Removing system noise from the STEREO magnetometer data

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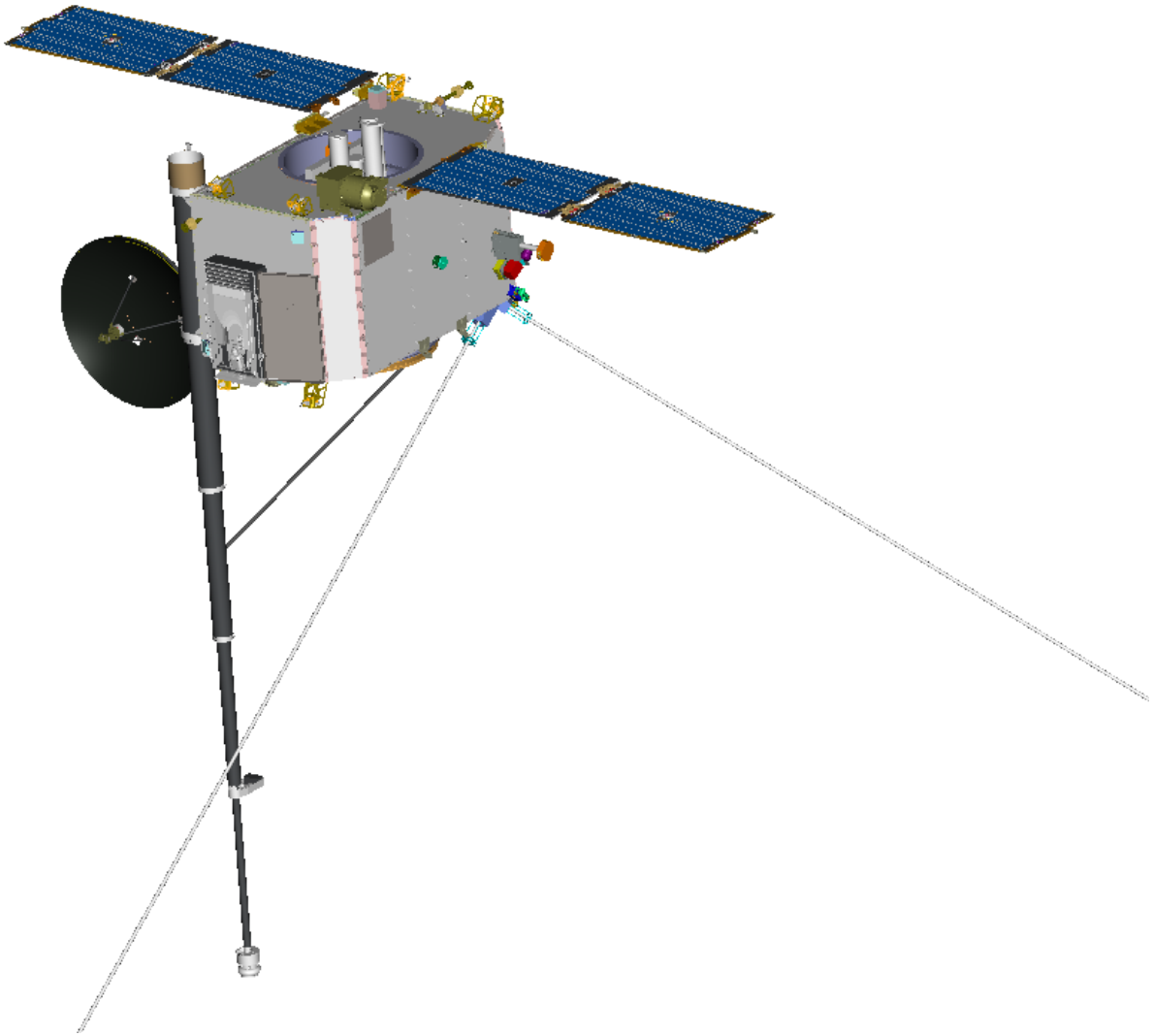
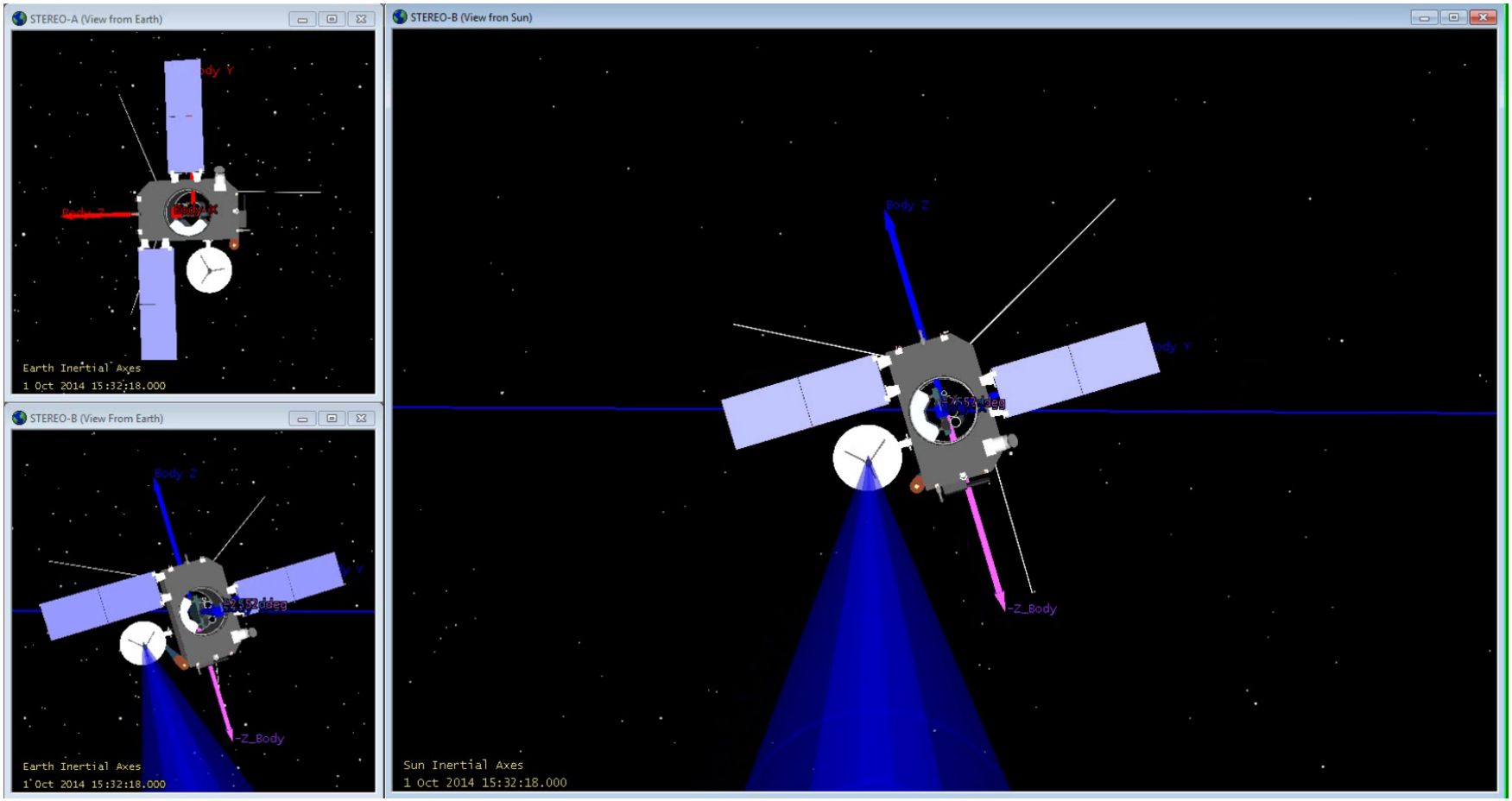
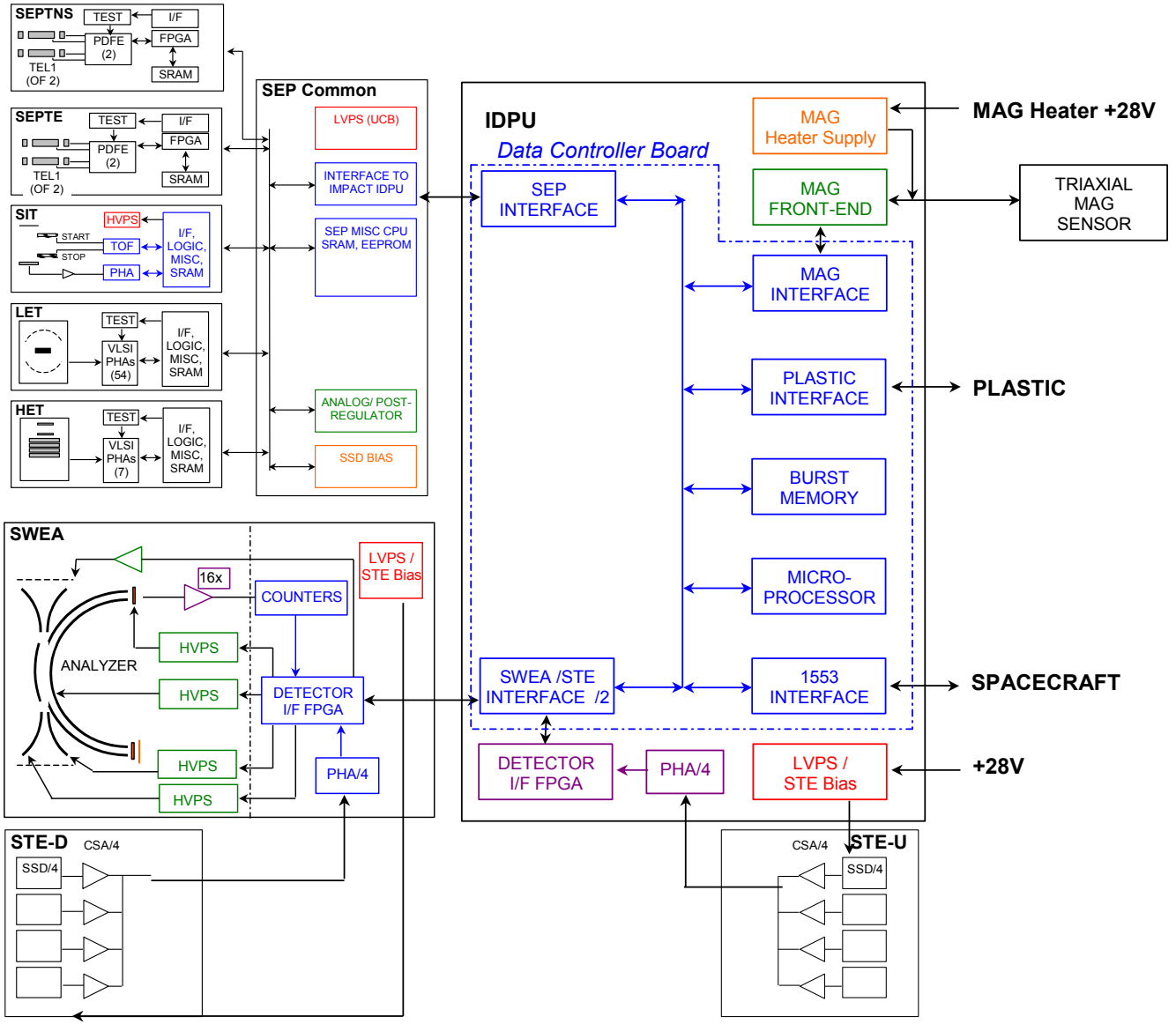
STEREO spacecraft (x2)



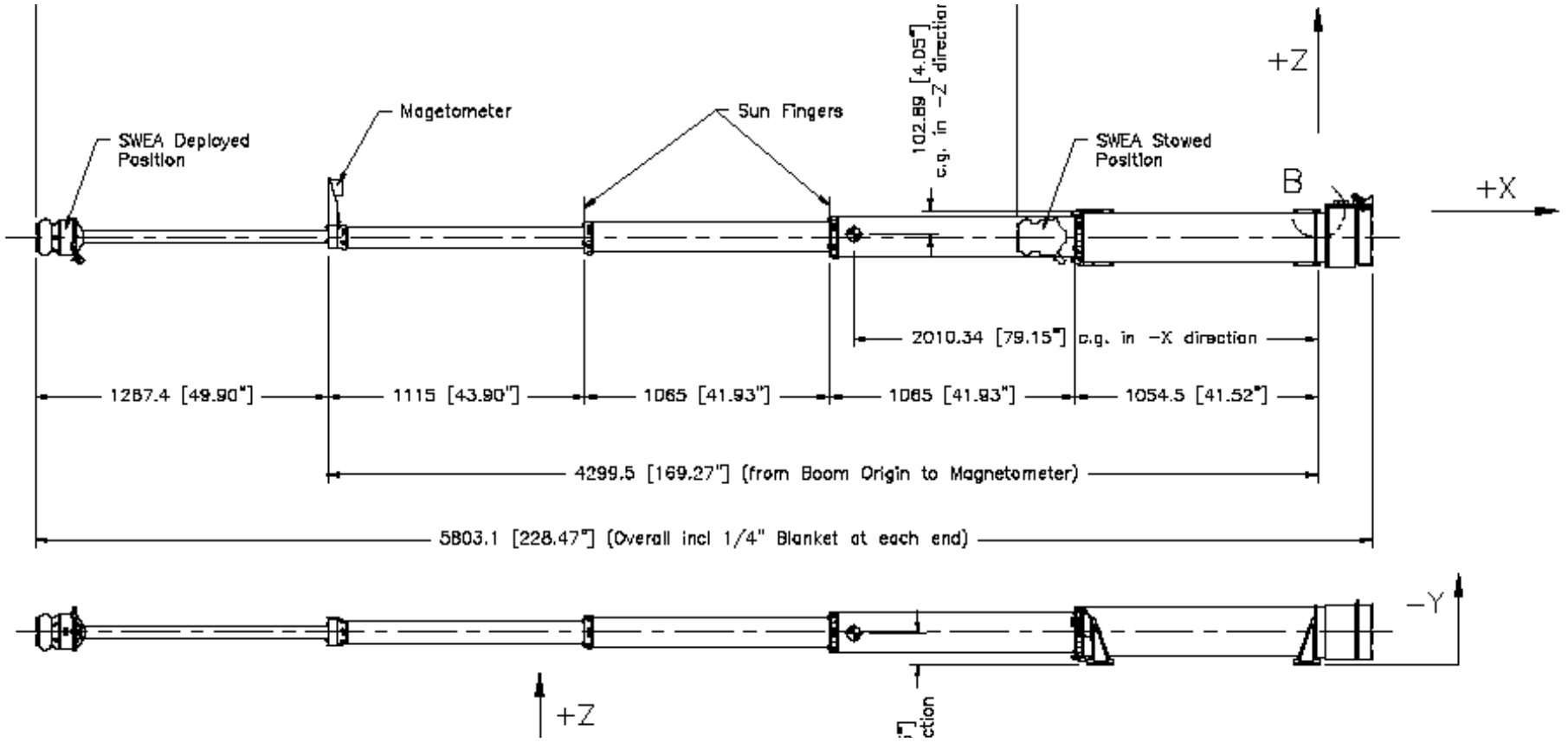
STEREO spacecraft ‘Behind’



IMPACT instrument block diagram

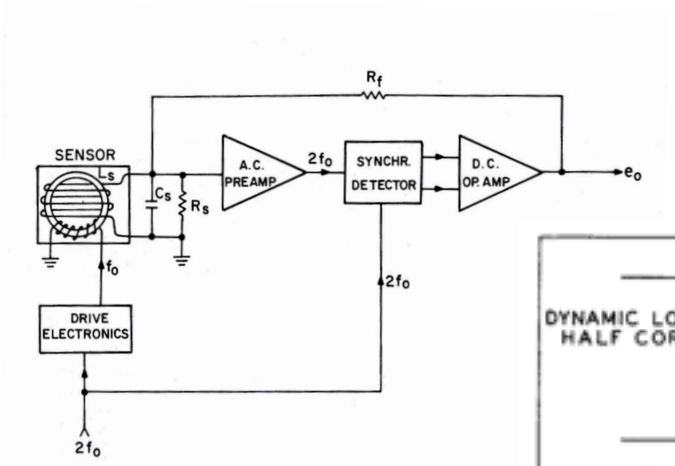


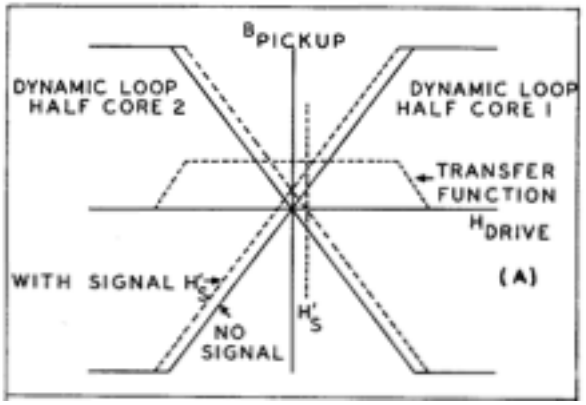
STEREO magnetic field measurements



Fluxgate Magnetometers

- Drive coil and pickup coil
- Ferrite-core is saturated by H_{apl} at drive frequency – alternately magnetized, neutral, inversely magnetized, etc.
- Current is induced in a pickup coil by dB/dt of the ferrite core
- In presence of external field core saturates more easily in one direction
- Modifies transfer function from H to B. Input current and output current from coils goes out of phase.
- These measurements are bedeviled by large spacecraft stray (DC) and fluctuating fields.
- Sensor must be boom-mounted, preferably ~10 m from s/c





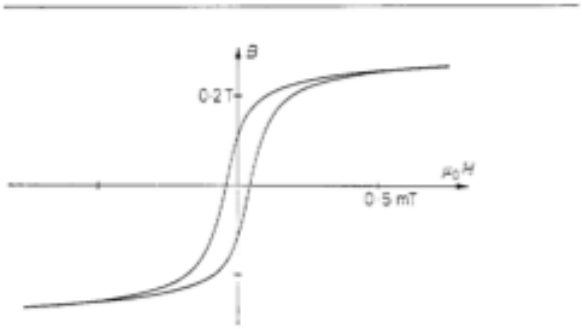
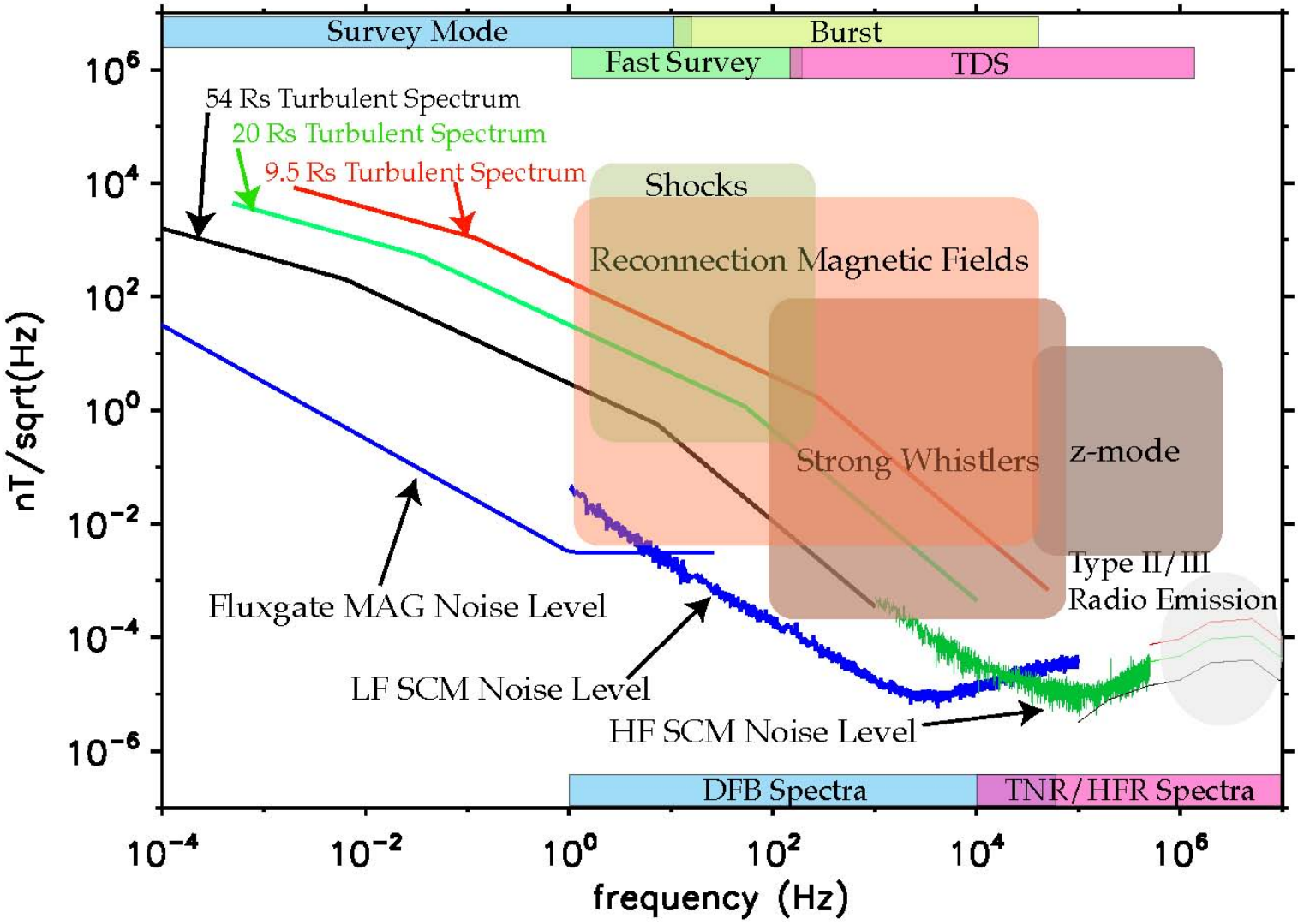
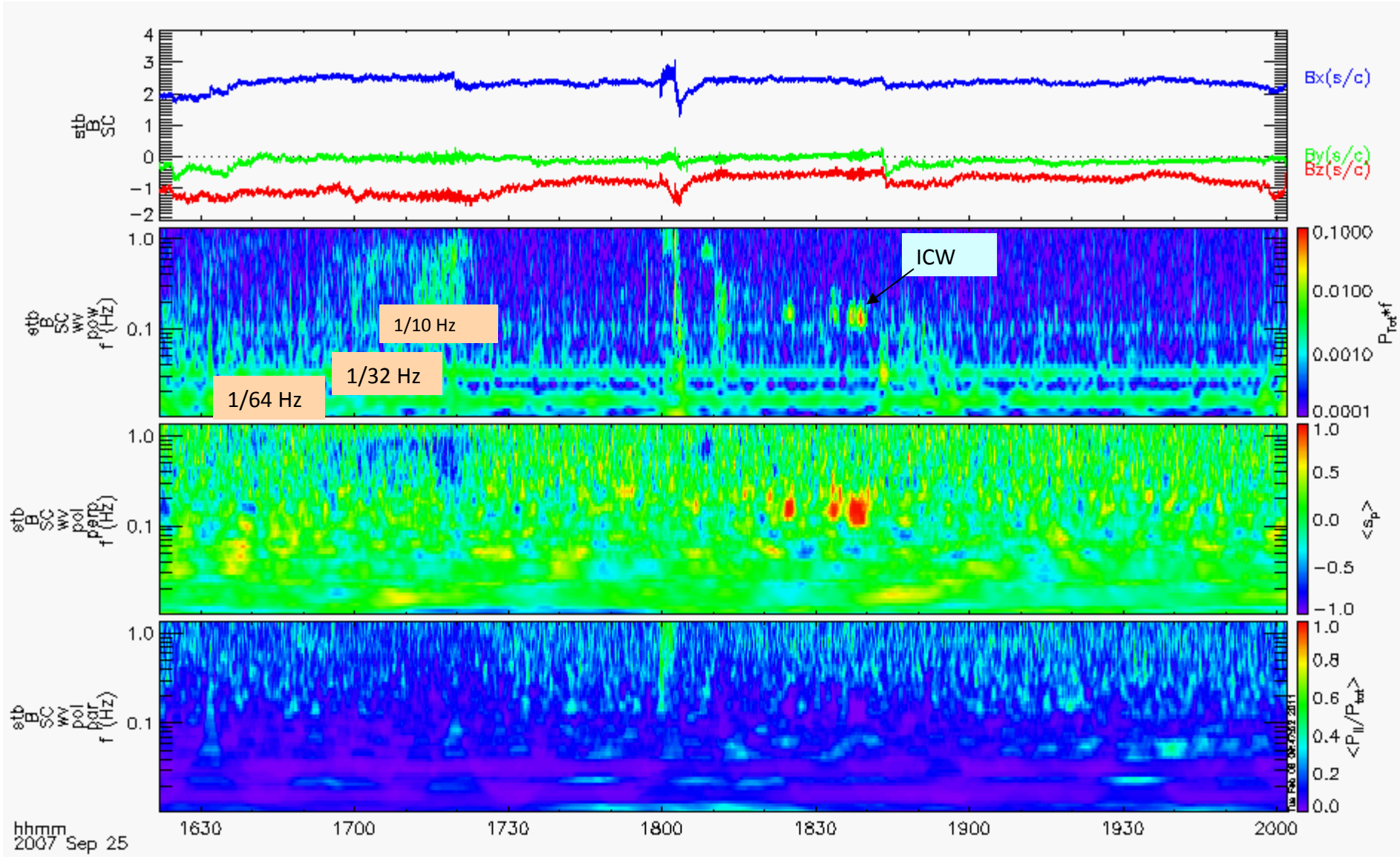


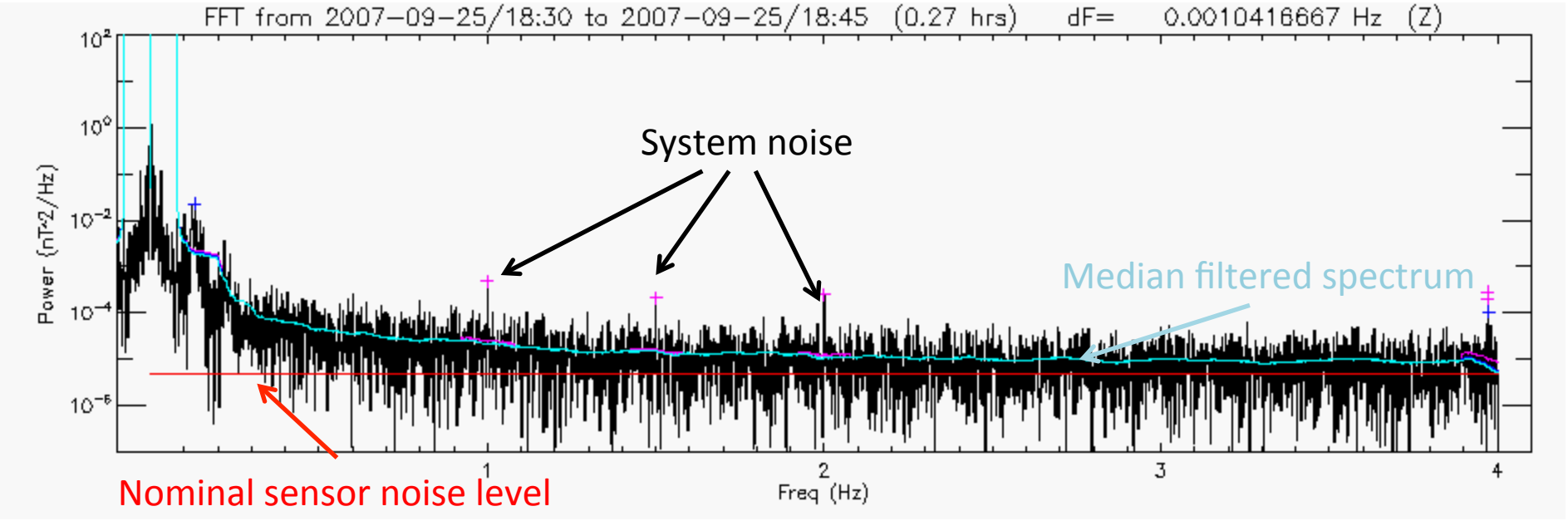
Figure 2 Magnetisation curve B against $\mu_0 H$ for a tube of Permax 51 ferrite (Ferroperm, Trørød, Denmark). The slope $dB/\mu_0 dH$ decreases for large $\mu_0 H$.

Magnetic field levels and instrument sensitivity



STEREO magnetic field measurements at 1 AU

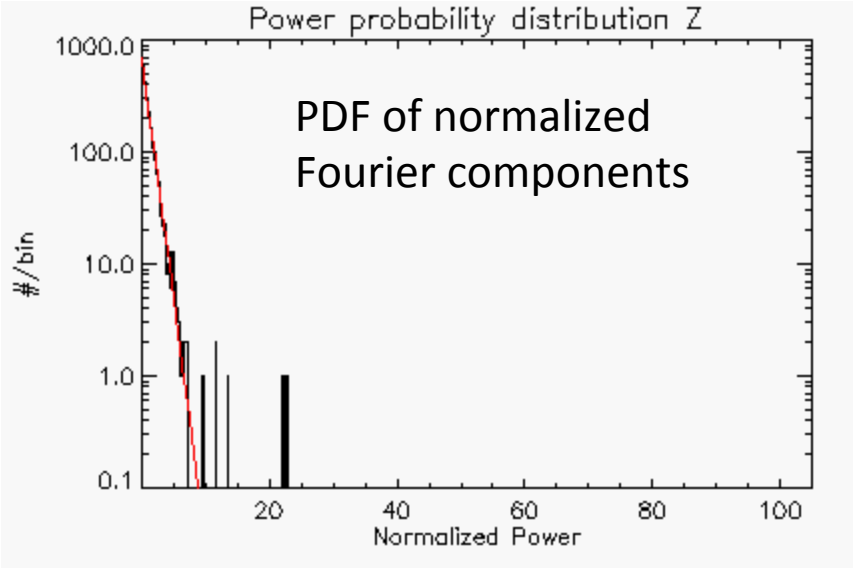


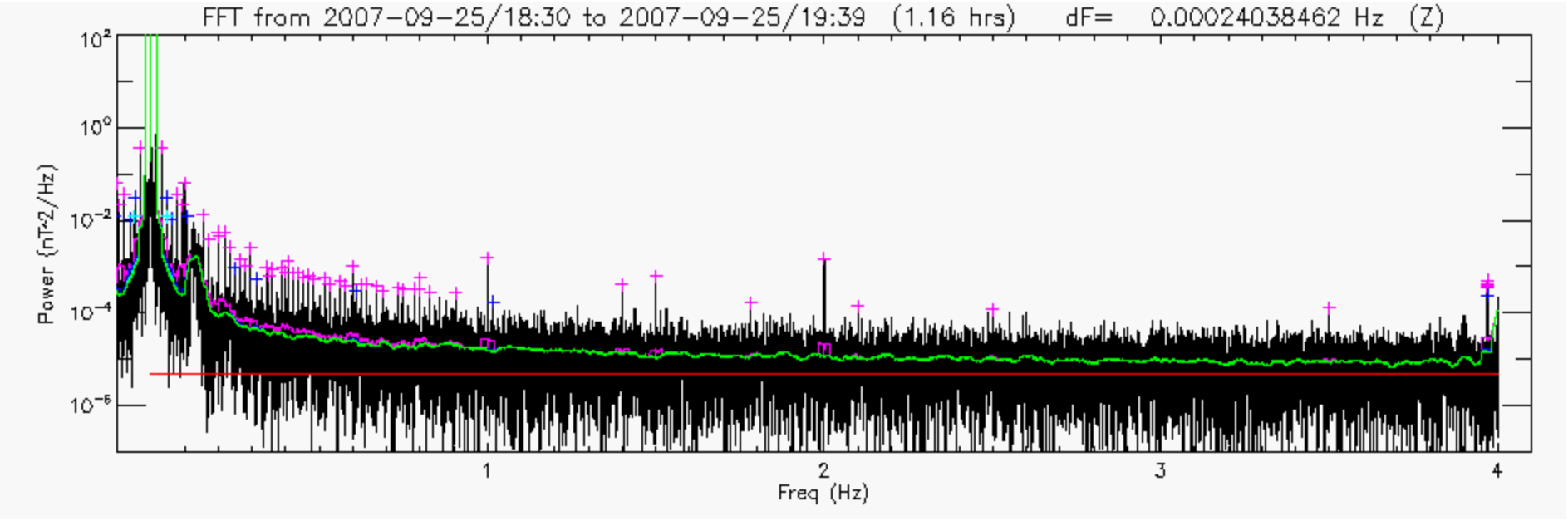


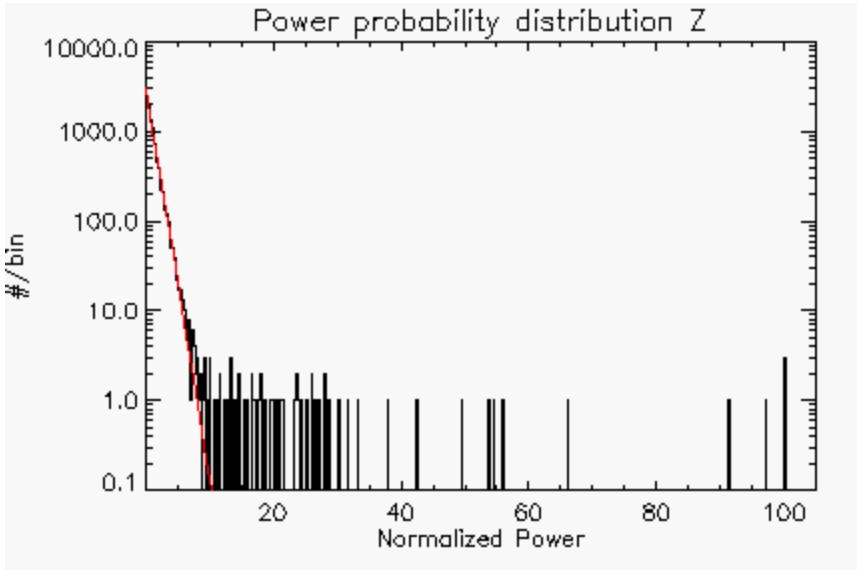
$\Delta f = 1/T = f_S/N$

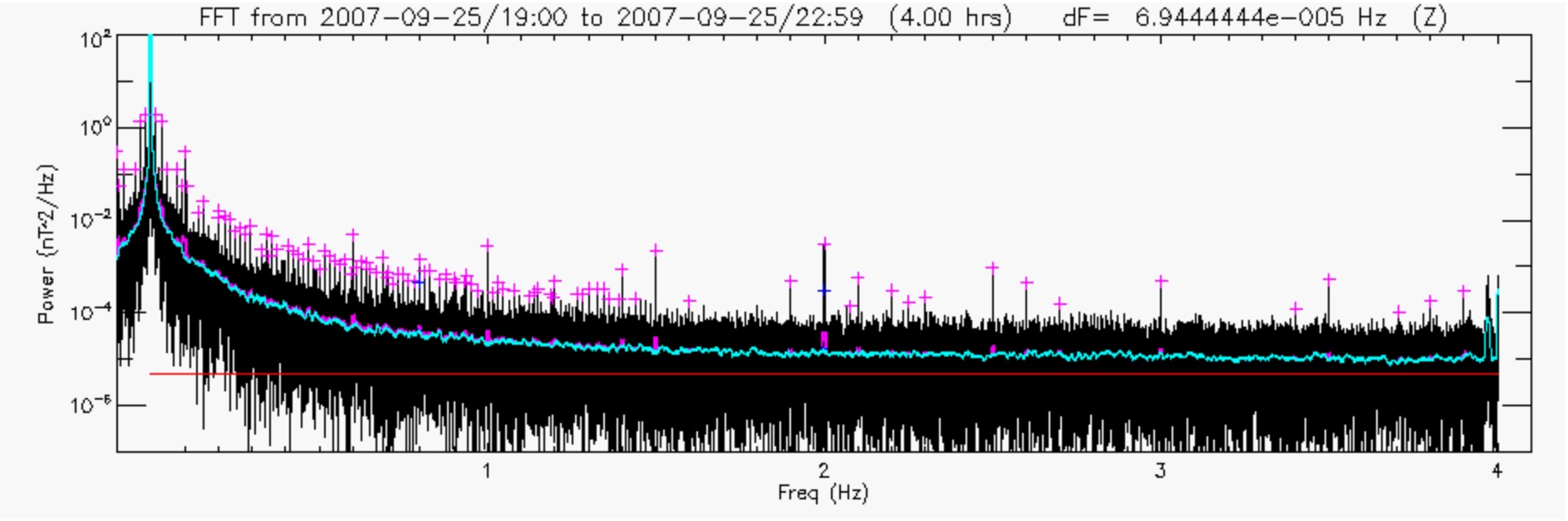
$f_S = 8$ s/s

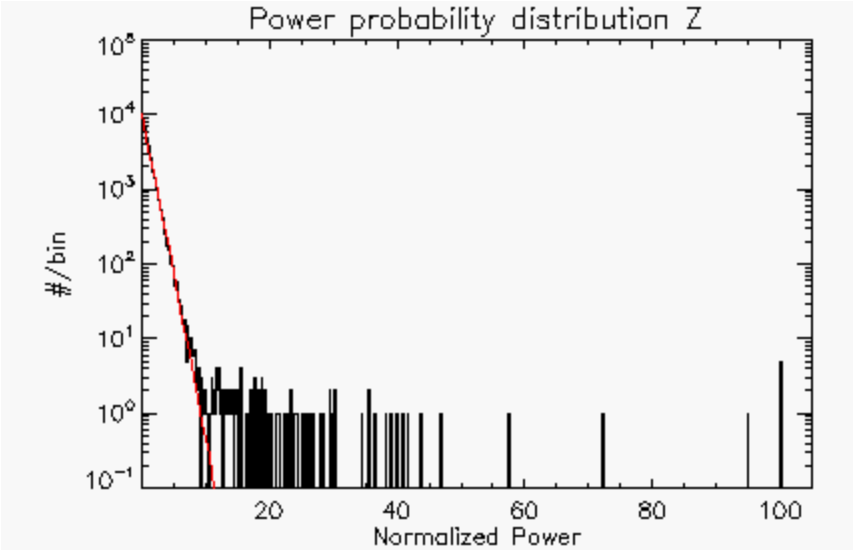
Noise is more-or-less time stationary

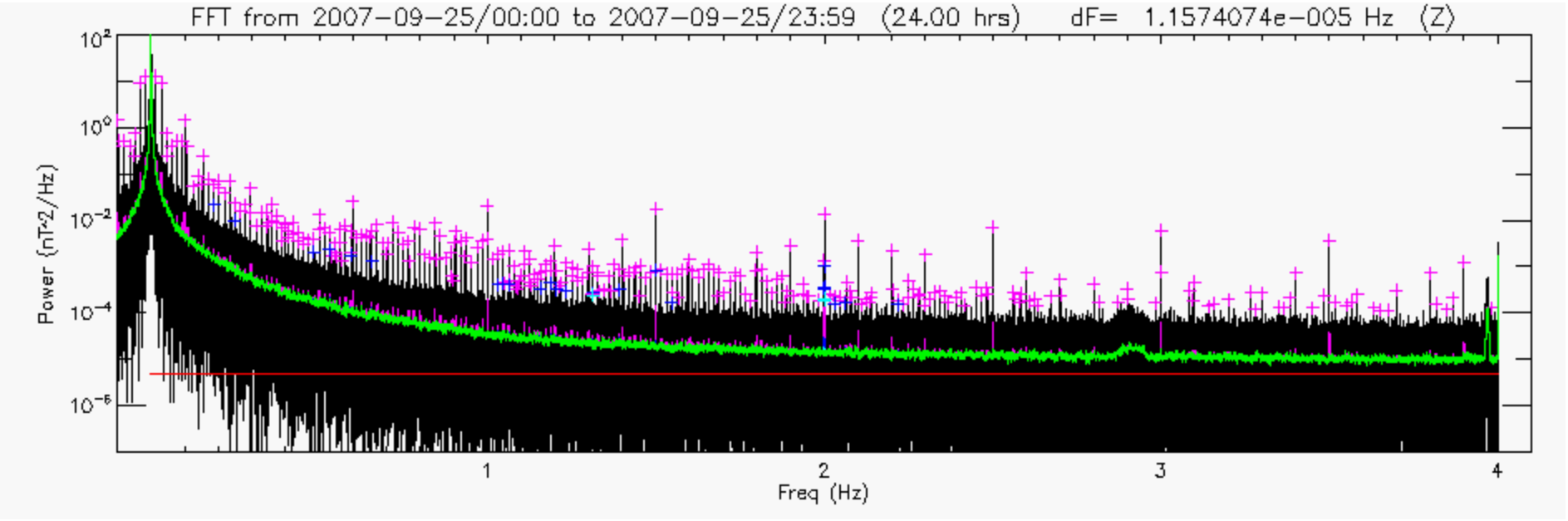


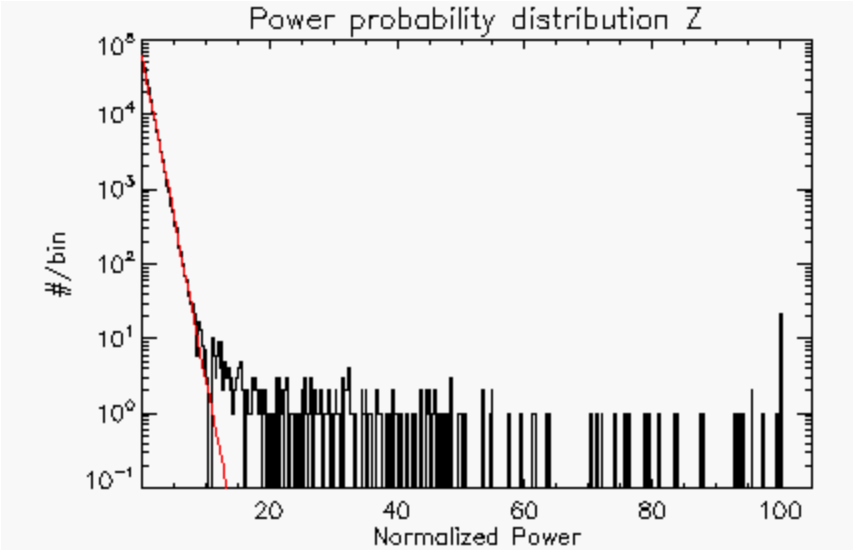

FFT from 2007-09-25/18:30 to 2007-09-25/19:39 (1.16 hrs) dF= 0.00024038462 Hz (Z)
Power (nT^2/Hz)
Freq (Hz)


Power probability distribution Z
#/bin
Normalized Power

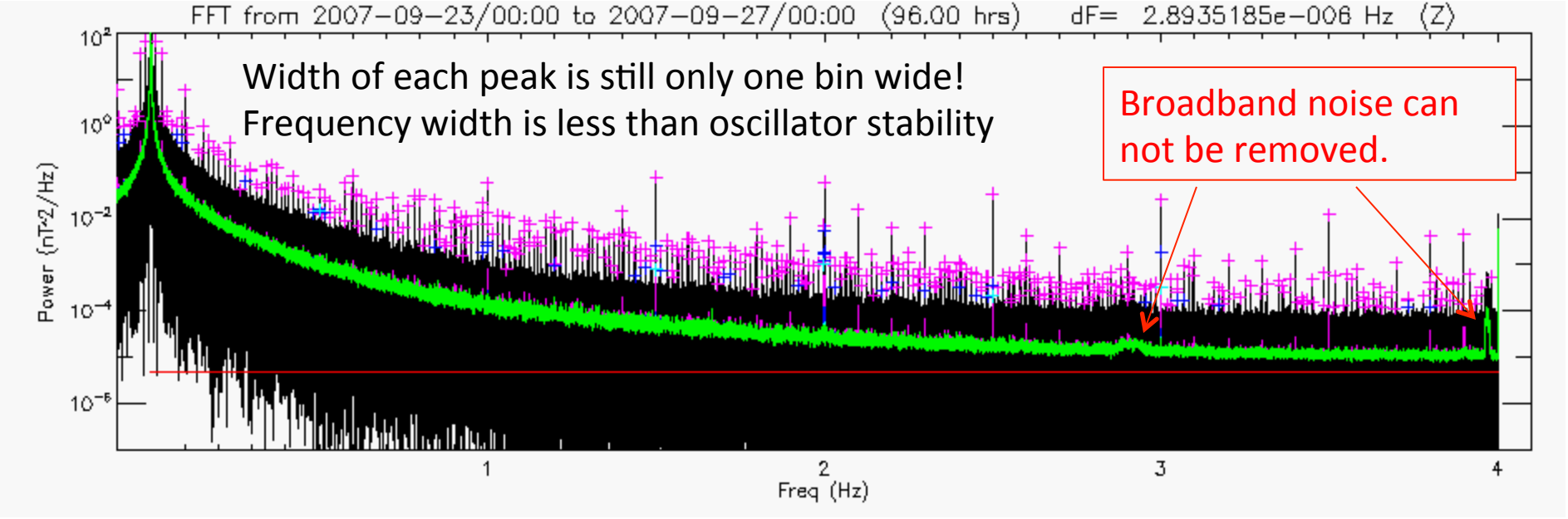

FFT from 2007-09-25/19:00 to 2007-09-25/22:59 (4.00 hrs) dF= 6.9444444e-005 Hz (Z)
Power (nT^2/Hz)
Freq (Hz)


Power probability distribution Z
#/bin
Normalized Power


FFT from 2007-09-25/00:00 to 2007-09-25/23:59 (24.00 hrs) dF= 1.1574074e-005 Hz (Z)
Power (nT^2/Hz)
Freq (Hz)

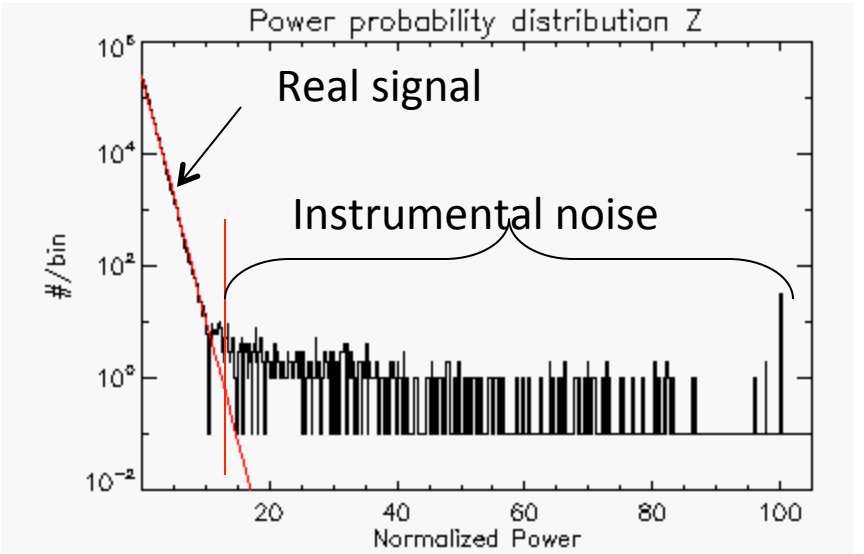

Power probability distribution Z
#/bin
Normalized Power

Noise removal in frequency domain



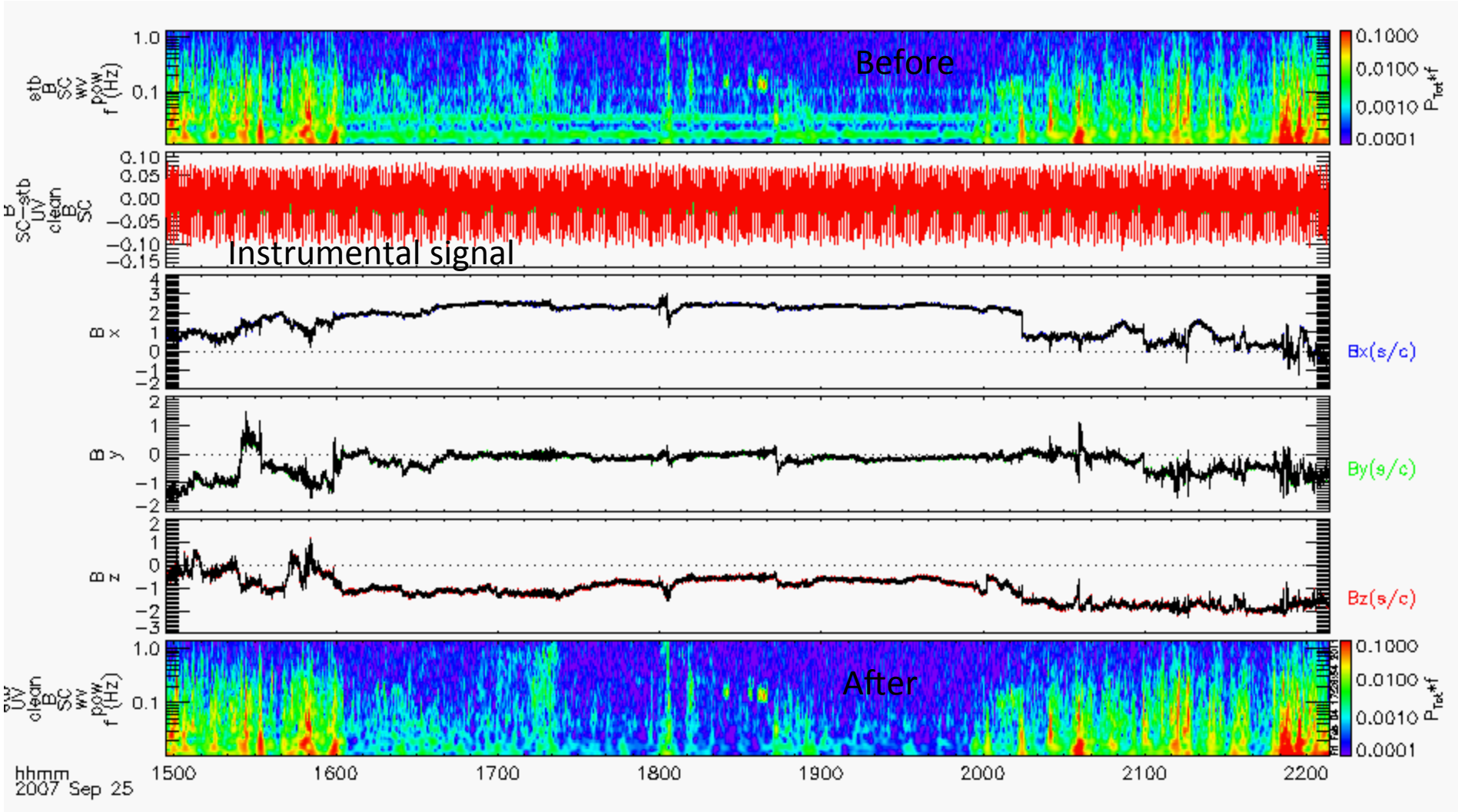
FFT of 2.7 million points
df= 3e-6 Hz

In frequency space the instrumental noise and signal are easily separable
Only a few hundred frequency components are needed to characterize the contamination waveform.

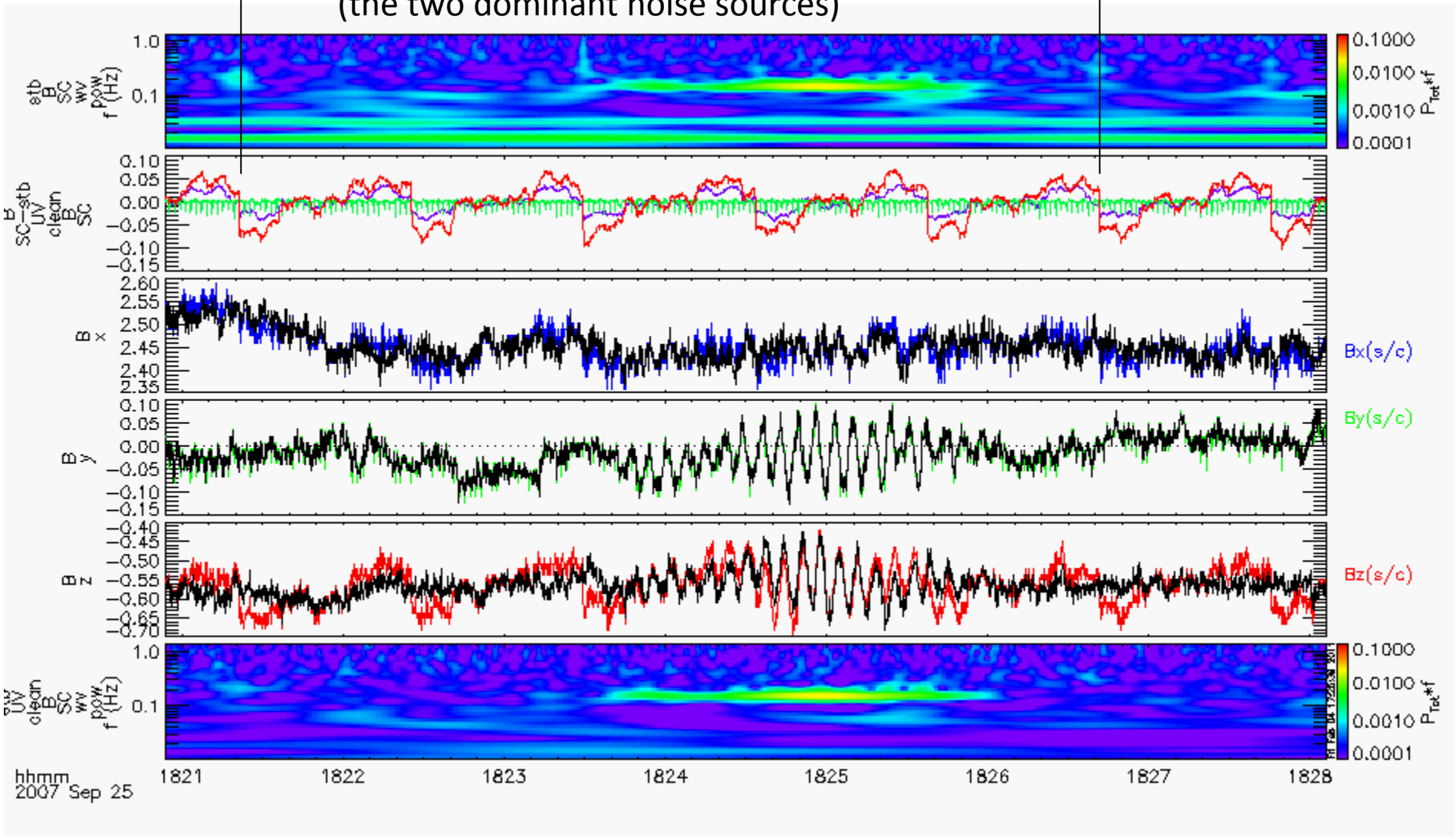


Cleaned data

Construct ‘noise signal’ from FFT inversion of non-Gaussian FFT coefficients
Subtract noise signal from total signal (in the time domain)



Cleaned data



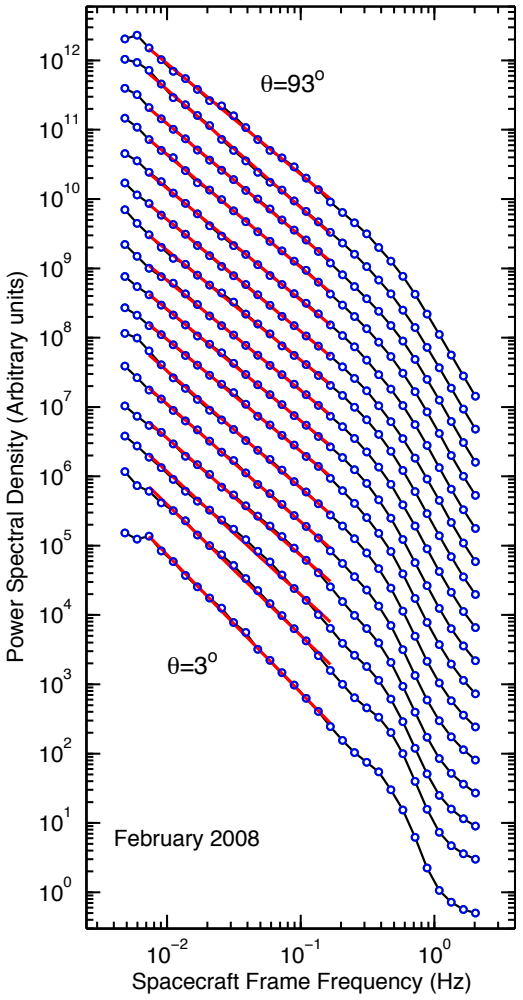
Caution!

Any ‘precision’ work with spacecraft magnetometer data needs careful analysis of raw data.

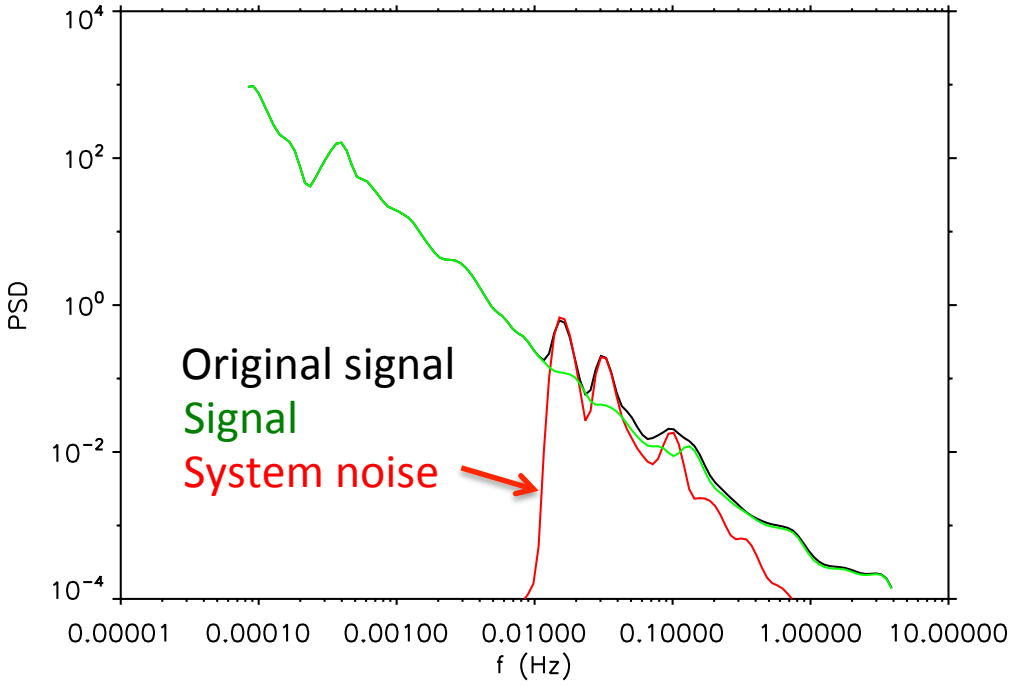
Common instrument/subsystem clocks allow for noise cleanup.

Must be done before any higher order analysis (including coordinate transformation from sensor system)

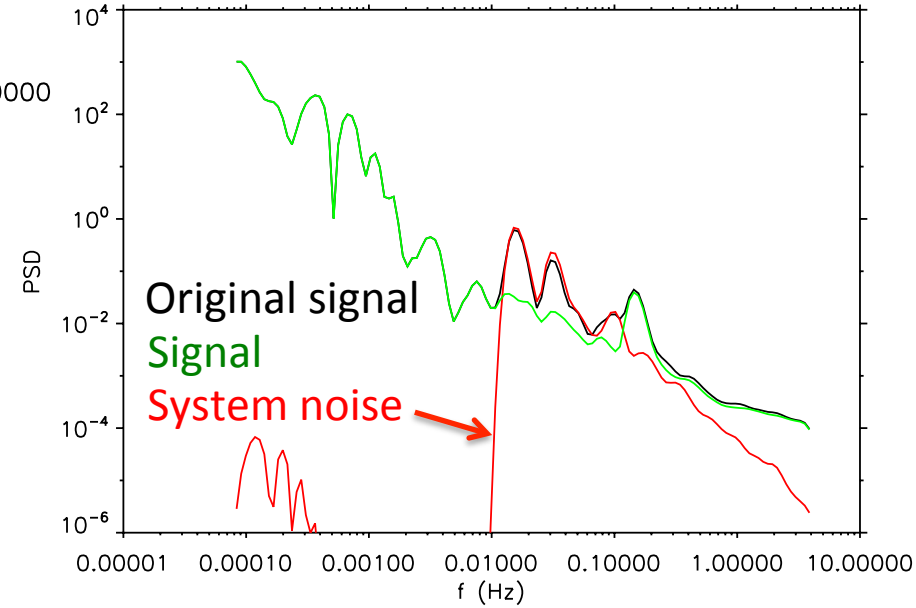
Affects weaker signals preferentially (and therefore higher frequencies, shorter spatial scales).



Power spectra are modified



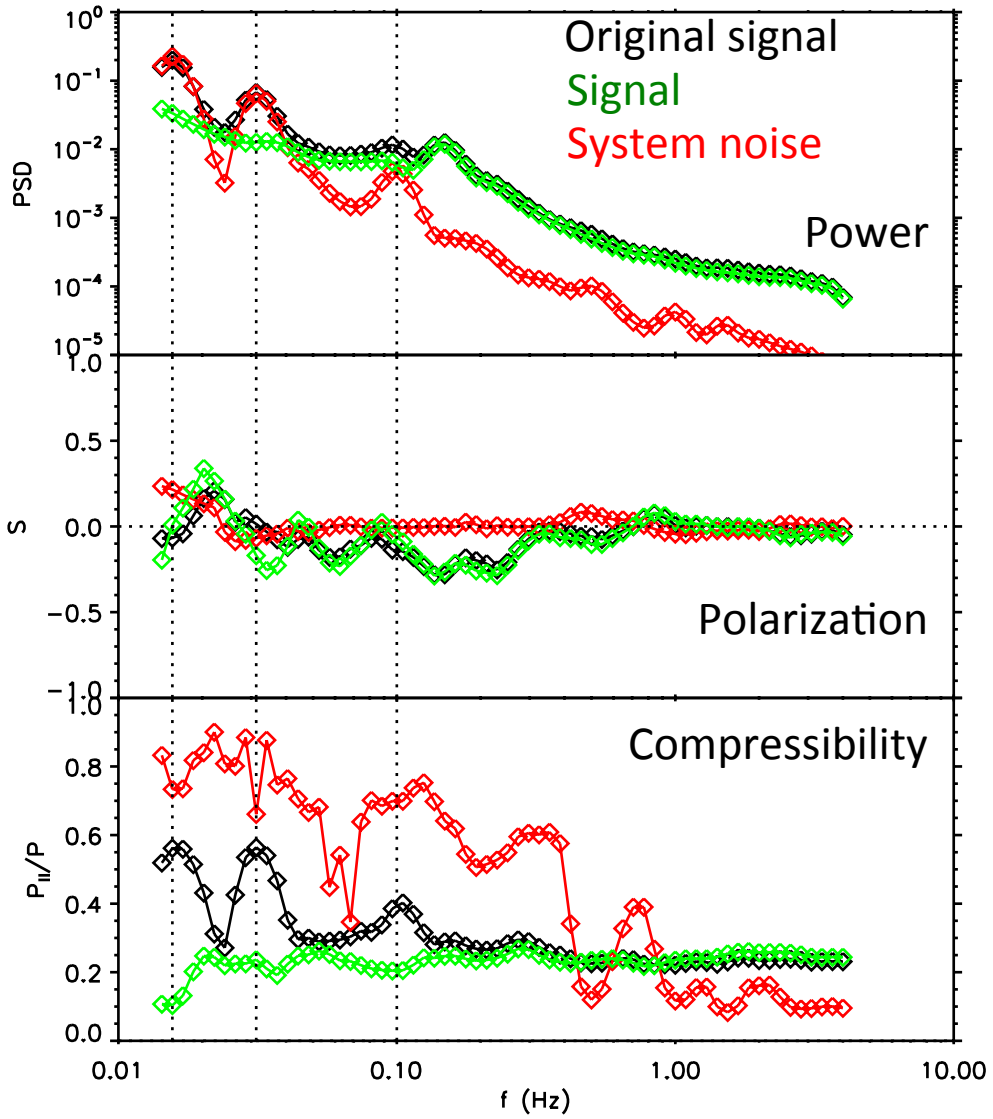
This can be especially subtle in wavelet spectra, which generally have broader spectral resolution and don't resolve individual tones



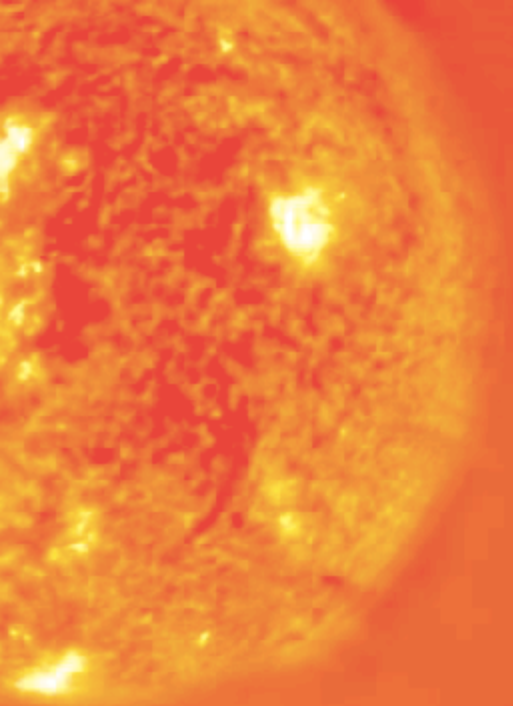
Derived quantities

System noise is in phase on all sensors – ‘polarization’ is zero

Compressibility may be modified by noise



- NASA ‘Living with a Star’ Mission
- Recommended by NAS for 30 years

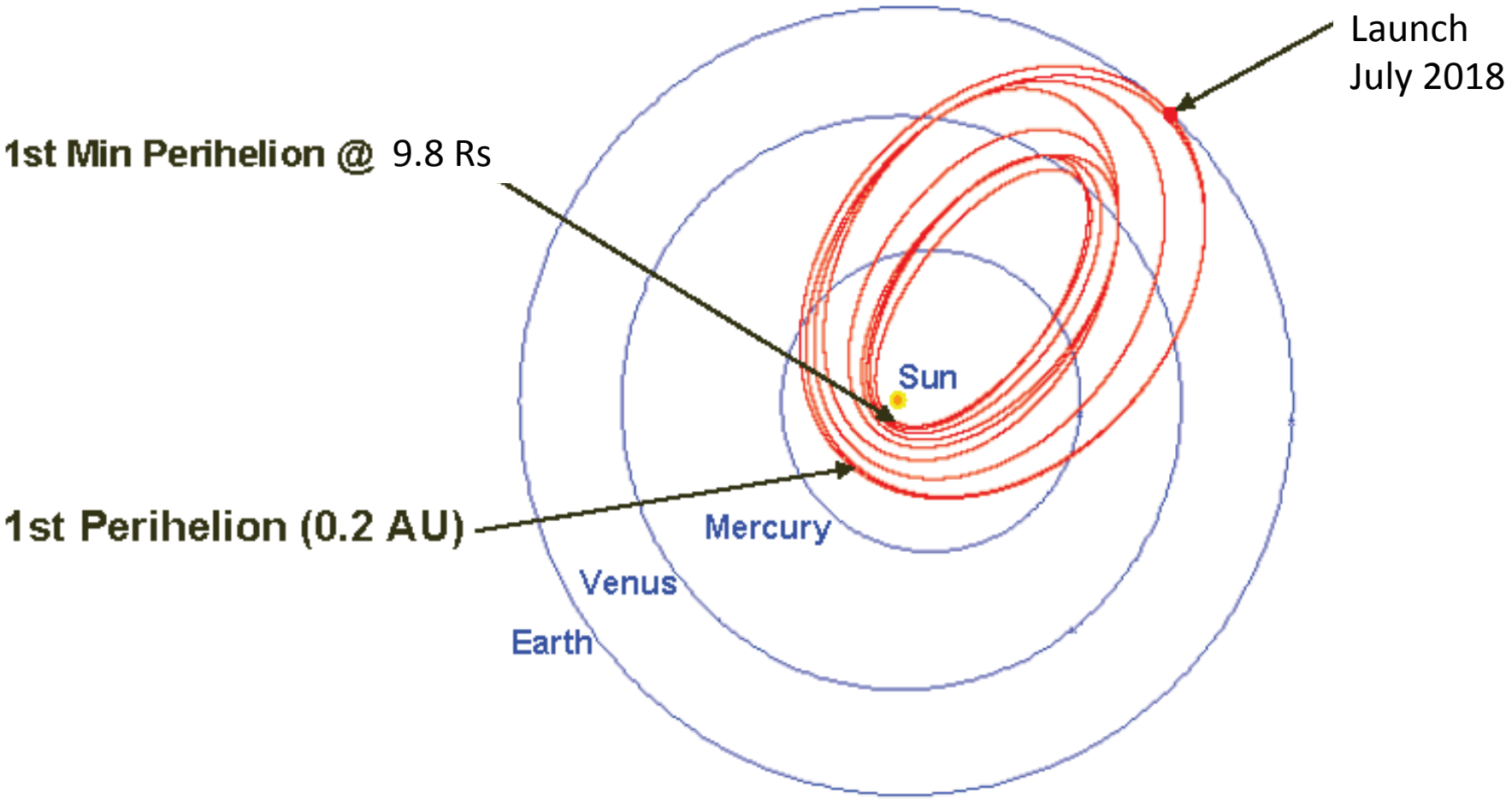


- Launch in 2018
- Mostly *in situ* instruments
- Perihelion at 9.8 Rs – within the Alfven radius

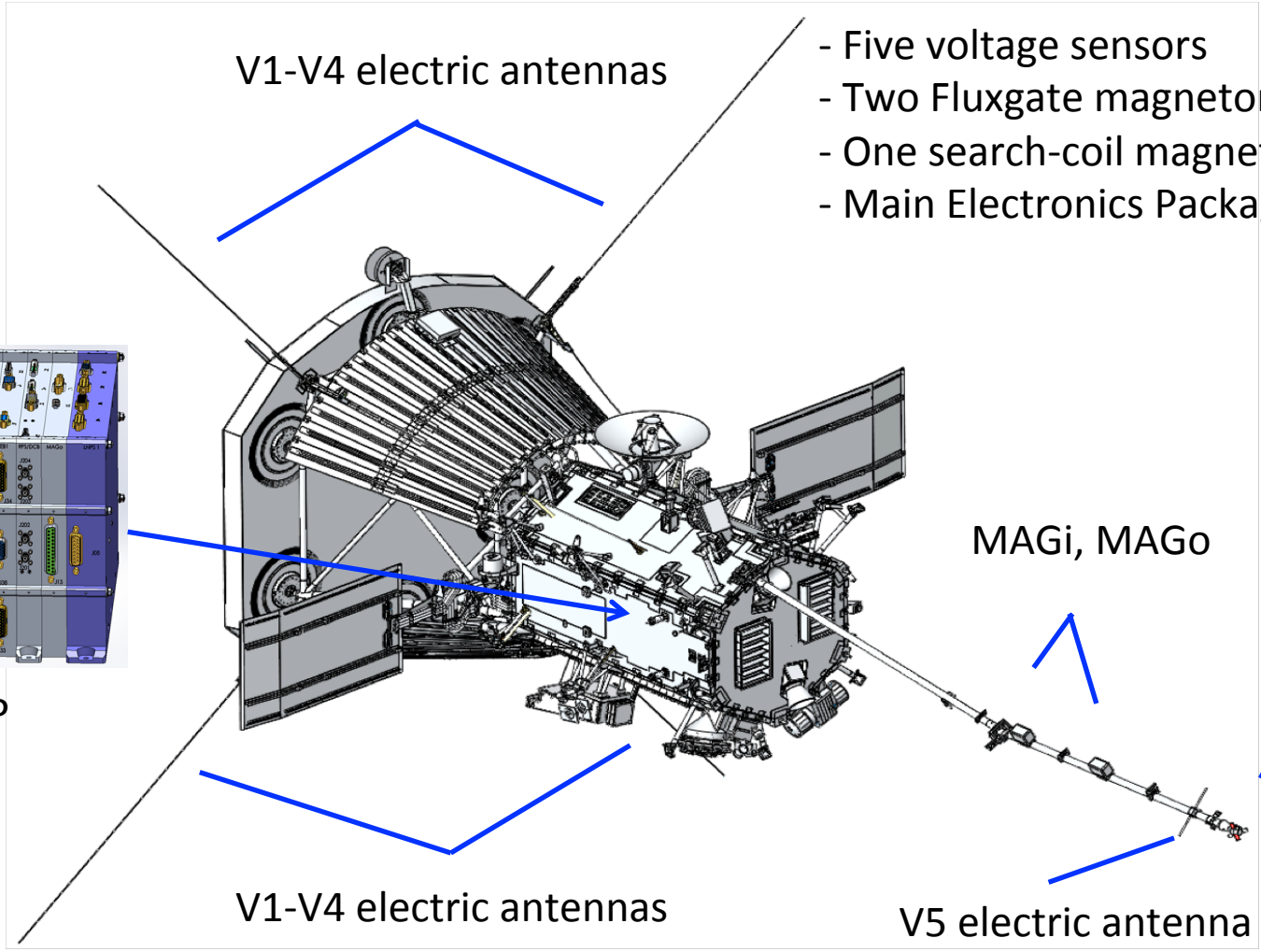
NASA Solar Probe Plus (SPP) mission

Johns Hopkins University / Applied Physics Laboratory

Solar Probe Plus



SPP/FIELDS Instrument Overview of Sensors

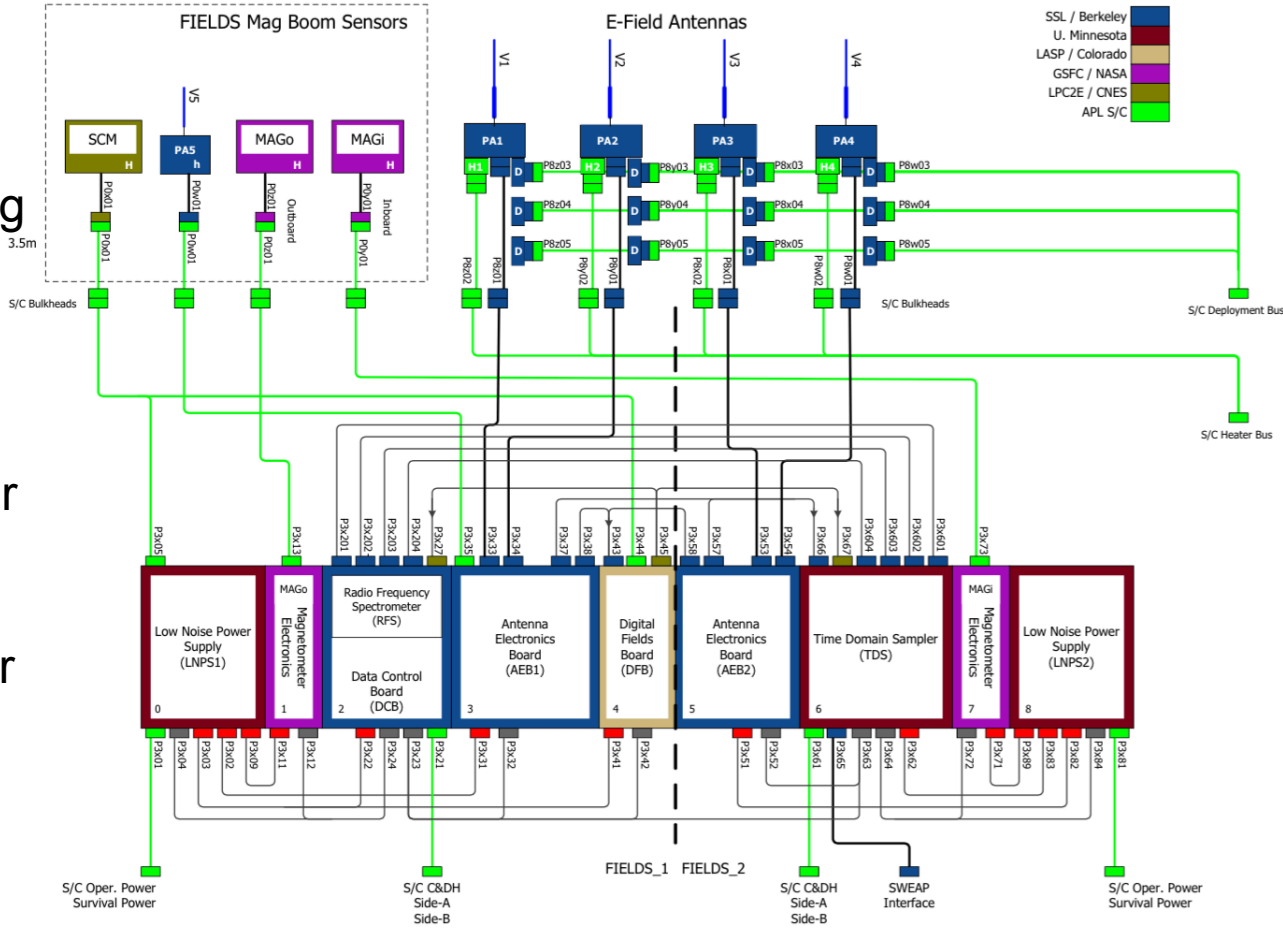


FIELDS Instrument Block Diagram

Two Sides
- Each has Spacecraft I/F
- Each has Magnetometer
- Each has Antenna Biasing
- Each has Power Supply

FIELDS1 also has
- Data Controller Board
- Radio Freq. Spectrometer
- Digital Fields Board
- SCM Calibration Control
- Absolute Time Sequencer
- TDS I/F

FIELDS2 also has
- Time Domain Sampler
- DCB I/F
- SWEAP I/F



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