



Goals for the Study of Mercury's Magnetosphere and Exosphere

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**Climate and Space Sciences &
Engineering**

The University of Michigan

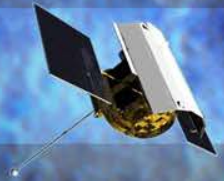
**Panel on Mercury and the Moon
Decadal Survey on Planetary
Science and Astrobiology
November 3, 2020**



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MErcury Surface, Space ENvironment, GEochemistry, and Ranging



Our Innermost Planet...

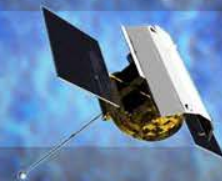




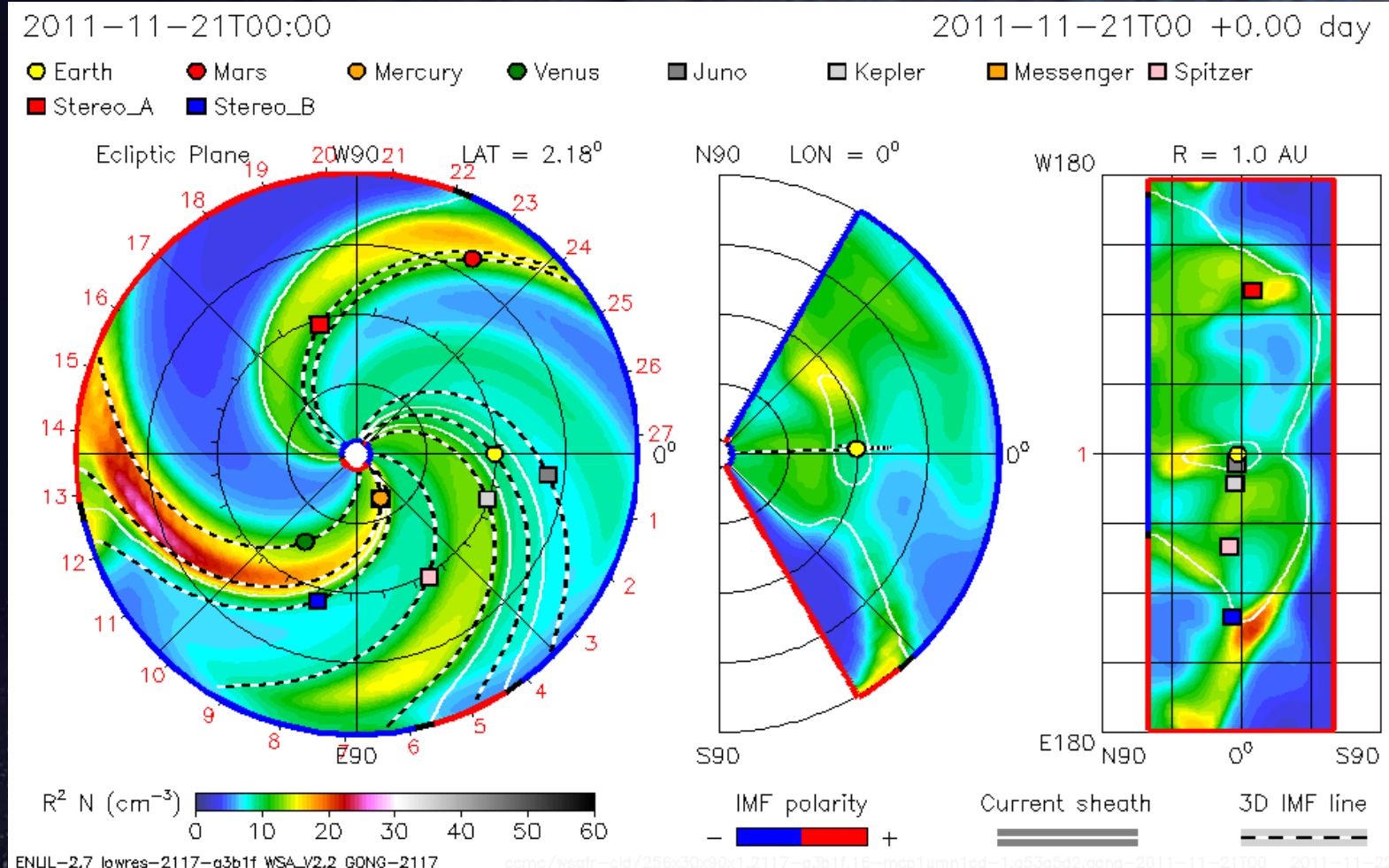
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Mercury orbits in the Sun's Outer Corona



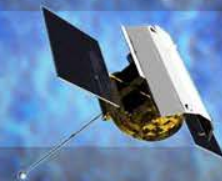
**Coronal Mass Ejection simulation using ENLIL – WSA Code
courtesy of NASA CCMC**



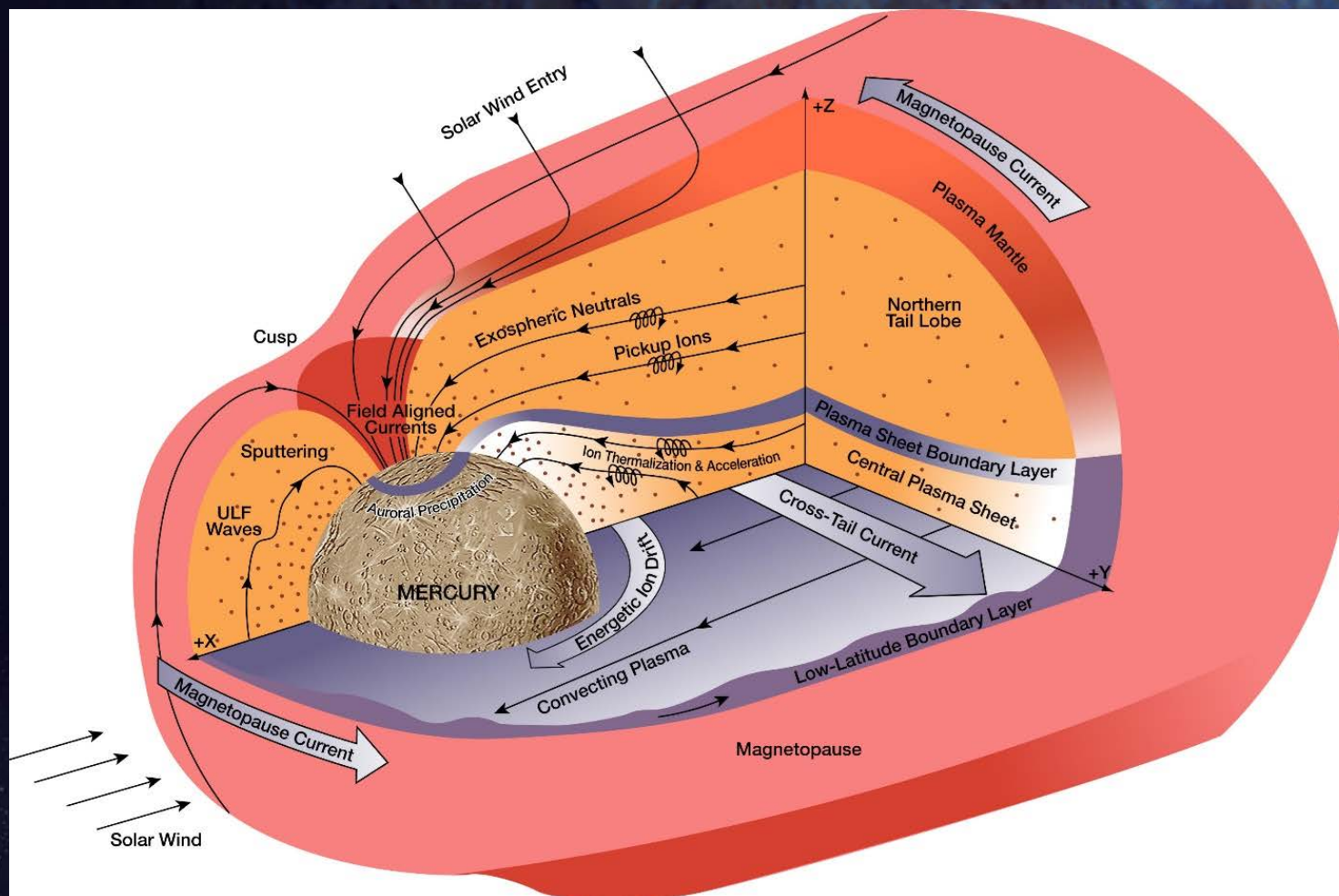
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Quiescent Magnetosphere



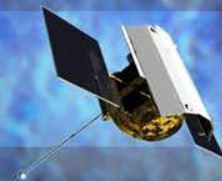
Slavin et al. (2008)



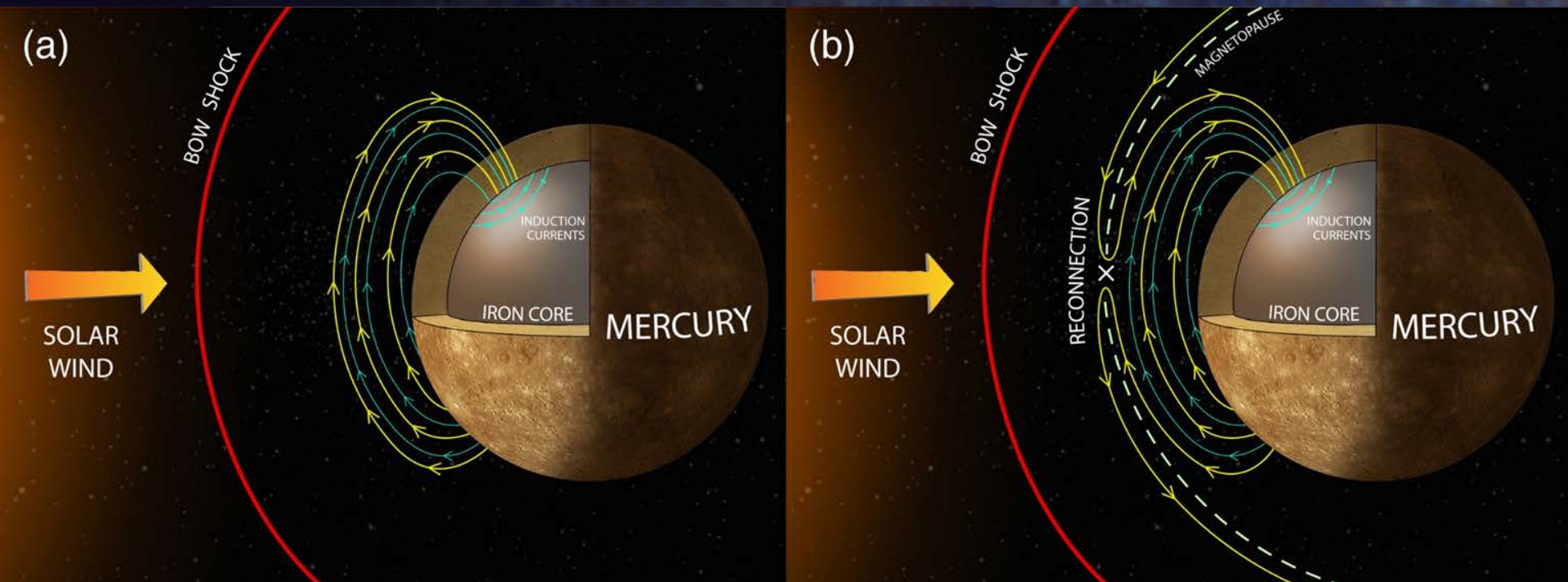
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Magnetosphere – Core Coupling



The harder the Solar Wind pushes ... the more induction currents add to Mercury's magnetic moment, but dayside magnetic reconnection has the opposite effect.

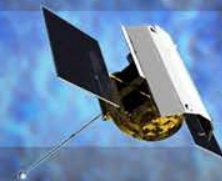
(Hood and Schubert, 1979; Slavin et al., 1979; 2014)



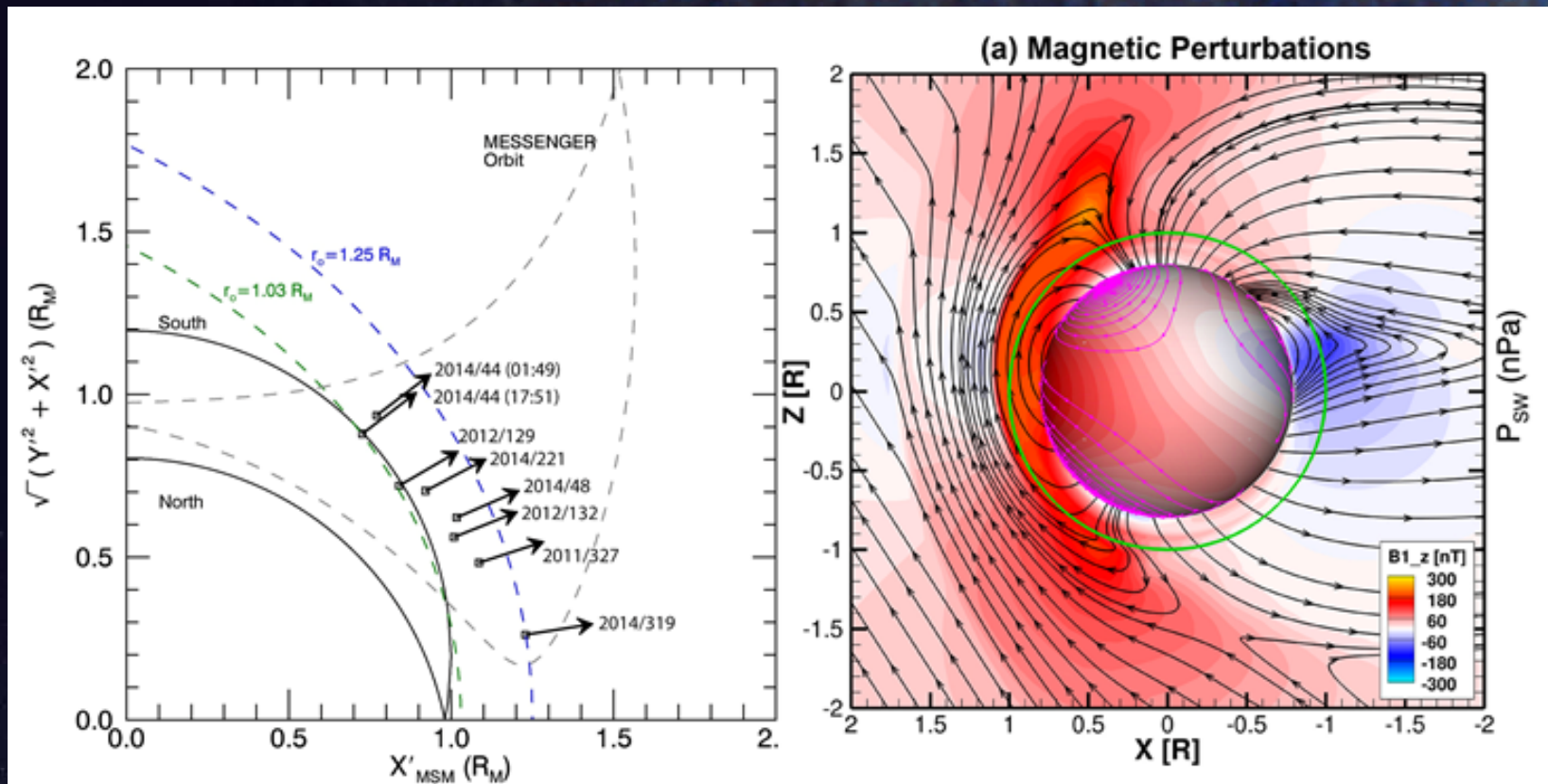
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Highly Compressed Magnetosphere Events



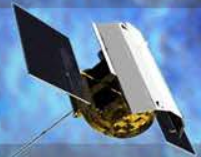
Jia et al., (2019)



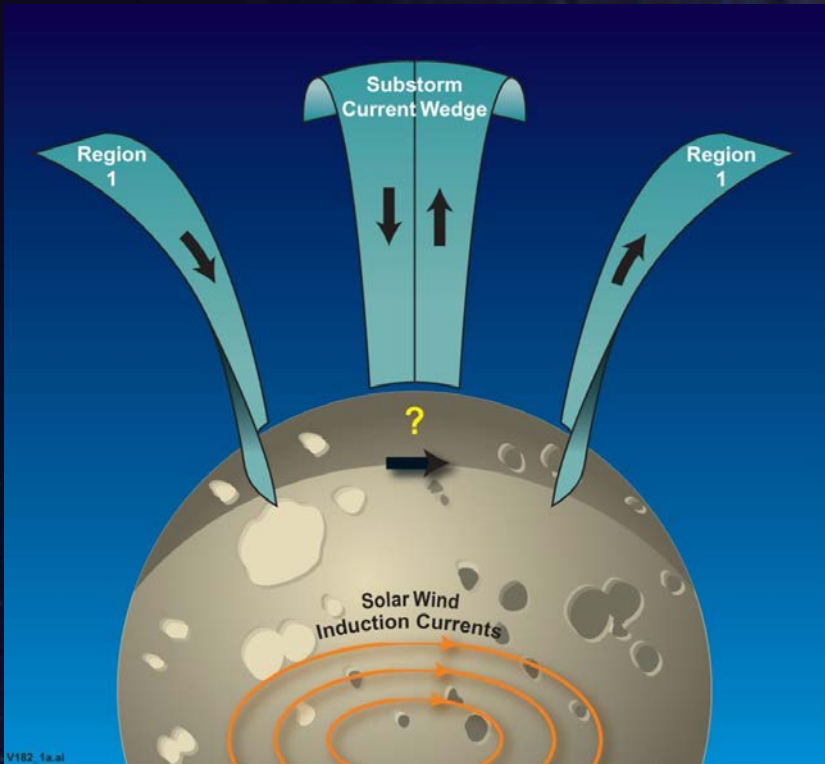
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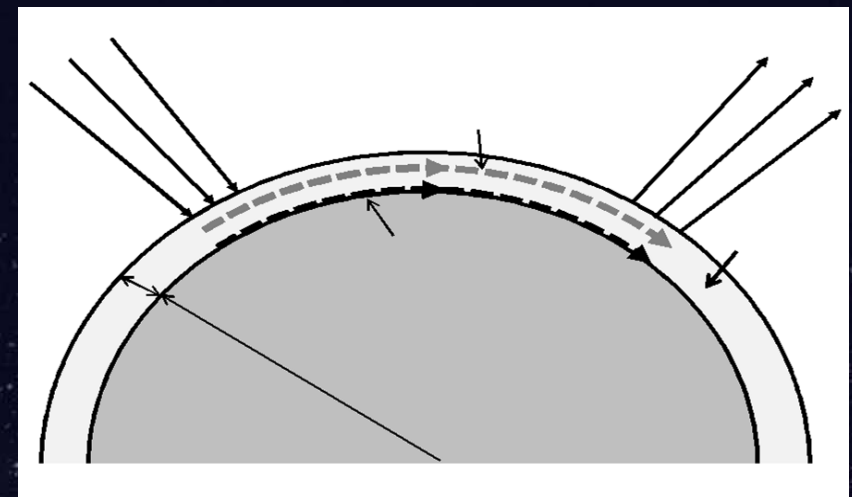
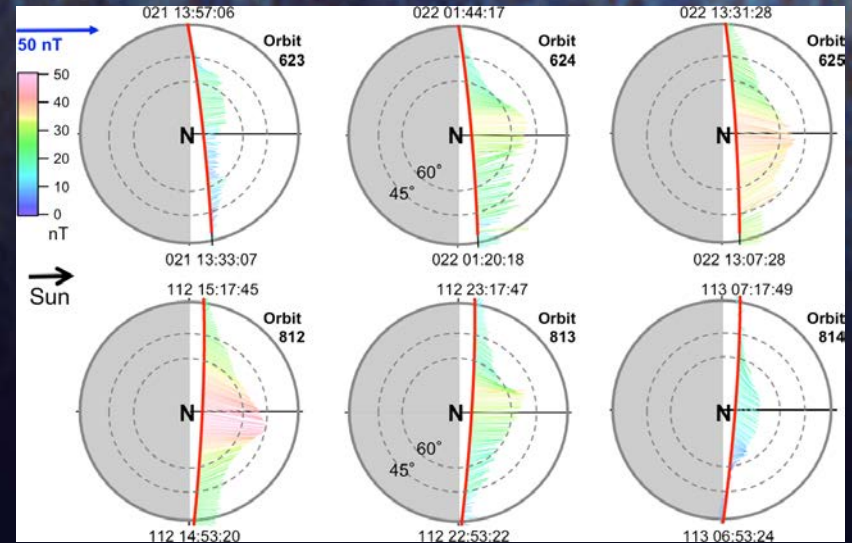
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Magnetosphere – Core Coupling: Field-aligned Currents



Slavin et al. (2007)



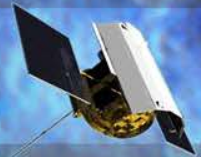
Anderson et al. (2014; 2016)



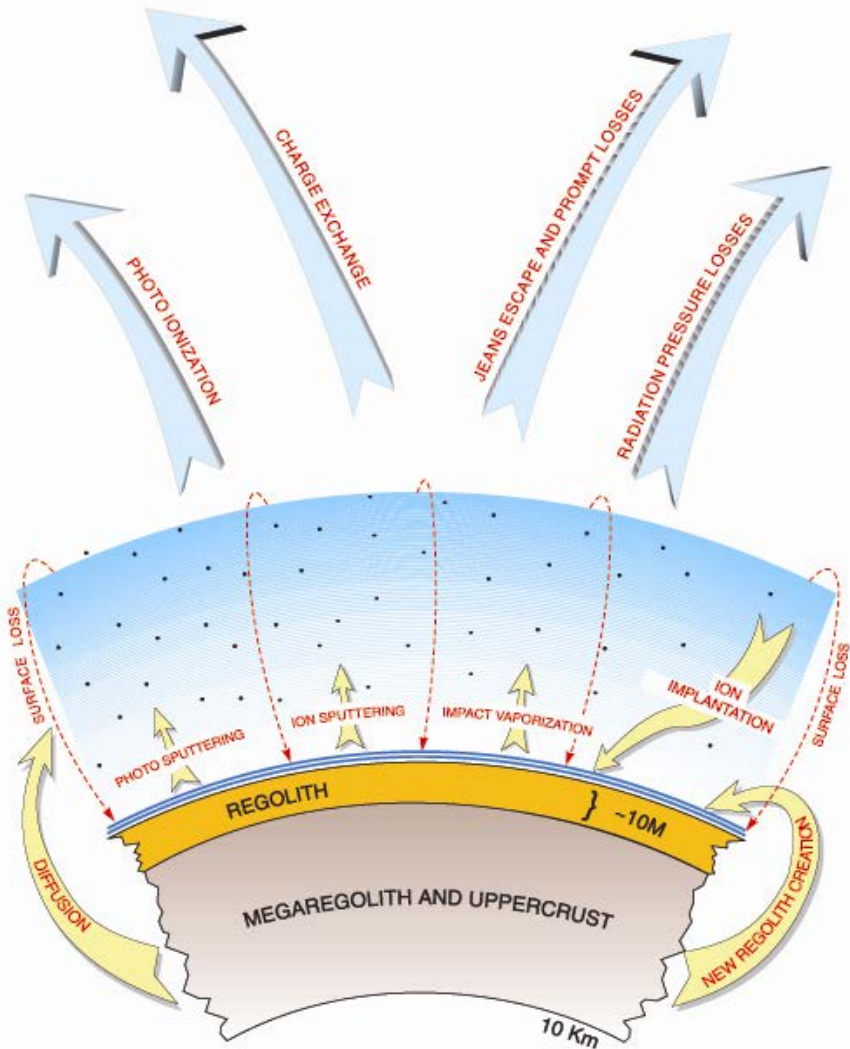
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Mercury Is Surrounded by a Surface-Bounded Exosphere



Exosphere replenished by the surface through:

□ Thermal processes (volatiles)

□ Non-thermal processes (refractories)

- micrometeoroid impacts
- UV photons
- solar wind sputtering

Known constituents:

He, Na, K, Mg, Ca, O

May contain additional surface-derived materials

Killen et al. (2001)



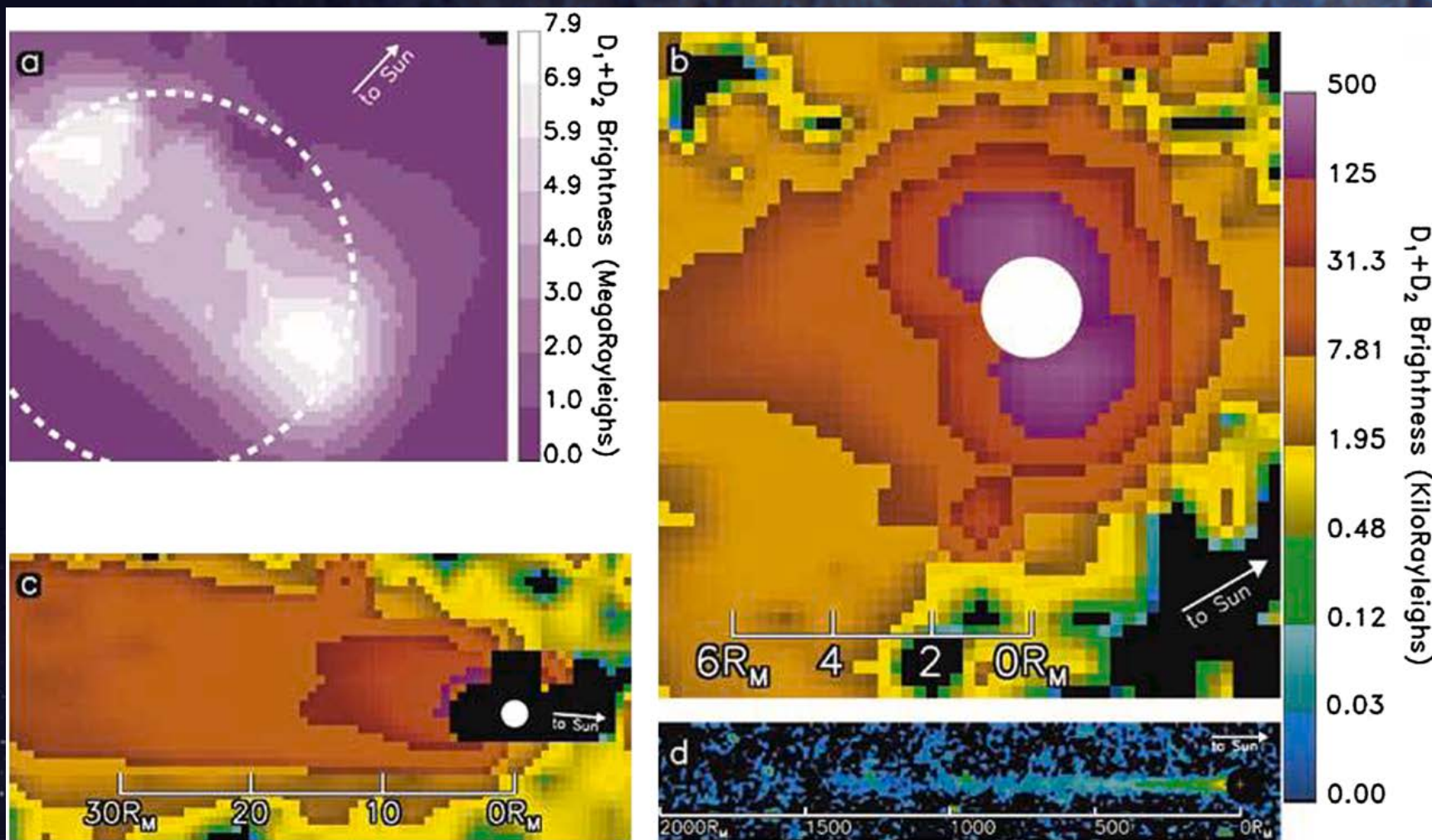
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Sodium Exosphere seen from Earth

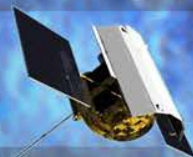




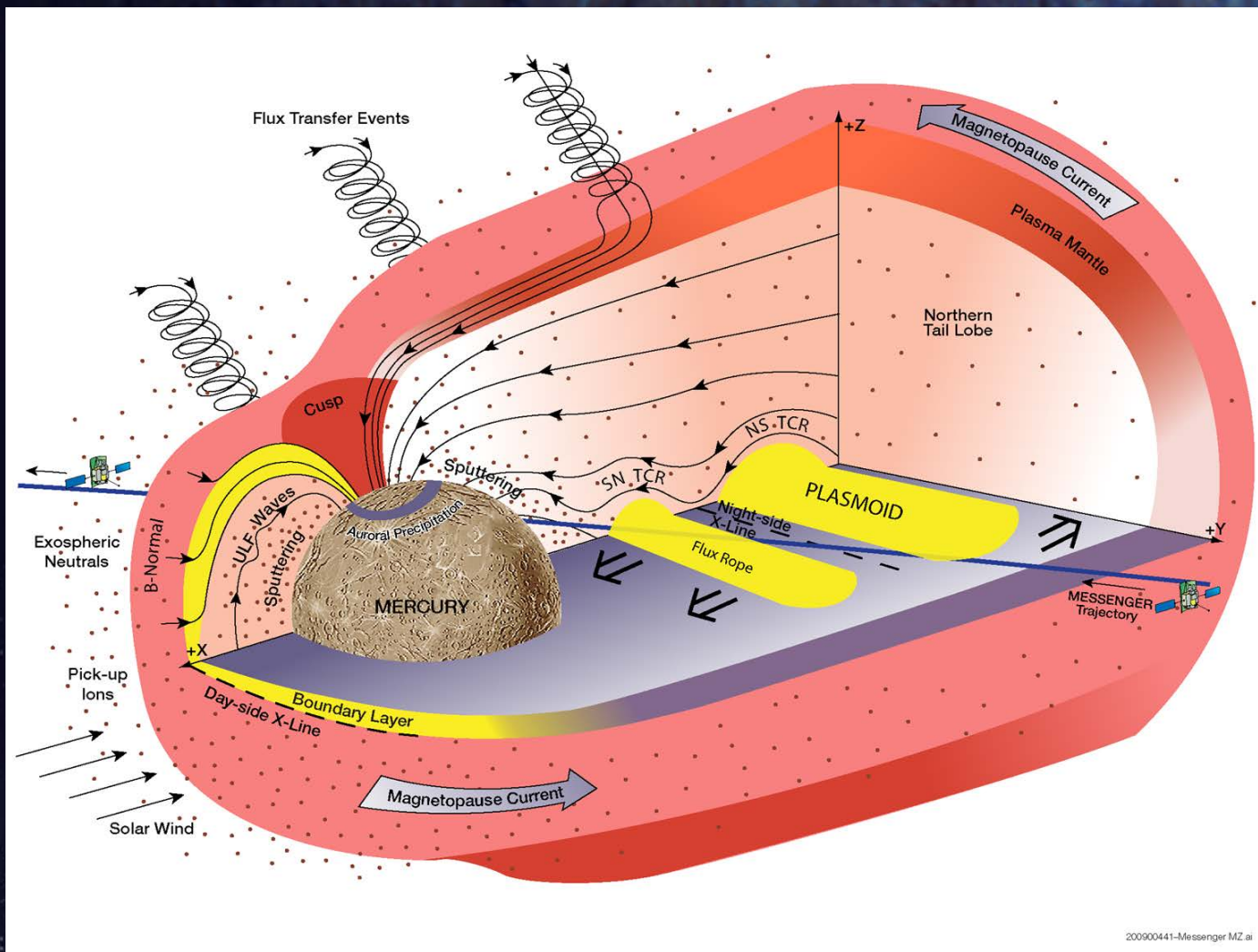
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Highly Disturbed Magnetosphere



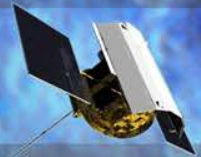
Slavin et al. (2009)



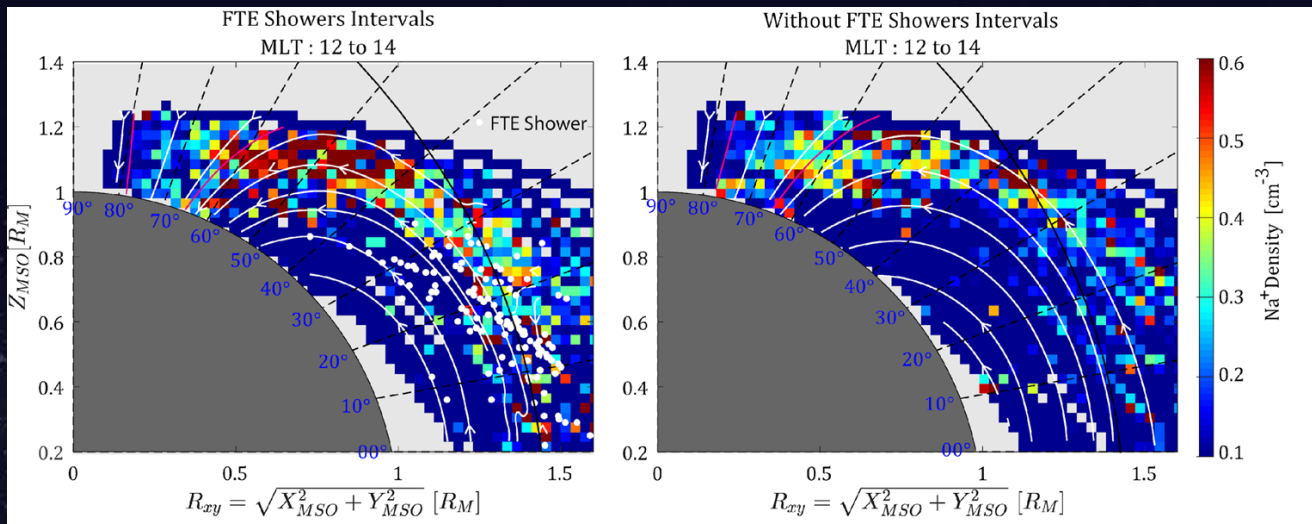
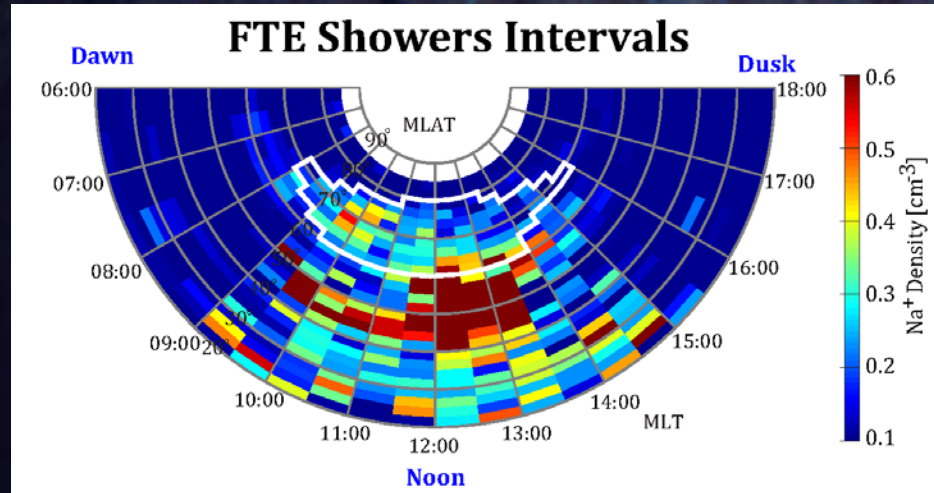
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Cusp Na⁺ Enhancement during FTE Showers



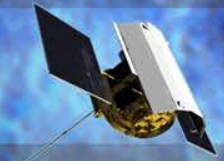
Sun et al. (in prep. 2020)



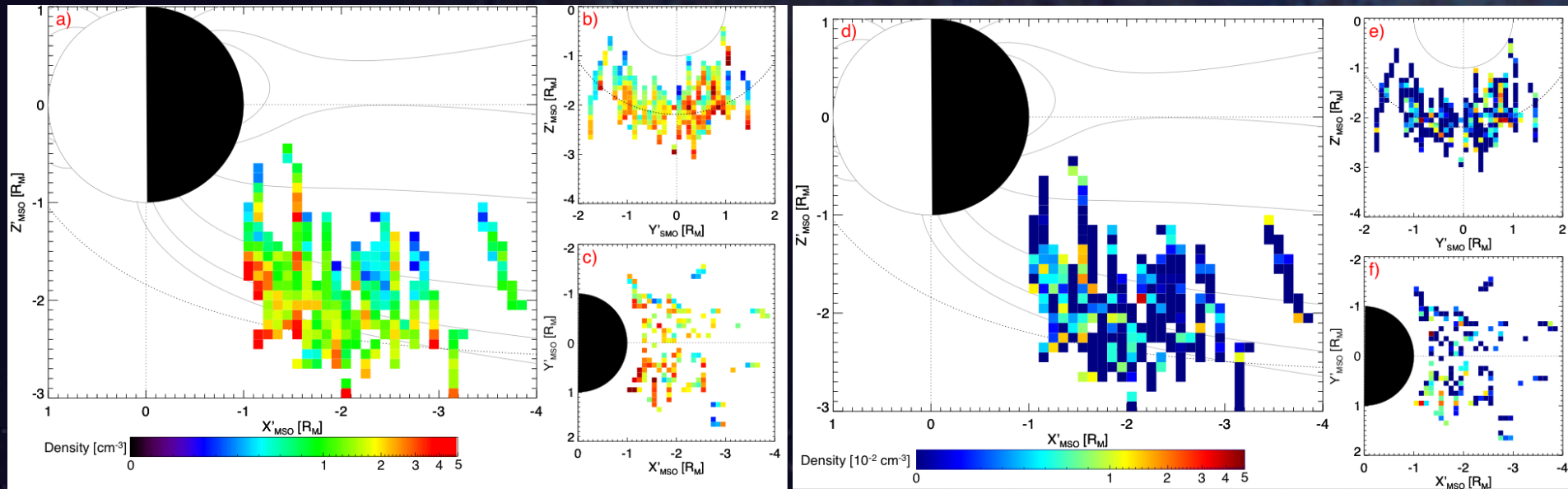
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Cusp Outflow - H^+ and Na^+ Plasma Mantles



H^+ Ions

Na^+ Ions

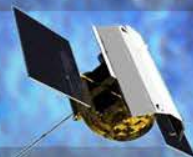
Jasinski et al. (2017)
DiBraccio et al. (2015)



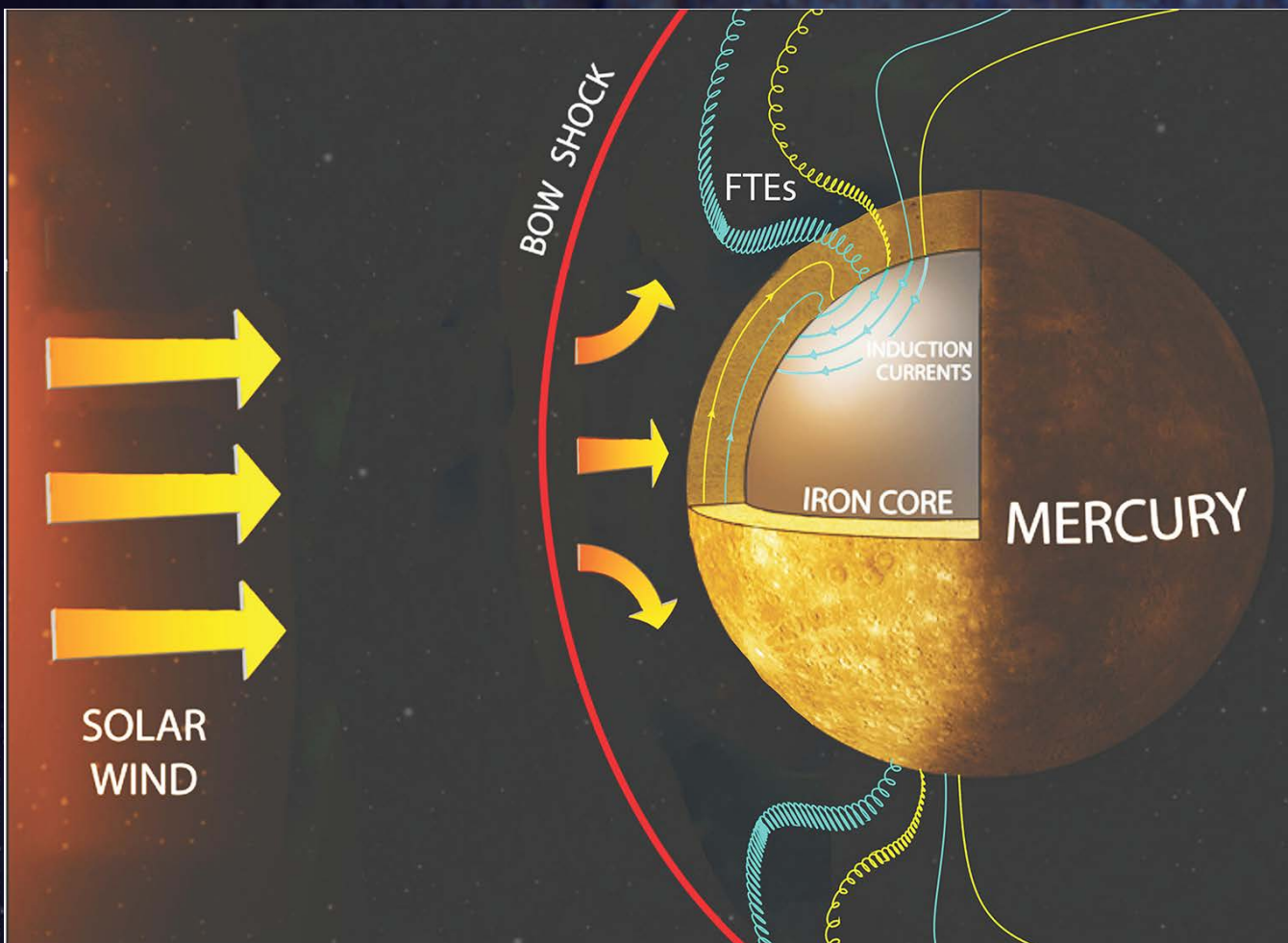
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Disappearing Dayside Magnetosphere (DDM)



Slavin et al. (2019)



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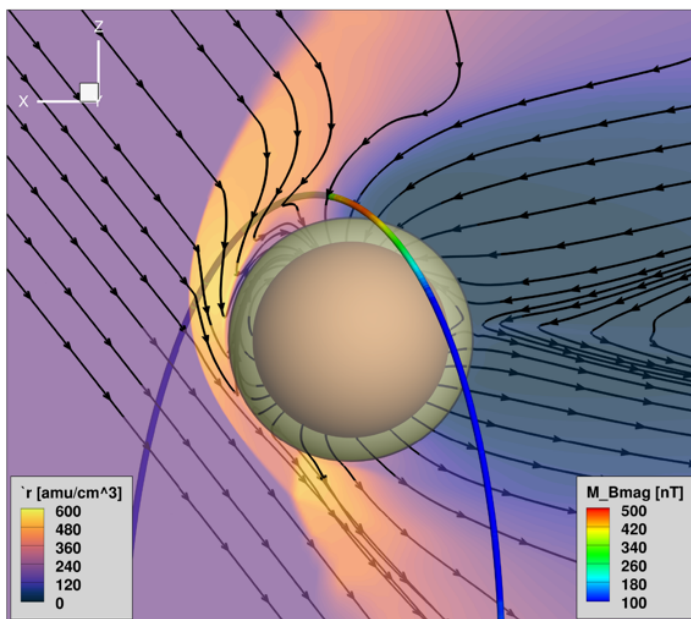
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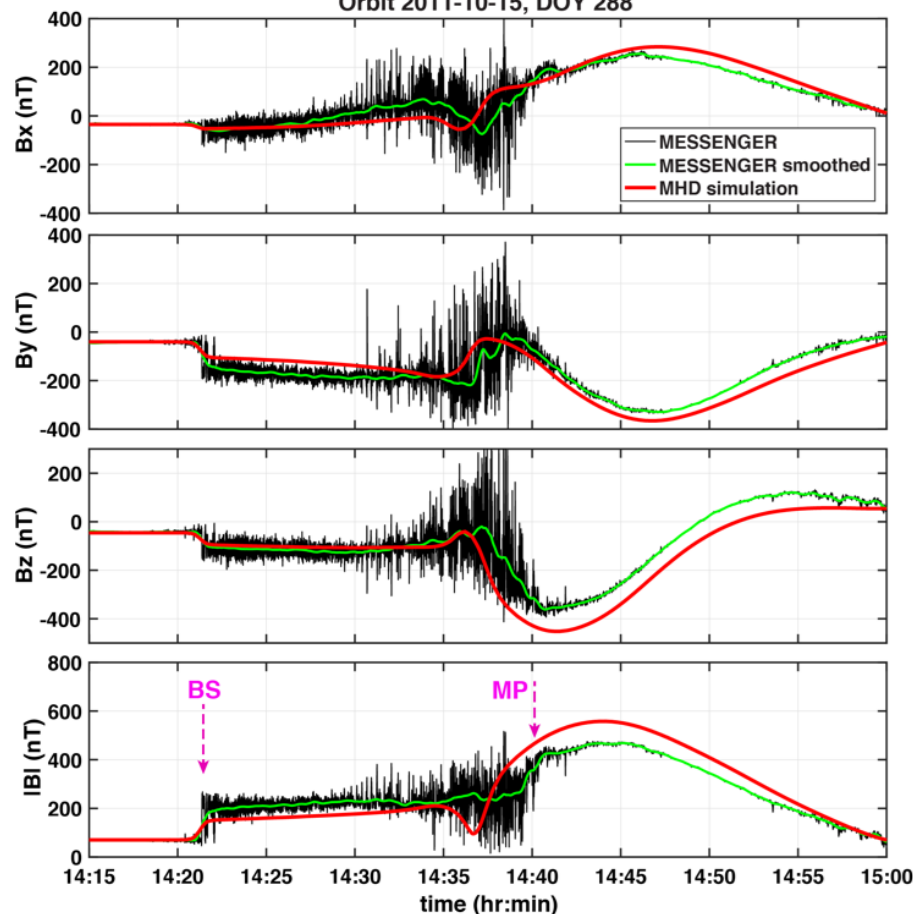


DDM Global MHD Simulation (~100 nPa)

(a) Simulated magnetospheric configuration for MESSENGER DDM event 2011-10-15, DOY 288



(b) Magnetic field comparison between MHD simulation and MESSENGER data
Orbit 2011-10-15, DOY 288



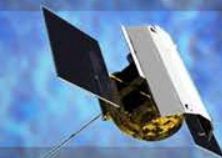
Jia et al. (In Prep 2020)



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Magnetosphere & Exosphere Science Goals

Magnetosphere – Core Coupling

- Determine the total variation in Mercury's magnetic moment due to internal induction currents.
- Do the magnetospheric magnetic field affect or interfere with Mercury's dynamo?
- Determine the Interior Electrical Conductivity (by Sounding) above the Core.
- In addition to Region 1, do other field-aligned current systems exist at Mercury (e.g. SCW FACs)?

Magnetosphere – Exosphere Coupling

- Does charged particle precipitation enhance Photon and Thermal – Desorption like at the Moon?
- Are the Na⁺ and O⁺ group ion enhancements in the magnetospheric cusp during Flux Transfer Showers due to sputtering? What is the acceleration process that gives them $E/q \sim 0.1 - 13$ keV? What are the neutral Na and O production rates?
- What are the production rates for all of the processes promoting neutral species into the Exosphere? What causes the geographic variations? The TAA variation?
- Does the solar wind impact the surface over most the dayside during DDM events? What is the effect on the Exospheric composition and density?

Magnetospheric Dynamics

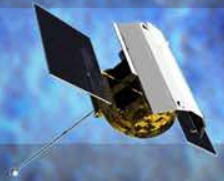
- How do magnetic storms and substorms differ within the Solar Systems only 2 Dungey-type magnetospheres (Mercury and Earth)?
- What are the sources and energies of the precipitating electrons that produce Mercury's X-ray Auroral Oval?
- How does such a small magnetosphere (magnetic tail width ~ 10 ion inertial lengths) produce bursts of electrons in the near-tail with energies up to several 100 keV?



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Thank you!

