

Radio and Plasma Waves instrument for Solar Orbiter

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INSTITUTE OF ATMOSPHERIC PHYSICS
ASCR

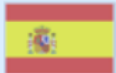











Akademie věd
České republiky

Strategie AV21
Špičkový výzkum ve veřejném zájmu



Payload

In-Situ Instruments				
EPD	Energetic Particle Detector	J. Rodríguez-Pacheco		Composition, timing and distribution functions of energetic particles
MAG	Magnetometer	T. Horbury		High-precision measurements of the heliospheric magnetic field
RPW	Radio & Plasma Waves	M. Maksimovic		Electromagnetic and electrostatic waves, magnetic and electric fields at high time resolution
SWA	Solar Wind Analyser	C. Owen		Sampling protons, electrons and heavy ions in the solar wind
Remote-Sensing Instruments				
EUI	Extreme Ultraviolet Imager	P. Rochus		High-resolution and full-disk EUV imaging of the on-disk corona
METIS	Multi-Element Telescope for Imaging and Spectroscopy	E. Antonucci		Imaging and spectroscopy of the off-disk corona
PHI	Polarimetric & Helioseismic Imager	S. Solanki		High-resolution vector magnetic field, line-of-sight velocity in photosphere, visible imaging
SoloHI	Heliospheric Imager	R. Howard		Wide-field visible imaging of the solar off-disk corona
SPICE	Spectral Imaging of the Coronal Environment	European-led facility instrument		EUV spectroscopy of the solar disk and near-Sun corona
STIX	Spectrometer/Telescope for Imaging X-rays	S. Krucker		Imaging spectroscopy of solar X-ray emission

RPW: Radio and Plasma Waves

PI: Milan Maksimovic (Observatoire de Paris-Meudon)

Instrument for measurement of electromagnetic fields and radio waves in the solar wind.

Electric field

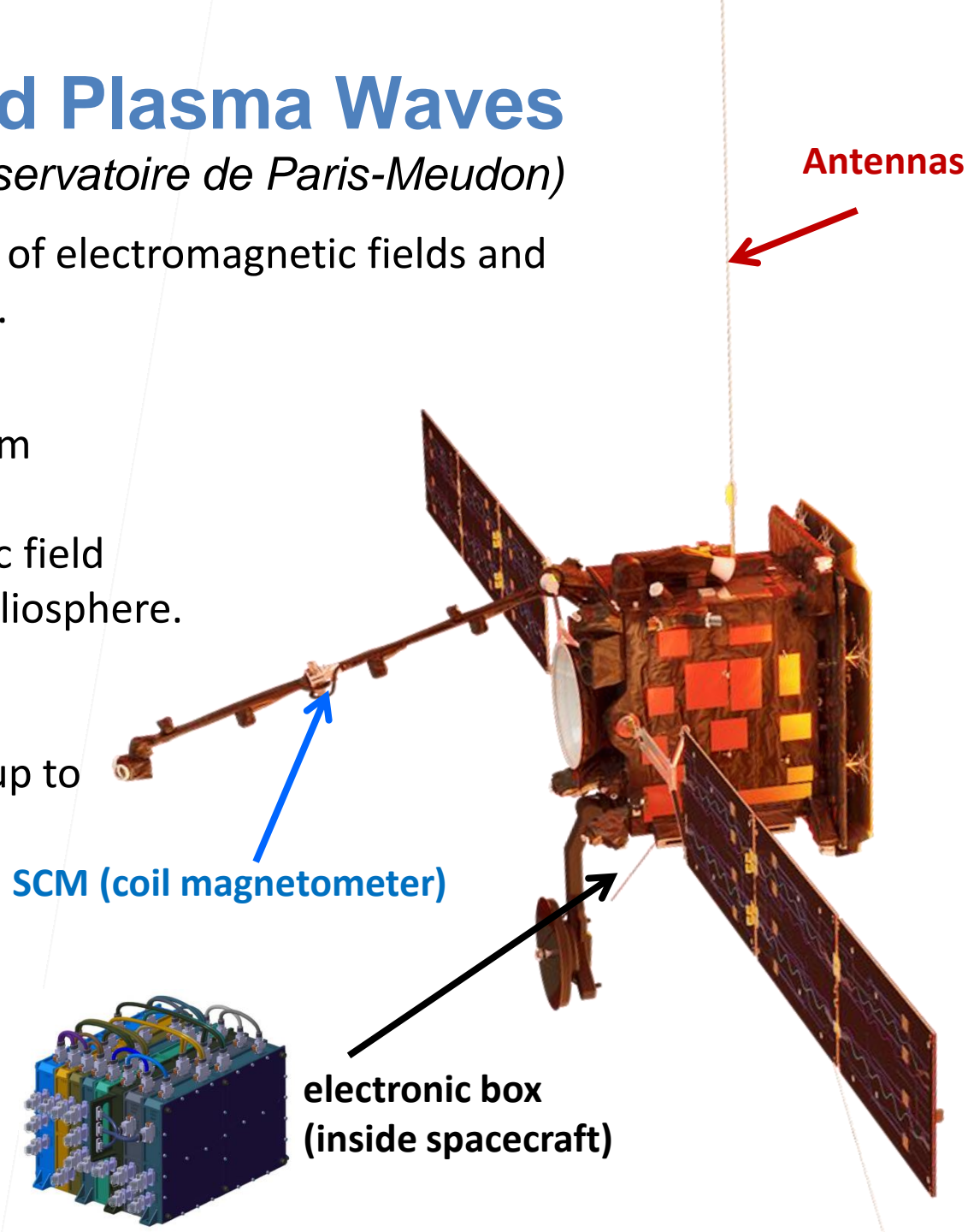
- 3 wire boom antennas 6.5m
- DC to 16 MHz
- First low frequency electric field measurements in inner heliosphere.

Magnetic field

- 0.1 Hz to 200 kHz
- Magnetic measurements up to plasma frequency

Electronics

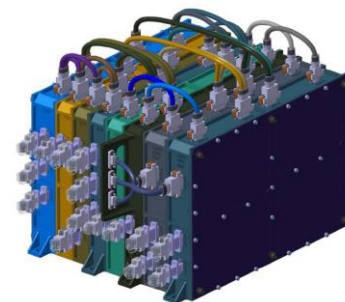
- Several (3) digital receivers with signal processing and on-board data analysis capability.



Solar Orbiter, Radio and Plasma Wave Instrument

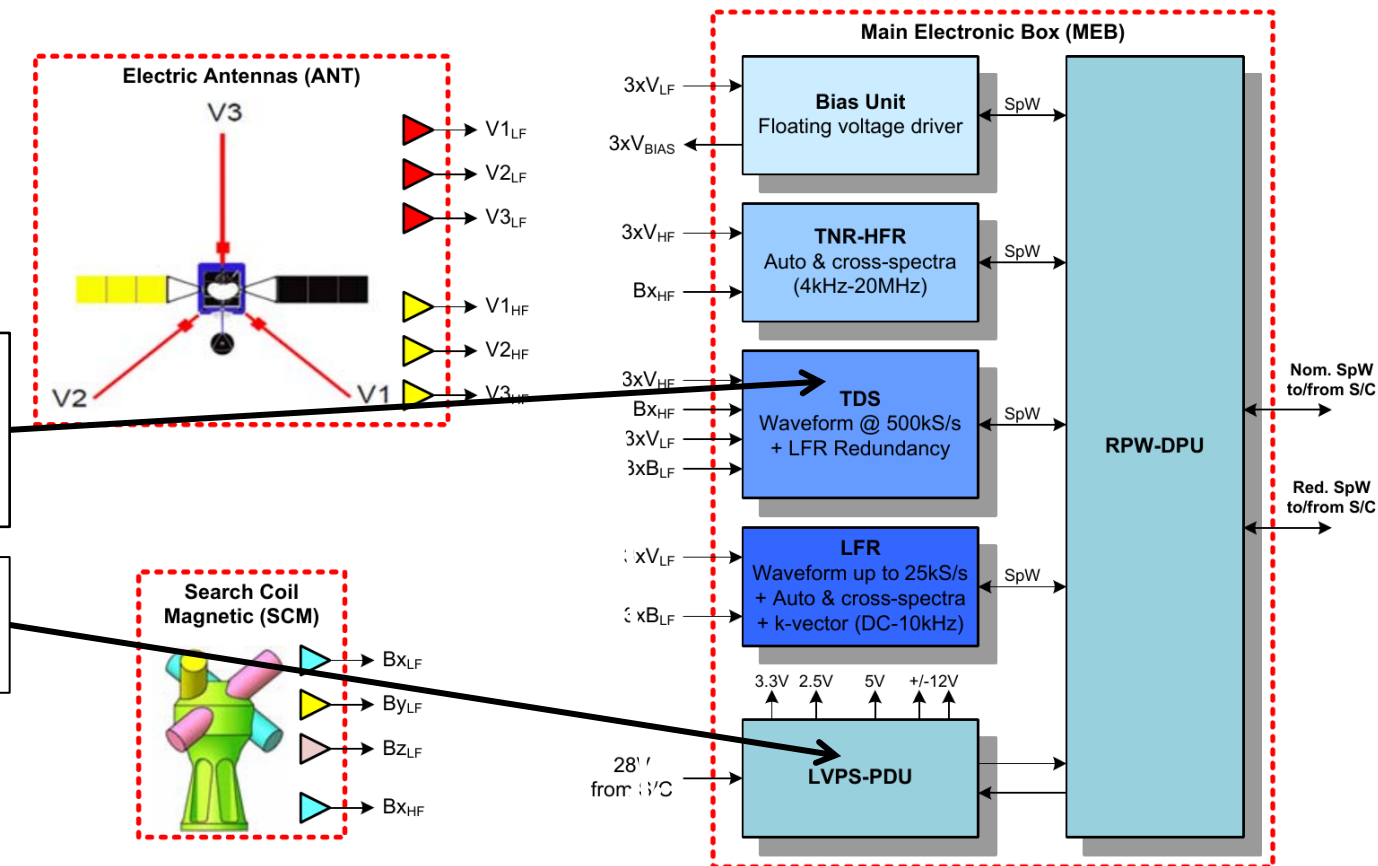
Consortium lead by LESIA / Paris Observatory, France

- Institutet för rymdfysik, Uppsala, **Sweden**
- Space Science Laboratory, Berkeley, **USA**
- Institut für Weltraumforschung, Graz, **Austria**
- CNRS (laboratories in Paris and Orléans), **France**
- Czech academy of Sciences (Institute of Atmospheric Physics & Astronomical Institute)



TDS wave analyzer:
*Institute of
Atmospheric Physics*

Power supply:
Astronomical institute

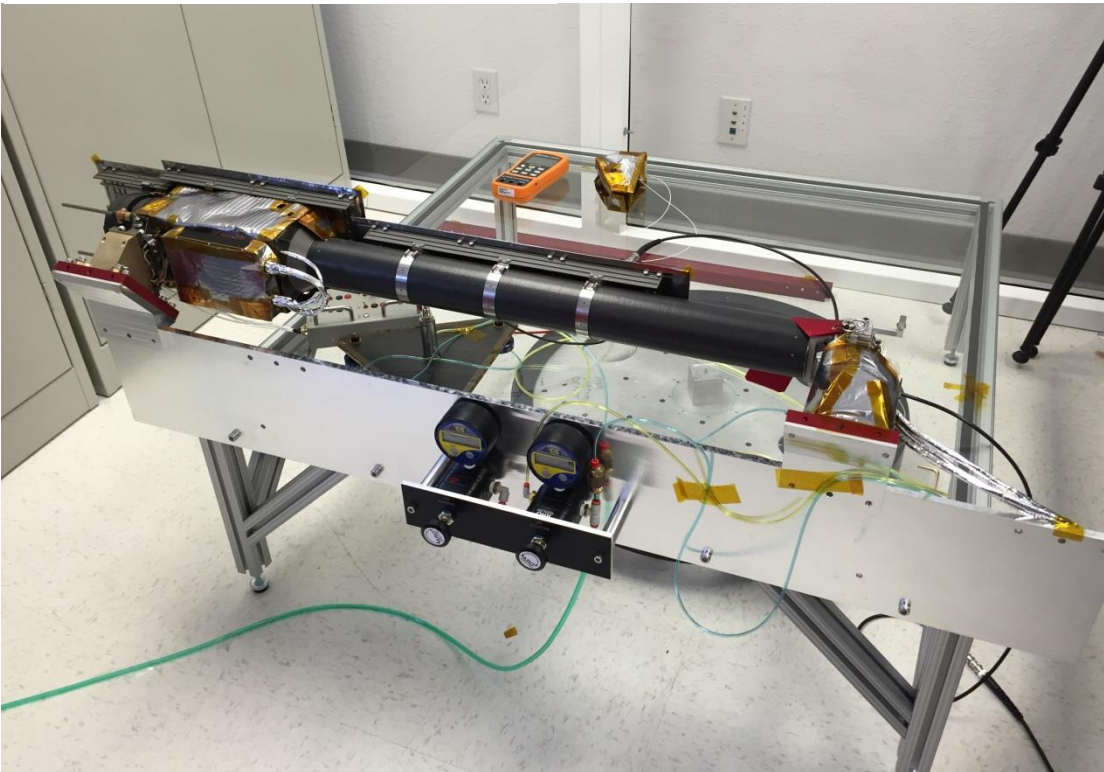


RPW sensors

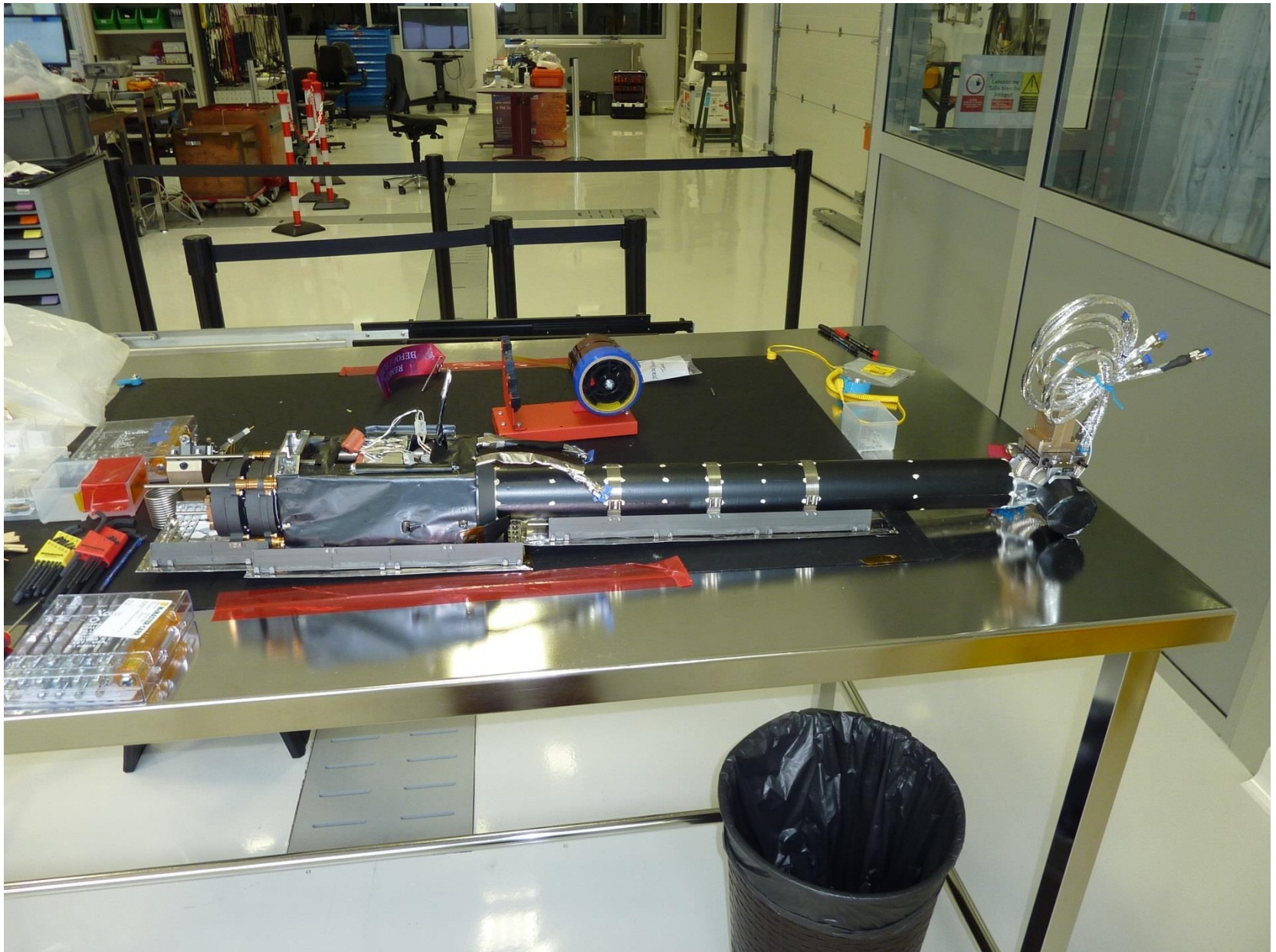


Search-coil
magnetometer
(SCM)

Electric antenna during
test at CNES:



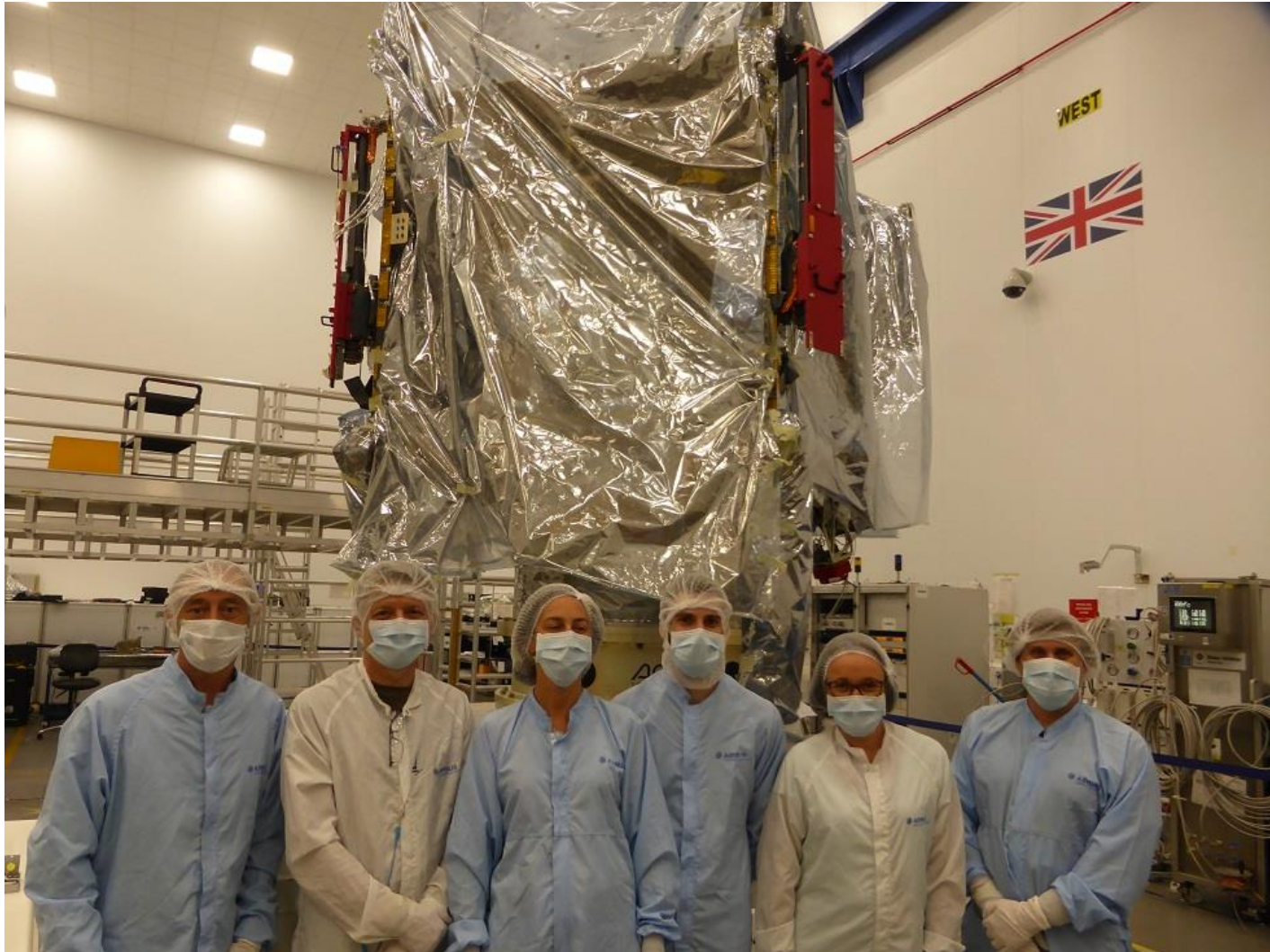
Antenna in a stowed state



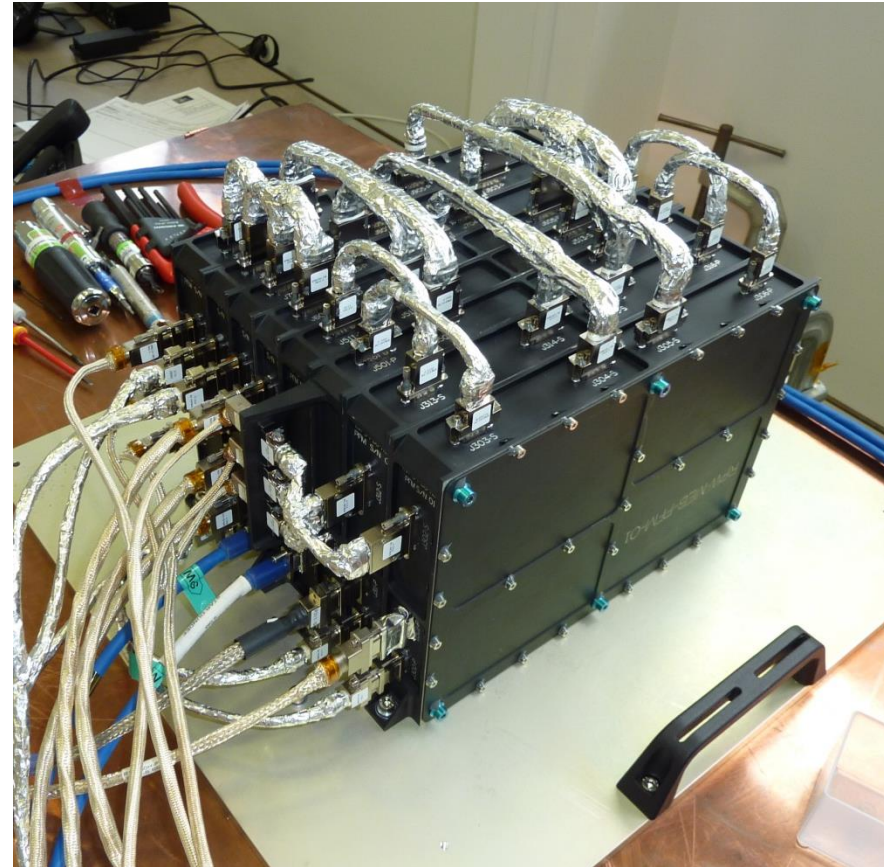
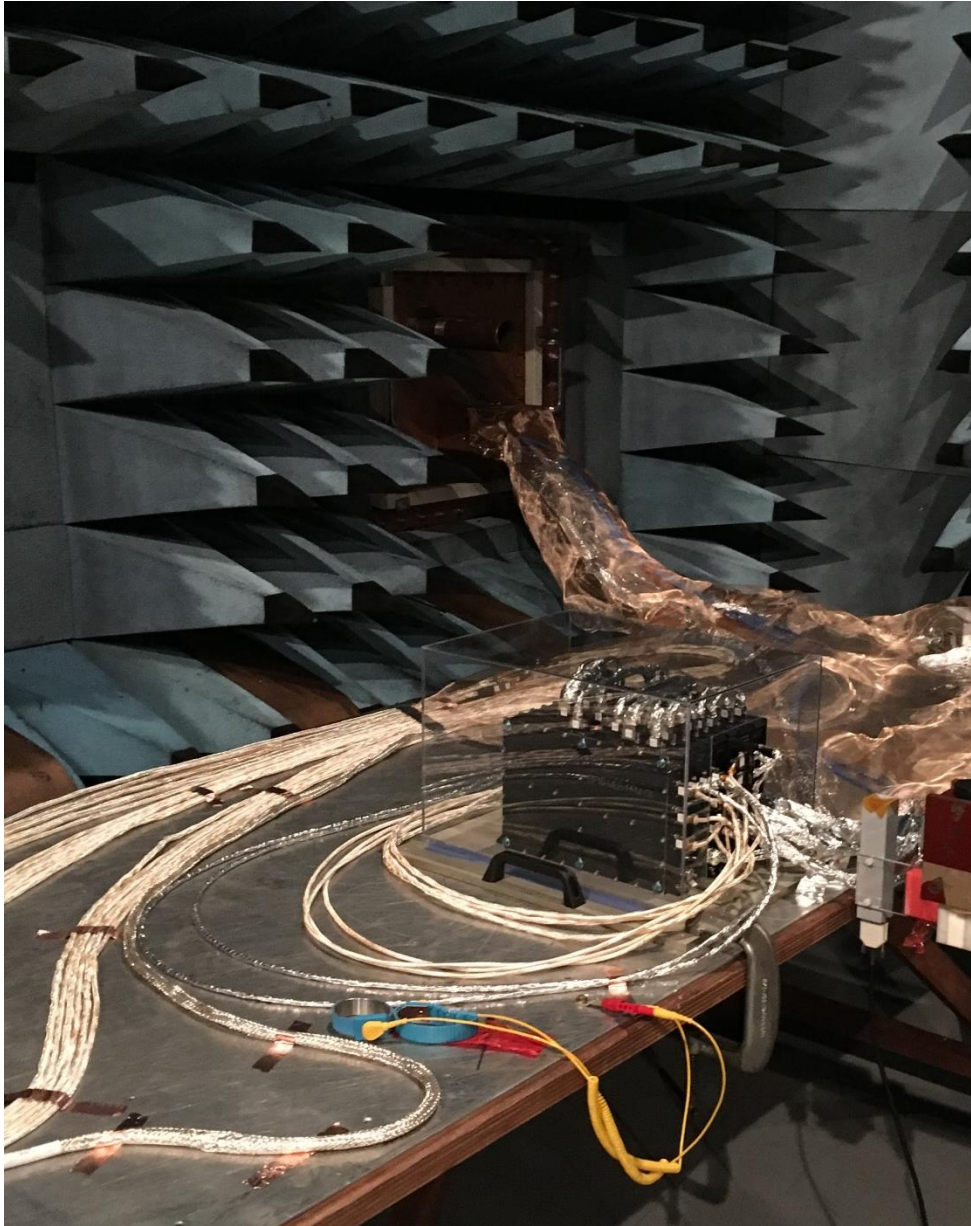
RPW antennas ready for delivery



RPW antennas integrated on the spacecraft (Airbus UK)



RPW main electronics box (MEB)

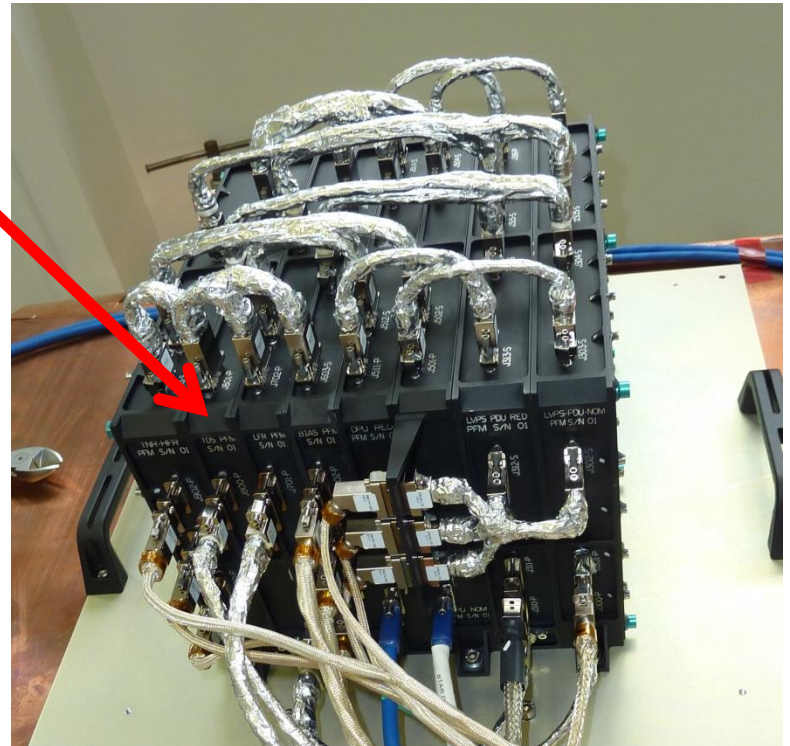
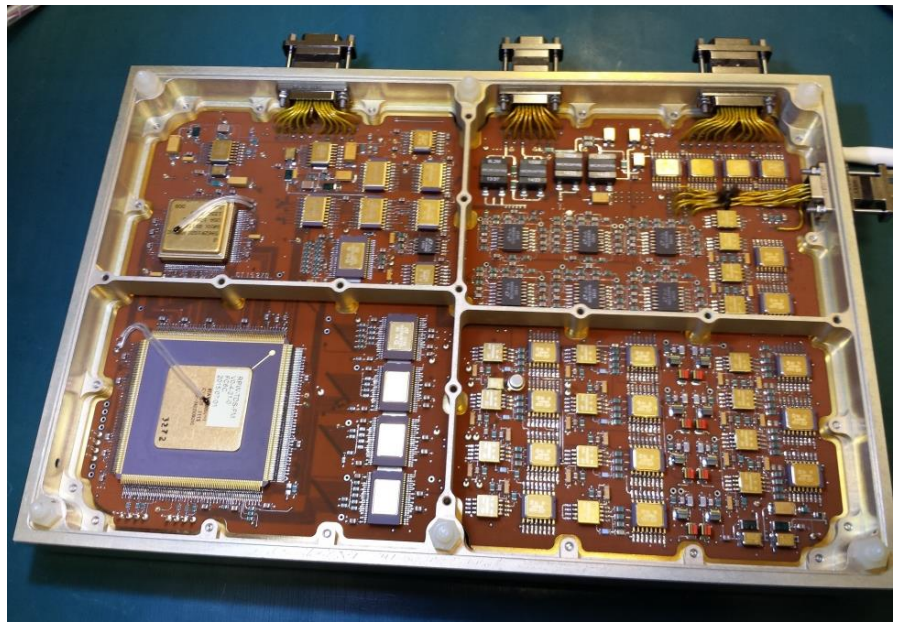


Solar Orbiter:

Time Domain Sampler

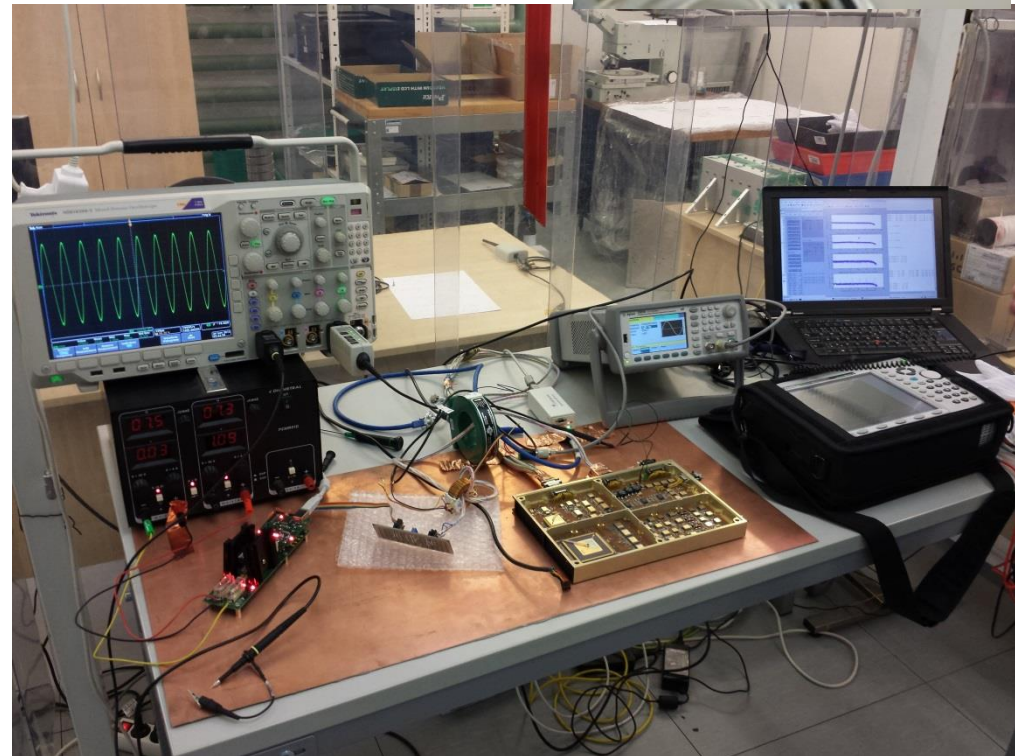
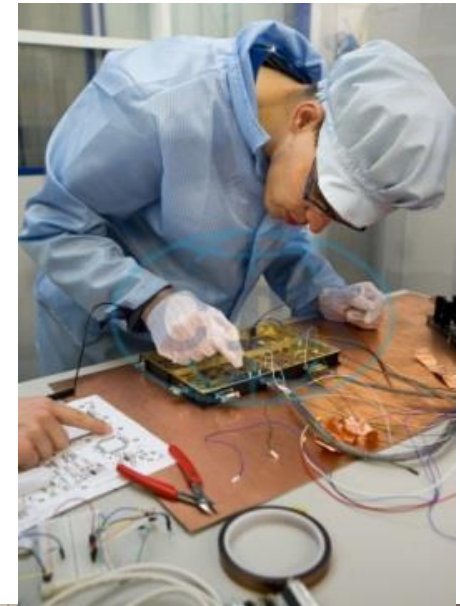
- One electronics circuit board inside the main electronics box (A5 format)
- Analog circuits and analog to digital conversion of electric and magnetic field measurement
- Frequency range: 200 Hz to 200 kHz
- Sophisticated digital signal processing to obtain maximum science within telemetry limits
 - interesting event detection and selection
 - statistics of dust impacts and wave observations

TDS



RPW Time Domain Sampler

- Hardware design, FPGA firmware development and flight software development all performed at Institute of Atmospheric Physics (IAP) in Prague.
- Flight model qualified assembly performed **by G. L. Electronics** company in Brno, Czech Republic.
- Testing and calibration performed in by IAP staff at **VZLU** company in Prague.
- Flight model and spare model delivered to CNES in 2016 (and to ESA in 2017)
- For IAP team, RPW was the first project under full ESA quality control.
- Project was funded through **ESA PRODEX** programme.



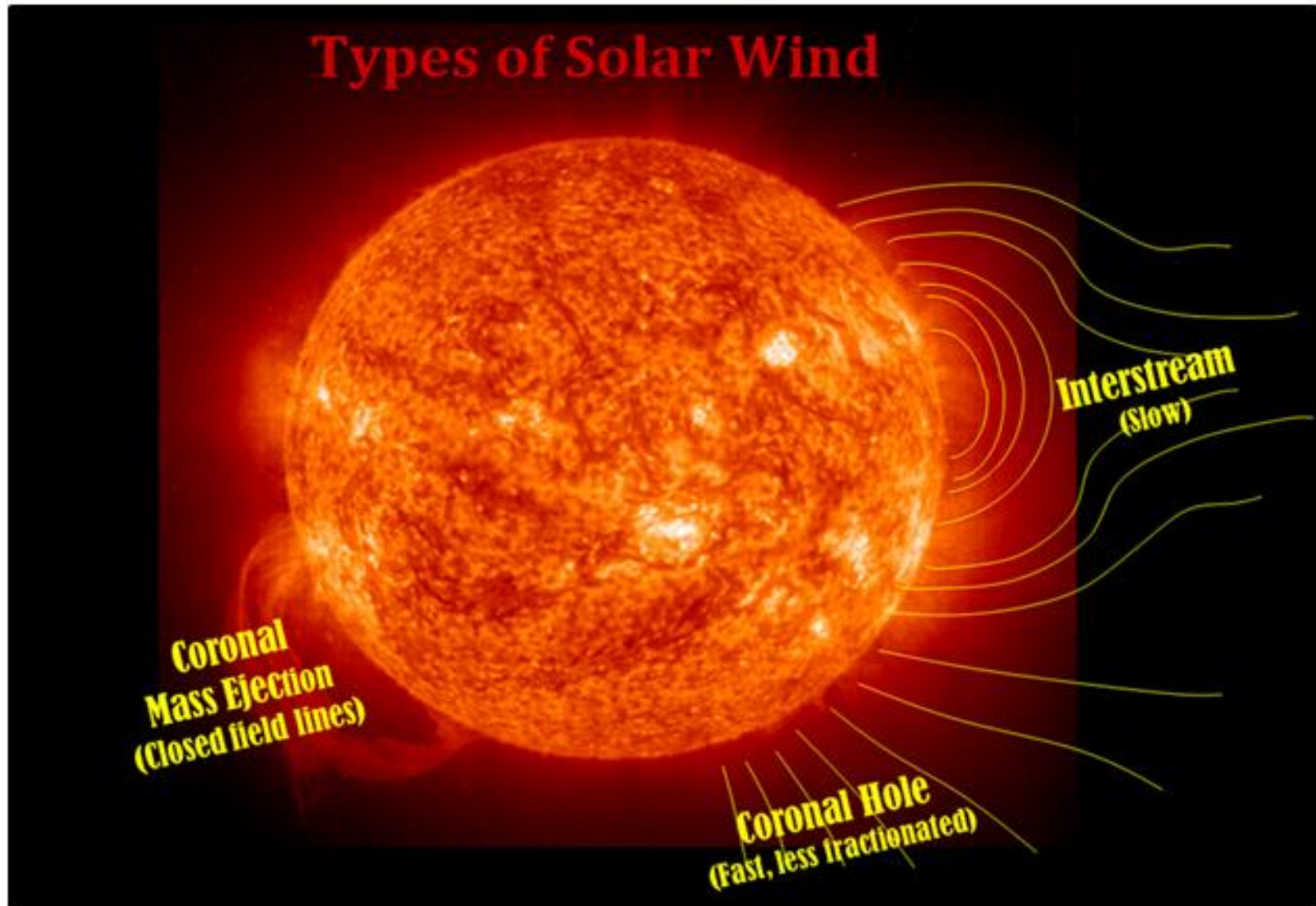
Science objectives

of

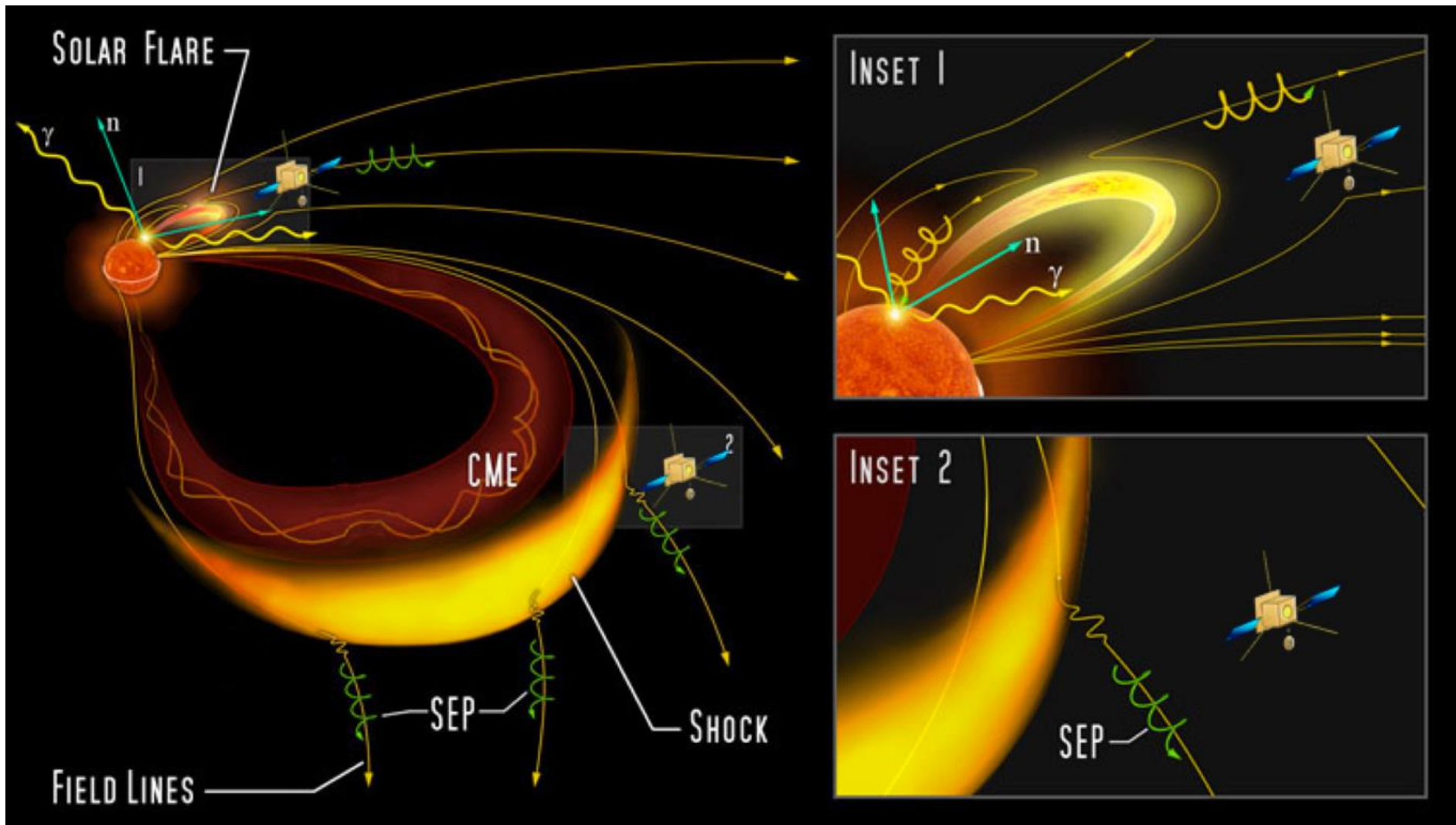
RPW instrument

The solar wind

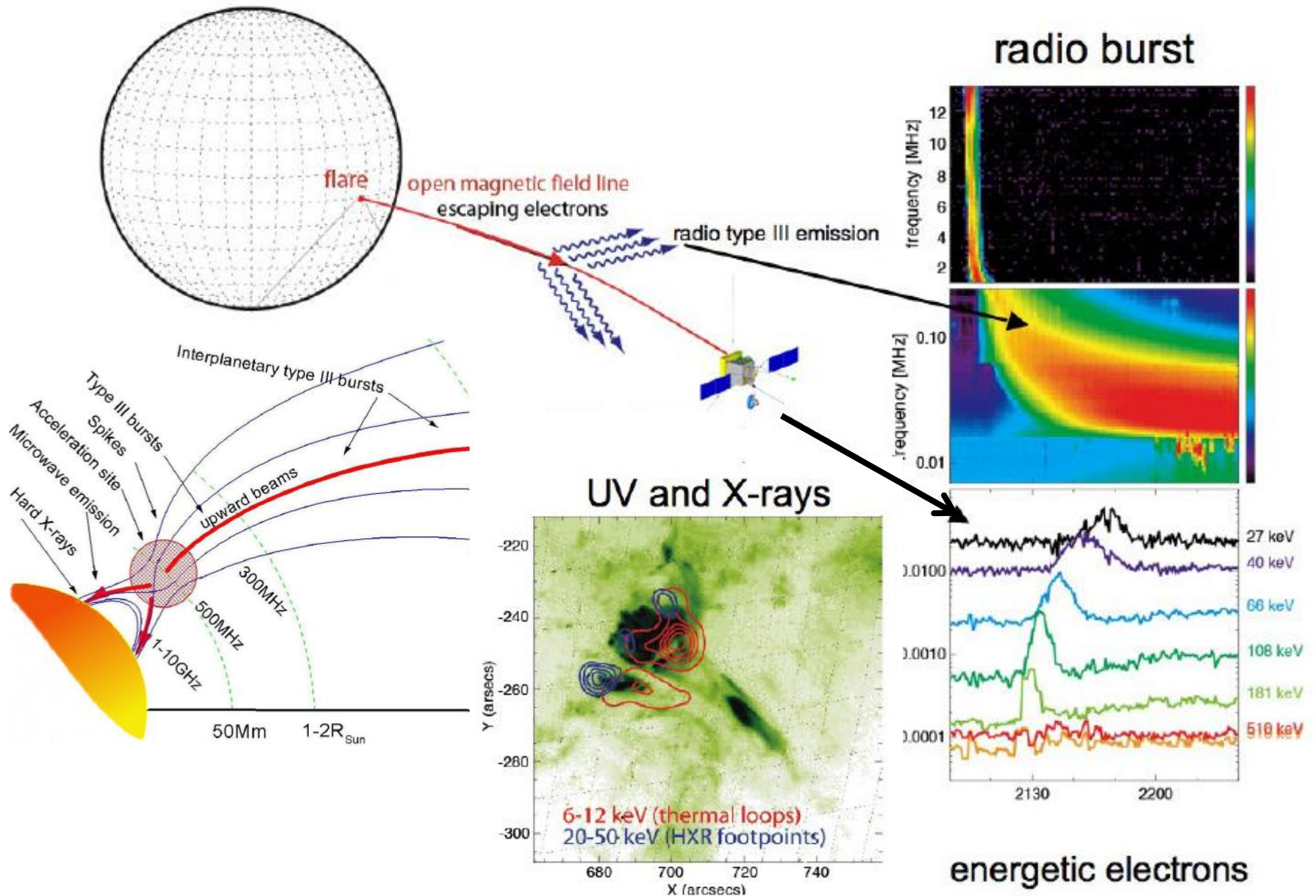
A flow of low density plasma (mainly protons and electrons) streaming from the Sun at a speed of ~ 500 km/s, filling the entire solar system.



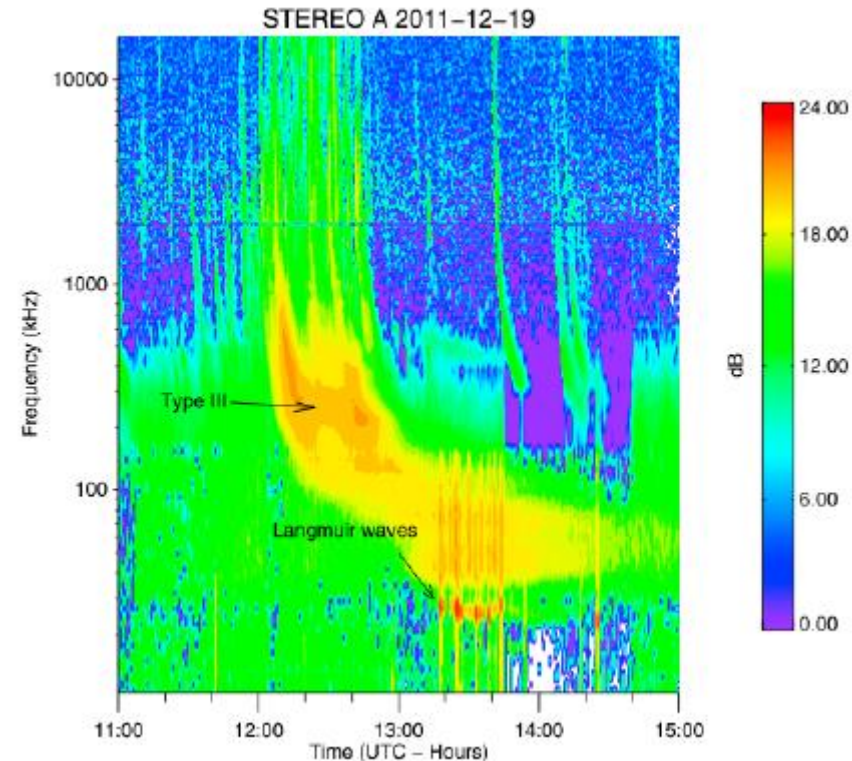
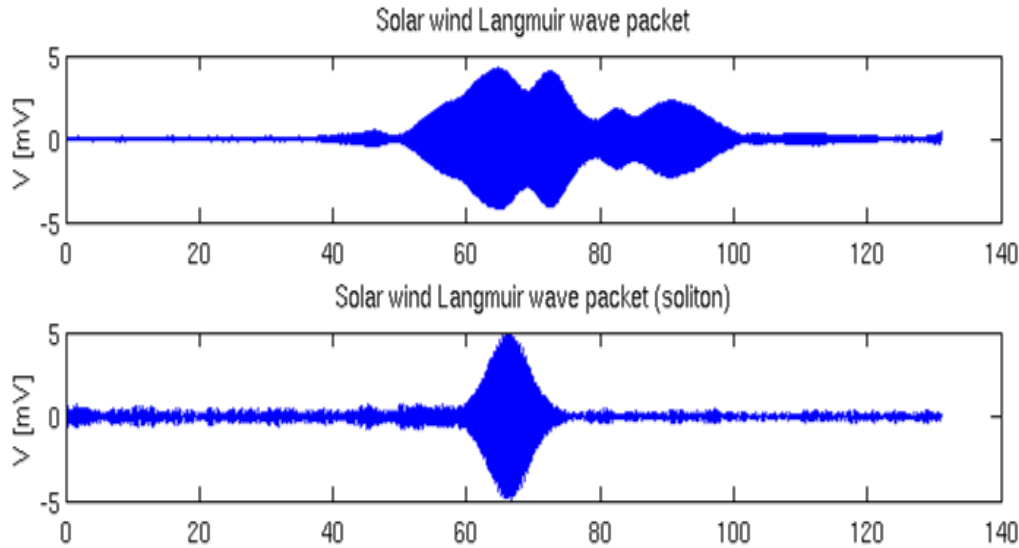
Solar flares, CME and energetic particles



RPW science objectives: type III radio bursts



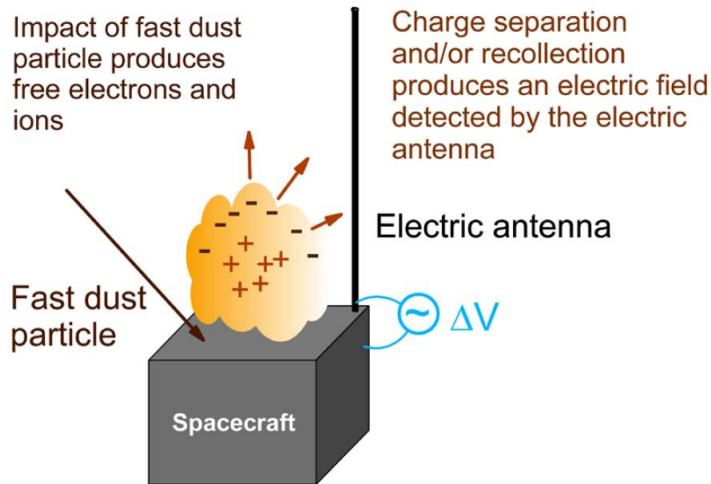
RPW science objectives: type III radio bursts



● Plasma waves (Langmuir waves)

- ➡ Source of type III radio waves
- ➡ generated by energetic electrons
- ➡ Isolated coherent wave packets sat plasma frequency (10 – 100 kHz)
- ➡ relatively rare, only appear when energetic electrons are present
- ➡ TDS analyzer implements algorithms for detection of the waves. This allows to send to the ground only the relevant segments of data.

RPW-TDS science: interplanetary dust

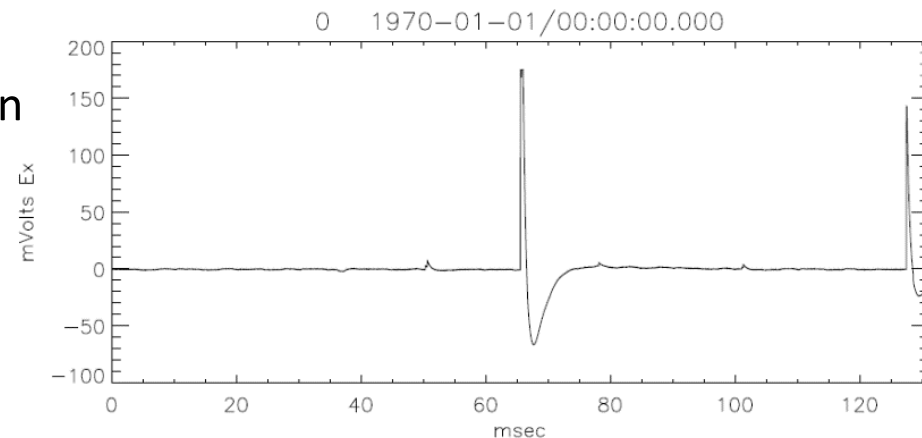


Released charge : $Q \simeq 0.7m^{1.02}v^{3.48}$

Induced voltage pulse on S/C of capacitance C : $\delta V \sim -Q/C$

Dust particles of micrometer size are common in the solar system. They originate from:

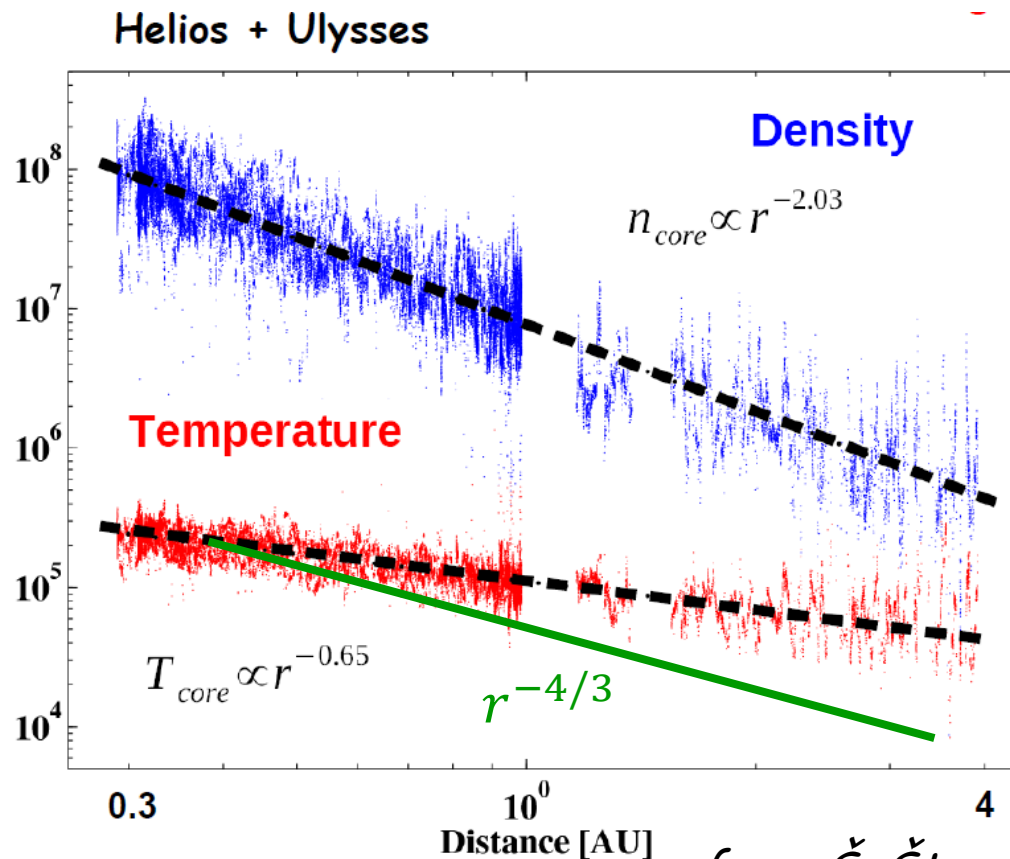
- meteoroids, comets and other solar system bodies
 - outside the solar system
- Dust impacts show up as intense and short spikes in voltage measured on antennas.
- TDS detects the pulses and calculates their statistical properties on-board.



Example of dust impact seen in E-field by STEREO spacecraft (NASA)

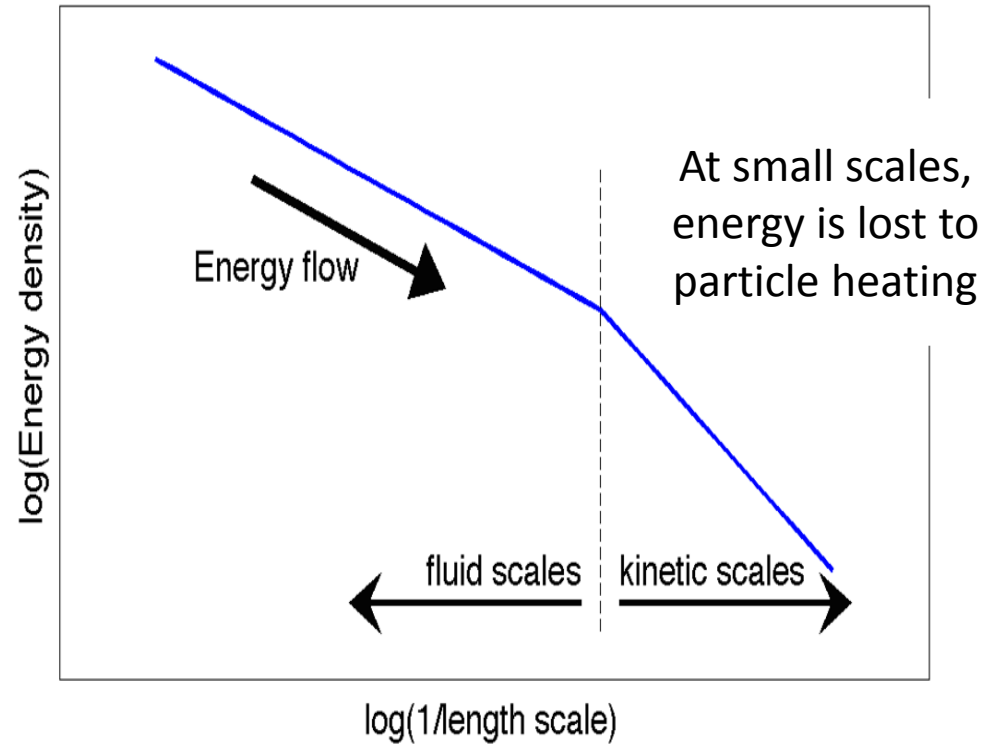
Other RPW science objectives: solar wind plasma turbulence

Plasma waves and turbulence are believed to contribute significantly to heating of solar wind plasma.



from Š. Štverák, PhD thesis

Heating of plasma in turbulence



*Karimabadi, H. et al.,
PoP, 2013*

Plasma turbulence dissipates at kinetic scales heating plasma and accelerating particles.

RPW observation of turbulence

The RPW instrument is well suited to observing the kinetic scale electromagnetic field oscillations

