Characterisation of whistler waves using Solar Orbiter data

Lucas COLOMBAN

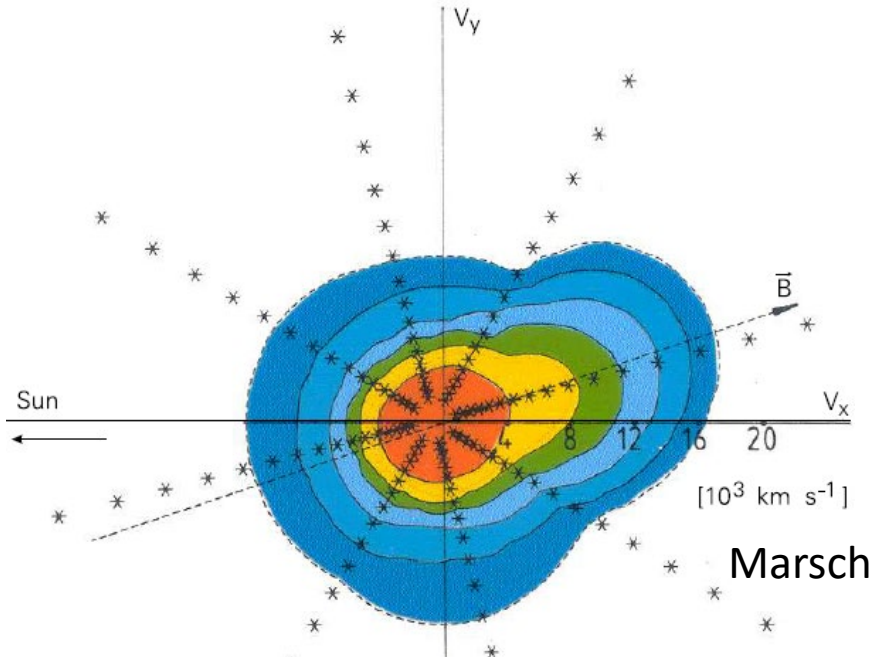
M. Kretzschmar, V. Krasnoselskikh, M. Maksimovic, D. Graham, Y. Khotyainsev, L. Berĉiĉ, M. Berthomier and the RPW team

Plan

- The interest of whistlers
- Data and method
- Whistlers study as a function of radial distance
- Whistlers study as a function of solar wind speed
- Conclusion

The solar wind heat flux

- 3rd moment of the distribution function
- It is carried by the electrons:
  A. In the fast wind: carried by the stralh
  B. In the slow wind: by the halo



Marsch 2006

- How is it regulated? $q_e \sim R^{-2.9}$ => Wave-particle interaction (Spitzer & Harm 1953)

Halekas et al 2020

What are whistlers ?

- Right-handed circularly polarized waves with a frequency smaller than the electron cyclotron frequency

- Model : cold electrons

$$\frac{k^2c^2}{\omega^2} = 1 + \frac{\omega_{pe}^2}{\omega(\omega_{ge}\cos\theta - \omega)}$$

- Parallel or oblique with respect to the background magnetic field

- They probably have a role in regulating the solar wind heat flux

Whistler's generations

Vasko et al 2019,

1) Fan instability (anomalous cyclotron resonance) => Oblique whistlers (Agapitov et al 2020, Cattell et al 2020), can regulate the heat flux in the fast solar wind (Vasko et al 2019, Verscharen et al 2019, Micera et al 2020,2021)

$$v_{||} = (\omega + \Omega_e)/k_{||}.$$

Tong et al 2019, Gary et al 1975

2) Whistler heat flux instability (normal cyclotron resonance)=> Quasi-parallel whistlers (Lacombe et al 2014, Kretzschmar et al 2021), role in the heat flux ? Tong et al 2019 -> Amplitudes too small, can't diffuse the strahl

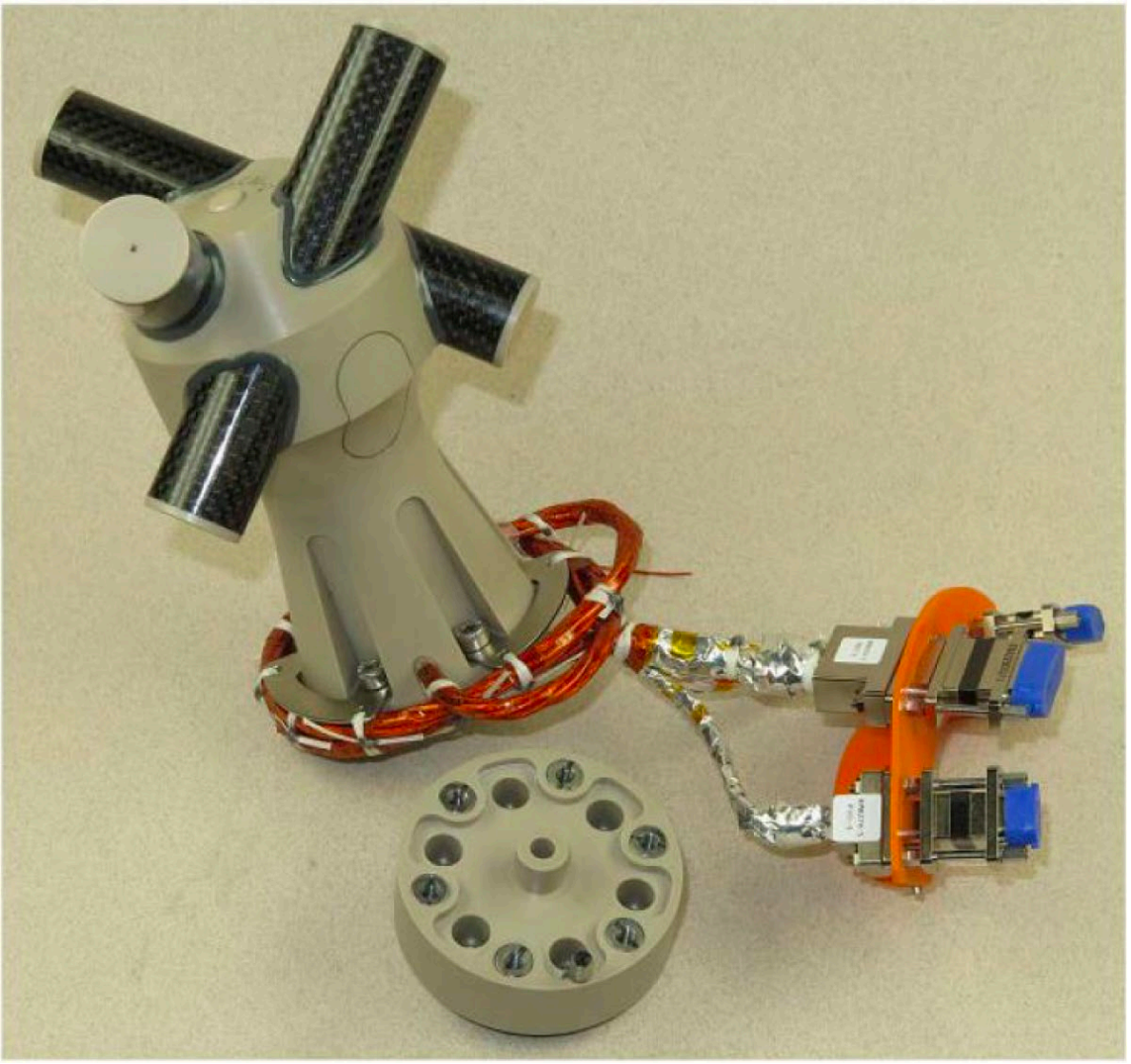
$$v_{||} = v_{\mathrm{cyclo}} \equiv \frac{\omega - \omega_{\mathrm{ce}}}{k_{||}}$$

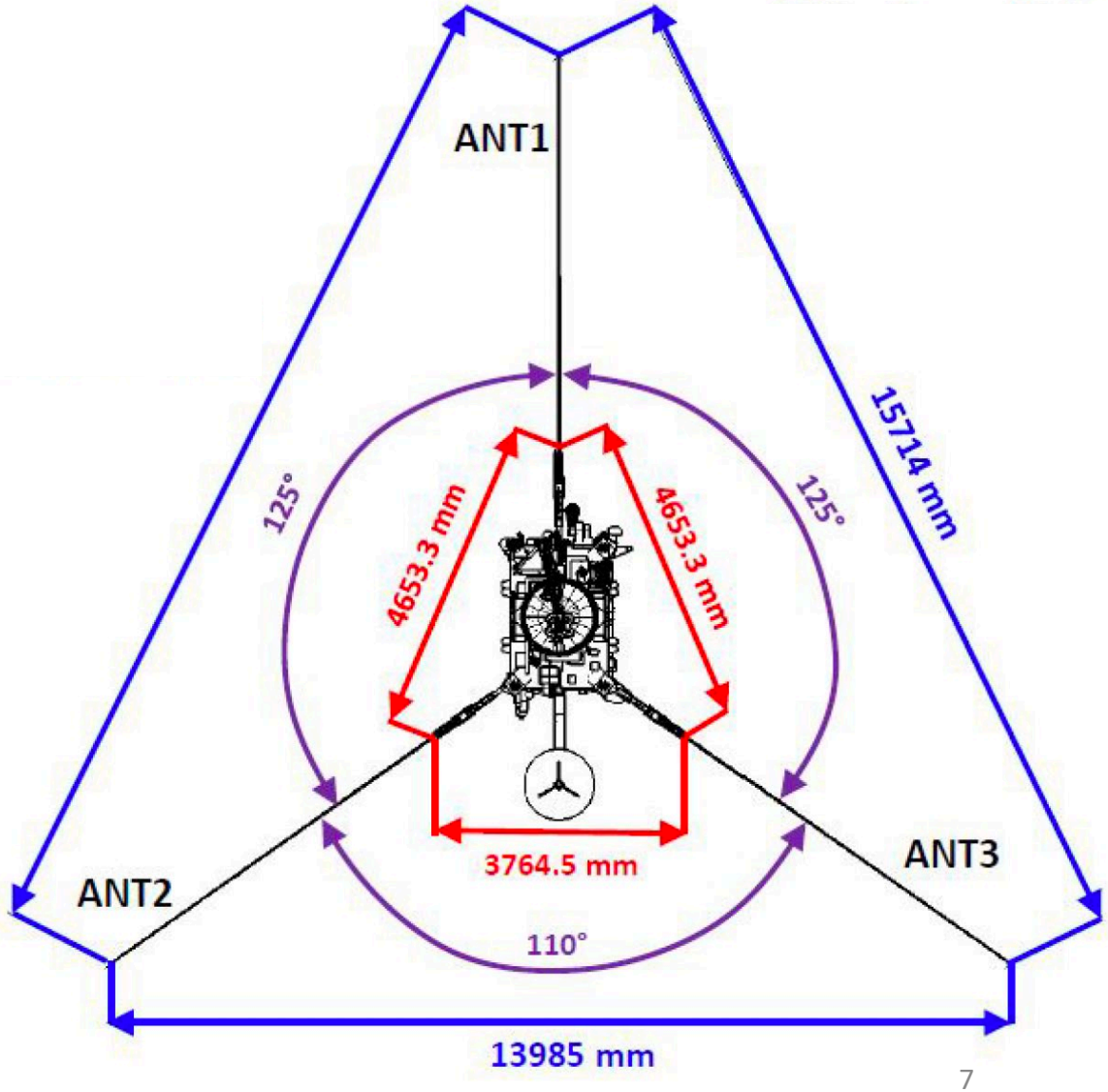
3) Suprathemal electron deficit (Berĉiĉ et al 2021) => Quasi-parallel whistlers, strahl diffusion

Objectives

- Oblique or parallel ?
- On what does their occurrence depend (radial distance, solar wind speed …) ?
- What are the general parameters of whistlers (amplitude, frequency ...) and what do they depend on?

RPW data

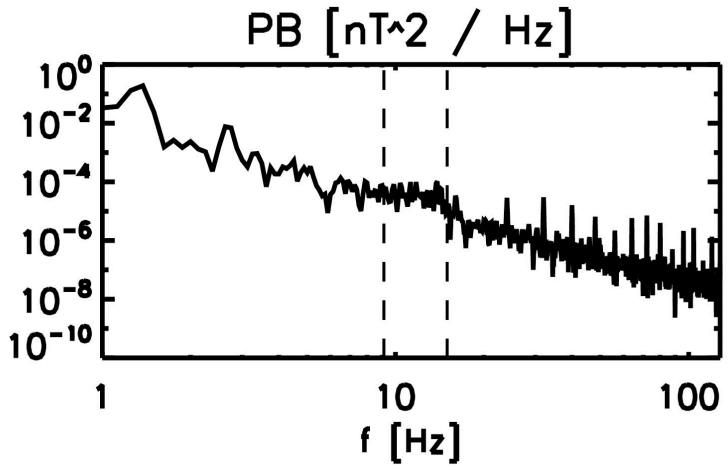



ANT1
ANT2
ANT3
125°
125°
110°
4653.3 mm
4653.3 mm
15714 mm
3764.5 mm
13985 mm

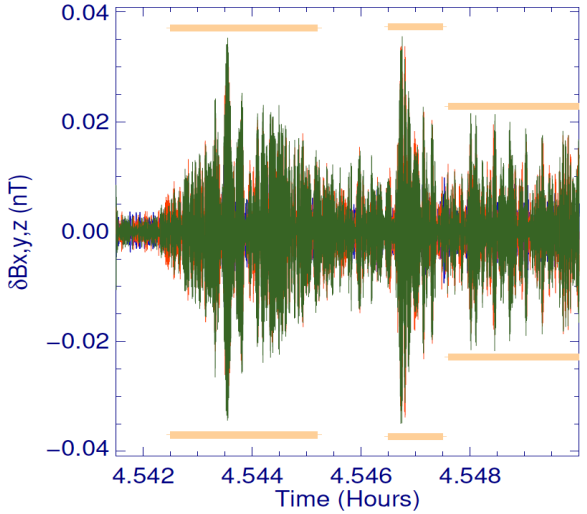
Whistler waves detection

- Search for spectral bumps

(power spectral density divided by the daily median spectrum)



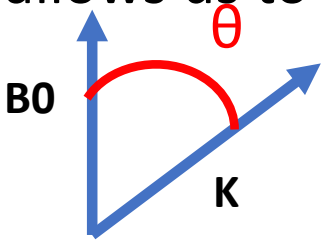
- Detect wave packets in snapshots with signal



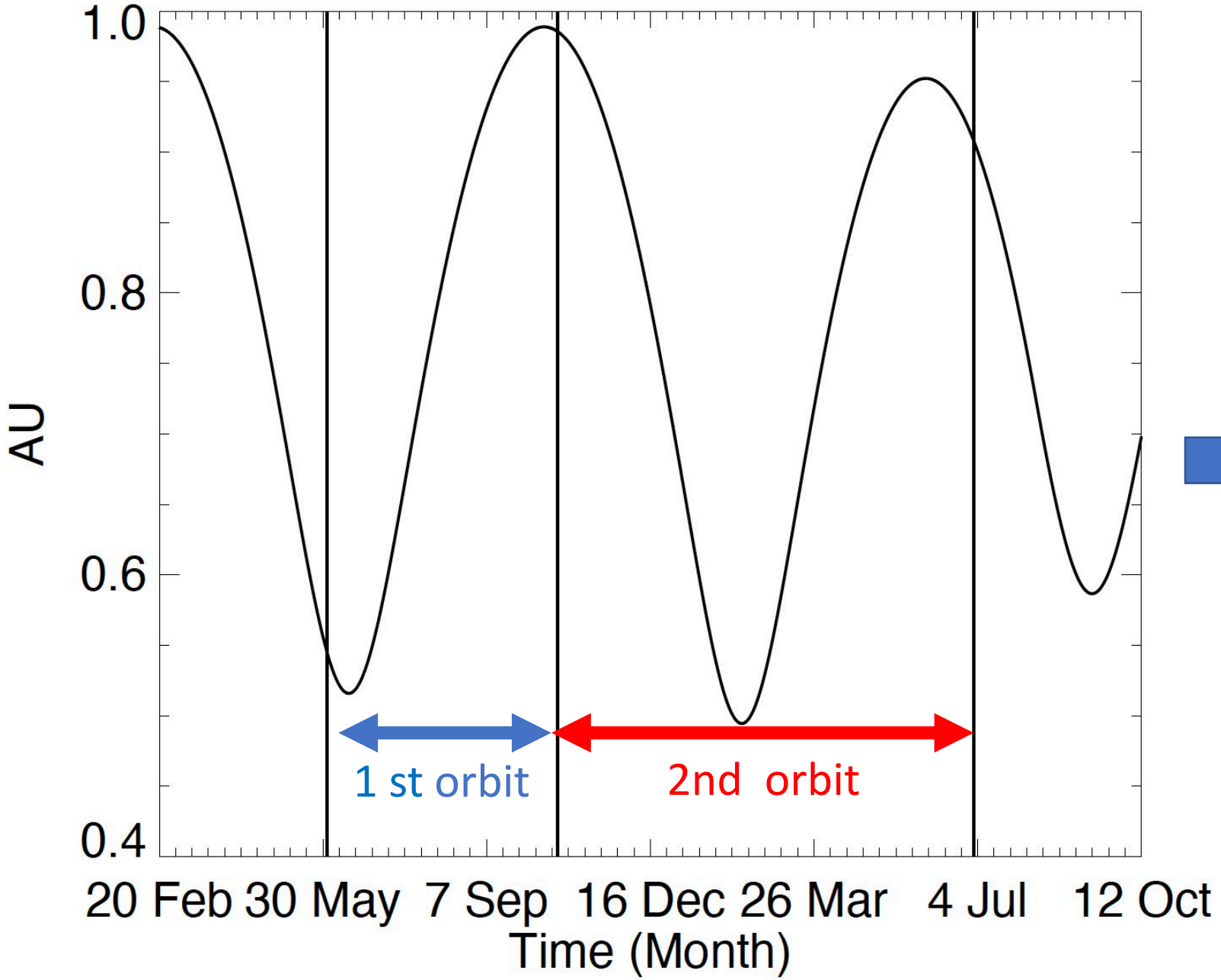
- We choose RH cases with coherence, polarization and planarity >0.6 (Santolik et al 2003, Taubenschuss et al 2019)

- Minimum variance analysis and the study of spectral matrices allows us to know the angle between the wave vector and the static magnetic field

(Paschmann et al 1998)

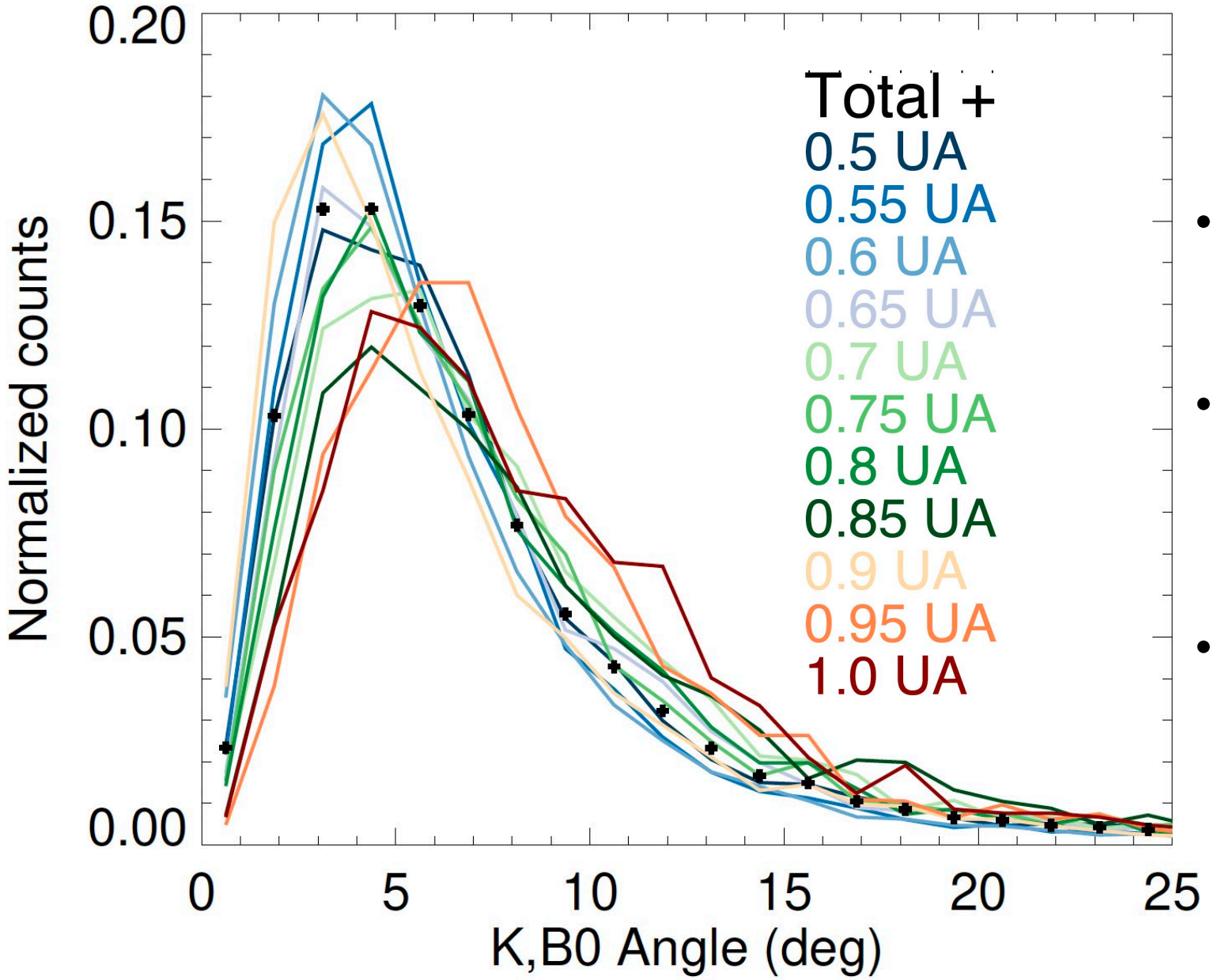


Trajectory



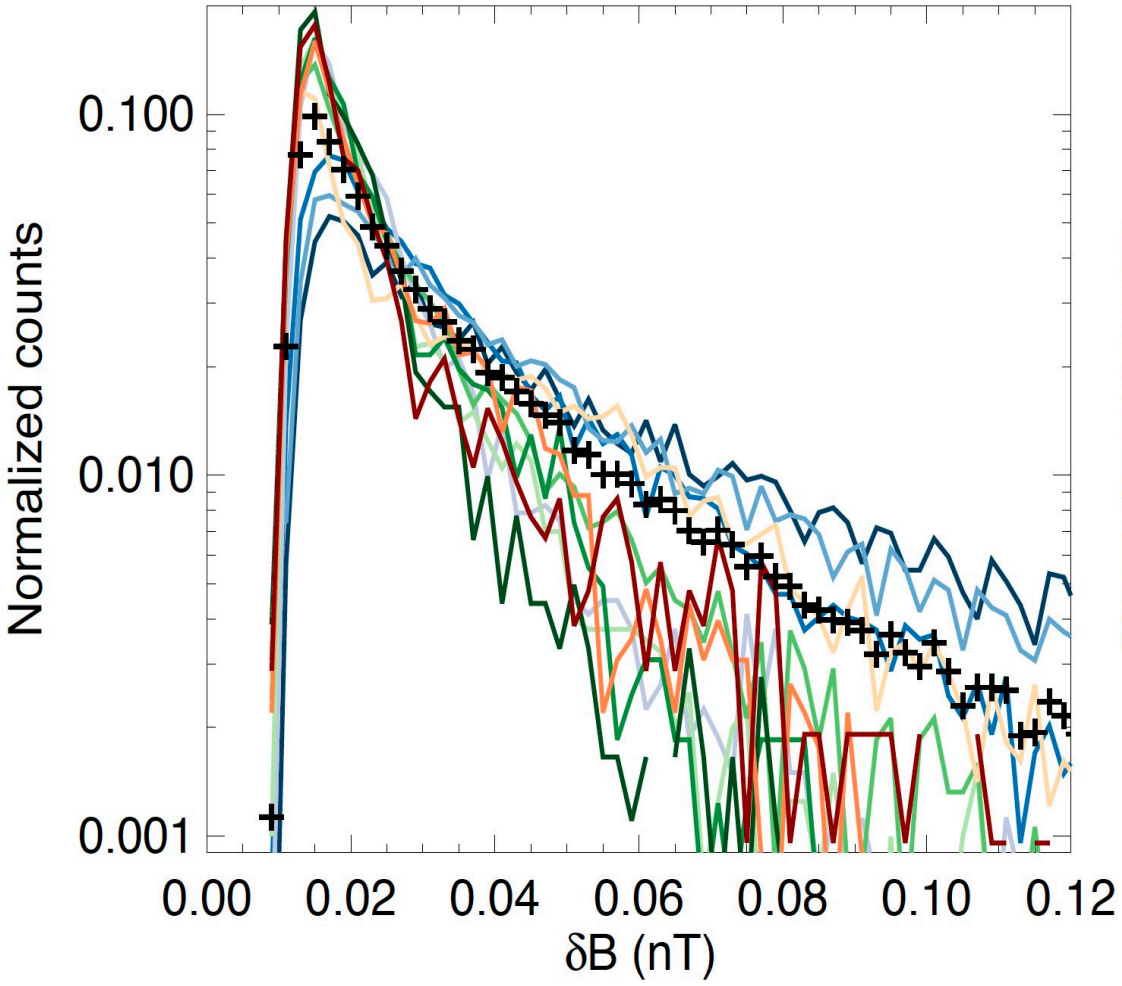
More than **50 000** waves packets that we have categorized as whistlers (extension of Kretzschmar et al 2021

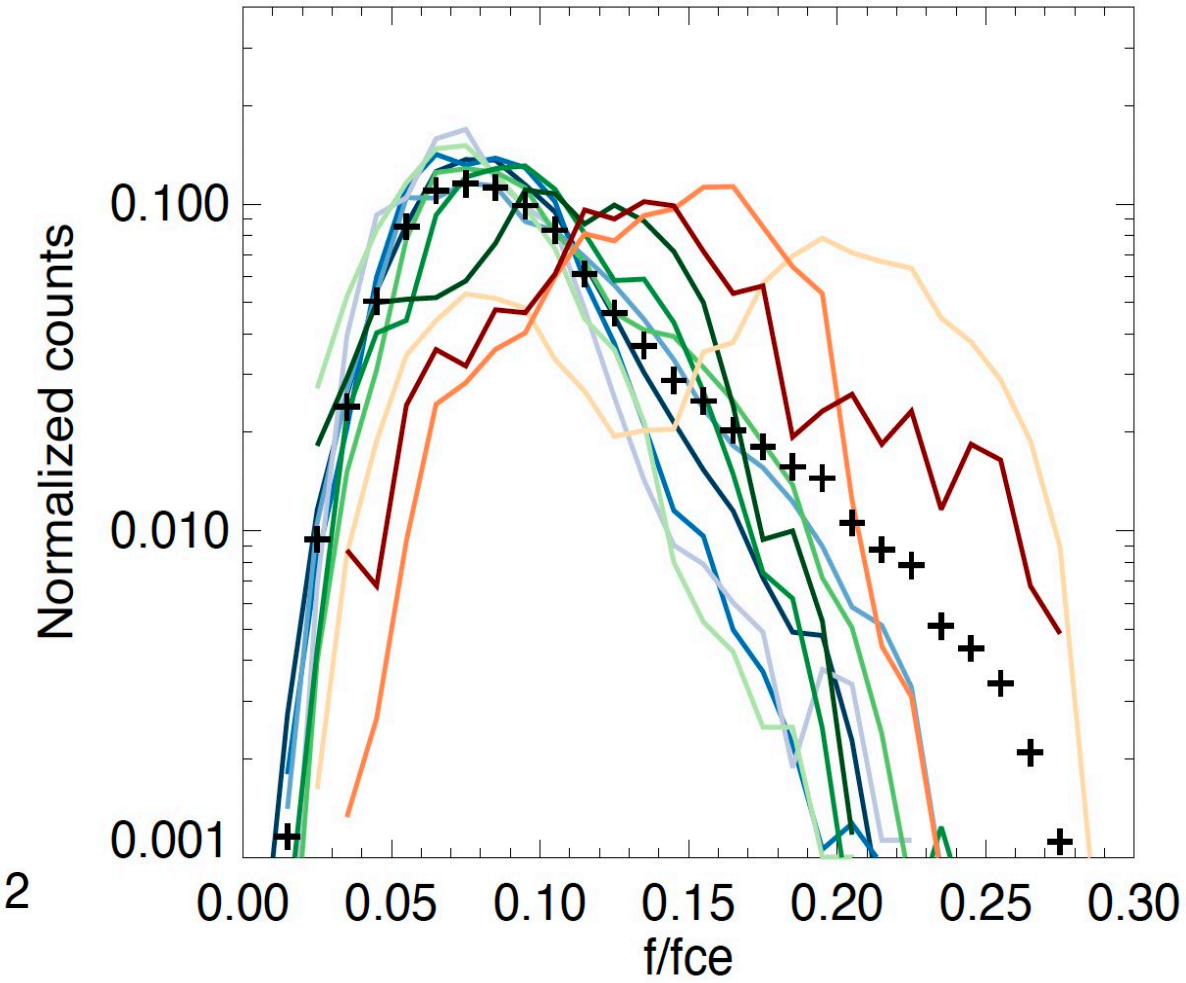
Influence of radial distance



- We have very aligned whistlers
- Very few obliques: only 2% have a propagation angle > 30°
- The angle does not clearly depend on the radial distance

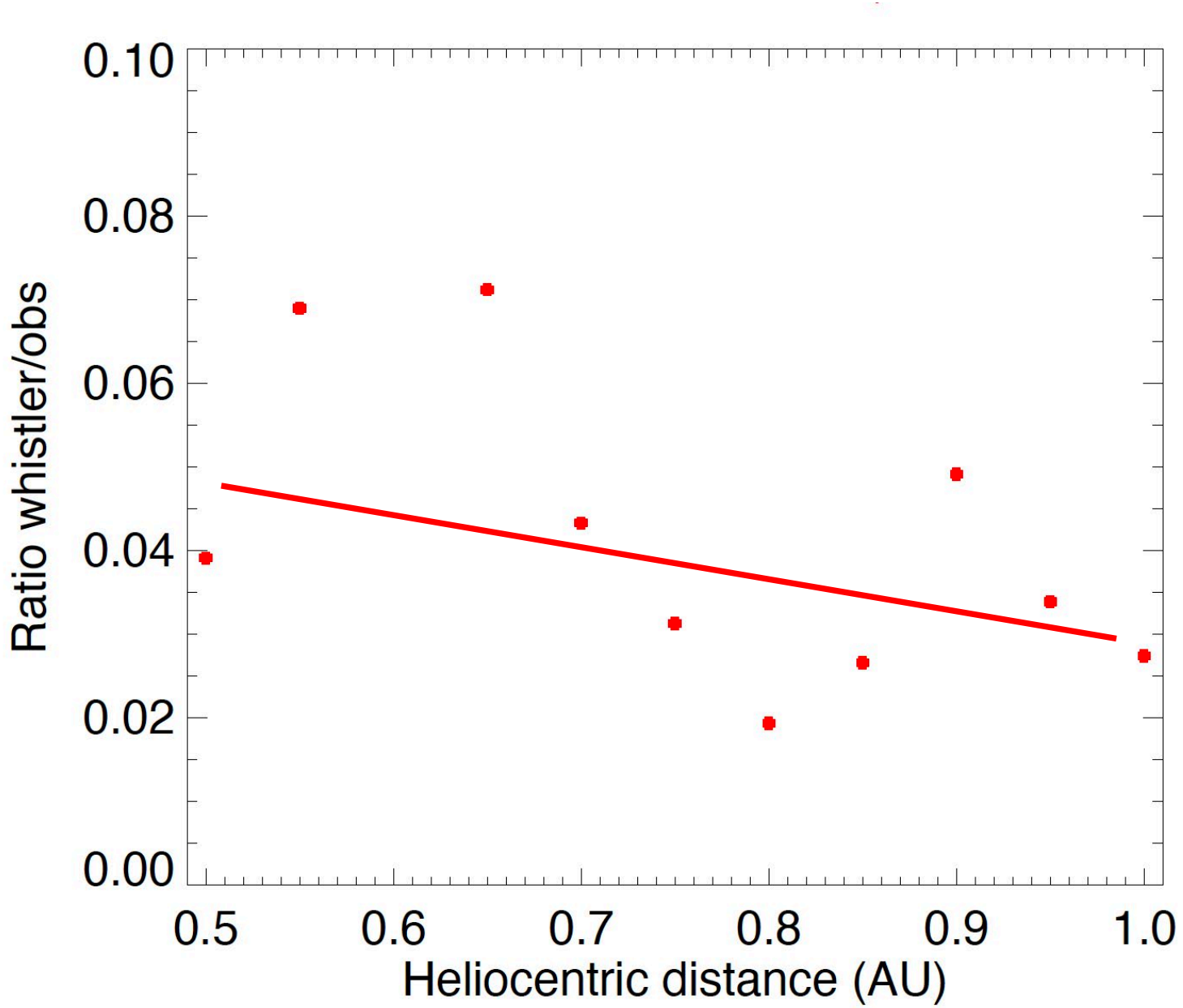
Influence of radial distance





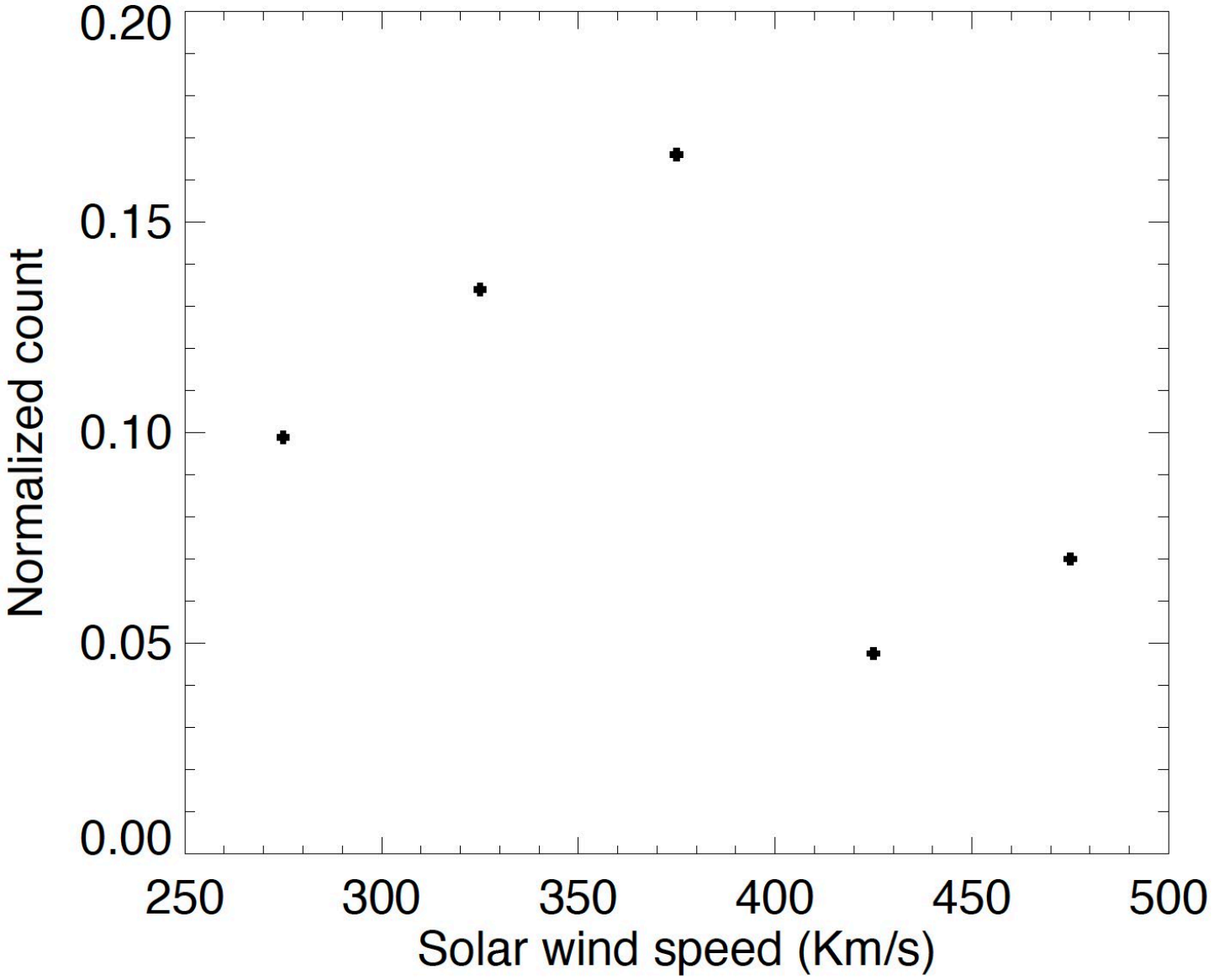
Total +
0.5 UA
0.55 UA
0.6 UA
0.65 UA
0.7 UA
0.75 UA
0.8 UA
0.85 UA
0.9 UA
0.95 UA
1.0 UA

Influence of radial distance



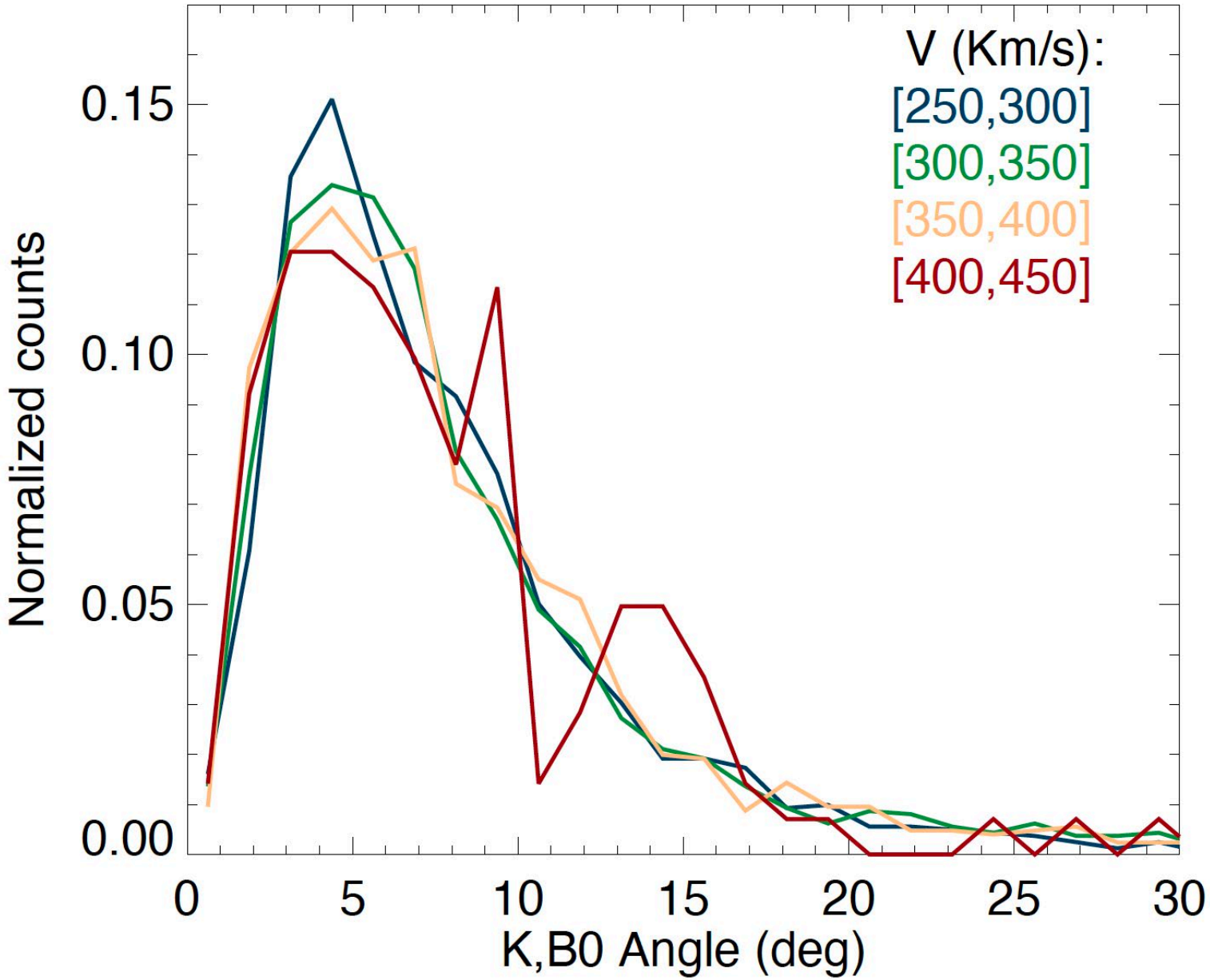
- Important fluctuations : Other parameters come into play
- Slight increase in occurrence when we get closer to the sun

Influence of radial solar wind speed

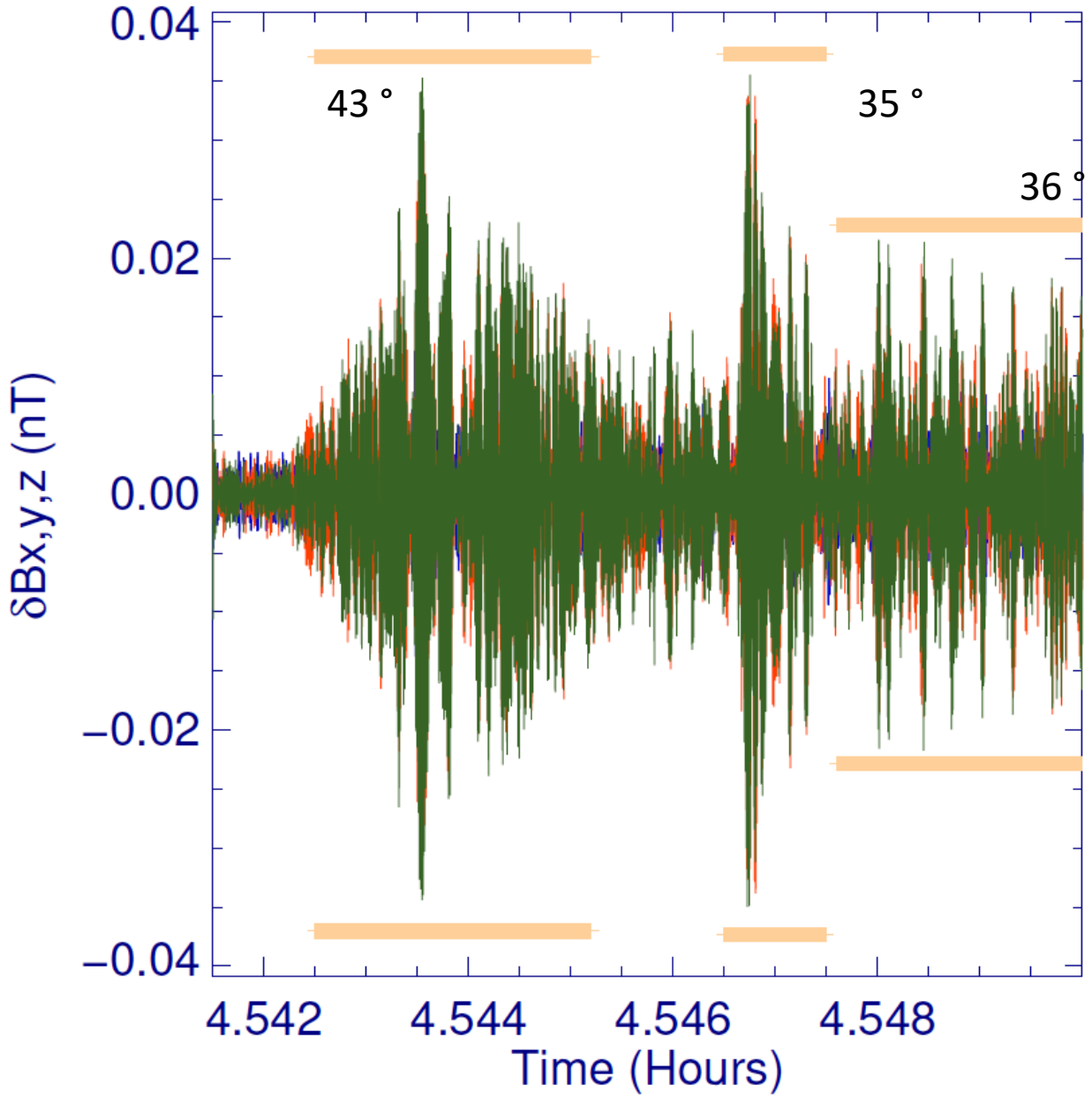


- Important fluctuations
- Need more data to have a complete picture
- Different from Helios

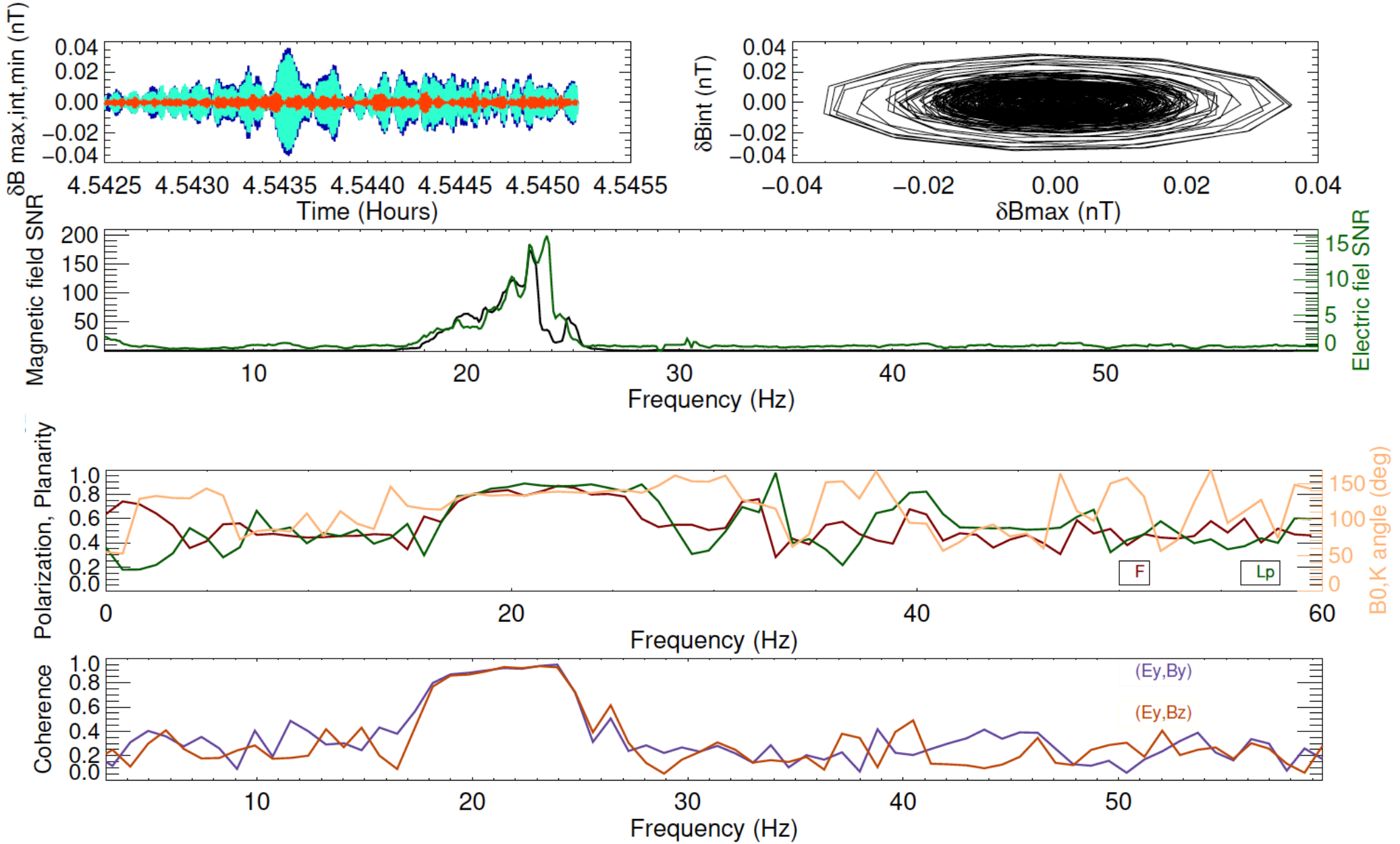
Influence of radial solar wind speed



Examples of oblique whistlers



Examples of oblique whistlers



Conclusion

Robust method to detect whistlers, allows for significant statistical analysis (50 000 waves packets)

We have very aligned and outward whistlers : no clear variation of the angle of propagation with radial distance or solar wind speed. Only 2% have a propagation angle > 30°

Able to deduce variations of certain parameters with radial distance (frequency, amplitude)

We need to extend the study with more data on solar wind speed

Occurrence depends on radial distance, solar wind speed