PREDICTIONS OF THE ION-PROFILE IN MERCURY'S MAGNETOSPHERE DURING BEPICOLOMBO'S SWINGBYS 2021-2025

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The BepiColombo mission is currently en route to Mercury and performs in total six swingbys at the inner planet of the Solar System before arriving in a final orbit around Mercury. These swingbys pose unique science opportunities as the spacecraft passes various regions of Mercury's magnetosphere.

We use a hybrid plasma model to extract proton energy profiles during nominal upstream conditions for the BepiColombo swingbys at Mercury between 2021 and 2025.

1. INTRODUCTION

Mercury possesses a weak intrinsic magnetic field that is influenced by the solar wind and Interplanetary Magnetic Field (IMF). The resulting magnetosphere is highly dynamic due to the proximity to the Sun.

We address the following questions:

What magnetospheric regions are expected to be seen during BepiColombo's swingbys?

&

What is the "typical" energy profile of solar wind ions penetrating Mercury's magnetosphere?

1.1. BEPICOLOMBO SWINGBY GEOMETRIES

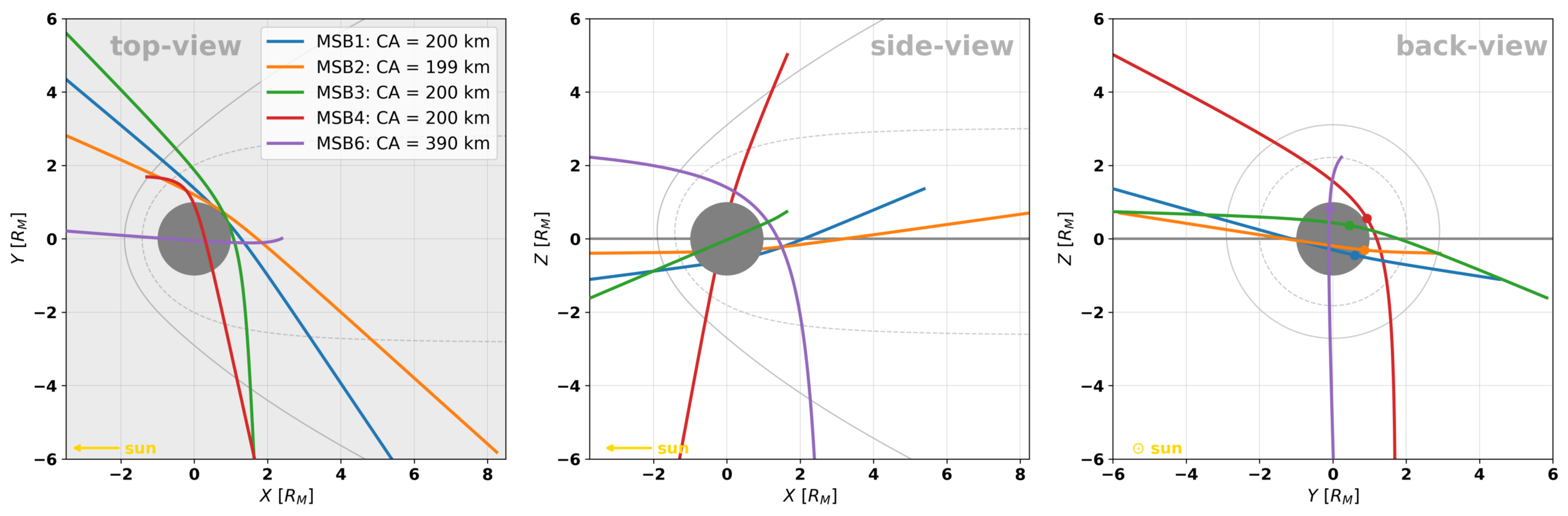

Fig. 1: BepiColombo Mercury swingby trajectories (MSB12346) in MASO (Mercury Anti Solar Orbital) coordinates; the equatorial plane is shown in grey; bow shock and magnetopause models [1,2] are displayed in solid and dotted grey lines; dots in the back-view indicate closest approaches

- **MSB (Mercury SwingBy) 1, 2, 3:** Mostly equatorial with increasing inclination. Possible tail current sheet, magnetopause (MP) and bow shock (BS) crossings, closest approaches outside MESSENGER coverage
- **MSB 4:** polar trajectory passing the dawnside from the north; MP and BS crossings
- (MSB 5: swingby not within Mercury's magnetosphere)
- **MSB 6:** polar trajectory passing the tail current sheet from the south; MP and BS crossings; possible reconnection site passage

2. HYBRID PLASMA APPROACH

Why hybrid? It has the advantage of a kinetic description of the ions, e.g., resolving non-Maxwellian distribution functions, while not being as computational expensive than fully kinetic models.

We use the global 3D hybrid model **AIKEF (Adaptive Ion-Kinetic Electron-Fluid)** [3,4]: ions are treated kinetically; electrons are a massless charge-neutralizing fluid. A Cartesian mesh grid that can be adapted in space and time is utilized.

2.1 SIMULATION INPUT PARAMETERS

The size of the simulation box is (12x12x12) R_M^3 to include all swingby trajectories. Upstream parameters are nominal [2], IMF direction is an equatorial Parker spiral angle [5]. The planetary magnetic field is considered up to the octupole moment [6].

- Solar wind (H^+) number density: 40 particles/cm^3
- IMF direction and magnitude: (-0.8, 0.6, 0.06) * 24 nT
- Upstream solar wind velocity: 400 km/s
- Planetary magnetic field (multipole): -190 nT, -75 nT, -22 nT

We show the model results in the XZ-plane (MASO) after ~270 seconds (real time) corresponding to about 3.6 solar wind box crossings in Fig. 2. This model handles reconnection self-consistently through anomalous resistivity. [7]

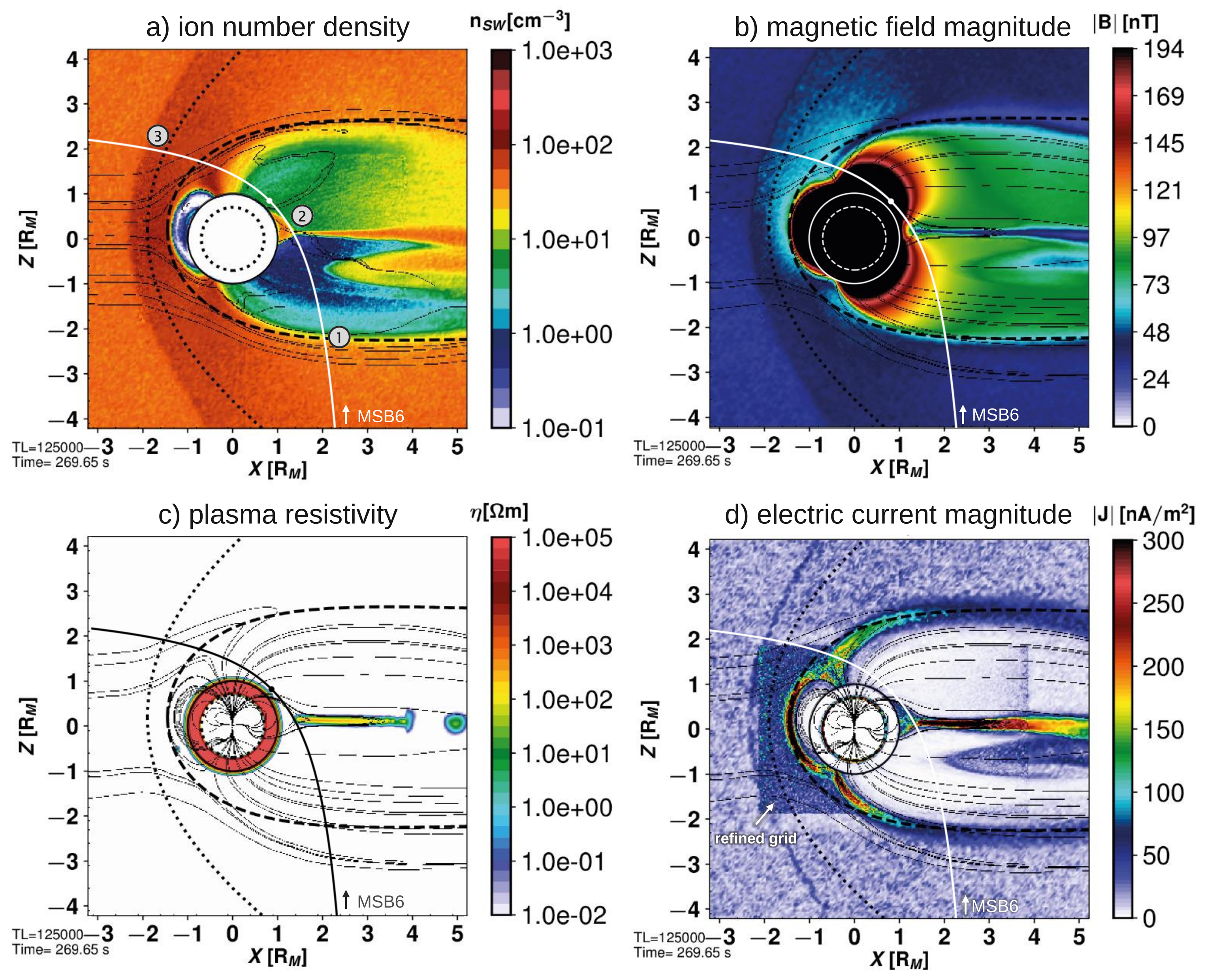

Fig. 2: Dotted and dashed lines denote bow shock and magnetopause [1,2]; circles represent surface and core mantle boundary; a) thin black lines correspond to plasma bulk velocity; bcd) thin black lines correspond to magnetic field; MSB6 trajectory events in a) explained in Fig. 3

3 BEPICOLOMBO: SWINGBY EXPECTATION

3.1 MODELED ION ENERGY PROFILES

By extracting the modeled ion velocities data along the trajectories, we can determine omnidirectional proton energy spectra, see Fig. 3.

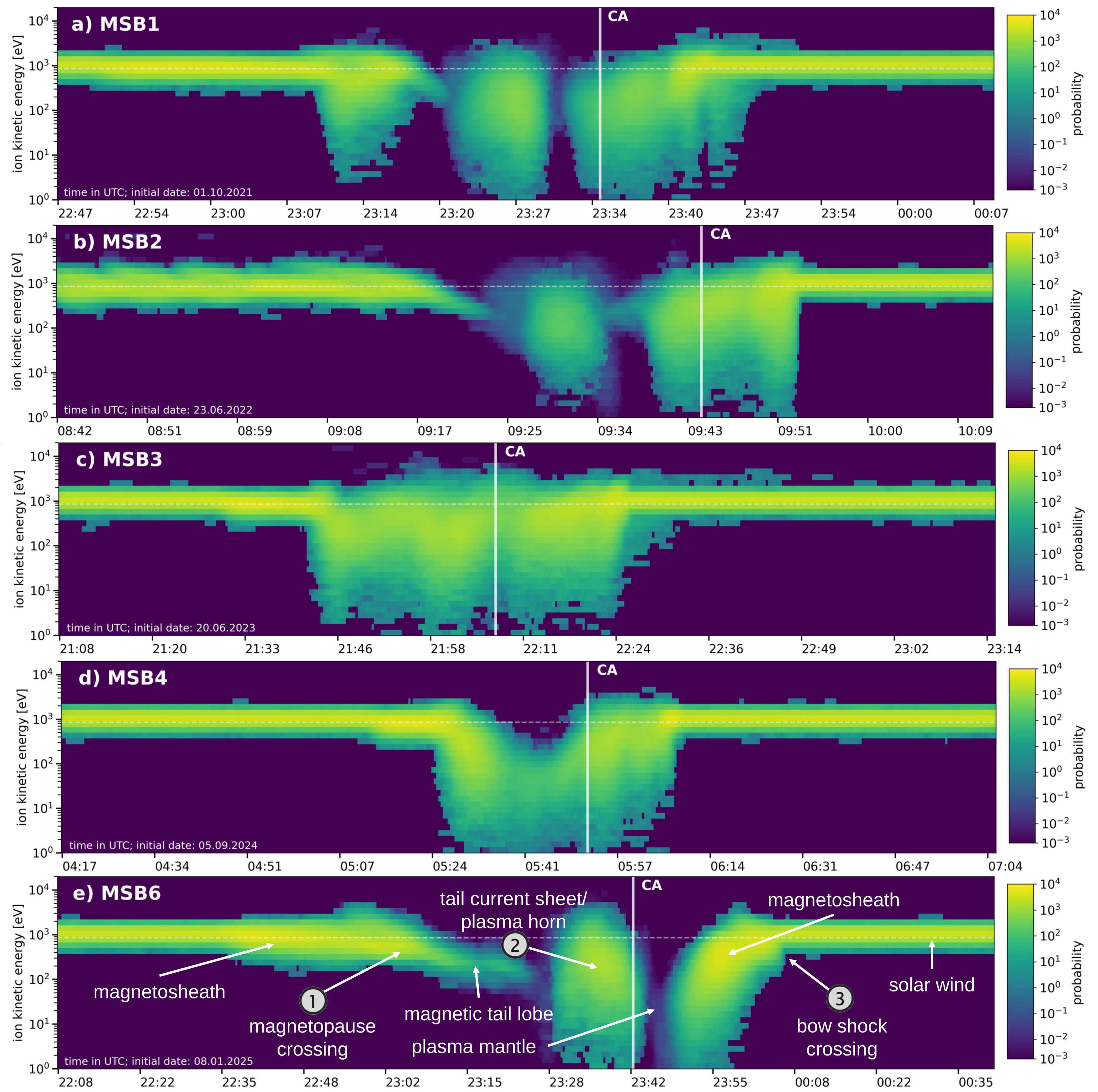

Fig. 3: Proton energy spectra (solar wind origin) along BepiColombo trajectory of MSB12346; CA denotes the Closest Approach; as an example, magnetospheric regions/crossings are denoted for e) MSB6 (ref. to Fig. 2)

SUMMARY & OUTLOOK

- Our hybrid model indicates a typical example of Mercury's magnetosphere, with plasma boundaries and magnetospheric region passages observed in ion energy profiles along BepiColombo's swingbys. The used analysis method allows to extract spectra from any ion species.
- **Outlook:** Provide field-of-view forecast scenarios that can be used for mission/operation planning for particle detectors on BepiColombo. Model multiple ion species (of planetary origin), global dynamic effects and a higher resolution.

[1] **Shue, J.-H.,** et al. (1997): "A new functional form to study the solar wind control of the magnetopause size and shape", https://doi.org/10.1029/97JA00196
[2] **Winslow, Reka M.,** et al. (2013): "Mercury's magnetopause and bow shock from MESSENGER Magnetometer observations.", https://doi.org/10.1002/jgra.50237
[3] **Müller, J.**, et al. (2011): "AIKEF: Adaptive hybrid model for space plasma *simulations*.", https://doi.org/10.1016/j.cpc.2010.12.033
[4] **Exner, W.,** et al. (2020): "Influence of Mercury's Exosphere on the Structure of the Magnetosphere", https://doi.org/10.1029/2019JA027691
[5] **James M. K.,** et al. (2017): "Interplanetary magnetic field properties and variability near Mercury's orbit", https://doi.org/10.1002/2017JA024435
[6] **Anderson, B. J.**, et al. (2012): "Low-degree structure in Mercury's planetary magnetic field", https://doi.org/10.1029/2012JE004159
[7] **Raeder, J.,** et al. (1998): "The Geospace Environment Modeling Grand Challenge: Results from a Global Geospace Circulation Model", https://doi.org/10.1029/98JA00014

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