Atelier « Quels outils pour l'analyse de Solar Orbiter »

04-06 Novembre 2014,
IAS Toulouse

L'instrument RPW

- Objectifs scientifiques et données
- Operations

RPW will make key measurements in support of three of the four top level scientific goals which drive the Solar Orbiter mission :

- RPW will allow to determine the properties, dynamics and interactions of plasma, fields and particles in the near-Sun heliosphere
- RPW will participate in the investigation of the links between the solar surface, corona and inner heliosphere
- RPW will explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun's magnetized atmosphere

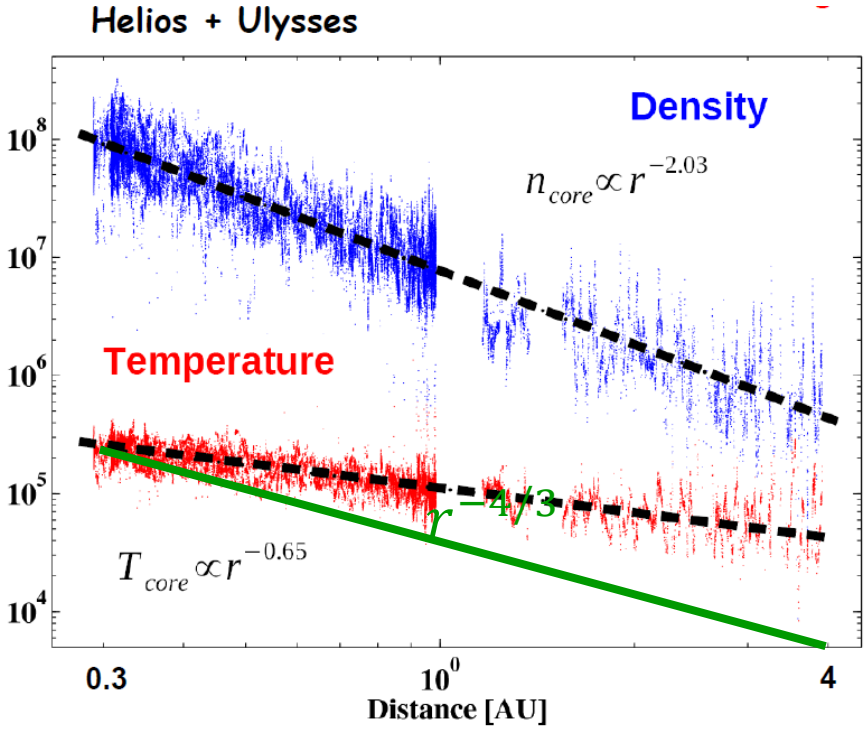
RPW will measure magnetic and electric fields at high time resolution using a number of sensors, to determine the characteristics of electromagnetic and electrostatic waves in the solar wind from almost DC to 20 MHz.

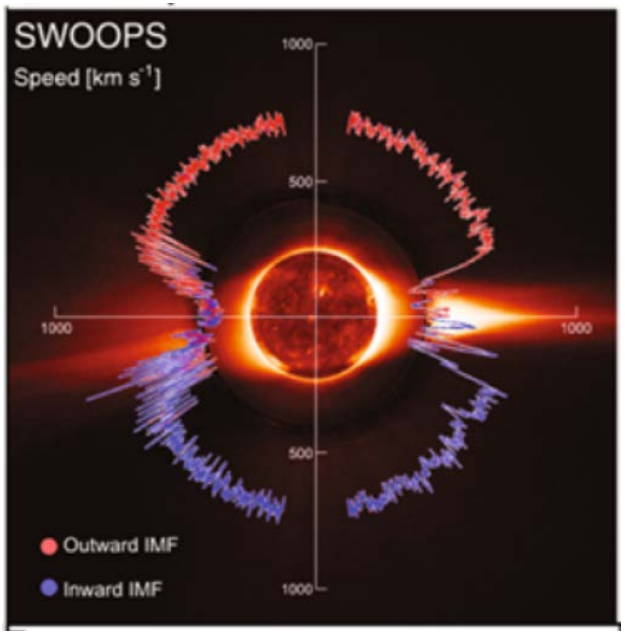
RPW specific science objectives

- Solar wind Microphysics, Turbulence, and Heating
- Interplanetary Shocks, Magnetic Reconnection, and Current Sheets
- Electron Density and Temperature from Quasi-Thermal Noise Spectroscopy
- Langmuir Waves and Electromagnetic Mode Conversion
- Solar Coronal and Interplanetary Radio Bursts
- Interplanetary Dust

In-situ Plasma waves : what do we observed and understand ?

Waves are believed to both heat & accelerate the Solar Wind



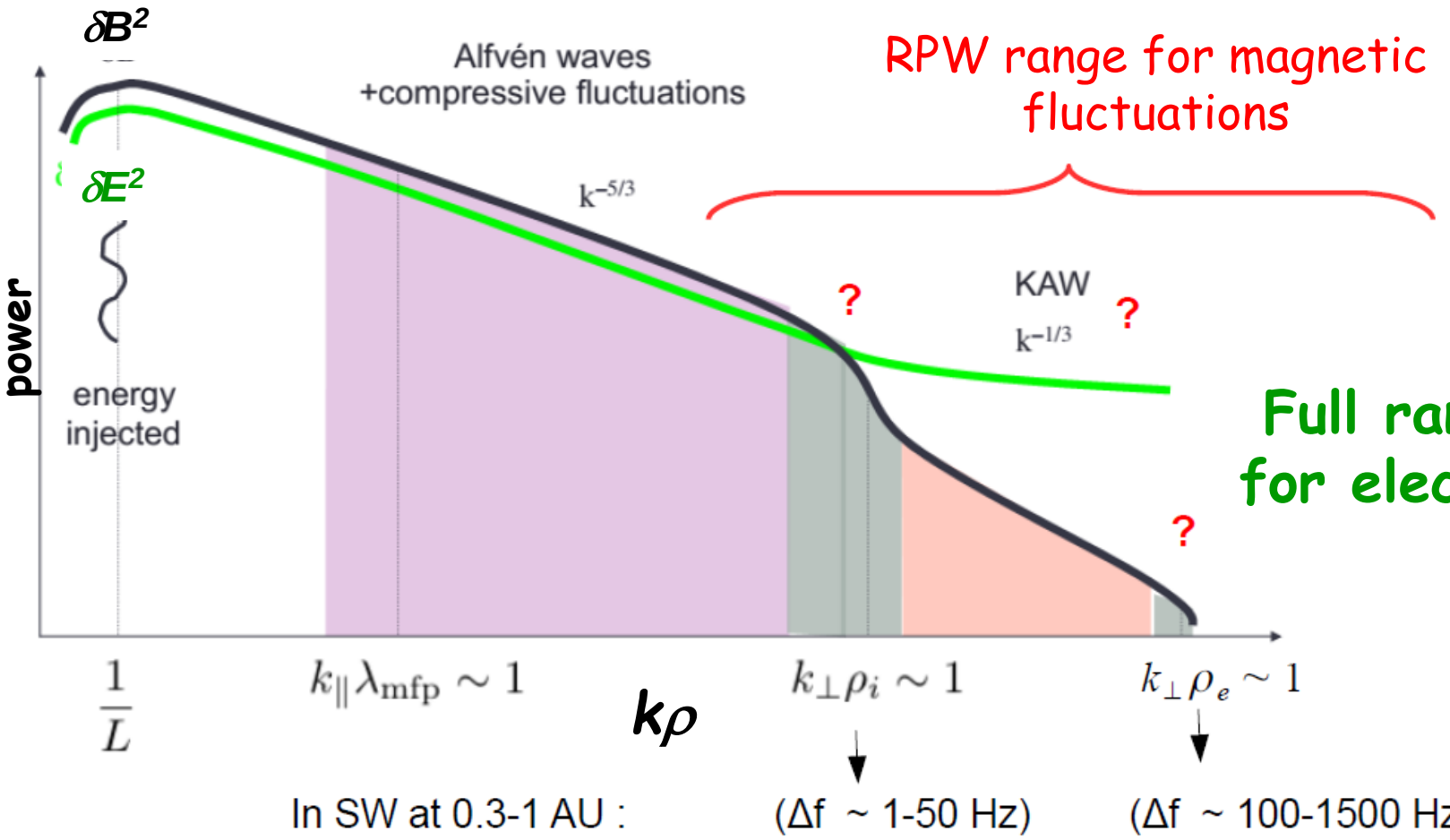


Stverak, PhD thesis

Turbulent heating/dissipation in the Solar Wind

Kinetic Alvèn Waves ? Whistler Waves ? Coherent structures ? Other ?

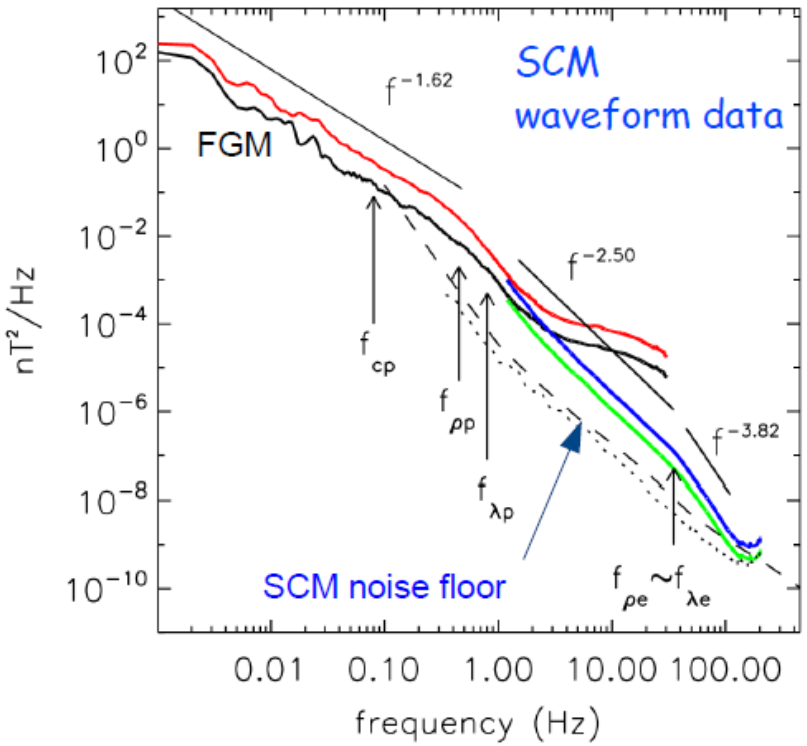
Turbulent energy cascade from large to small scales



Evidences for a Cascade well above the proton scales up to the electron typical scales (gyroscale and above ?)

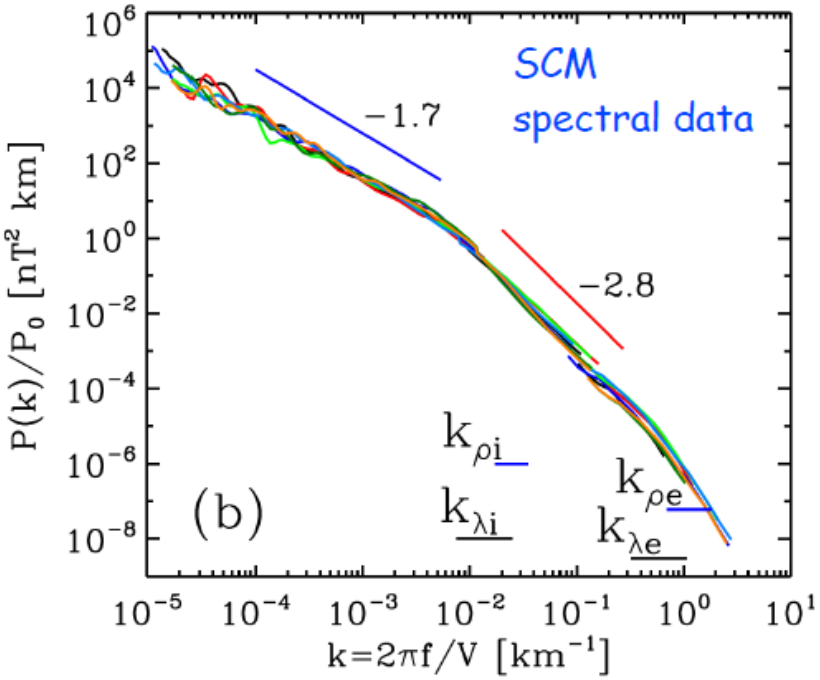
Cluster

A first case study



Sahraoui et al., PRL, 2009

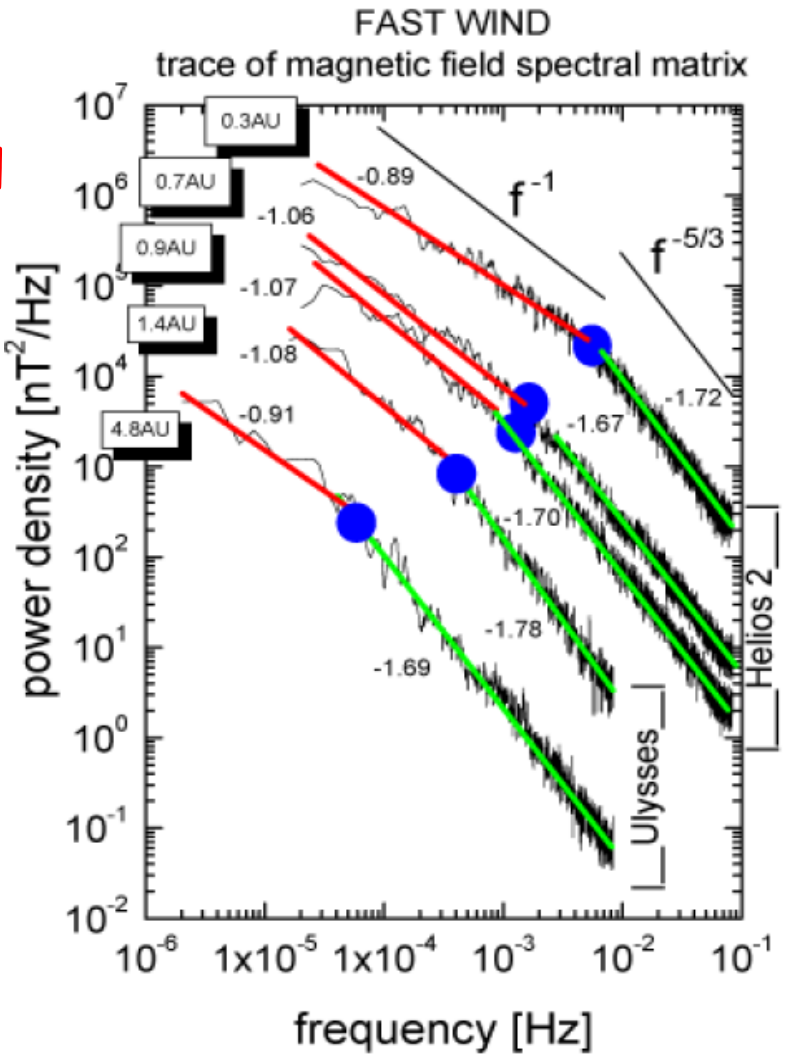
Another similar study (several cases)

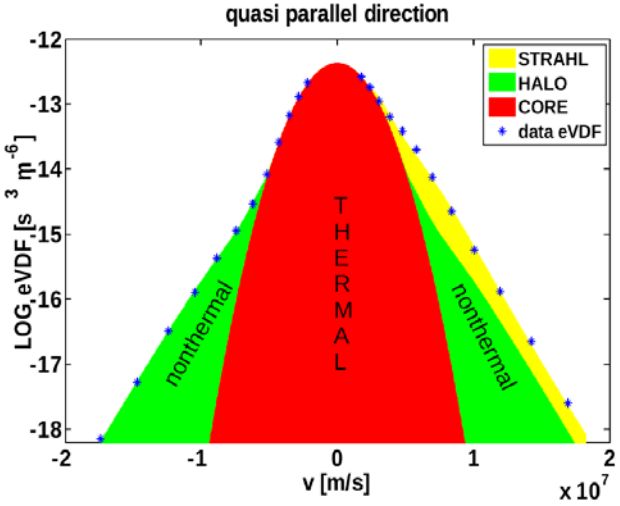


Alexandrova et al., PRL, 2009

- Exponential decrease or power law ?
- Observational limitations : noise floor both for dE2 and dB2

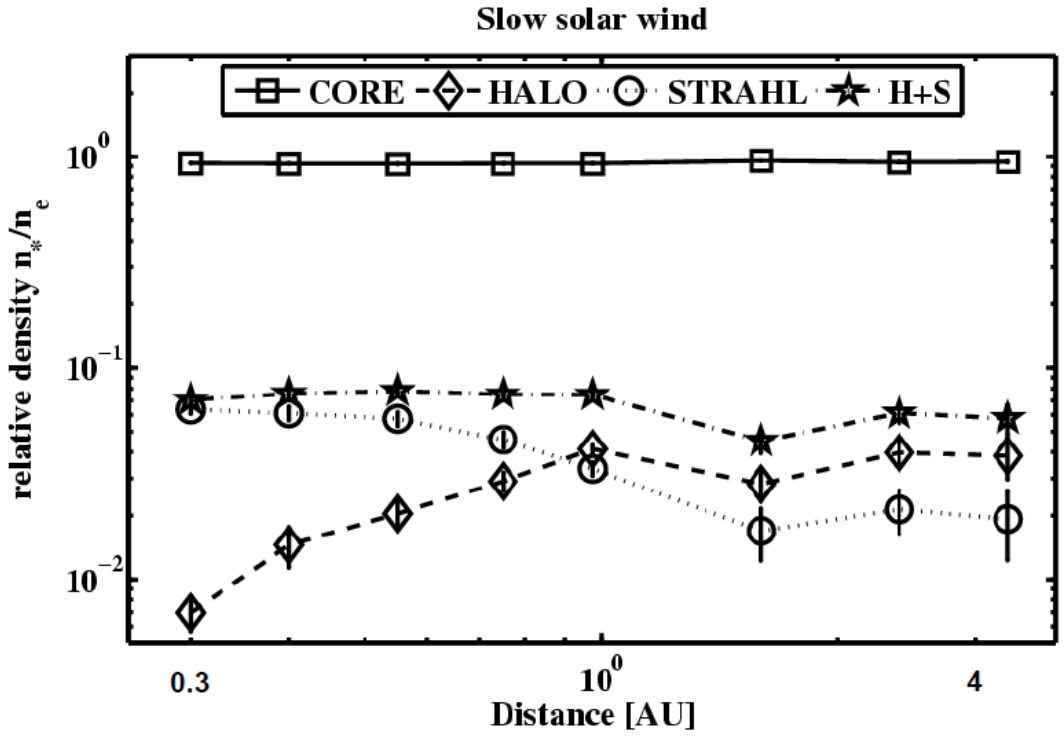
Even with the same search coil sensitivity as on Cluster, RPW will make important improvements





Which kind of particles/waves interactions can explain the evolution of electron VDFs ?

Helios, Cluster, Ulysses



Data set : ~ 240,000 samples from 0.3 to 4 AU

Stverak et al., JGR, 2009

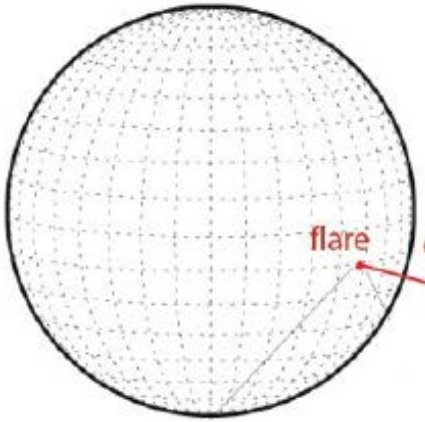
Maksimovic et al., 2005

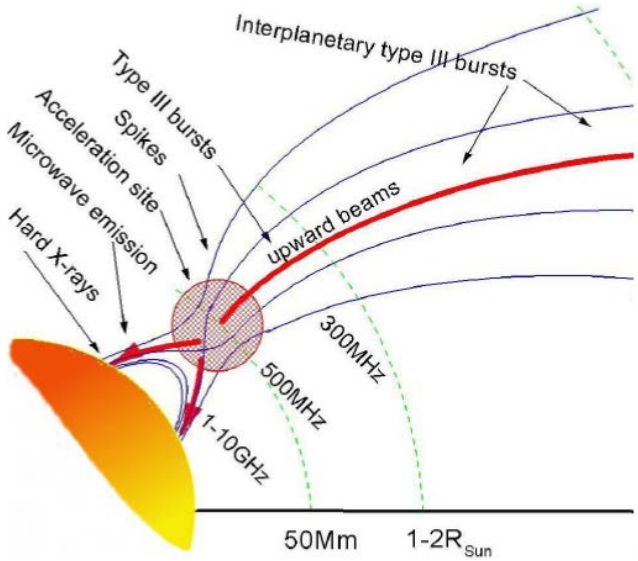
During expansion, strahl is transformed into halo by wave-particle interactions ?

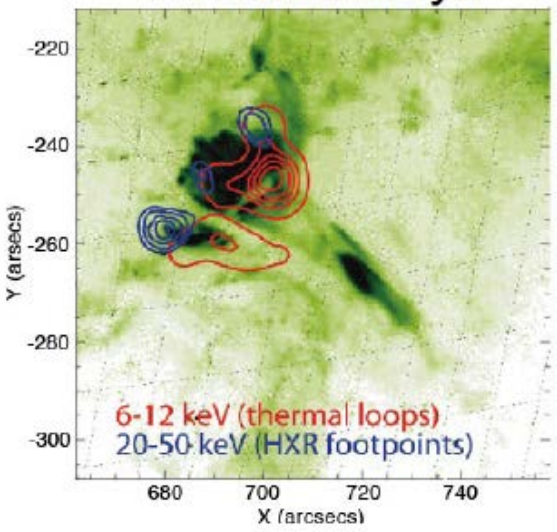
Radio waves :

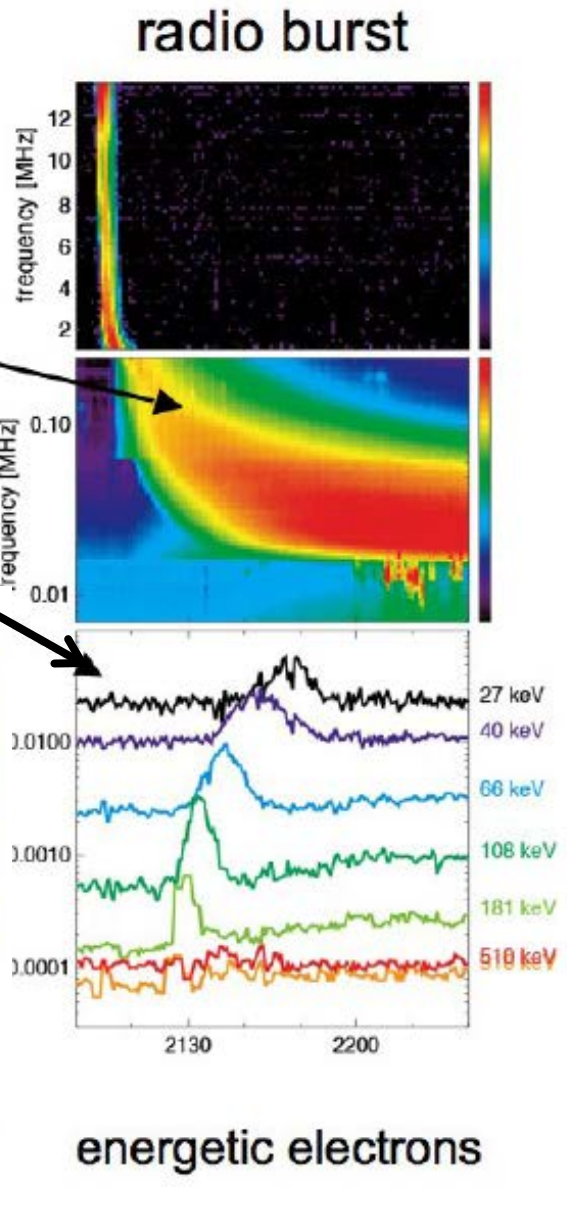
what do we observed and understand ?

Solar Radio Bursts

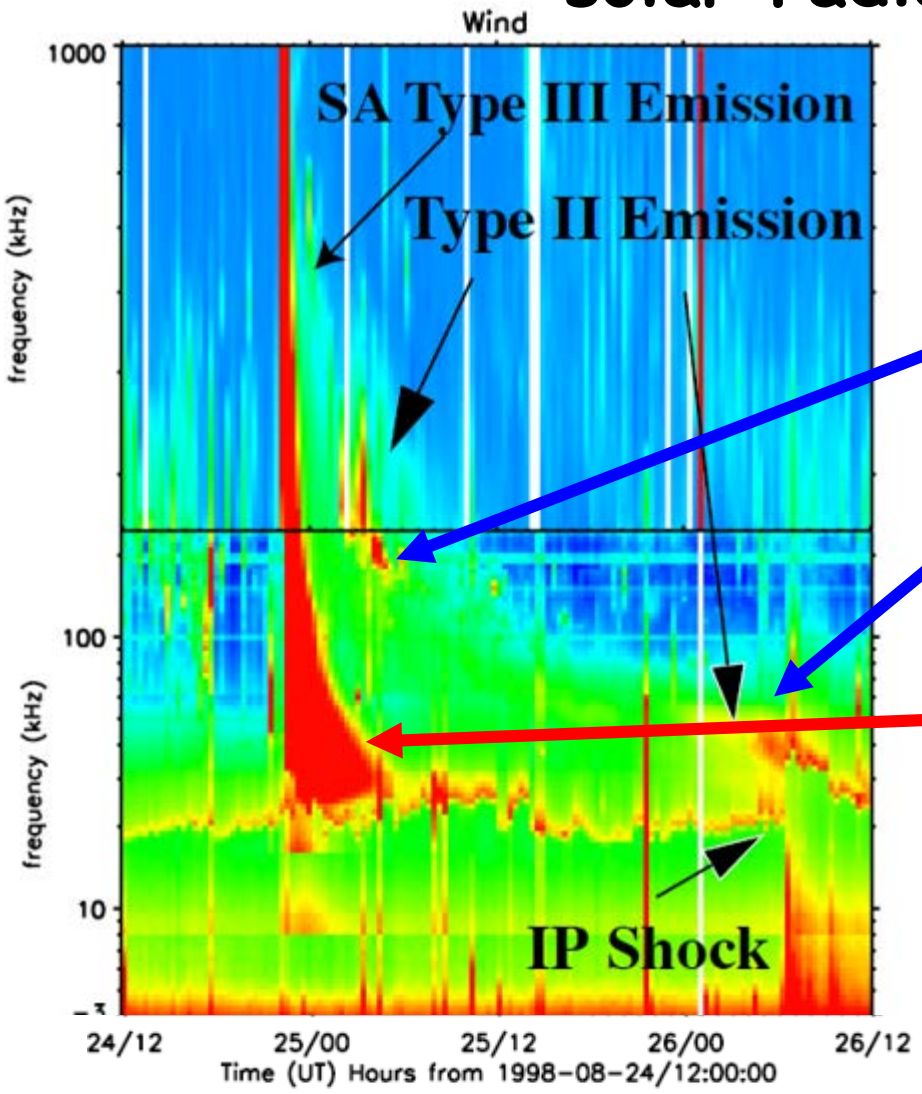


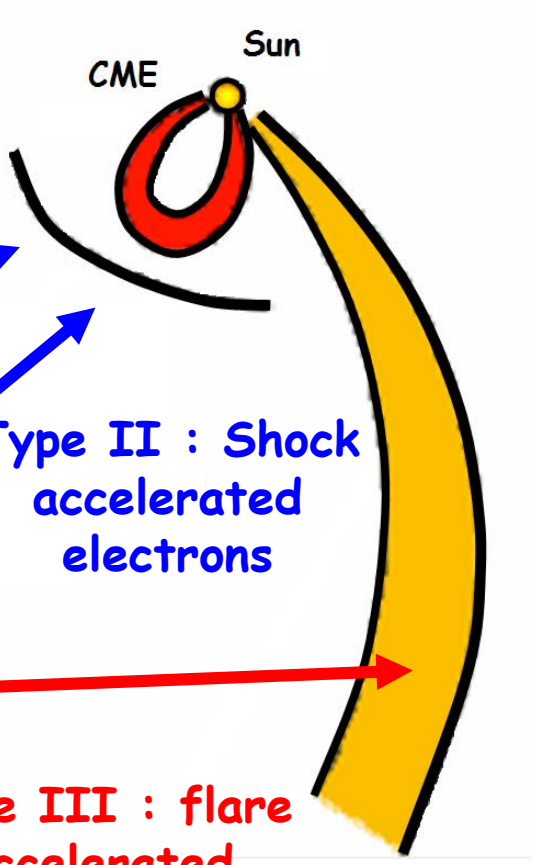






Type III & Type II solar radio bursts



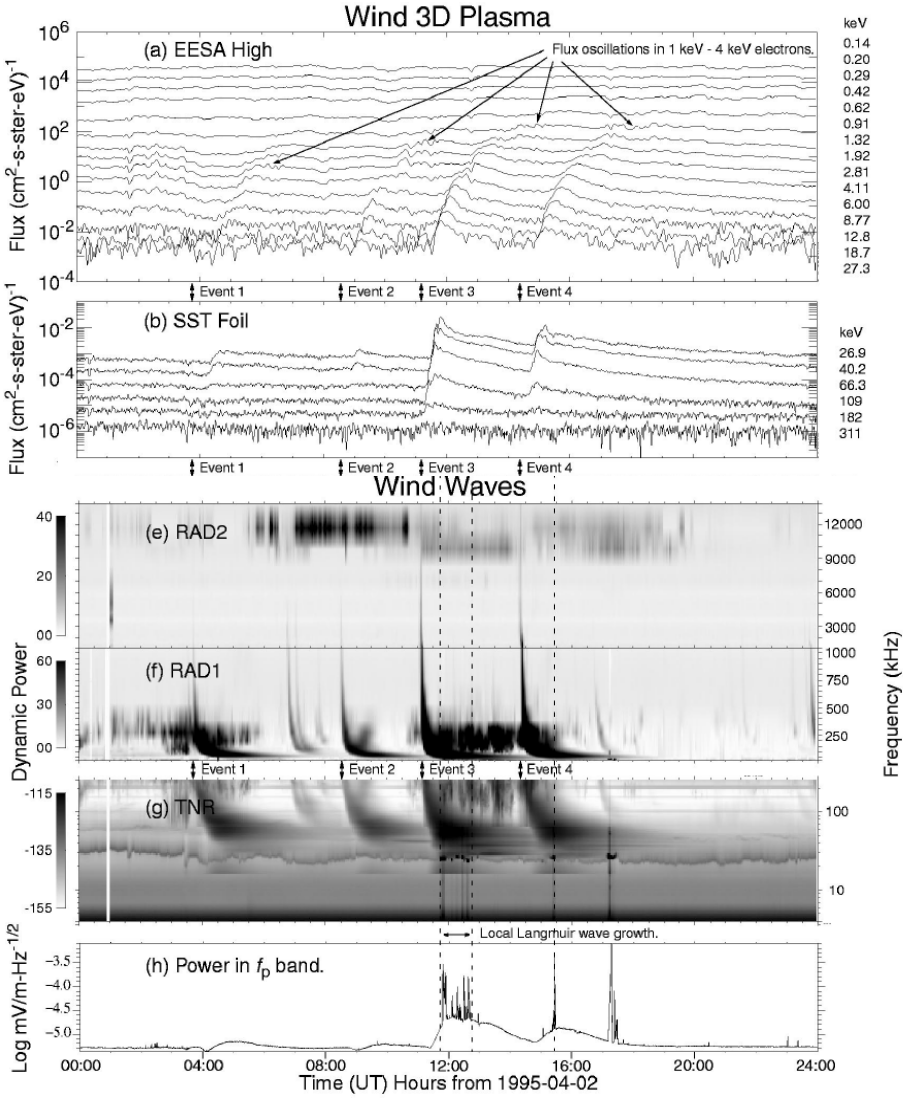


Type II : Shock accelerated electrons

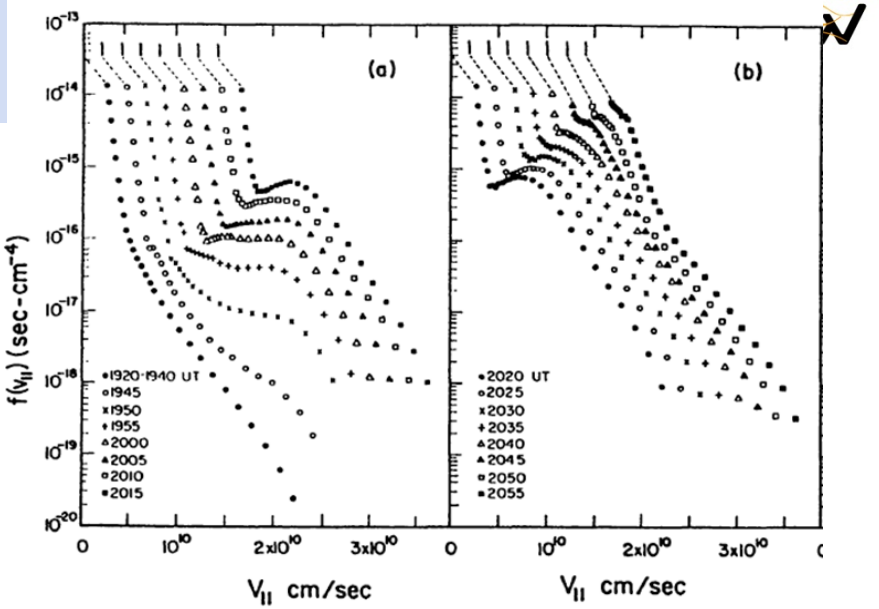
Type III : flare accelerated electrons

+ direction finding

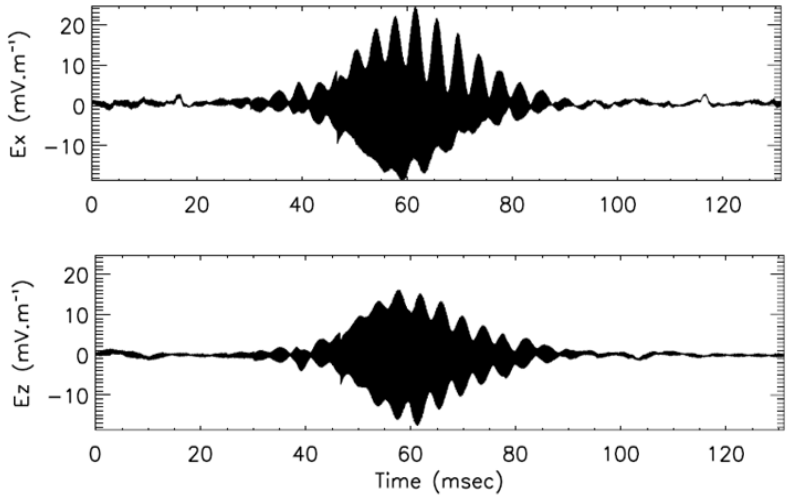
In-situ Type III and II measurements will be available on SO



Adapted from [Ergun et al., 1998]

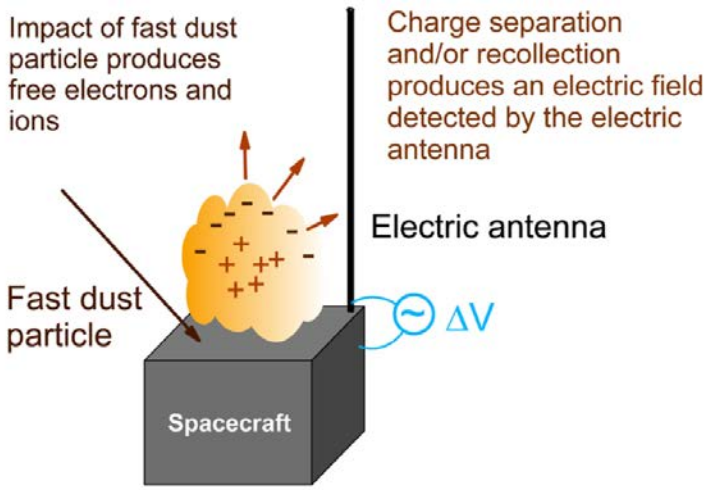


Adapted from [Lin et al. 1981]



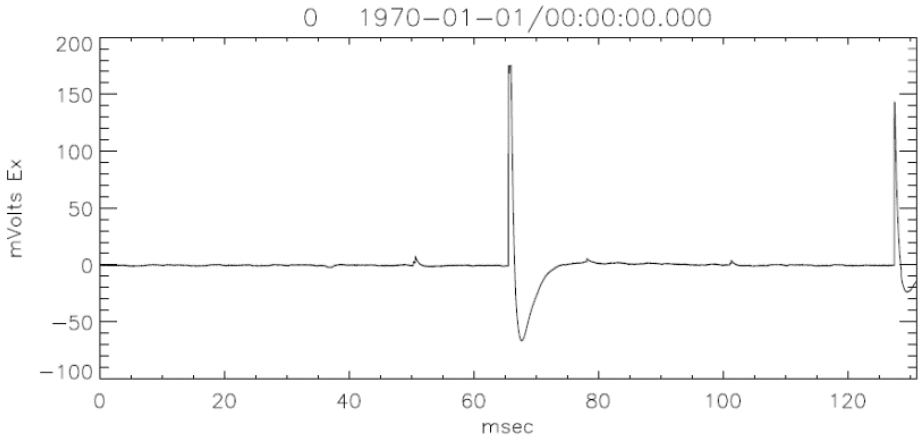
Swaves

Interplanetary Dust

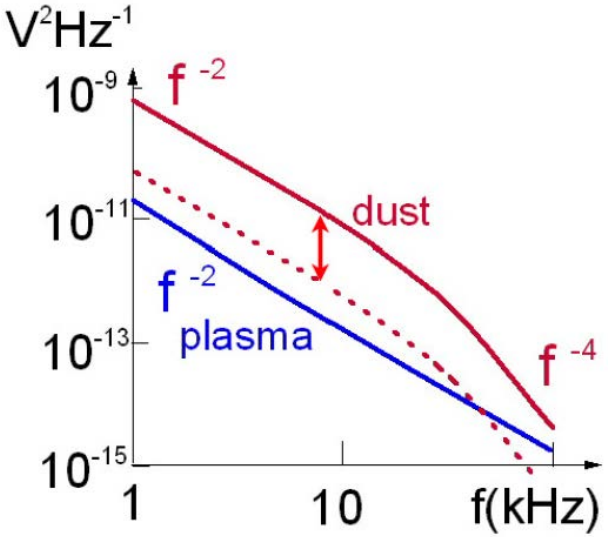


Released charge : $Q \simeq 0.7 m^{1.02} v^{3.48}$

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

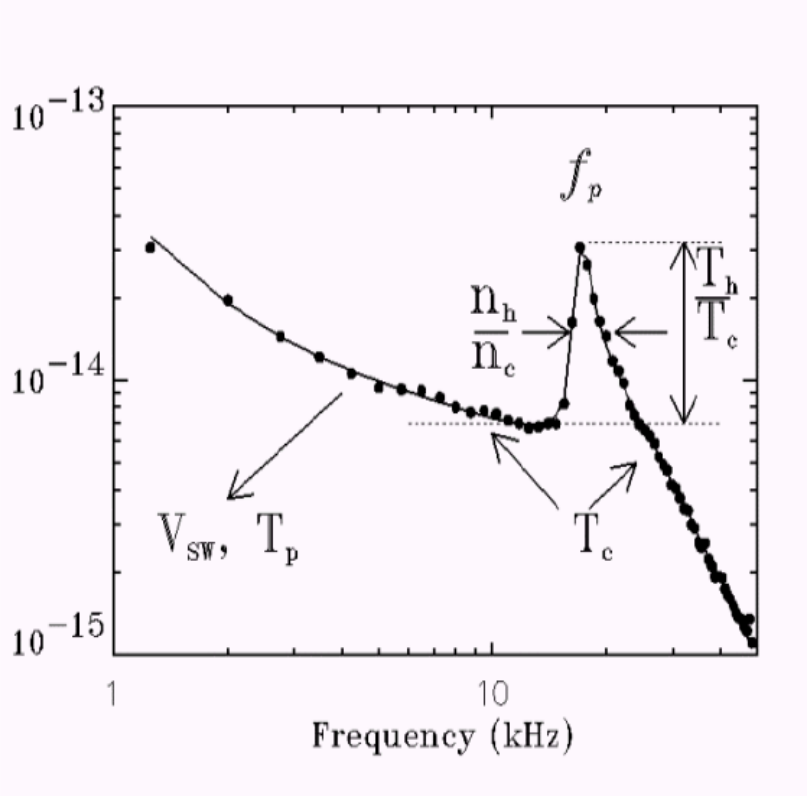


Temporal domain



Spectral domain

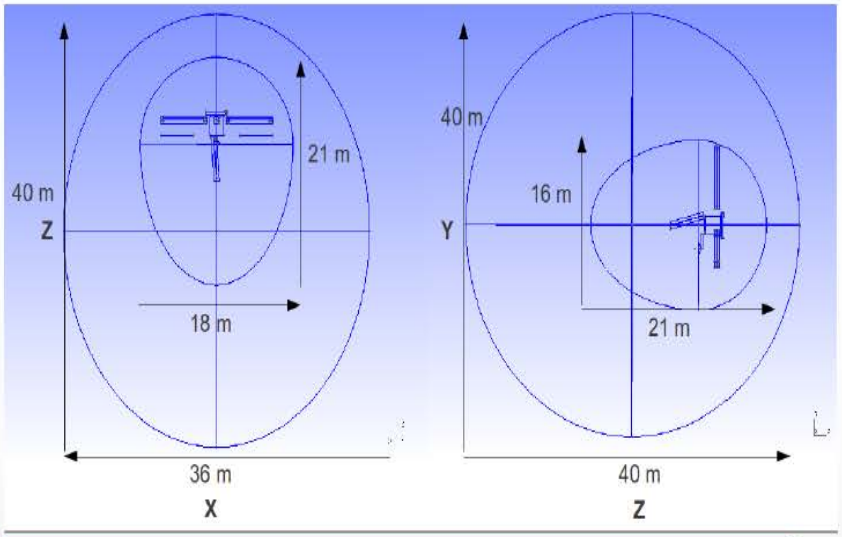
Electron Density and Temperature from Quasi-Thermal Noise Spectroscopy

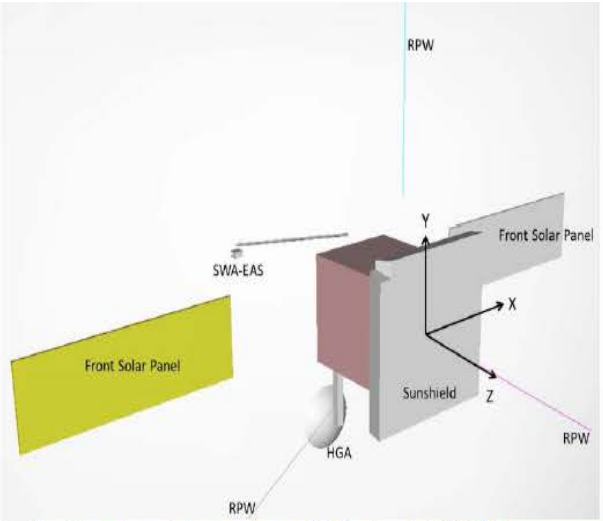


An antenna with L ~ 5 to 6 m & D~1 to 1.5 cm is fine

Measure precisely both the electron density and temperature, with accuracies respectively of a few % and 10 %, at perihelion when the $L > \lambda_D$.
Measure the electron density at other radial distances with an accuracy that will depend on L/λ_D.
Characterize the non-thermal character of the electron distributions at perihelion.

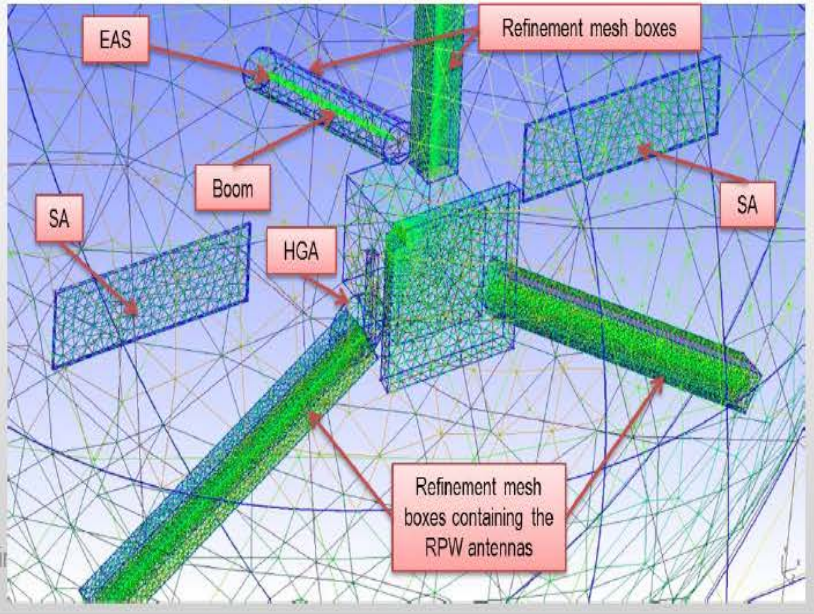
Simulations SPIS



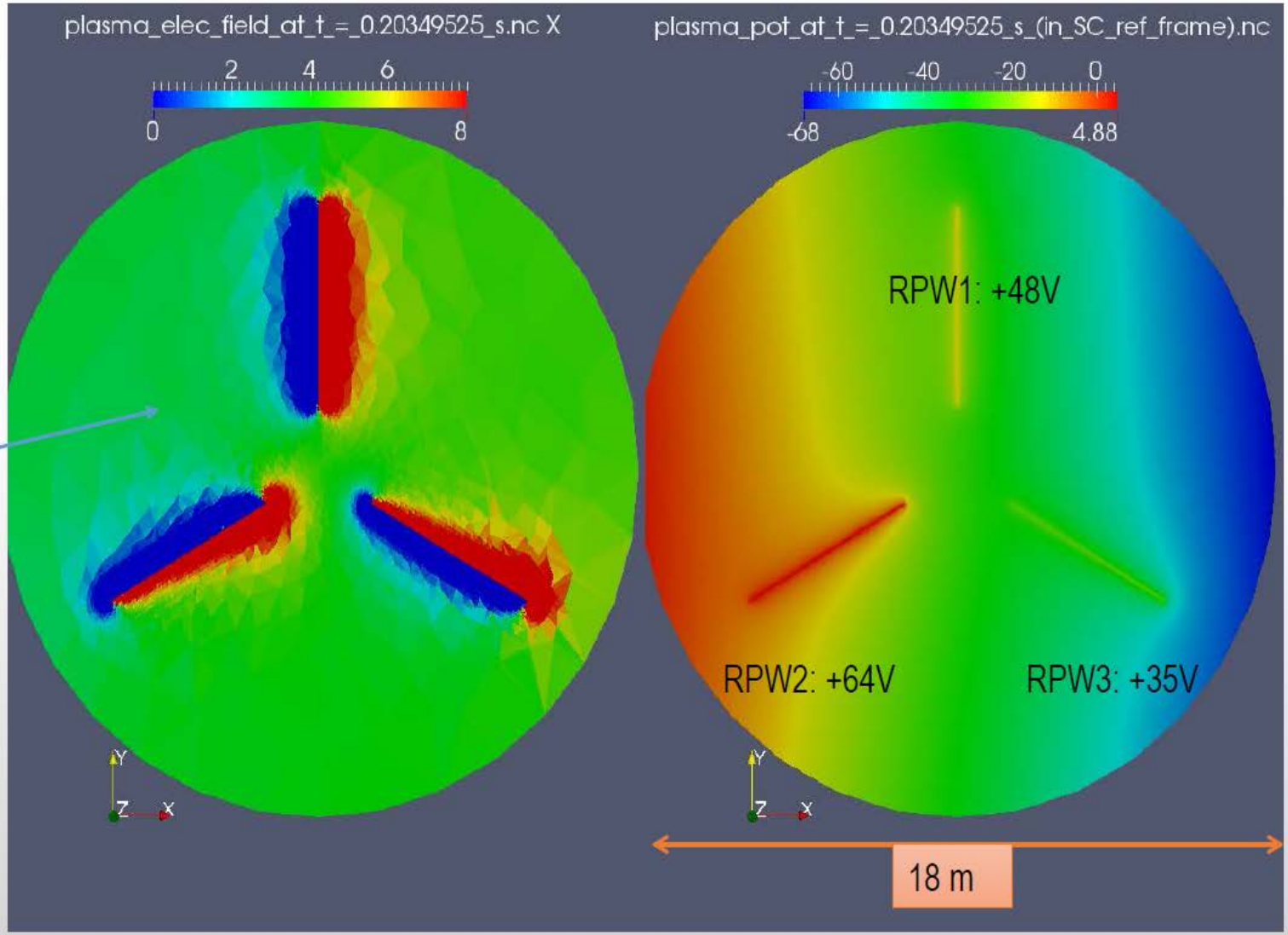


Meshing:
- ✓From 5mm → 1.5m
- ✓~ 270000 tetrahedra

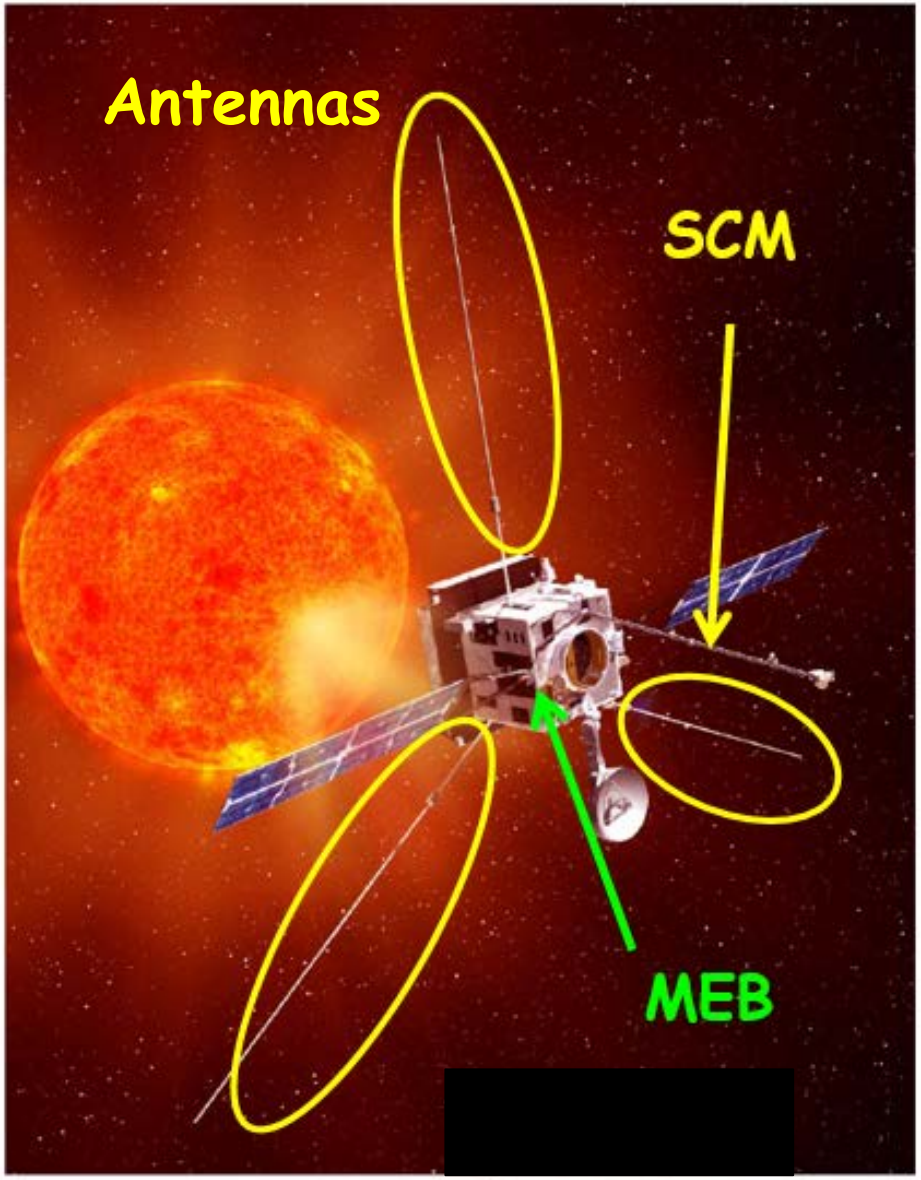
Main dimensions of the spacecraft:
- ✓Body: 1.7 x 1.7 x 1.8 m
- ✓Shield: 2.5 x 2.5 x 0.9 m
- ✓Solar arrays: 3.8 x 1.2 x 0.02 m
- ✓HGA: 0.5 m (radius) and 0.2 m (prof.) + support : 1.4 m (long) x 0.1 m (large)
- ✓Rear boom with EAS : 4 m (long) x 0.02 m (radius)
- ✓3 RPW (LESIA): 5 m (long)
- ✓EAS box: 0.2 x 0.2 x 0.1



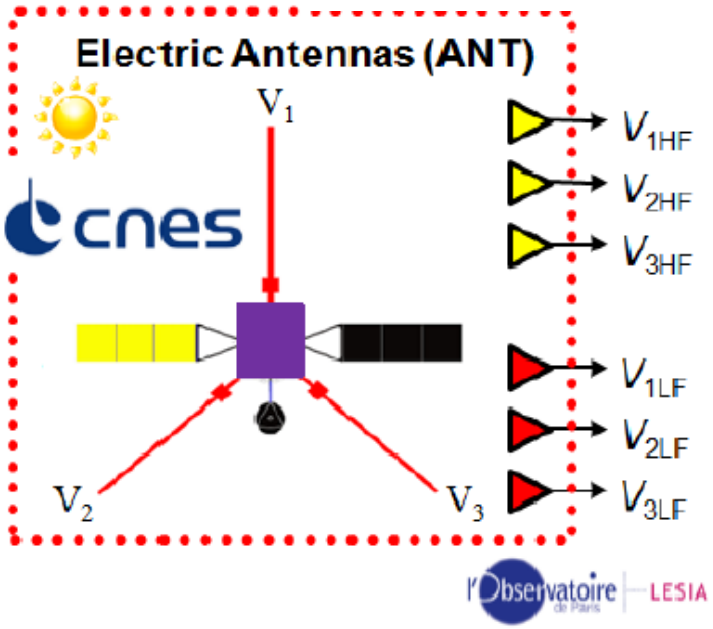
Plasma E_x in the SC reference frame (rescaled): the background VxB field of 4V/m appears

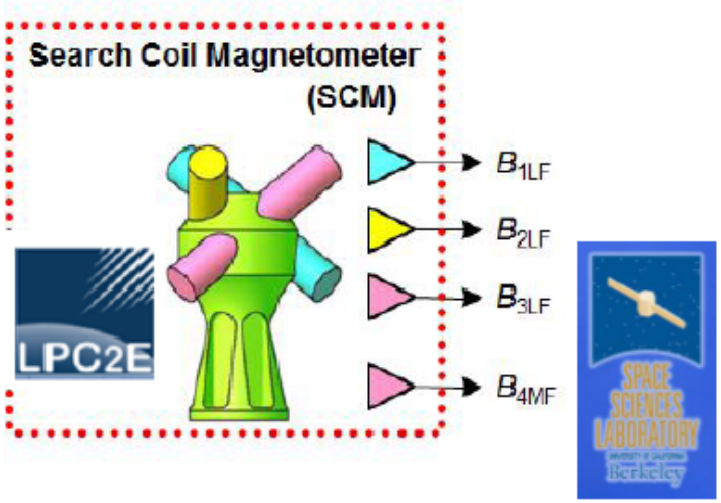


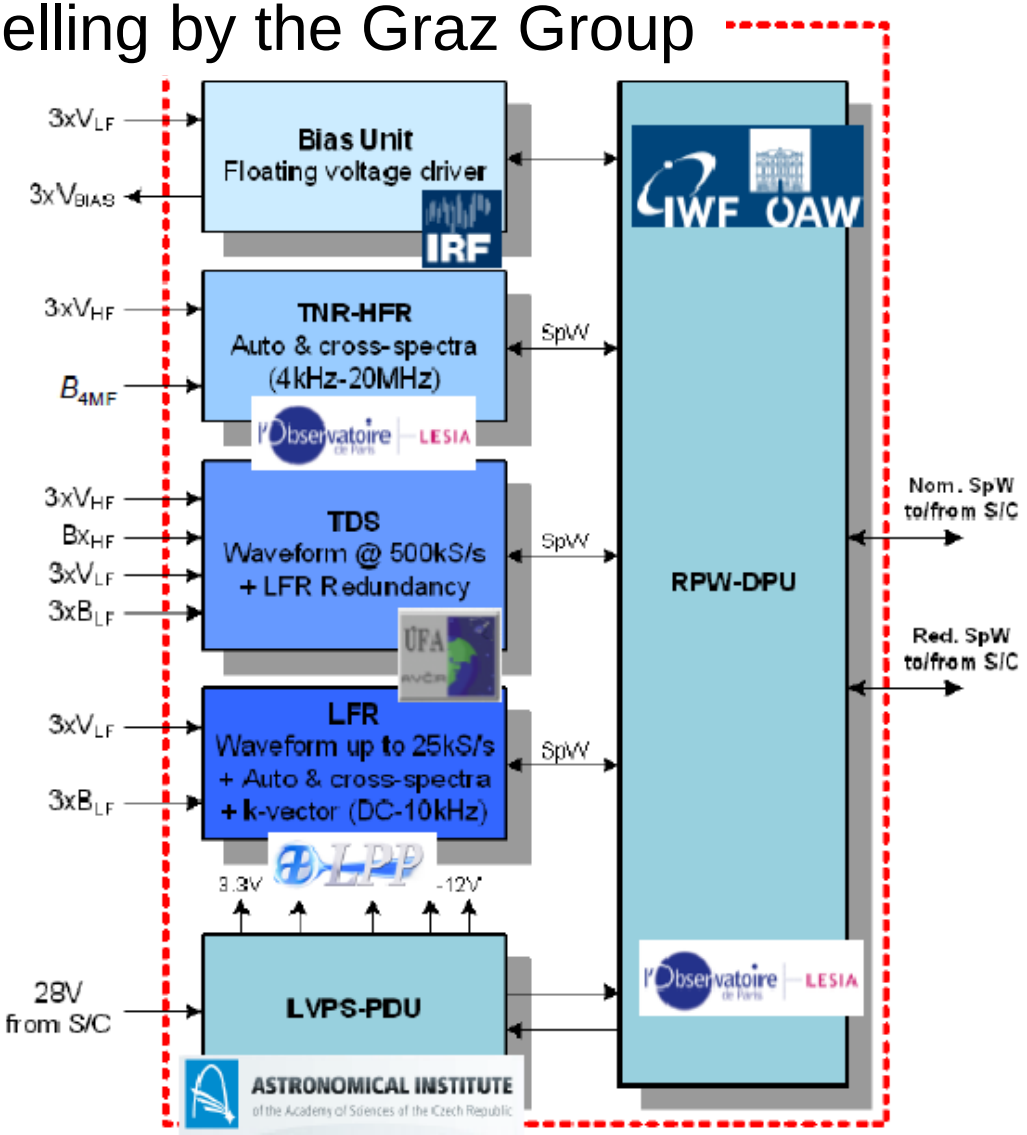
RPW : a (very) brief description



+ Antenna modelling by the Graz Group







DC Efield expertise & calibration, link to SPP

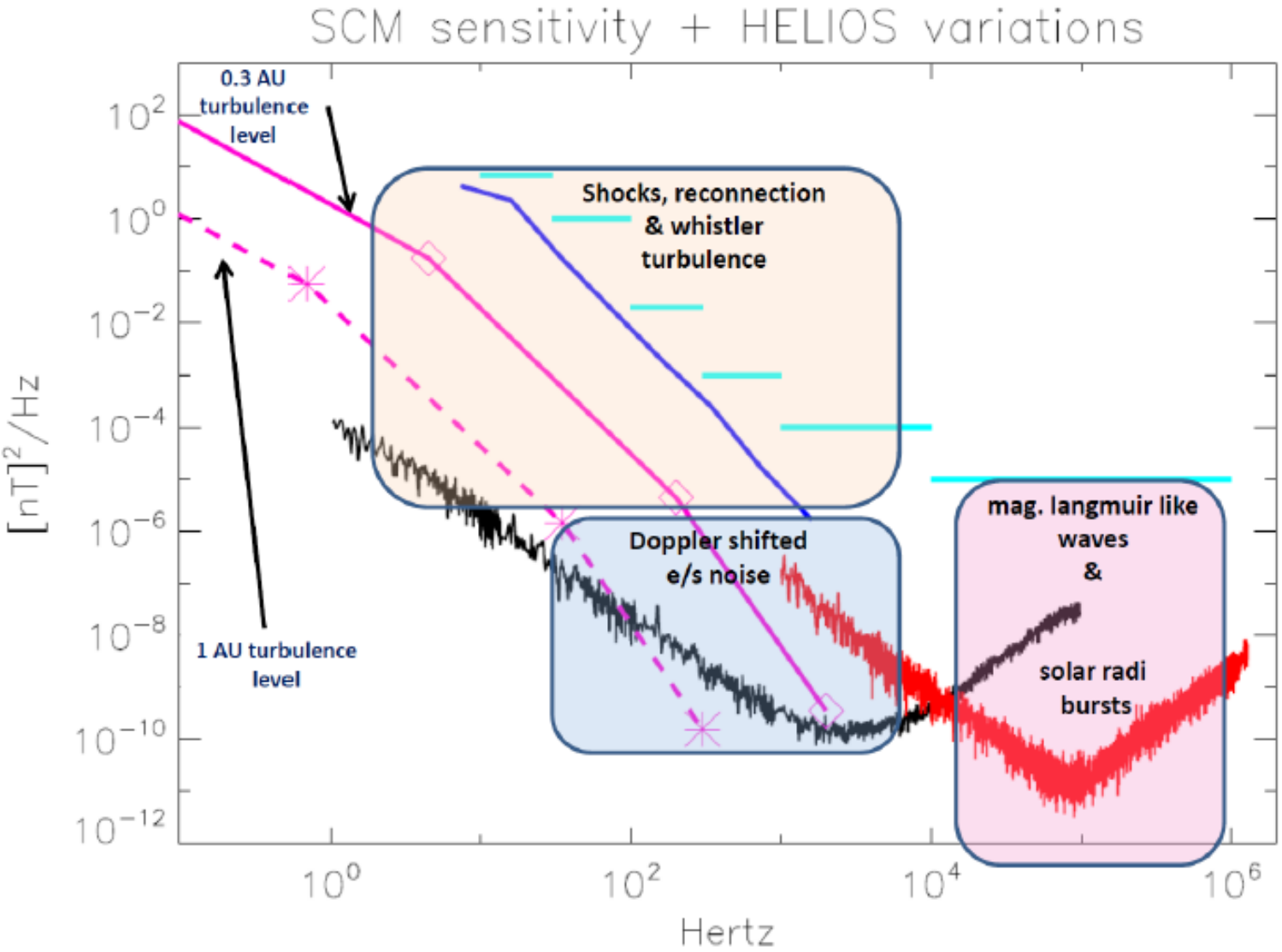
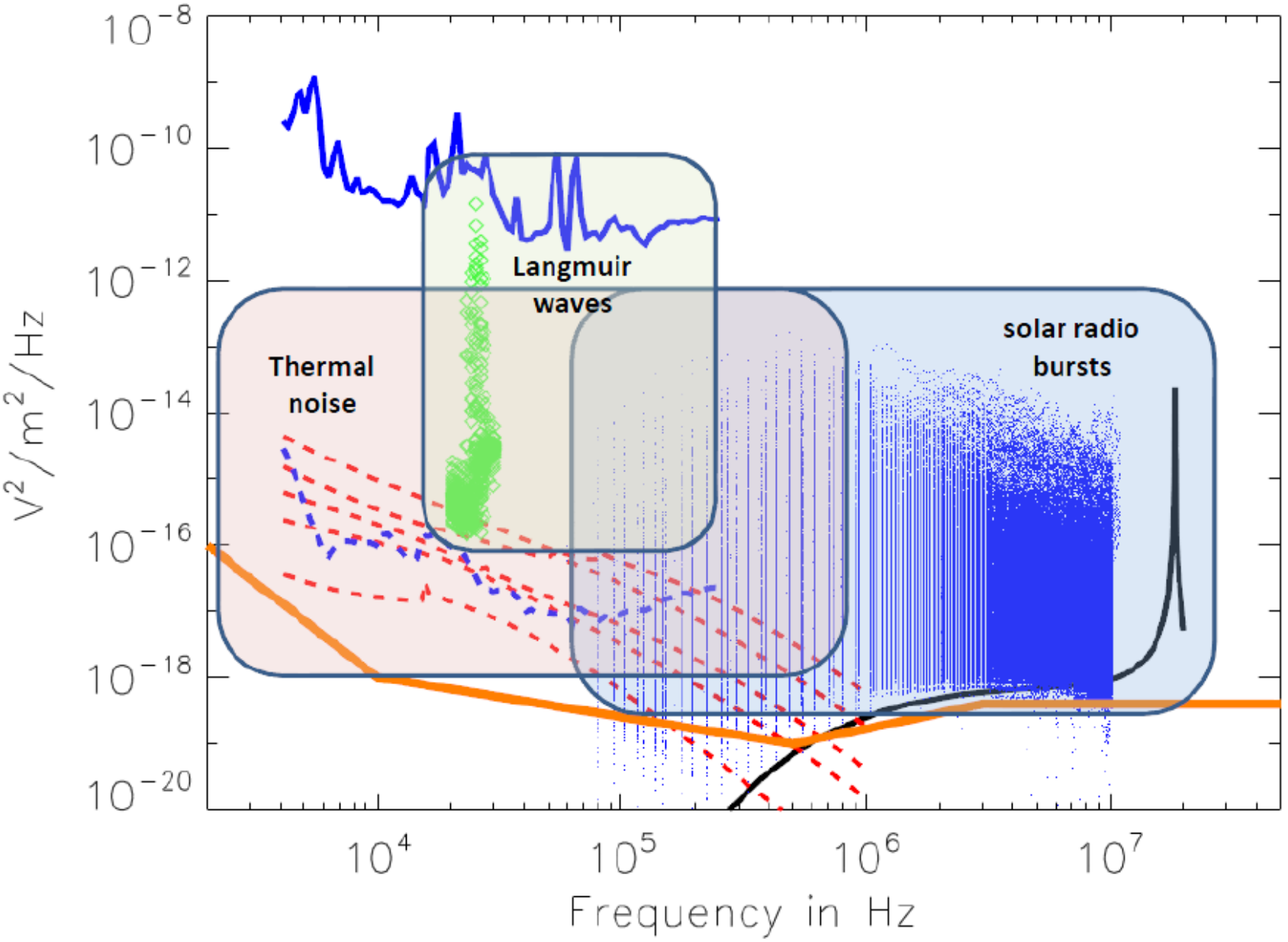
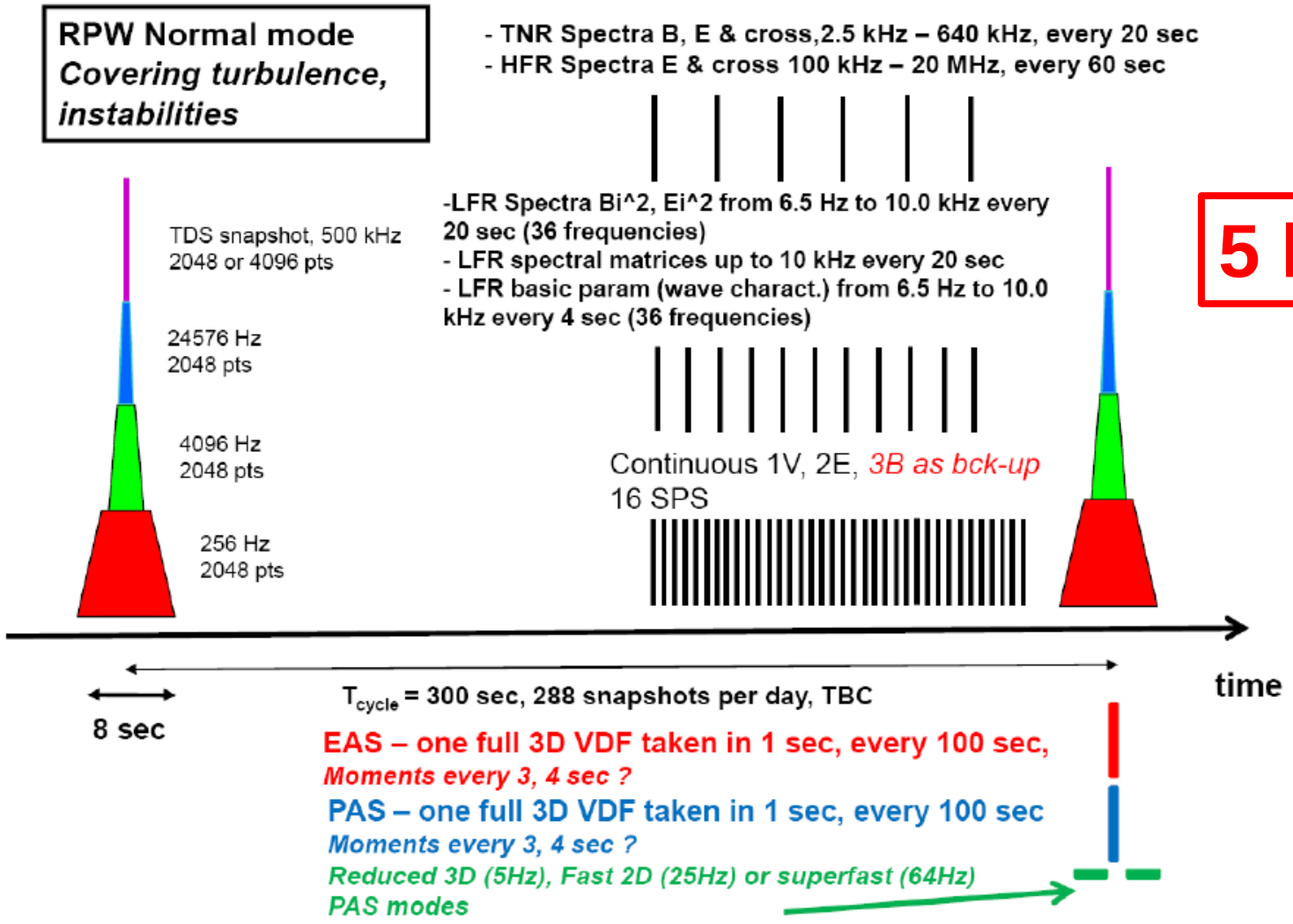


Figure 10: Magnetic field fluctuations of various natural phenomena that will be observed by the RPW instrument


10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{-16}
10^{-18}
10^{-20}
$V^2/m^2/Hz$
Langmuir waves
Thermal noise
solar radio bursts
10^4
10^5
10^6
10^7
Frequency in Hz

LFR Waveforms	LF E(1V+2E)	16 HZ	
	LF 3B 16Hz	16 HZ	Si MAG OFF
	LF E(1V+2E) + 3B	256 Hz	Burst mode
	LF E(1V+2E) + 3B	4 kHz	Burst mode
	LF E(1V+2E) + 3B	25 kHz	Burst mode
LFR basic param	set 1 : B^2 & E^2	4 sec	
	set 1 : wave norm vector	4 sec	
	set 1 : param ellipticity	4 sec	
	set 1 : deg of polarization	4 sec	
	set 1 : Poynting flux	4 sec	
	set 1 : Phase speed	4 sec	
LFR basic param	set 2 : spectral matrices Bi^2, Ei^2	20 sec	
	set 2 : spectral matrices	20 sec	
	LFR High res Full spec mat / Auto	3600 sec	
	LFR High res Full spec mat / Real	3600 sec	
	LFR High res Full spec mat / Im	3600 sec	
THR	TNR AGC	12 sec	
	TNR auto	12 sec	
	TNR cross	12 sec	
	HFR1 AGC	12 sec	
	HFR1 auto	12 sec	
	HFR2 AGC	12 sec	
	HFR2 auto	12 sec	
TDS	TDS regular snpashots	288	
	TDS triggered snapshots	60	Augmenté si Burst mode
	TDS statistics	ttes les 10 sec	
	TDS histograms 1D	ttes les 300 sec	
	TDS histograms 2D	ttes les 1800 sec	

RPW Normal/Survey Mode



RPW Selected Burst Mode 1 (SBM1)

Shock crossing (~10 to 13 min., 1/5days)

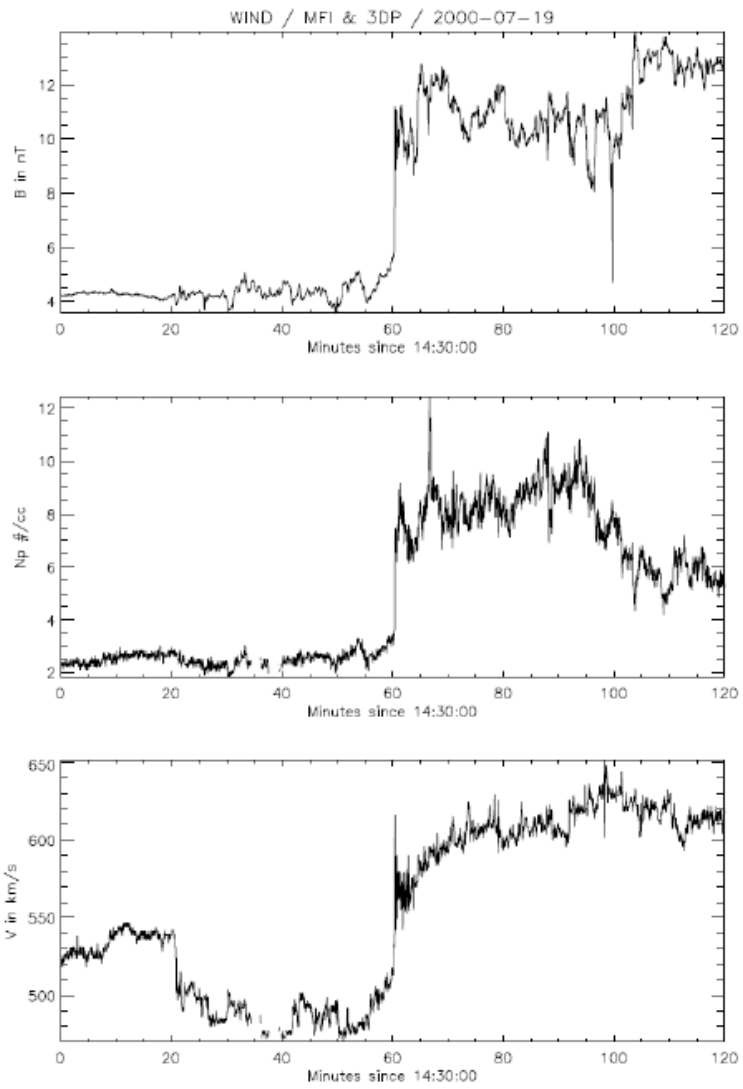
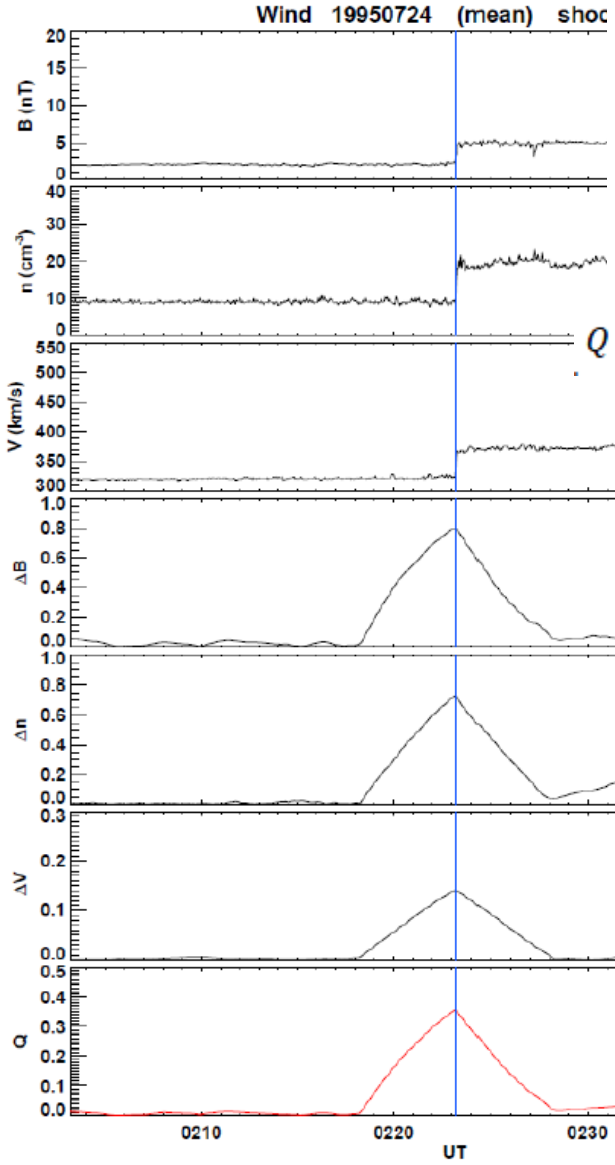


Figure 1 : Example of a quasi-perpendicular shock crossing by the WIND S/C.



$$\Delta B = \frac{2 \times |B_2 - B_1|}{B_1 + B_2}$$

$$\Delta Np = \frac{2 \times |Np_2 - Np_1|}{Np_1 + Np_2}$$

$$\Delta V = \frac{2 \times |V_2 - V_1|}{V_1 + V_2}$$

$$Q = \alpha \Delta B + \beta \Delta Np + \gamma \Delta V$$

$$\alpha + \beta + \gamma = 1$$

RPW Selected Burst Mode 2 (SBM2)

In-situ Type III (up to ~120 min., 100 to 150 total)

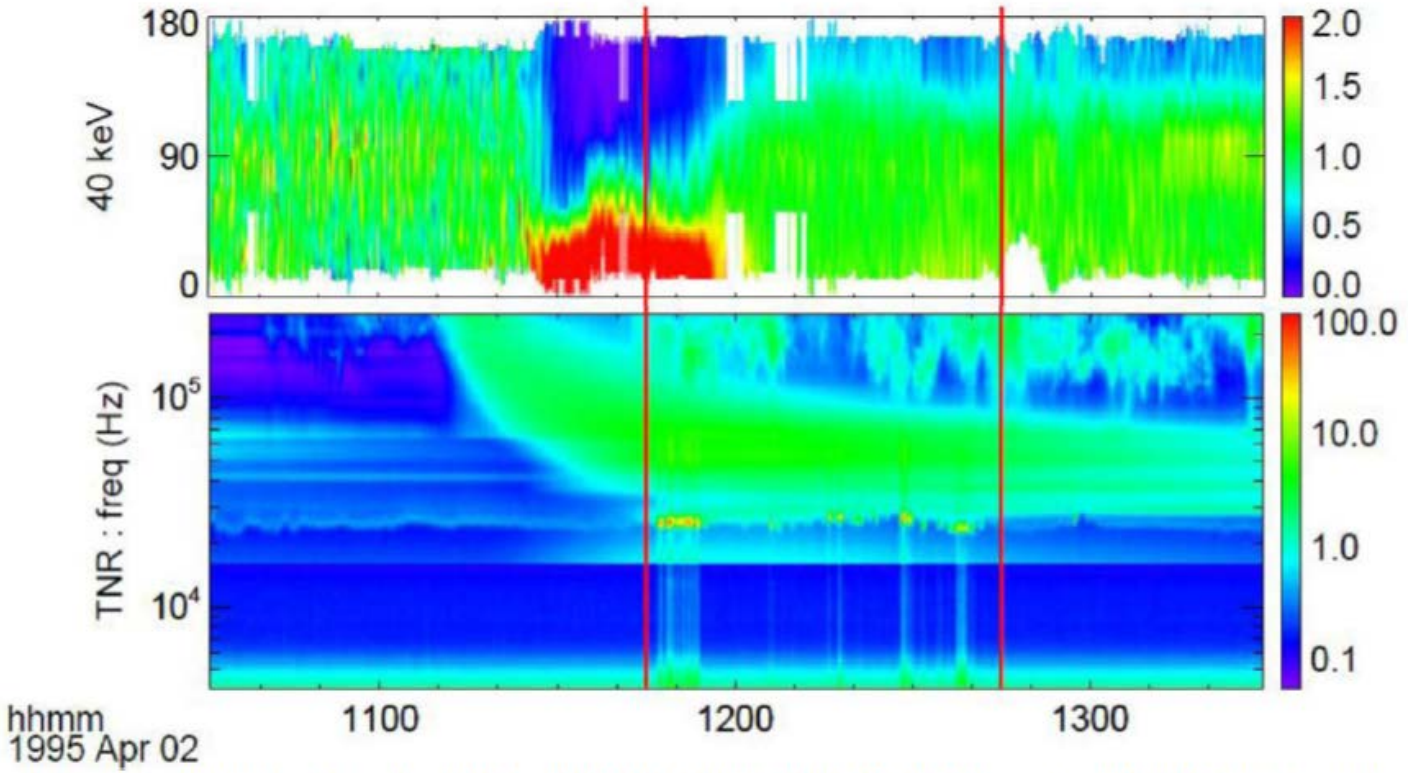


Figure 3 : Example of an in-situ Type III burst observed by the WIND spacecraft.The upper panel displays the anisotropy of the solar energetic electrons at 40 keV as a function of time and for different angles with respect to the mag field (between 0° & 180°). The red color corresponds to the anti-sunward electrons. The lower panel represents the TNR radio data of interest.

	L0 (at LESIA)	L1 (produced @ Lesia) *HK data produced at the same time*	L2 (to be delivered to ESAC? - TBC)	L3 (to be delivered to ESAC)
DESCRIPTION	Raw RPW data after MOC decommutation	RPW telemetry data (data sent internally to DPU) + absolute time of measurement + decompression Separate files for separate products	RPW data in Receivers & pre-amps calibrated units Separate files for separate products	RPW data in Physical units + sensor calibration
LFR		Waveform + other products in TM units Integers	mV, V^2/Hz	mV/m, nT nT^2/Hz
TDS		Waveform + other products in TM units Integers	mV	mV/m, nT
THR		AGC values (0-4096) Auto values integers	V^2/Hz	SFU (W/m^2/Hz) nT^2/Hz
BIAS		Bias current in TM units - TBC		

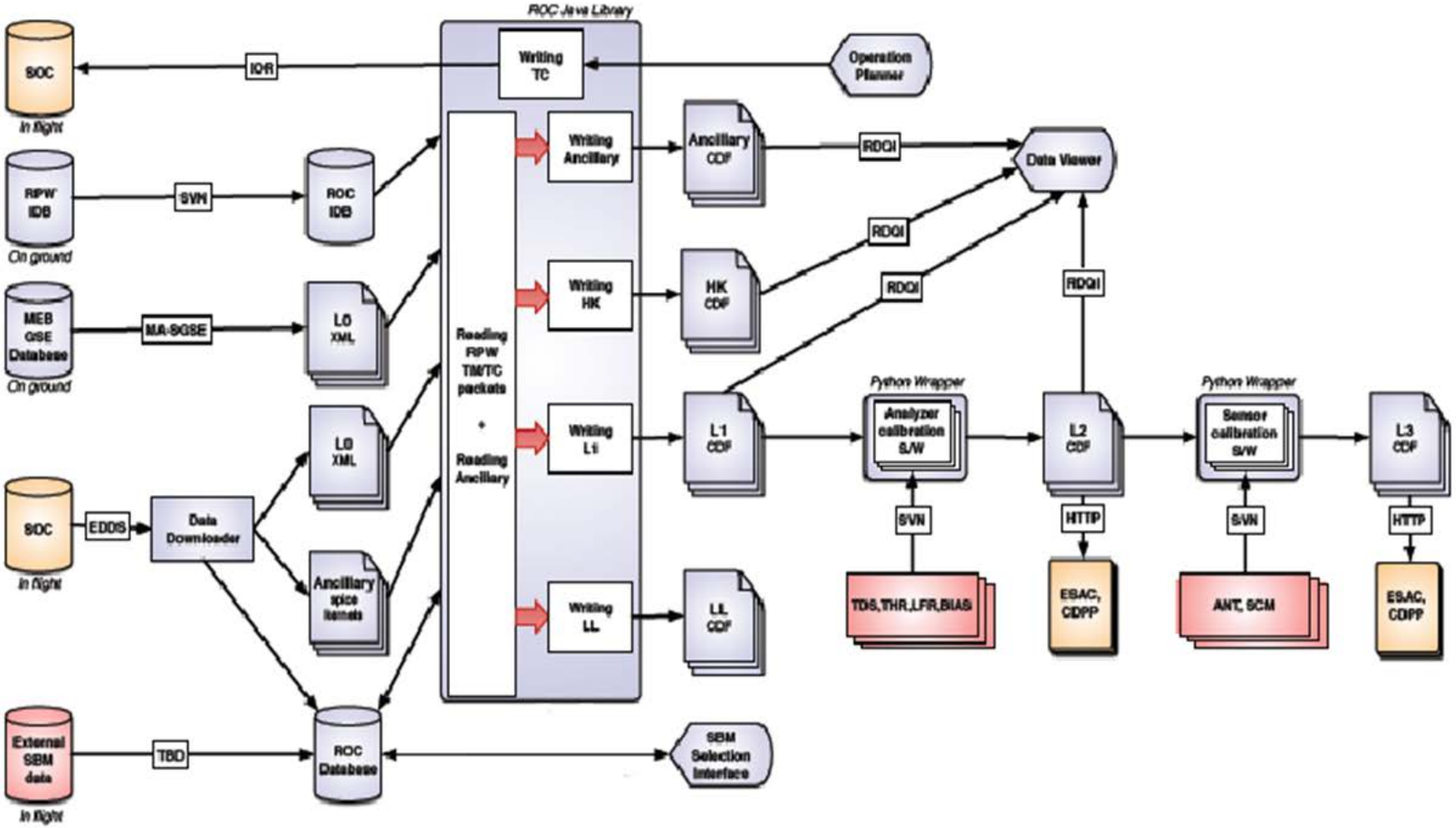
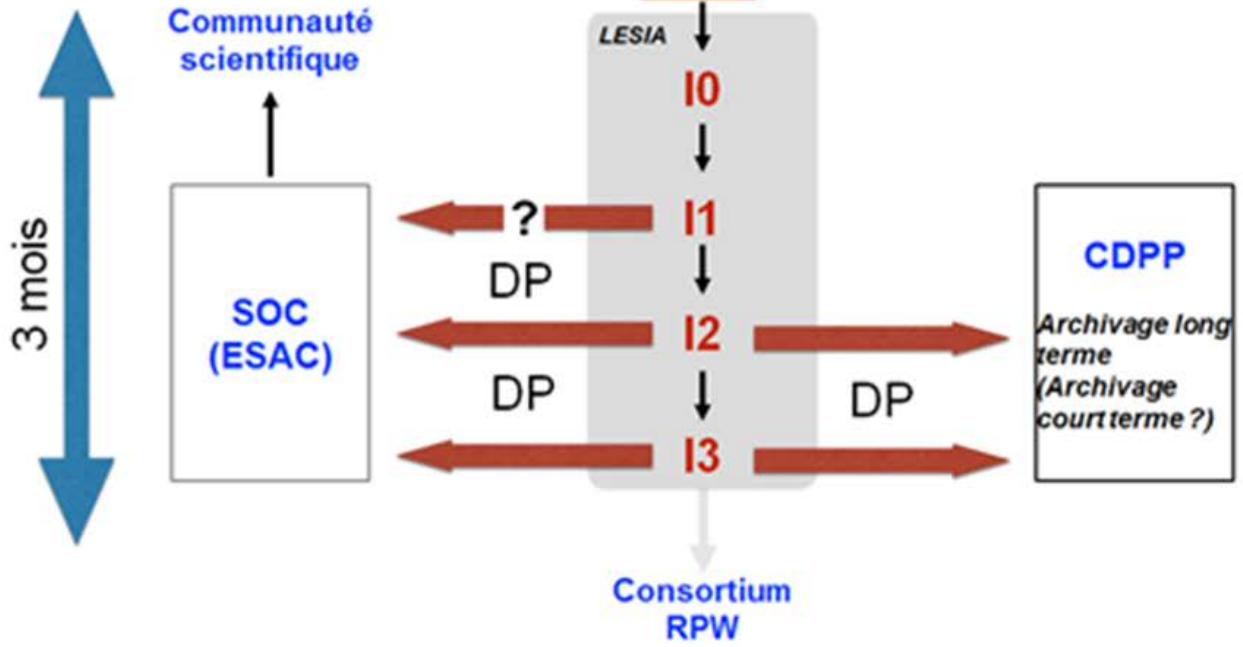


Fig 3. Chaîne de traitement complète des données RPW

La fourniture des données à l'ESAC, au Consortium RPW et à La communauté scientifique

Data Products (DP):

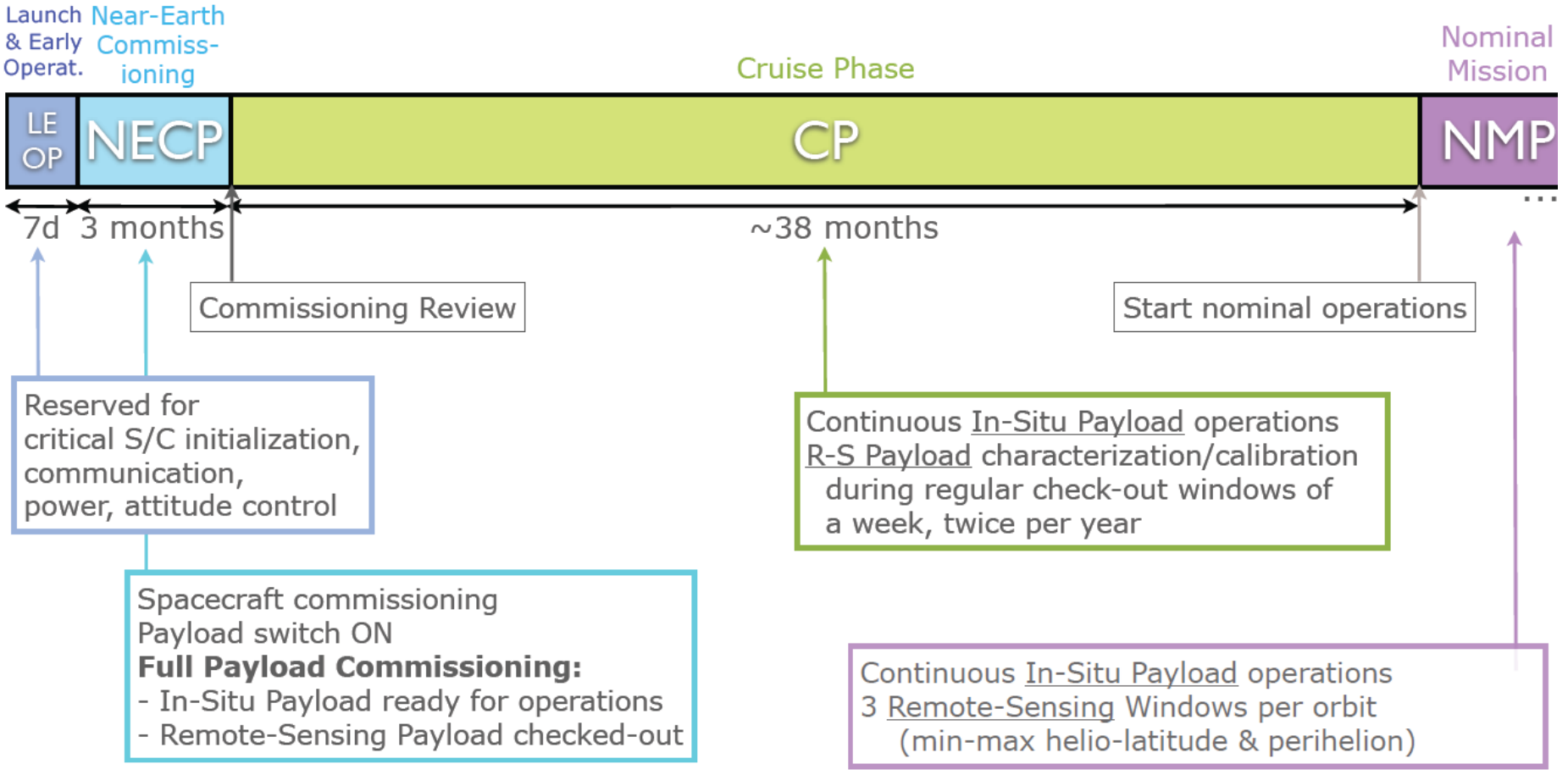
- *survey/sbm (CDF-ISTP)*
- *summary plots*
- *géométrie (antennes) (SPICE?)*



Recette en vol de RPW

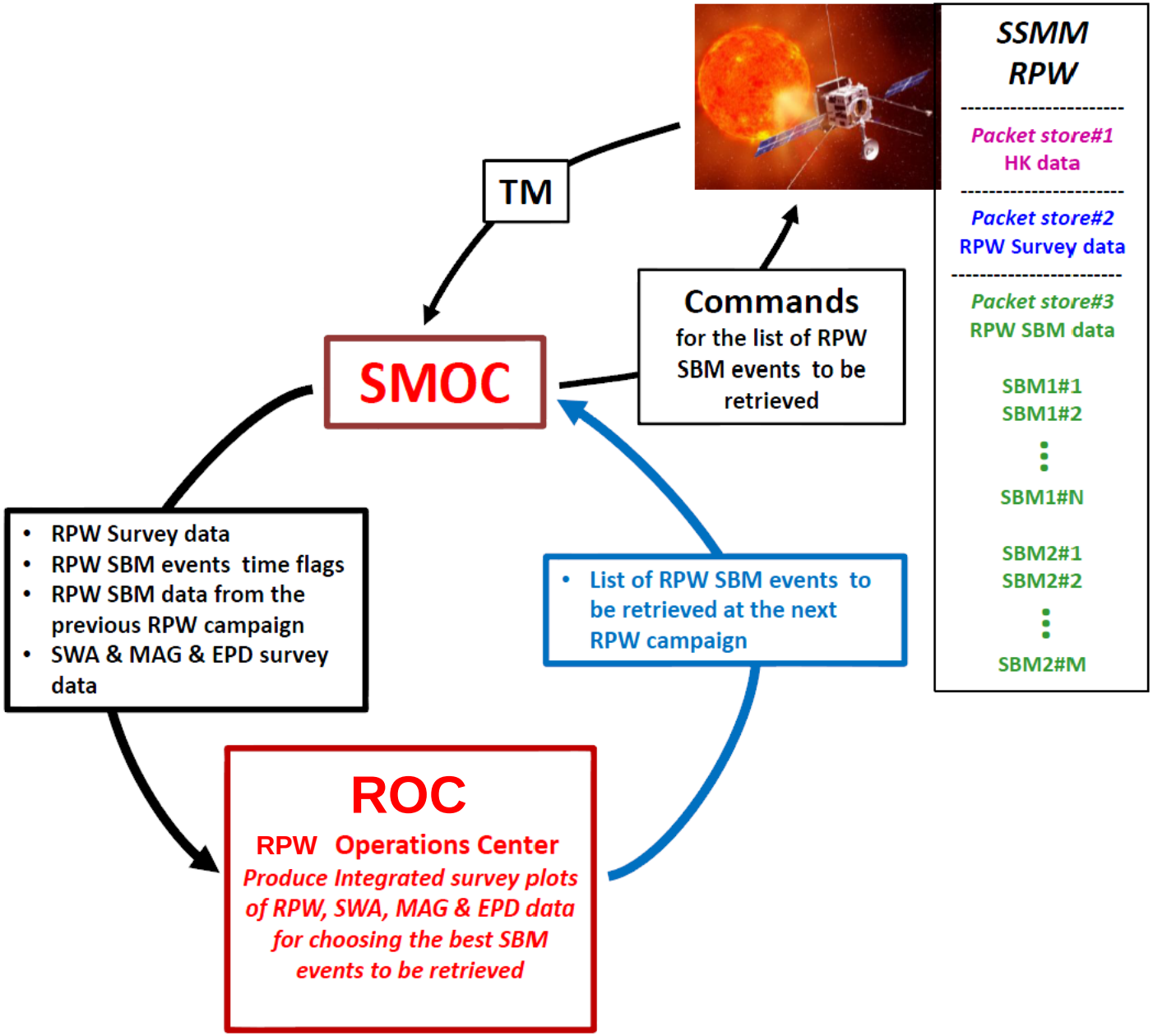
Commissioning/Calibration timeline

esa

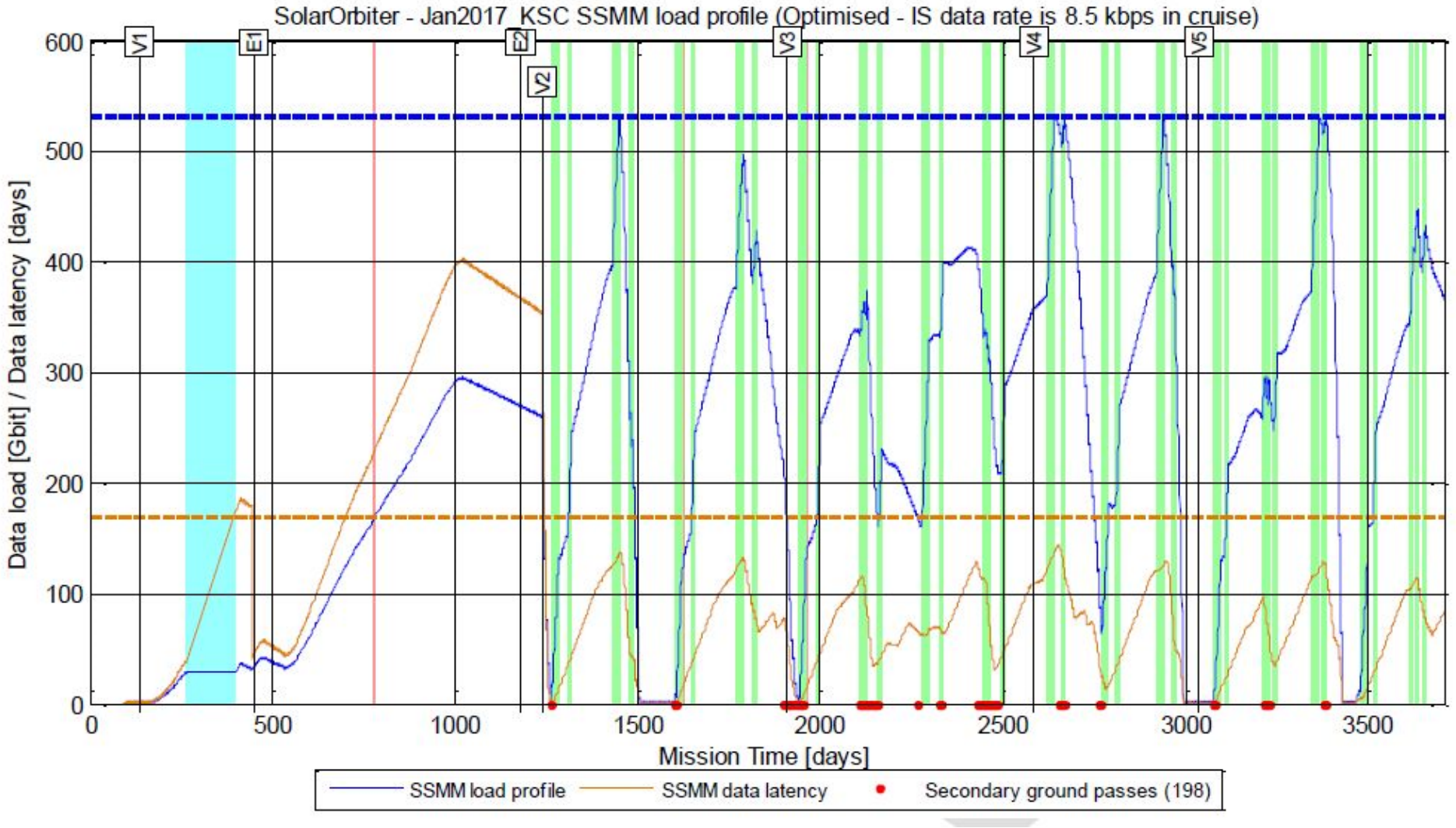


Opérations RPW

- Pendant le NECP
  - Deploiement des antennes
  - Déploiement du bras instrumental et mise en route du SCM
  - Campagne d'inter-compatibilité EMC
- Pendant la phase de croisière
  - Amélioration de l'étalonnage des antennes électriques
  - Finalisation des algorithmes de détection des évènements burst
  - Finalisation de l'étalonnage des récepteur
- Pendant la phase nominale
  - Gestion de l'état de santé de l'instrument
  - Gestion des évènements en burst mode


TM
SMOC
Commands
for the list of RPW SBM events to be retrieved
SSMM
RPW
Packet store#1
HK data
Packet store#2
RPW Survey data
Packet store#3
RPW SBM data
SBM1#1
SBM1#2
SBM1#N
SBM2#1
SBM2#2
SBM2#M
• RPW Survey data
• RPW SBM events time flags
• RPW SBM data from the previous RPW campaign
• SWA & MAG & EPD survey data
• List of RPW SBM events to be retrieved at the next RPW campaign
ROC
RPW Operations Center
Produce Integrated survey plots of RPW, SWA, MAG & EPD data for choosing the best SBM events to be retrieved

Profil de télémétrie et de charge du SSMM



Low latency data : flux radio à 1 MHz pour RPW