Global hybrid modeling of ultra-low frequency solar wind foreshock waves at Mercury, Venus and Mars

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EGU General Assembly 2022
EGU22-5255, PS2.2
May 26, 2022

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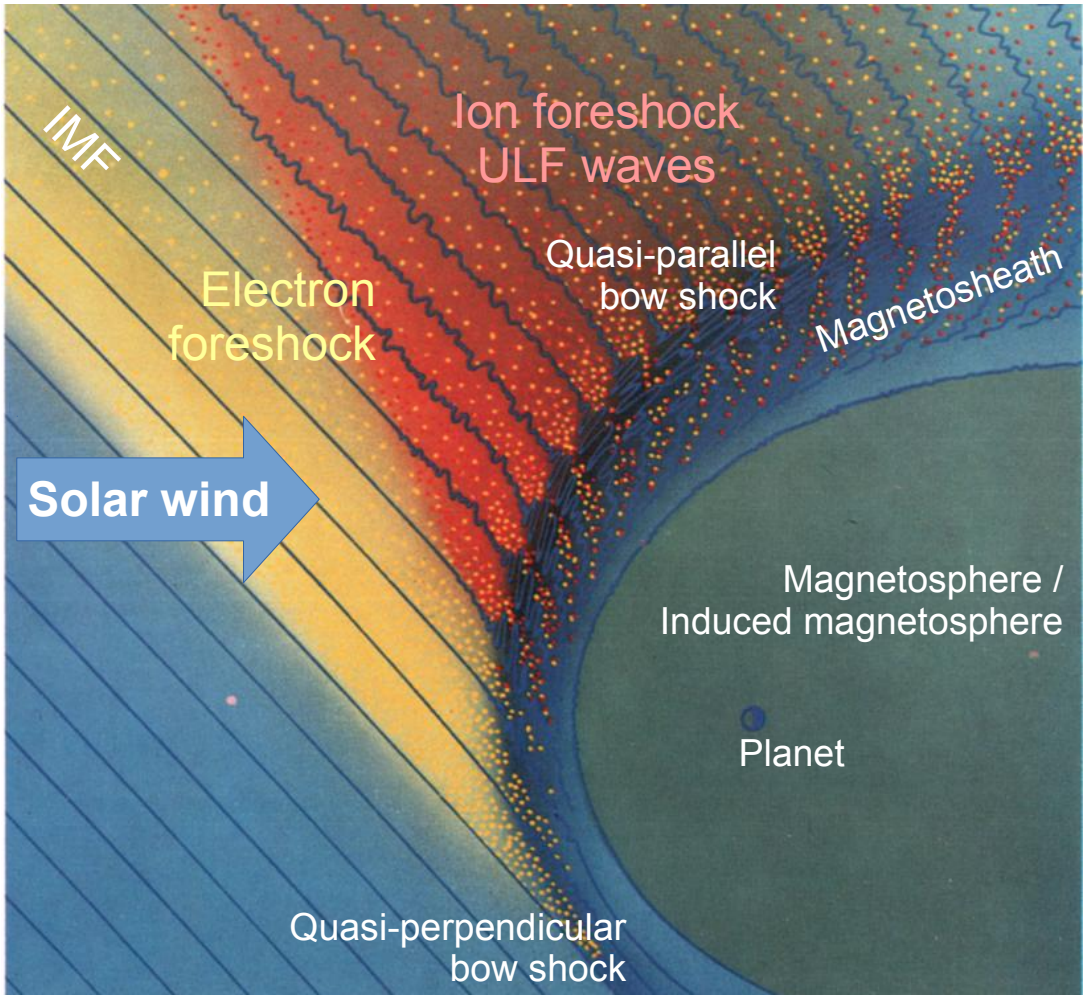
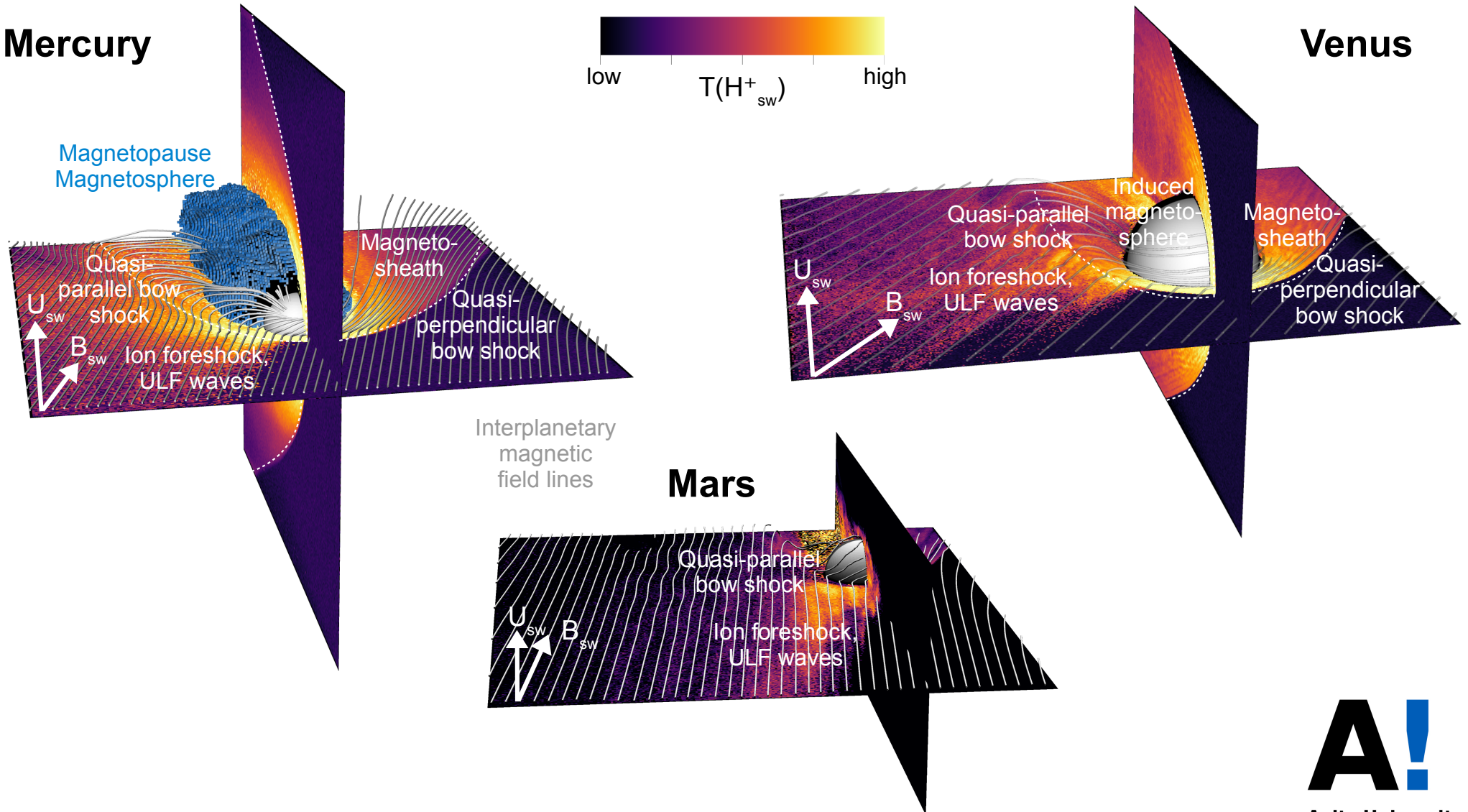
Foreshocks

- Foreshock forms upstream of a planetary bow shock by backstreaming charged particles scattered at the bow shock
- Large-scale ultra-low frequency (ULF) waves are excited in the regions of significant backstreaming ion populations (the ion foreshock) ahead of the quasi-parallel bow shock
- ULF waves convect downstream with the solar wind and can interact and transmit through the bow shock

Adapted from Tsurutani&Rodriguez, 1981



Global hybrid simulation runs



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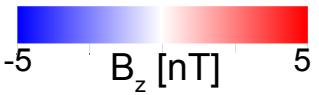
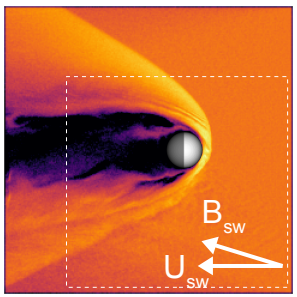
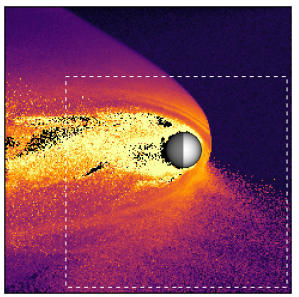
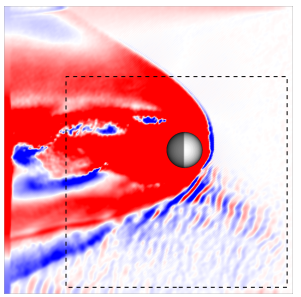
Equatorial plane comparison



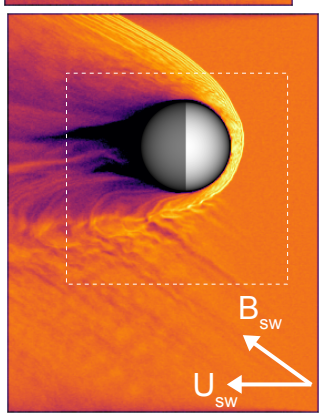
Mercury

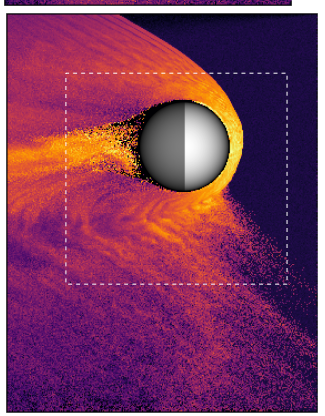


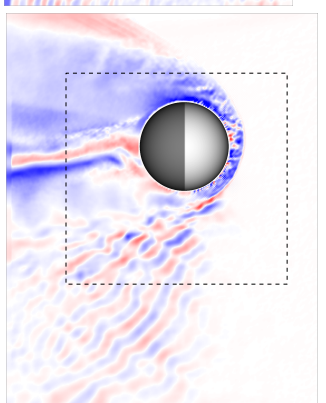




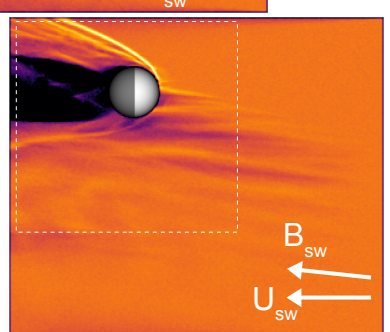
Venus

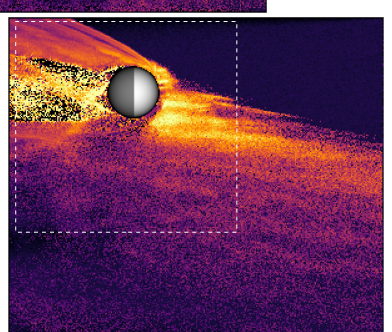


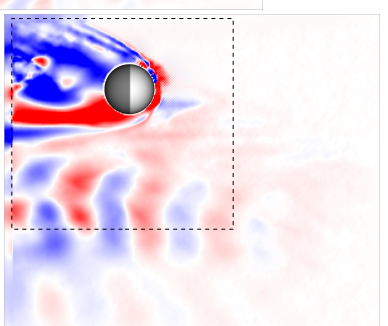




Mars

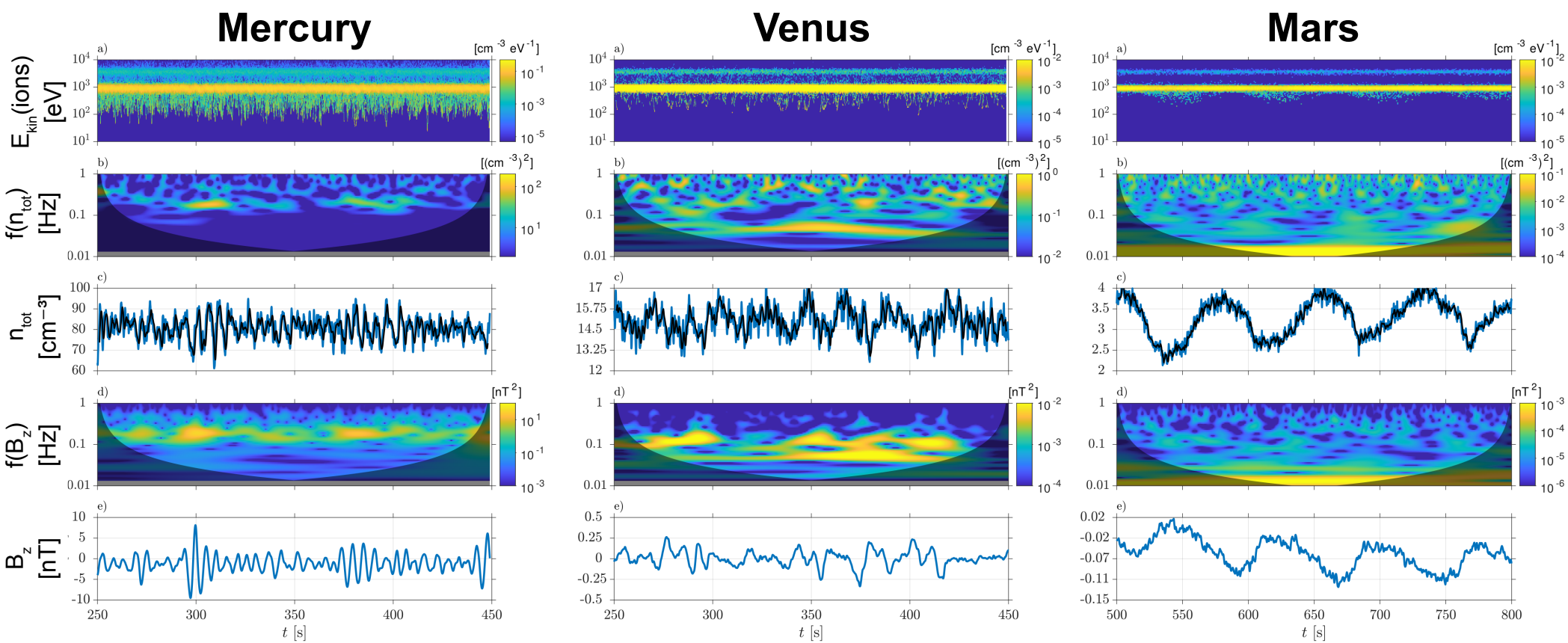






$10 \times B_z$

Foreshock time series and waves



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Summary

- Global hybrid simulations show how solar wind foreshocks and ULF waves form ahead of planetary quasi-parallel bow shocks
- Wave frequencies scale as 1/B as expected
- Wave lengths smallest at Mercury, largest at Mars
- Foreshock ULF waves modulate ions escape and precipitation

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References

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- *Jarvinen R., Alho M., Kallio E., Pulkkinen T.I. (2020),* ***Oxygen Ion Escape From Venus Is Modulated by Ultra-Low Frequency Waves,*** *Geophys. Res. Lett., 47, 11, doi:10.1029/2020GL087462*
- *Jarvinen R., Kallio E., Pulkkinen T.I. (2022),* ***Ultra-low Frequency Foreshock Waves and Ion Dynamics at Mars****, J. Geophys. Res. 127, 5, doi:10.1029/2021JA030078*

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