The Solar Orbiter RPW experiment: needs for spacecraft potential modelling

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- **The mission science objectives**
- **Needs for good 'DC' E-field measurements**
- **Simulation of the Antennas Radio pattern**
- **Background eVDFs**
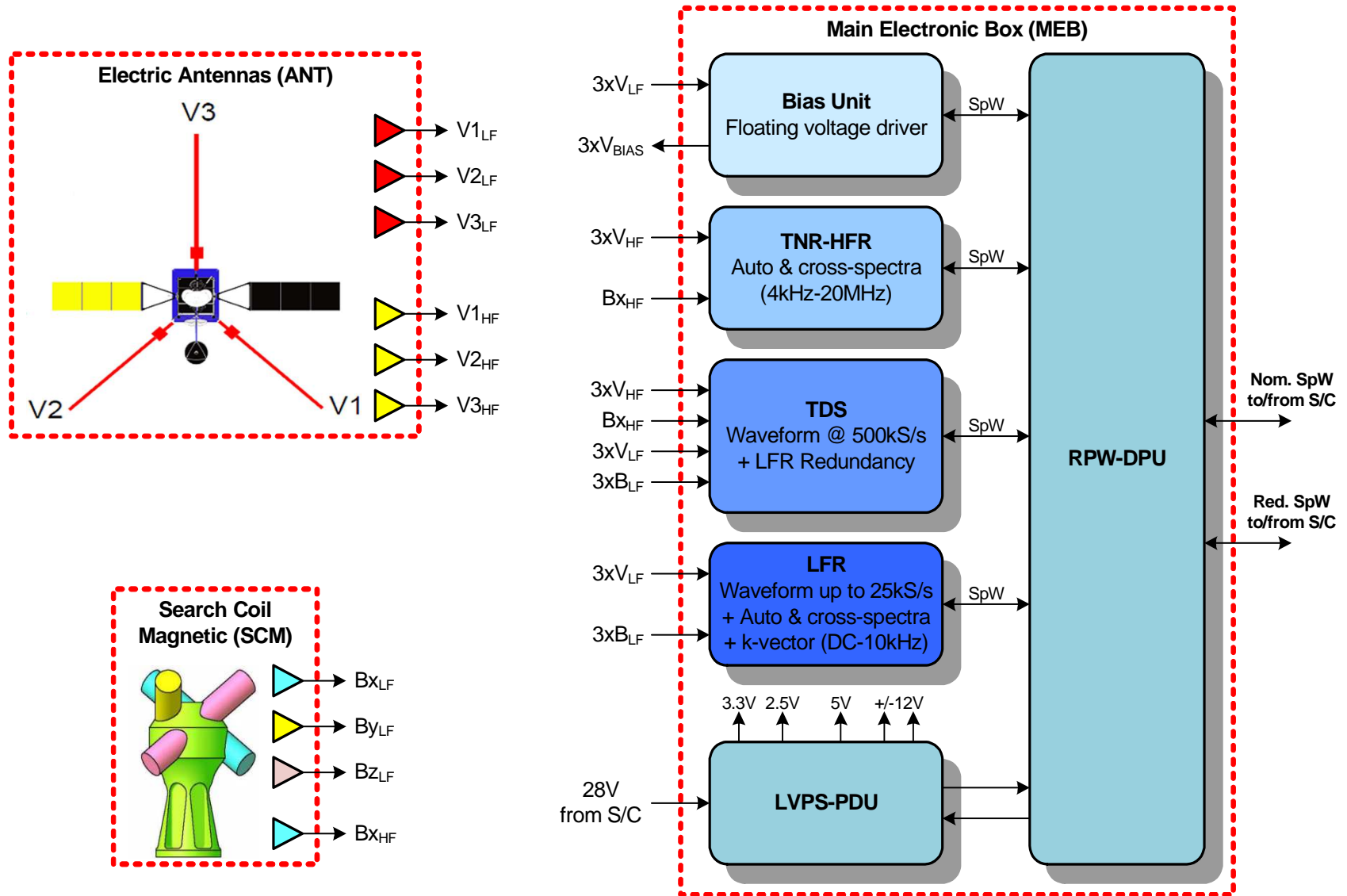- **Possible simulations for Dust/Spacecraft interactions**

SPINE XVII Workshop, Uppsala, 17-19/01/2011
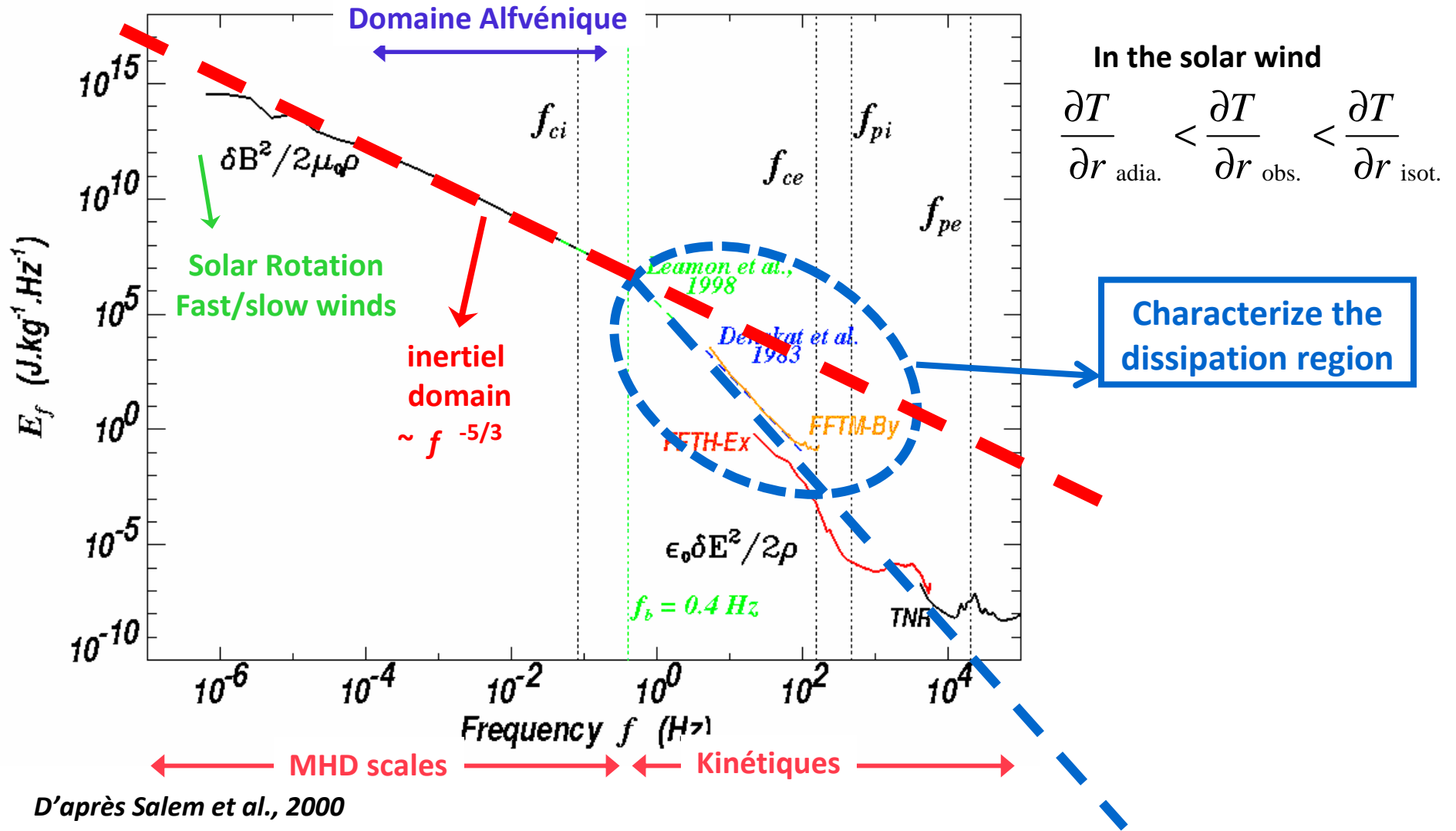
- ESA mission with NASA participation
- Up to 0.28 AU with dedicated in-situ & remote sensing instrumentation
- Out of ecliptic observations
- M-class ESA Cosmic Vision (2017)

> Moving parts (panels, High Gain antenna TBC)
> Thermal bending of antenna (<50cm at the tip)
> Thermal environment : up to 10 Solar constants (SPP up to 500) → include thermionic emission ?

Instrument block Diagram

Electric Antennas (ANT)

V3

V1

V2

$V1_{LF}$
$V2_{LF}$
$V3_{LF}$

$V1_{HF}$
$V2_{HF}$
$V3_{HF}$

Search Coil Magnetic (SCM)

Bx_{LF}
By_{LF}
Bz_{LF}
Bx_{HF}

Main Electronic Box (MEB)

$3xV_{LF}$ →
$3xV_{BIAS}$ ←

Bias Unit
Floating voltage driver

SpW ↔

$3xV_{HF}$ →
Bx_{HF} →

TNR-HFR
Auto & cross-spectra
(4kHz-20MHz)

SpW ↔

$3xV_{HF}$ →
Bx_{HF} →
$3xV_{LF}$ →
$3xB_{LF}$ →

TDS
Waveform @ 500kS/s
+ LFR Redundancy

SpW ↔

$3xV_{LF}$ →
$3xB_{LF}$ →

LFR
Waveform up to 25kS/s
+ Auto & cross-spectra
+ k-vector (DC-10kHz)

SpW ↔

RPW-DPU

Nom. SpW to/from S/C

Red. SpW to/from S/C

3.3V   2.5V   5V   +/-12V

28V
from S/C →

LVPS-PDU

Need for good 'DC' E-field measurements

Domaine Alfvénique

f_{ci}

f_{pi}

f_{ce}

f_{pe}

E_f $(J.kg^{-1}.Hz^{-1})$

$\delta B^2/2\mu_0\rho$

Solar Rotation
Fast/slow winds

inertiel
domain
$\sim f^{-5/3}$

Leamon et al., 1998

Derobat et al. 1983

FFTM-By

FFTH-Ex

$\epsilon_0\delta E^2/2\rho$

$f_b = 0.4\ Hz$

TNR

Frequency f (Hz)

MHD scales

Kinétiques

In the solar wind

$$\frac{\partial T}{\partial r}_{\text{adia.}} < \frac{\partial T}{\partial r}_{\text{obs.}} < \frac{\partial T}{\partial r}_{\text{isot.}}$$

Characterize the dissipation region

D'après Salem et al., 2000

Need to observe electric field associated to Alfvénic fluctuations...

Poynting flux $S = \delta E \times \delta B/\mu_0$

Courtesy S. Bale

Cluster measurements of the E field of solar wind turbulence show that:

1. The cascade is Alfénic, E & B strongly correlated
2. Short λ E field power is enhanced
3. E/B ratio is consisyent with Alfénic inertial range and evolution to KAW at short λ
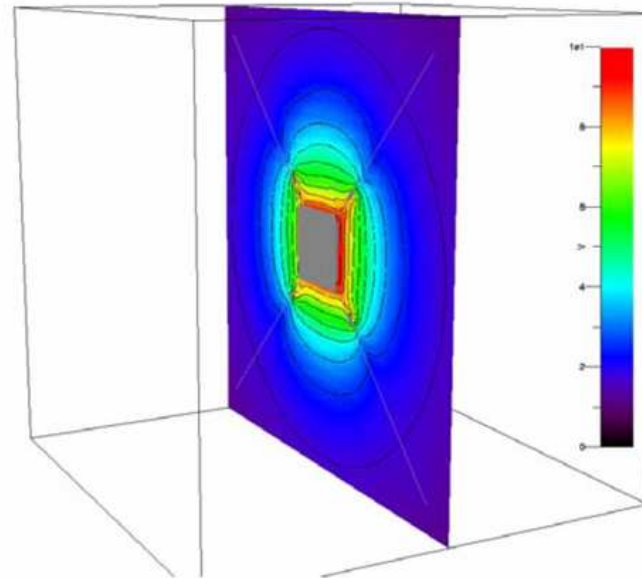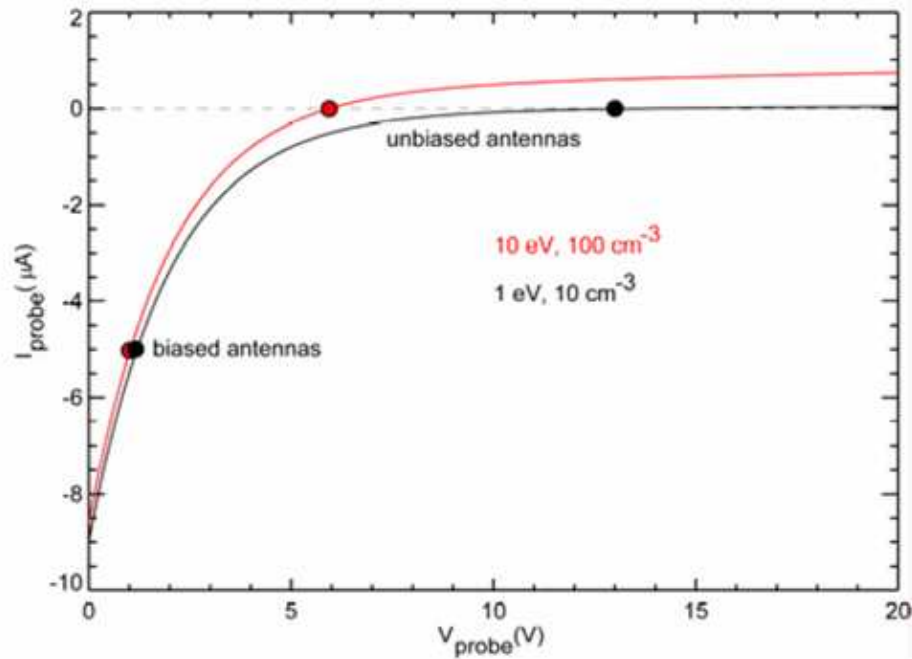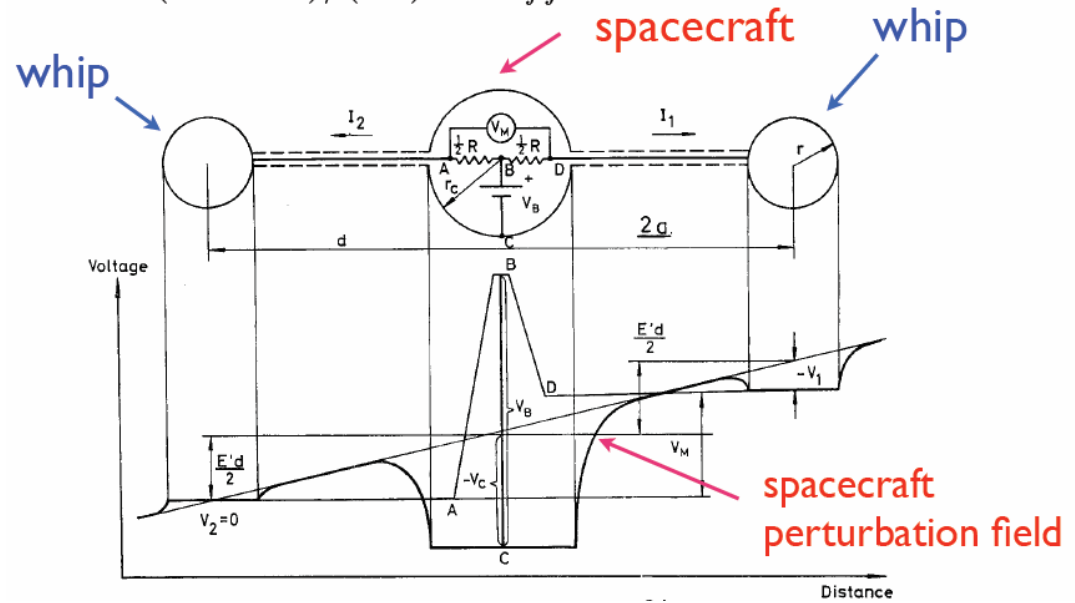4. Density (S/C pot.) spectrum is $k^{-5/3}$
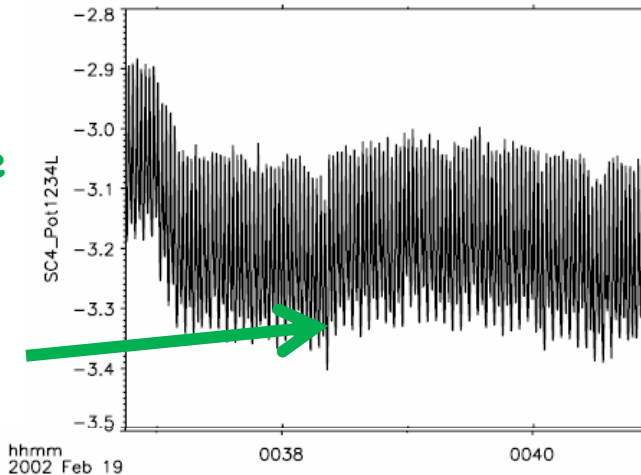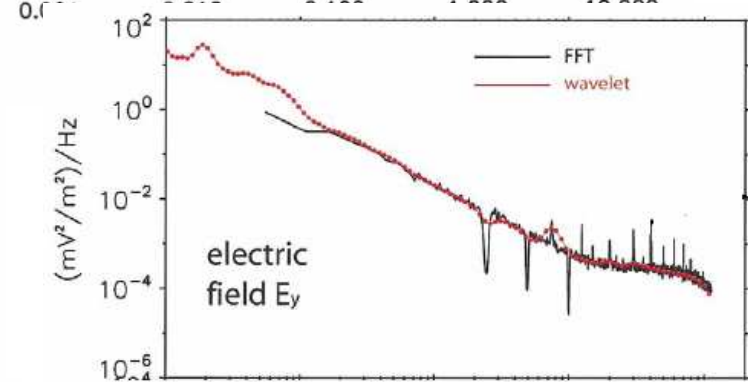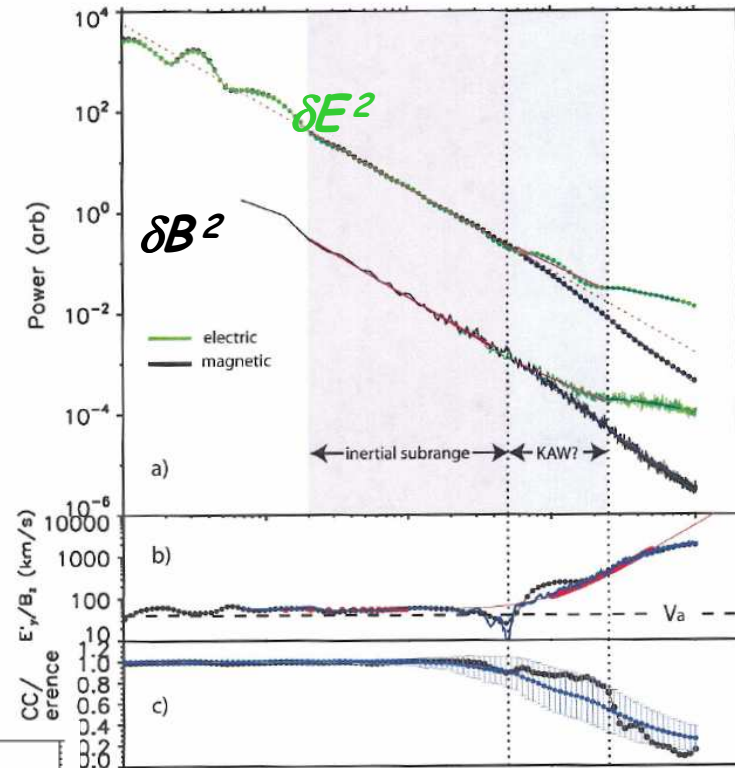
Measurements not easy because of S/C charging

Spin tone in the raw E data

Initial simulations by C. Cully

$$E_{12} = (V_1 - V_2)/(2L) + E_{offset}$$

Simulation of the Antennas Radio pattern (H. Rucker, Gräz)

Bending 0.5 m, no shift

	Open feeds			Base cap. 70pF		
	Length/ m	Theta/°	Phi/°	Length/ m	Theta/°	Phi/°
A1	4.25	81.9	0.1	1.75	83.3	0.1
A2	4.20	81.2	-128.5	1.71	82.4	-127.7
A3	4.20	80.2	128.3	1.71	82.4	127.8

Solar Orbiter

ANT1 h_eff
no shift of footpoint

Wiregrid/patchgrid simulations

Z-Axis

Y-Axis

X-Axis
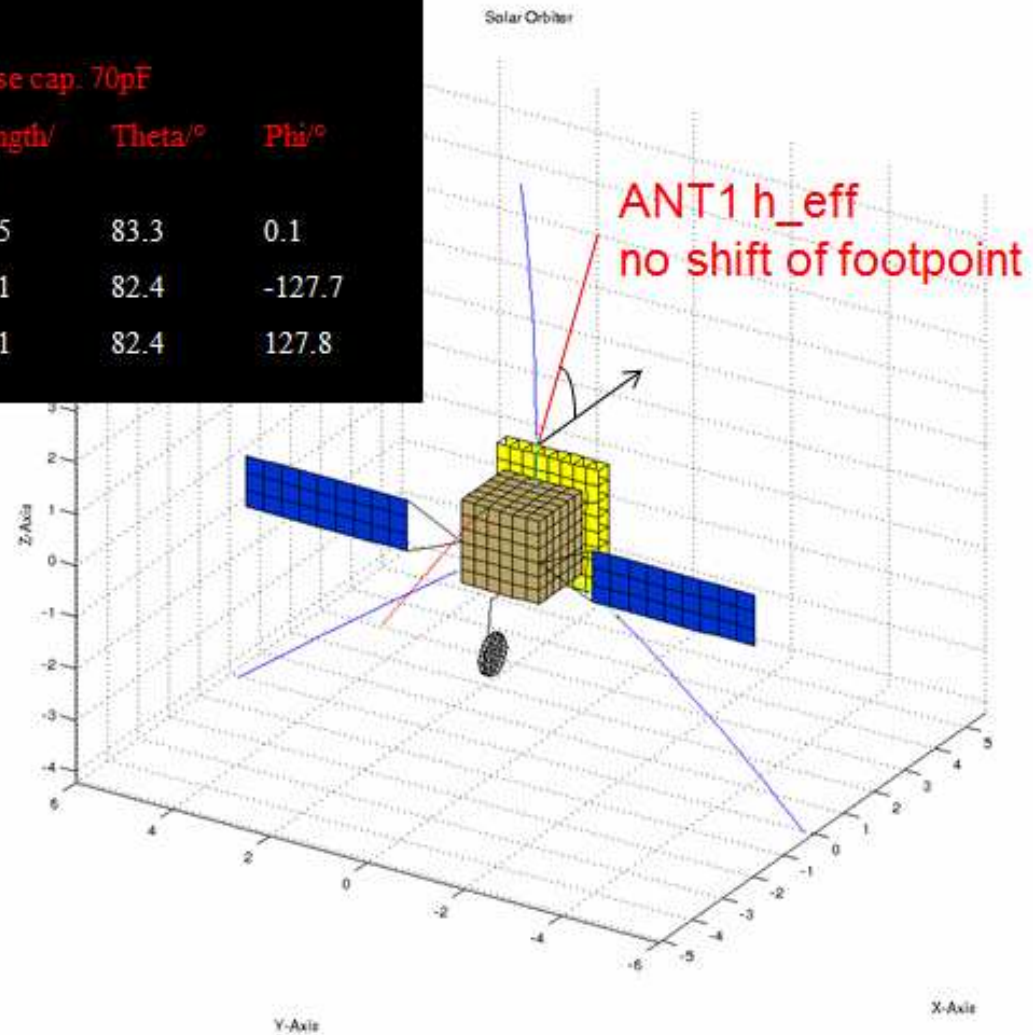
Needs for good modeling of the ambient electrons in the Solar Wind

Radial evolution of electron distribution functions
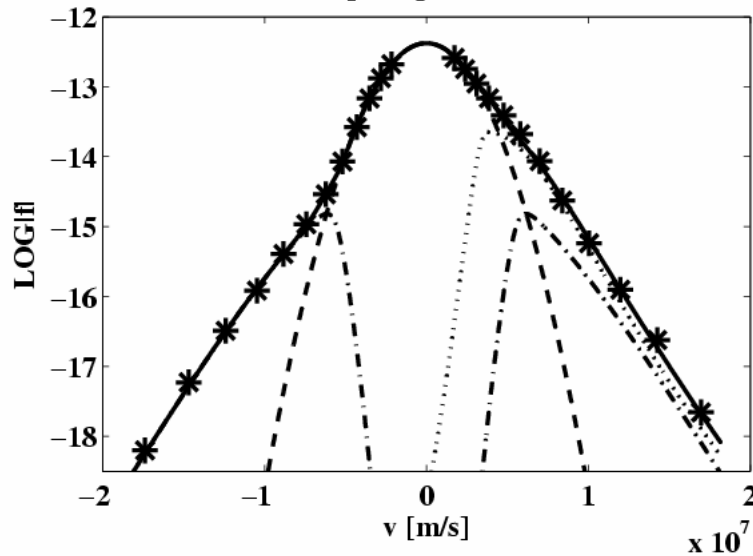## Stverak et al., JGR, 2009
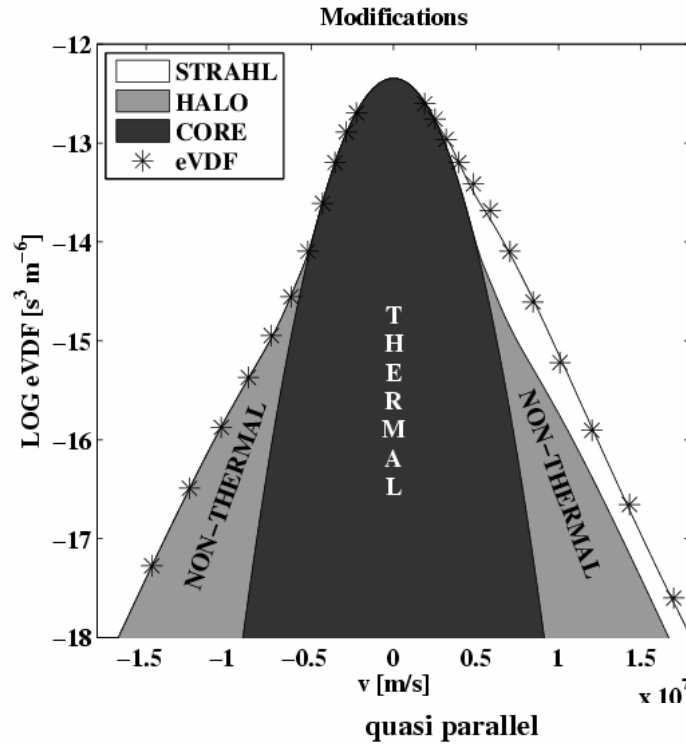
Core : bi-Maxwellian * flat-top

$$f_c = A_c \exp\left[-\frac{m}{2k}\left(\frac{1}{T_{c\perp}}v_\perp^2 + \frac{1}{T_{c\parallel}}(v_\parallel - \Delta_c)^2\right)\right],$$

Halo : bi- Kappa * (1-flat-top)

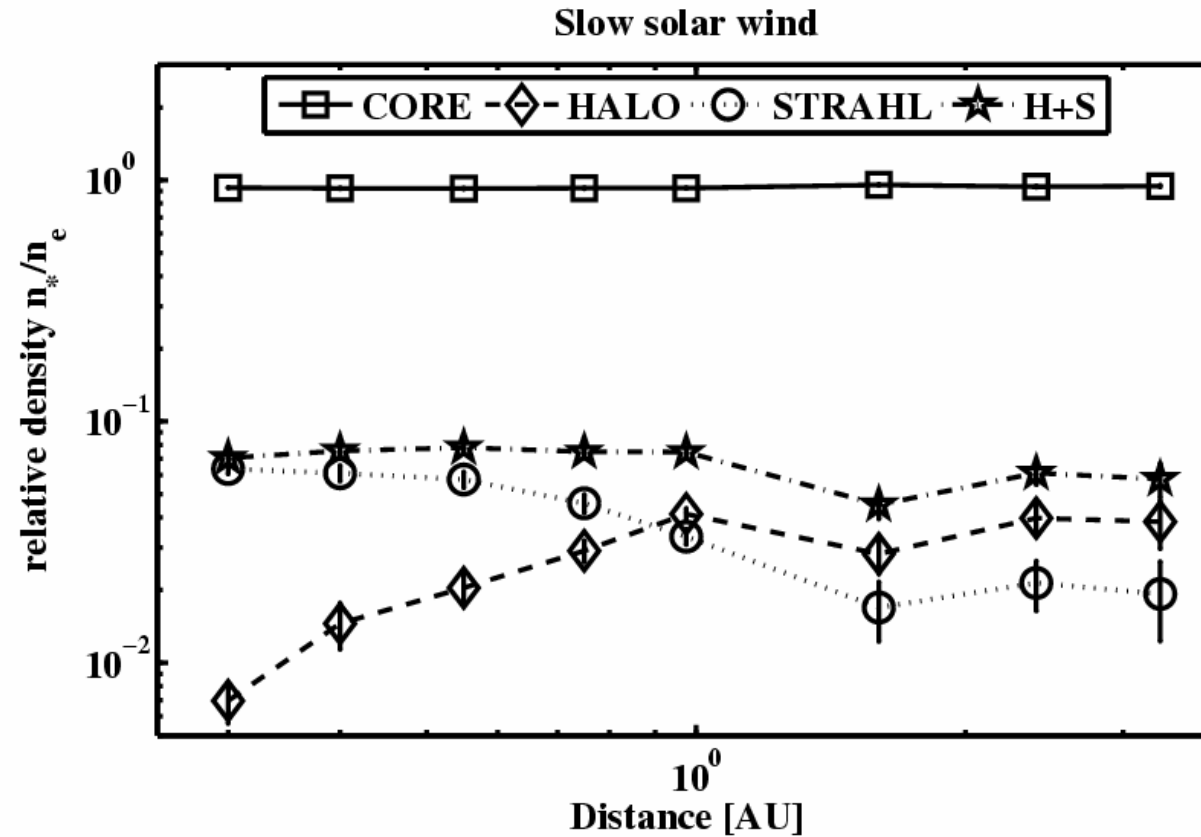$$f_{h,\kappa} = A_h\left(1 + \frac{m}{k(2\kappa_h - 3)}\left(\frac{v_\perp^2}{T_{h\perp}} + \frac{v_\parallel^2}{T_{h\parallel}}\right)\right)^{-\kappa_h - 1},$$

Strahl : bi- Kappa * (1-flat-top) from antisunward dir.

$$f_s = A_s\left(1 + \frac{m}{k(2\kappa_s - 3)}\left(\frac{v_\perp^2}{T_{s\perp}} + D\frac{(v_\parallel - \Delta_s)^2}{T_{s\parallel}}\right)\right)^{-\kappa_s - 1}$$
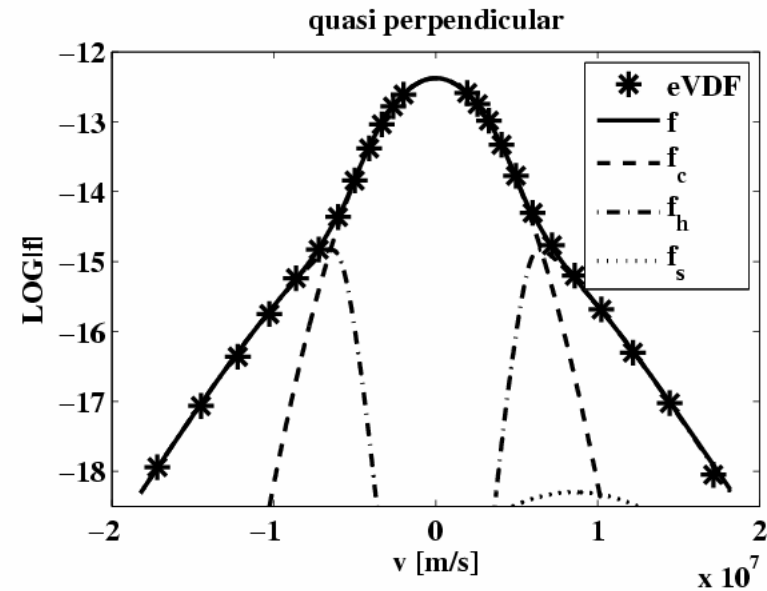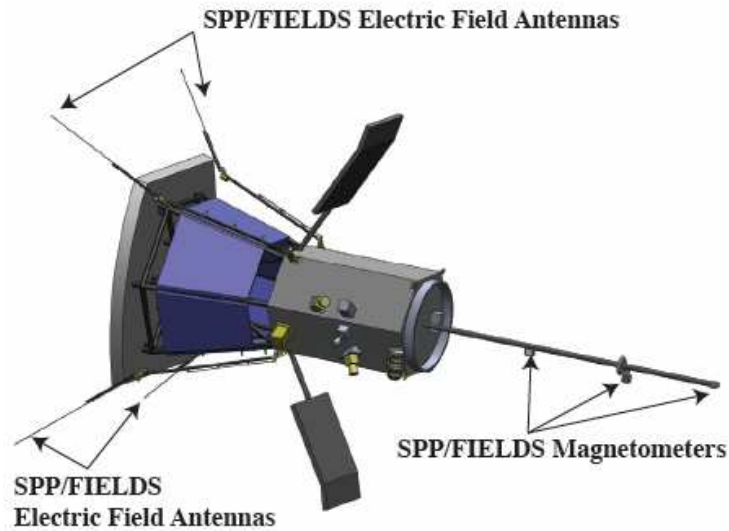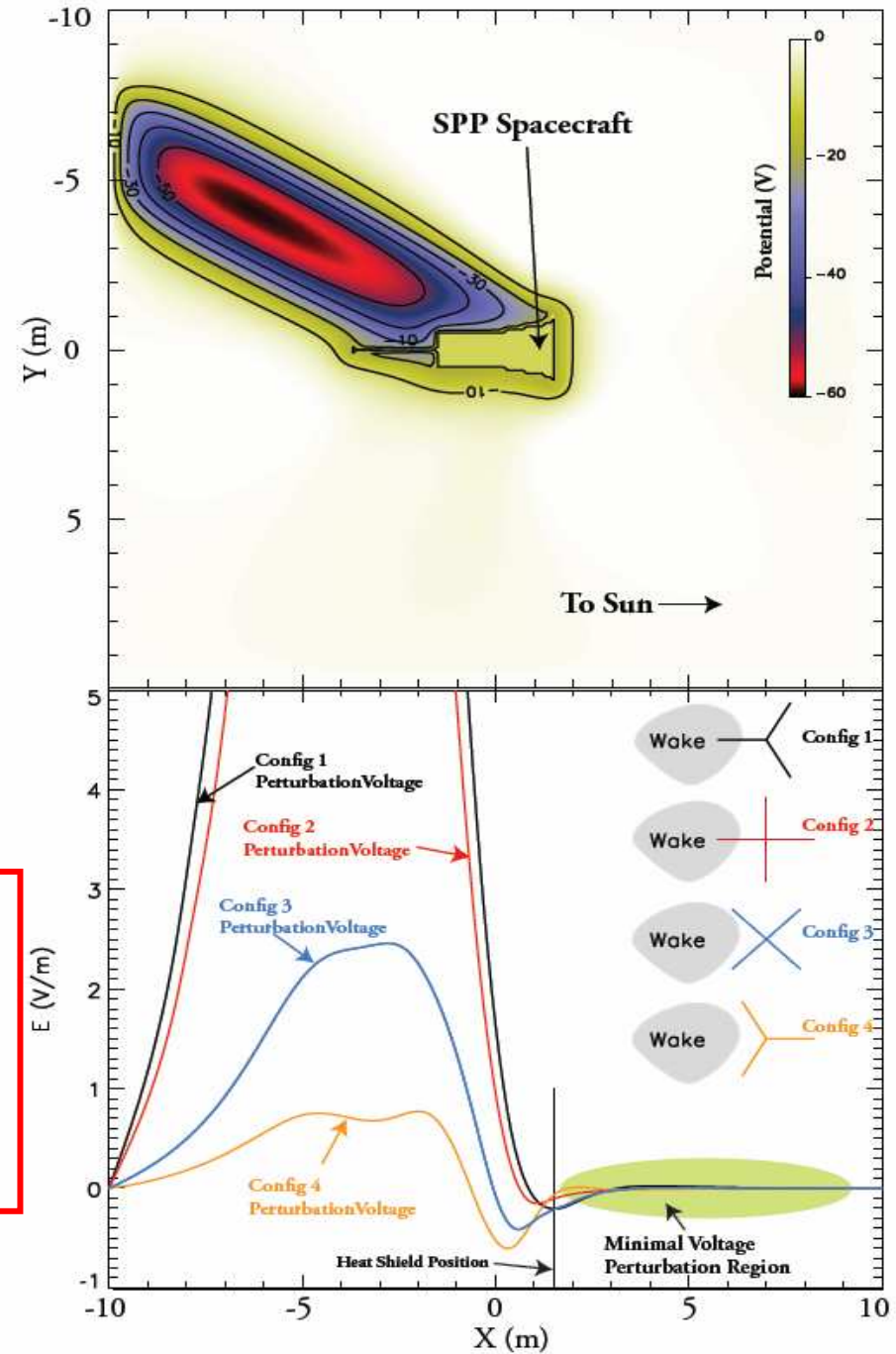
Helios, Cluster, Ulysses

Slow solar wind

Strahl is transformed into halo with distance
by particle/wave interactions ?

Impact for SPIS of a beamed suprathermal population
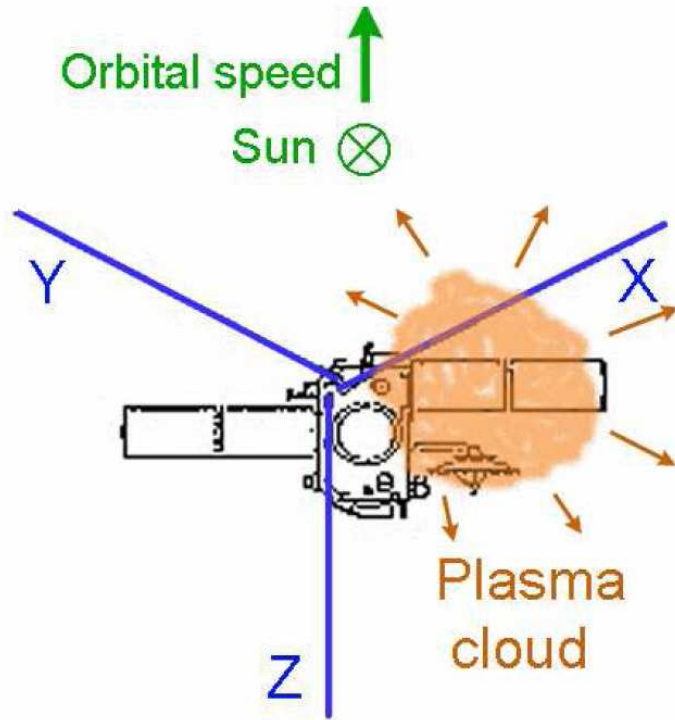instead of an isotropic one ?

Solar Probe Plus, Ergun et al, 2010

- **Need to confirm these results with SPIS**
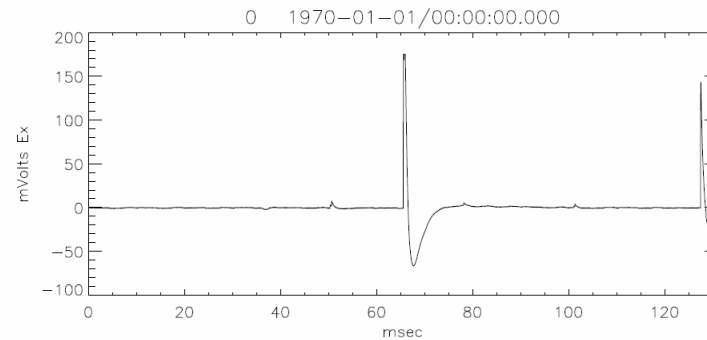- **At which heliocentric distance does the S/C pot. become < 0 ?**

Possible simulations for Dust/Spacecraft interactions

Orbital speed

Sun ⊗

Y

X

Z

Plasma cloud

What is exactly the interaction Plasma cloud / ambient plasma / spacecraft ?

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

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

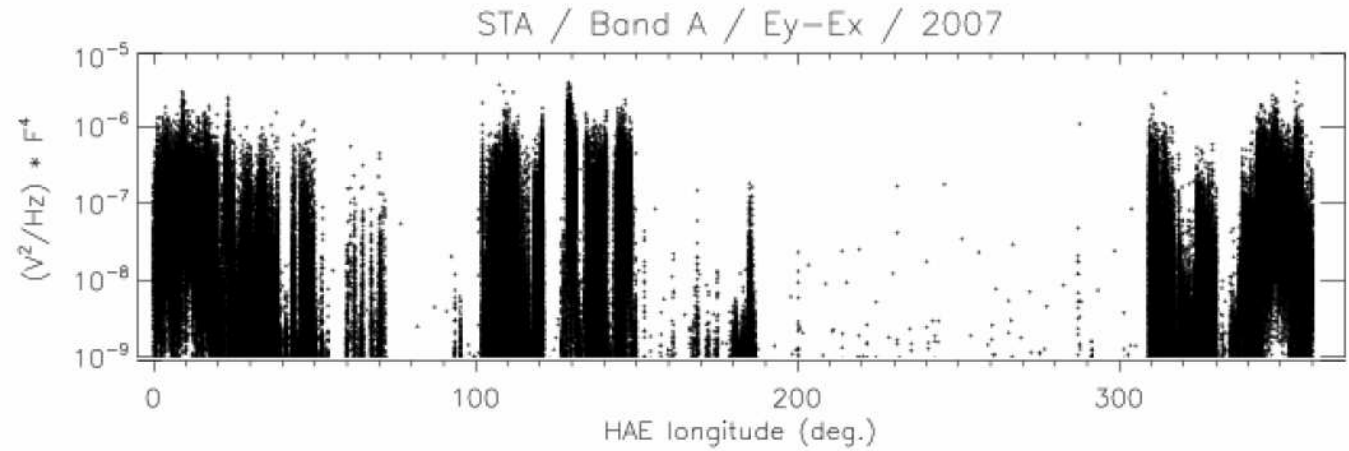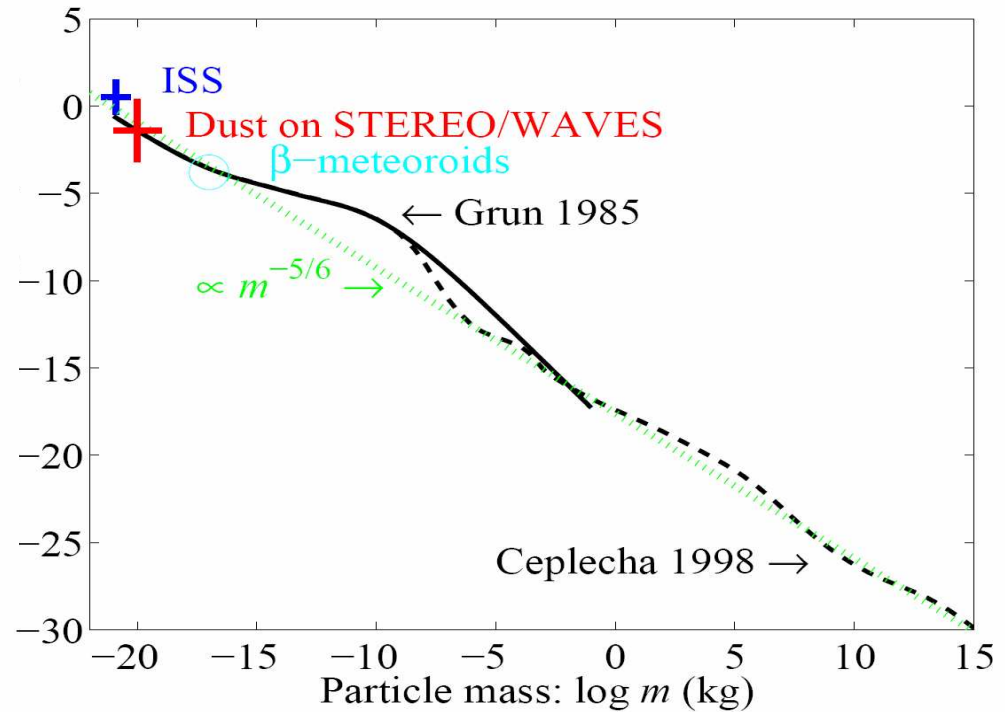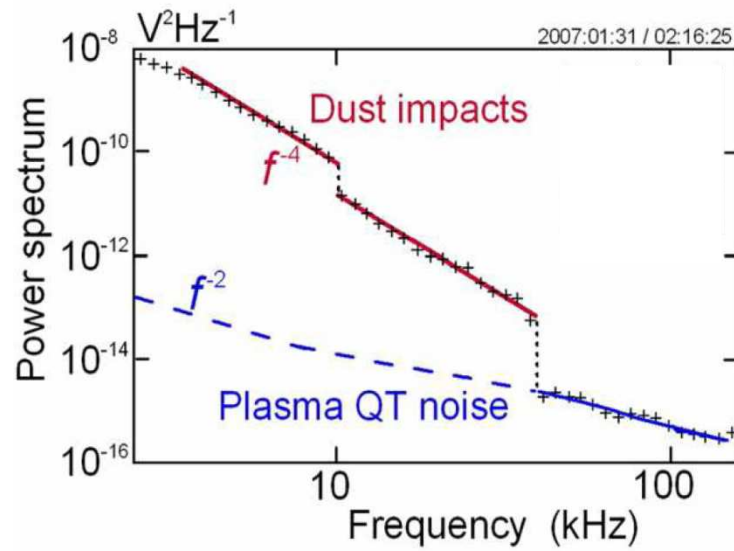**Very large flux on Stereo**

$\rightarrow$ *A nanoparticle @ 300 km/s* $\sim$ *a grain of mass 10^4 greater @ 20 km/s*

Picked-up by the -VXB field

Figure 3. Average power observed by the STEREO/WAVES low frequency receiver (normalised to f_{kHz}^4 and integrated in the lower band) on STEREO A as a function of ecliptic longitude in 2007.

Requirements for SPIS Simulations

- VxB field
- Moving solar panels, High Gain antenna (TBC)
- Antenna bending
- Thrusters (talk by Volodya)
- Taking into account the observed shape of e VDFs
- Interaction Plasma cloud / ambient plasma / spacecraft

Suggestion : set rapidly a specific SPINE Working Group for solar Orbiter (RPW, SWA, SPIS)