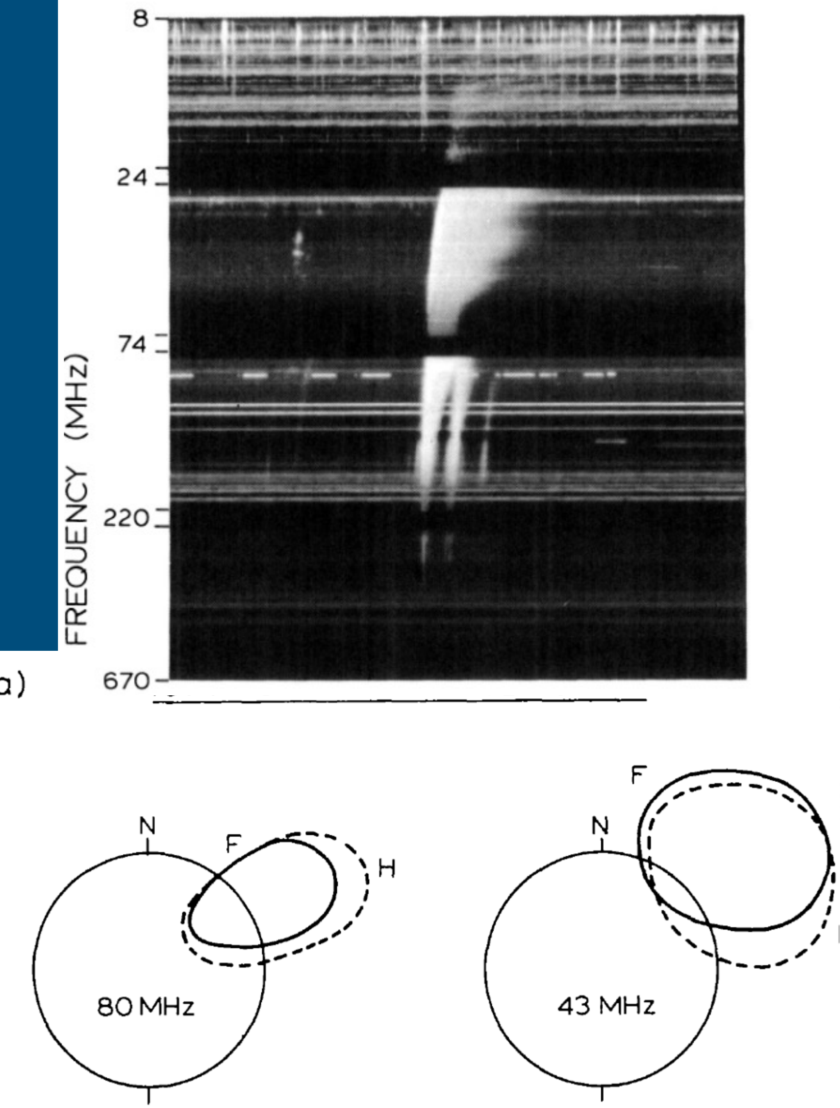
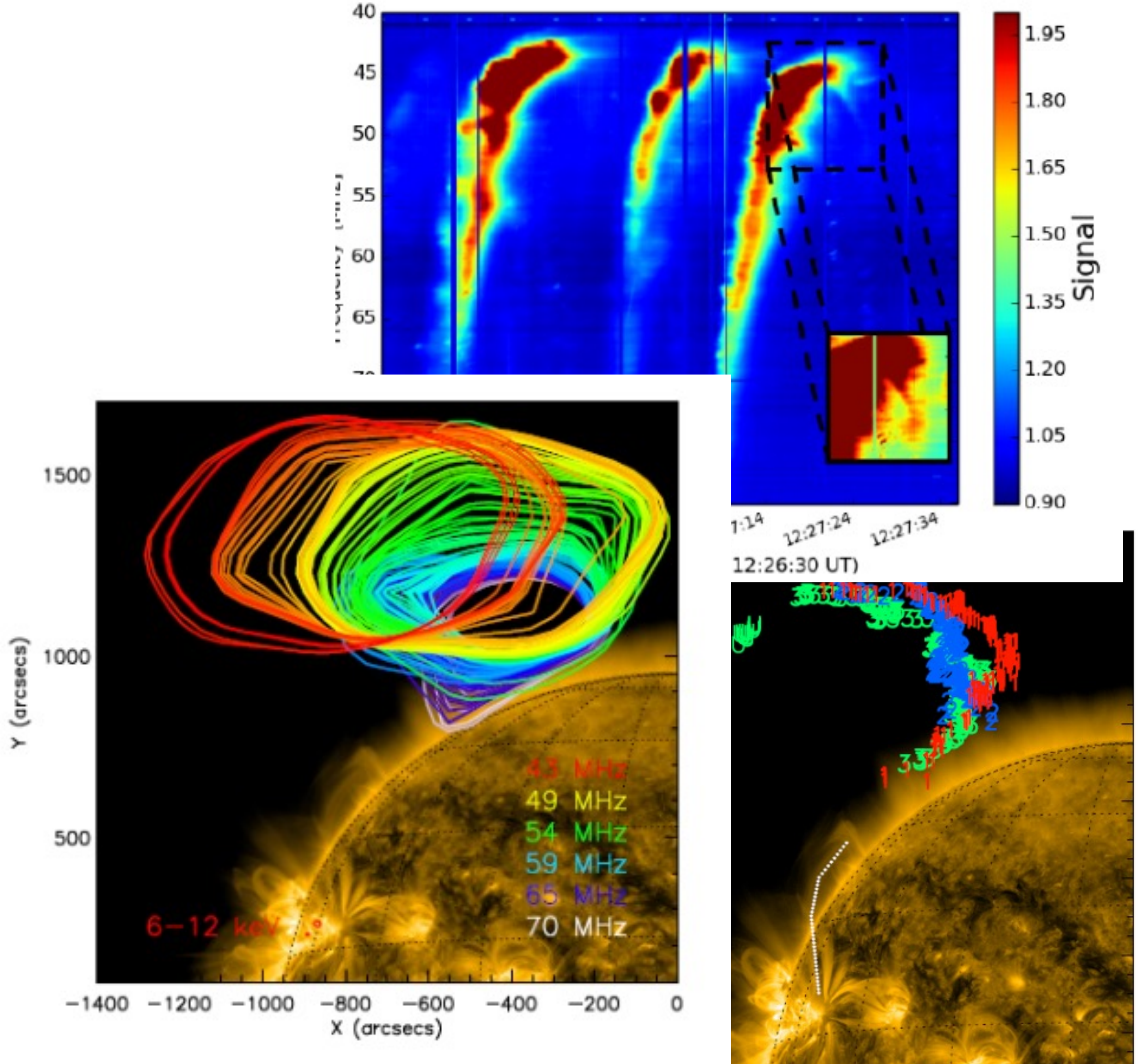
Solar radio observations of electron beams



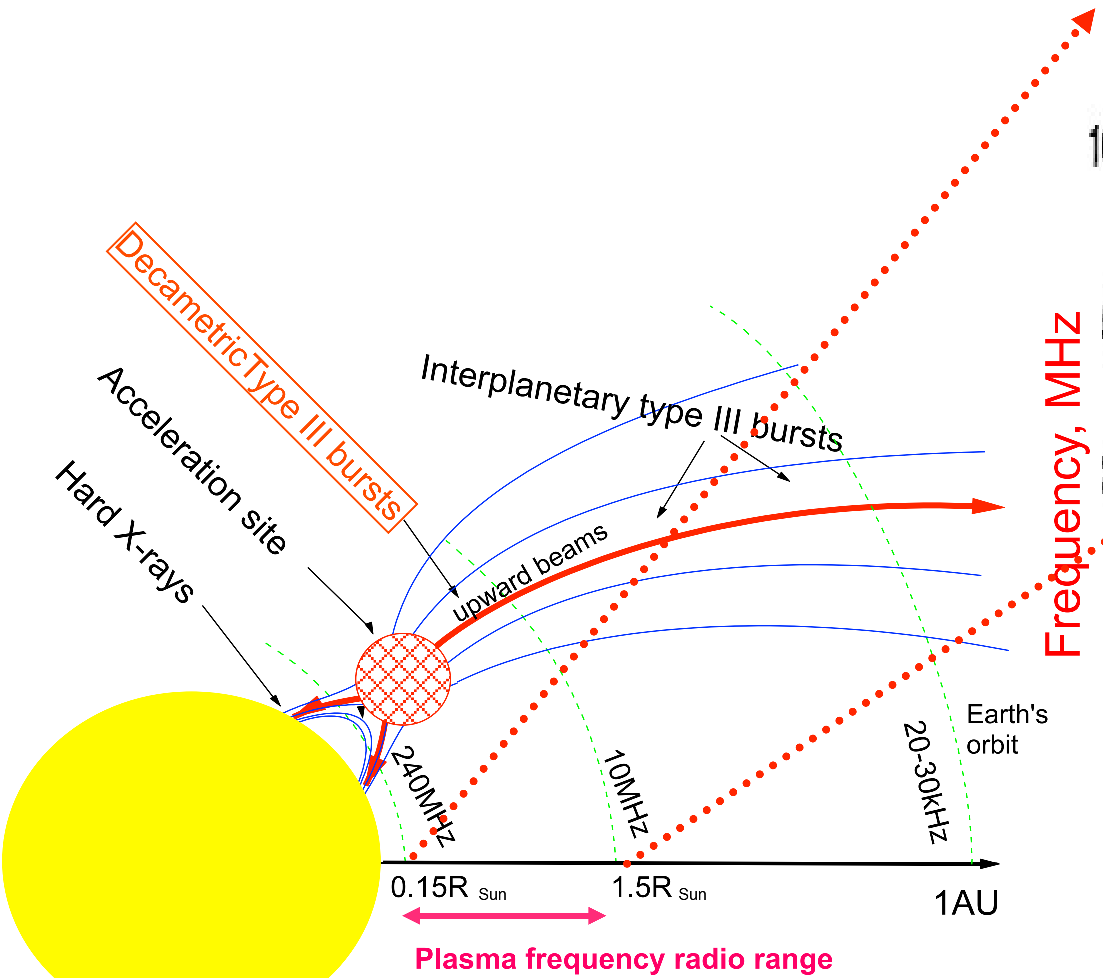
From Dulk and Suzuki, 1980

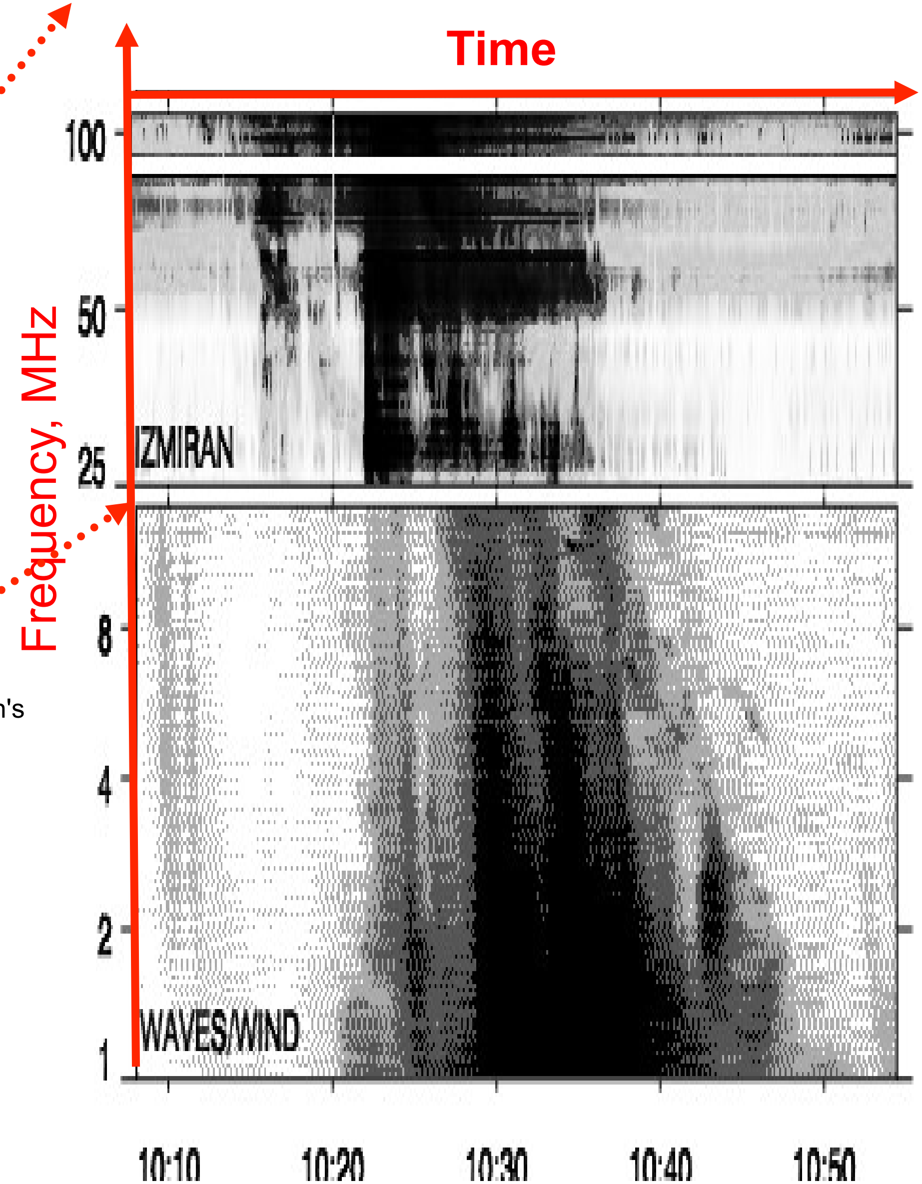


From Reid & Kontar, 2017

=> Typical half-power sizes around 20 arcmin near 40 MHz

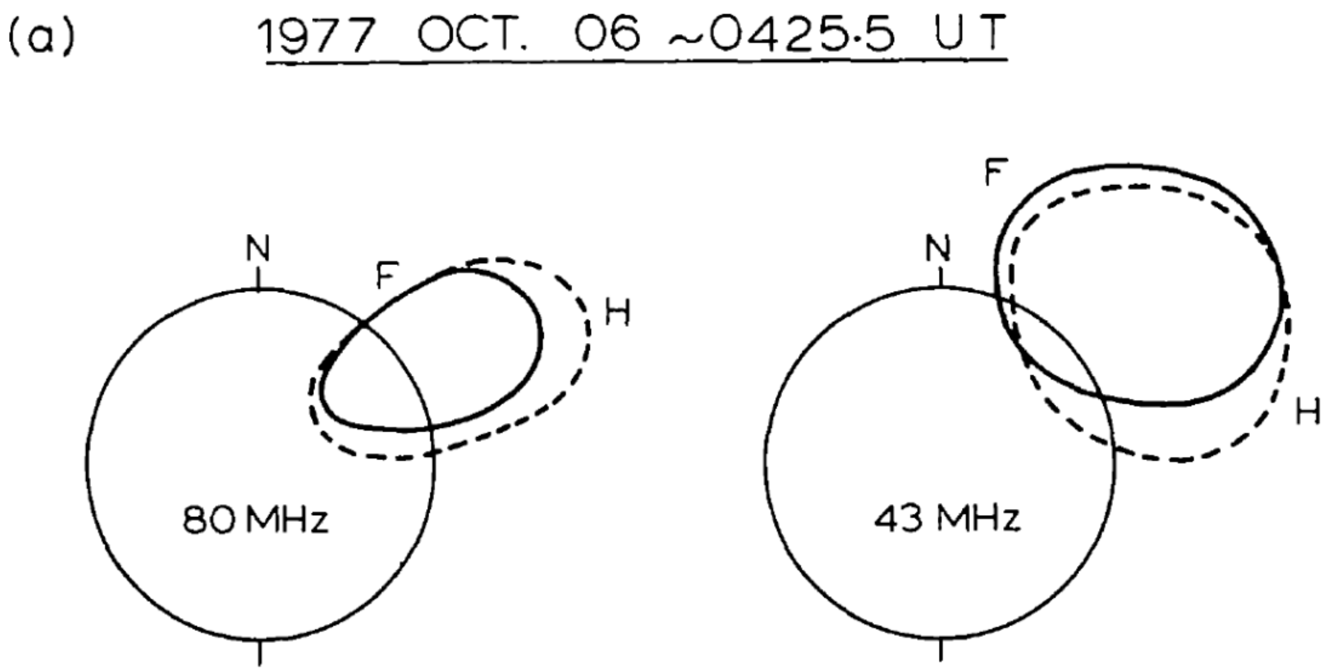
Flares and accelerated particles





$$\nu_p = \sqrt{\frac{n_e e^2}{\pi m_e}},$$ <= plasma frequency

Solar radio imaging dilemma



Dilemma in solar radio imaging … How to interpret the images?

What **chiefly** determines the observed positions and sizes of solar radio sources? Intrinsic properties of the emitter or the radio wave propagation effects?

Radio wave propagation

Since the first solar radio observations, the radio wave propagation was studied

Fokker, 1965; Steinberg et al., 1971, Steinberg, J.-L. 1972, Riddle, A. C. 1974 Pick et al 1981; ….

Radio wave in the corona are affected

- **refraction**
- **scattering**
- **absorption**

The observed source size is:

$$\theta = \sqrt{\theta_0^2 + \langle \Delta\theta^2 \rangle}$$

"true" source size

The dispersion relation for electromagnetic waves

$$\omega(k)^2 = \omega_{pe}^2 + k^2 c^2$$

The dispersion relation for electromagnetic waves:

$$n^2 = 1 - \frac{f_{pe}^2}{f^2}$$

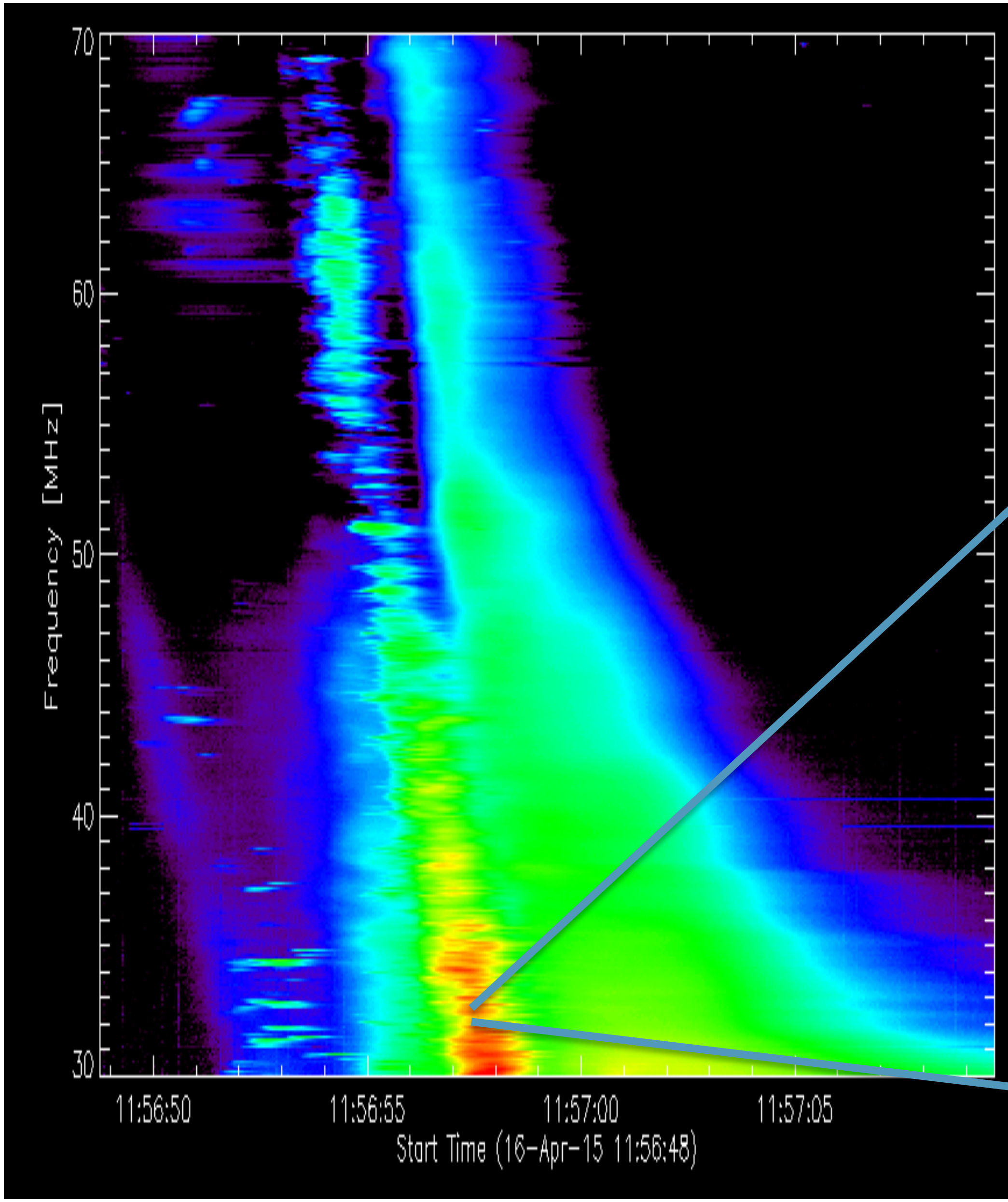
=> **Waves close to plasma frequency (plasma emission) are strongly affected by propagation affects.**

Radio wave propagation effects

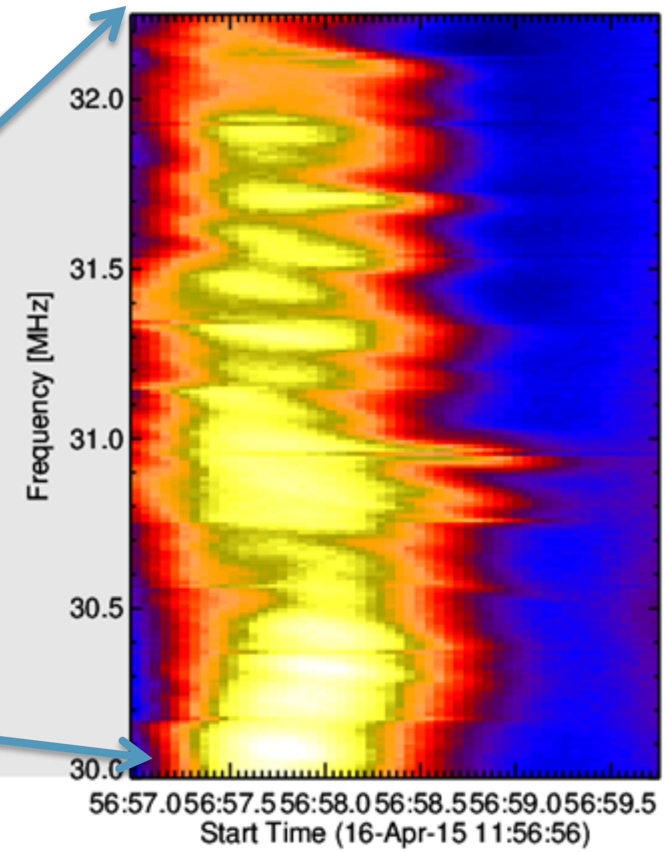
Radio wave propagation affects:

- Time-profiles of the bursts (decay is normally longer)
- The position of the source (frequency dependent)
- The size of the sources
- Polarization of the bursts

Fine radio structures

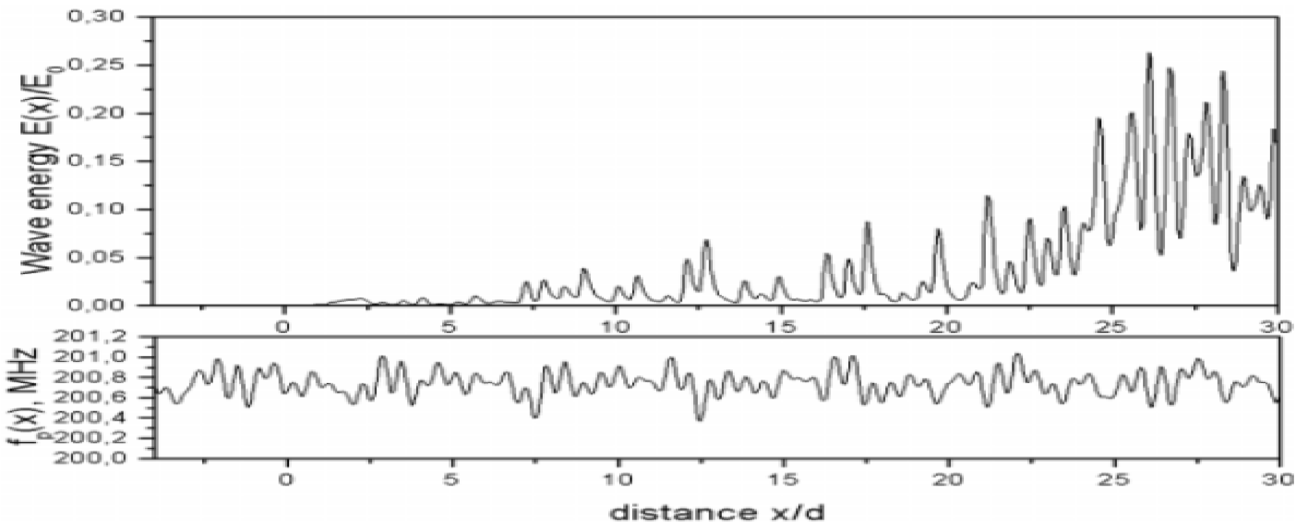


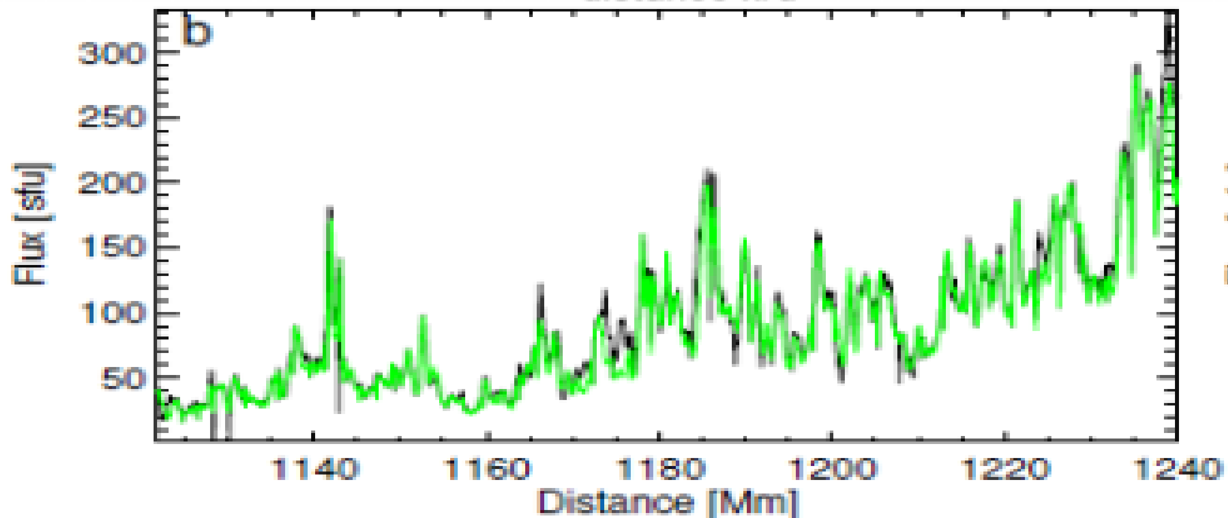
Narrow-band emission (~0.1 MHz) corresponds to small (~0.1 arcmin) intrinsic sizes at fundamental.



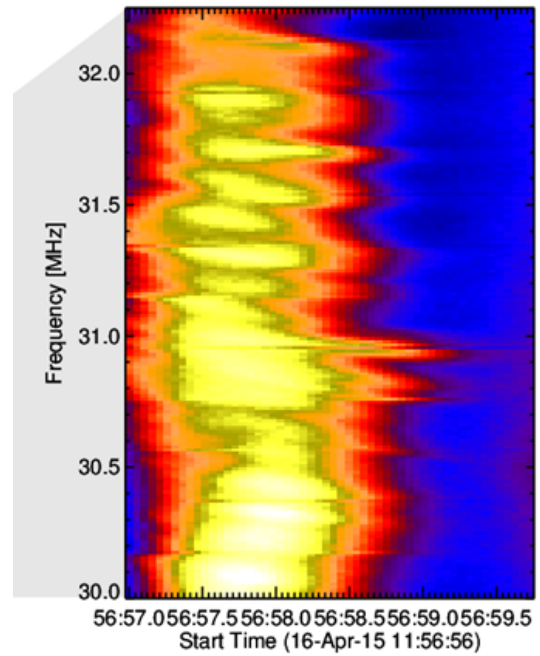
Fine structures are believed to be produced due to density fluctuations in plasma Takakruka (1976) and numerical simulations Kontar (2001).

Numerical simulations

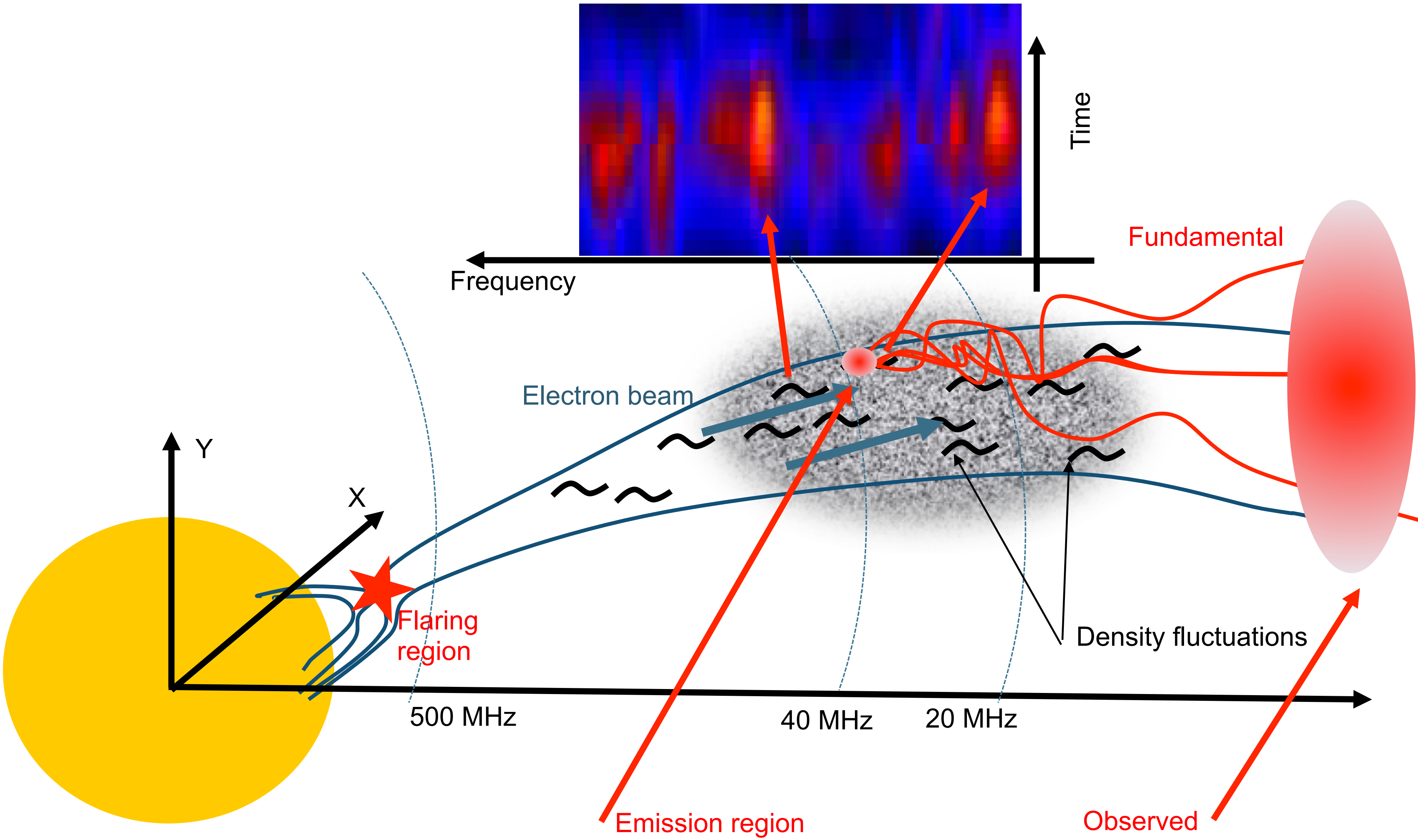




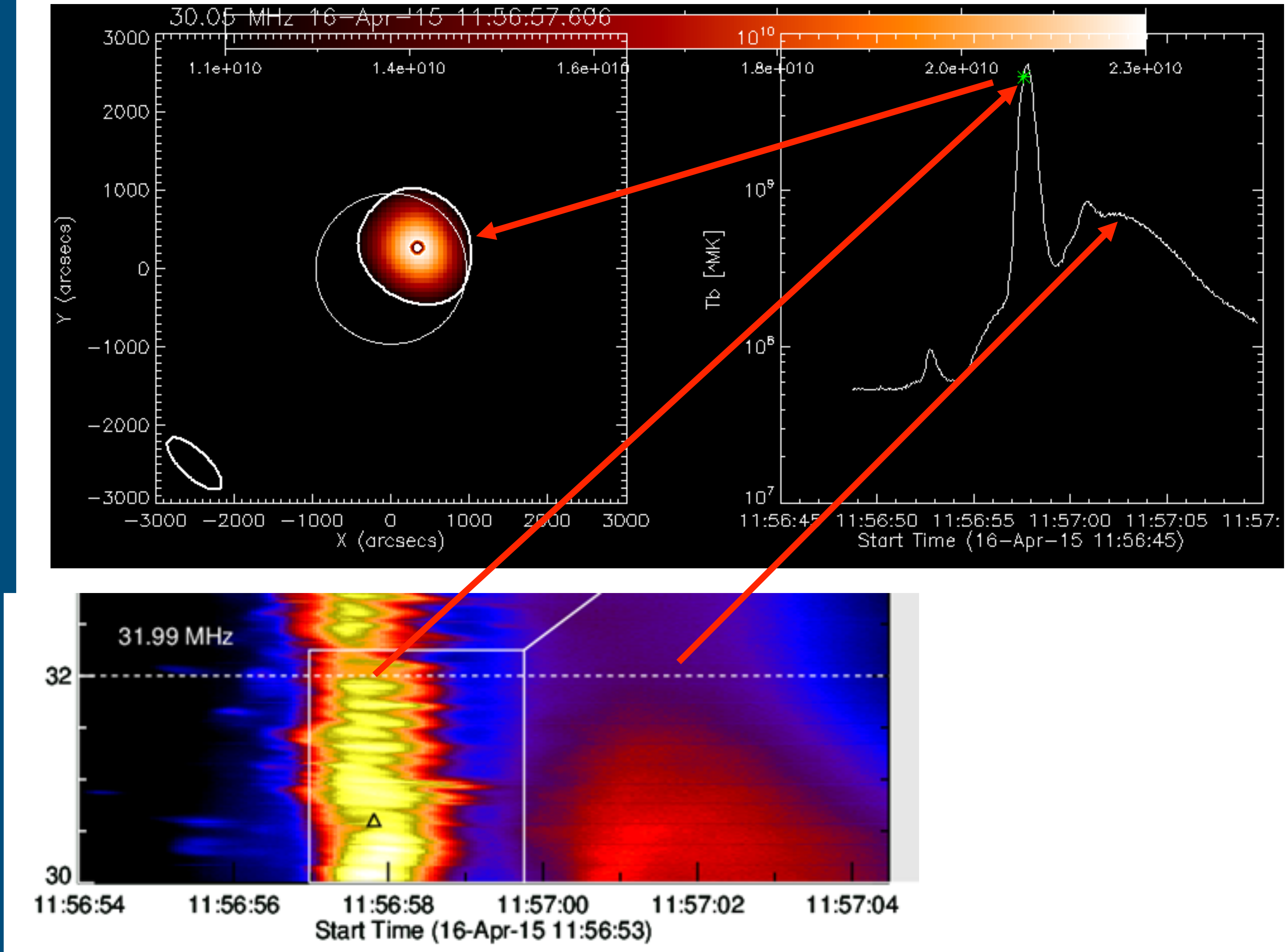
Observations:



Observed radio structures

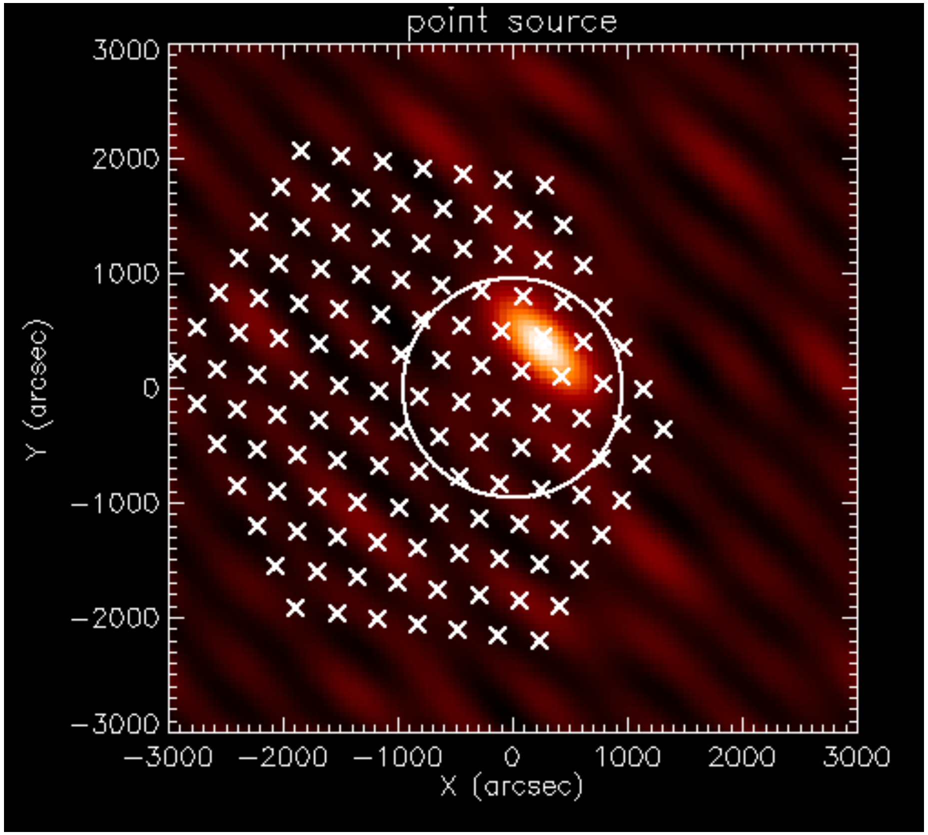


Imaging fine structures

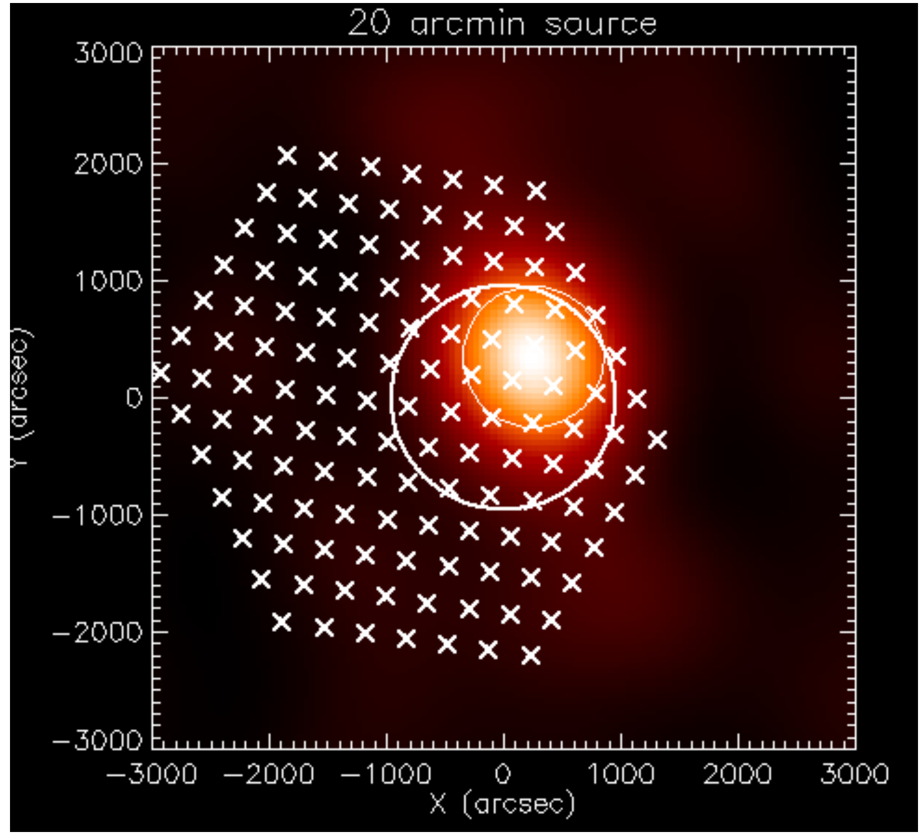


Simulated LOFAR radio sources

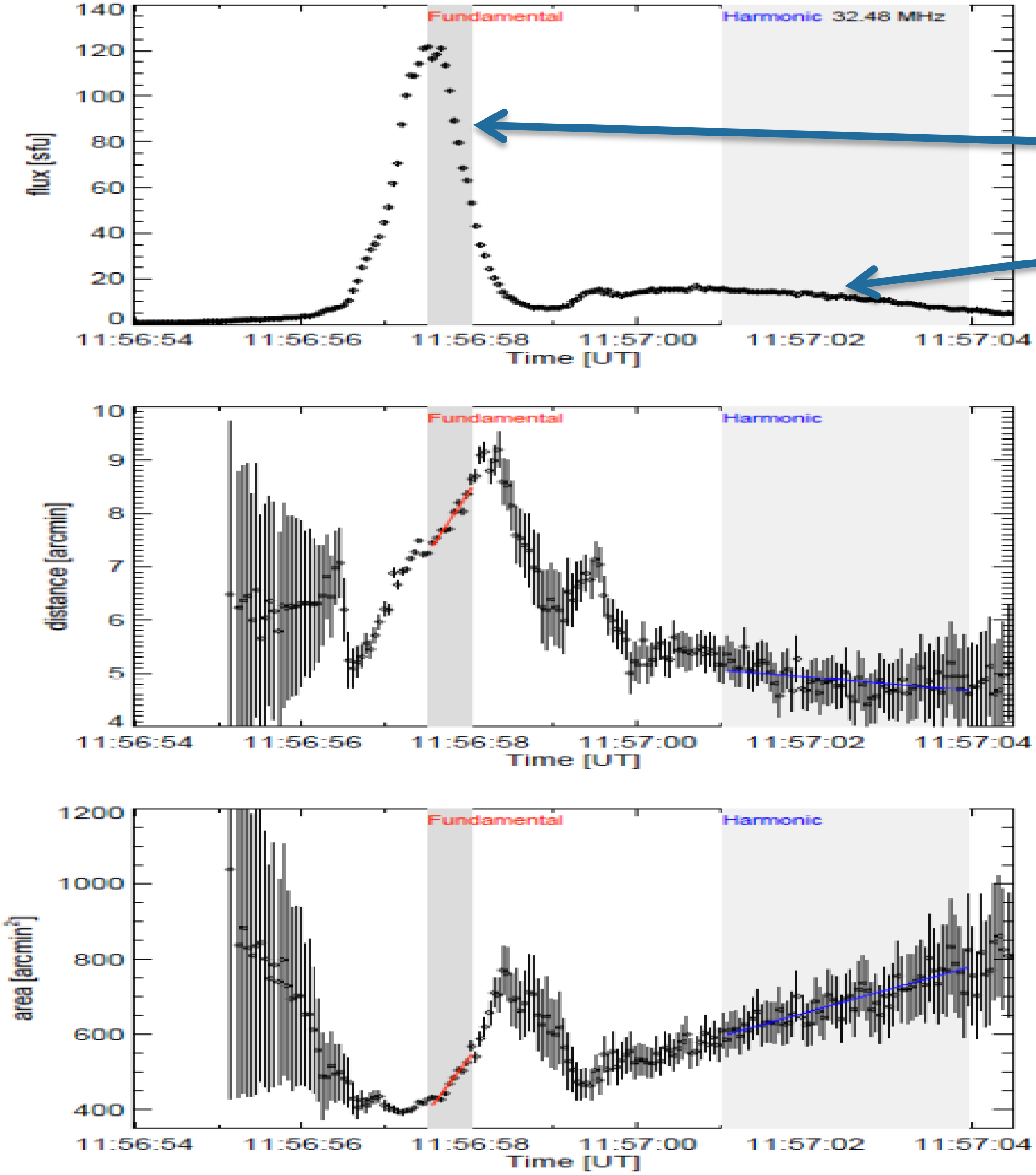
Sources convolved with LOFAR TAB PSF:



Point source (~1 arcmin) required by plasma emission model



20 arcmin sources



Fundamental

Harmonic

Radial Position

AREA

Summary

First spectroscopic imaging observations of fine structures of type IIIb

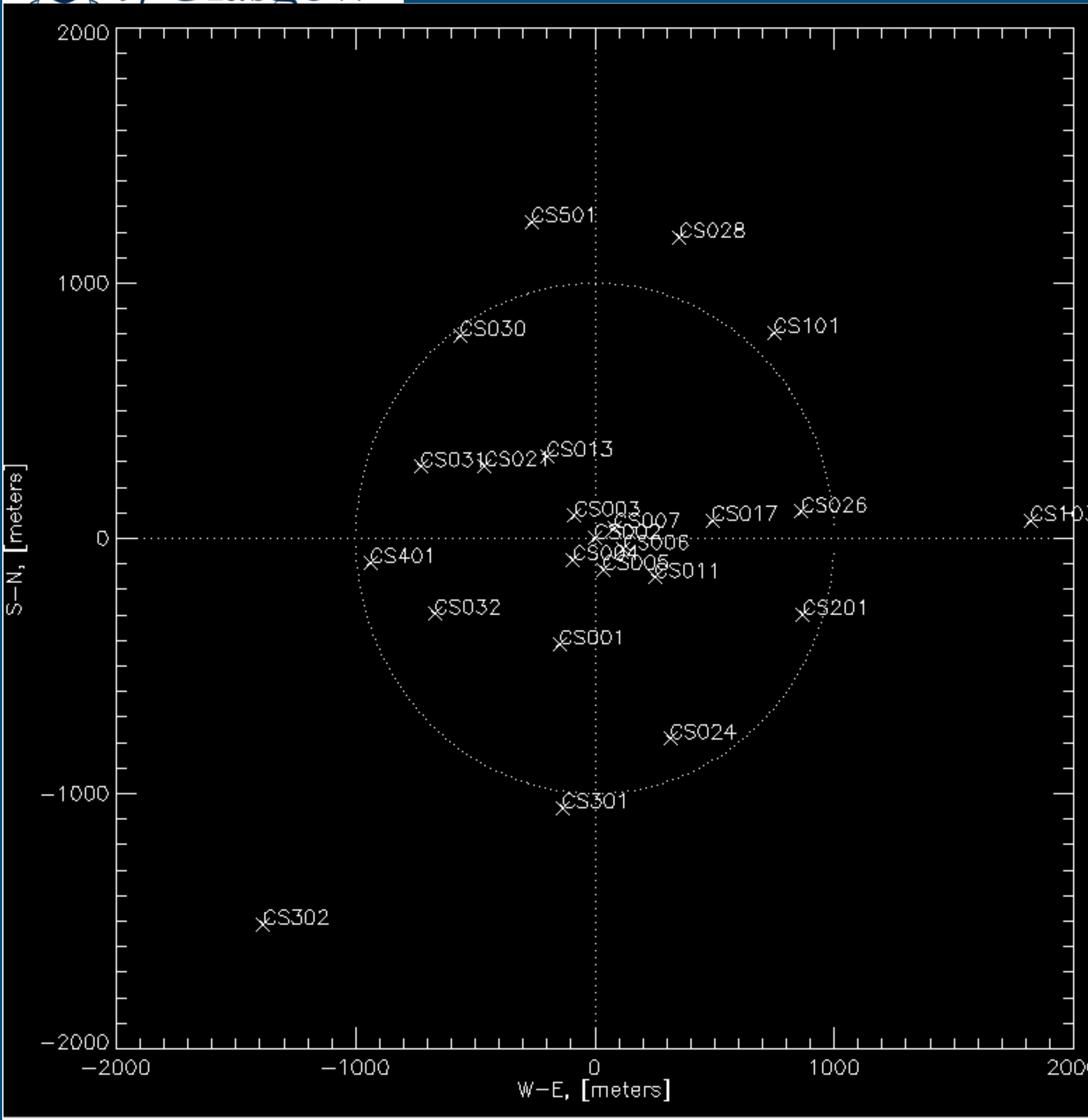
The TAB image sources are inconsistent with small sources required by plasma emission.

The intrinsically small source sizes (~0.1 arcmin) are observed as 20 arcmin sources.

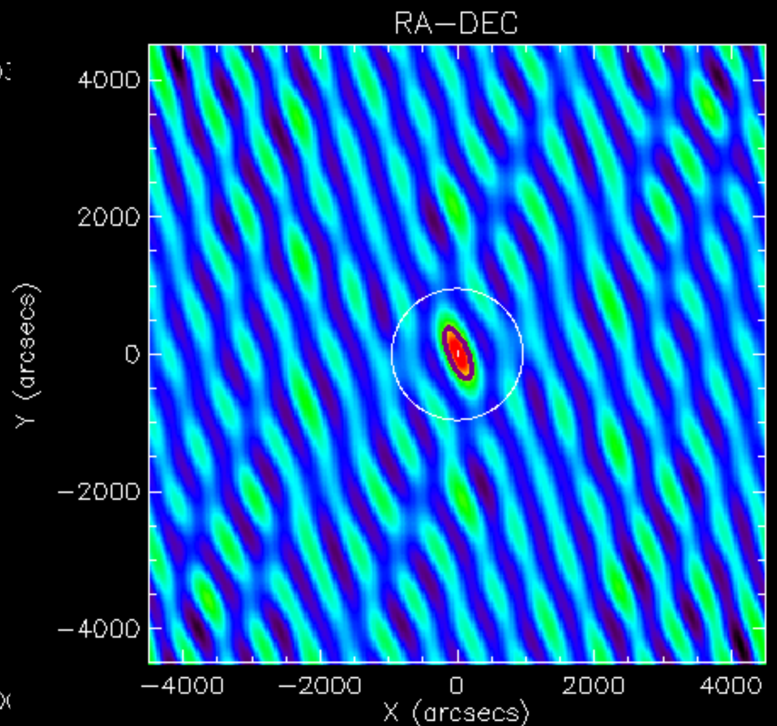
The results consistent that we can see ‘light propagation’ in the scattering solar atmosphere.

Help to observationally investigate the radio wave propagation effects and provides observational limitations on the turbulence in radio emission region.

Simulated radio sources



LOFAR core with the largest baseline around 3.5 km



Crab observations at 80 MHz

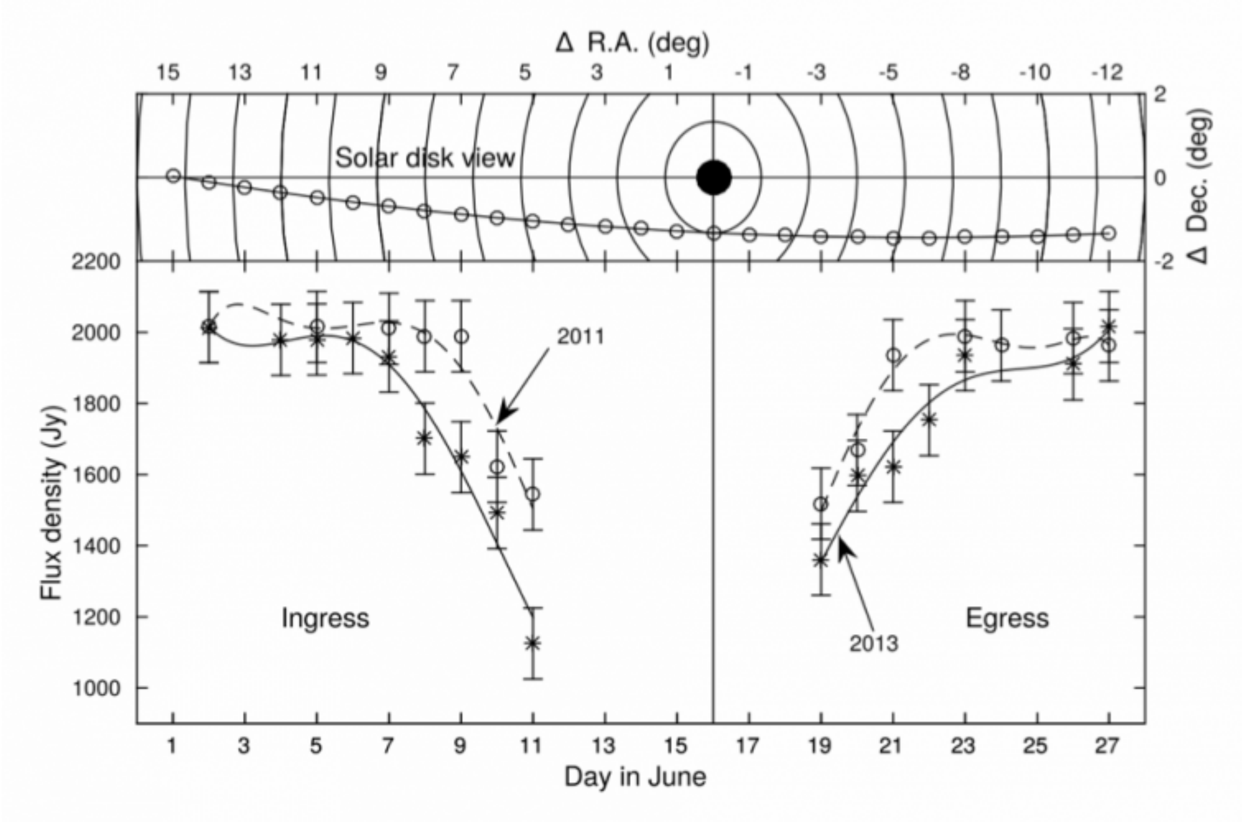


Figure from Sasikumar Raja et al (2016) Crab nebula occultation. The filled circle indicates the Sun and open circles represent the position of the Crab nebula with respect to the Sun on different dates; The closest concentric circle around the Sun has a radius of 5 R⊙. Density fluctuation area measured at R>10 R⊙

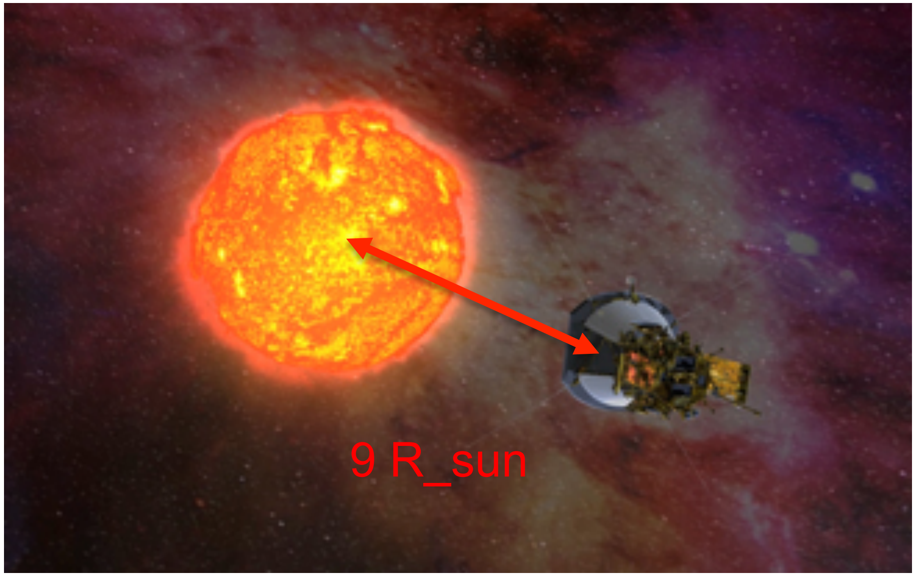
“Solar & Heliospheric physics” Working Group

http://astronomers.skatelescope.org/science-working-groups/shi/

solar radio astronomers from **4 continents** and **20 countries** (e.g. UK, Belgium, France, USA, India, China, France, Australia, Greece, Portugal, Kenya, Ireland, Brazil,…)

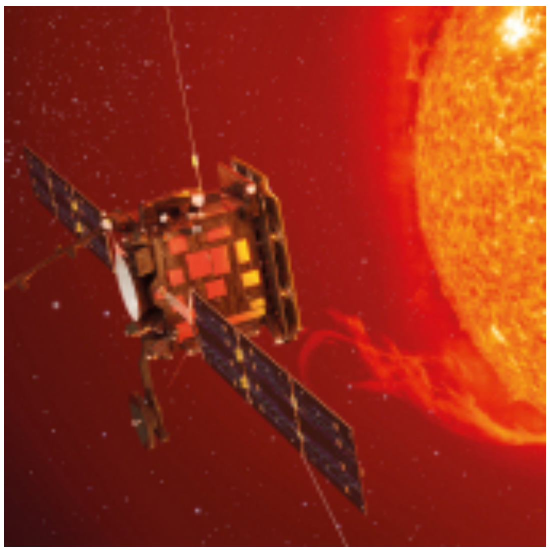
Over **60 members**

Broad science interests include: the Sun (both active and quiet Sun), magnetic reconnection, solar corona/solar wind, solar flares, coronal mass ejections, Sun-Earth system, and ionosphere



NASA Solar Probe Plus is in the definition stage and is scheduled to launch in 2018:
First close approach in December, 2024
First SKA observations 2014

Science objectives:
1) Coronal heating and solar wind acceleration
2) Production, evolution and transport of solar energetic particles



SKA observations will be complemented with new in-situ and remote observation of the Sun in the inner heliosphere

ESA Solar Orbiter to be launched in 2018 (approach the Sun ~0.3AU)