Solar Orbiter's RPW Low Frequency Receiver (LFR) : In-flight performance and observations of whistler mode waves

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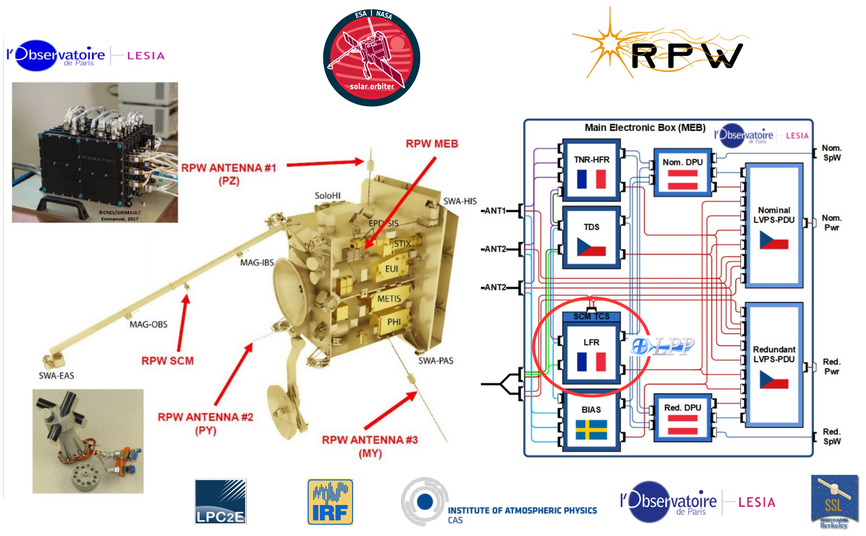
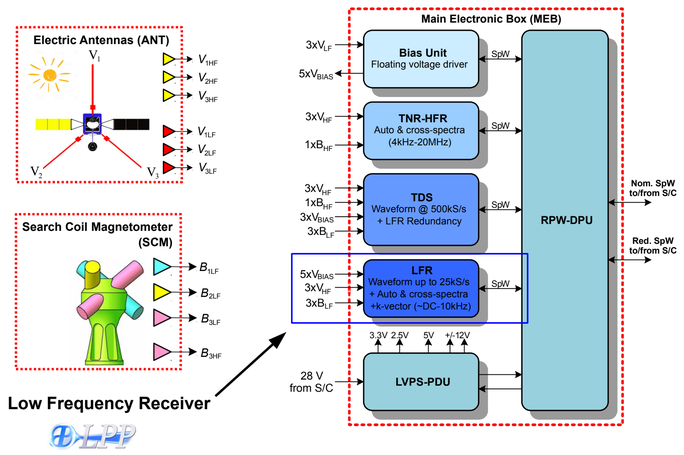


RPW Instrument Overview

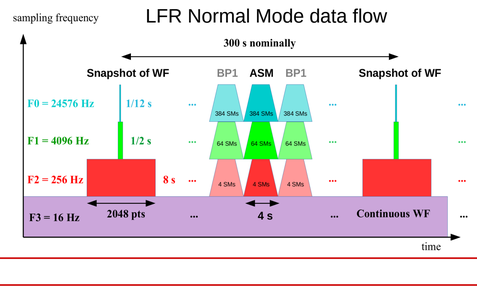


Low Frequency Receiver (LFR)

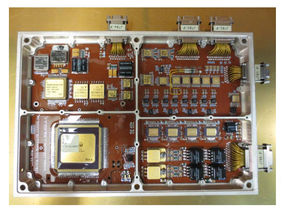
LFR nominal inputs : **3 B + 2 E + 1 V (≤ 10 kHz)**

The LFR signal processing, based on a FPGA, provides routinely,
- waveforms (SWF & CWF)
- spectral matrices (ASM & BP2)
- basic wave parameters (BP1)

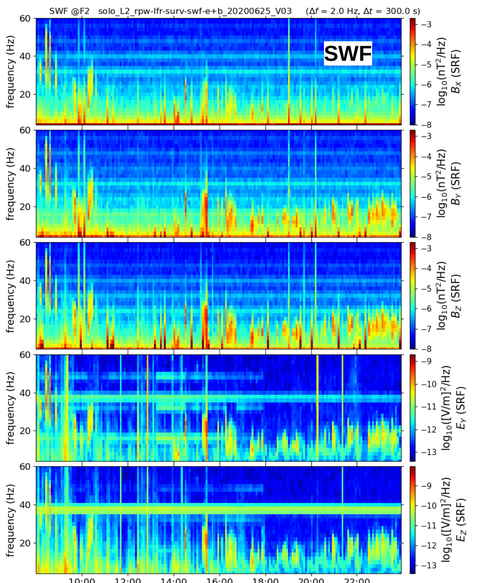
at different time and frequency resolutions:



LFR data are calibrated at LESIA by the **ROC production pipeline**, using the calibration softwares of the teams (SCM, BIAS & LFR):
- SCMCAL (LPCE2, Orléans, France)
- BICAS (IRF, Uppsala, Sweden)
- LFR-CALBUT (LPP, Palaiseau, France)



LFR FM board



Wave parameters computed from the **SWF** (every 300 s, Δ*f* = 2Hz) compared with those computed in part onboard (every 20 s, Δ*f* = 8 Hz, **BP2 data set**)

$$\left.\begin{aligned}\mathbf{n}\times\tilde{\mathbf{E}} &= \frac{\omega}{K}\tilde{\mathbf{B}}\\ \tilde{\mathbf{E}}\cdot\mathbf{B}_0 &= 0\end{aligned}\right\} \Rightarrow \tilde{\mathbf{E}} = -\frac{\omega}{K}\frac{\mathbf{B}_0\times\tilde{\mathbf{B}}}{\mathbf{n}\cdot\mathbf{B}_0}$$

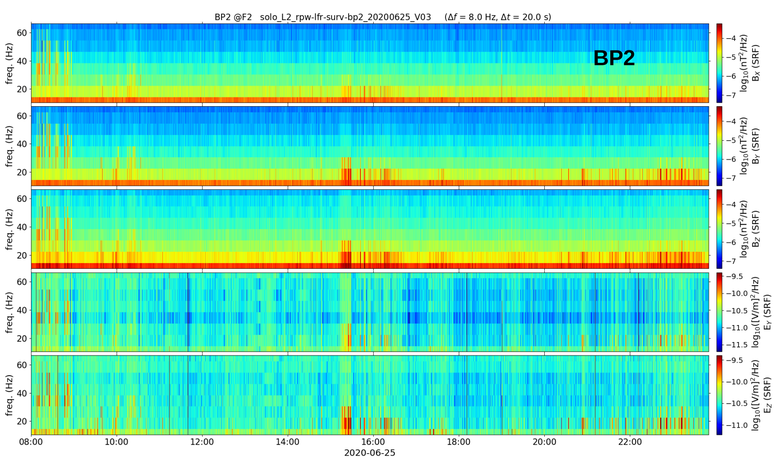
$$\frac{\omega}{K} \approx \frac{(\mathbf{n}\cdot\mathbf{B}_0)\left\langle\hat{E}_Y\hat{B}_Y^*\right\rangle_t/\rho_{E_YB_Y}}{B_{0X}\left\langle\hat{B}_Z\hat{B}_Y^*\right\rangle_t/\rho_{B_ZB_Y} - B_{0Z}\left\langle\hat{B}_X\hat{B}_Y^*\right\rangle_t/\rho_{B_XB_Y}} = \hat{v}_{\varphi 2}(\omega)$$

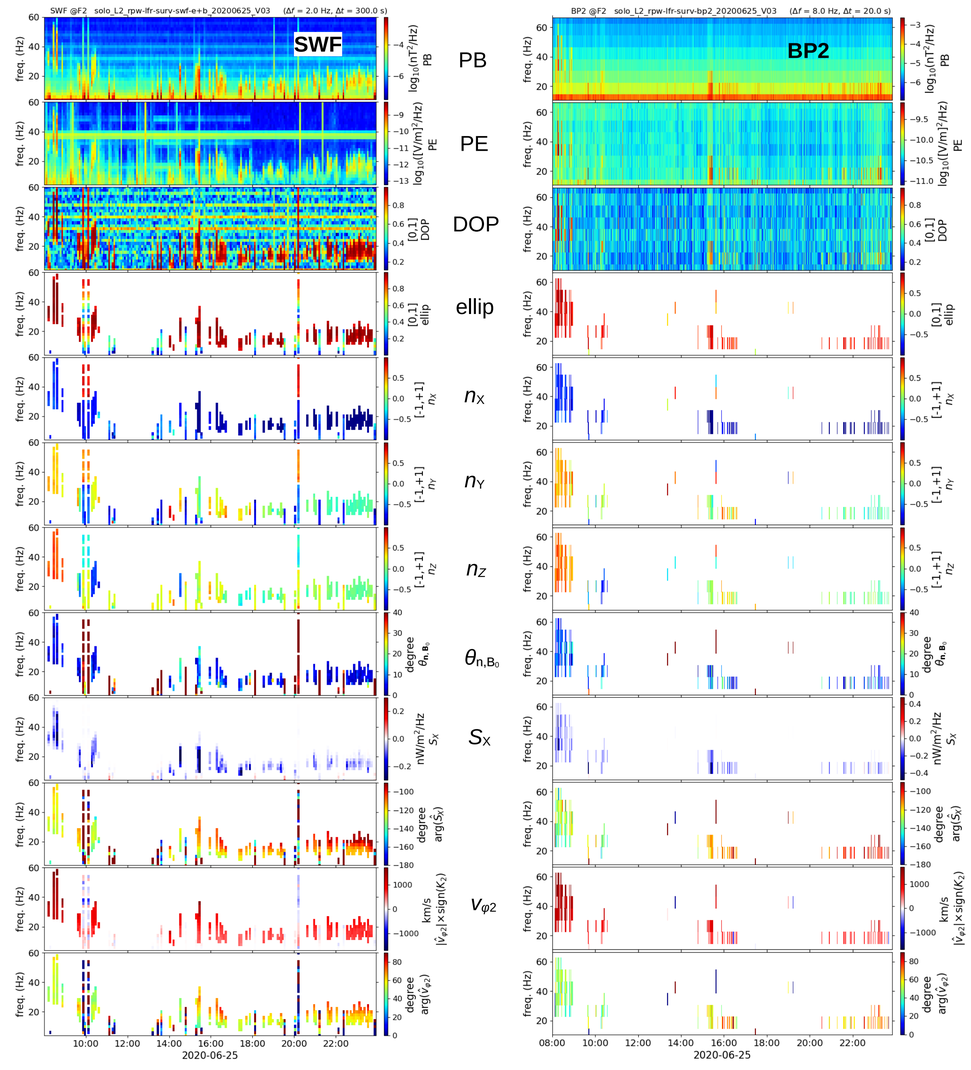
with **n**, the wave normal vector (Means, JGR, 1972), and :

$$\mathbf{k} = \mathbf{n}\times K$$

$$\rho_{ij} = \frac{\left|\left\langle\hat{P}_i\hat{P}_j^*\right\rangle_t\right|}{\sqrt{\left\langle\hat{P}_i\hat{P}_i^*\right\rangle_t\left\langle\hat{P}_j\hat{P}_j^*\right\rangle_t}}$$

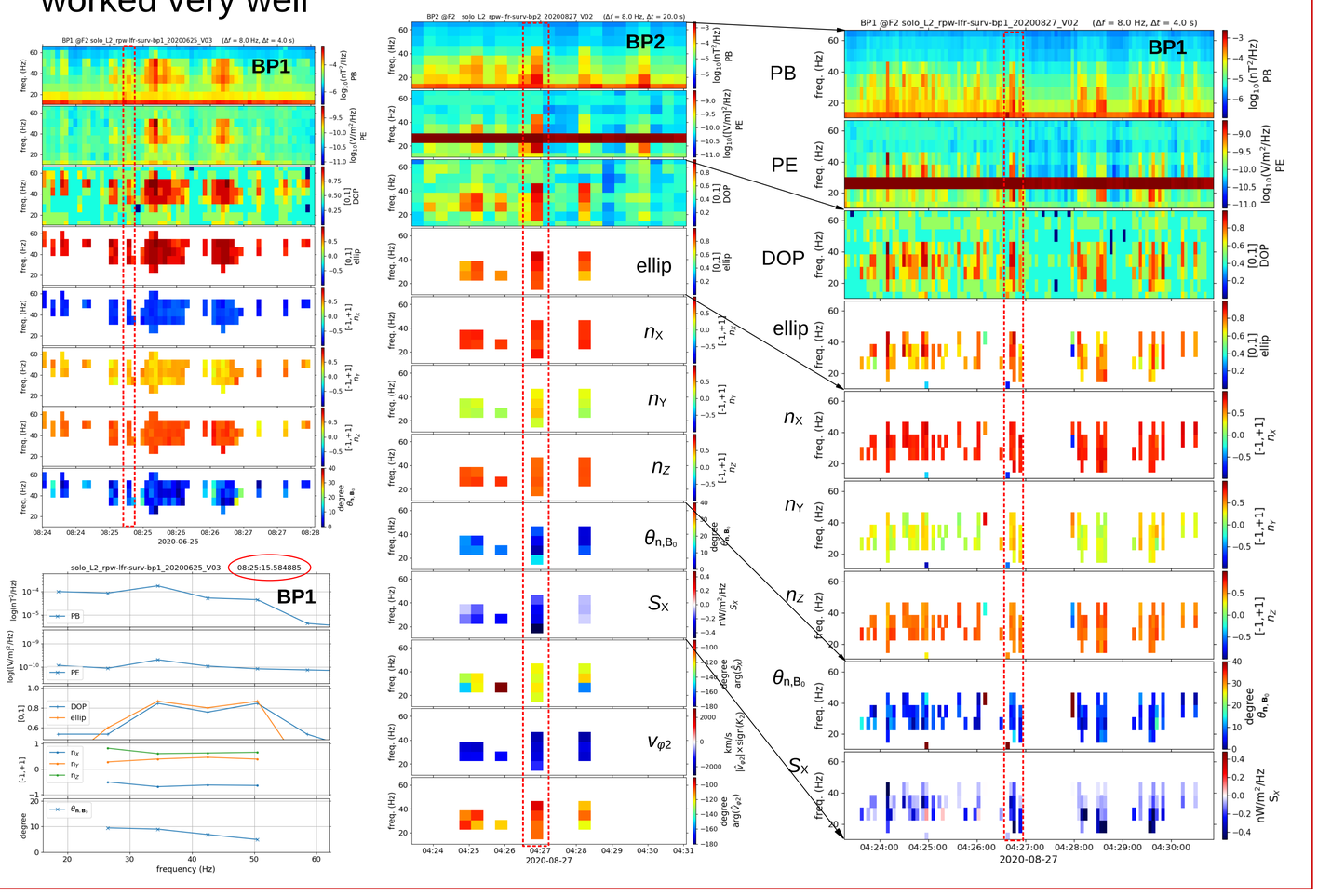
$$\frac{\omega}{K} \approx \frac{n_Y\left\langle\hat{E}_Z\hat{B}_X^*\right\rangle_t/\rho_{E_ZB_X} - n_Z\left\langle\hat{E}_Y\hat{B}_X^*\right\rangle_t/\rho_{E_YB_X}}{\left\langle\hat{B}_X\hat{B}_X^*\right\rangle_t} = \hat{v}_{\varphi 1}(\omega)$$



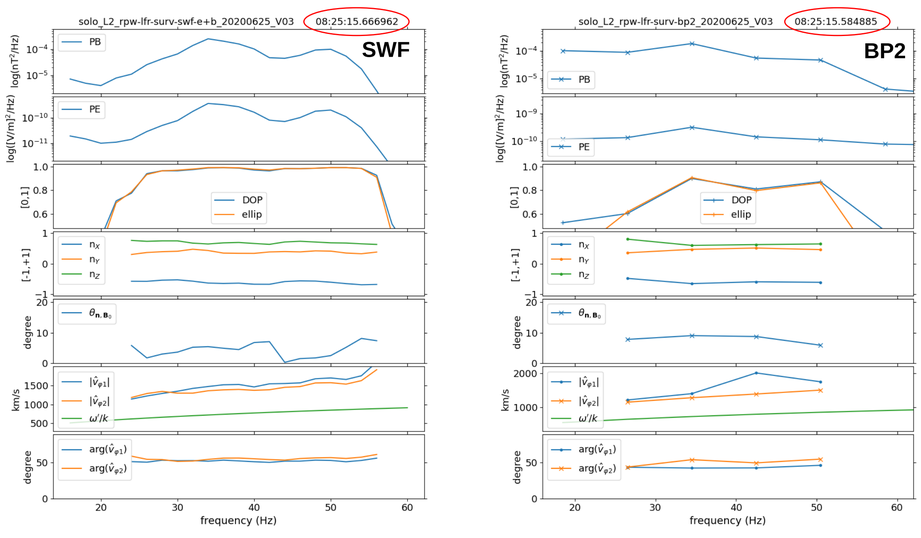


Wave parameters computed onboard every 4 s with Δ*f* = 8Hz (BP1 data set)

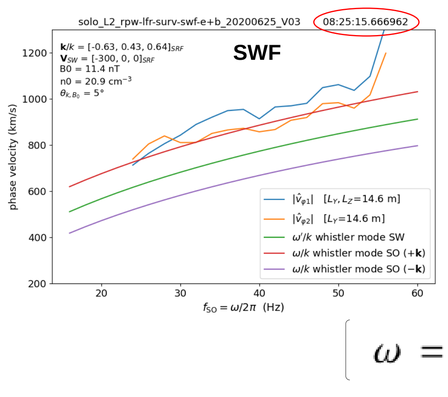
Illustration of the **intermittency** of the whistler mode waves and the correct calculation of the most compressed onboard data products (BP1 data set), including the **Poynting flux S_X**, showing that the update of the kcoefficients worked very well



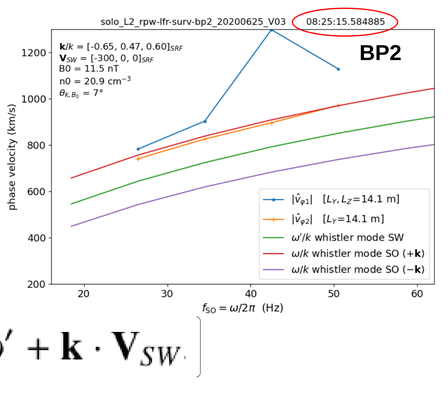
Identification of whistler mode waves in the solar wind



Phase velocity measured (orange) from waveforms (SWF data set) compared with that of the theoretical (red) Doppler shifted (+**k**) whistler mode



Phase velocity measured (orange) from onboard spectral data products (BP2 data set) compared with that of the theoretical (red) Doppler shifted (+**k**) whistler mode



$$\omega = \omega' + \mathbf{k}\cdot\mathbf{V}_{SW}$$

More details can be found in **Chust et al. A&A, 656, A17 (2021)** (Solar Orbiter Cruise Phase Special Issue)