



University
of Glasgow

SOLAR SCIENCE WITH LOFAR

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“**Solar and Space Weather**” KSP unites solar radio astronomers from Germany, France, Austria, Sweden, UK

2nd “**Solar and Space Weather**” KSP workshop will be held in Potsdam
June 24-25, 2009

Currently 7 UK institutes expressed interest in LOFAR **Solar/Solar-Terrestrial studies**:

- 1) Aberystwyth University
- 2) University of Glasgow
- 3) University College London (UCL)
- 4) University of Manchester
- 5) Rutherford Appleton Laboratory (RAL)
- 6) University of Southampton
- 7) Queen Mary University London

Solar emission mechanisms:

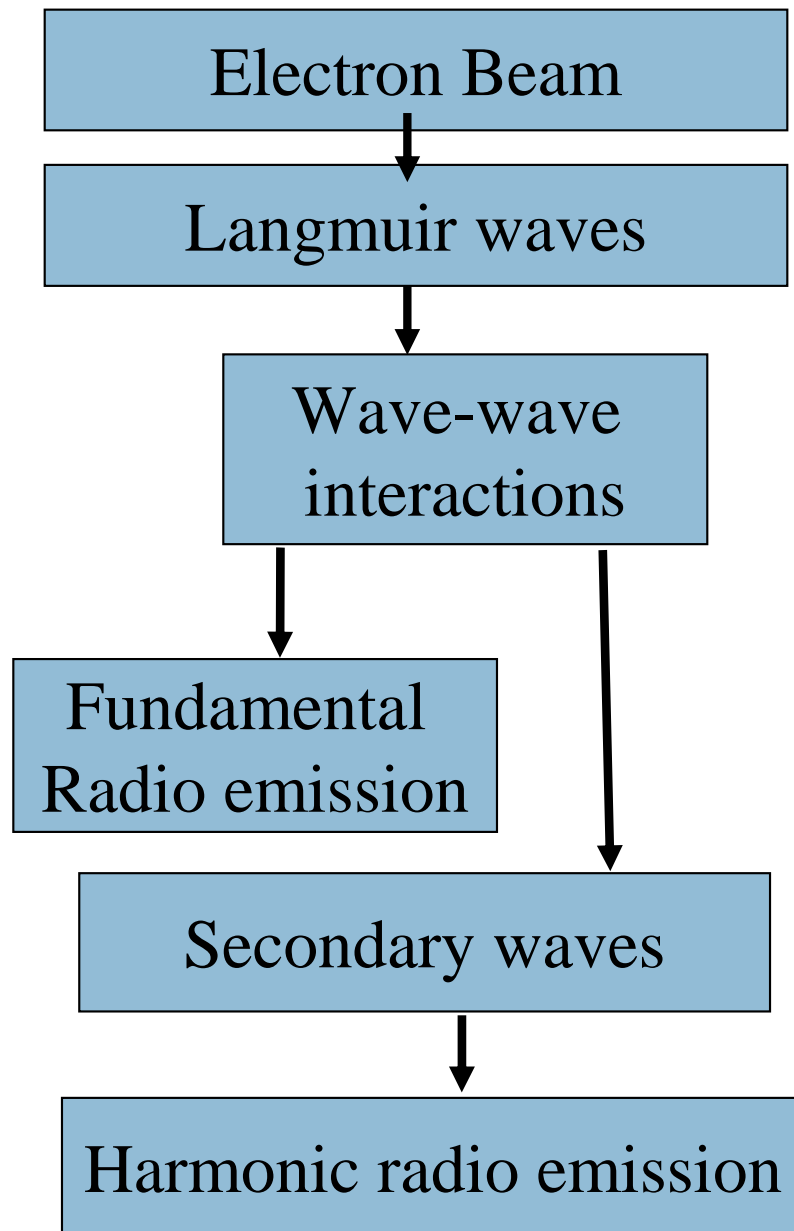
Free-free emission (collisions of electrons with protons and other particles)

Gyromagnetic emission (cyclotron and gyrosynchrotron)

Coherent emission due to wave-wave and wave-particle interaction (strongest in LOFAR frequency range)

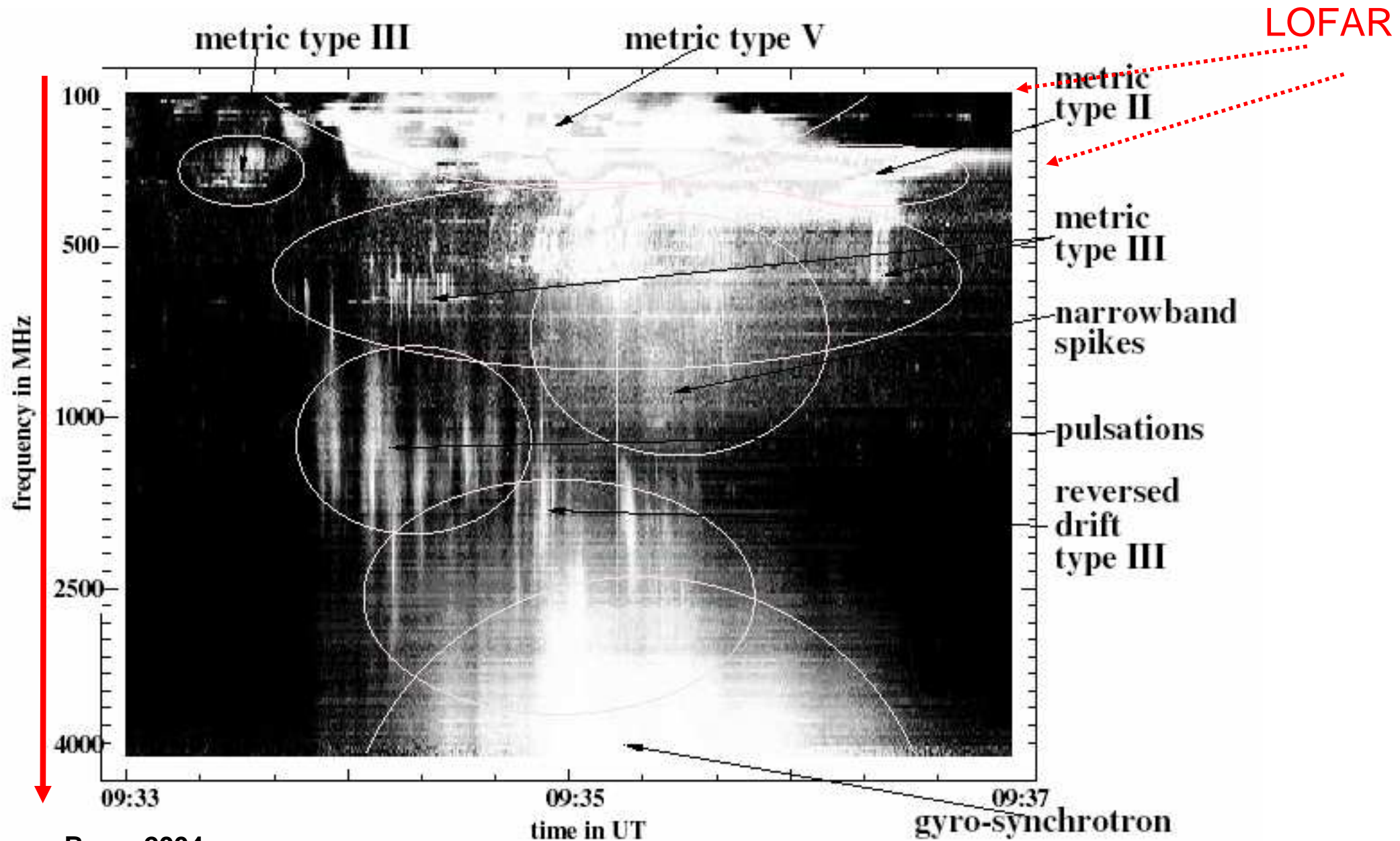
$$\nu_B = \frac{eB}{2\pi m_e c}, \quad \leq \text{gyrofrequency}$$

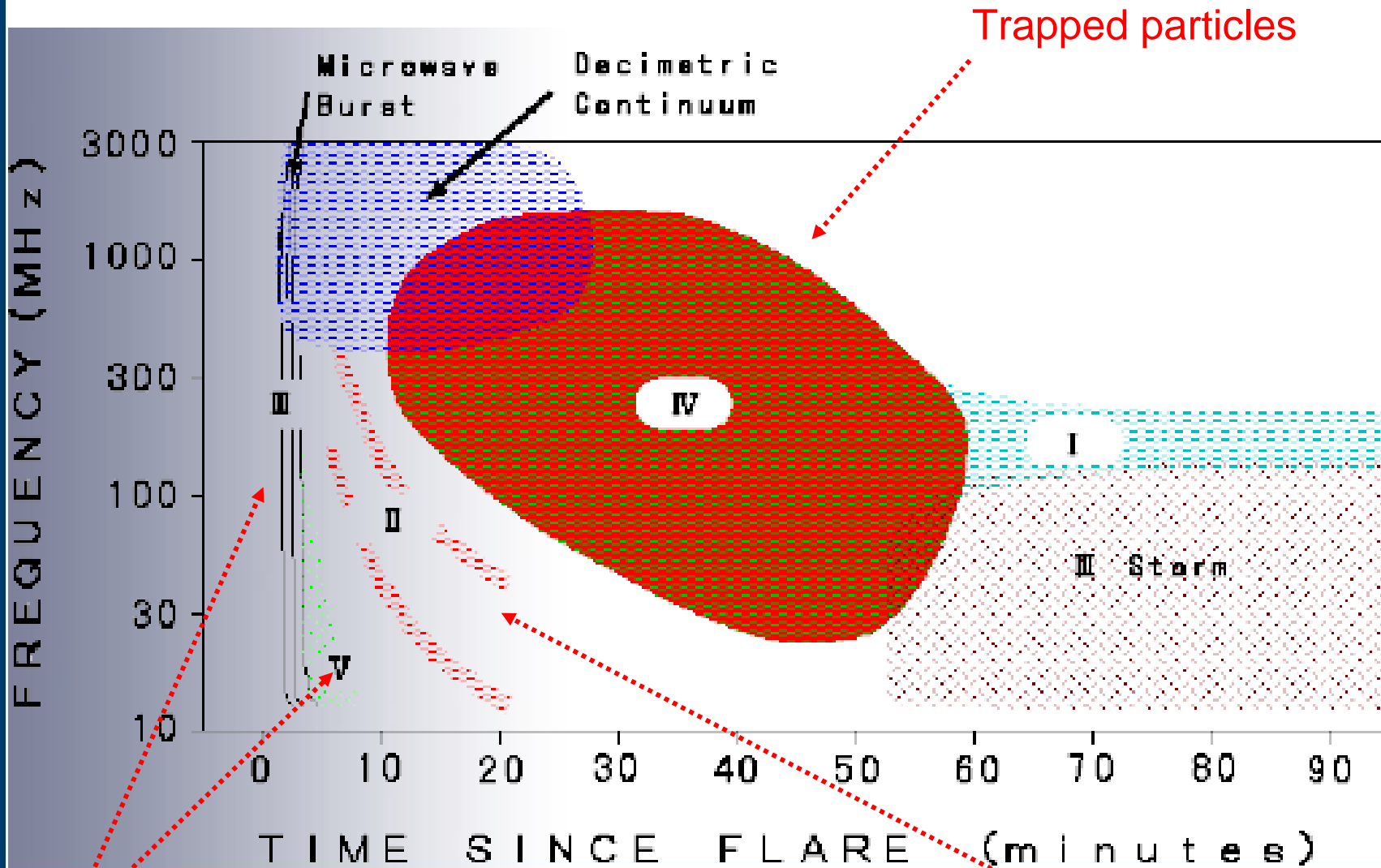
$$\nu_p = \sqrt{\frac{n_e e^2}{\pi m_e}}, \quad \leq \text{plasma frequency}$$





A typical dynamic spectrum of an active Sun

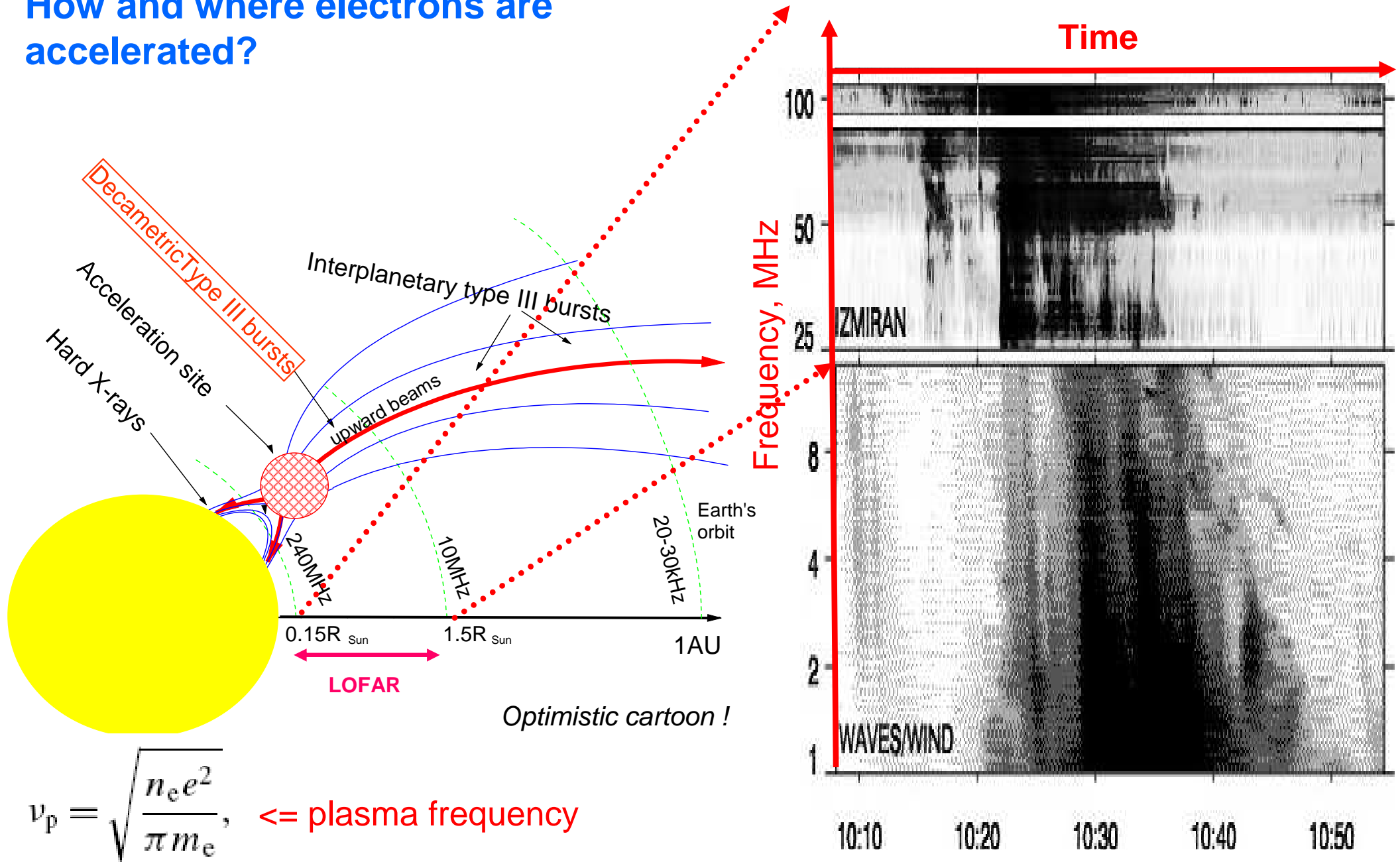




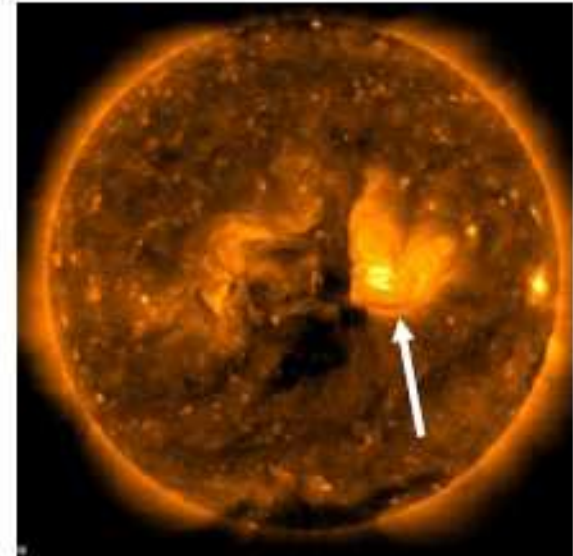
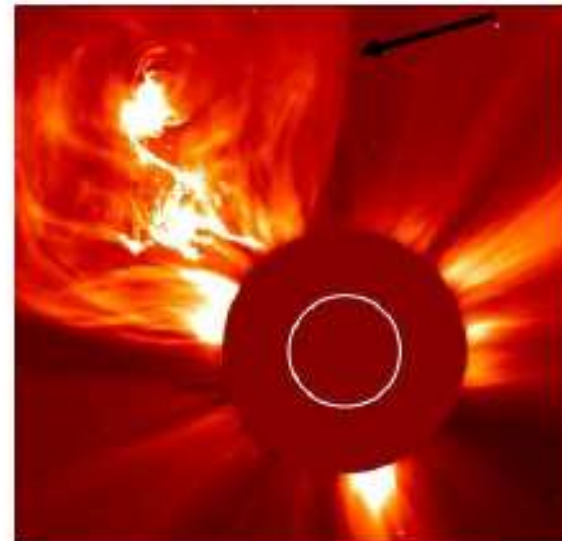
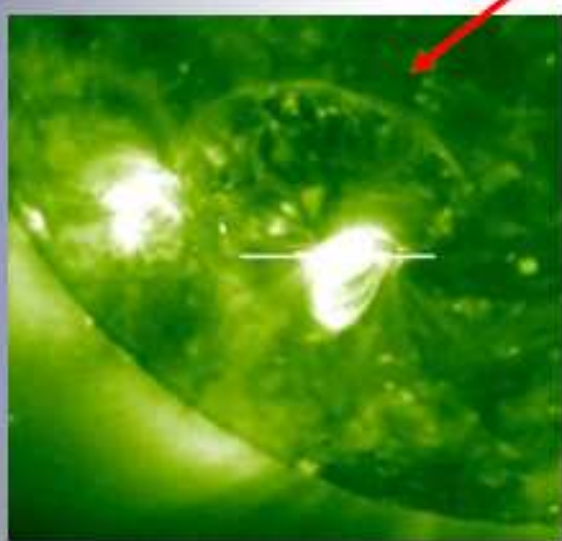
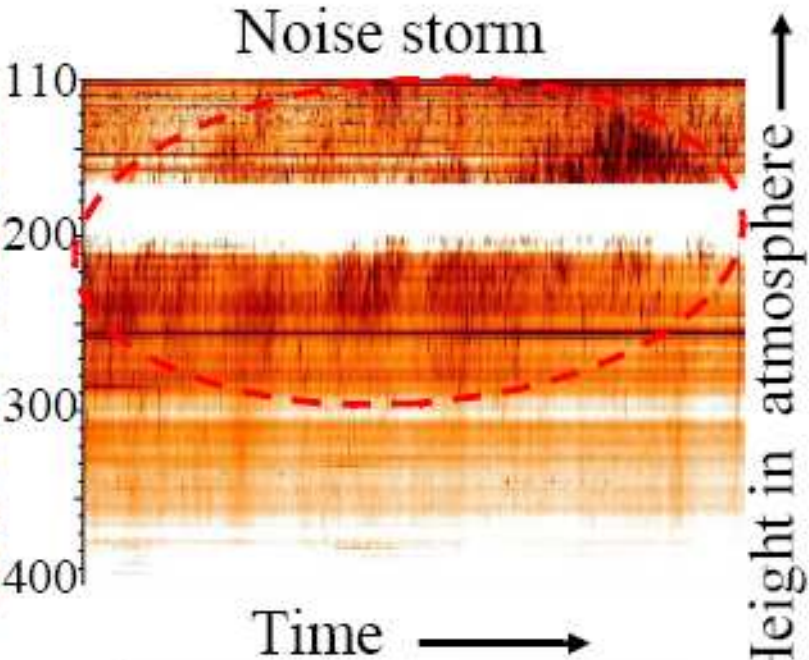
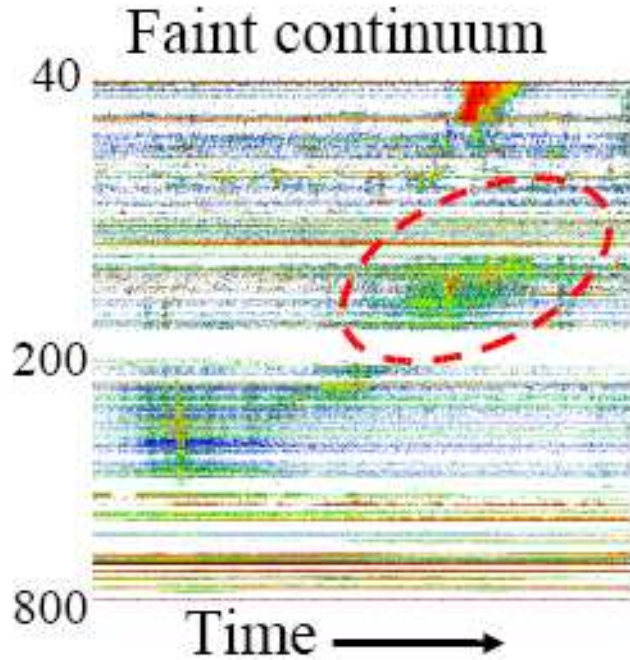
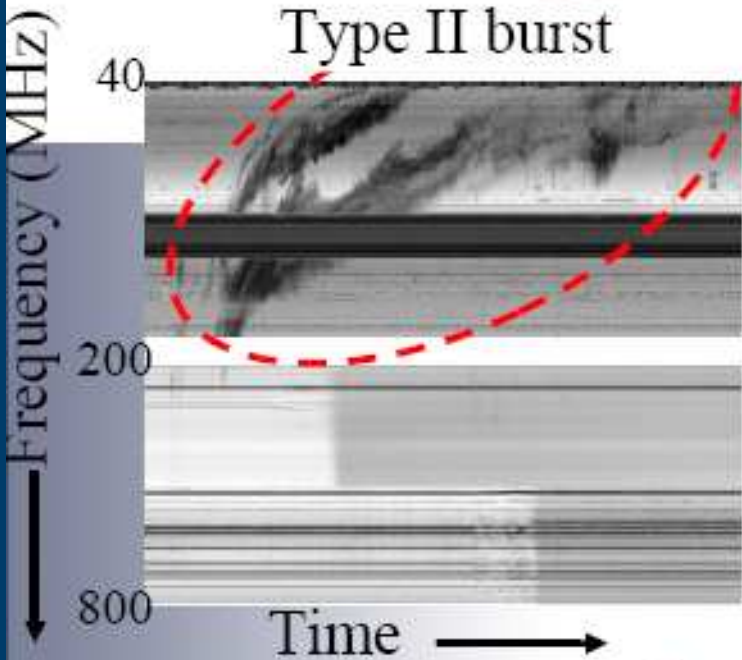
Signatures of energetic electrons

Signatures of shocks

How and where electrons are accelerated?



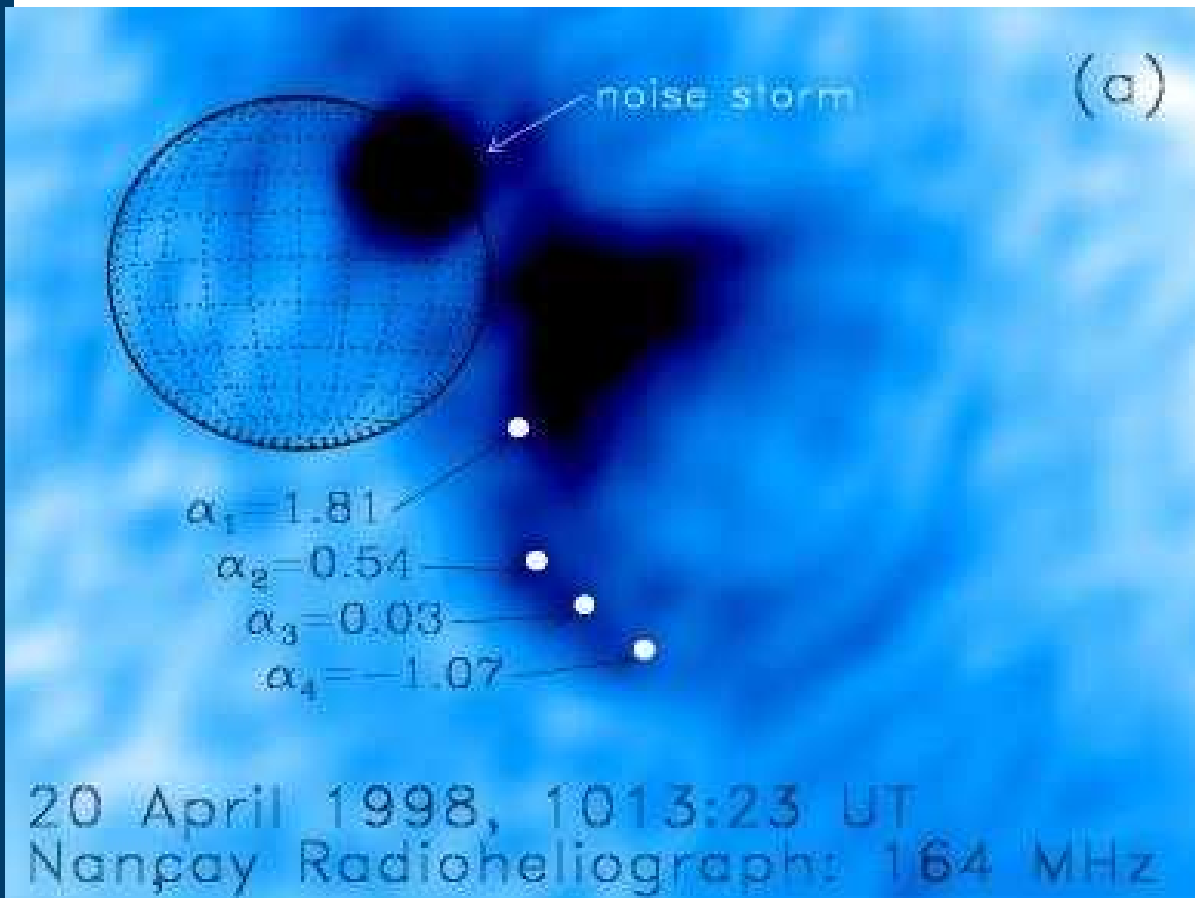
$$v_p = \sqrt{\frac{n_e e^2}{\pi m_e}}, \quad \leq \text{plasma frequency}$$



• Large shock wave

• Coronal mass ejection

• AR/coronal heating?



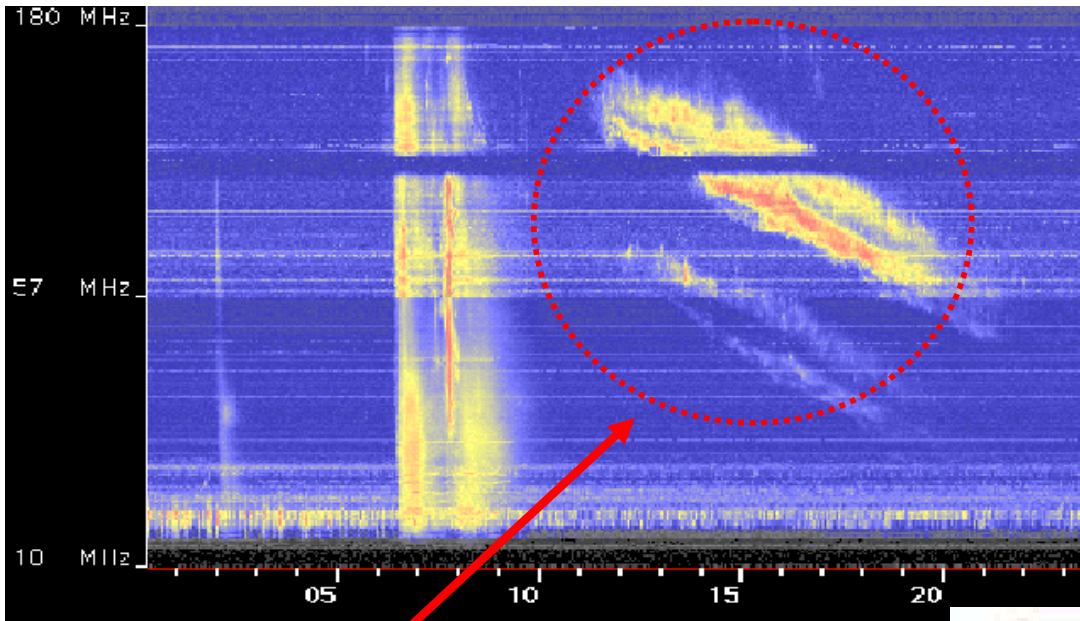
Radio emission is gyrosynchrotron from electrons trapped in weak-field structures:

- electron energy distribution
- magnetic field strength/direction
- dynamic evolution of coronal structures

Image of a CME at 164MHz using the Nancay Radioheliograph (Bastian et al. 2001)

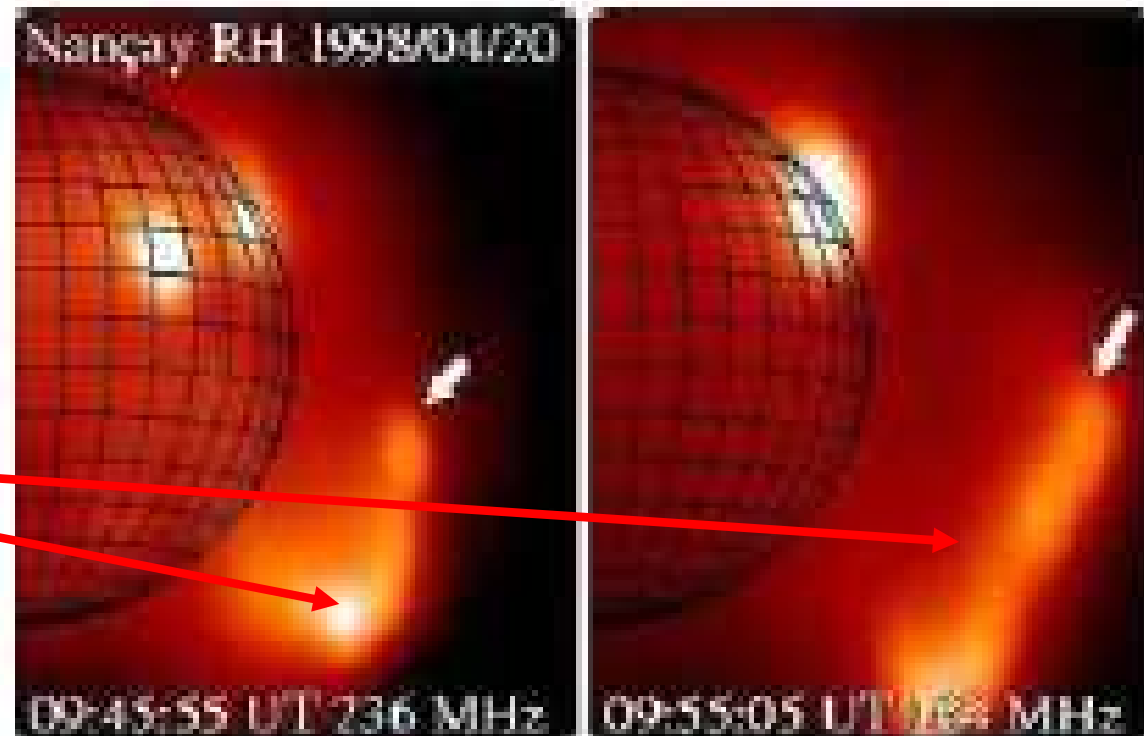
Key questions:

- What is CME/flare relationship?
- How do they develop and evolve into interplanetary disturbances?
- What are their effects on the surrounding solar/heliospheric plasma?

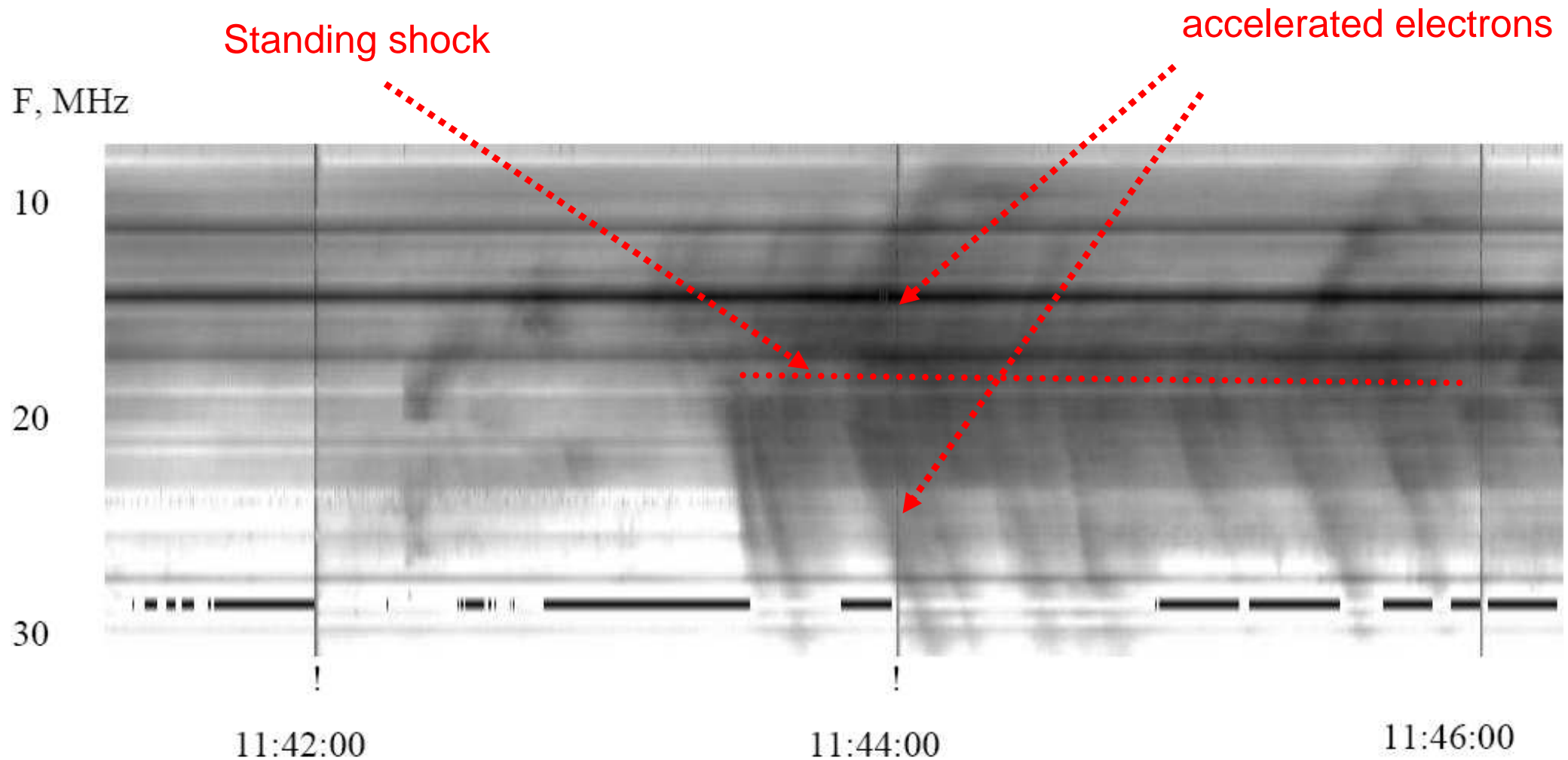


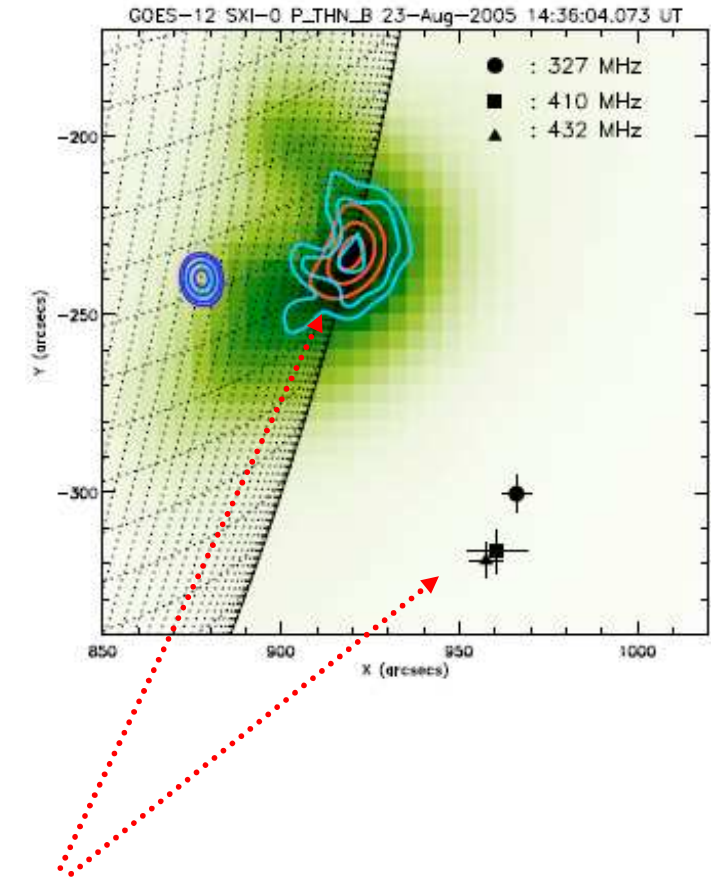
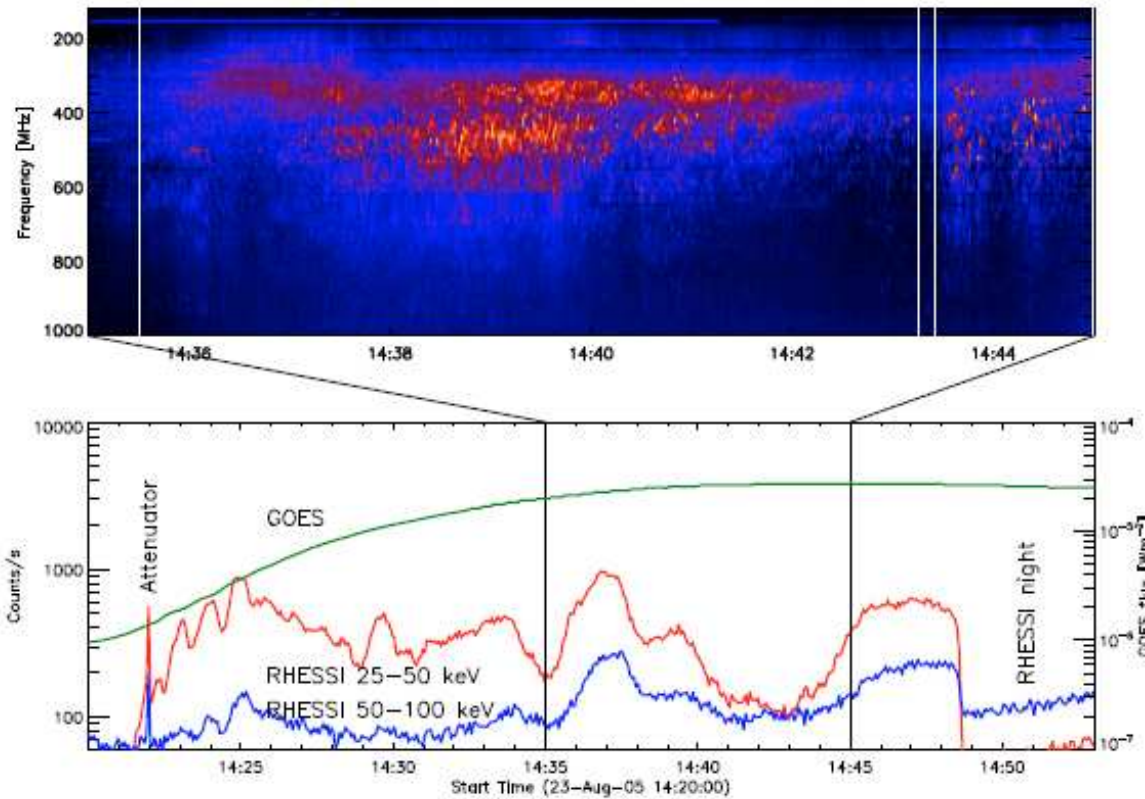
Formation and propagation of the shocks of the shocks

Type II radio burst → prime diagnostic of outward-moving coronal shock waves



Type II with herring-bone structure: acceleration of electrons by shocks



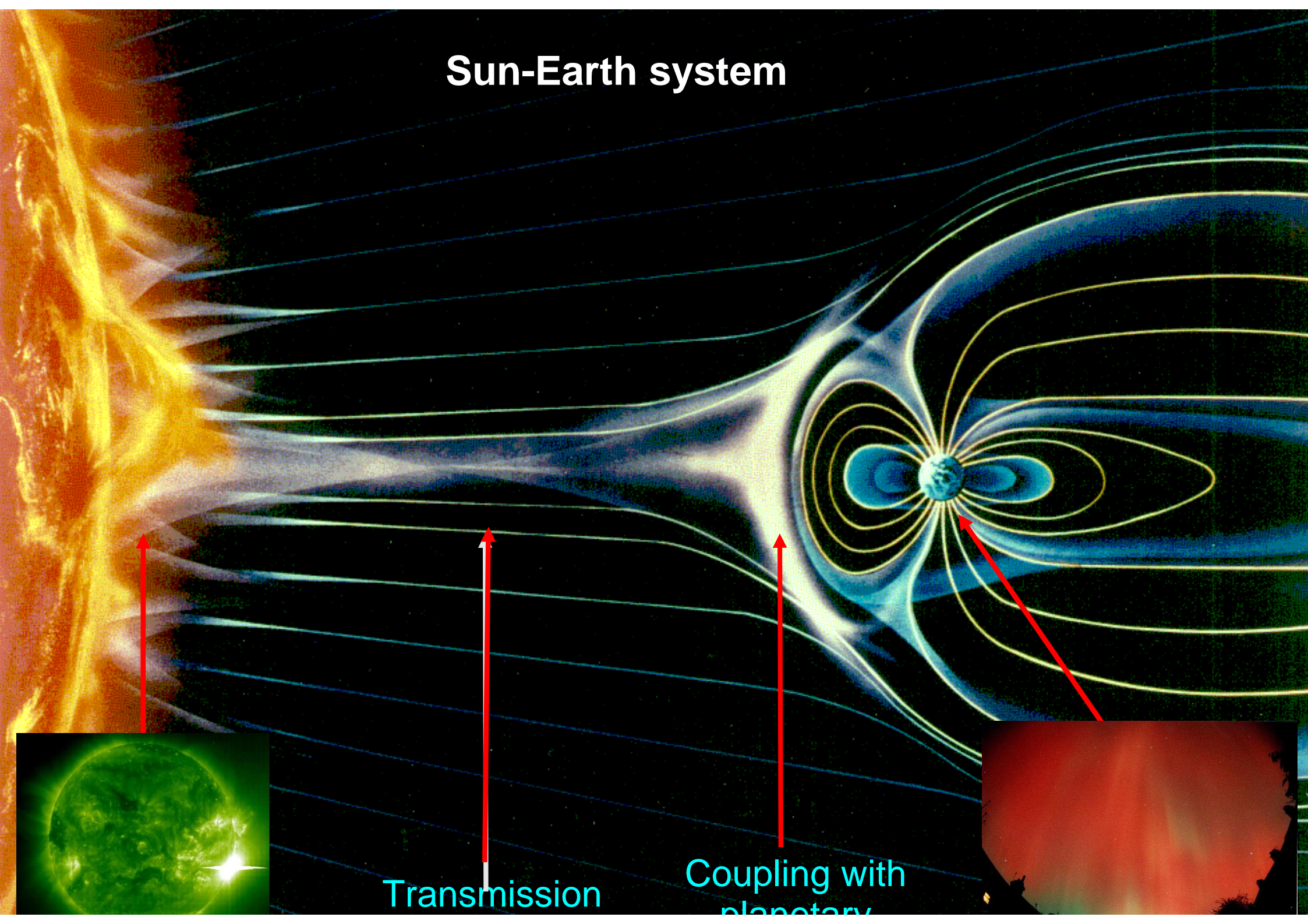


Battaglia and Benz, 2009

Note displacement from the flaring site

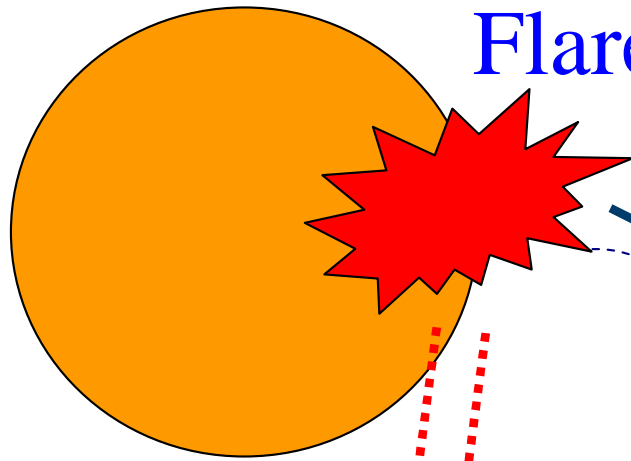
What is the nature of radio spikes and their relation to solar energetic particles?

Sun-Earth system



Transmission

Coupling with
planetary



Flare

X-rays

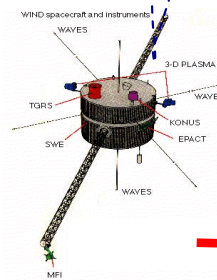
electrons

LOFAR will observe radio signatures of energetic electrons in the corona

X-rays

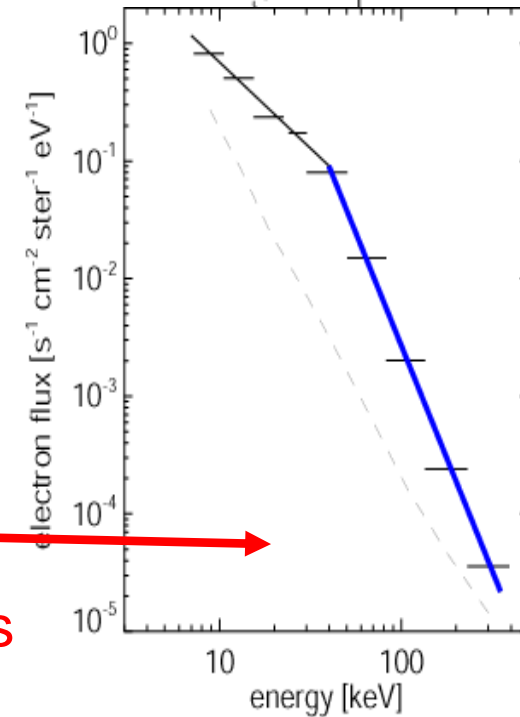
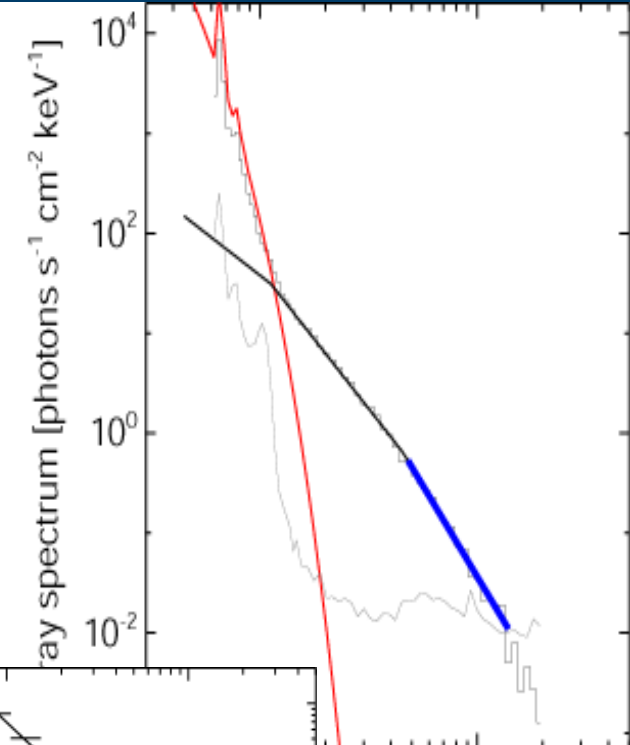


RHESSI



WIND

In-situ measurements



Radio gives a unique insight into key questions in Solar and Solar-Terrestrial Physics:

- **particle acceleration and energy release during solar flares**
- **production and effects of CMEs and shocks**
- **coronal heating**
- **‘Space Weather’ (the influence of the Sun on the heliosphere)**

LOFAR offers fast, multi-frequency imaging of the Sun and has a potential to improve our understanding greatly.