MULLARD SPACE SCIENCE LABORATORY

UCL

Whistler instability driven by the sunward electron deficit in the solar wind: High-cadence Solar Orbiter observations

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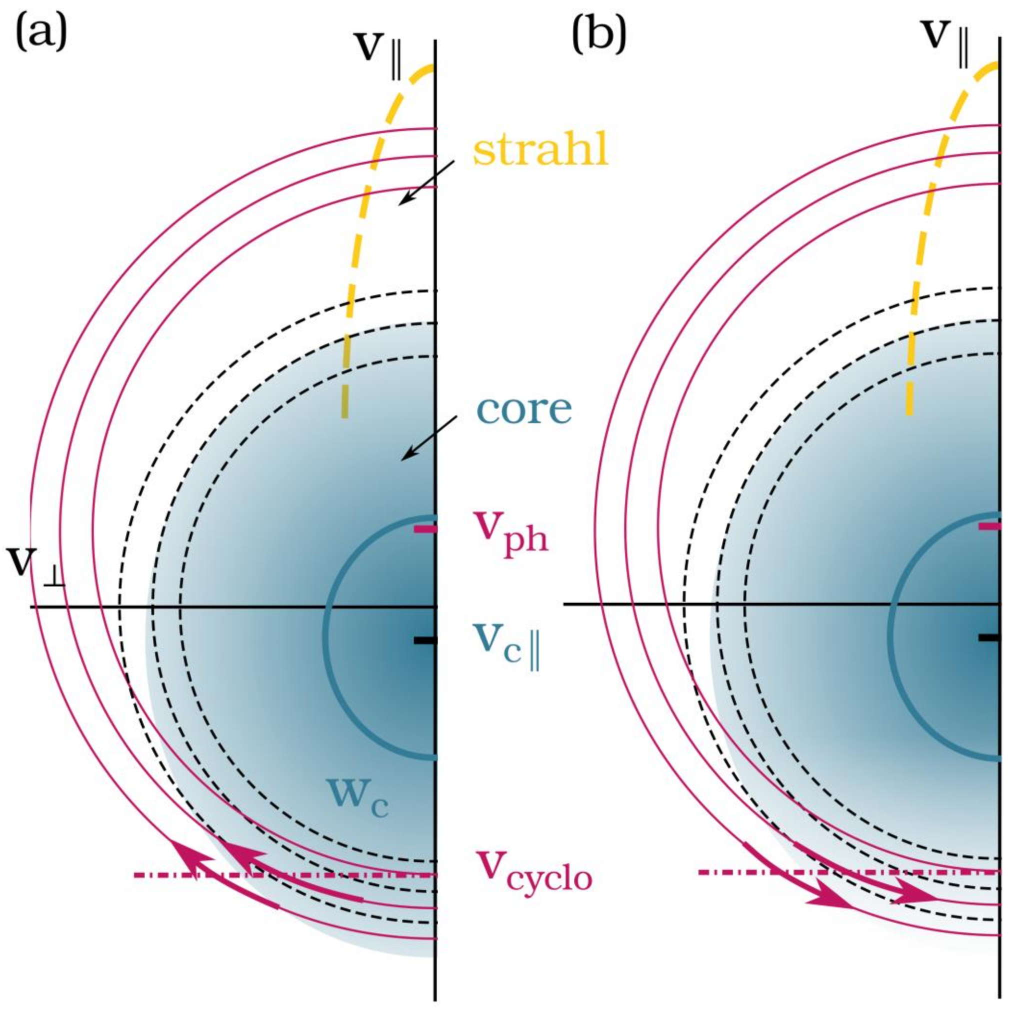
16th ESPM (7/9/2021)

Whistler instability driven by the sunward deficit



- The sunward deficit is a new feature observed in the near-Sun solar wind

- Resonant electrons following the quasilinear diffusion paths either:

(a) Gain energy or
(b) Loose energy.

- This results in quasi-parallel whistler wave

(a) Damping or
(b) Growth.

Solar Orbiter observations

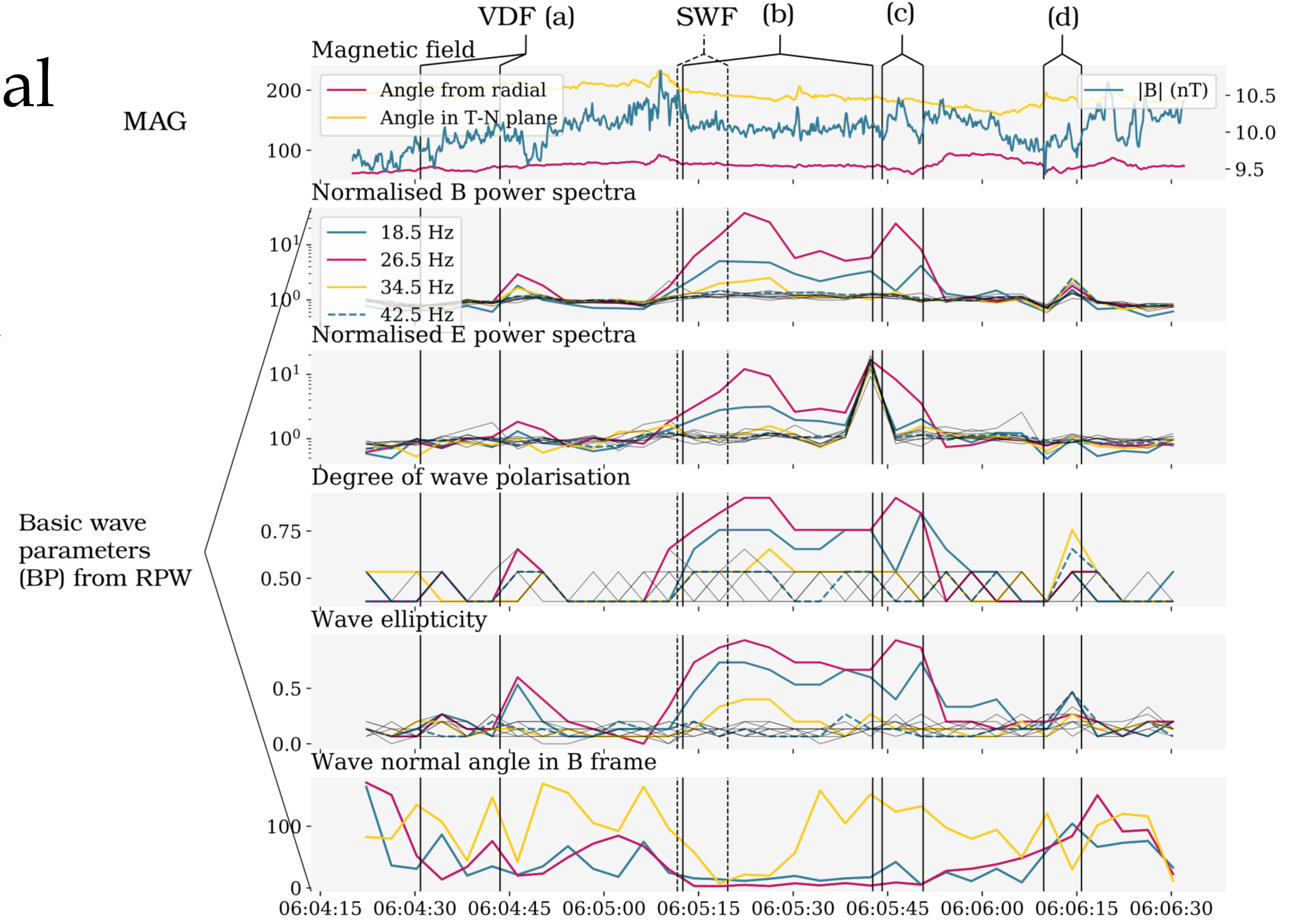
- The Solar Wind Analyser (SWA):
  - Electron Analyser System (EAS) burst mode (8 Hz) – new measurement technique based on the current orientation of the magnetic field
- Magnetometer (MAG):
  - magnetic field vector (8 Hz)
- Radio and Plasma Waves (RPW):
  - Onboard computed basic wave parameters (4 s time resolution)
  - Snapshot waveform (8 s, 256 Hz)

- Selected interval is from June 24th, 2020, when SO was at a heliocentric distance of 112 R_S.

Selected interval

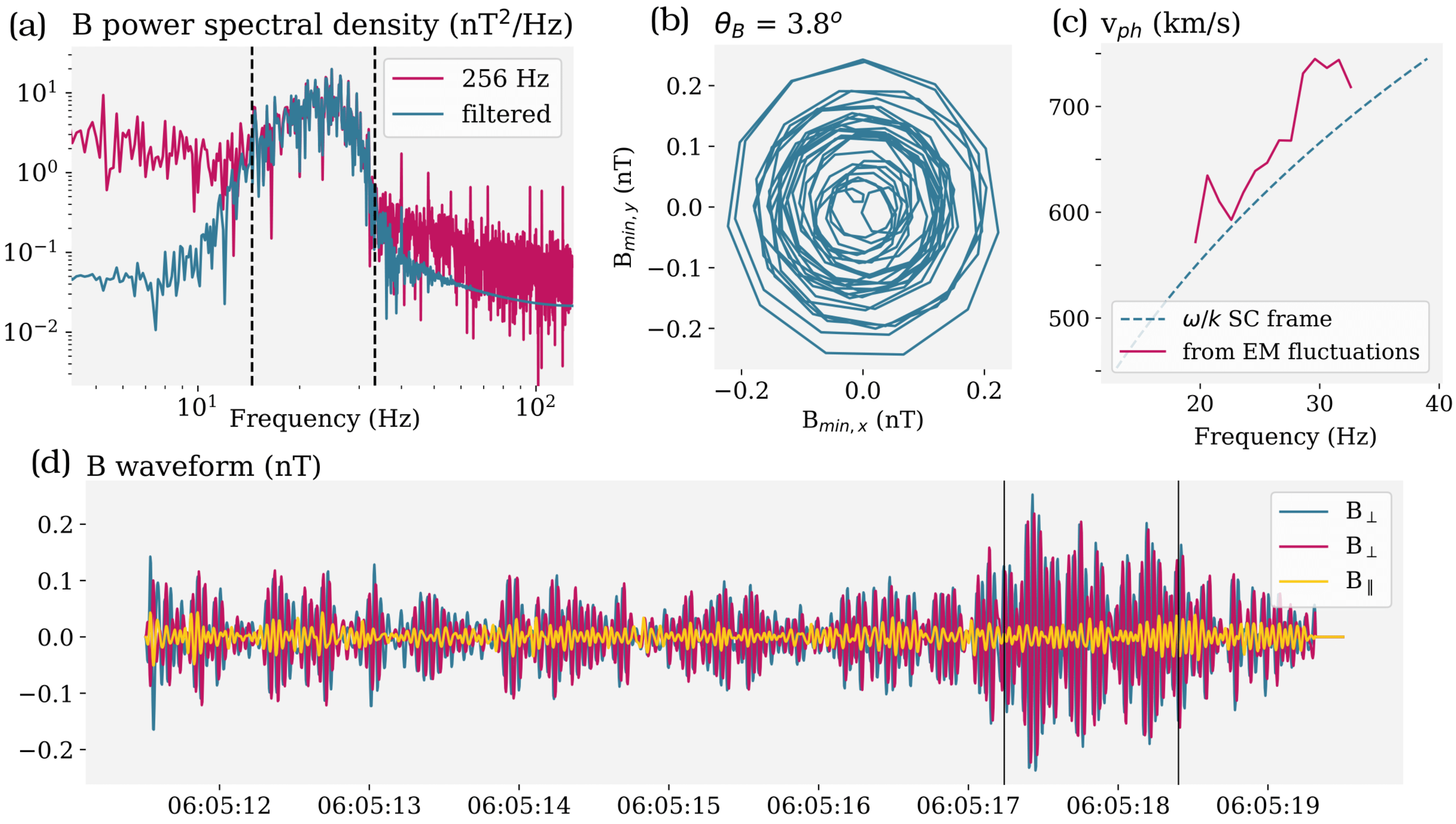
- Enhanced B and E fluctuations in frequency bins 18.5 and 26.5 Hz, with high polarisation and ellipticity

- Wave normal angle is close to direction of background B field

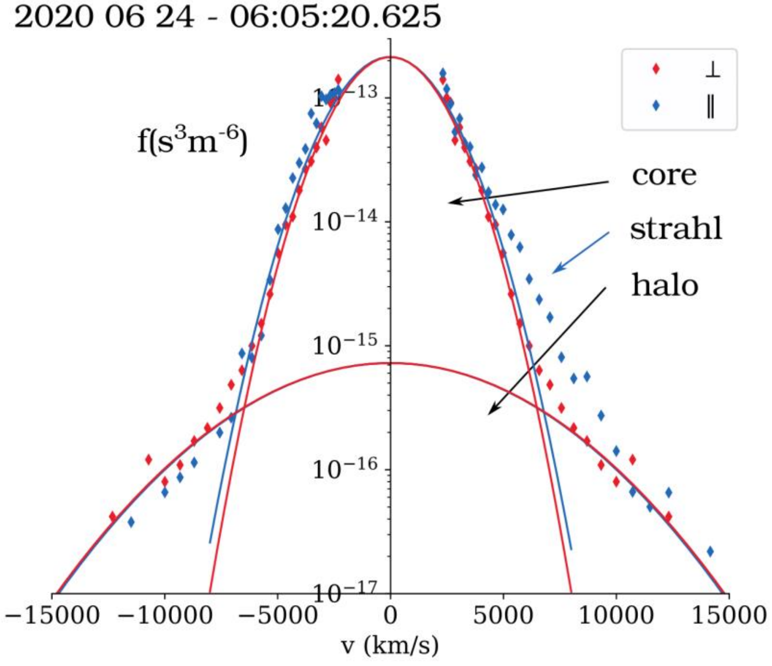


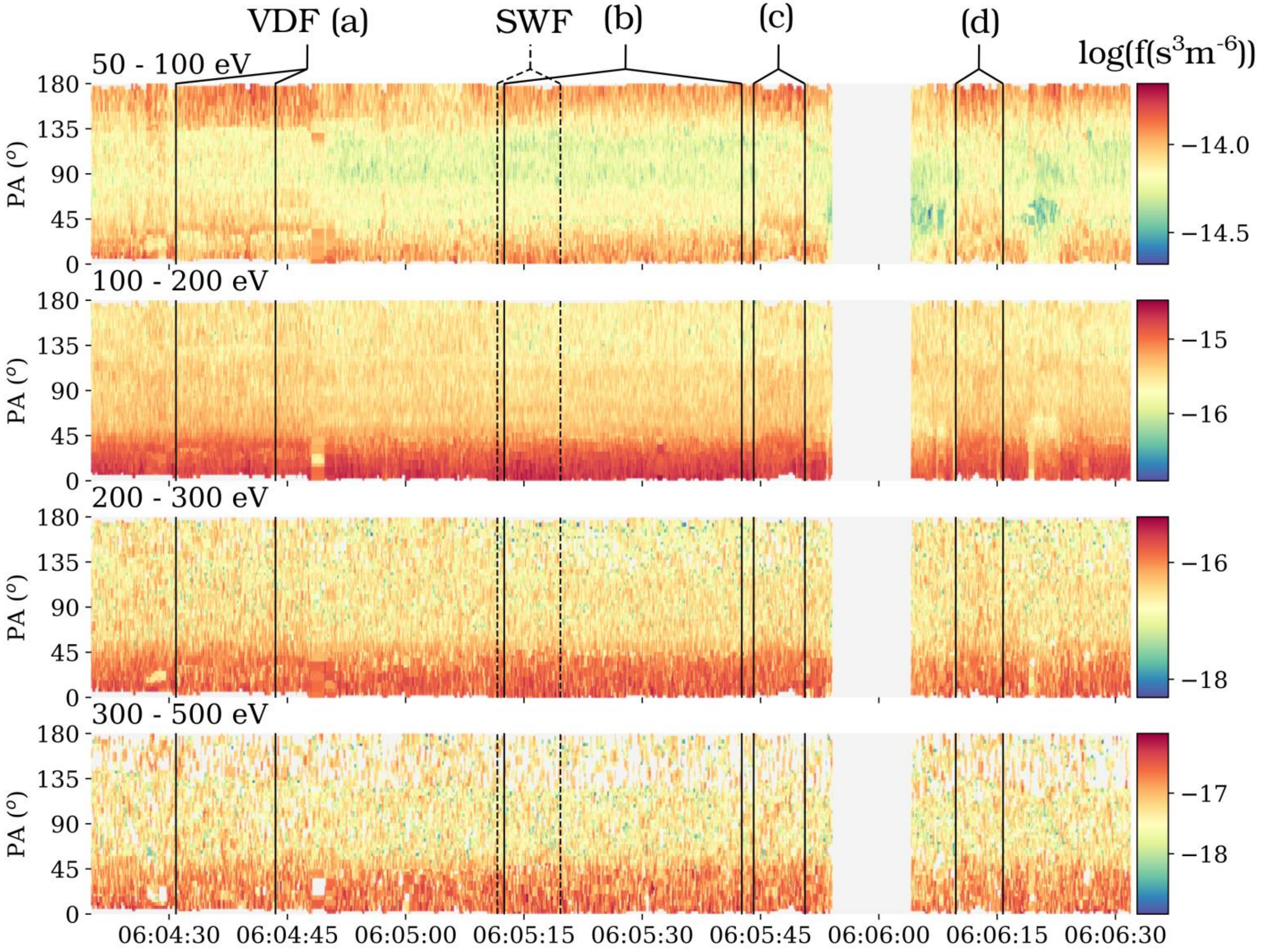
Snapshot waveform (SWF)

- $\Delta f = 20$ Hz
- $f_w = 24$ Hz
- $\omega = 0.085\ \omega_{ce}$
- $B_w = 0.15$ nT
- $B_0 = 10.1$ nT

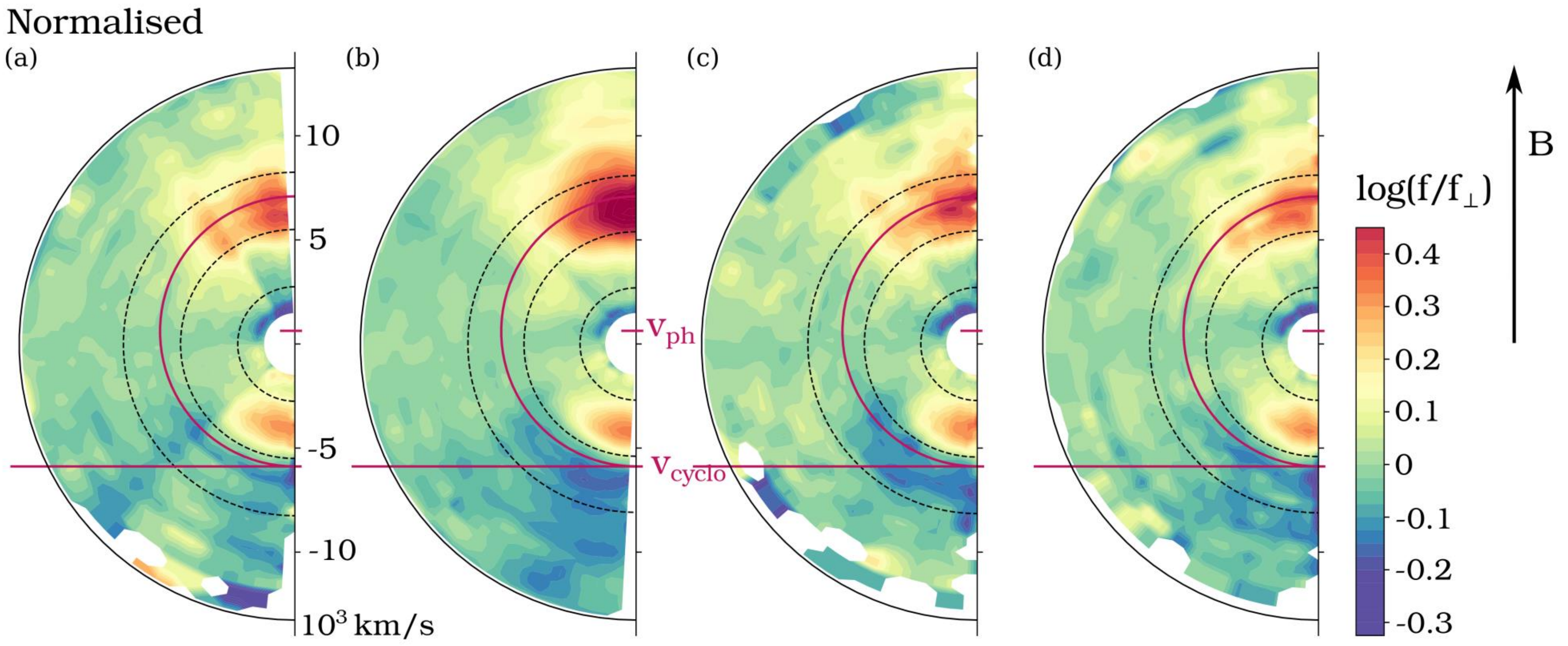


EAS burst mode electron distributions



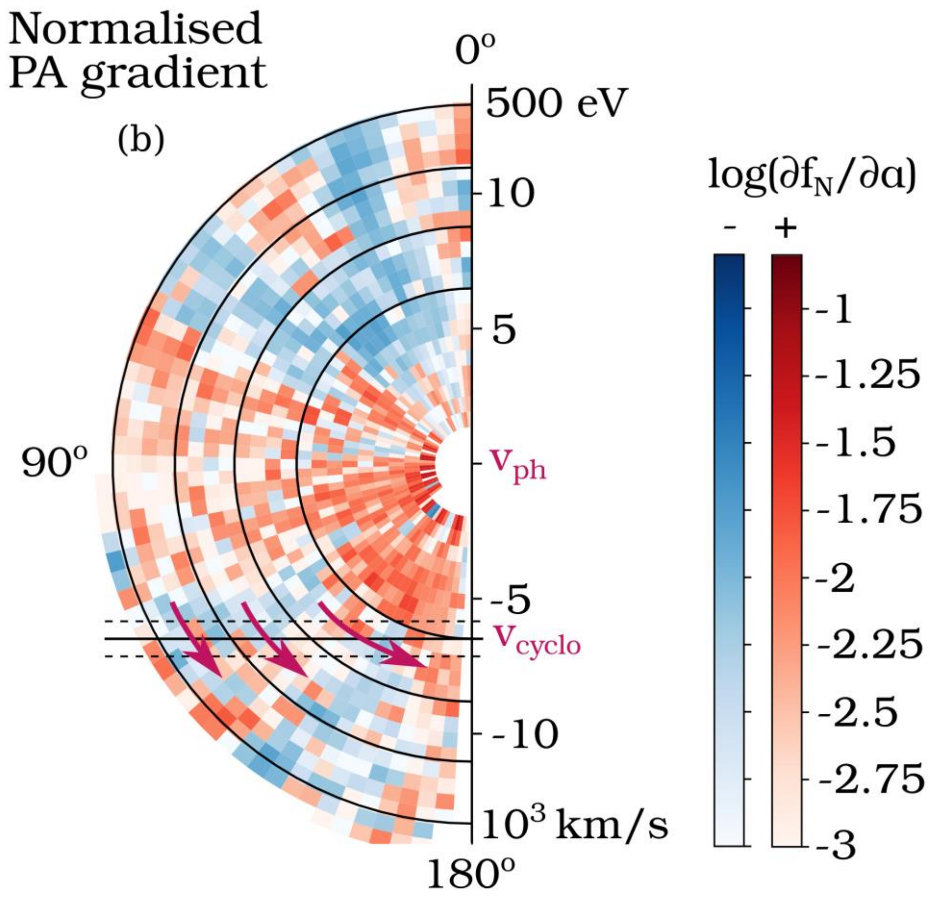


Time-averaged VDFs



- Electron VDF is divided by a cut along the perpendicular direction
- Allows a direct comparison of different pitch-angles to the VDF at pitch angle 90 deg

Pitch-angle gradient in wave reference frame



- The sunward deficit is more pronounced in examples (b) and (c) coinciding with whistler waves

- Cyclotron resonant velocity matches the position of the deficit in the velocity space

- The pitch-angle gradient for the electrons with velocities close to v_{cyclo} is negative:

Electrons following the diffusion paths loose energy, which corresponds to scenario (b).

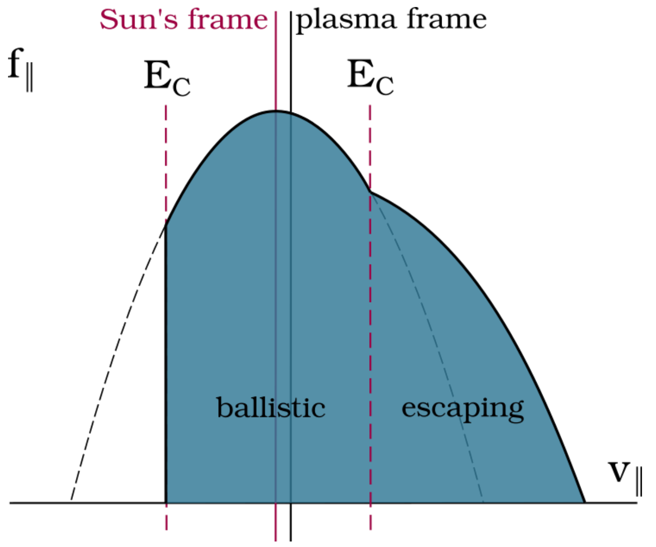
Conclusions

- We propose an instability scenario in which quasi-parallel whistler waves are created by the quasilinear diffusion of resonant electrons associated with the sunward electron deficit in phase-space
- We analyse simultaneous observations of high-cadence electron VDFs and quasi-parallel whistler waves from SO
- The sunward deficit is more pronounced in examples coinciding with whistler waves
- Cyclotron resonant velocity matches the position of the deficit in the velocity space
- The pitch-angle gradient for the electrons with velocities close to v_{cyclo} is negative: electrons following the diffusion paths loose energy (scenario (b))

Discussion: The origin of the sunward deficit

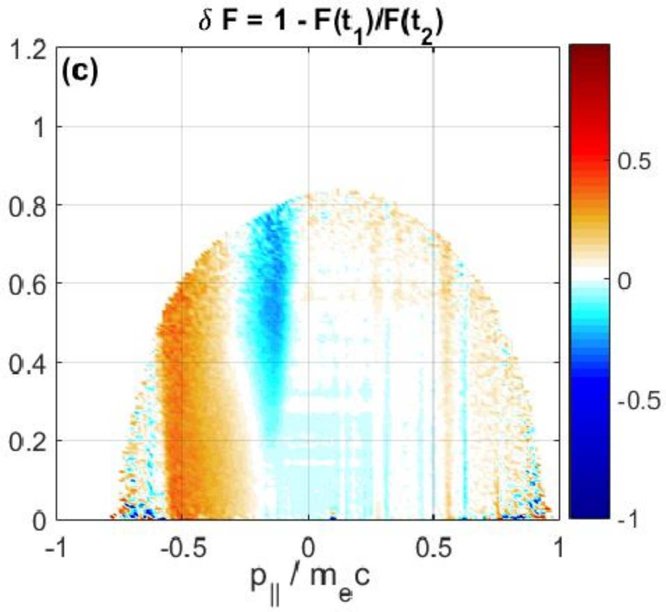
1: The sunward deficit is the remnant of the exospheric electron cutoff

- Halekas et al. (2021), Bercic el al. (2021 - in revision)



2: Nonlinear evolution of the whistler heat flux instability

- Kuzichev et al. (2019)



3: Following the oblique whistler heat flux instability

- Micera et al. (2020, 2021)