Mercury's Ring Current: MESSENGER Observations

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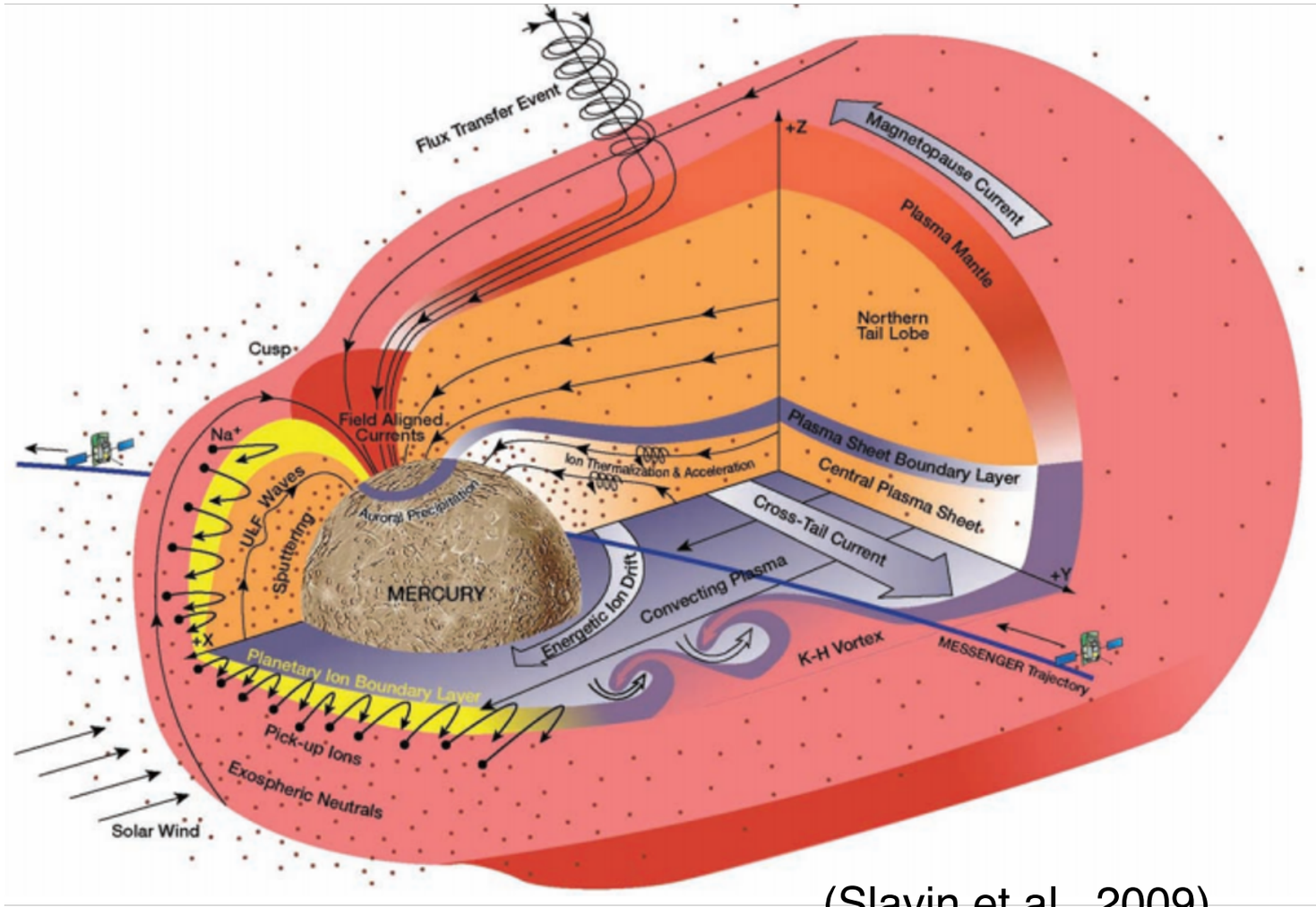
Introduction

- 0.39 AU away from the sun
- Intrinsic dipole field with northwards offset of $0.2R_M$ (= 2440 km) and a small magnetic moment of 190 nT R_M^3
- Average subsolar magnetopause $=1.45\ R_M$
- Plasma composition: H^+, He^+, Na^+, O^+, etc. (solar wind or by some photochemical process escaping from Mercury)



(Slavin et al., 2009)

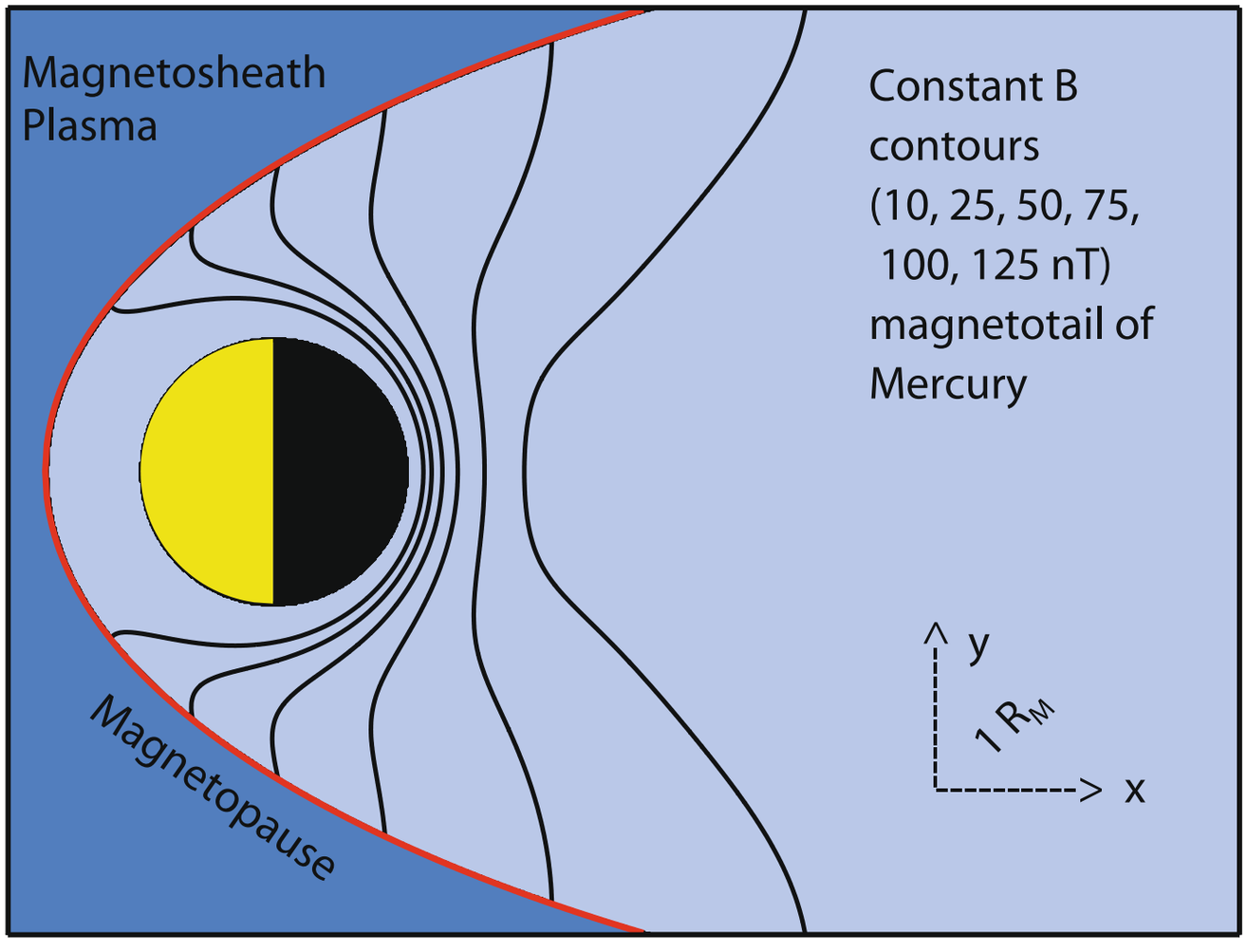
- Mercury has all kinds of structures (e.g., magnetotail, plasma mantle, and polar cusp), magnetospheric activity (e.g., substorm injections) and current systems (e.g., cross-tail current, field-aligned current)

Introduction

The magnetic gradient and curvature drift of energetic ions can form a longitudinal electric current around a planet known as the **ring current**, that has been observed in the intrinsic magnetospheres of Earth, Jupiter, and Saturn.

In this small magnetosphere (average magnetopause = 1.45 R_M) trapped particles cannot exist to the extent observed in the terrestrial magnetosphere. Therefore, no classical ring current is expected.

We present conclusive evidence of Mercury's ring current based on 5-years MESSENGER observations



(Baumjohann et al., 2020)

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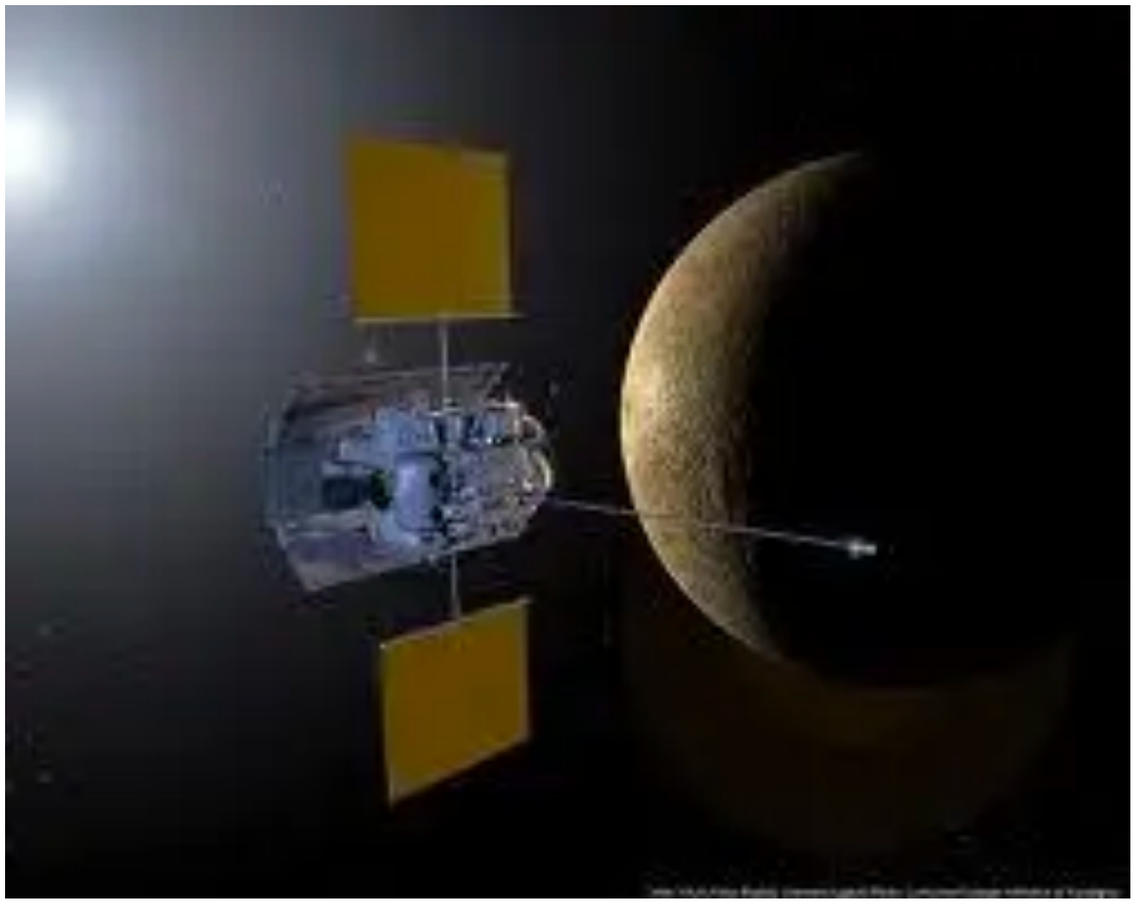
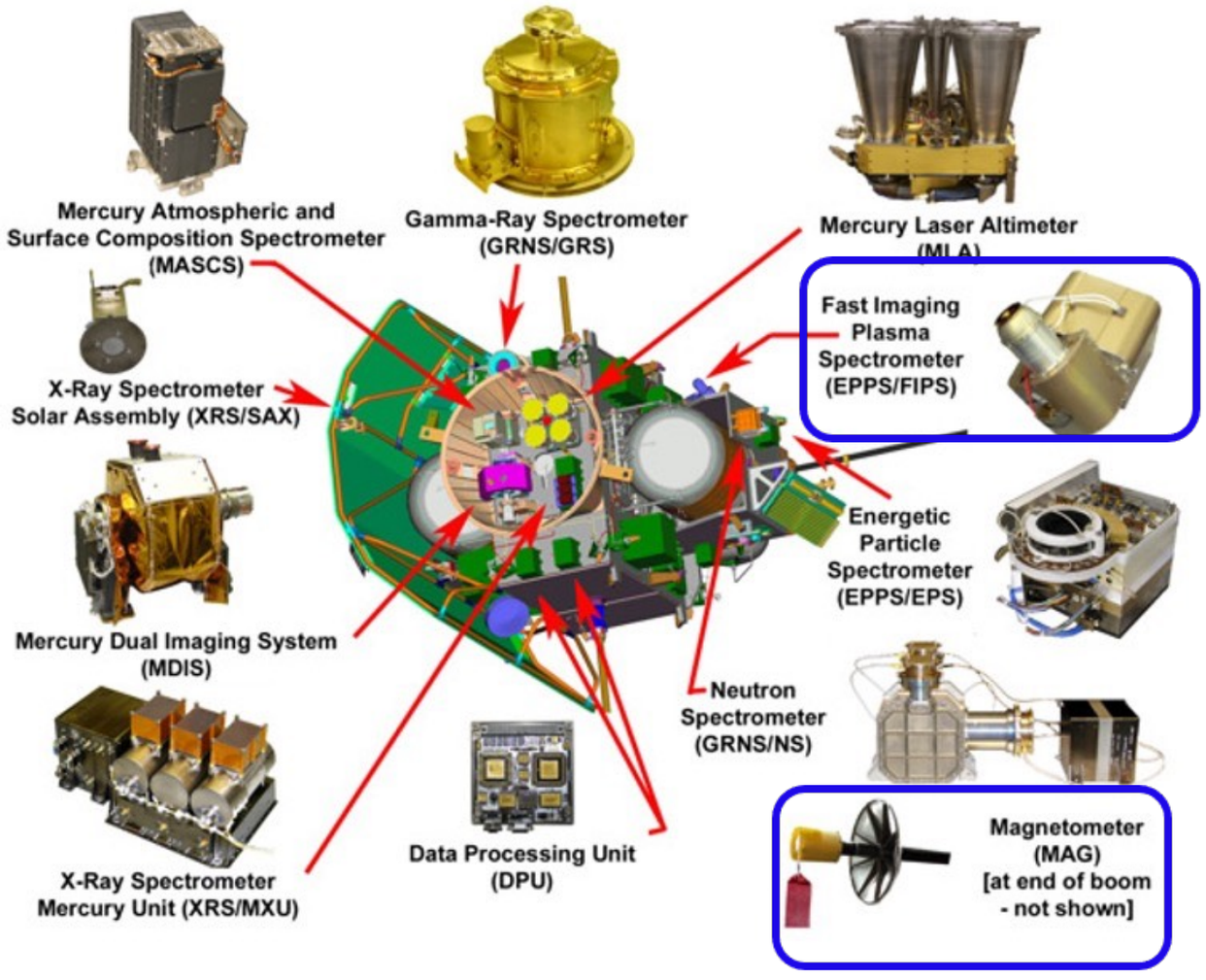
MESSENGER satellite



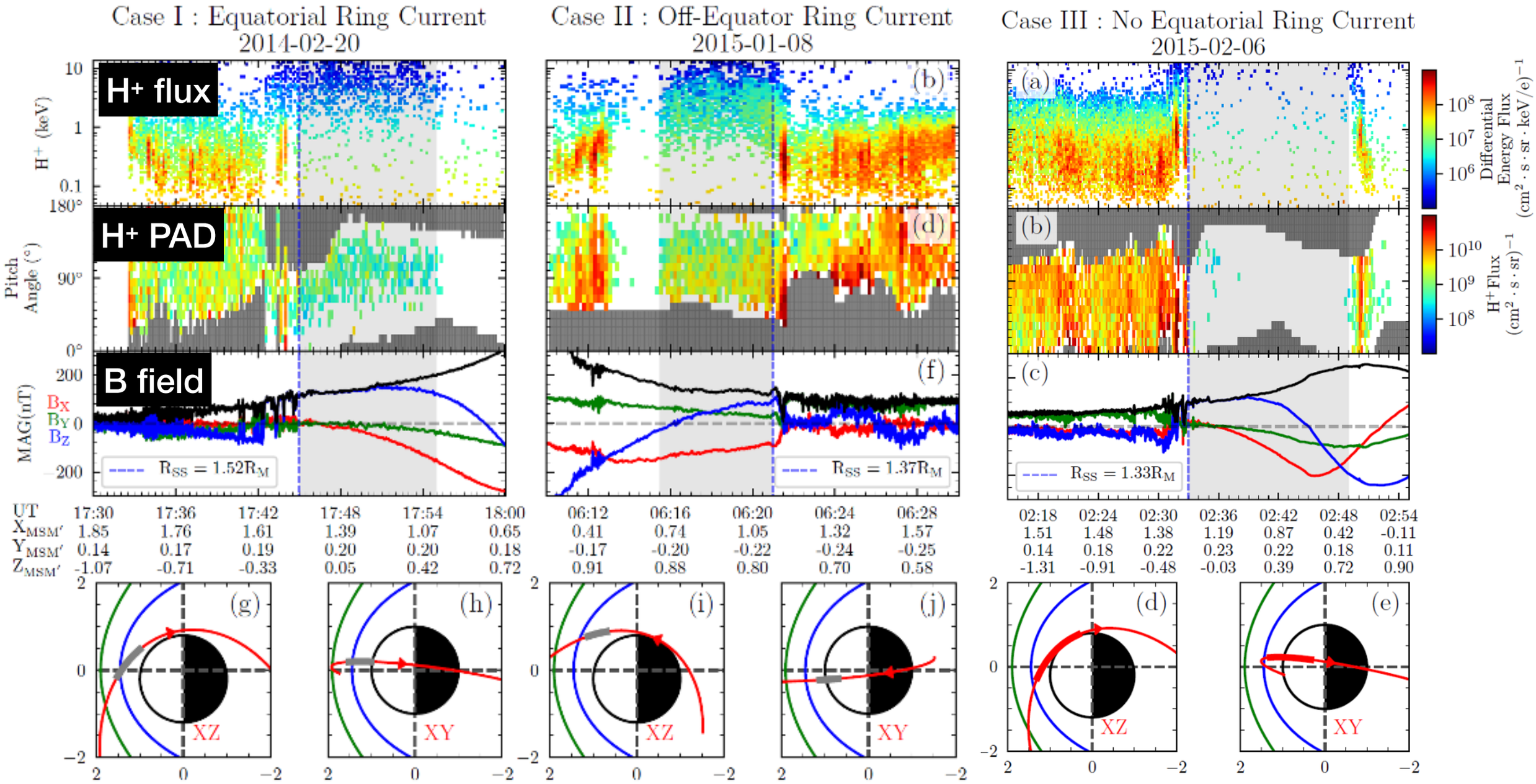


MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER):

- Launched in 2004, entered Orbit in 2011, and ended in April 2015
- Scientific objectives: 1) To study geological history; 2) Study the chemical composition of mercury's surface; 3) Determine the size and state of mercury's inner core; 4) Clarify the properties of magnetic fields
- Magnetometer (MAG) & Low energy Ion mass Spectrometer (FIPS: 46eV-13.3 keV)

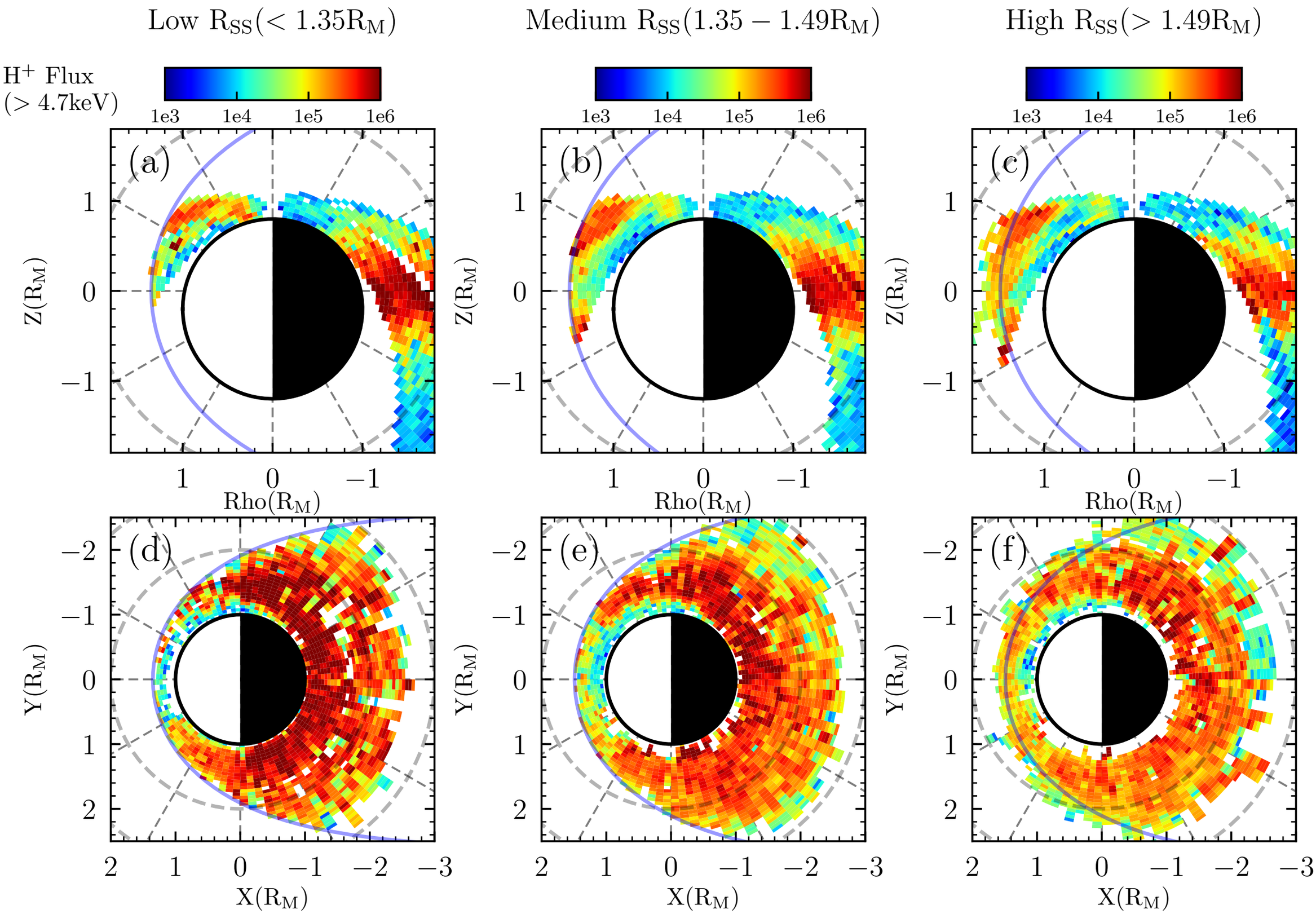
Events study

Rss=1.52 | **Rss=1.37** | **Rss=1.33**

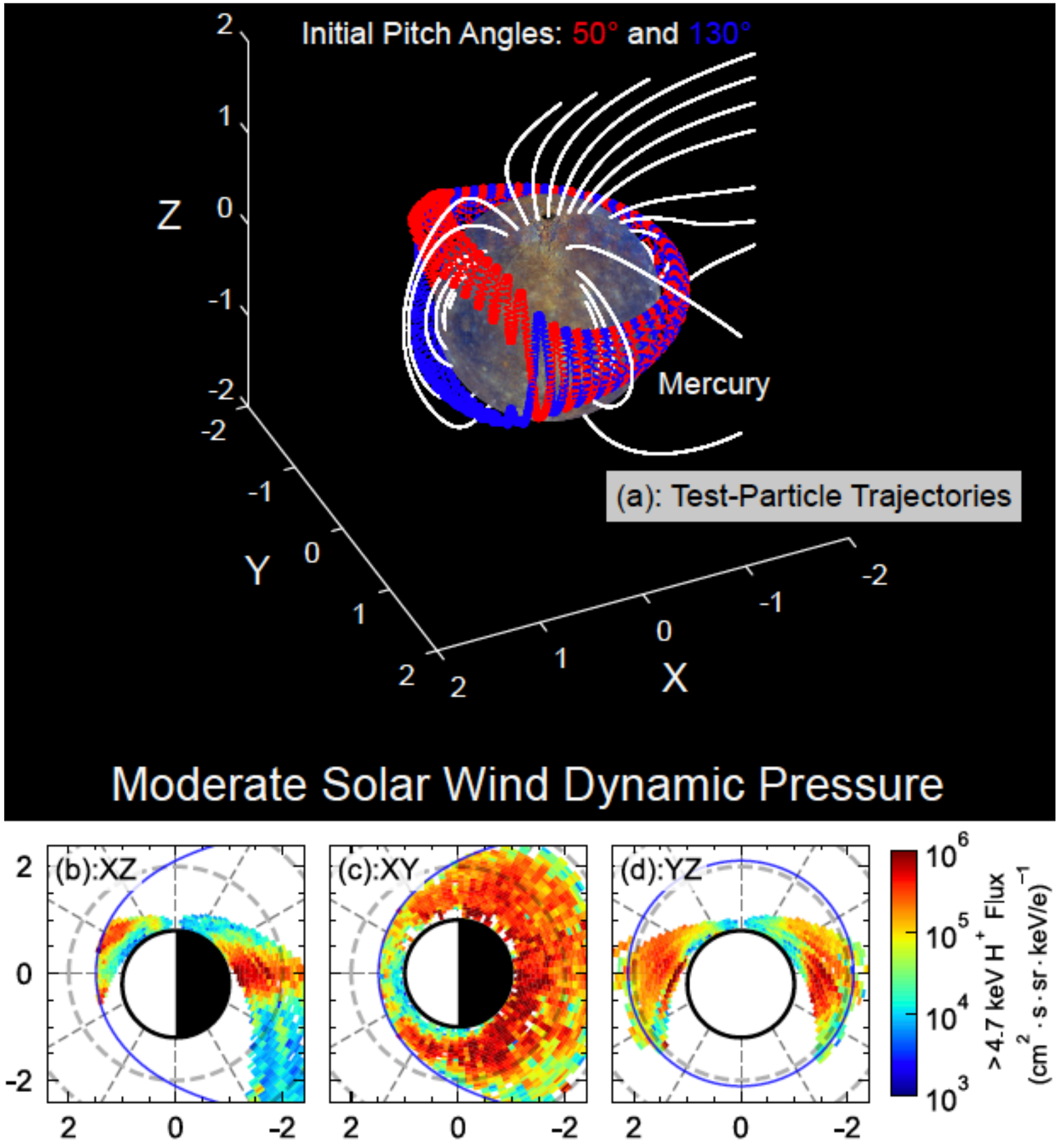


Under different solar wind forcing, the energetic protons have different behaviors

Statistical results



Comparison between observations and simulations



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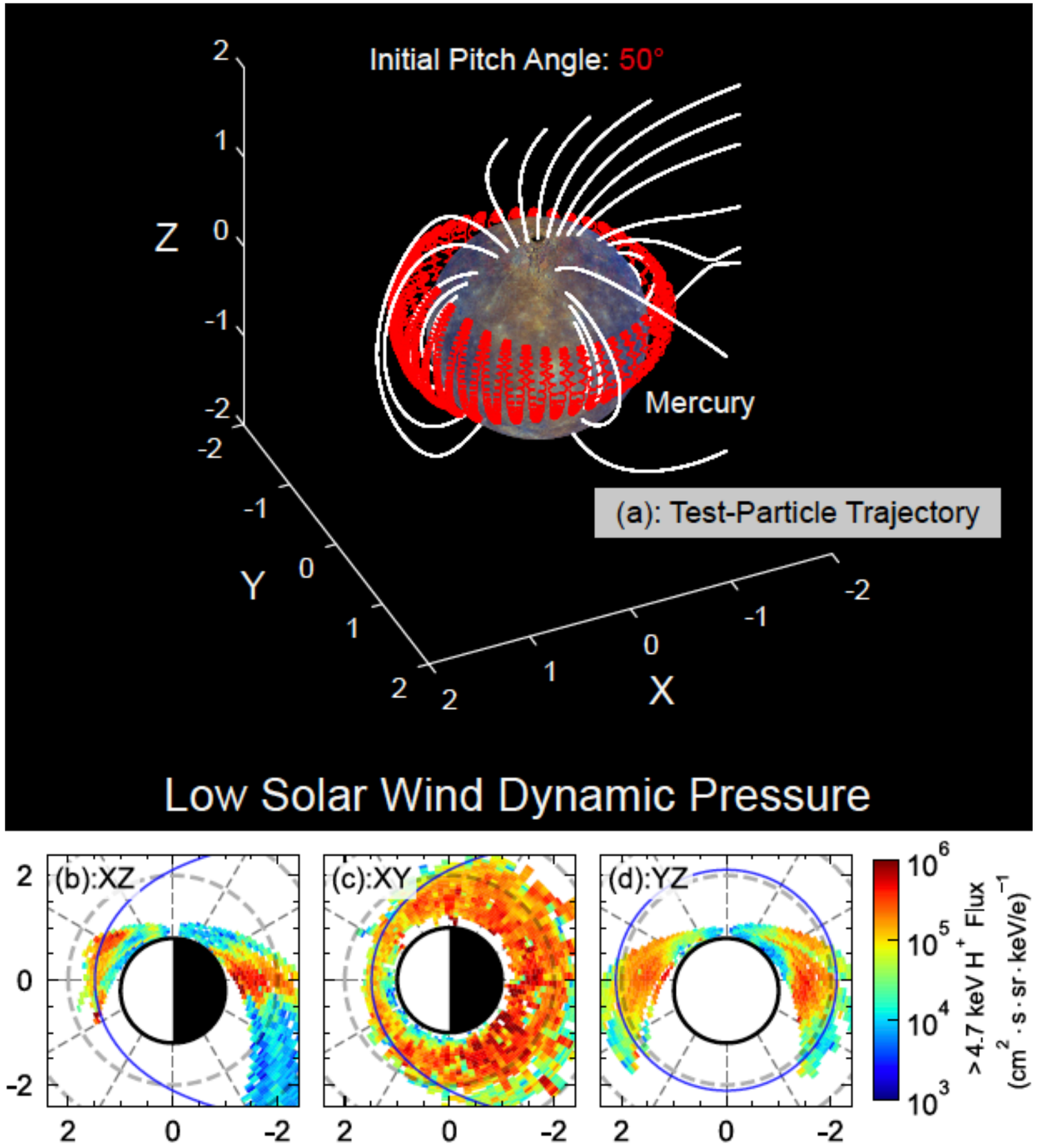
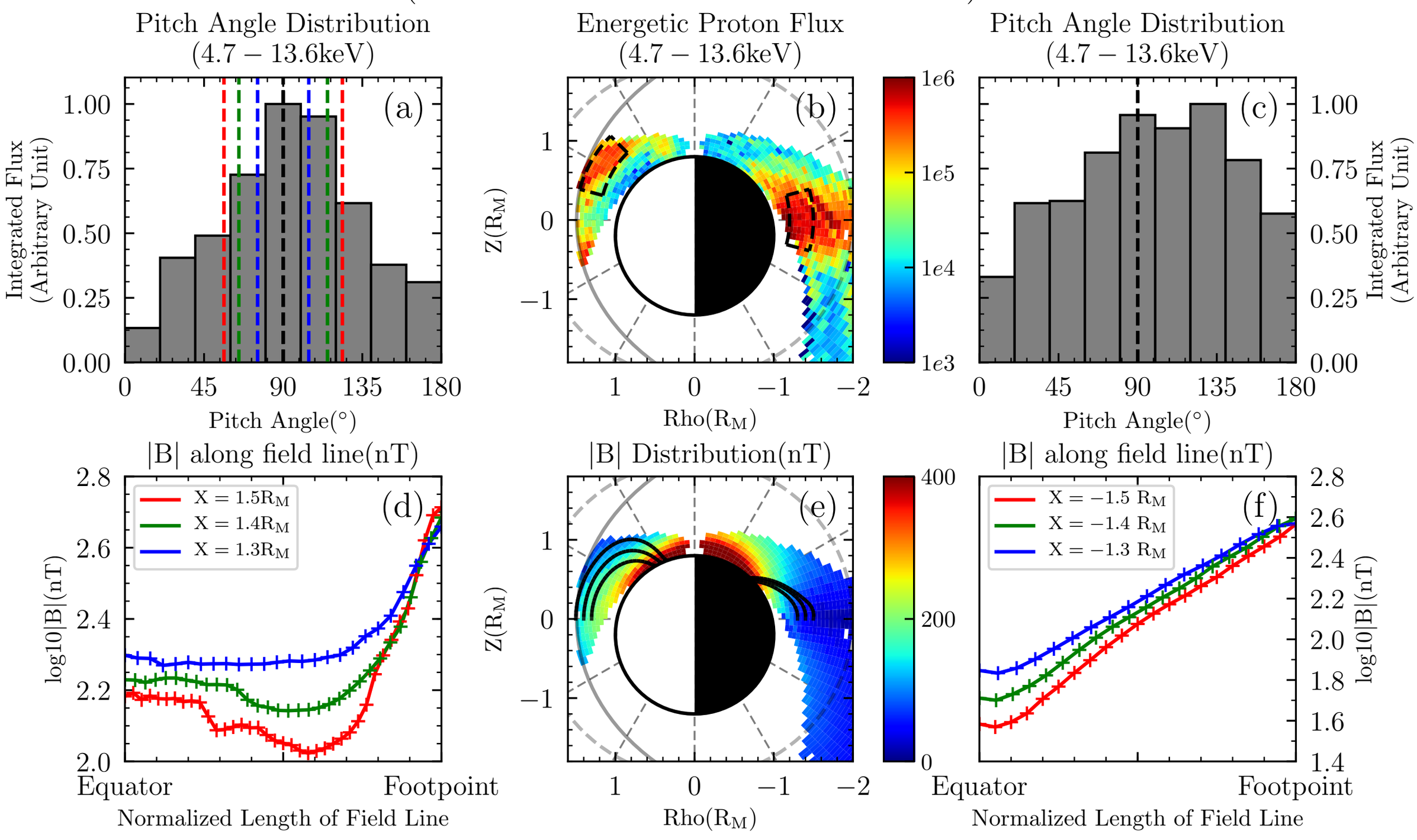
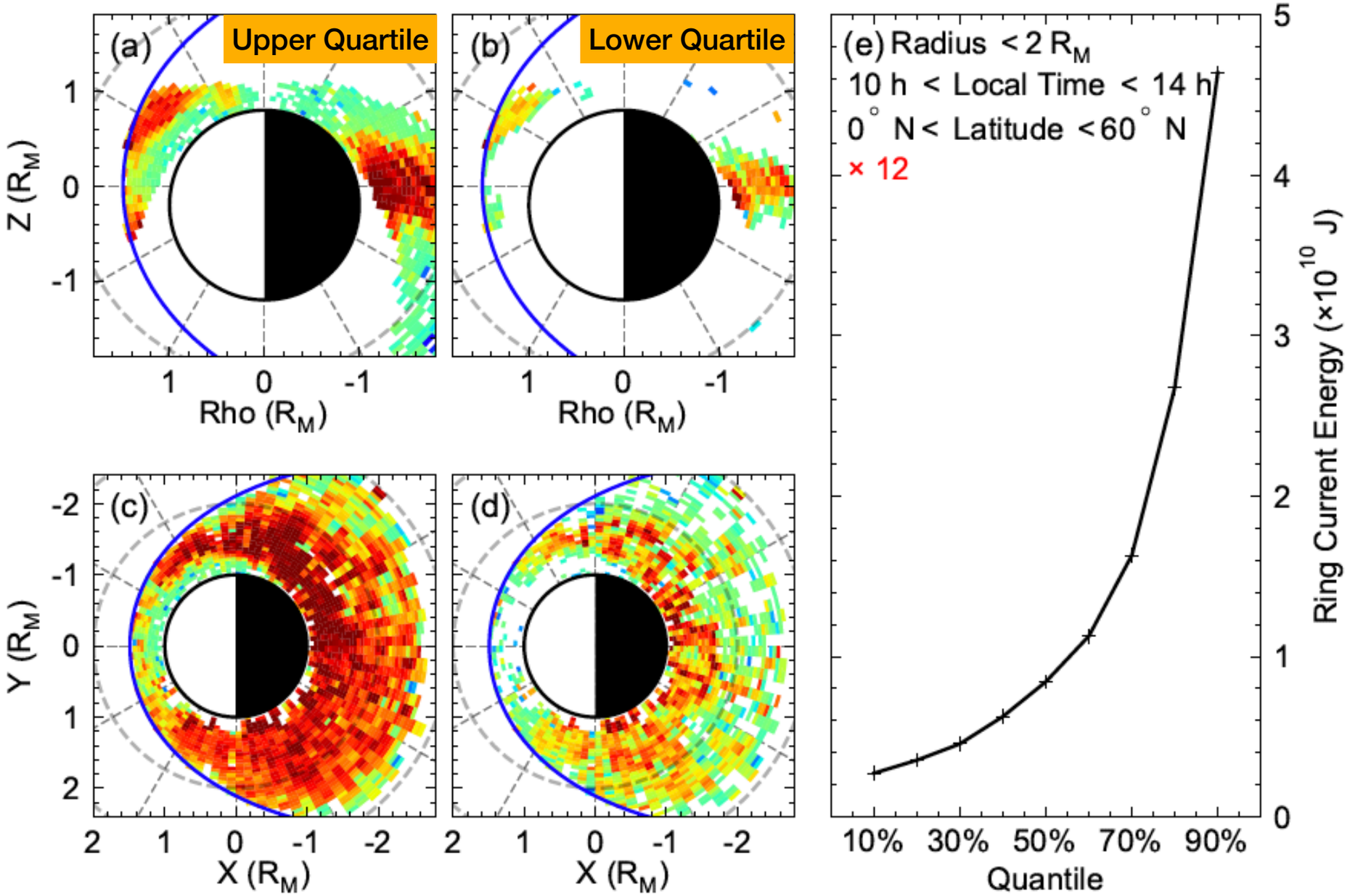


Discussion



90 degree dominant pitch angle distributions and the off equator B field minimum on the dayside

The variability of ring current



- The total energy carried by the magnetospheric ring current is estimated **0.2-5x10^{10}J** in a simple dipole treatment.
- According to the DPS relation, this proton ring current can cause a magnetic disturbance of **0.2-3.5 nT** at the ring current's center, which is equivalent to a geomagnetic storm with **Dst = from -35 to -556 nT** on Earth.

Summary

In this study, by using the MESSENGER observation from 2011 to 2015, we provide solid evidence of the existence of Mercury's ring current and found:

- The ring current has a **bifurcated morphology** on the dayside caused by the proton's Shabansky orbit under normal solar wind condition and it is confirmed from magnetic field observations and the test particle simulations.

- The estimated total energy carried by the ring current is ~ 0.2-5x10^{10}J, which would trigger a magnetic storm with a magnetic field depression of **0.2-3.5 nT** at the ring current's center on Mercury, and it is equivalent to a geomagnetic storm with **Dst = from -35 to -556 nT** on Earth.

Reference: J.-T. Zhao, Q.-G. Zong*, C. Yue*, W.-J. Sun, H. Zhang, X. -Z. Zhou, G. Le, R. Rankin and Y. Wei. Observational evidence of ring current in the magnetosphere of Mercury. ***Nature Communications***, 13, 924 (2022). https://doi.org/10.1038/s41467-022-28521-3

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