Stereoscopic Observations of Solar Type III radio bursts in the outer Corona

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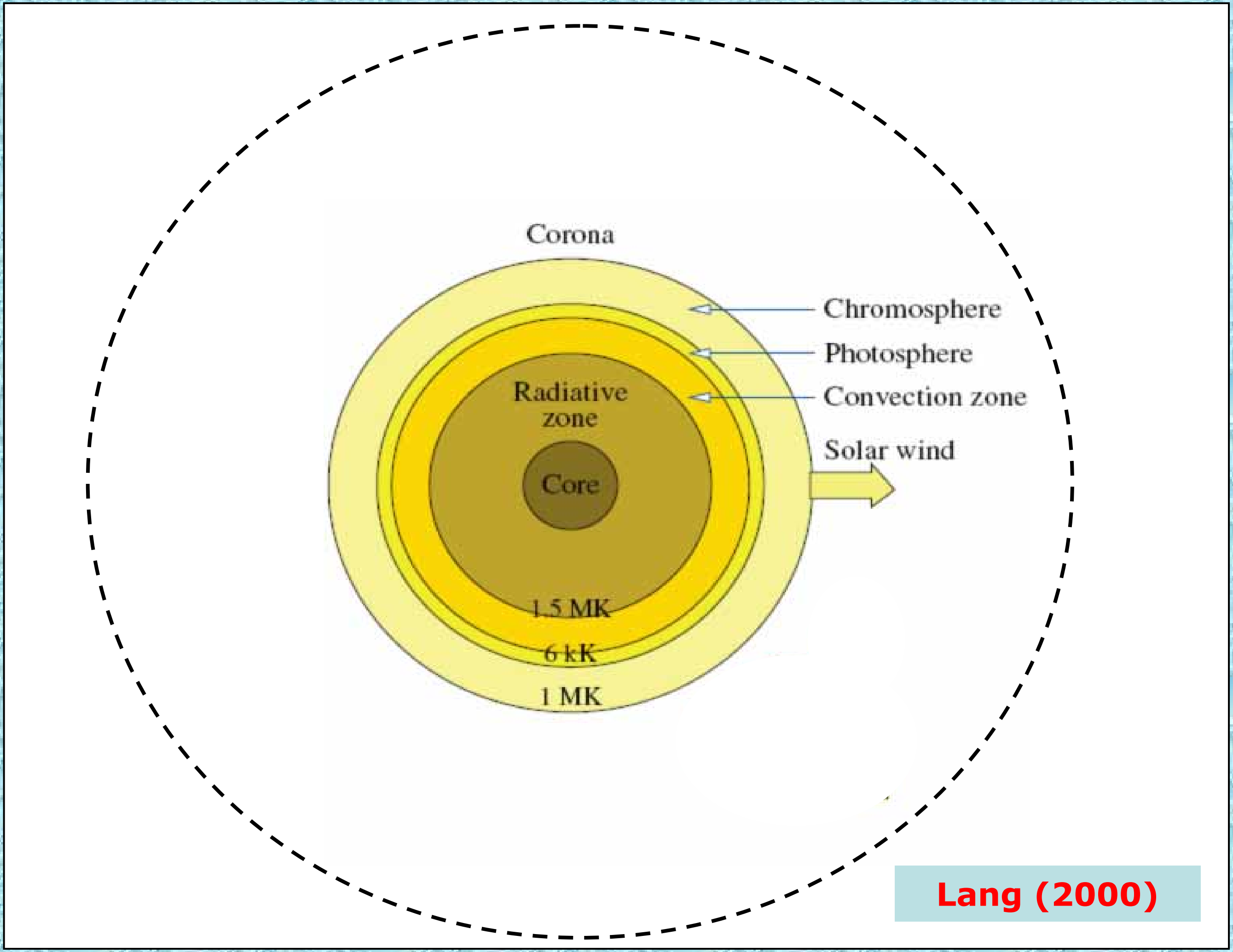
1. ‘Atmosphere’ of the Sun
2. Radiophysics of the Solar Corona
3. Spectral analysis of Type III interplanetary bursts
4. Remote sensing of the interplanetary medium
5. Outlook

1. ‘Atmosphere’ of the Sun



1. 'Atmosphere' of the Sun

- **Baumbach-Allen Model (1923): Electron density versus Solar radii**

$$N_e(r) = 10^8 \times \left[1.55\left(\frac{r}{R_\odot}\right)^{-6} + 2.99\left(\frac{r}{R_\odot}\right)^{-16}\right] \quad \mathrm{cm}^{-3}$$

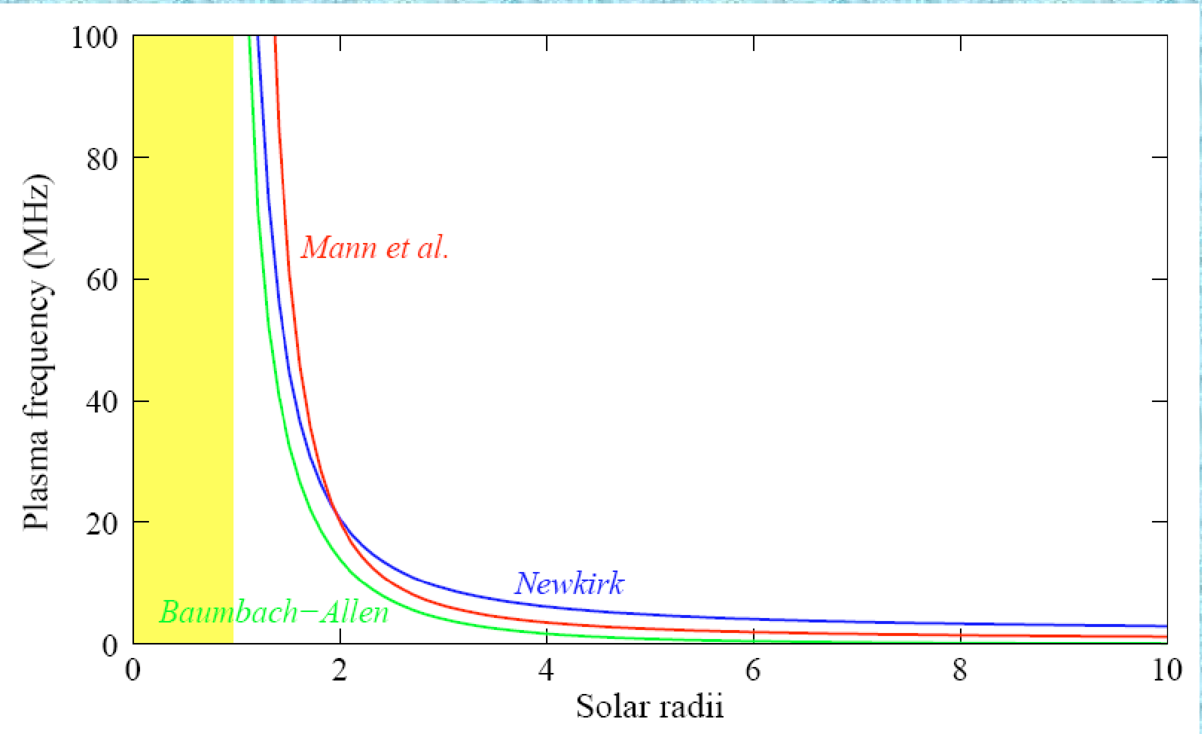
- **Electron density versus plasma frequency**

$$f_p\,(kHz) \;=\; (2\pi)^{-1}\sqrt{ne^2/m\varepsilon_0} \approx\; 8.98\,\sqrt{n_e}$$

↓

- **Relationship between the plasma frequency and the Solar radii**

1. 'Atmosphere' of the Sun



The radially dependent plasma frequency of the solar corona according to the models: Baumbach-Allen (1923), Newkirk (1961), and of Mann et al. (1998). (Bo, 2002)

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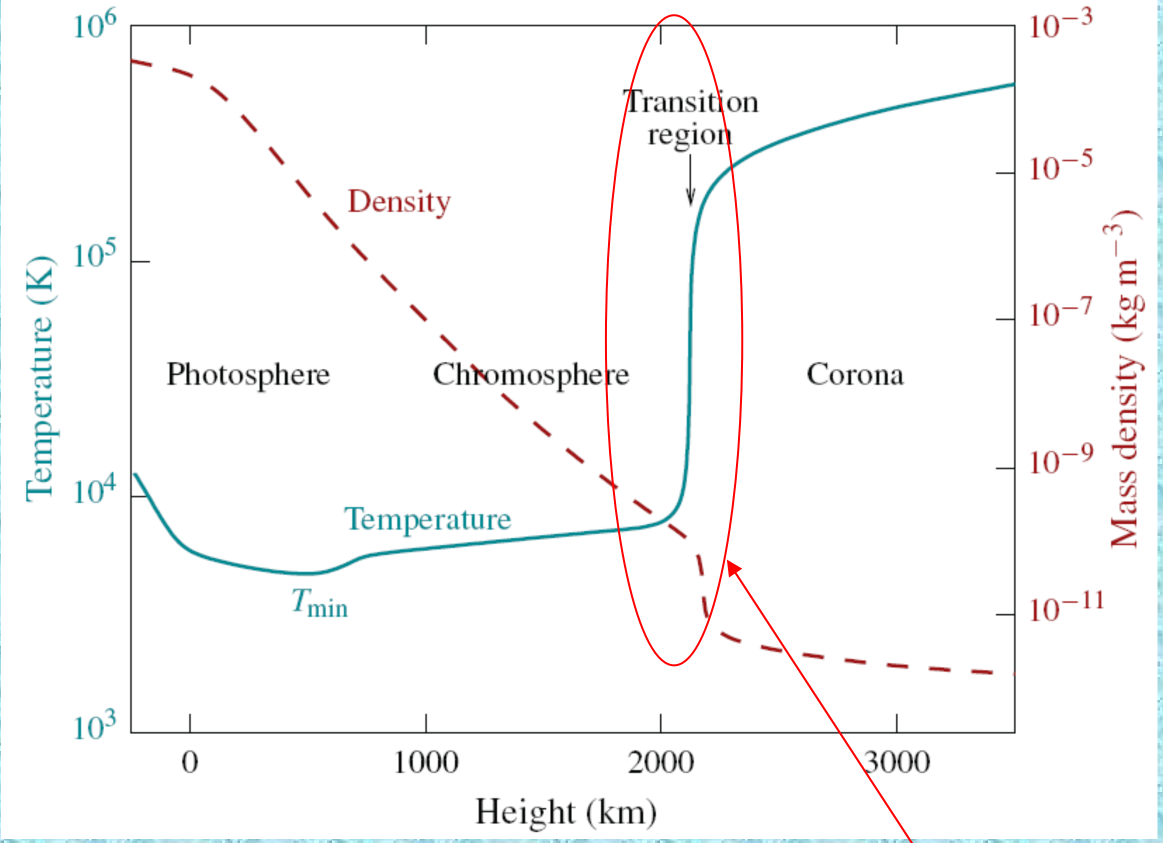
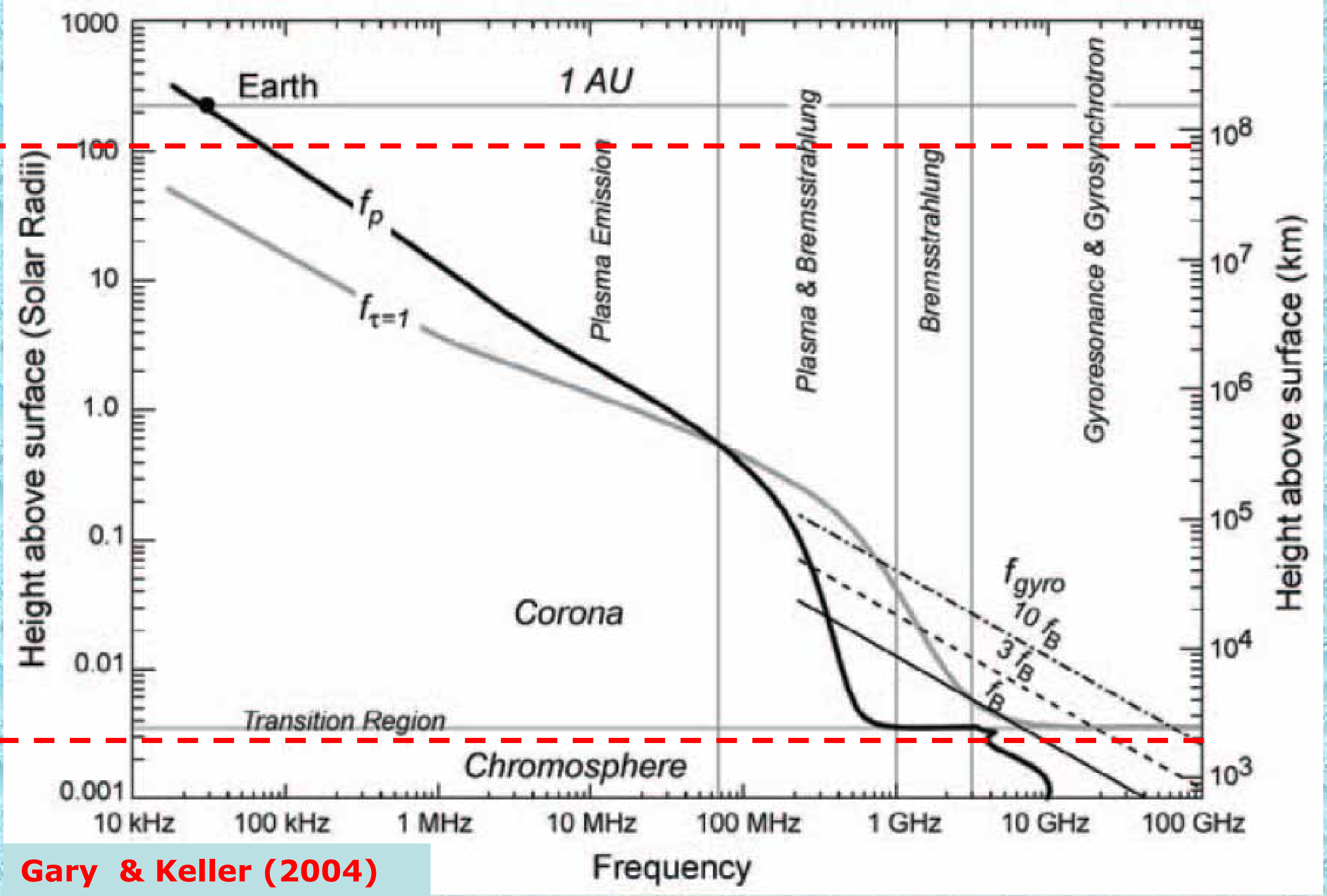


Sketch of the temperature and gas mass density in the solar photosphere, chromosphere, and lower corona, including the transition region (Khotyaintsev 2006).

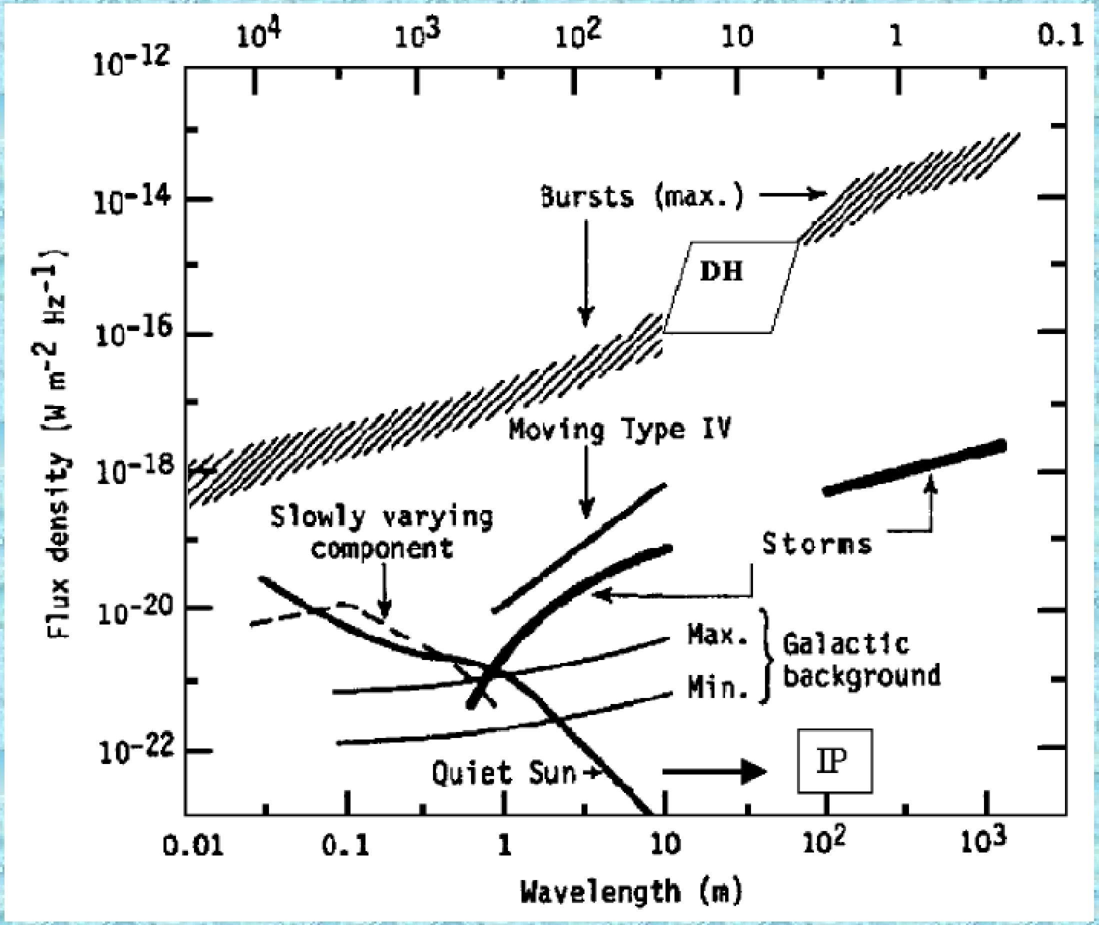
Effect of the Solar magnetic field?

2. Radiophysics of the Solar Corona



Gary & Keller (2004)

2. Radiophysics of the Solar Corona



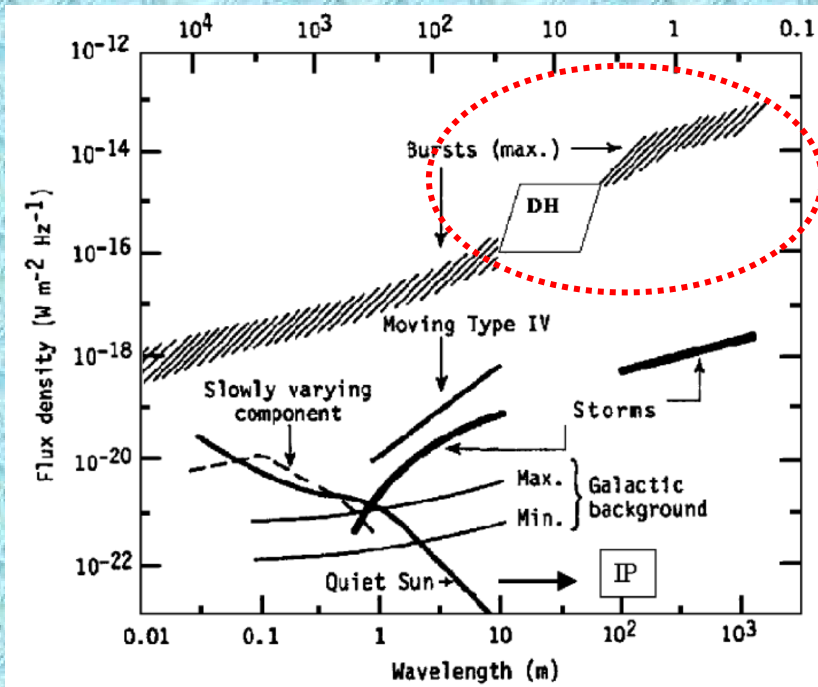
Schematic diagram showing the flux densities of various phenomena 0.01 m to 1 km. In the top the corresponding frequencies are marked in MHz. (McLean and Labrum, 1985).

2. Radiophysics of the Solar Corona

	Wavelengths	Brightness temperature	Emission mechanism
Quiet Sun	sub-mm-DAM	$\lesssim 10^4$ - 10^6 K	bremsstrahlung
Active regions	sub-mm-DAM centimeter	10^4 - 3×10^6 K 1-3 $\times 10^6$ K	bremsstrahlung gyroresonance
Flares	mm - m cm - dm dm - km	10^6 - 10^{10} K to 10^{15} K to 10^{17} K	gyrosynchrotron cyclotron maser plasma radiation

The increase of the temperature in the Solar Corona is due to the effect of the Solar magnetic field on the ionized particles.

3. Spectral analysis of Type III radio bursts



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	dm - km	to 10^{17} K	plasma radiation

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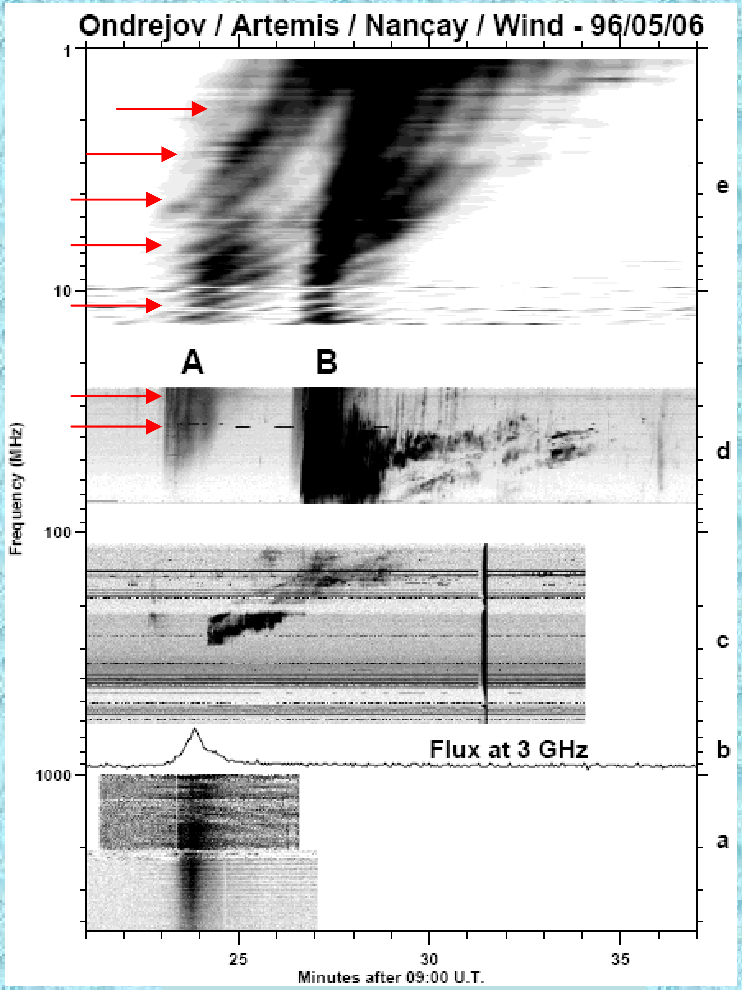
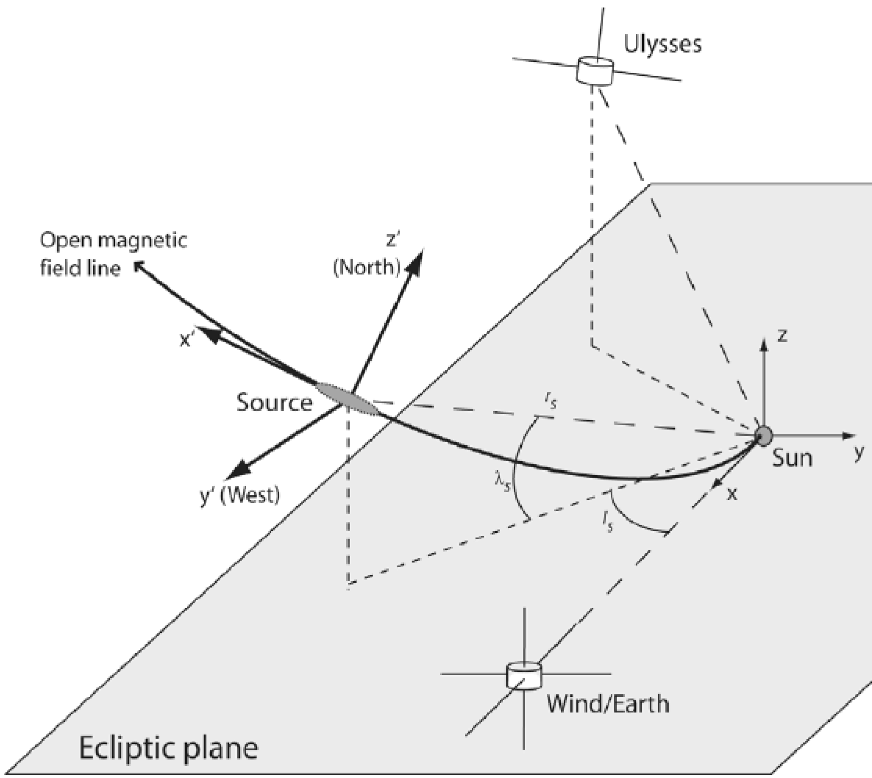


Bougeret et al. (1998)

Type III radio bursts are produced by beams of energetic electrons ejected from the Sun traveling outward along open magnetic field lines through the corona and the interplanetary space. Along their path they generate, at each level, Langmuir waves at the local plasma frequency:

$$f_p\,(kHz) \;=\; (2\pi)^{-1}\sqrt{ne^2/m\varepsilon_0} \approx 8.98\sqrt{n_e}$$

3. Spectral analysis of Type III radio bursts

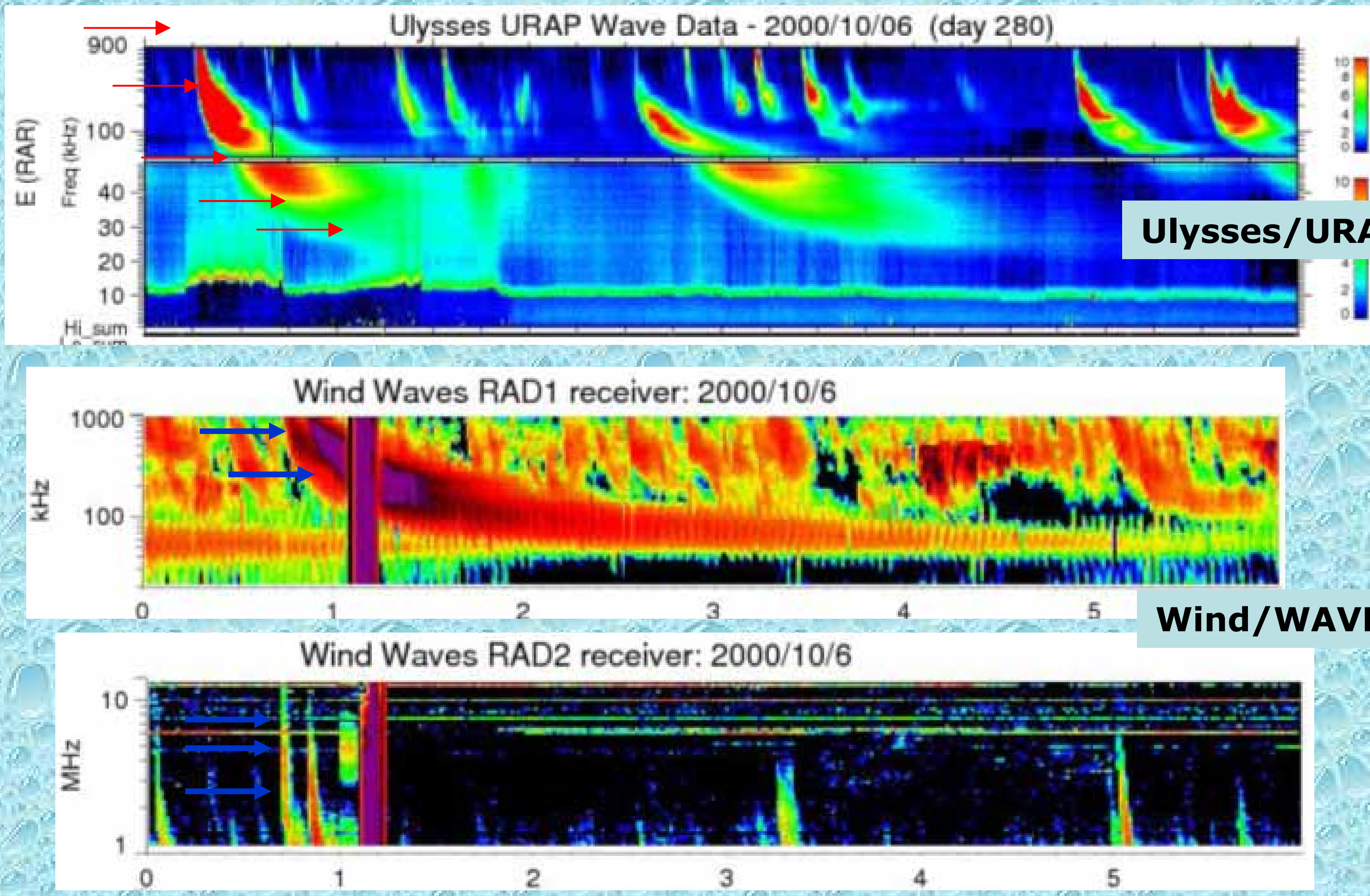


Spacecraft coordinates

Heliographic location of Spacecraft				
Date	Spacecraft	r(AU)	Latitude	Longitude
Oct., 06th, 2000 @ 01:00	Ulysses	2.6	-75°	185°
	Wind	1.0	+7°	280°
	Cassini	4.4	0°	65°
Oct., 10th, 2000 @ 15:30	Ulysses	2.5	-78°	190°
	Wind	1.0	+4°	240°
	Cassini	4.6	0°	65°
Nov., 19th, 2000 @ 08:00	Ulysses	2.3	-80°	210°
	Wind	1.0	+1.0	65°
Nov., 20th, 2000 @ 00:30	Ulysses	2.3	-80°	210°
	Wind	1.0	+1.0	55°
	Cassini	4.8	0°	65°

Solar Type III radio bursts in the outer Corona

3. Spectral analysis of Type III radio bursts



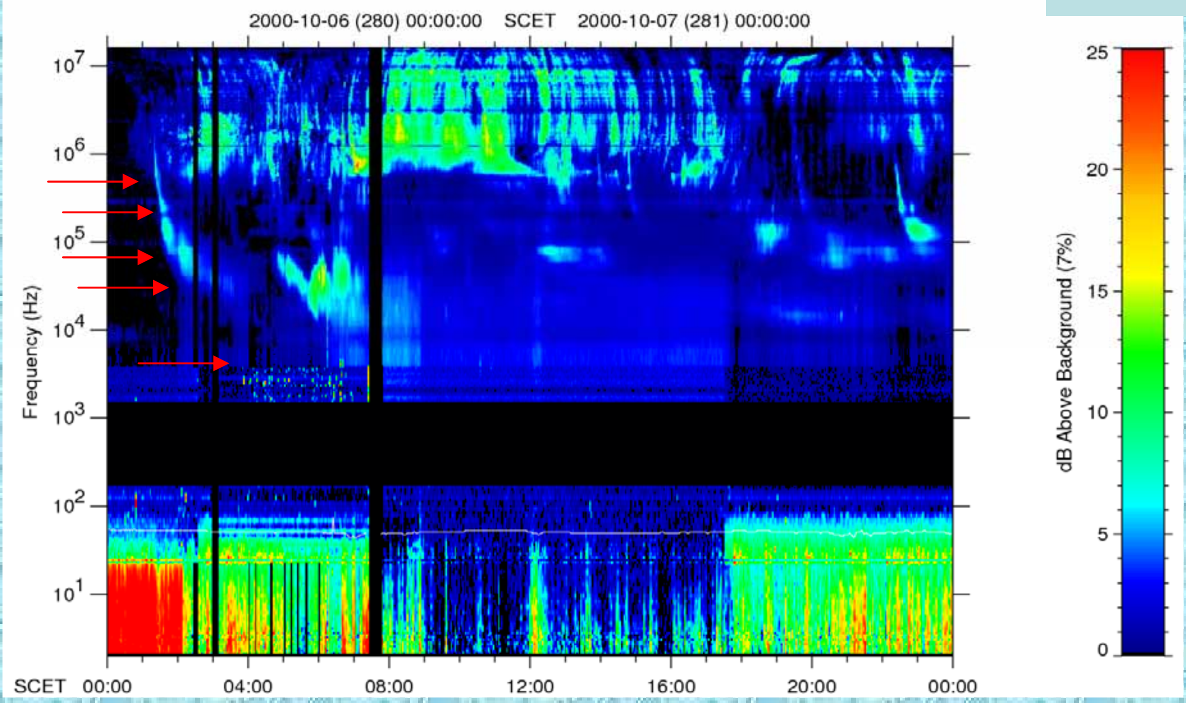
Ulysses/URAP experiment

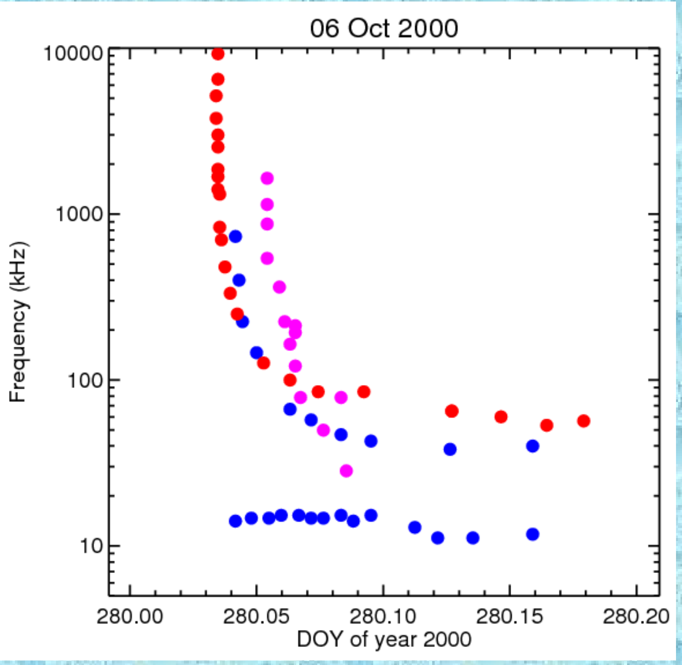
Wind/WAVES experiment

Solar Type III radio bursts in the outer Corona

3. Spectral analysis of Type III radio bursts

Cassini/RPWS experiment





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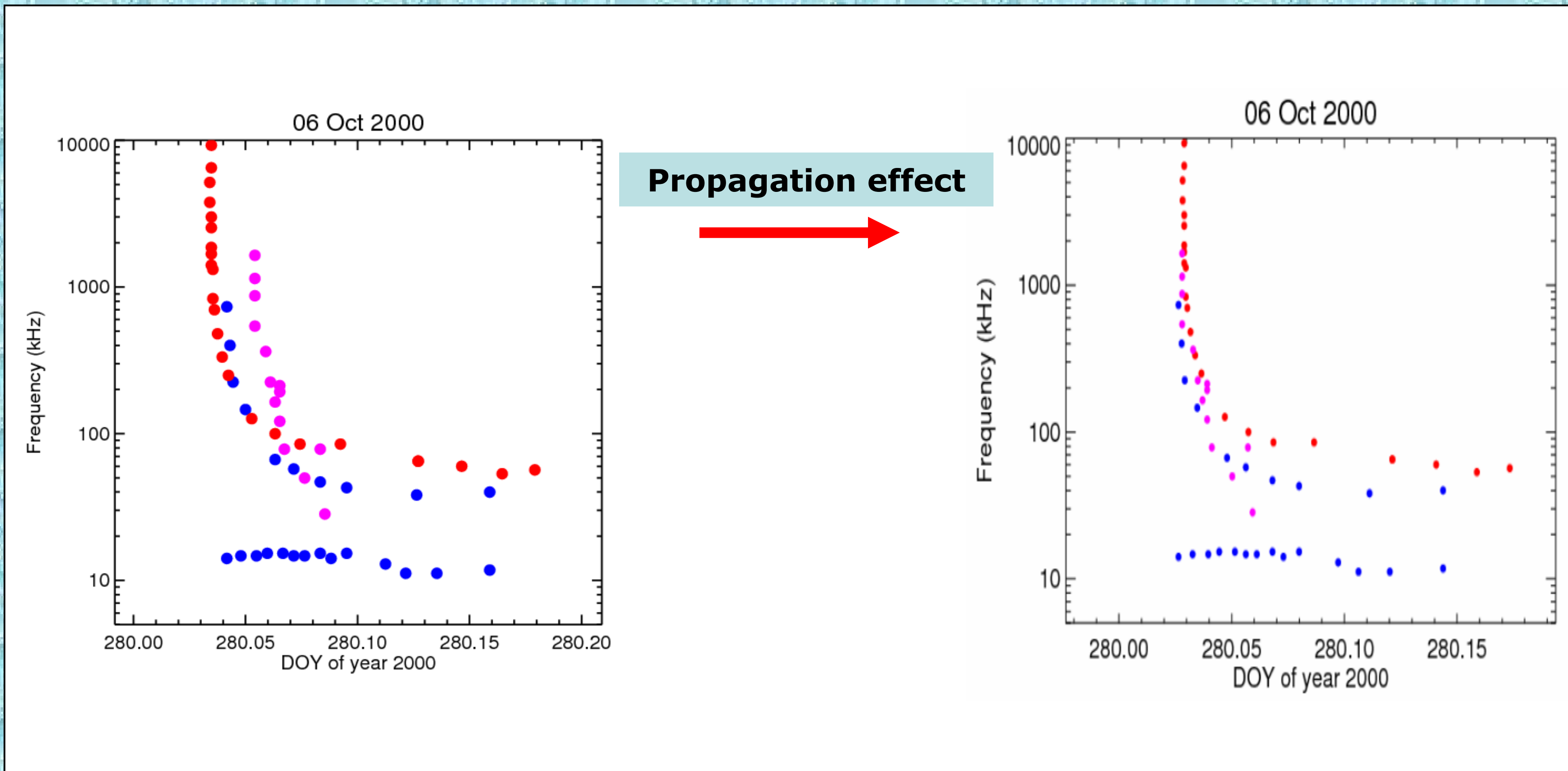
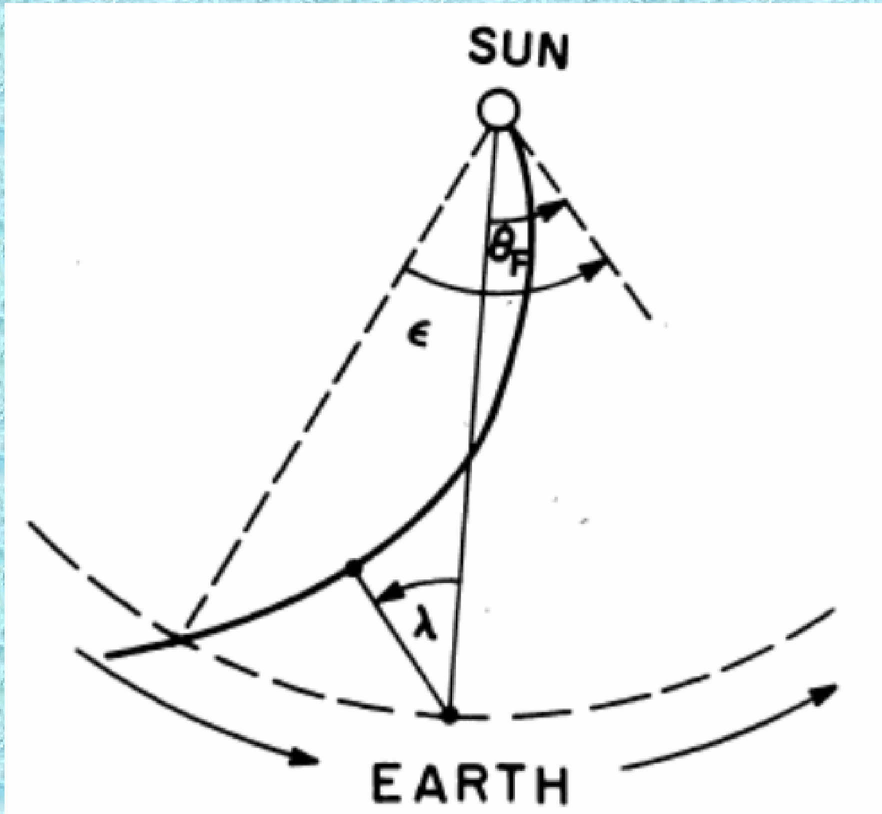


4. Remote sensing of the interplanetary medium

Model geometry of the type III burst exciter trajectory viewed from the north (Alvarez et al, 1975).



$$\theta(r) = \theta_F - \frac{r\Omega}{V}$$

The shape and location of the spiral are determined by the velocity of the solar wind, V, which is assumed to be constant, and by the heliographic longitude θ_F.

4. Remote sensing of the interplanetary medium

- **Model of electron density (Bougeret et al., 1983)**

$$N_e(r) = 6.14 r^{-2.10}\ \mathrm{cm}^{-3}$$

- **Relationship between plasma frequency and electron density**

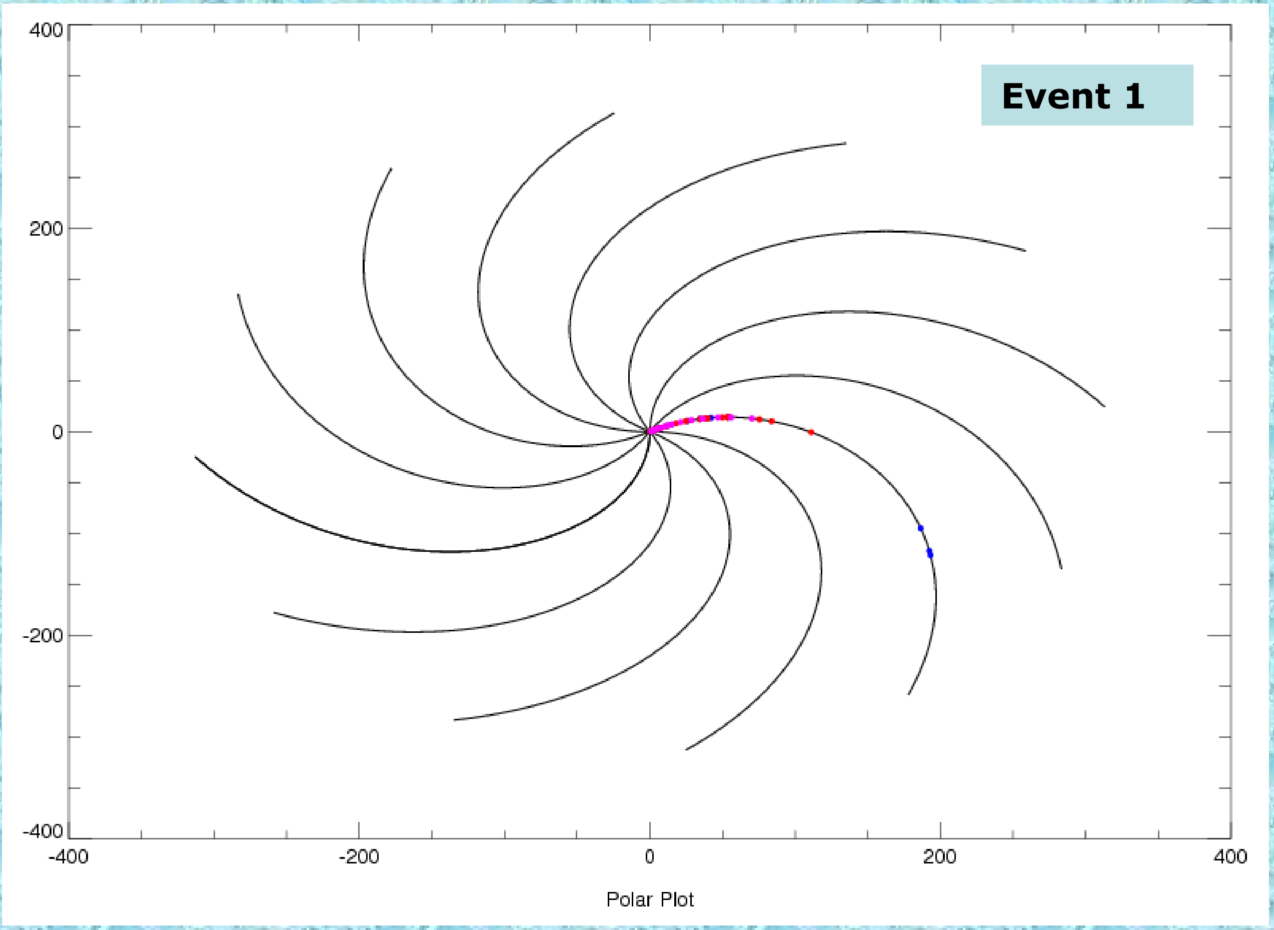
$$f_p\,(kHz) \;=\; (2\pi)^{-1}\sqrt{ne^2/m\varepsilon_0} \approx 8.98\sqrt{n_e}$$

- **Relationship between observed frequency and distance r**

$$f_{\mathrm{pe}}(r) = 22.5 r^{-1.05}\ \mathrm{kHz}$$

$$\theta(r) = \theta_F - \frac{r\Omega}{V}$$

4. Remote sensing of the interplanetary medium



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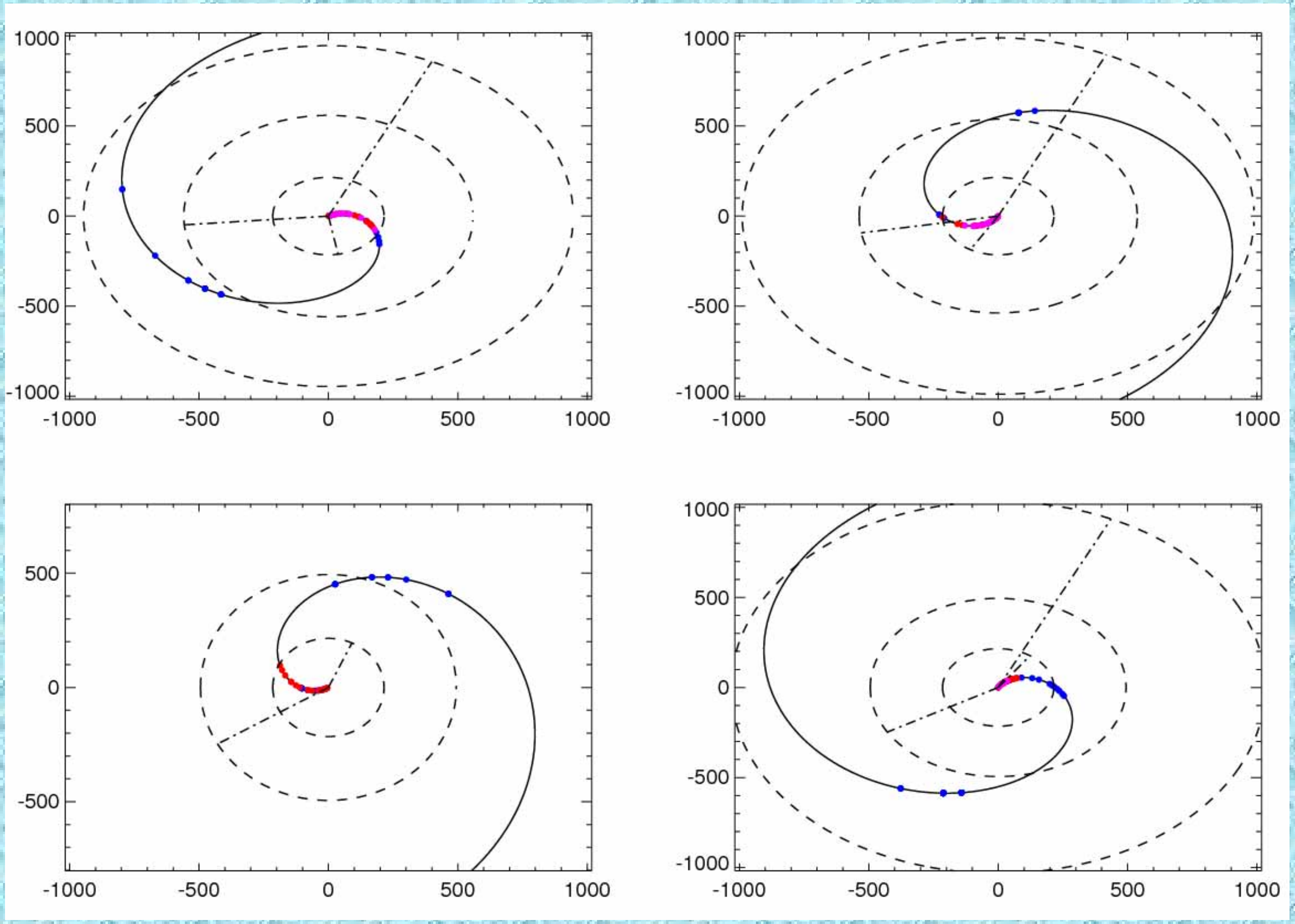
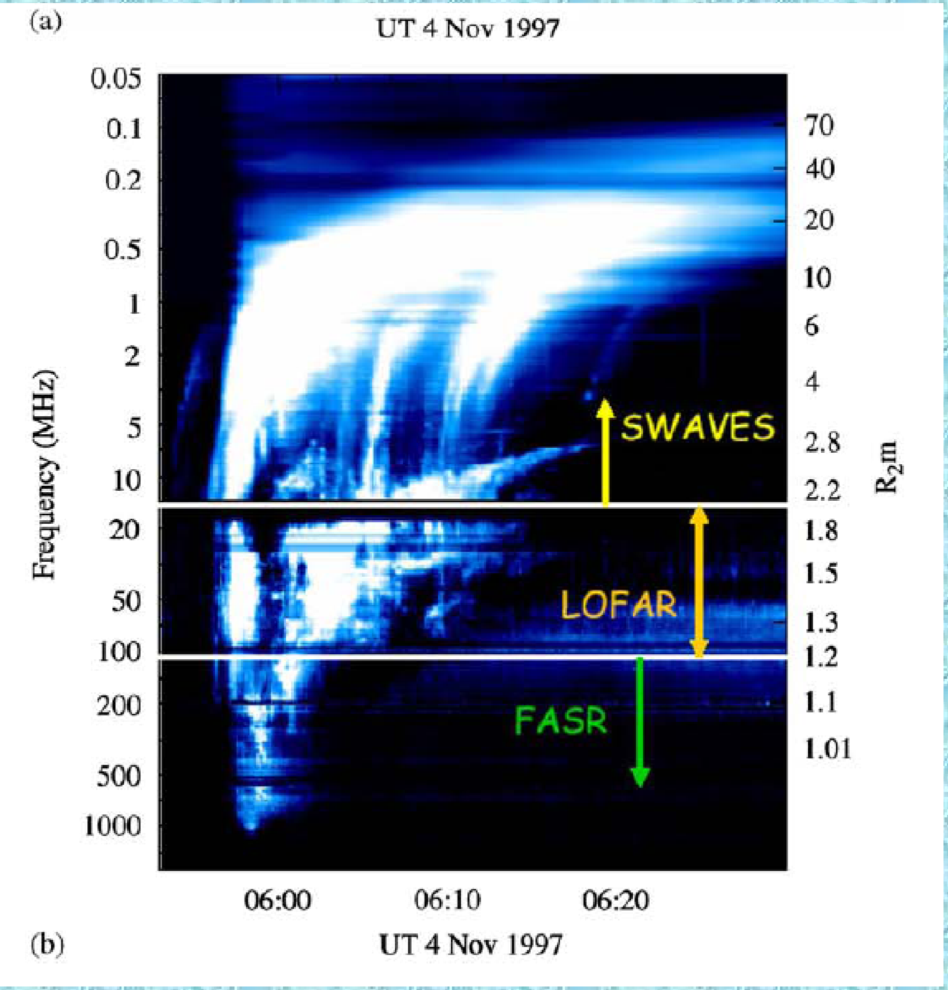


5. Outlook

1. Future Solar Mission: Solar Orbiter and Solar Probe



5. Outlook

2. Ground-based observations: LOFAR

The LOw Frequency ARray (LOFAR): Antenna station array configuration. (Danielsson, 2007)