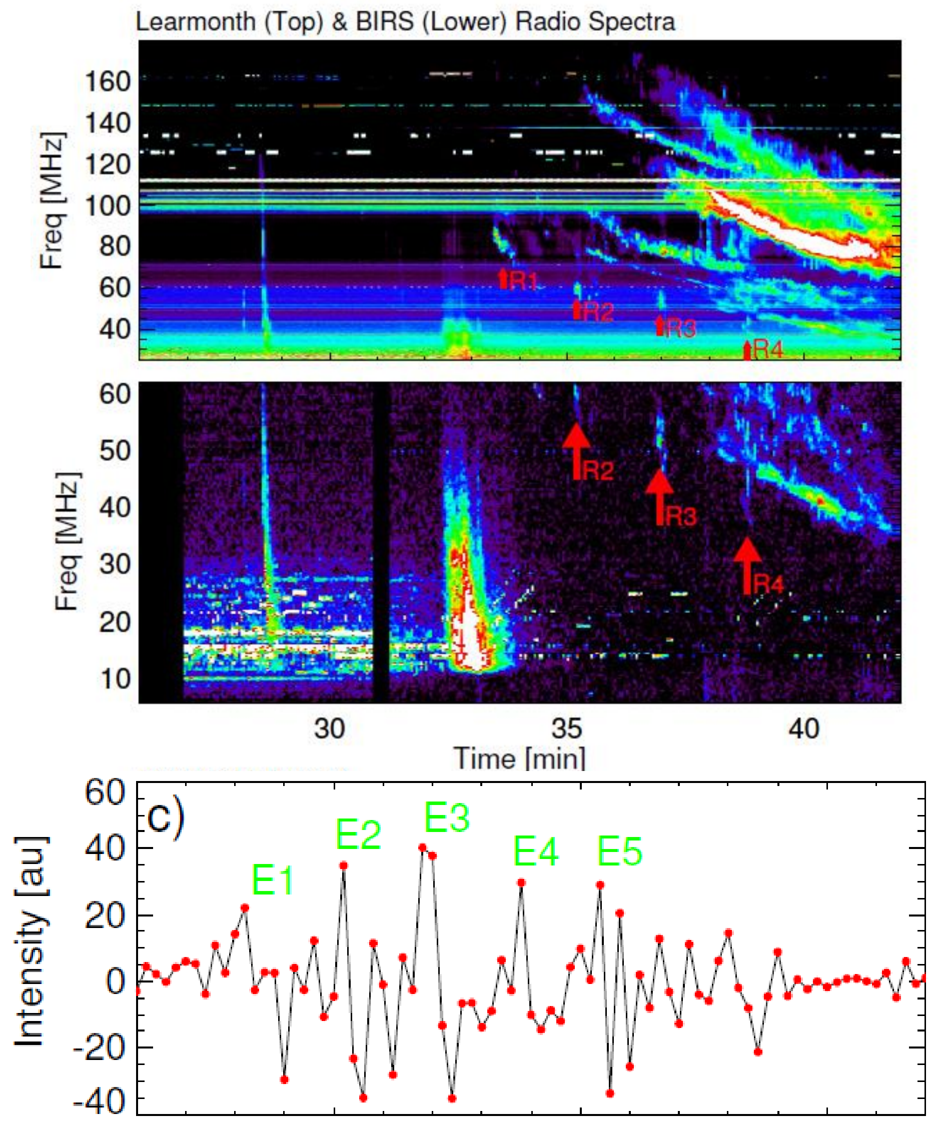
Emission layer width can be estimated through the upper and lower frequencies of each radio spark, giving:
L=[29, 24, 26, 32] Mm

Drift velocities calculated from the Harmonic lanes:
V_{drift}=[630, 380, 550] km s^{-1}

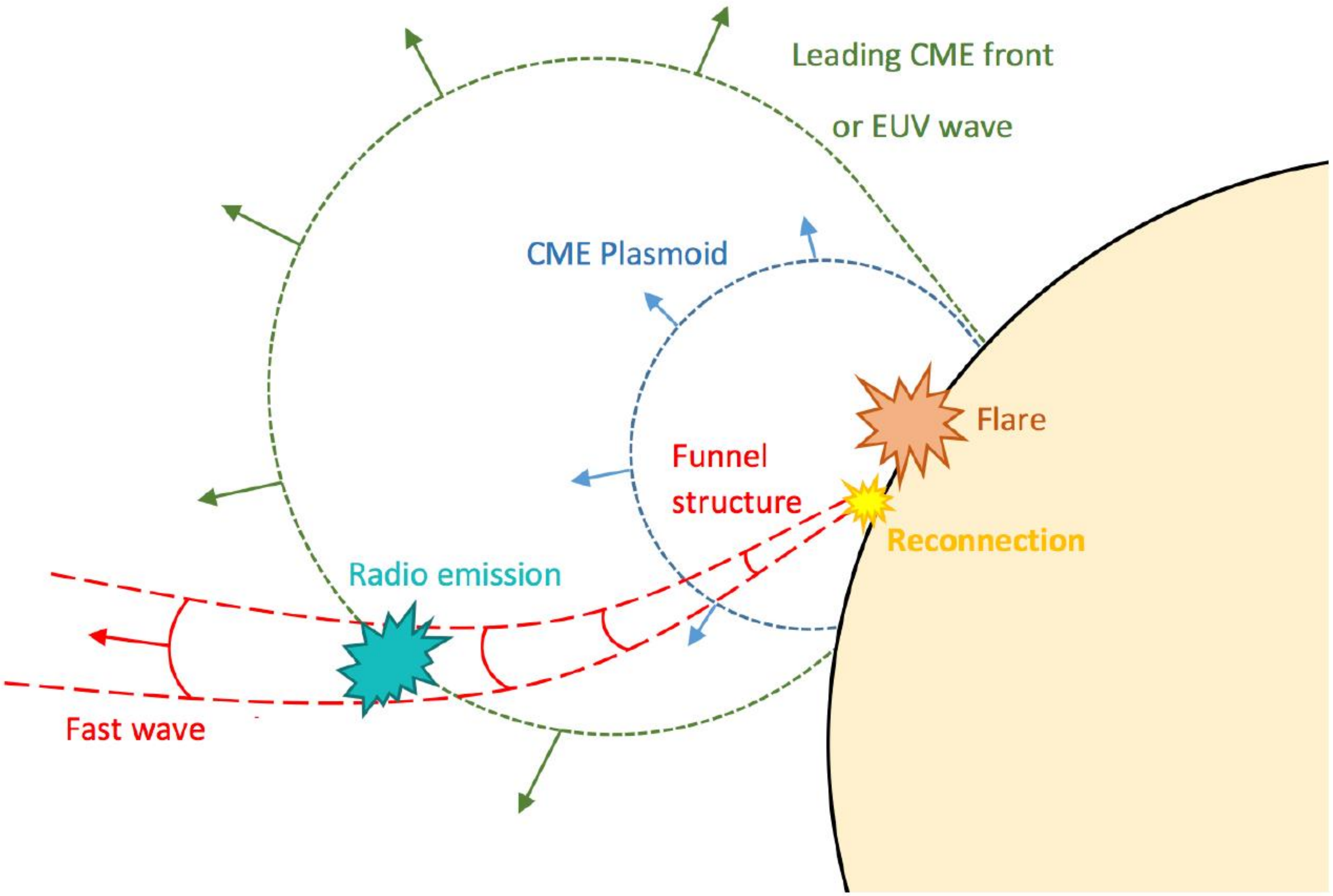
H1/F1 drift velocity matches radio sparks drift velocity, indicating they may share the same emission location.

Fast waves (EUV) as the driver?

- Δt_{radio}= 1.72±0.12 min
  Δt_{EUV} = 1.7±0.2 min
- Matching EUV emission with the radio features can give a propagation velocity
- E1 - R1: v= 676, 997, 1126, 1393 km s^{-1}
- E2 - R1: v= 1010, 1560, 1757, 2111 km s^{-1}
- E3 - R1: v= 2111, 3560, 3839, 4100 km s^{-1}
- Clearly non-relativistic velocities. Particle acceleration takes place at the emission location, or is constant and modulated by the EUV enhancements.



Interpretation



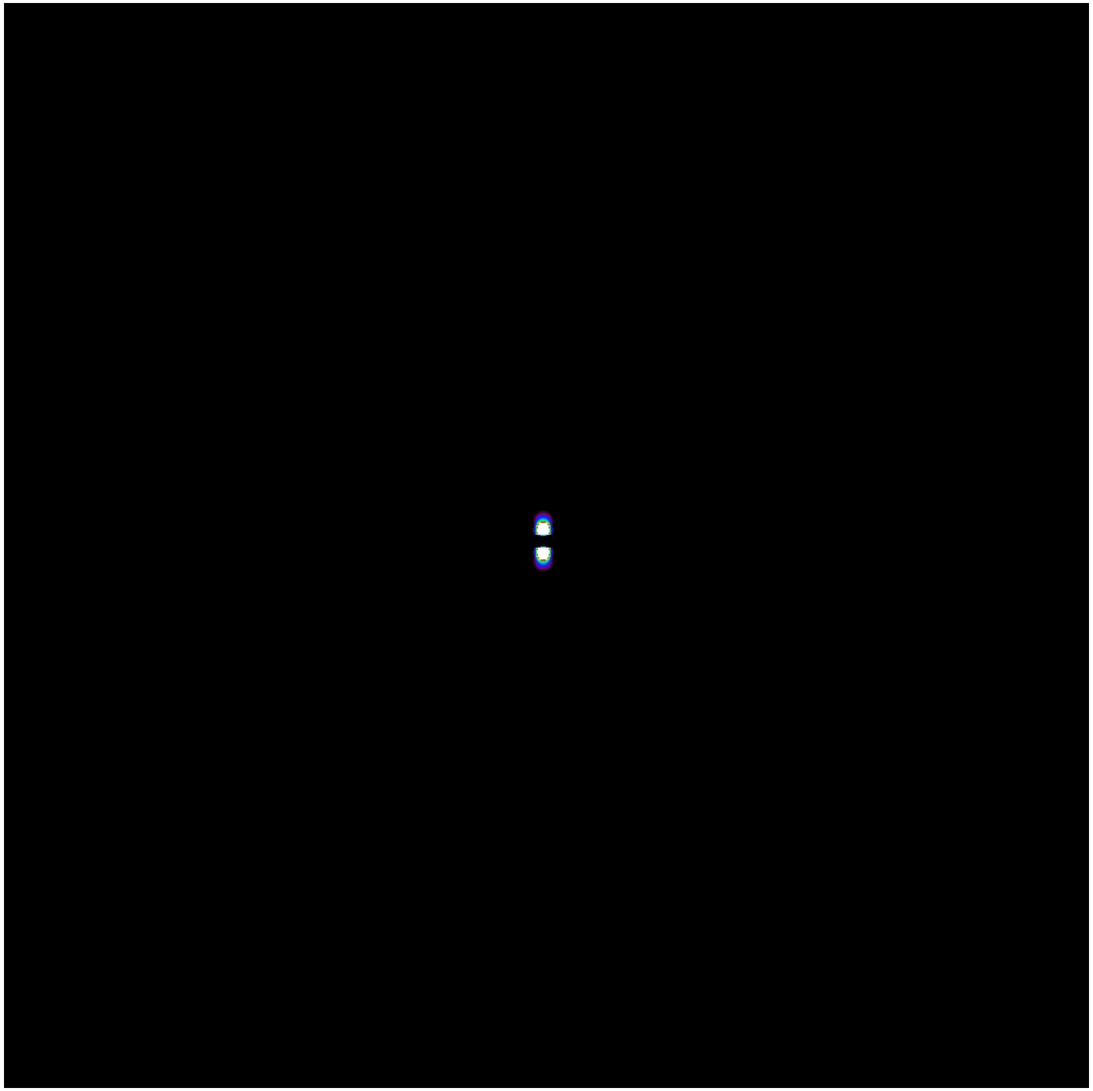
Summary

- The period of the radio ‘sparks’ matches the period of the EUV enhancements.
- The speed of the emission location obtained from the drift of the ‘sparks’ approximately matches the speed of the CME leading edge/ EUV wave.
- The height of the radio emission matches the observed (and then projected forward using the velocity) location of the CME leading edge/EUV wave.
- Using the time delay between the EUV and radio features (and the height above the surface) propagation velocities in the range of fast waves are obtained for the travel of the EUV enhancements to the radio emission location.
- Interpretation: A series of fast waves are produced by the active region during the flare and excite/induce radio emission at the plasma frequency where the guiding structure intersects the EUV wave.

Numerical follow up

- The radio bursts may be produced when the guided waves shock in the corona.
- Could also occur for other wave train events, providing additional information.
- Simulate fast waves in a wave guide using MHD code Lare 2D.
- Increase the amplitude of the initial perturbation and look for signatures of shocks in the guided and leaky waves.

Numerical follow up



Numerical follow up