Comparative study of the ion foreshock for terrestrial planets: 3D global hybrid simulations

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Planetary foreshocks provide interesting space regions to investigate solar wind plasma processes in micro-, meso- and macro-scales. Most of the foreshocks are associated with planets that have a global intrinsic magnetic field (Mercury, Earth, Jupiter, Saturn, Uranus, Neptune). Each planetary foreshock is, however, different because the properties of the solar wind plasma and the direction of the interplanetary magnetic field, both its nominal magnitude and direction, change when moving away from the Sun. The sizes of the magnetospheres, and the corresponding bow shocks, also differ from the "pocket size" Hermean magnetosphere to the large Jovian magnetosphere.

Moreover, there are two planets, Venus and Mars, which do not have a global intrinsic magnetic field, but instead, have so called induced magnetospheres. At these planets, the solar wind flows close to the atmosphere where the planetary neutral and ion densities can be high. The bow shocks of Venus and Mars are also closer to the planet and its ionosphere compared to the magnetized planets. Therefore, one may ask what similarities and differences the Venusian and Martian foreshocks may have compared to the foreshocks of magnetized planets.

Simulation studies of planetary bow shocks and foreshocks are commonly based on 1D, 2D and 3D hybrid models where ions are treated as (macro)particles while electrons form a massless charge neutralizing fluid. This approach makes it possible to resolve self-consistently non-Maxwellian ion velocity distributions, counter streaming ions and associated waves, wave-particle interactions and instabilities.

In the presentation, we will discuss basic properties of different planetary ions foreshocks and make quantitative comparisons of the properties of different terrestrial foreshock regions by using recent 3D hybrid model simulations [1, 2].

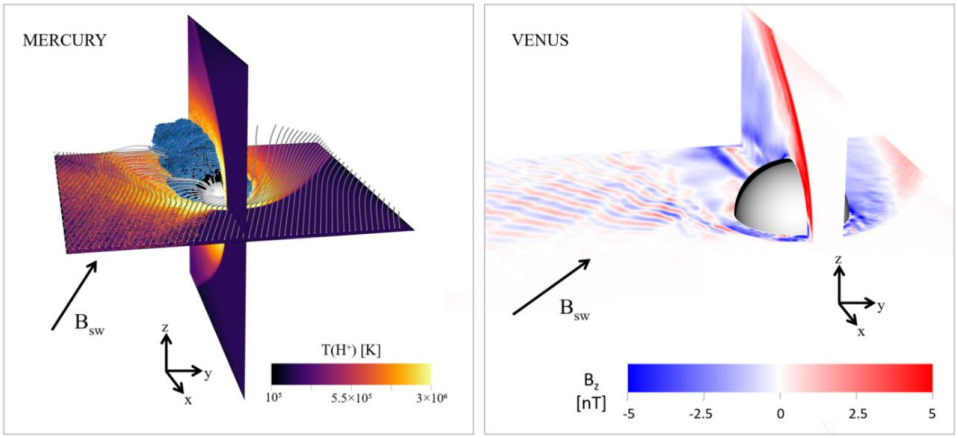

Figure 1. (left) Mercury's foreshock region simulated by a 3D hybrid model. The color on the z=0 and y=0 planes show the temperature of the solar wind protons. (right) Venus' foreshock region simulated by a 3D hybrid model. The color on the z=0 and y=0 planes show the magnetic field North-South component (B_z). The arrows show the direction of the interplanetary magnetic field (B_{sw}) and the coordinate axes. See more about the used simulation model in [1] and [2]. (*Figures by Riku Jarvinen, Aalto University*)

References

[1] Jarvinen, R., M. Alho, E. Kallio and T. I. Pulkkinen, "Ultra-Low Frequency Waves in the ion Foreshock of Mercury: A Global Hybrid Modeling Study", *Monthly Notices of the Royal Astronomical Soci*ety, **491**, 3, 2019, pp. 4147-4161, doi.org/10.1093/mnras/stz3257.

[2] Jarvinen, R. M. Alho, E. Kallio and T. I. Pulkkinen, "Oxygen Ion Escape from Venus is modulated by Ultra-Low-Frequency Waves", Geophysical Research Letters, VOL. **47**, 11, 2020, https://doi.org/10.1029/2020GL087462.