Transport of solar wind energy into planetary magnetospheres: A comparison of the magnetospheres of Mercury and Saturn

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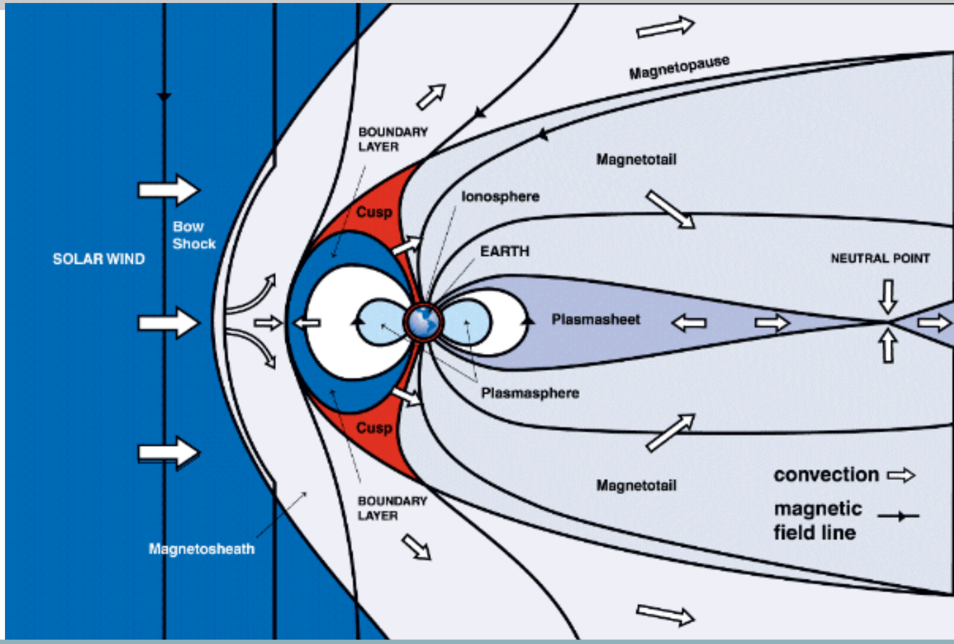
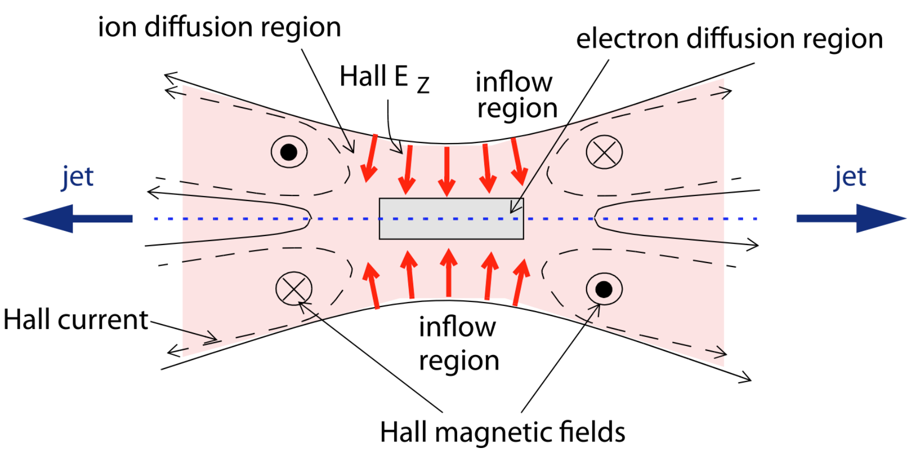
- Studies of Earth's magnetosphere provide us with a template for studying the solar wind-magnetosphere interaction in the case of other systems

- Magnetic reconnection and growth of the Kelvin-Helmholtz (K-H) instability are two processes that promote energy transport across Earth's magnetopause

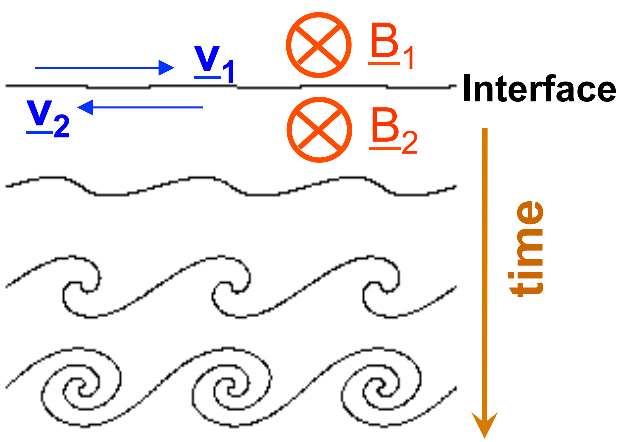


MAGNETIC RECONNECTION



Taken from Paschmann, GRL (2008)

GROWTH OF THE KELVIN-HELMHOLTZ INSTABILITY

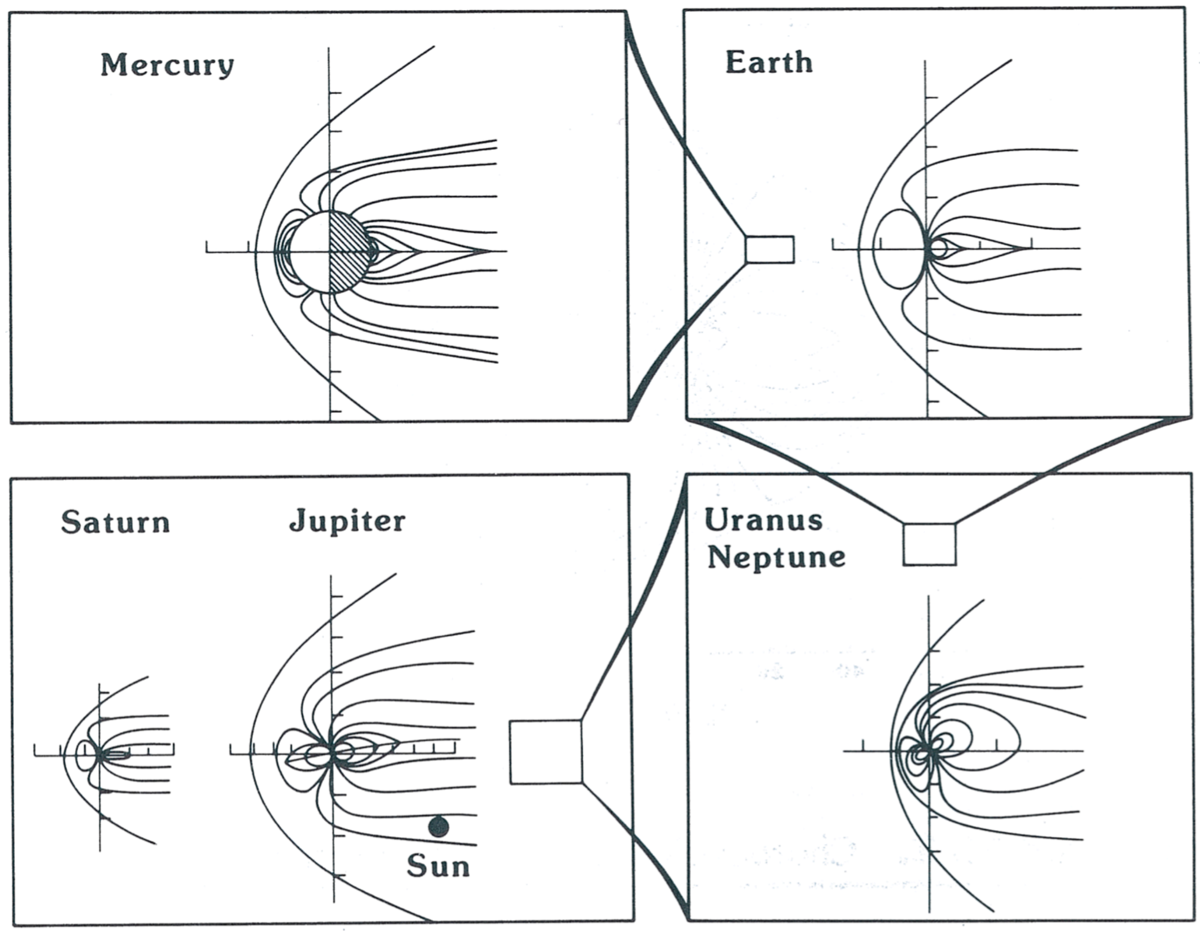


- Our understanding of these two processes is evolving, and Earth's solar wind-magnetosphere interaction is the subject of much research attention

- Each magnetosphere is a unique point in solar system parameter space where we can test our current understanding of these fundamental processes

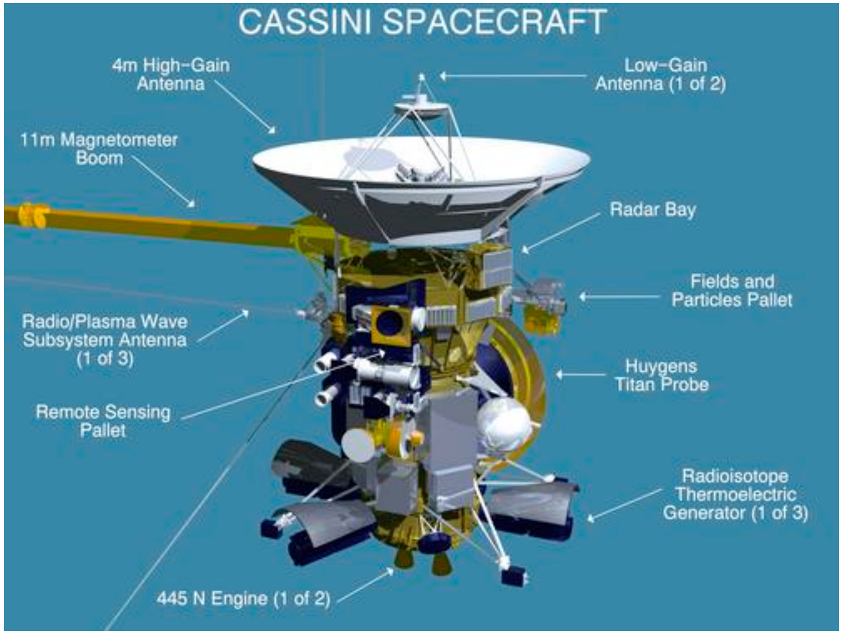
- Recent planetary missions have significantly improved our ability to make such comparisons

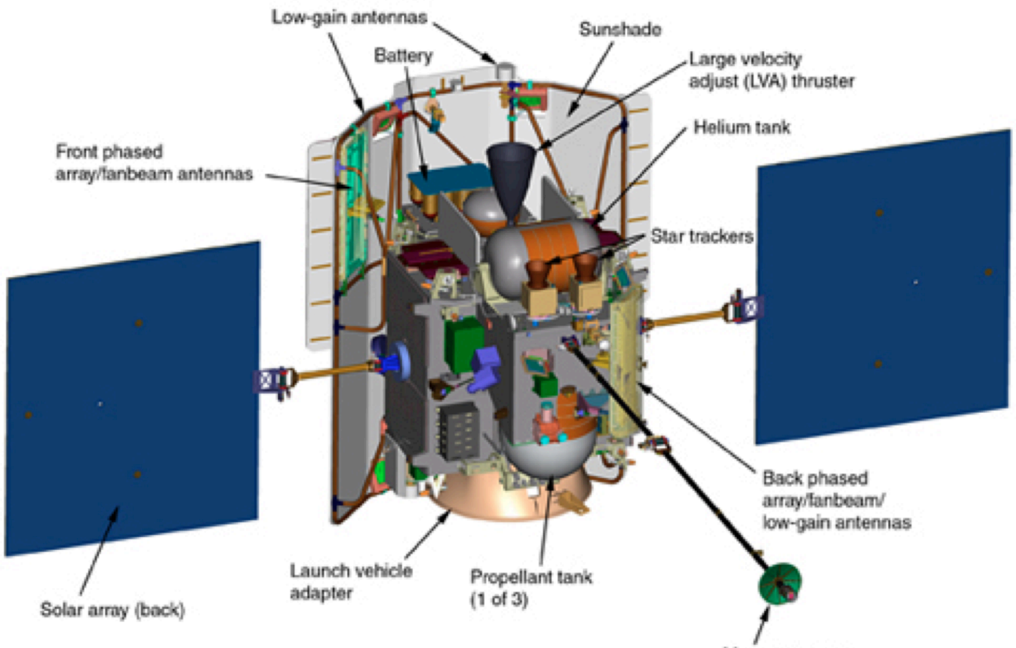
Taken from Walker and Russell (1995)



- In March 2011 the MESSENGER spacecraft became the first Mercury orbiter, and the Cassini spacecraft will continue to orbit Saturn until 2017

- These two missions have vastly increased the number of observations of the respective planetary magnetopauses





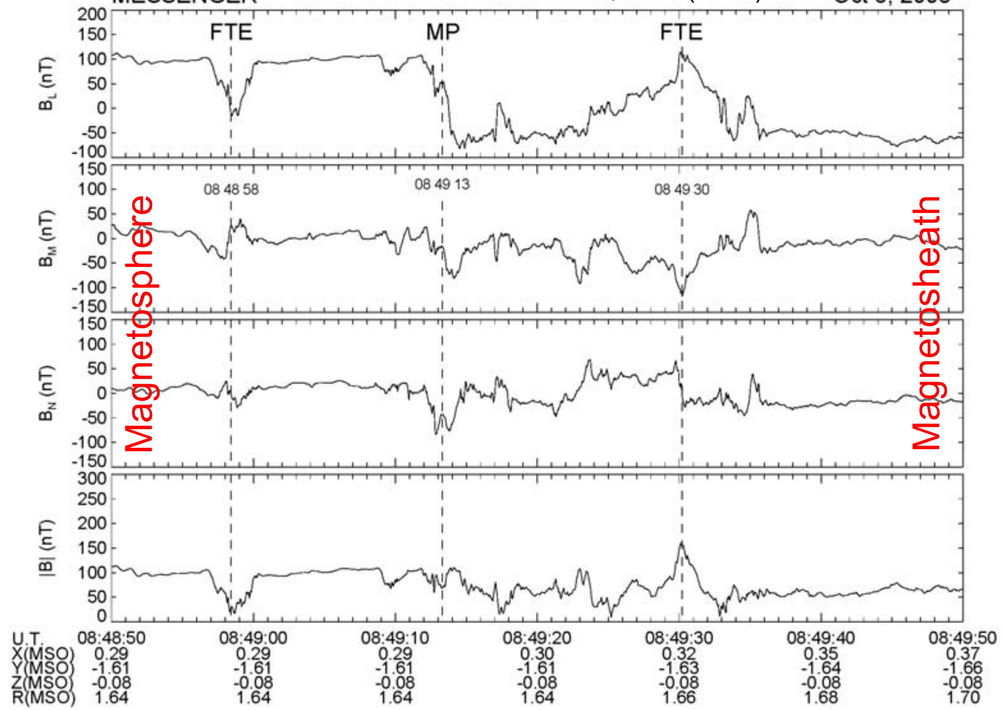
Credit: NASA/JHUAPL

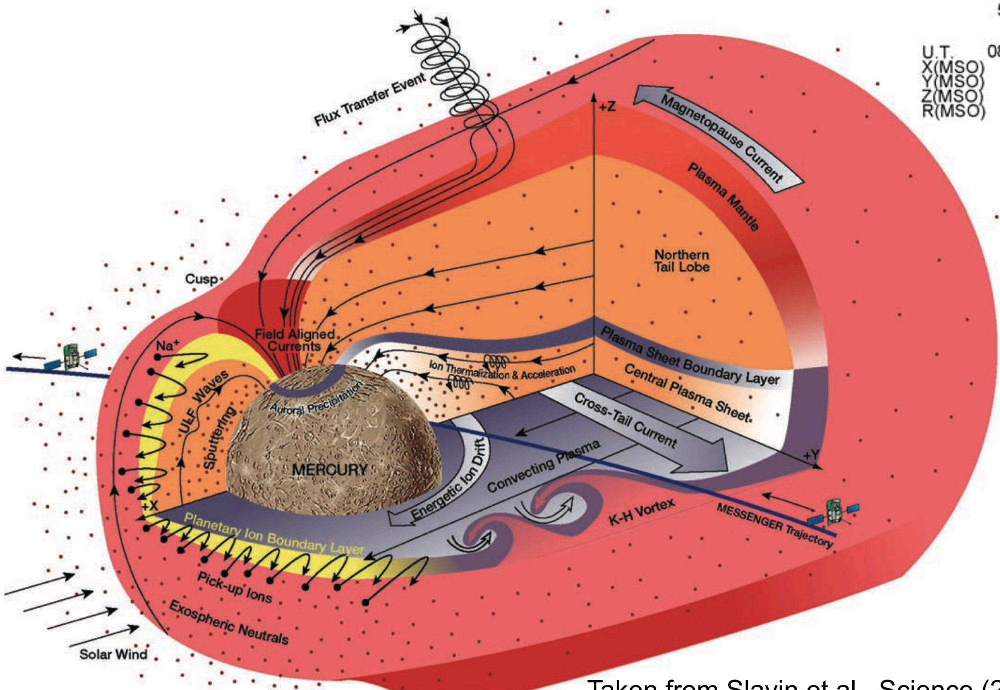
- The magnetospheres of Mercury and Saturn are dramatically different, partly because of the very different solar wind conditions

- Data returned by MESSENGER and Cassini allow us to make what may be the most important comparison of magnetospheres to date

- Mercury's magnetosphere is extremely sensitive to the solar wind
- MESSENGER has revealed extensive evidence for magnetopause reconnection, including signatures of Flux Transfer Events (FTEs)
- Dungey cycle timescale: ~2 min

Taken from Slavin et al., GRL (2010)





Taken from Slavin et al., Science (2009)

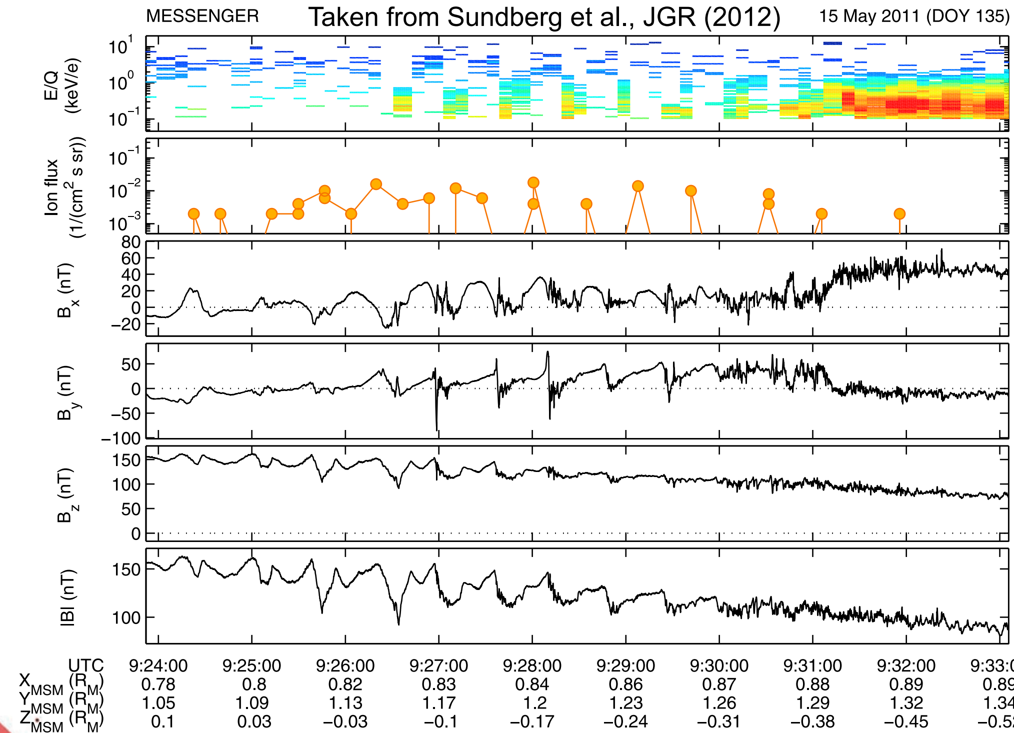
- A single FTE can account for as much as ~5% of the total magnetic flux in the lobes of the magnetotail
- Solar wind conditions at Mercury (particularly the low-Mach numbers) are expected to produce a low-β magnetosheath that favours magnetopause reconnection

Also see: Slavin et al., Science (2008)

- MESSENGER has encountered clear evidence for waves and vortices on the magnetopause resulting from the growth of the K-H instability

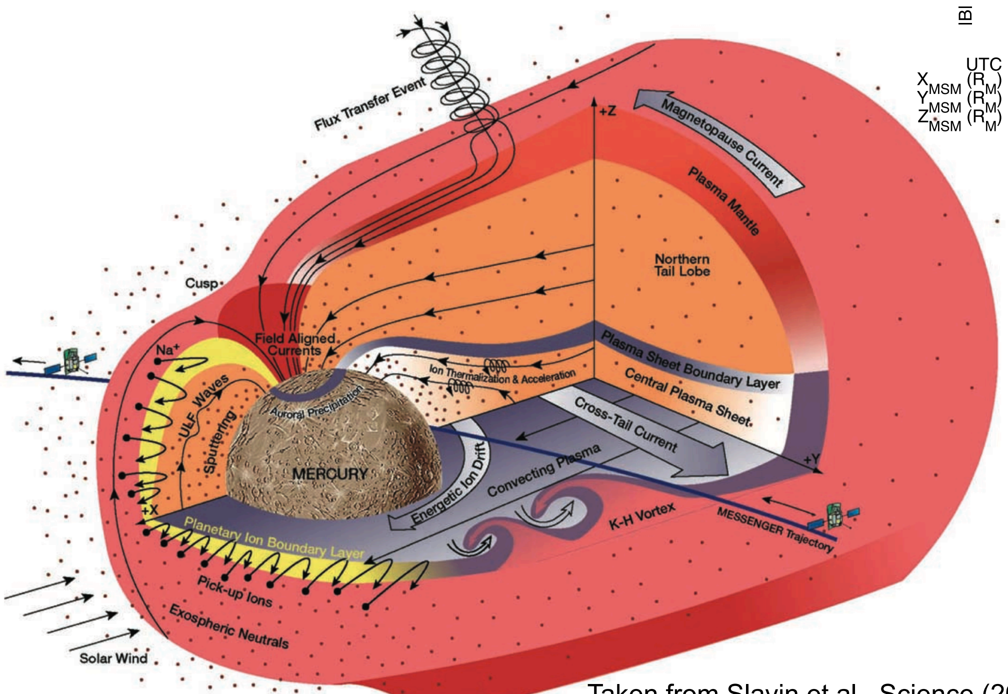
- These structures form almost always under northward Interplanetary Magnetic Field (IMF) conditions

Taken from Sundberg et al., JGR (2012)



- "Sawtooth" oscillation of the magnetic field y-component and strong field strength fluctuations are indicative of vortices

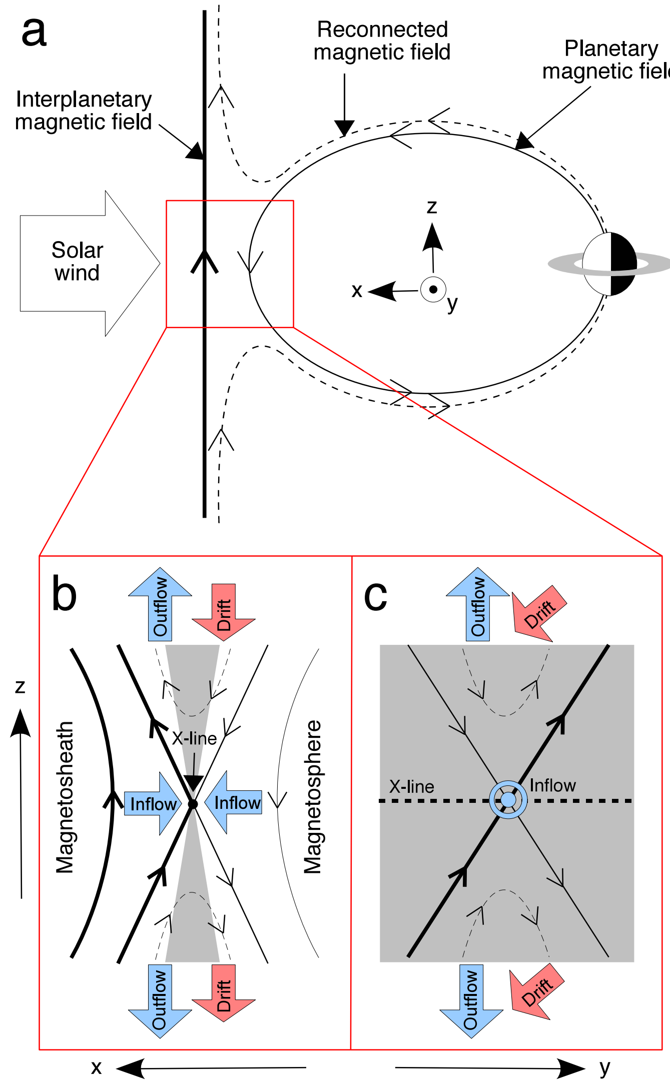
- More K-H vortex encounters have been detected at dusk than at dawn, possibly a finite gyroradius effect



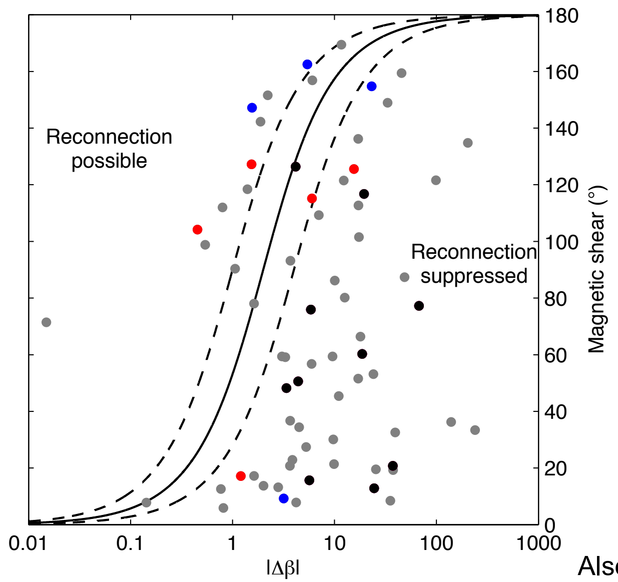
Taken from Slavin et al., Science (2009)

Also see: Slavin et al., Science (2008); Boardsen et al. GRL (2010); Sundberg et al., P&SS (2010, 2011)

- Some evidence for magnetopause reconnection has been identified, but not in the form of detection of reconnection jets
- The flux transfer event signatures seen at Earth have not been identified at Saturn, using a large database of crossings
- Plasma β conditions are expected to make conditions less favorable for reconnection than at Earth's magnetopause



Taken from Masters et al., GRL (2012)



Taken from Masters et al., GRL, (2012)

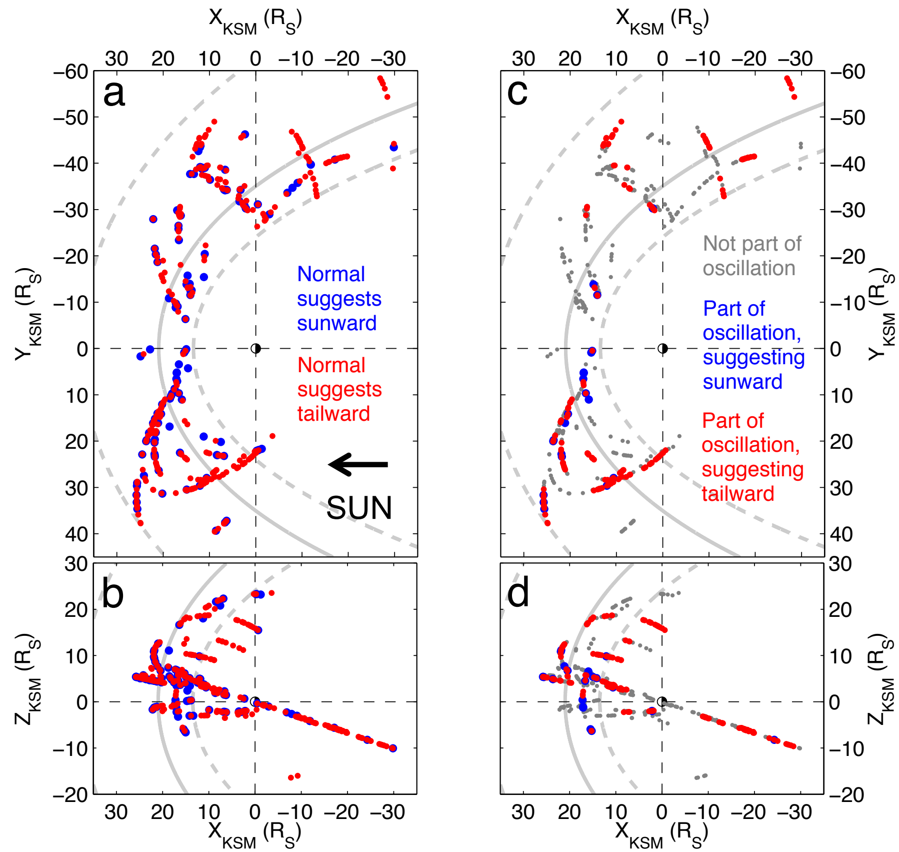
Also see: McAndrews et al, JGR (2008); Lai et al., JGR (2012); Badman et al., JGR (2012)

- Growth of the Kelvin-Helmholtz (K-H) instability was expected to produce a dawn-dusk asymmetry in magnetopause surface wave activity and vortices

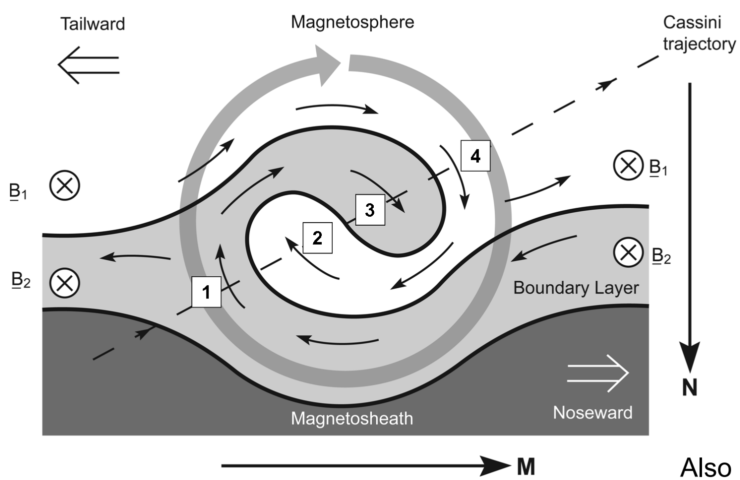
- Surface waves are common,
K-H instability is likely a major driver

- No local time asymmetry in wave activity, has been identified, likely due to an asymmetry in the orientation of the magnetospheric magnetic field

Taken from Masters et al., P&SS (2012)



Taken from Masters et al., JGR (2010)



- Although an encounter with a K-H vortex on the inner edge of the boundary layer has been identified, little evidence for magnetopause vortices has been found

Also see: Fukazawa et al., GRL (2007a, b); Masters et al, P&SS (2009); Cutler et al., JGR (2011); Delamere et al., JGR (2011); Wilson et al., JGR (2011); Walker et al., JGR (2011)

Summary

- The MESSENGER and Cassini spacecraft allow us to make a thorough comparison between the nature of solar wind energy transport into the magnetospheres of Mercury and Saturn

- Magnetic reconnection at the magnetopause:
  - Magnetosheath β conditions tend to increase with heliocentric distance
  - Simulations and observations strongly suggest that higher β is less favorable for reconnection
  - Does this explain the clear Mercury-Saturn difference in this respect?

- Growth of K-H instability at the magnetopause
  - Also a clear difference between Mercury and Saturn
  - Is this related to differences in the (poorly constrained) local conditions?
  - Do higher Mach numbers of the sheath flow at Saturn restrict vortex formation?

- This comparison significantly clarifies, and may significantly improve, our understanding of the solar wind-magnetosphere interaction at all planets, both solar system and extrasolar

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