ULF Wave Polarization Dynamics as a Key to Understand Wave-Particle Interactions in the Magnetosphere

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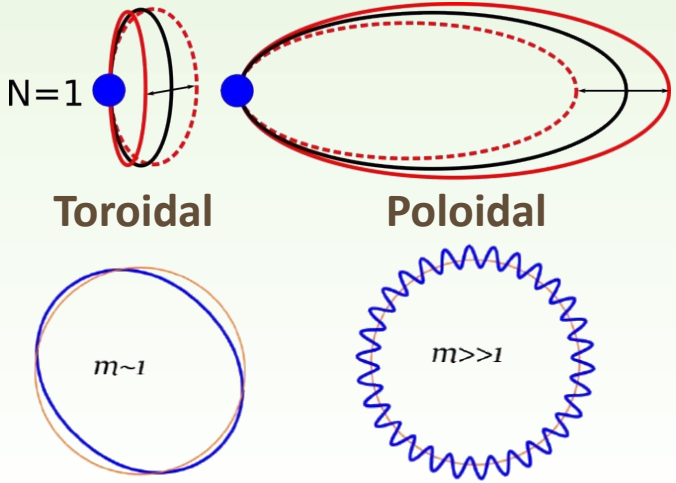
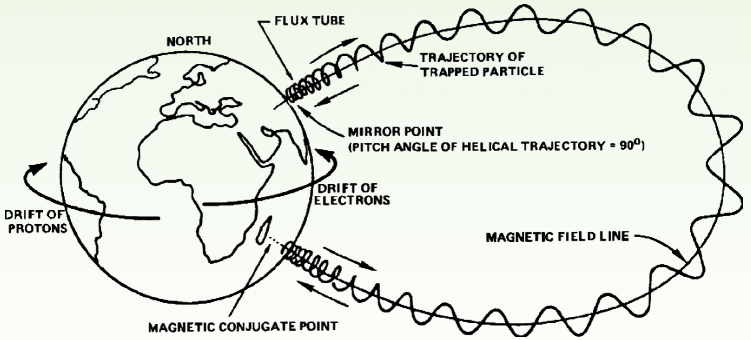
Brief background

•Ultralow frequency (ULF) waves in Pc4 (45–150 s) and Pc5 (150–600 s) bands are eigenoscillations of terrestrial magnetic field-lines responsible for large-scale energy transfer throughout the magnetosphere



[Klimushkin+, 2021]

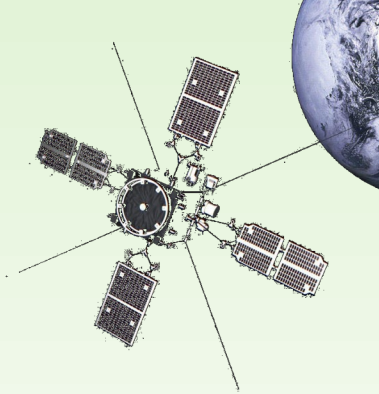


•Toroidal and poloidal waves are Alfvén waves excited by external and internal sources, respectively

•Compressional waves along field-lines occur in ULF range as well, but rarely

•ULF wave-particle interactions are of a special interest

What is this study about?



Statistical analysis of ULF waves observation in the magnetosphere by Arase satellite in 2017–2020 *[Rubtsov+, 2023a,b, JGR]*

Details:

- Spatial distribution of occurrence rate and wave frequency of toroidal, poloidal and compressional waves during disturbed and quiet geomagnetic conditions

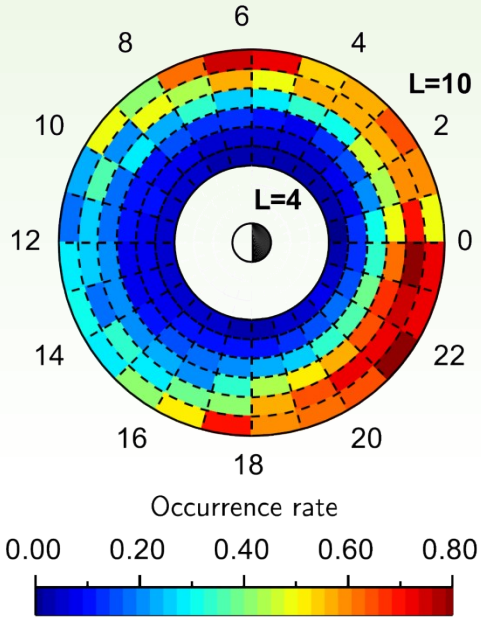
- Searching for separate clusters of ULF waves according to its average polarization that might be connected to a particular energy source

- Polarization change in time or space. Future direction in ULF wave study

Spatial distributions

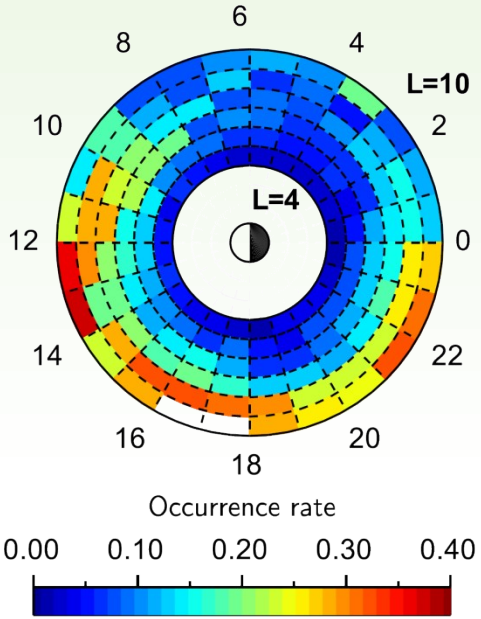
- 3 observations of all MLTs in L = 4–10 of the magnetosphere in 2017–2020

Toroidal



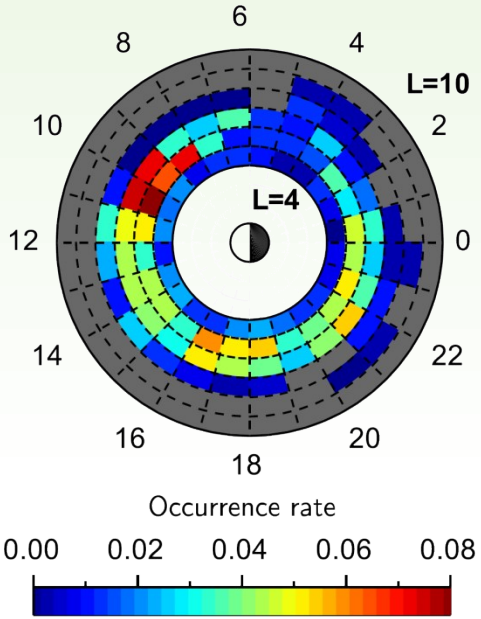
$\langle b_a \rangle > \langle b_r \rangle, \langle b_{||} \rangle$

Poloidal



$\langle b_r \rangle > \langle b_a \rangle, \langle b_{||} \rangle$

Compressional



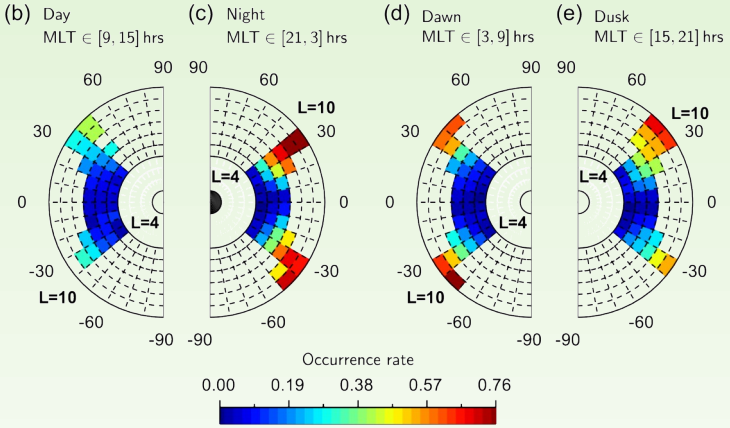
$\langle b_{||} \rangle > \langle b_r \rangle, \langle b_a \rangle$

Spatial distributions

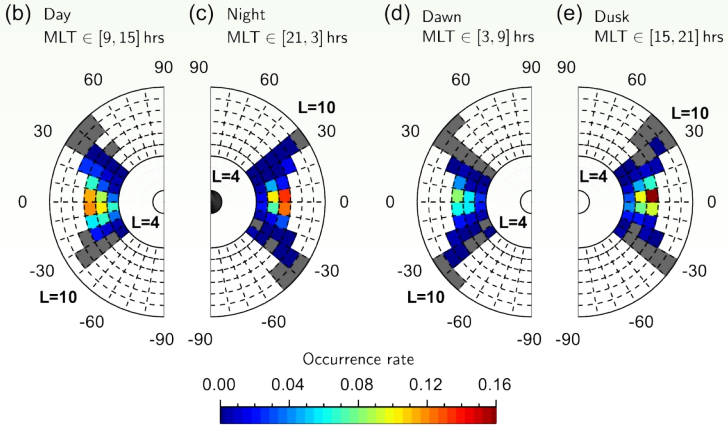
Latitudinal distributions:

- Higher harmonics of toroidal waves
- Odd and even harmonics of poloidal waves
- All the compressional waves near equator

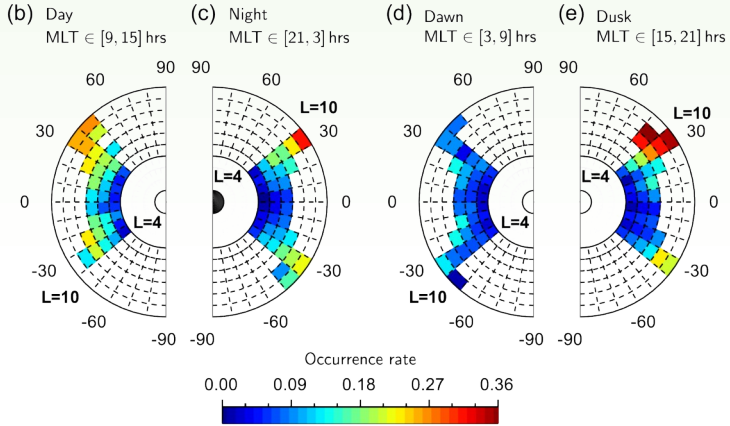
Toroidal waves



Compressional waves

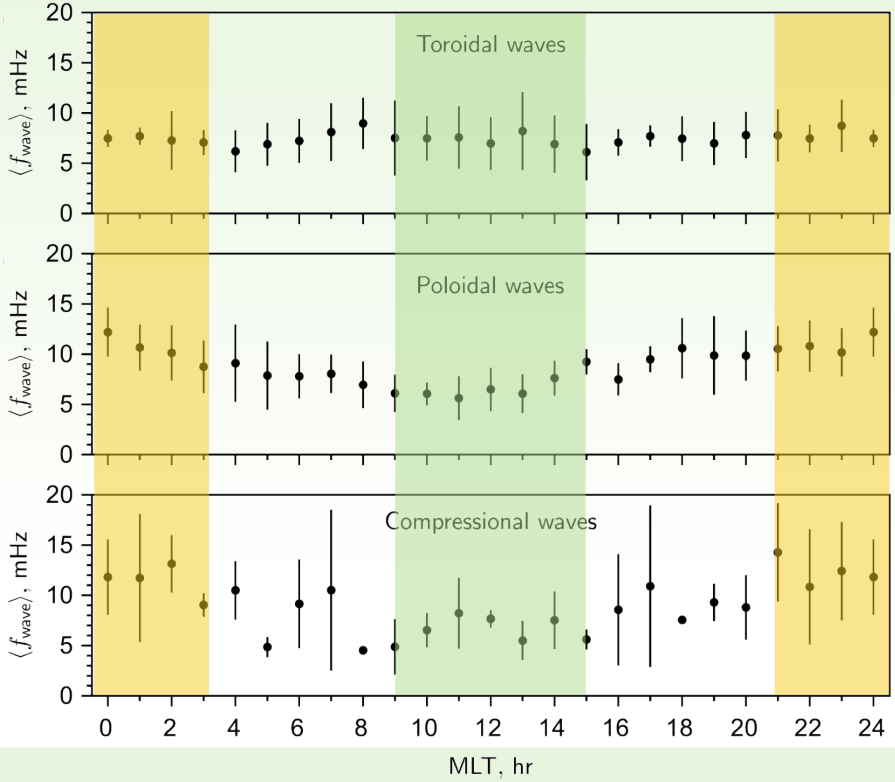


Poloidal waves

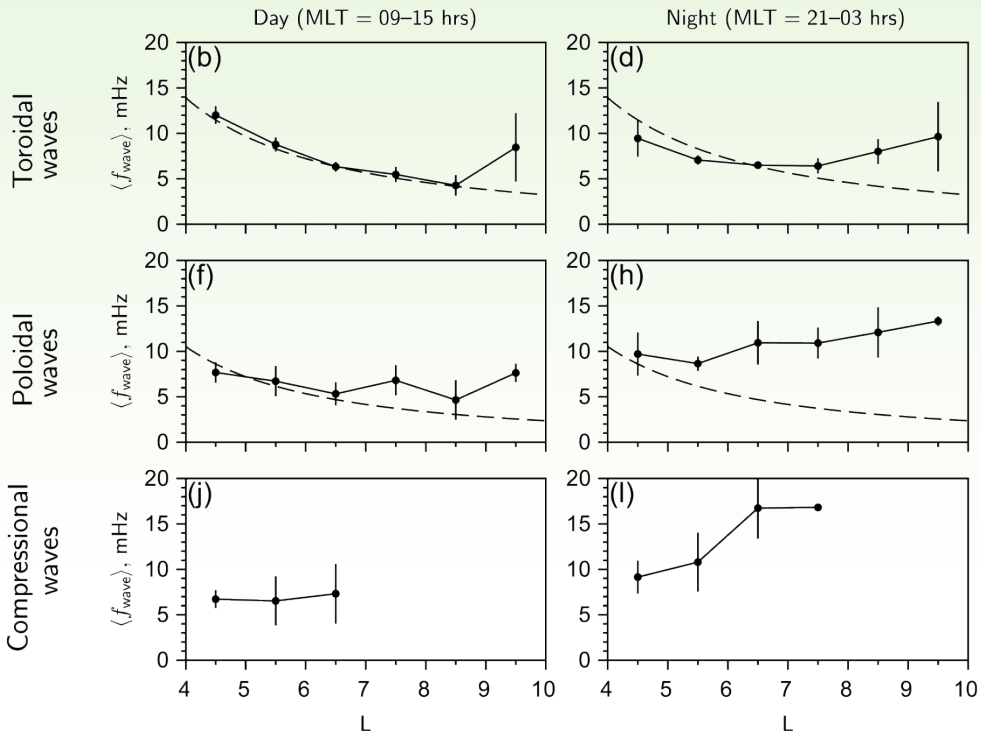


Wave frequency distribution

by MLT for all L-shells



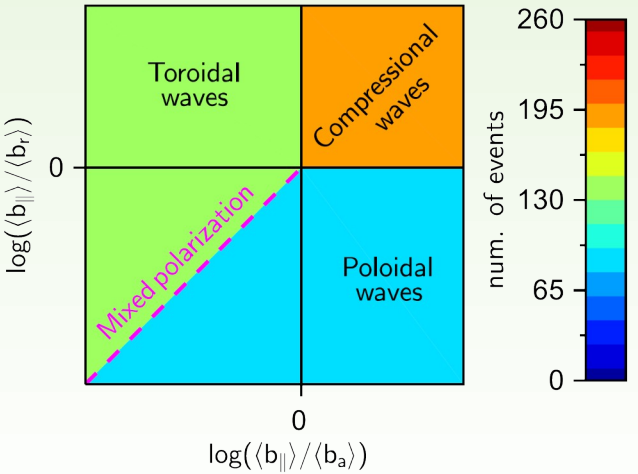
by L-shell for MLT = 09–15 and 21–03

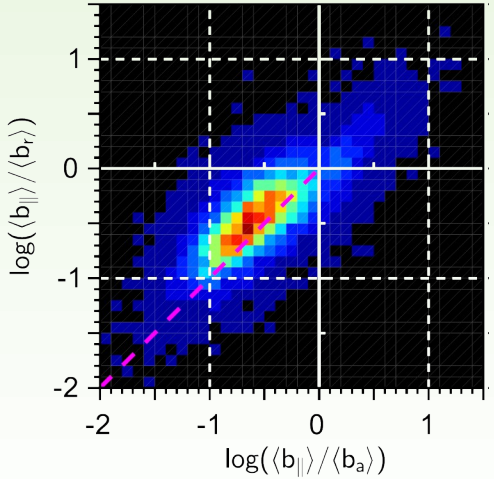


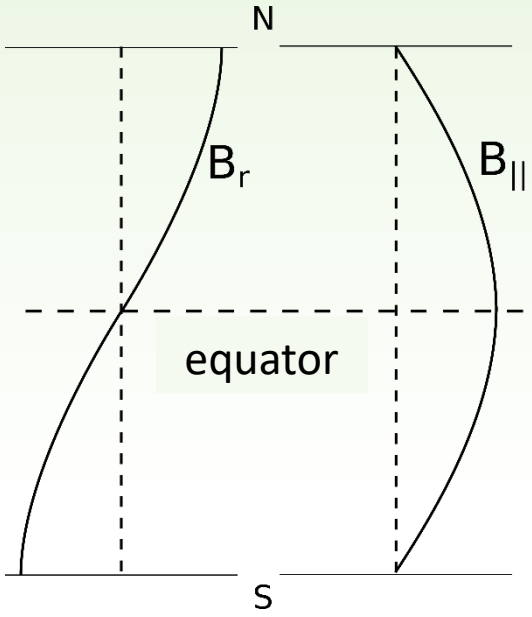
Dawn and dusk sectors in SI for [Rubtsov+, 2023a, JGR]

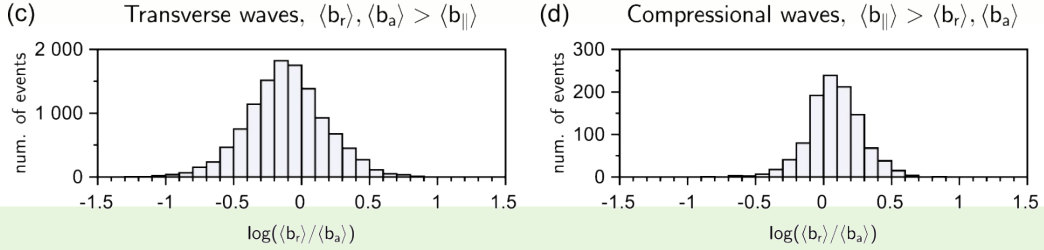
Polarization features

Single cluster without separate groups of toroidal/poloidal waves





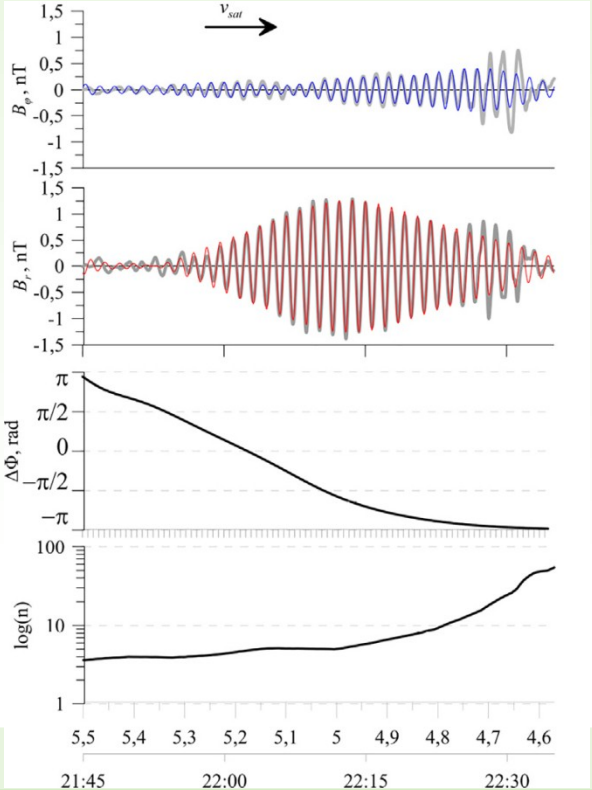


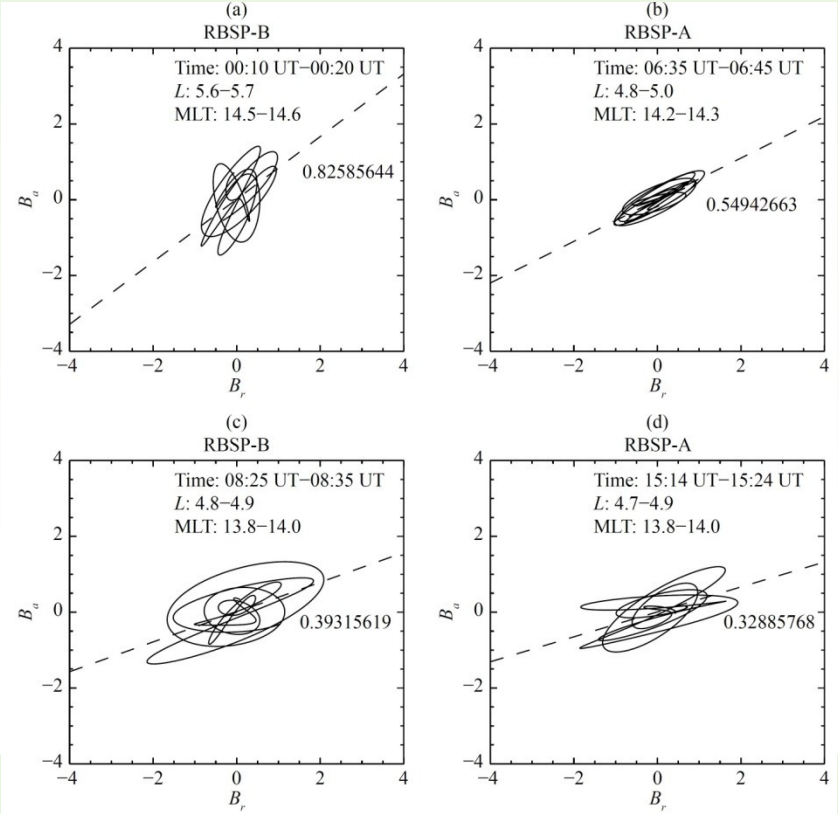


Polarization features

Polarization change during single spacecraft pass: space or time effect?

[Kozlov+, 2024]





[Wei+, 2019]

Polarization features

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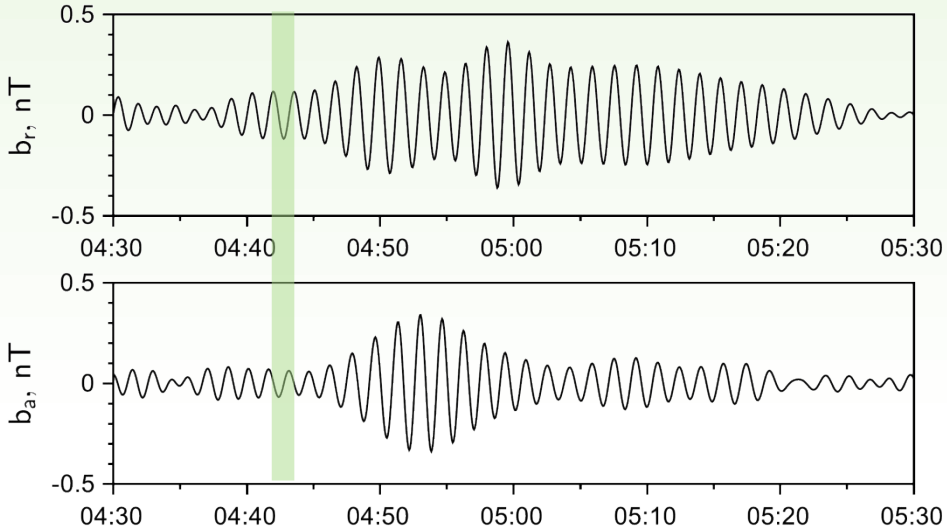
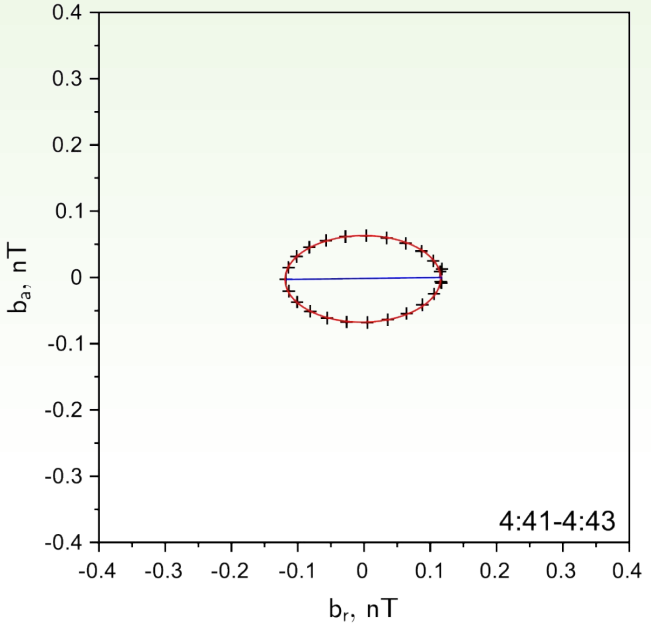
Theories support both scenario, but statistical study is necessary to confirm





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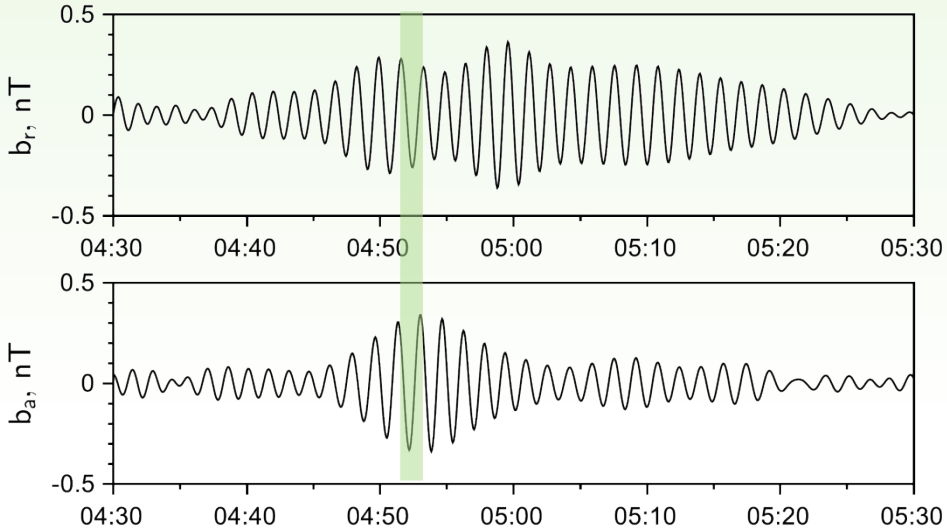

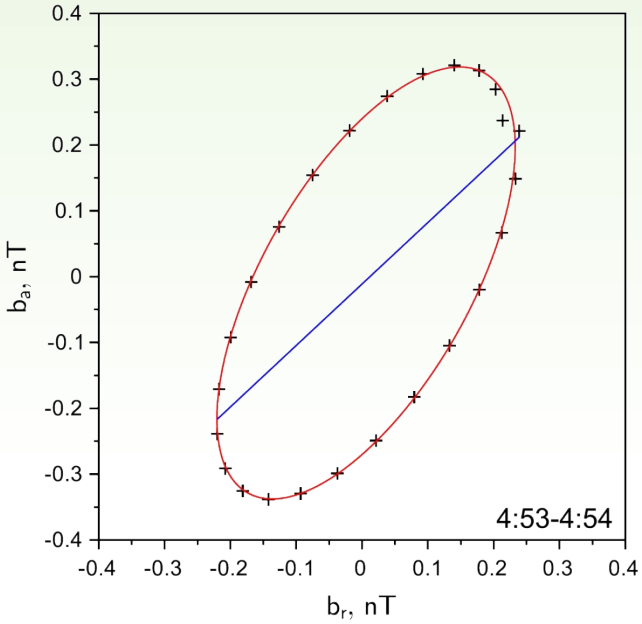

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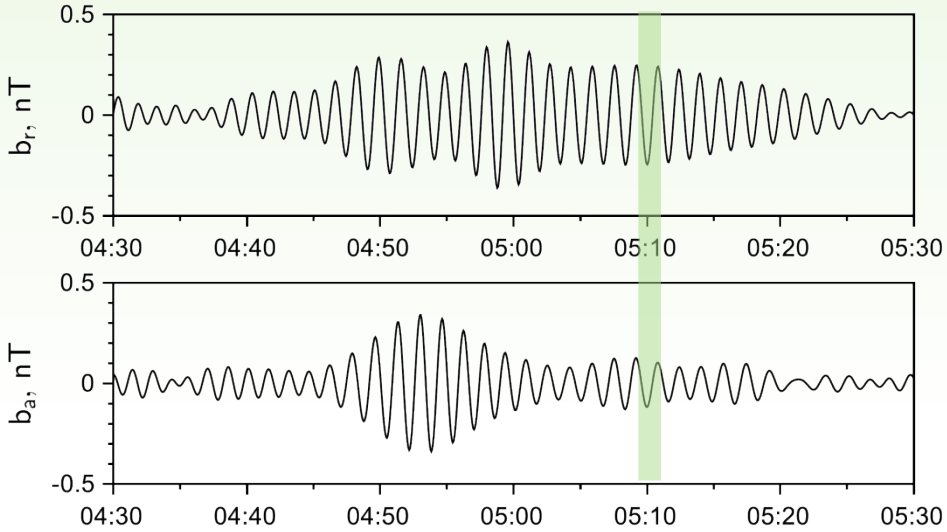

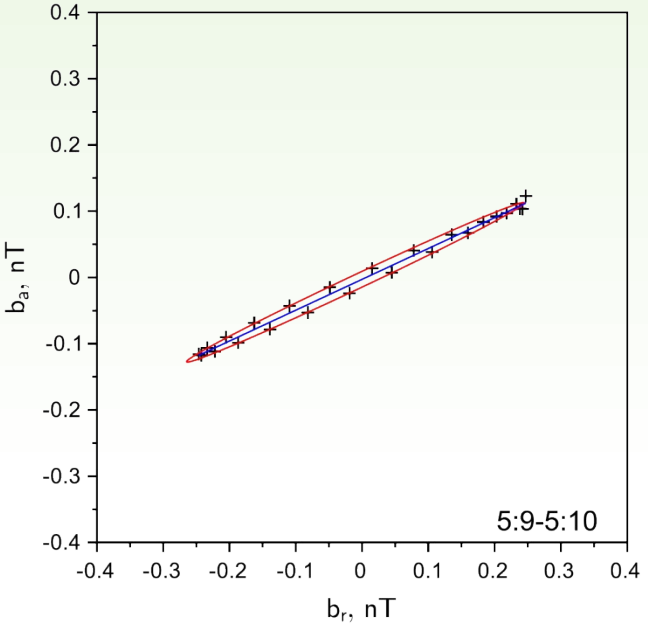

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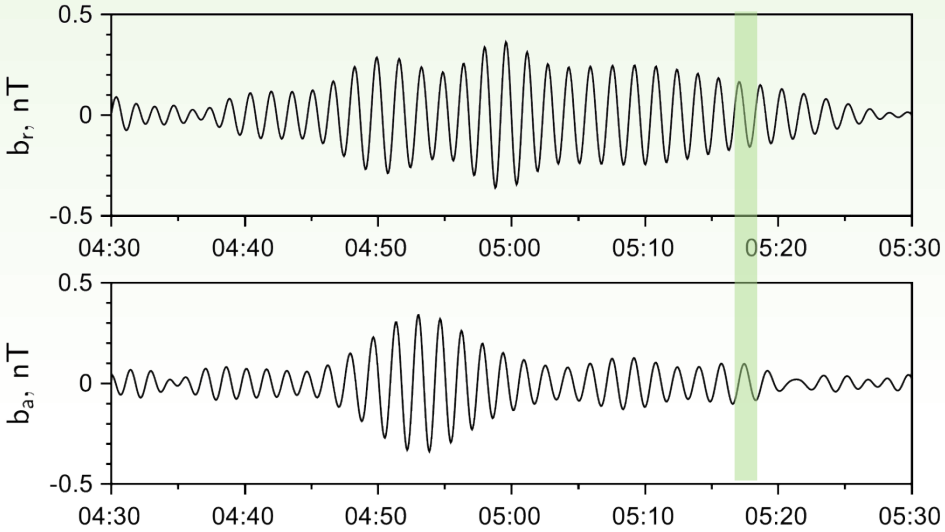
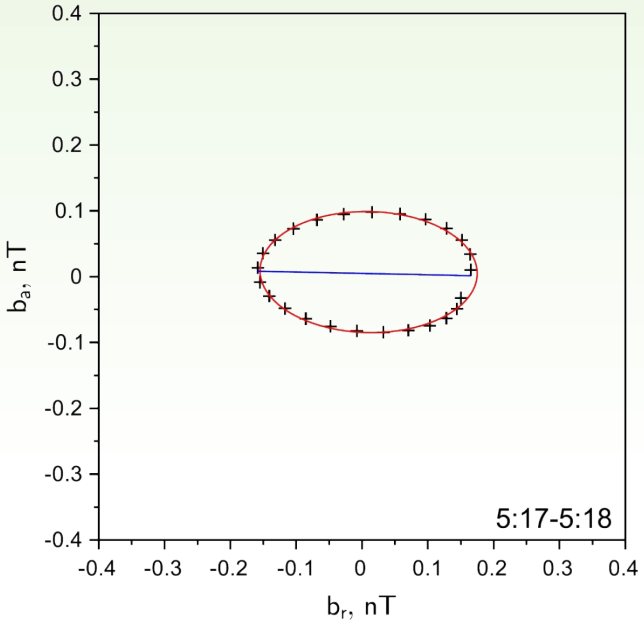
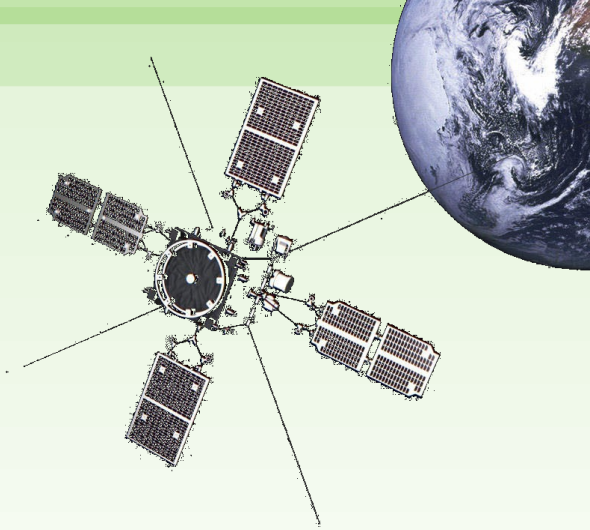




Conclusions

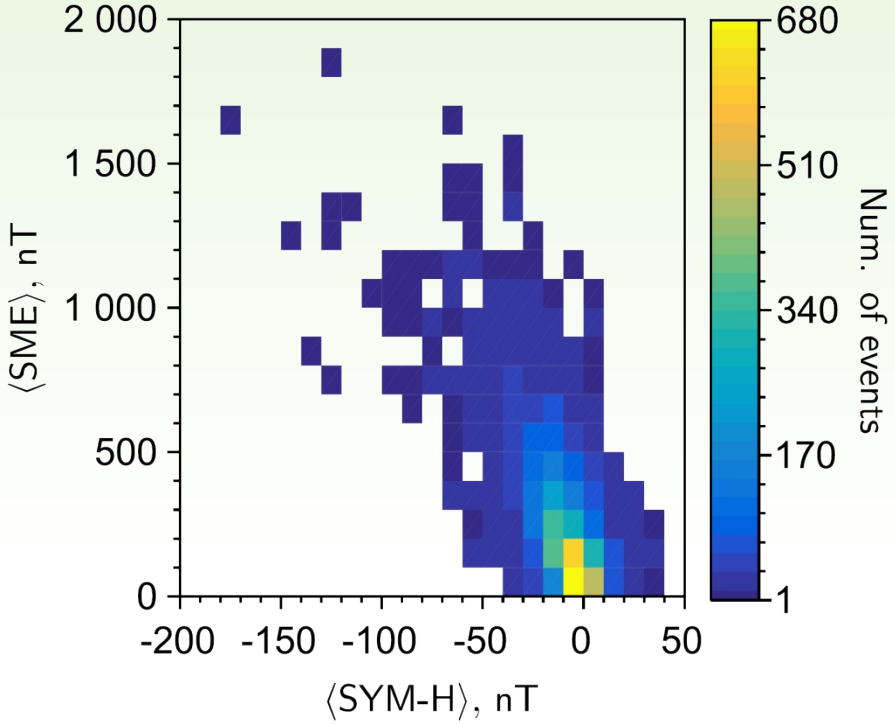
- Toroidal, poloidal and compressional waves have clear difference in spatial distributions
- No separate clusters on polarization diagram
- Mixed transverse polarization is the most common
- Polarization change in time and/or space is proposed as a reason
- Wave-particle interactions are affected by the polarization change due to the azimuthal electric field

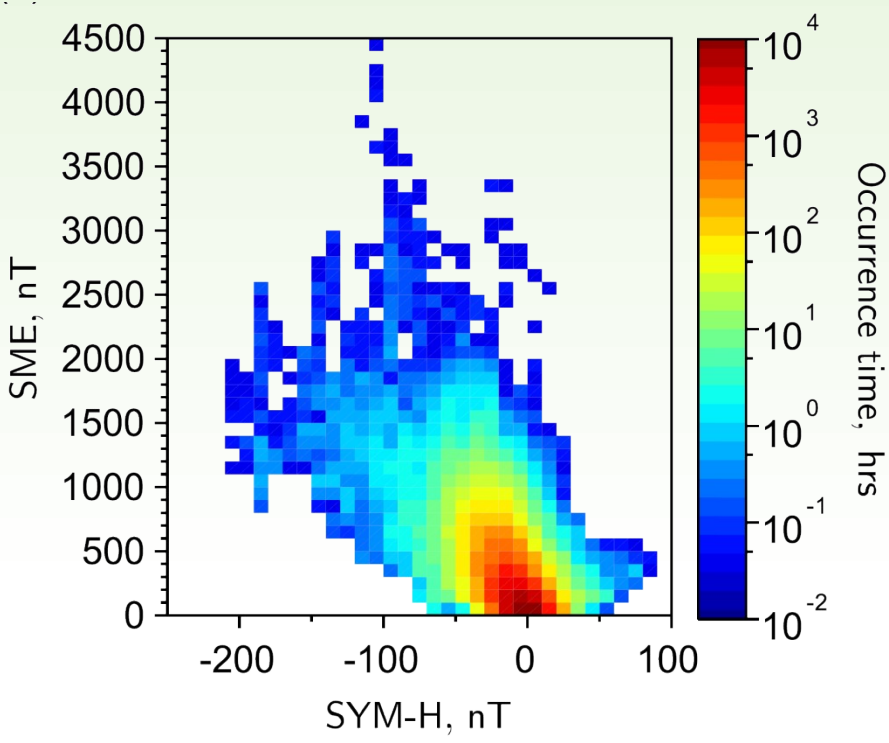


Thanks for your attention!

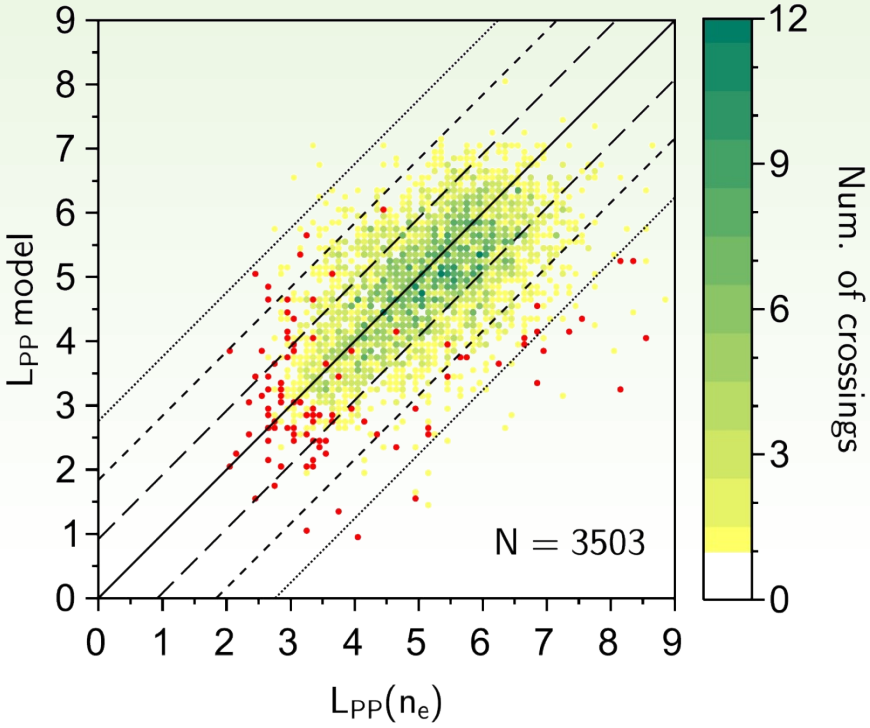
Contact: avrubtsov@iszf.irk.ru

SME and SYM-H distribution in 2017–2020

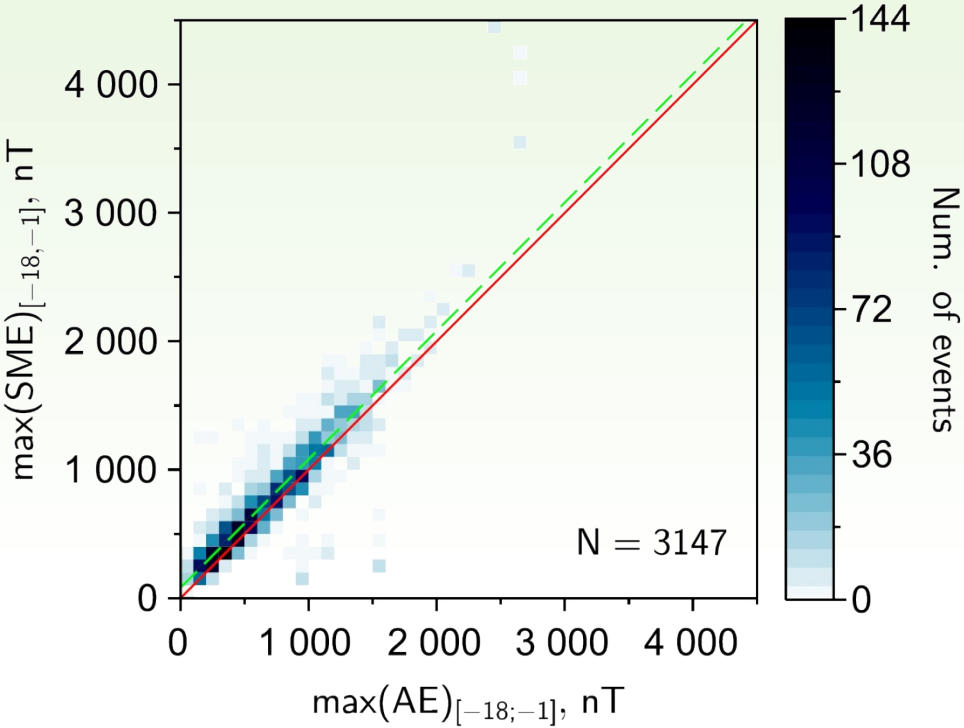




NSW-GDP model verification

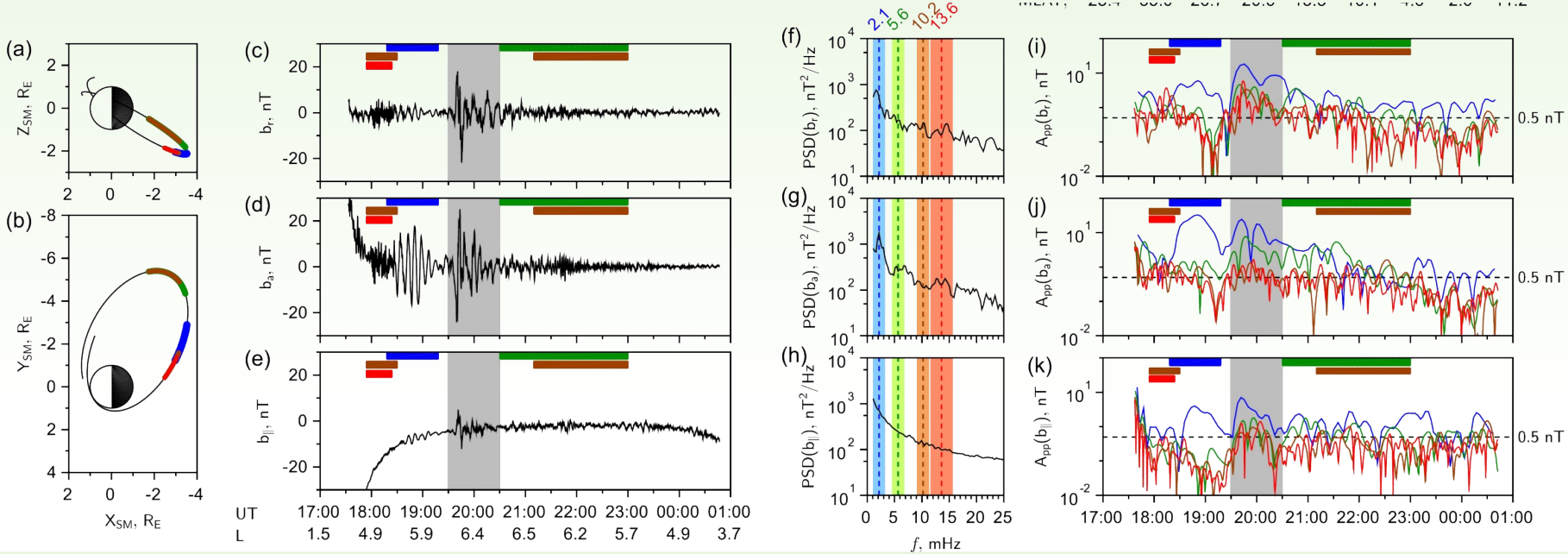


March 2017–March 2019

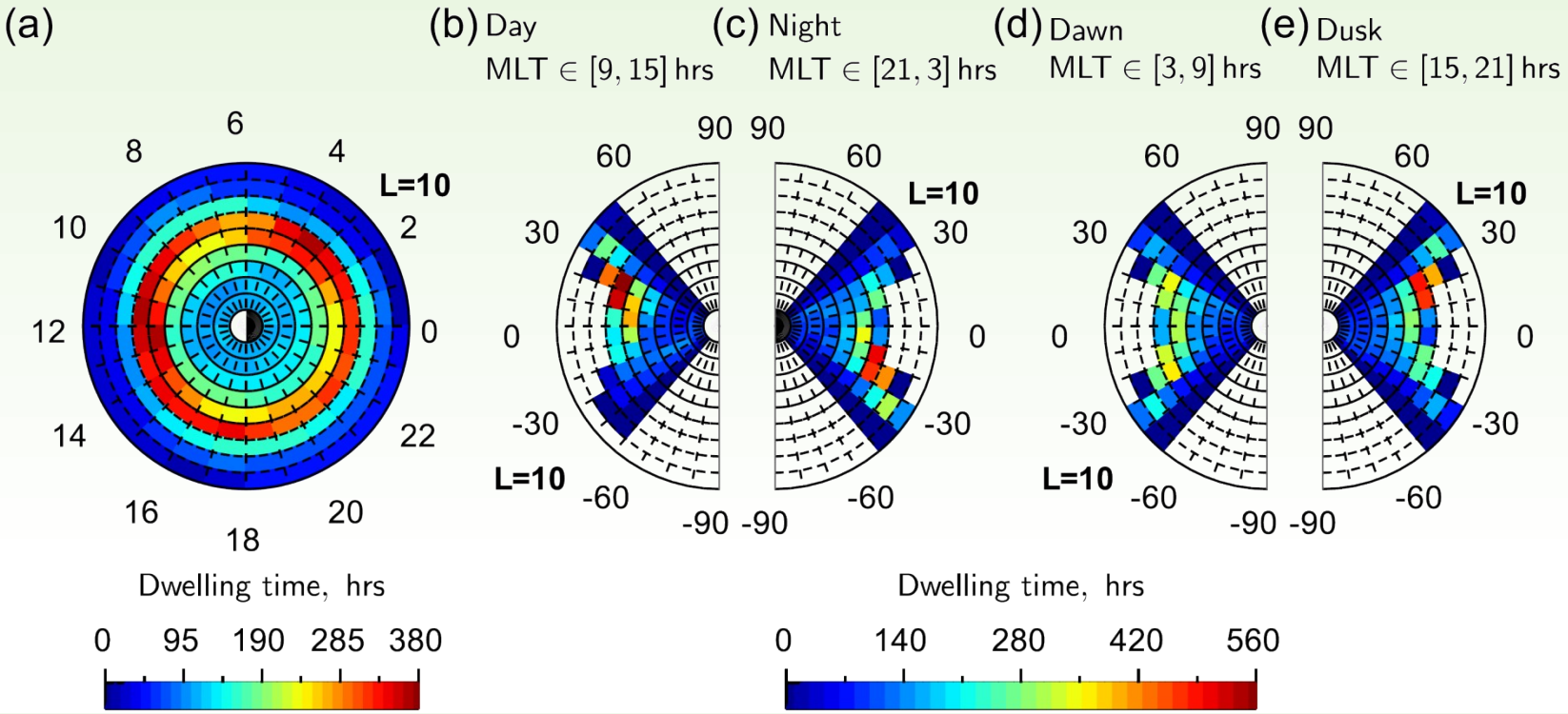


Wave selection

- Peaks in spectra
- Large enough amplitude for at least 5 periods



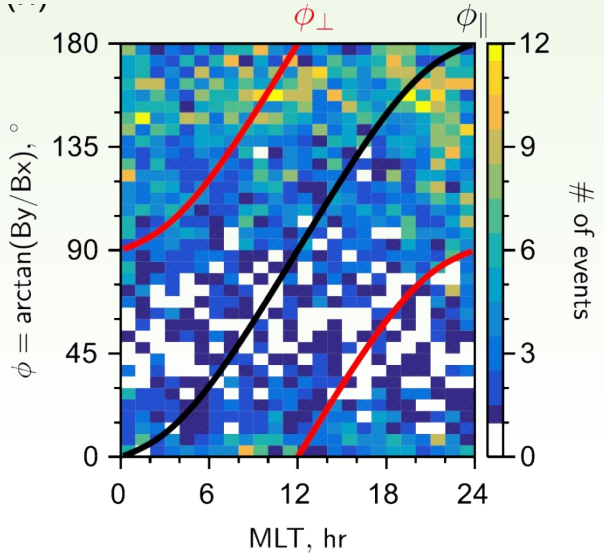
Arase observations coverage in 2017–2020



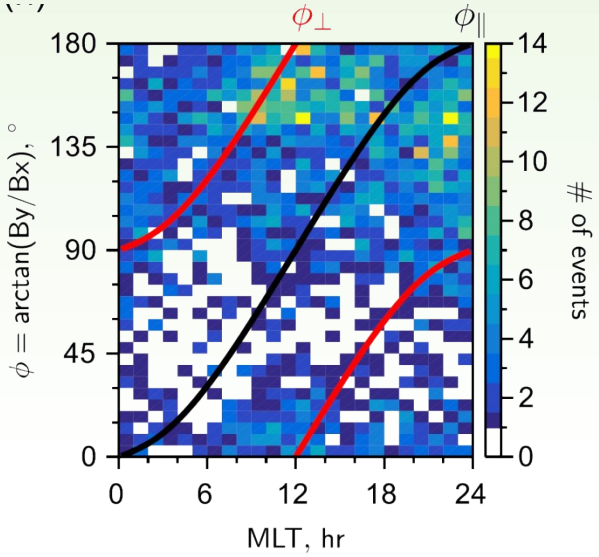
Interplanetary magnetic field

- Perpendicular or parallel By/Bx to the magnetopause affects ULF waves?

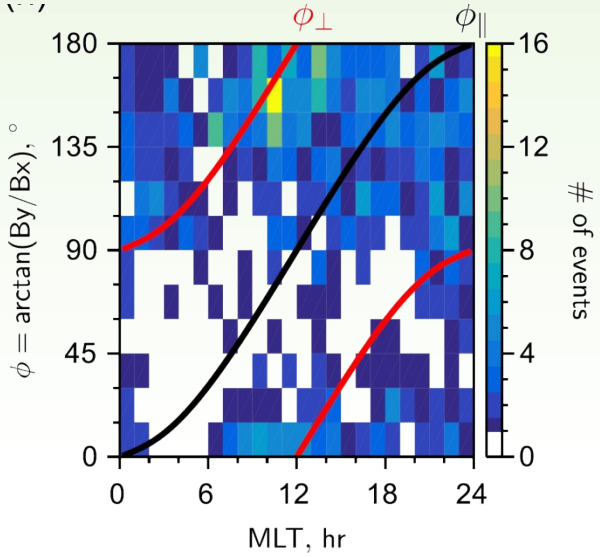
Toroidal



Poloidal

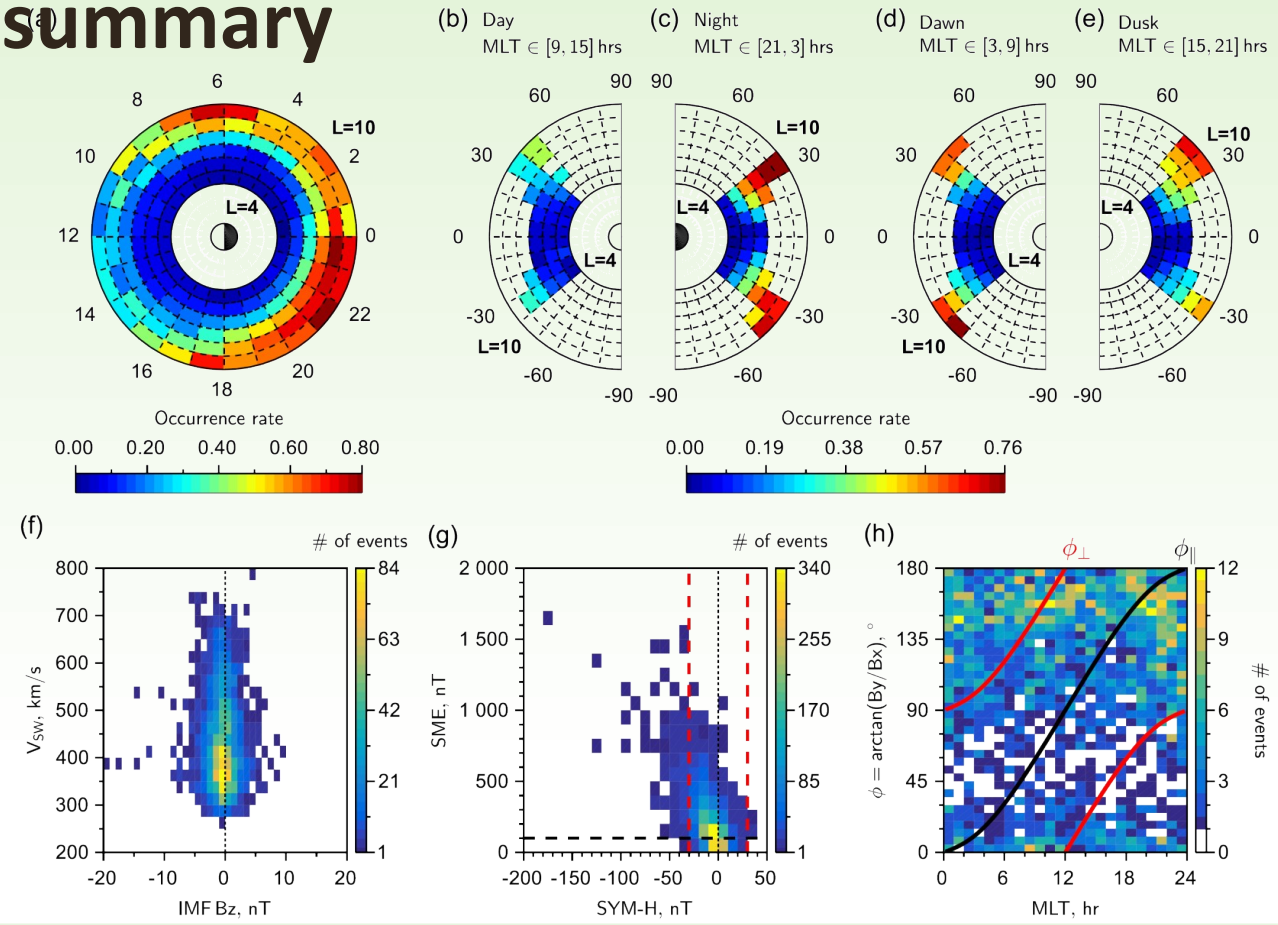


Compressional

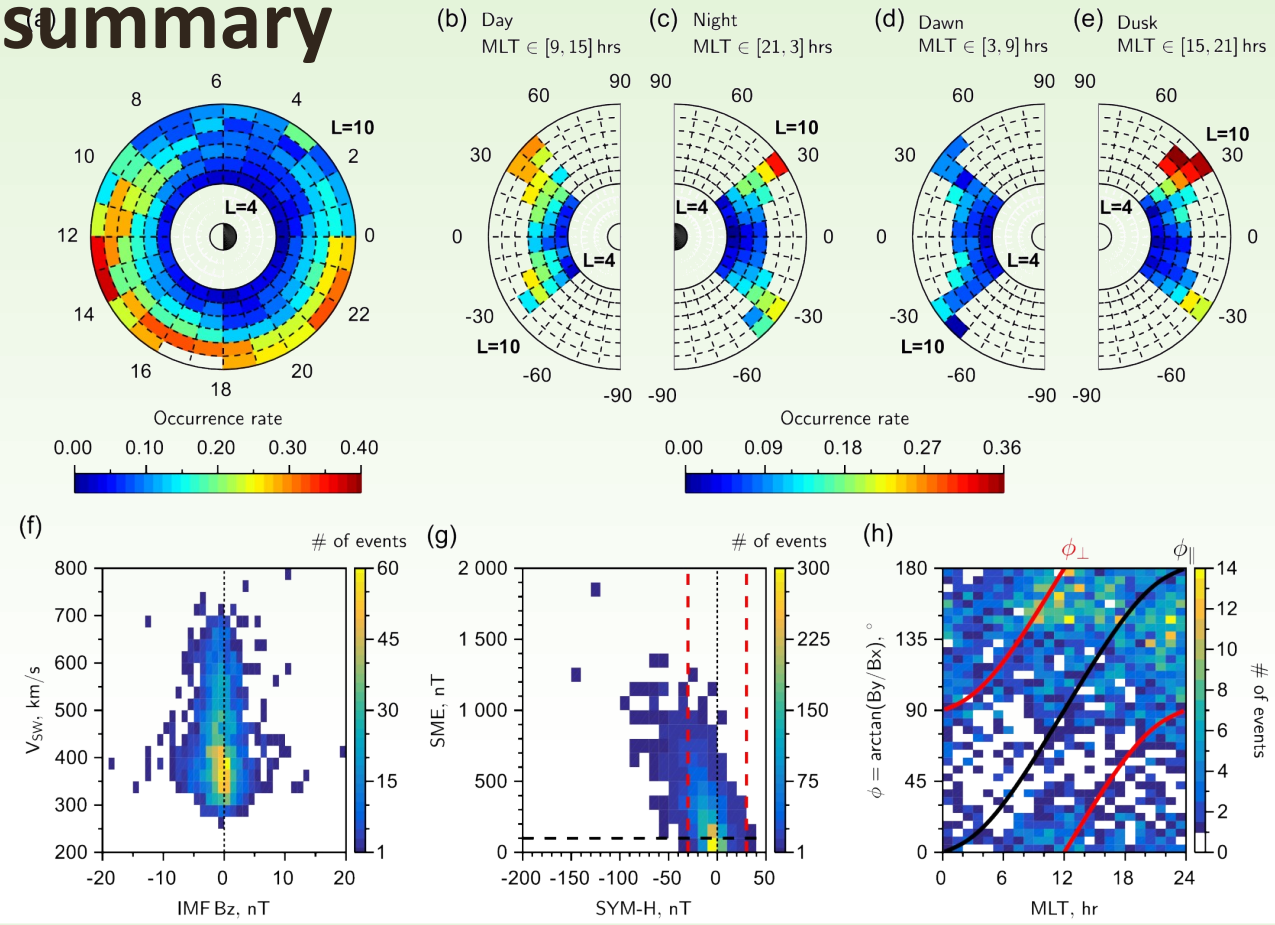


Shue+ [1997] model was used to calculate $\phi_\parallel$ and $\phi_\perp$ tracks

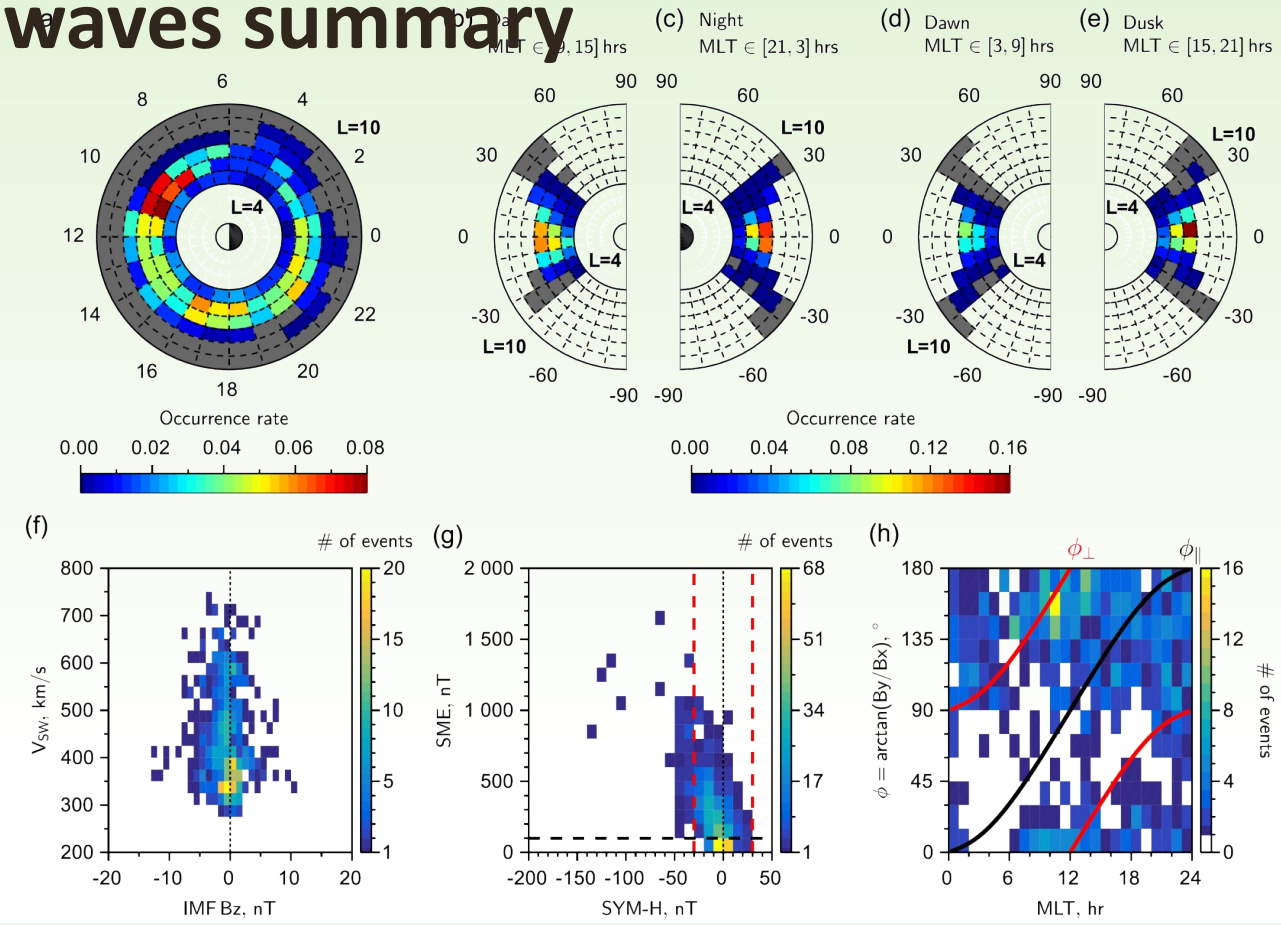
Toroidal waves summary



Poloidal waves summary

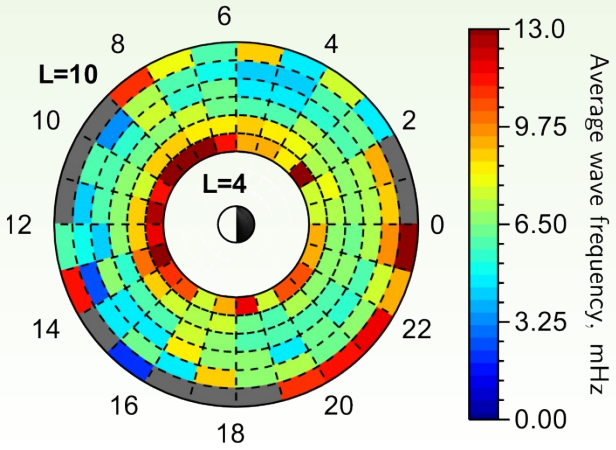


Compressional waves summary

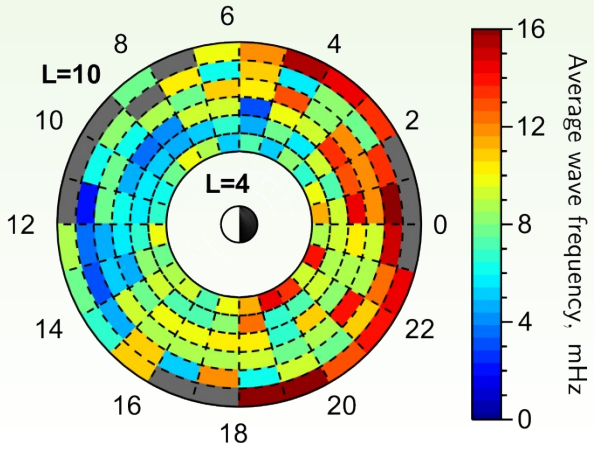


Average wave frequency on L-MLT diagram

Toroidal



Poloidal



Compressional