Cassini/Huygens at Saturn

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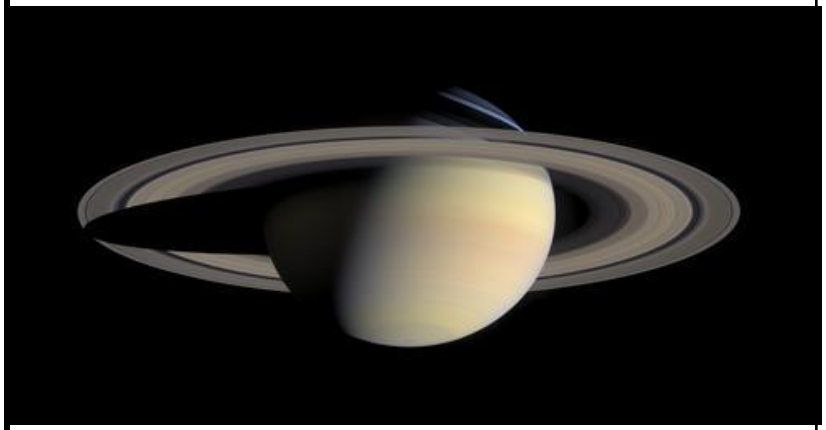
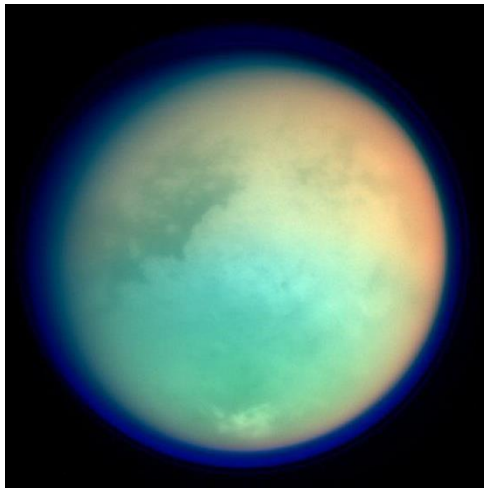
Cassini Science Targets

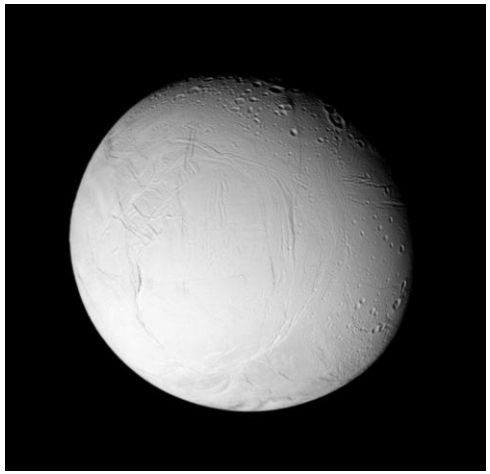
Saturn and Rings



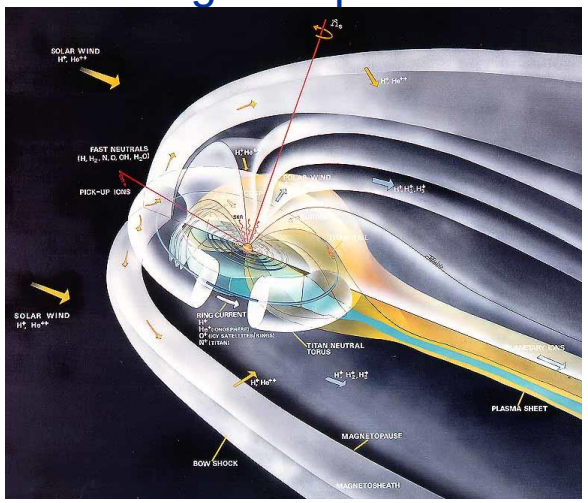
Titan

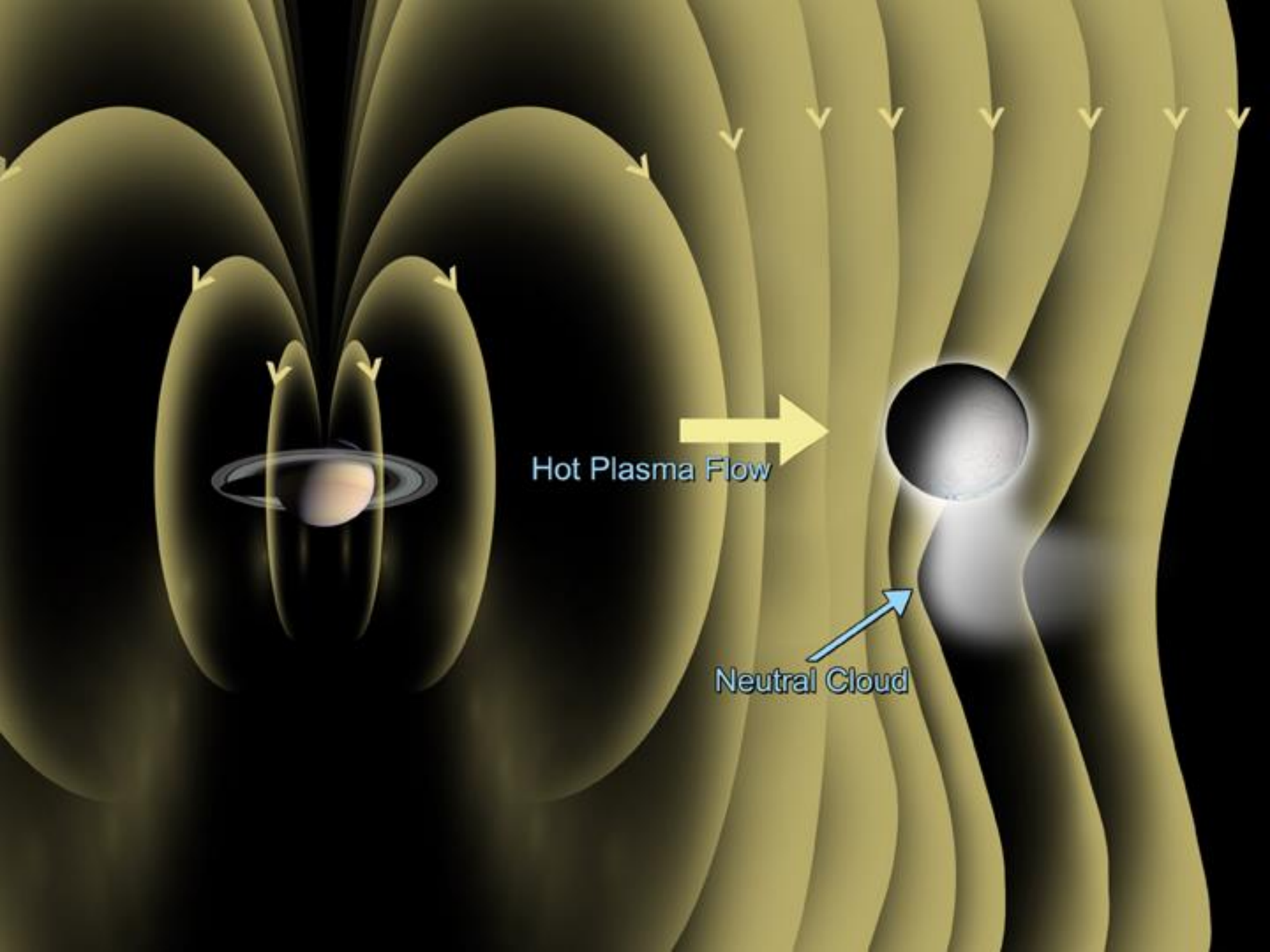


Icy Satellites

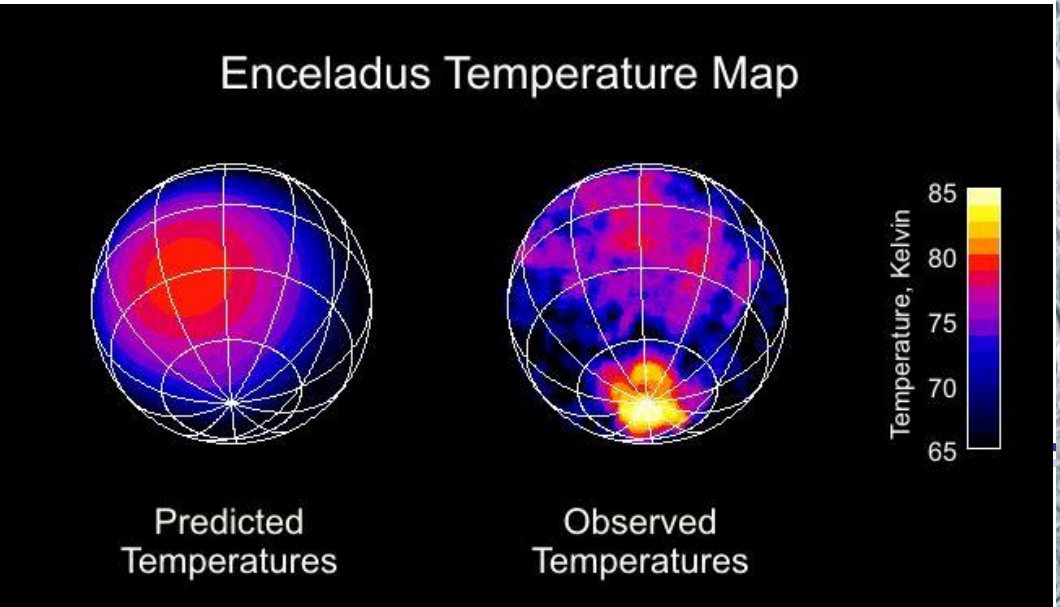


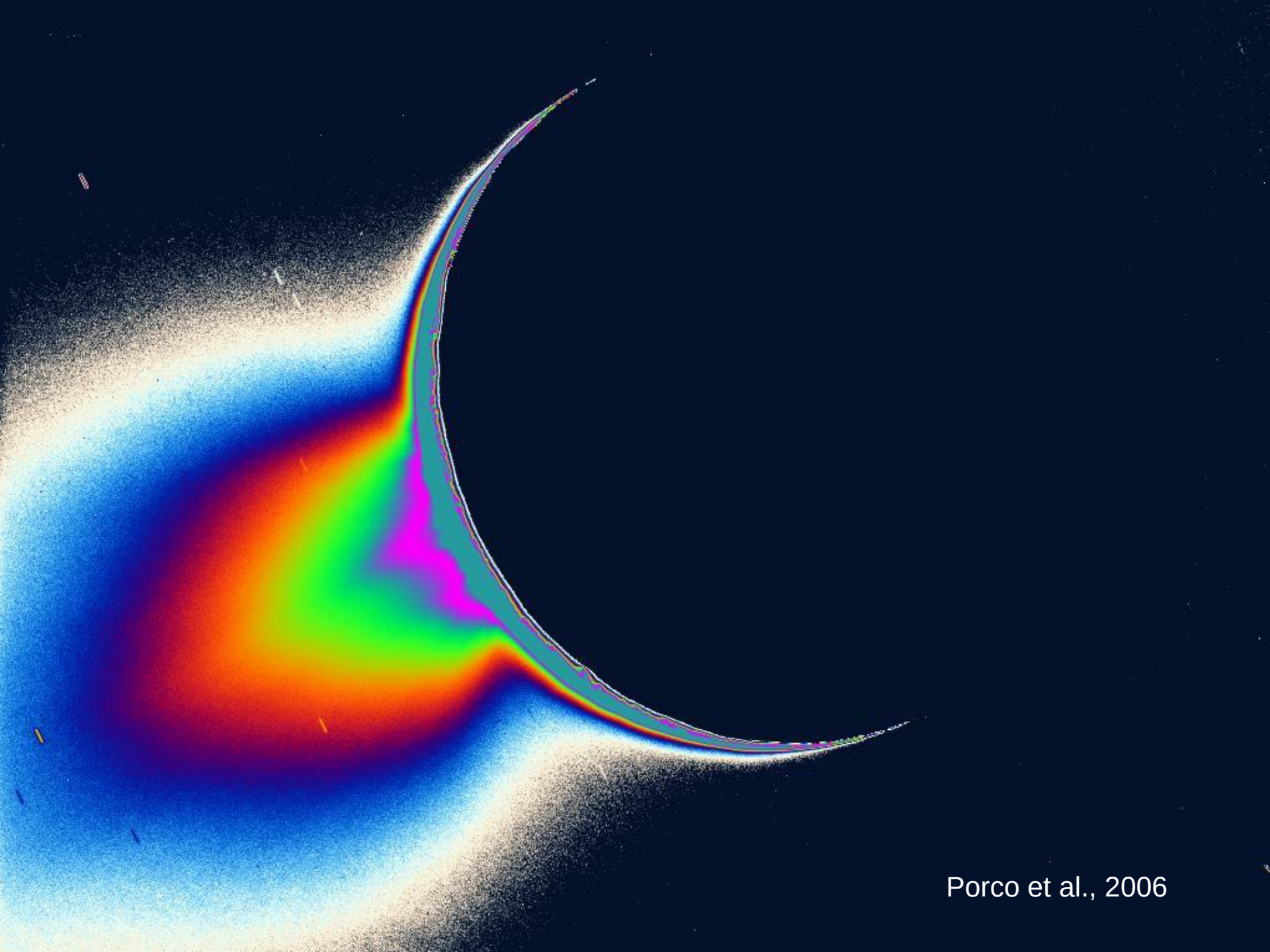
Magnetosphere



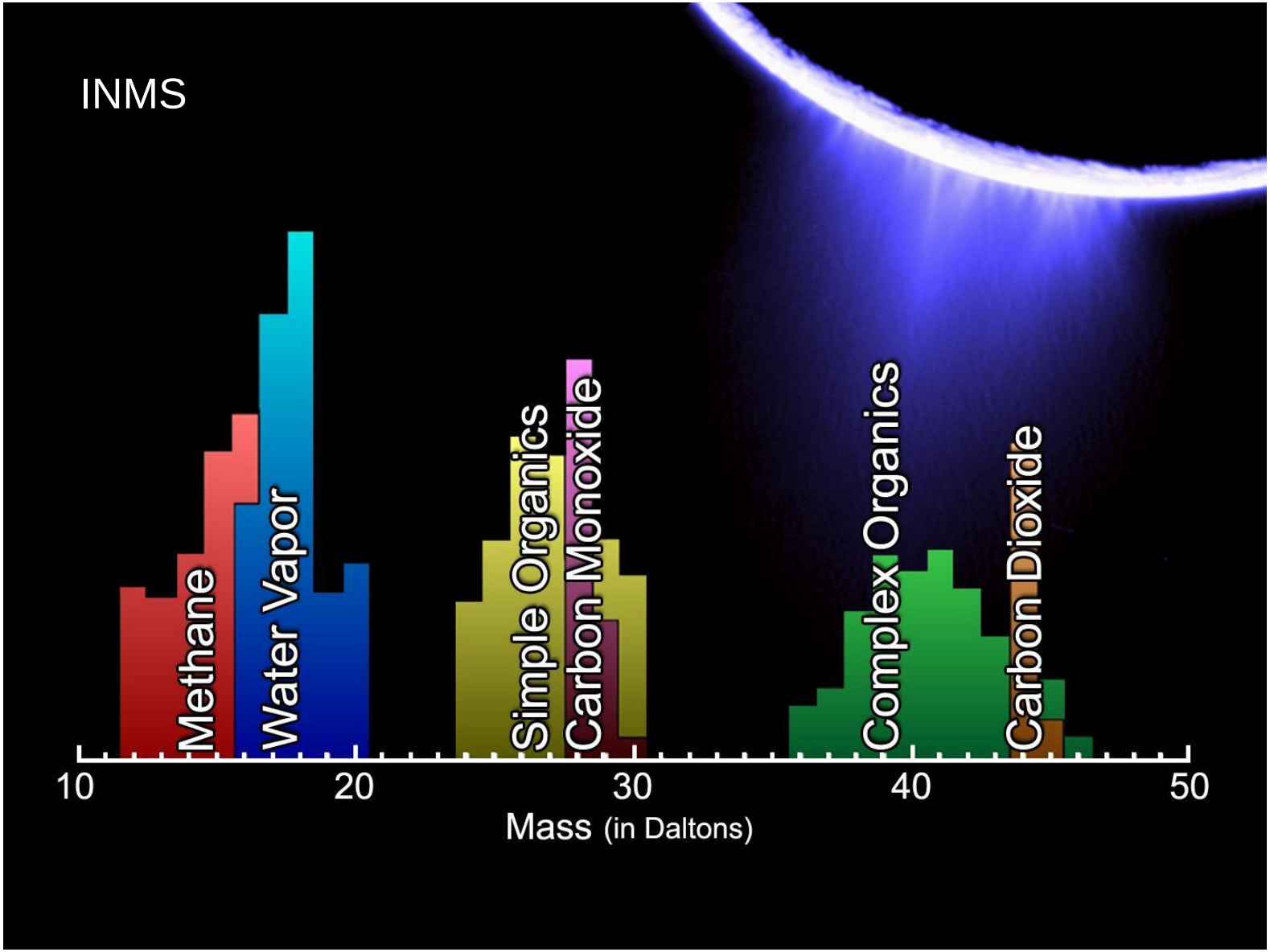

Hot Plasma Flow
Neutral Cloud

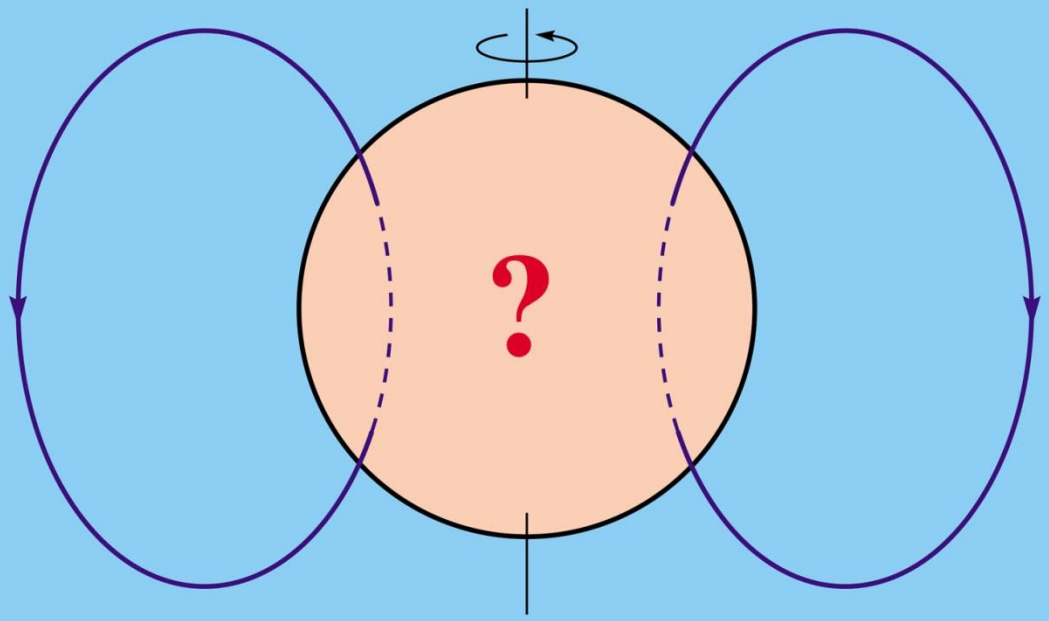
- Fractures/ Tiger Stripes near south pole
- Warm Spot near south pole
- Internal heat leaking out?
- Warmest temperature over one of fractures
- ISS & CIRS data (Porco et al., Spencer et al, 2006)



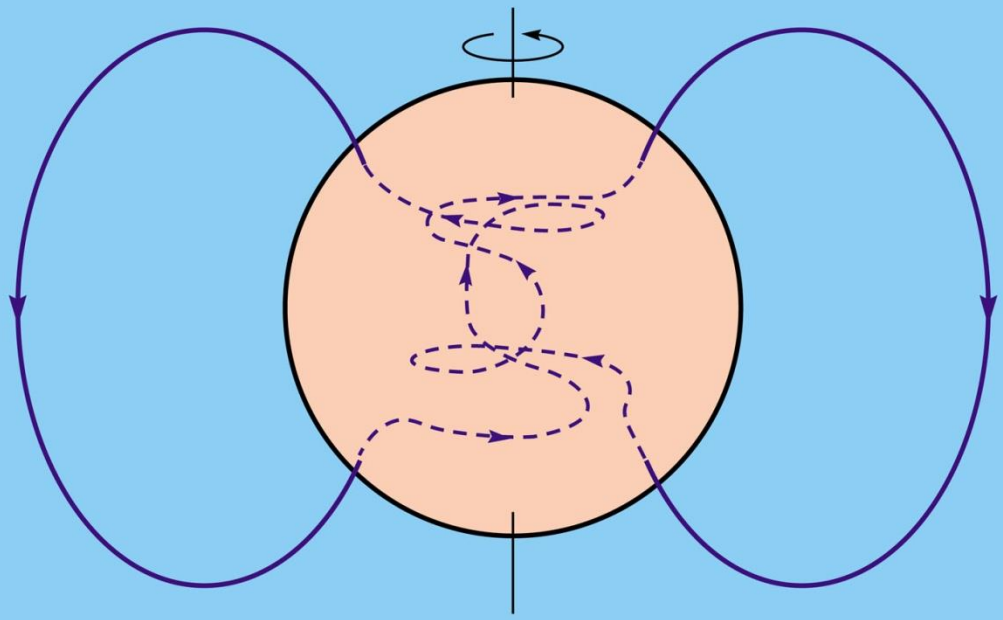


Porco et al., 2006


INMS
Methane
Water Vapor
Simple Organics
Carbon Monoxide
Complex Organics
Carbon Dioxide
10
20
30
40
50
Mass (in Daltons)



Where does Saturn's field come from ?



Field is generated by dynamo action deep inside

Our knowledge about Saturn's internal magnetic field prior to the Cassini Grand Finale

- Axisymmetric magnetic moments up to degree 3 well resolved [Dougherty et al., 2005; Burton et al., 2009; Cao et al., 2011]

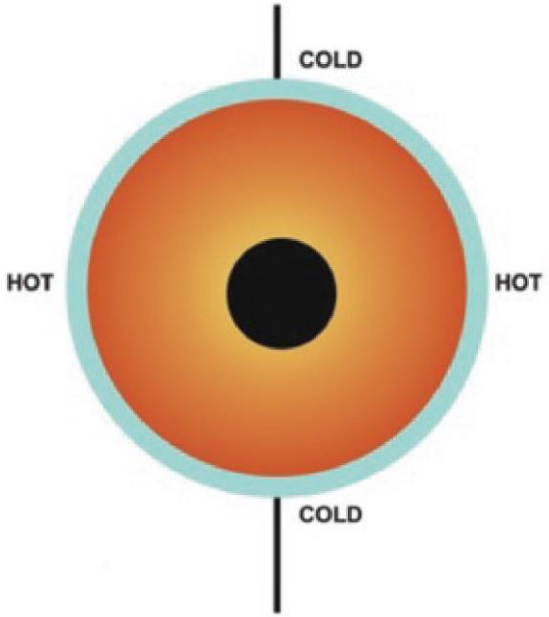
- Hint for axisymmetric degree 4 & 5 moments ~ 100 nT from Cassini Saturn Orbital Insertion [Cao et al., 2012]

- Highly axisymmetry field with dipole tilt < 0.06 degrees [Cao et al., 2011], less stringent constraints on non-axisymmetry of degree 2 and beyond

- Very slow secular variation, -1.2 +/- 1.6 nT/yr [Cao et al., 2011], at least an order of magnitude smaller than that of the geomagnetic field

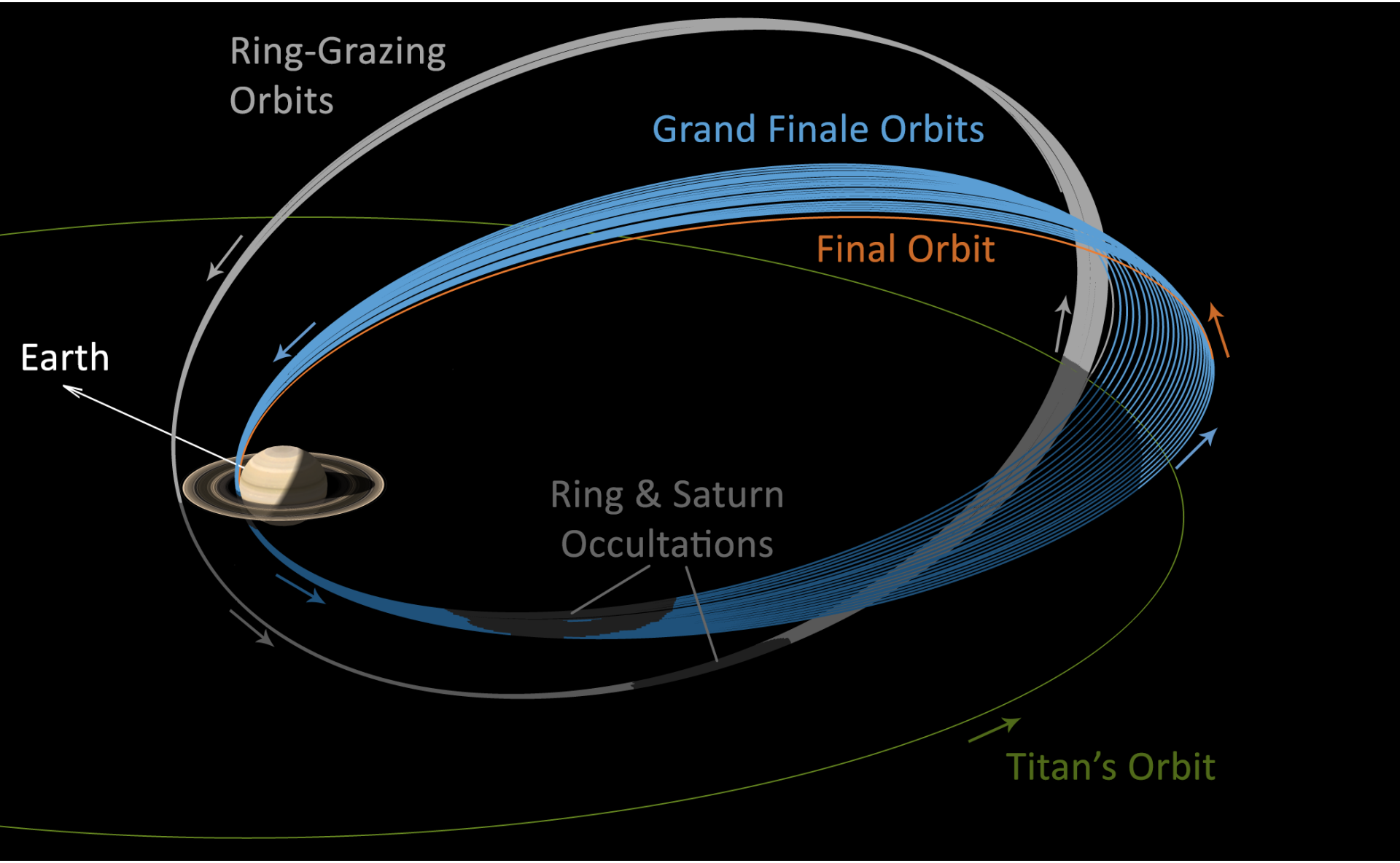
Current Theoretical Explanation for the Extreme Axisymmetry

- Proposed by Stevenson [1980, 1982]
- A stably stratified and electrically conducting fluid layer on top of Saturn's dynamo region electromagnetically filtered out the non-axisymmetric part of dynamo-generated magnetic field
- Differential rotation in the stable layer is a key ingredient
- Qualitatively supported by numerical simulations [Christensen & Wicht 2008; Stanley 2010]
  - dipole tilt can be as small as 0.6 degrees in the simulations, still an order of magnitude larger than observed upper limits

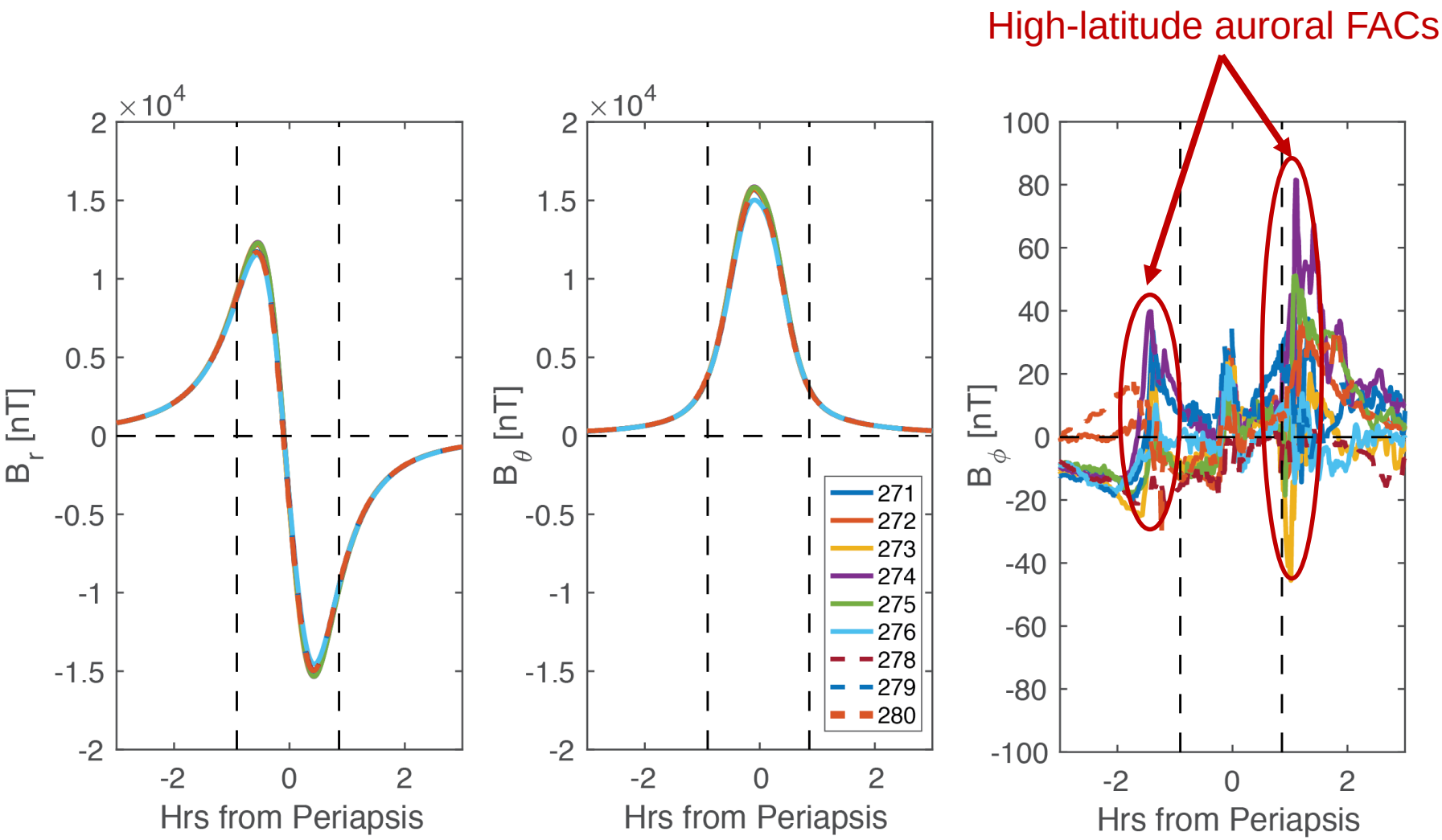


[Stanley 2010]

End of Cassini mission – 15th September 2017

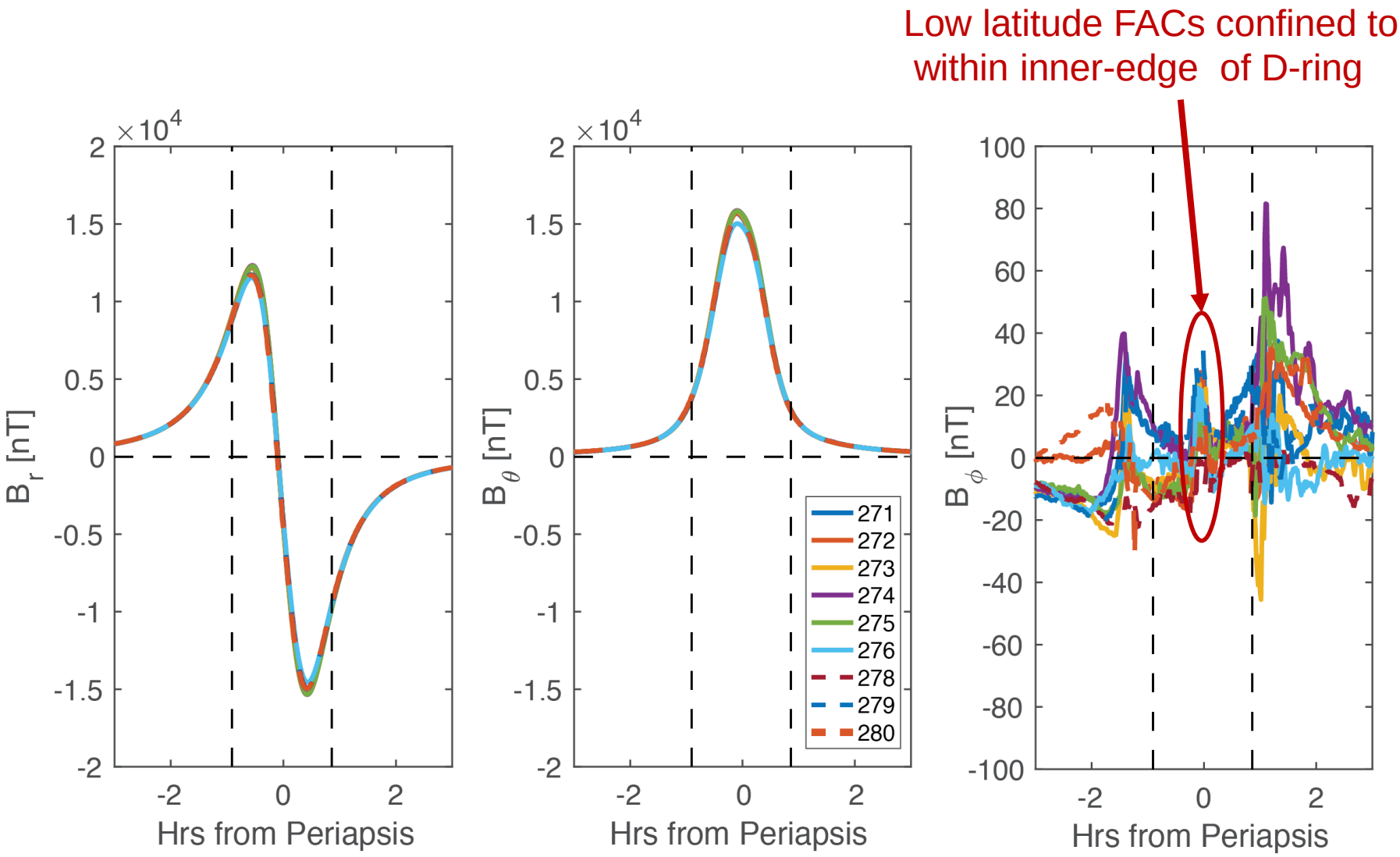


Calibrated MAG data from 9 Grand Finale orbits

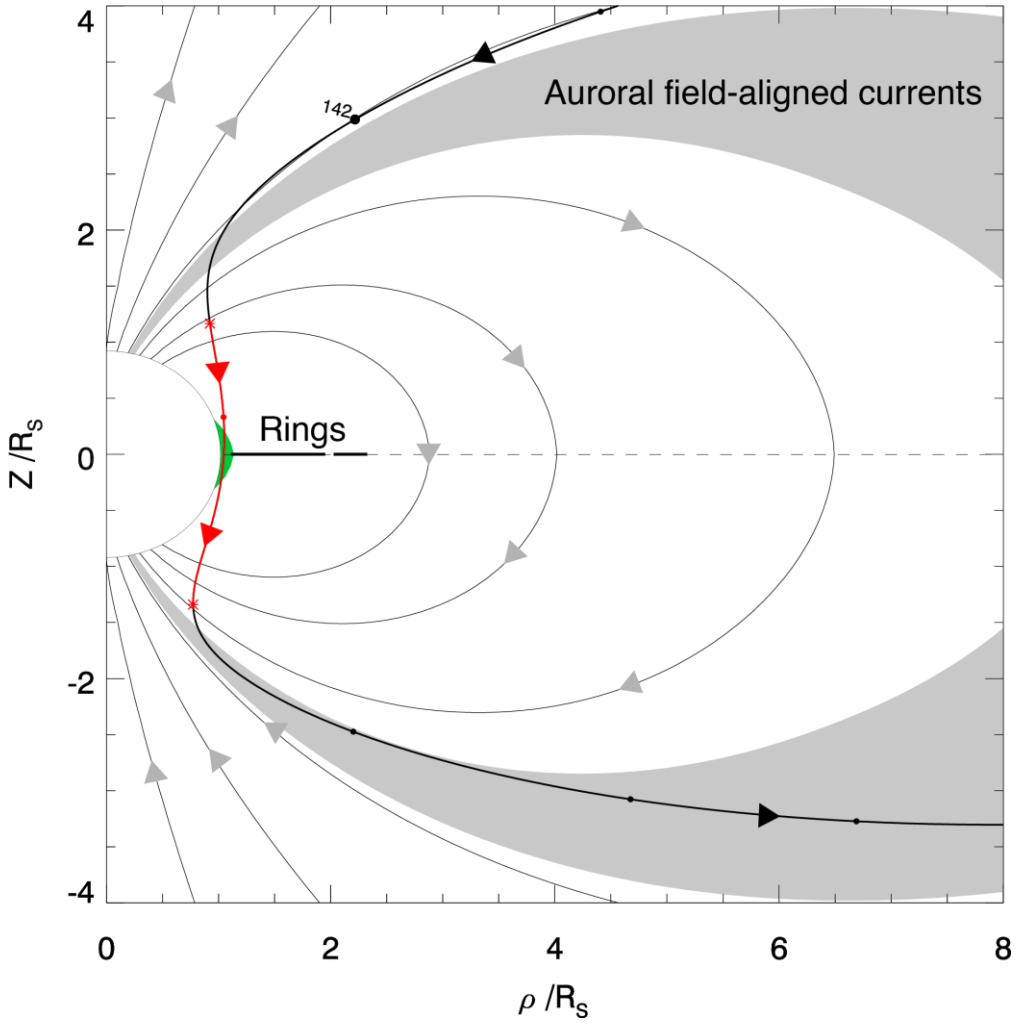


Dougherty et al., 2018, Science

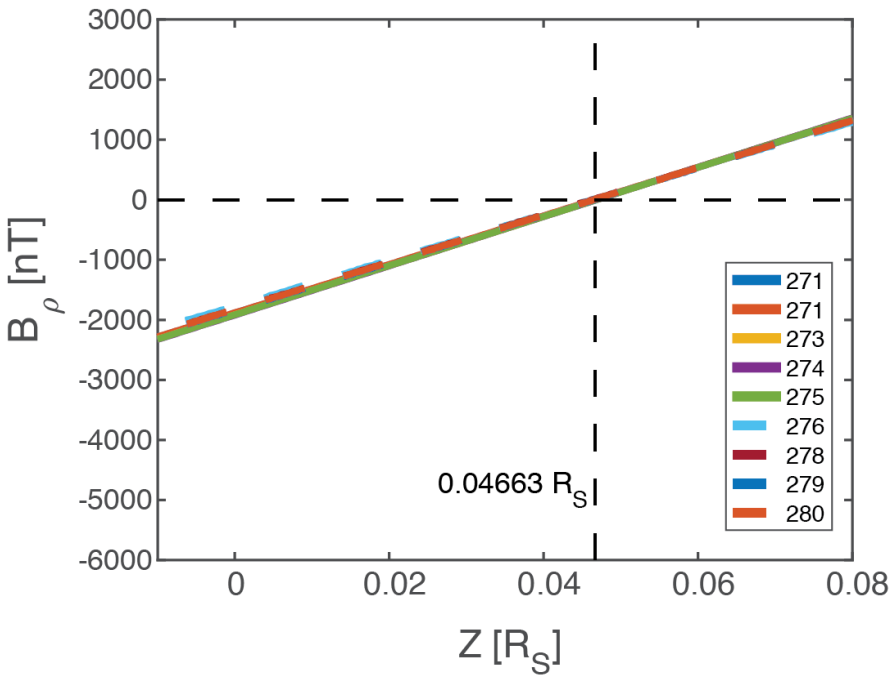
Calibrated MAG data from 9 Grand Finale orbits

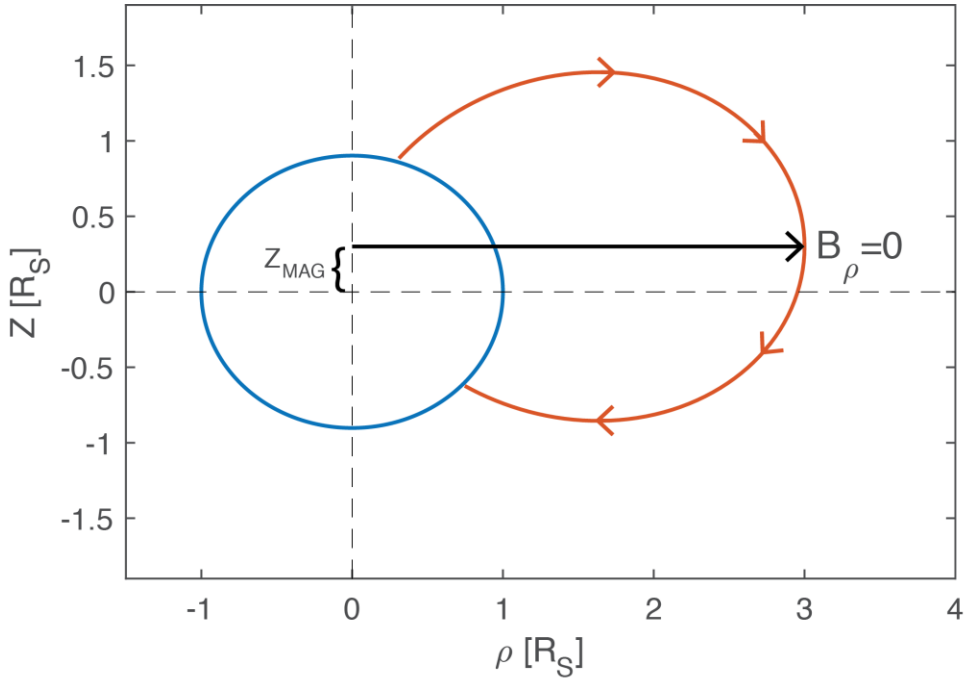


A new field-aligned current system connecting Saturn and inner-edge of D-ring

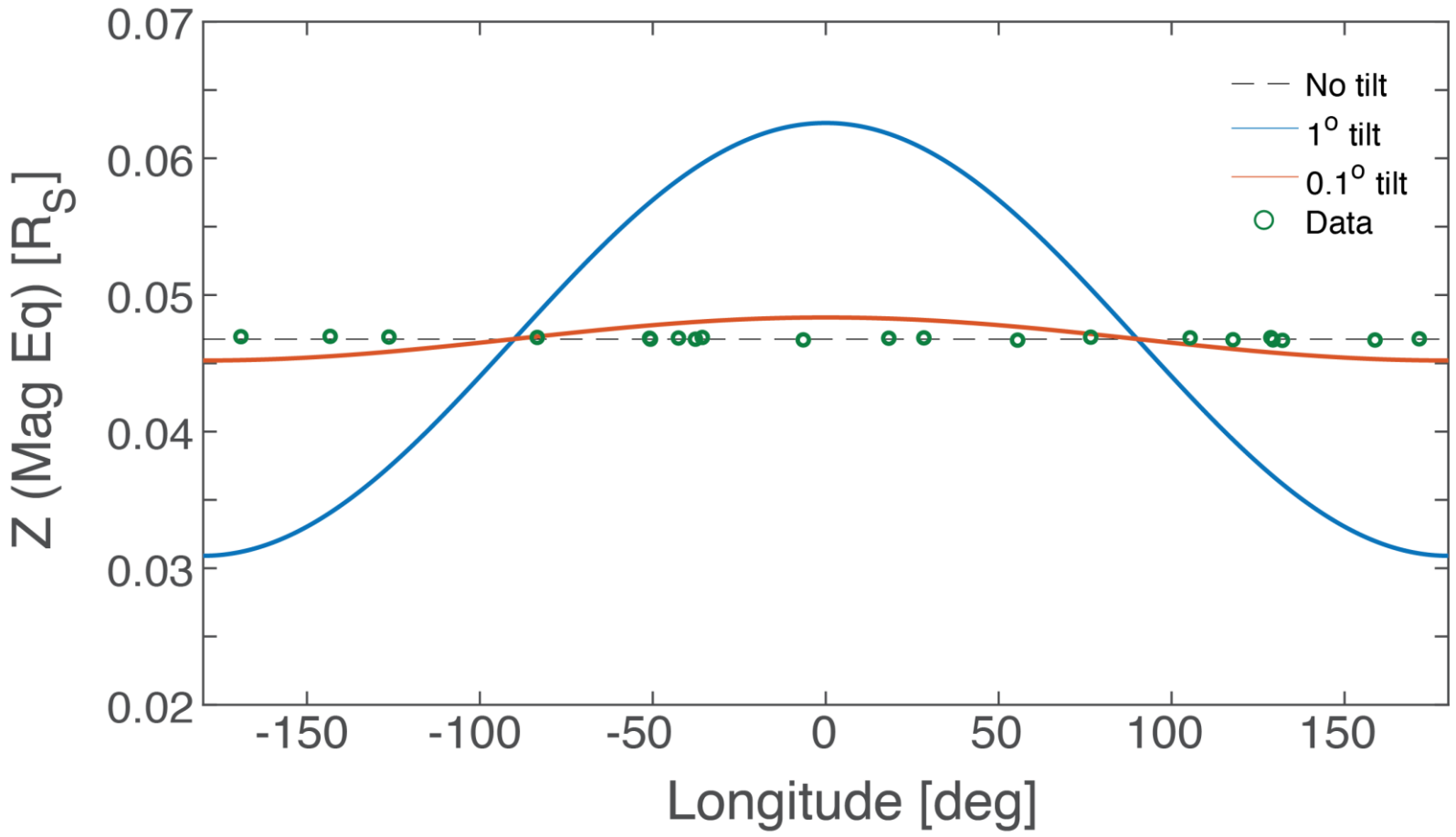


Saturn's magnetic equator northward offset directly measured along Grand Finale Orbits





Longitudinal variation of Saturn's magnetic equator measured along Grand Finale Orbits $< 18\ km$



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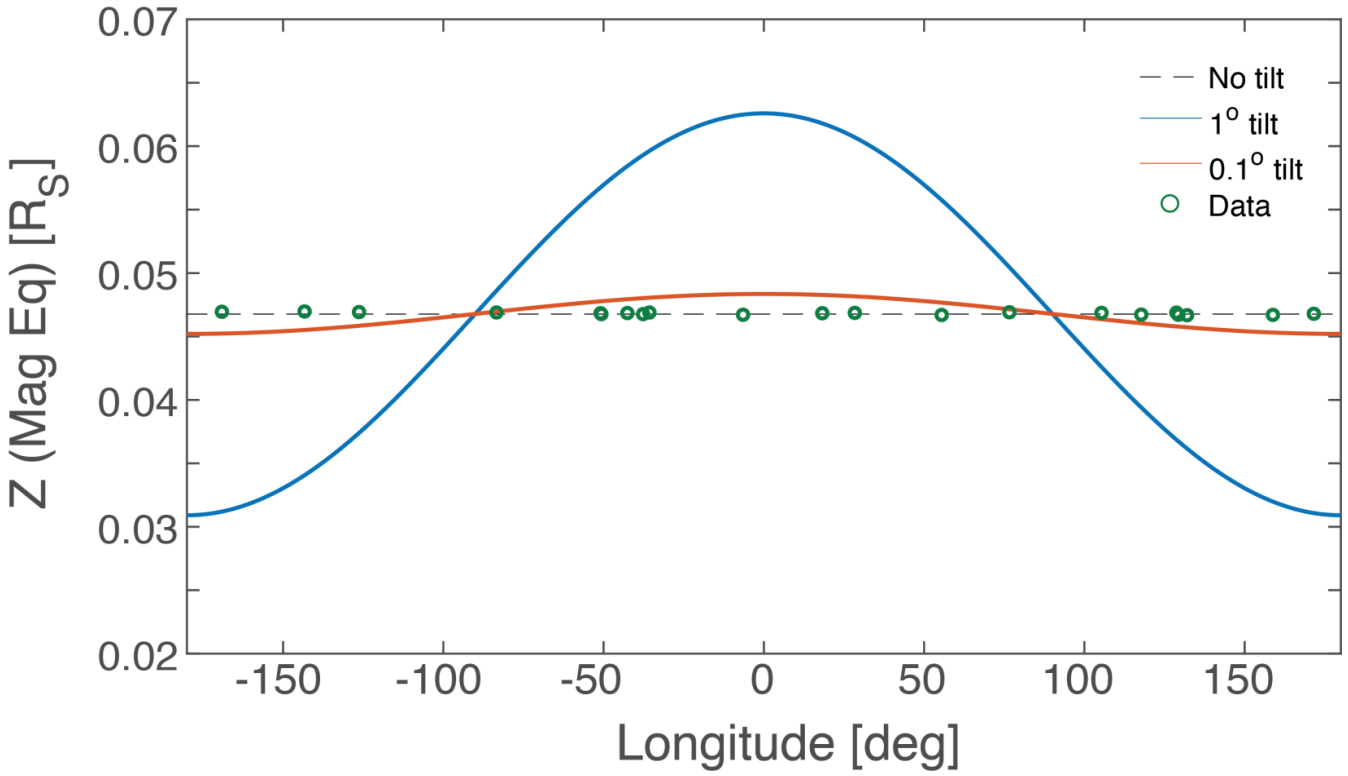
1° tilt ~ 1900 km ΔZ
0.1° tilt ~ 190 km ΔZ

Measured $\Delta Z < 18\ km$
Dipole tilt $< 0.0095°$

Saturn's magnetic dipole tilt < 35 *arcseconds*

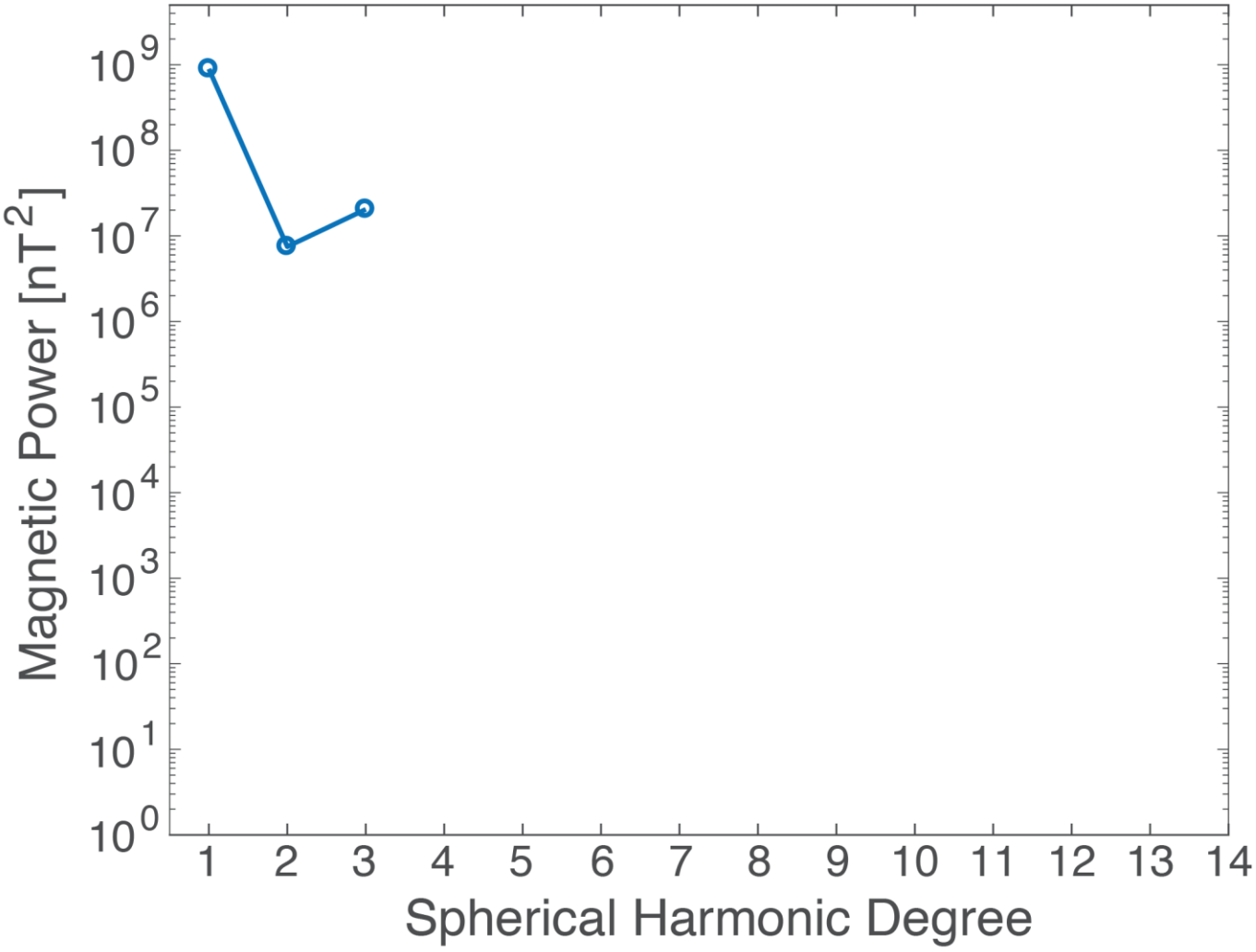


Dipole tilt of Saturn:
< 1° (Smith et al. 1981)
< 0.06° (Cao et al. 2011)
< **35 arcseconds**
(this study)

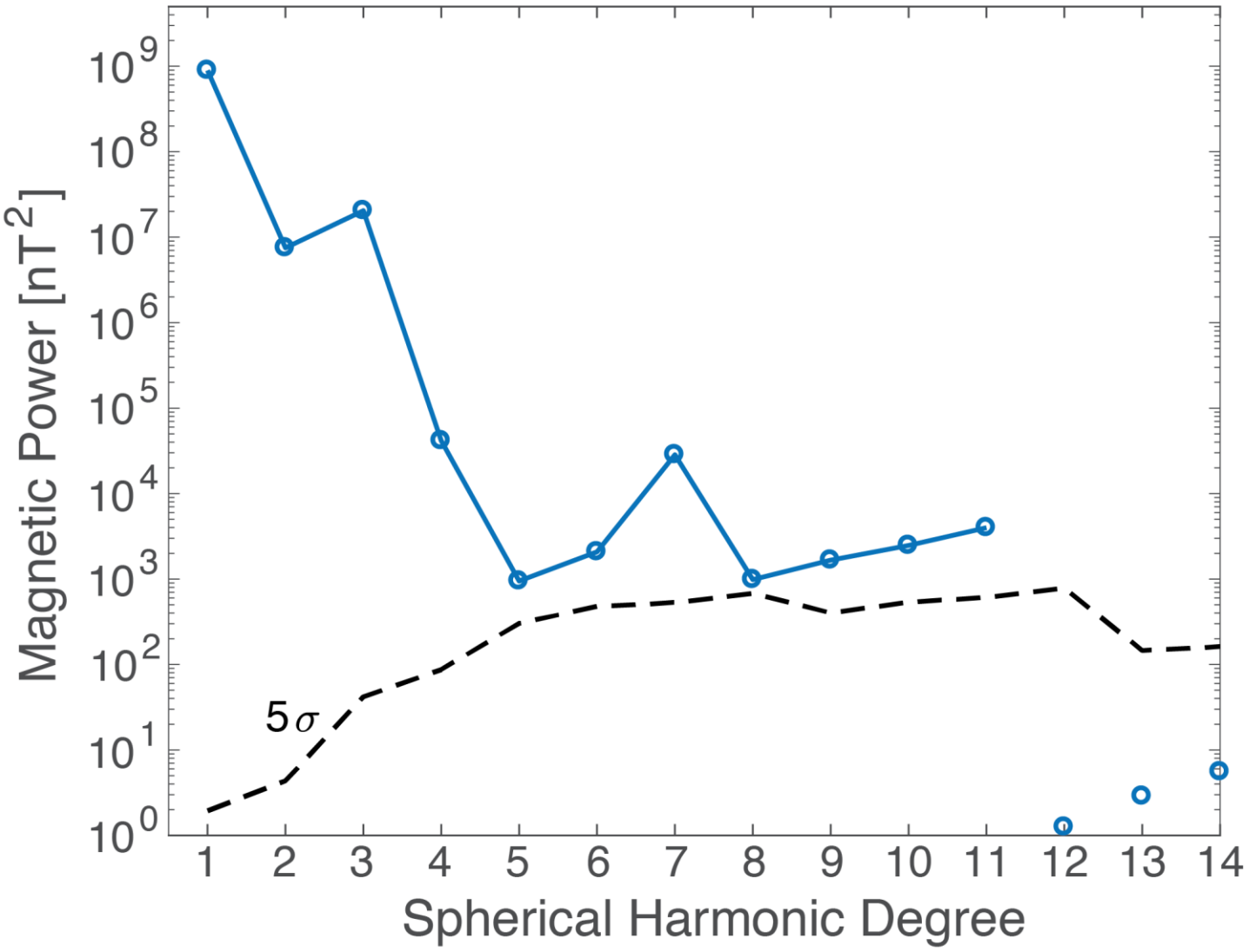
1000 times smaller than that of Earth and Jupiter

Cannot claim detection of purely axisymmetric field yet, some/all of variations could be due to external effects, such as PPOs and FACs

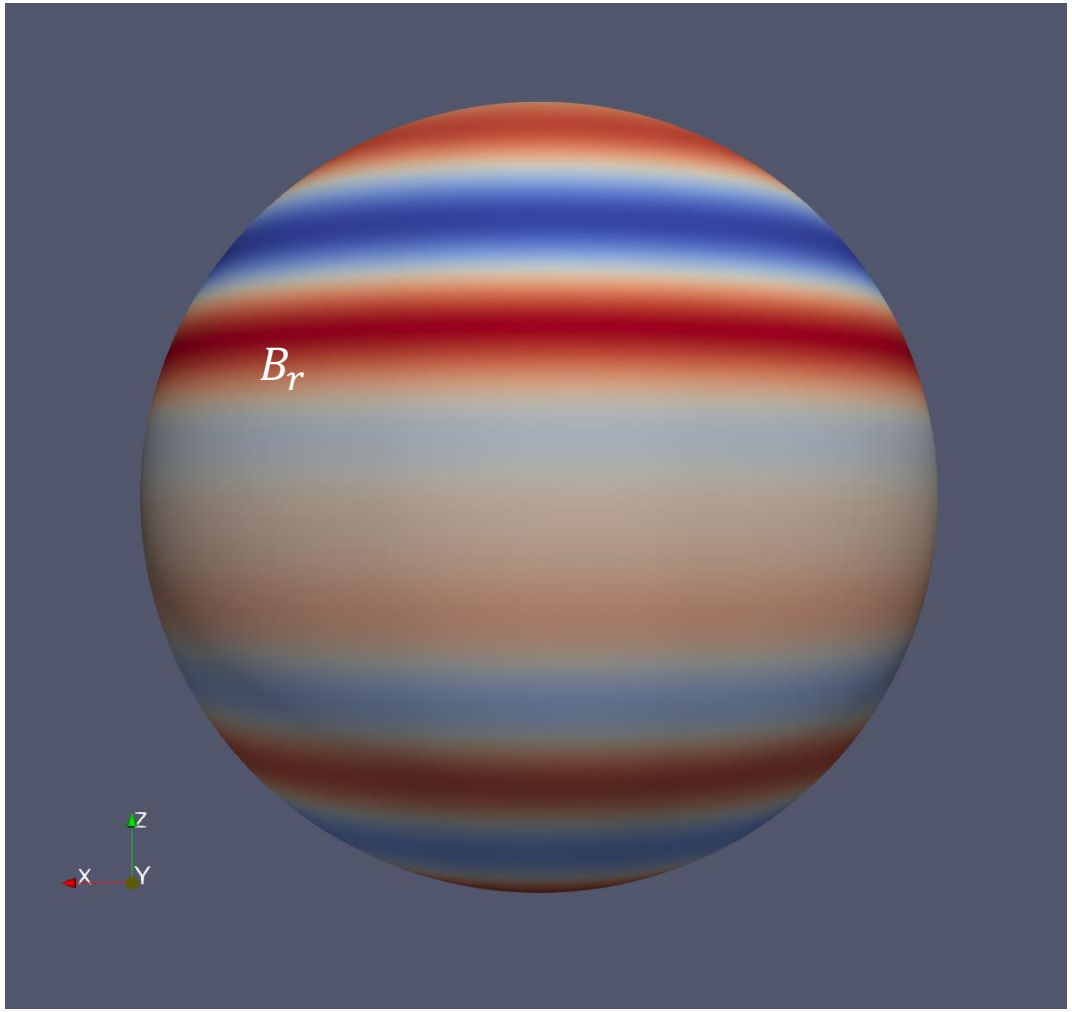
What we knew before Cassini Grand Finale



What we know now



Inferred small-scale magnetic structures at 0.75Rs



+/- 10% of deep dynamo field

- Field beyond degree 3
- Magnetic evidence for deep differential rotation [Cao & Stevenson 2017; Glatzmaier 2018]
- Consistent with gravity measurements
  [Iess et al. 2018, under review]

Summary and outlook

- Cassini Grand Finale MAG measurements revealed that Saturn's magnetic field is unique and full of surprises:
  - low-latitude field-aligned current system inside the D-ring
  - Saturn's magnetic dipole tilt < 35 arcseconds
  - axisymmetric small-scale magnetic structures beyond degree 9

- Magnetic evidence for deep differential rotation inside Saturn

- Continue to:
  - understand and quantify magnetospheric/ionospheric signatures
  - investigate the effects of the rings