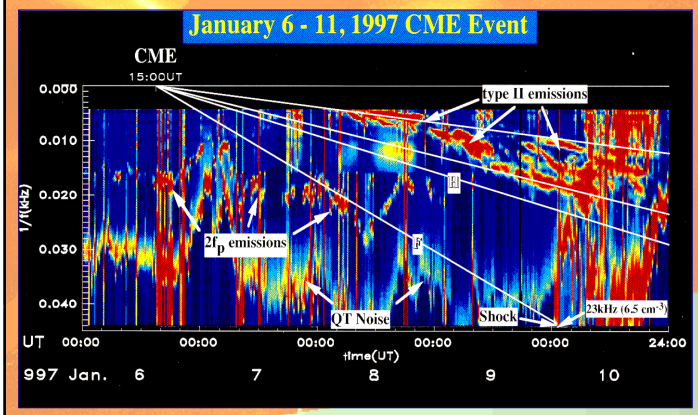
Space Instrumentation (7)

Lectures for the IMPRS June 23 to June 27 at MPAe Lindau
Compiled/organized by Rainer Schwenn, MPAe,
supported by Drs. Curdt, Gandorfer, Hilchenbach, Hoekzema, Richter, Schühle

Wed, 25.6., 15:00 Radioastronomy from space (RS)



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The Nobeyama (Japan) radioheliograph

Large antenna arrays are needed for imaging objects on the sky in radiofrequencies, also for imaging the sun in radiofrequencies

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Radiobursts from the Sun

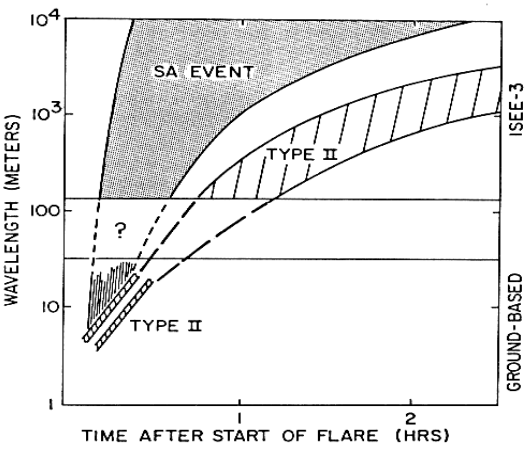
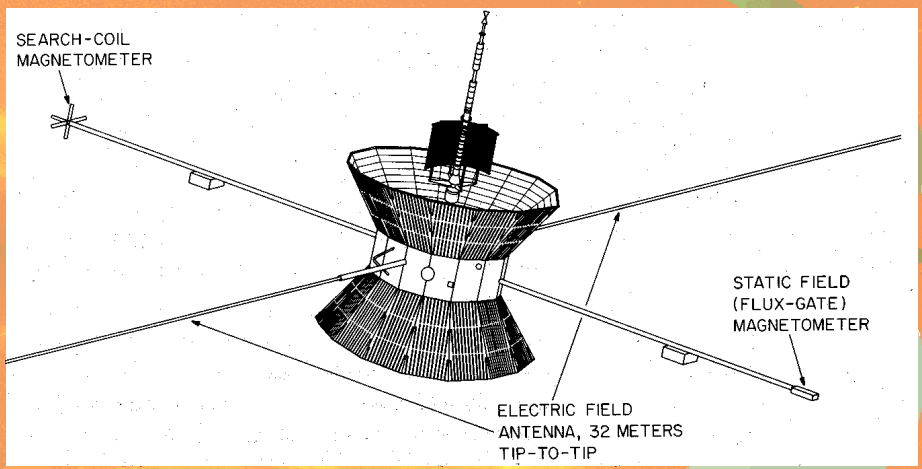
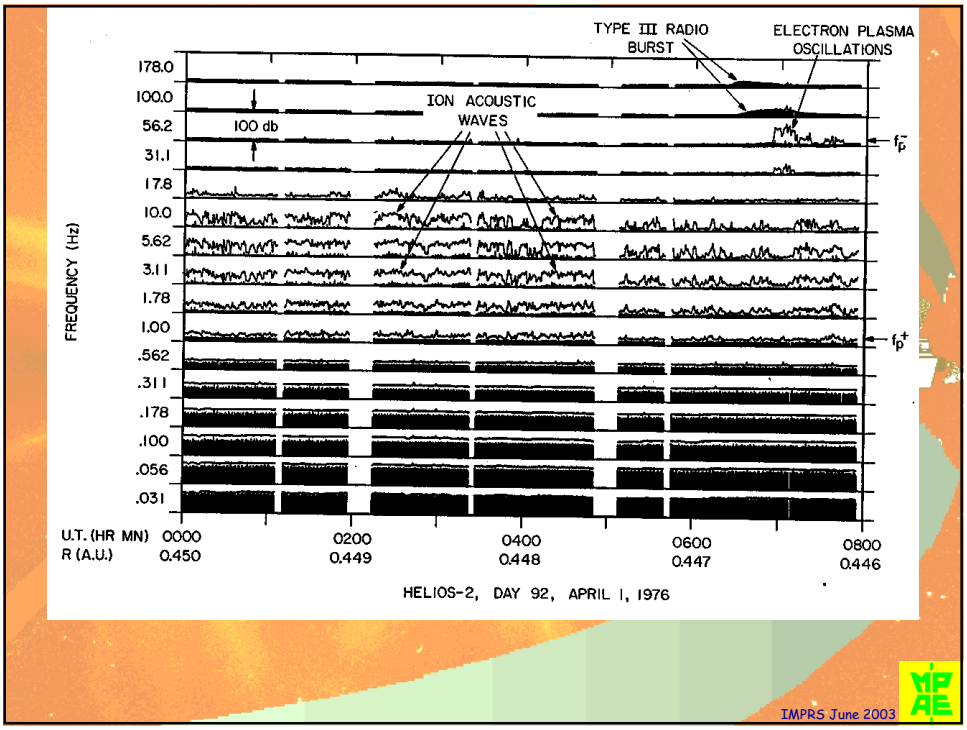


Fig. 3 A schematic representation of the relationship between meter wavelength type II activity with herringbone structure and the activity observed at kilometer wavelengths. Only the long wavelength elements of the herringbone structure are shown. Note the absence of such structure on the type II burst at kilometer wavelengths.

The Helios solar probes



Most spacecraft carry electric dipole antennae



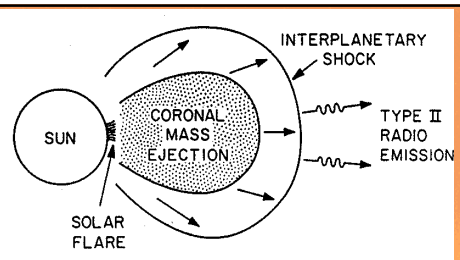


Fig. 3. Type II solar radio bursts are produced by interplanetary shocks driven by coronal mass ejections.

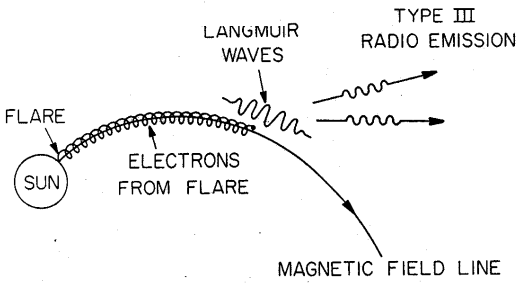
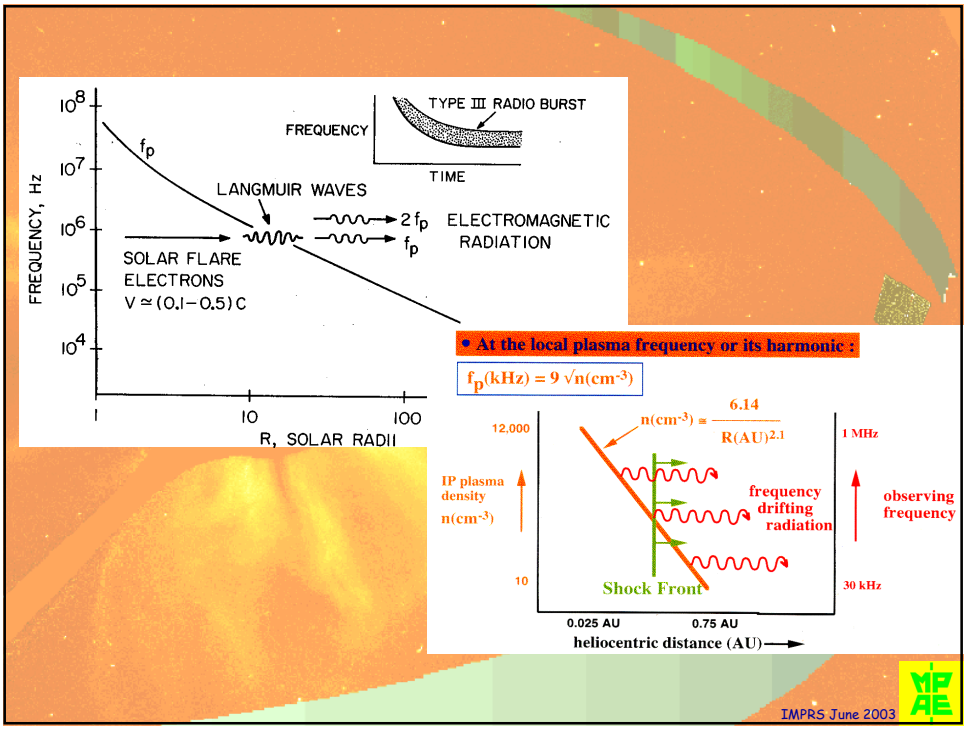


Fig. 1. Type III radio bursts are produced by energetic electrons from solar flares. The electrons stream outward from the Sun along the solar wind magnetic field lines and produce electrostatic oscillations called Langmuir waves. The Langmuir waves then mode convert to electromagnetic radiation via nonlinear wave-wave interactions.


FREQUENCY, Hz
10^8
10^7
10^6
10^5
10^4
f_p
LANGMUIR WAVES
SOLAR FLARE ELECTRONS
V ≃ (0.1–0.5) C
2 f_p
f_p
ELECTROMAGNETIC RADIATION
FREQUENCY
TIME
TYPE III RADIO BURST
1
10
100
R, SOLAR RADII
• At the local plasma frequency or its harmonic :
$f_p(kHz) = 9\sqrt{n(cm^{-3})}$
$n(cm^{-3}) \cong \frac{6.14}{R(AU)^{2.1}}$
12,000
10
IP plasma density $n(cm^{-3})$
1 MHz
30 kHz
observing frequency
frequency drifting radiation
Shock Front
0.025 AU
0.75 AU
heliocentric distance (AU)
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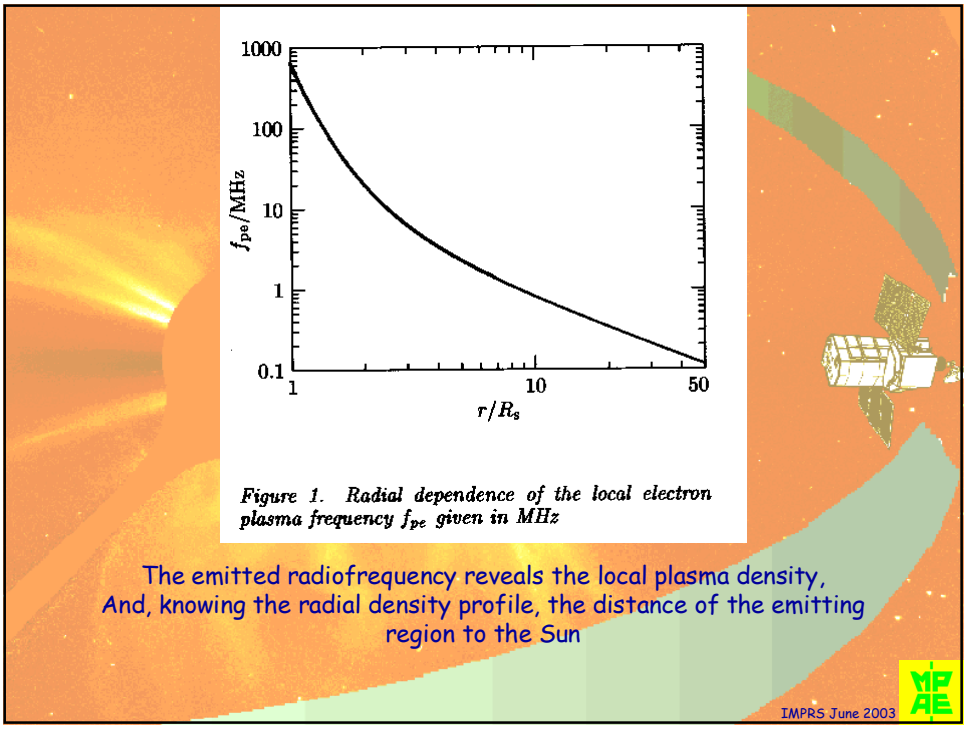
1000
100
10
1
0.1
f_{pe}/MHz
1
10
50
r/R_s
Figure 1. Radial dependence of the local electron plasma frequency f_{pe} given in MHz
The emitted radiofrequency reveals the local plasma density,
And, knowing the radial density profile, the distance of the emitting region to the Sun
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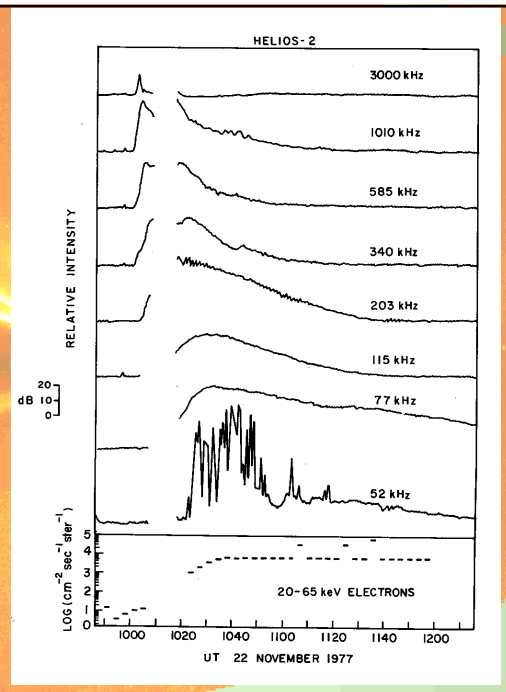

A classcical Type III radio burst: energetic electrons progressing out from the Sun

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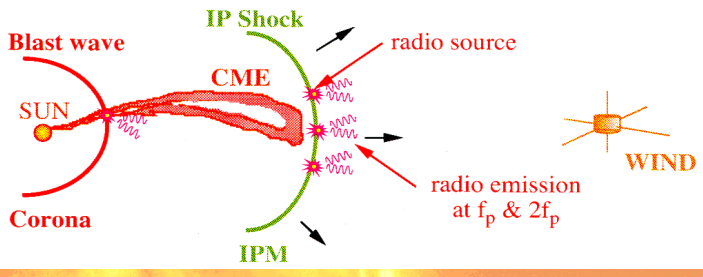
Type II Radio Emissions are generated

- By electrons accelerated at blast wave shocks (corona) or at IP shocks driven by CMEs (IPM)



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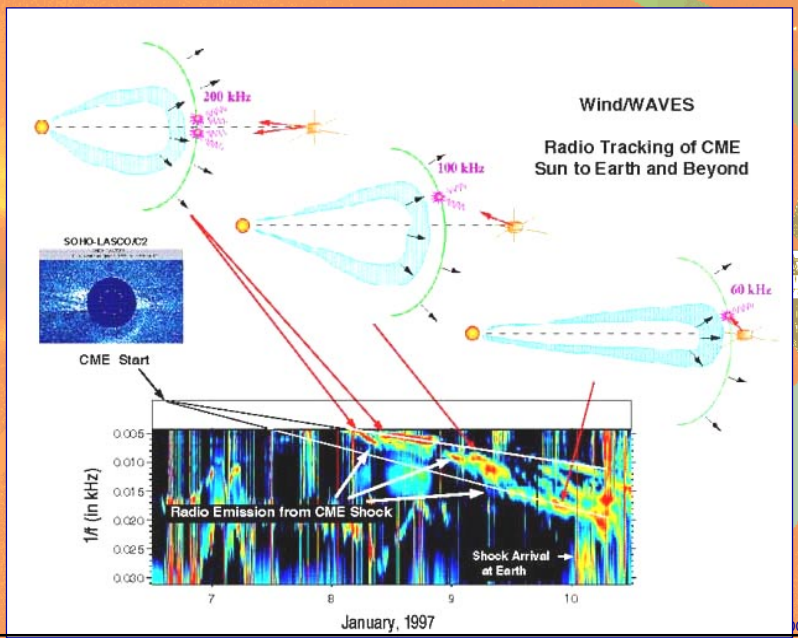
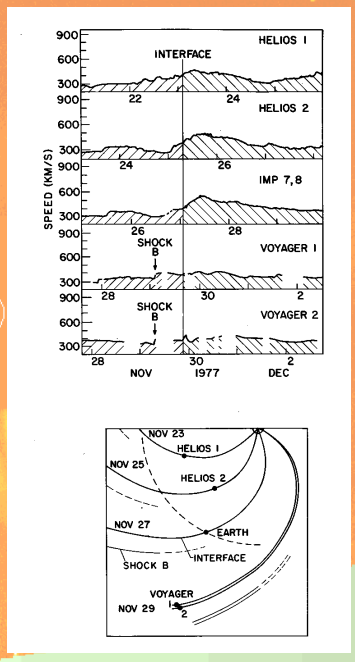
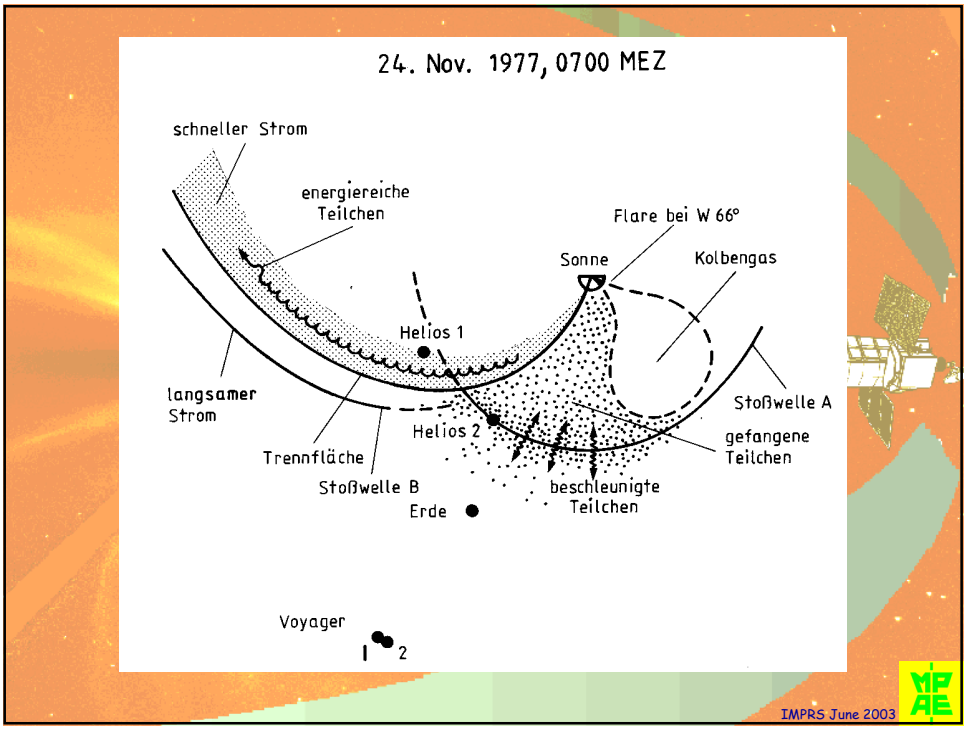
Radio signals („bursts") as remote sensors







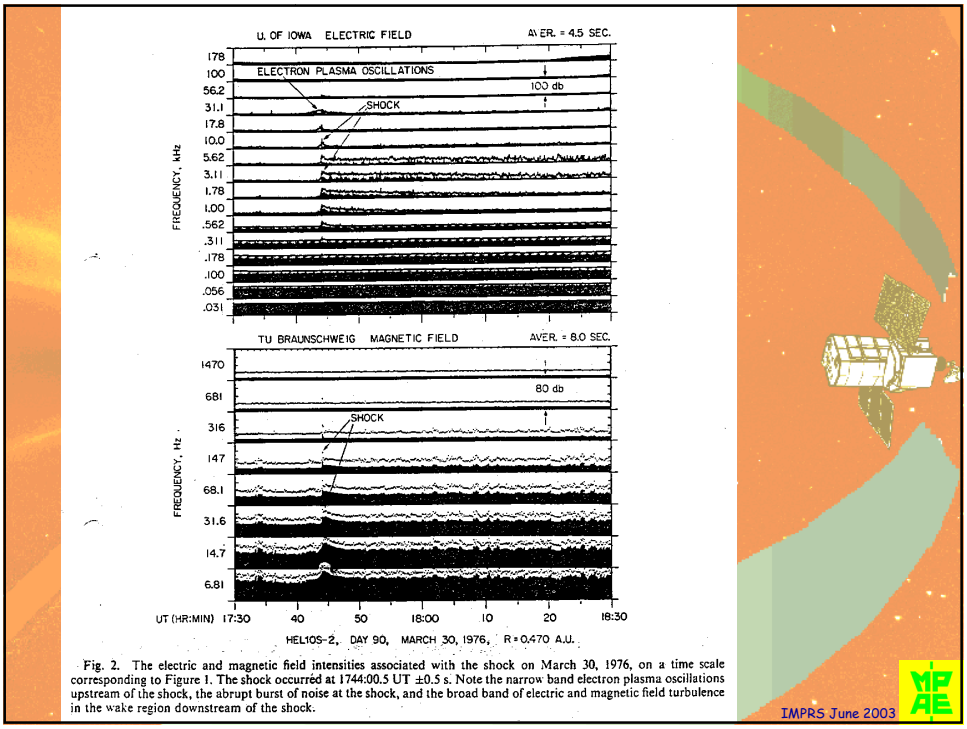
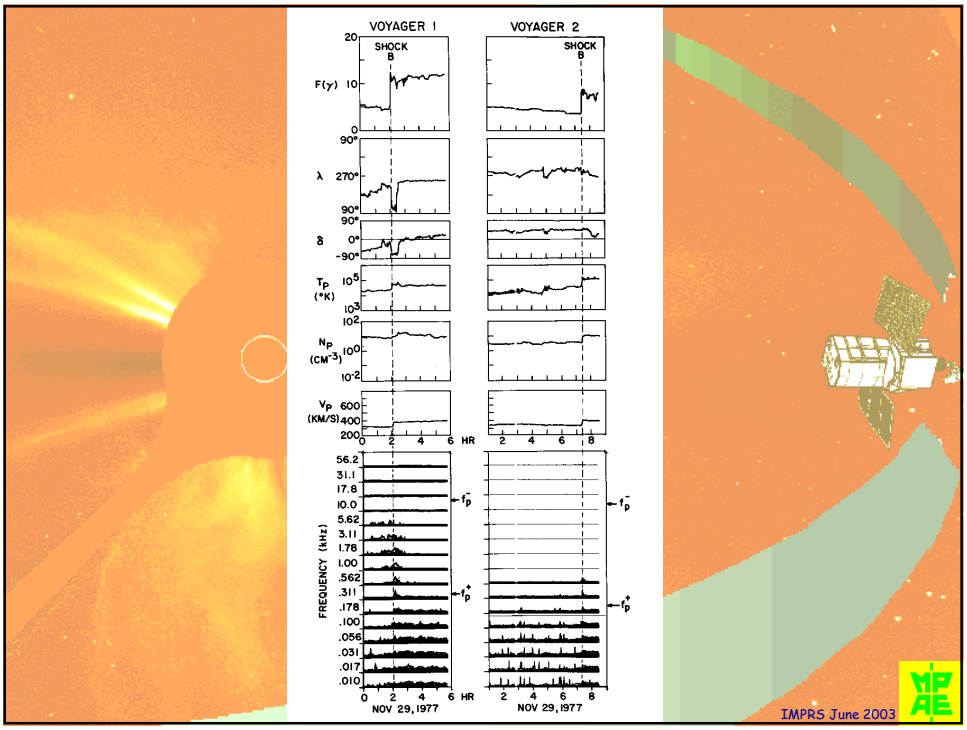


Fig. 2. The electric and magnetic field intensities associated with the shock on March 30, 1976, on a time scale corresponding to Figure 1. The shock occurred at 1744:00.5 UT ±0.5 s. Note the narrow band electron plasma oscillations upstream of the shock, the abrupt burst of noise at the shock, and the broad band of electric and magnetic field turbulence in the wake region downstream of the shock.


VOYAGER 1
VOYAGER 2
SHOCK
B
F(γ)
λ
δ
T_p (°K)
N_p (CM^{-3})
V_p (KM/S)
FREQUENCY (kHz)
f_p^-
f_p^+
NOV 29, 1977
NOV 29, 1977
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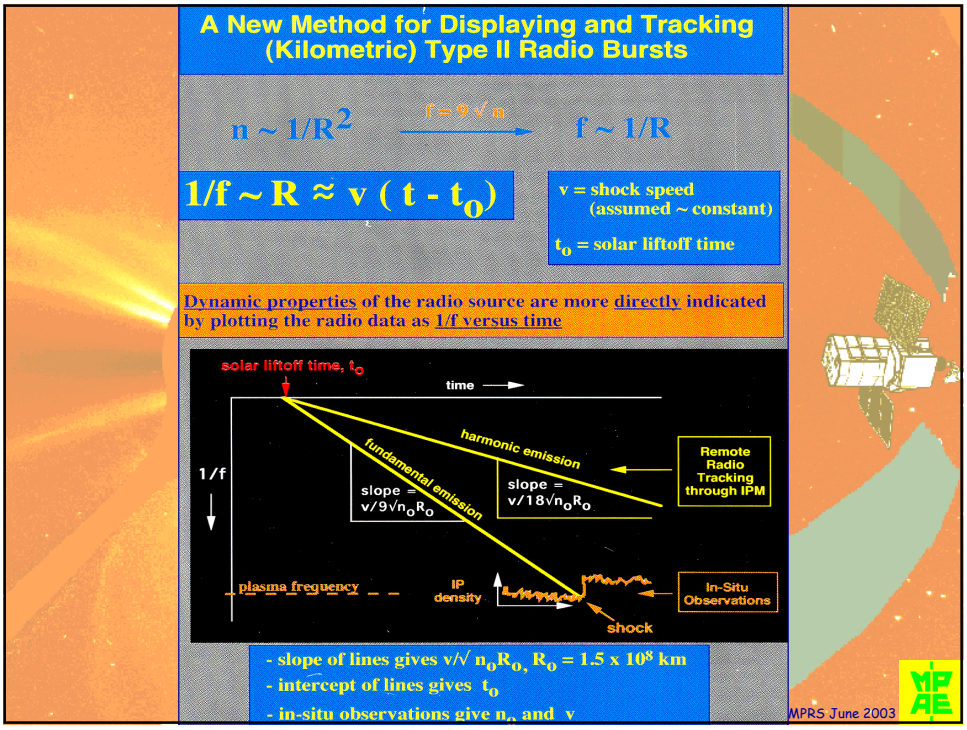
A New Method for Displaying and Tracking (Kilometric) Type II Radio Bursts
$n \sim 1/R^2$
$f = 9\sqrt{n}$
$f \sim 1/R$
$1/f \sim R \approx v\,(t - t_o)$
v = shock speed (assumed ~ constant)
t_o = solar liftoff time
Dynamic properties of the radio source are more directly indicated by plotting the radio data as 1/f versus time
solar liftoff time, t_o
time
1/f
harmonic emission
fundamental emission
slope = $v/9\sqrt{n_o}R_o$
slope = $v/18\sqrt{n_o}R_o$
Remote Radio Tracking through IPM
plasma frequency
IP density
In-Situ Observations
shock
- slope of lines gives $v/\sqrt{n_o}R_o$, $R_o = 1.5 \times 10^8$ km
- intercept of lines gives t_o
- in-situ observations give n_e and v
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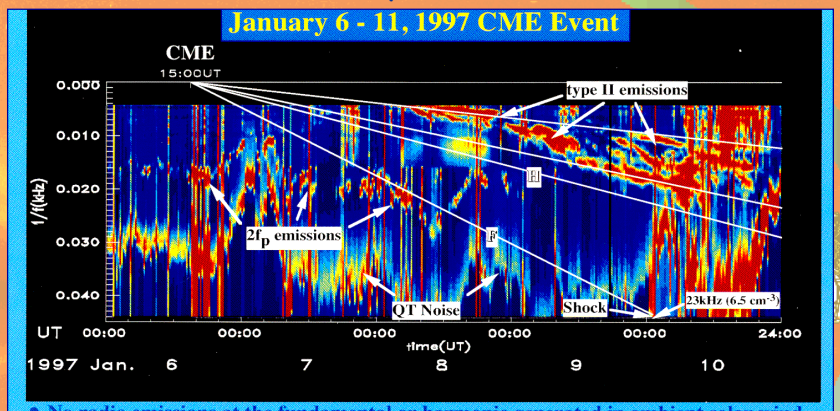
„Solar Cosmic Rays" cause radio bursts



- No radio emissions at the fundamental or harmonic generated in ambient solar wind upstream of shock
- Intense narrow-band radio emissions organized between straight lines of slope = 2 & 6 x 10^{-8} kHz^{-1} s^{-1} ⇒ radio emissions from high density regions of the IPM
- In-situ measurements of shock at ~01:00 UT on January 10 imply: n_o = 6.5 cm^{-3} (upstream density), v = 500 km/s
- Radio emissions observed from ~0.5 AU to 1.2 AU

http://lep694.gsfc.nasa.gov/waves/

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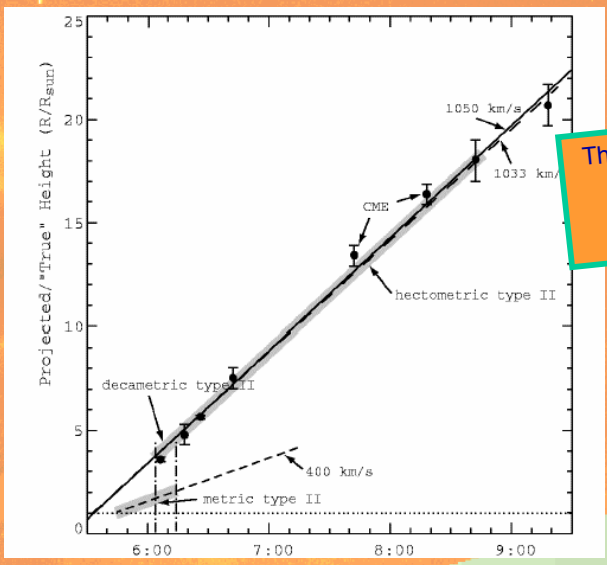
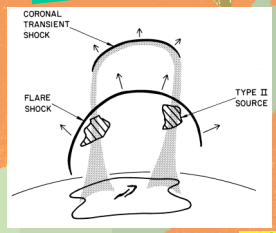
Radio signals („bursts") as remote sensors



The CME shock runs ahead of and simultaneously to the metric type II shock. They cannot be the same!

Maybe they can!



Height-time diagram of the May 3rd, 1999, CME, as determined from **LASCO**, and from drift rates of type II radio emission.

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Where the heliosphere ends

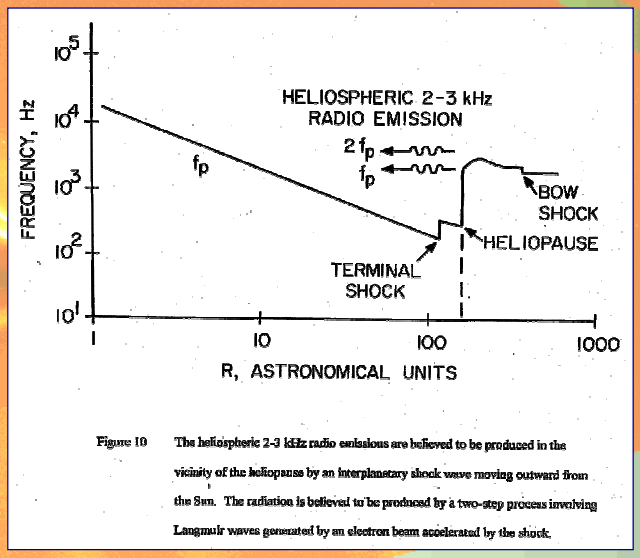
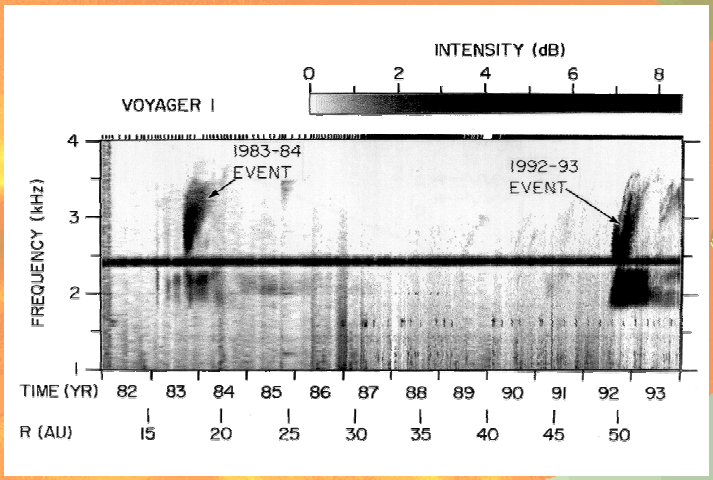


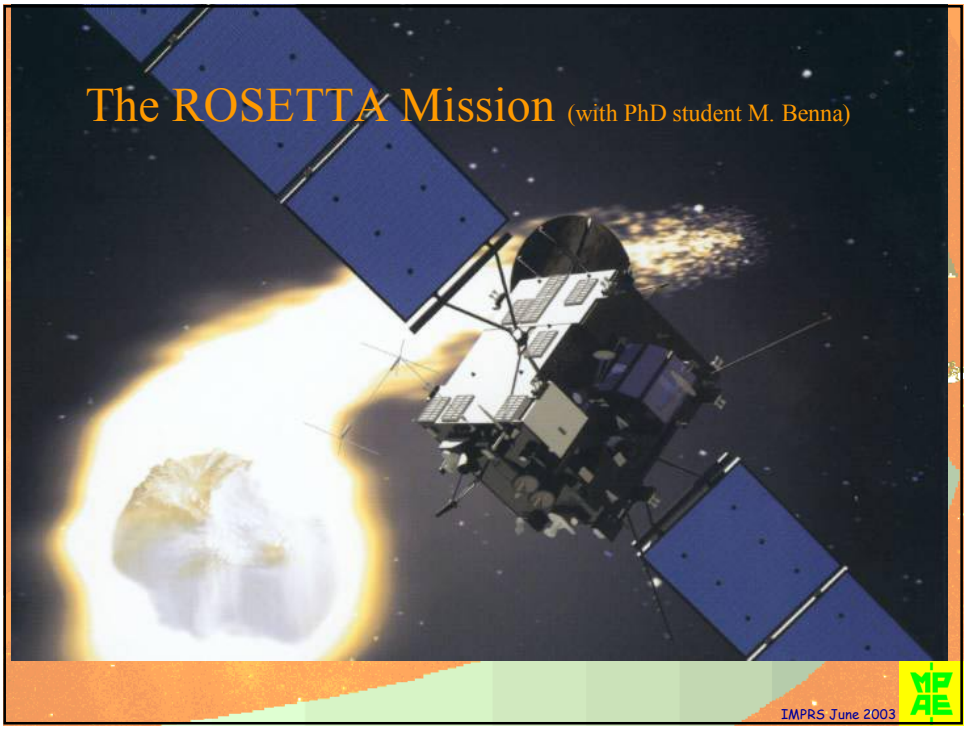
Figure 10 The heliospheric 2-3 kHz radio emissions are believed to be produced in the vicinity of the heliopause by an interplanetary shock wave moving outward from the Sun. The radiation is believed to be produced by a two-step process involving Langmuir waves generated by an electron beam accelerated by the shock.

Radio signals from the heliopause!

Where the heliosphere ends



Radio signals from the heliopause!


The ROSETTA Mission (with PhD student M. Benna)
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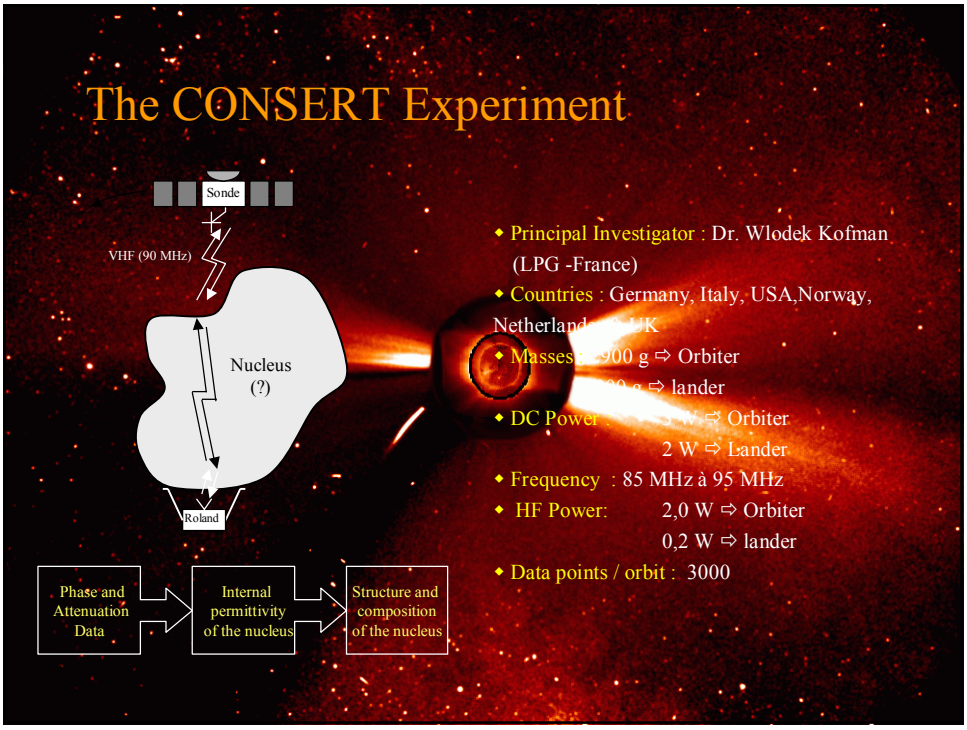
The CONSERT Experiment
Sonde
VHF (90 MHz)
Nucleus
(?)
Roland
Phase and Attenuation Data
Internal permittivity of the nucleus
Structure and composition of the nucleus
Principal Investigator : Dr. Wlodek Kofman (LPG -France)
Countries : Germany, Italy, USA,Norway, Netherland UK
Masses 900 g ⇨ Orbiter
⇨ lander
DC Power W ⇨ Orbiter
2 W ⇨ Lander
Frequency : 85 MHz à 95 MHz
HF Power: 2,0 W ⇨ Orbiter
0,2 W ⇨ lander
Data points / orbit : 3000

Computation of dielectric properties ...

Porosity Distribution

Maxwell-Granett Mixing Laws
S[illegible] & Kong*
3 compone[illegible]
silicates, water ice & voids

Density distribution

Dielectric permittivity distribution (at 100 MHz)

Dielectric Absorption (at 100 MHz)

* Shivola A. & Kong J., 1988, IEEE Trans. Geo. & Rem. Sens., 26, p.420-429.