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The impact of near-zero obliquity on the evolution of Mercury

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Image Credit: NASA/Johns Hopkins Univ. Appl. Phys. Lab./Carnegie Inst. Washington

Near-zero obliquity

- Inclination of rotational axis
  - Very small: <0.1 degree

    [e.g., *Mazarico et al.*, *JGR*, 2014]

- North-south symmetric, latitude-dependent solar radiation
  - Large surface temperature variation [e.g., *Vasavada et al.*, 1999]
    - Cold at the poles
    - Hot at the equator

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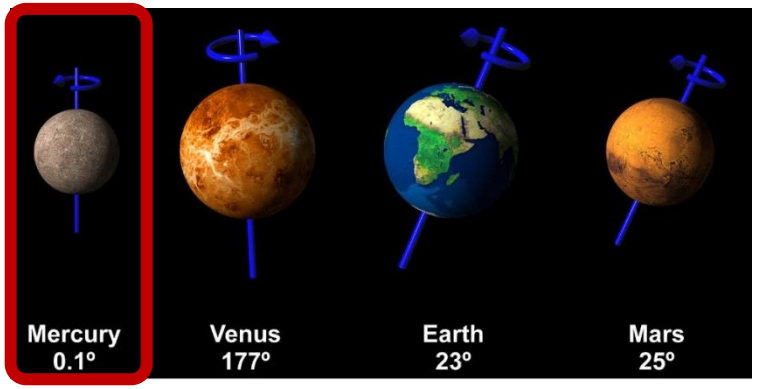
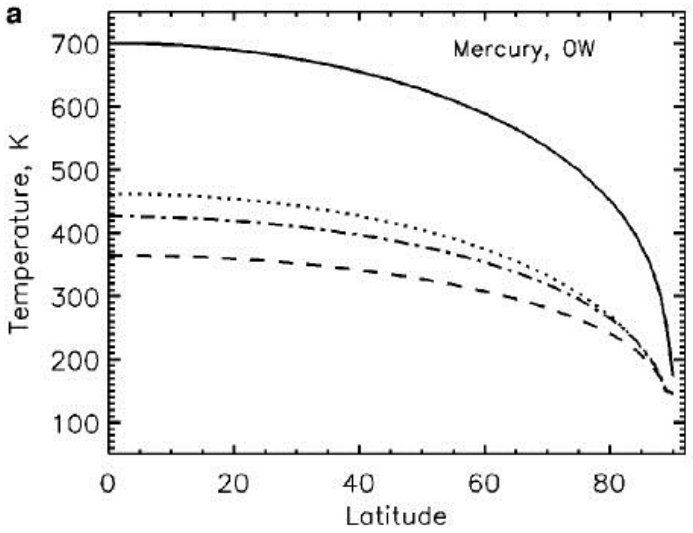


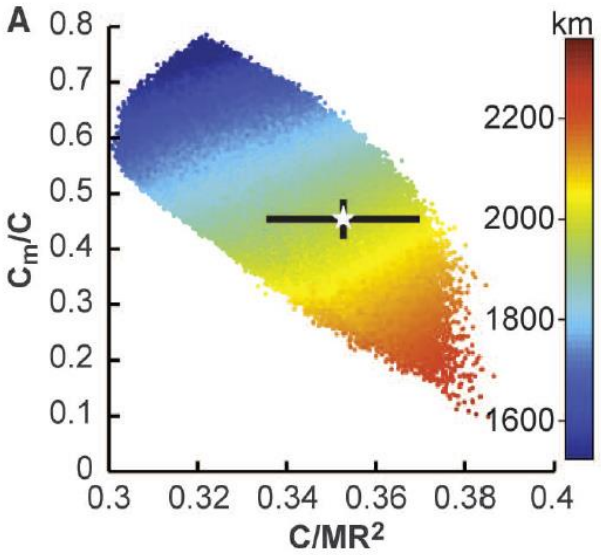


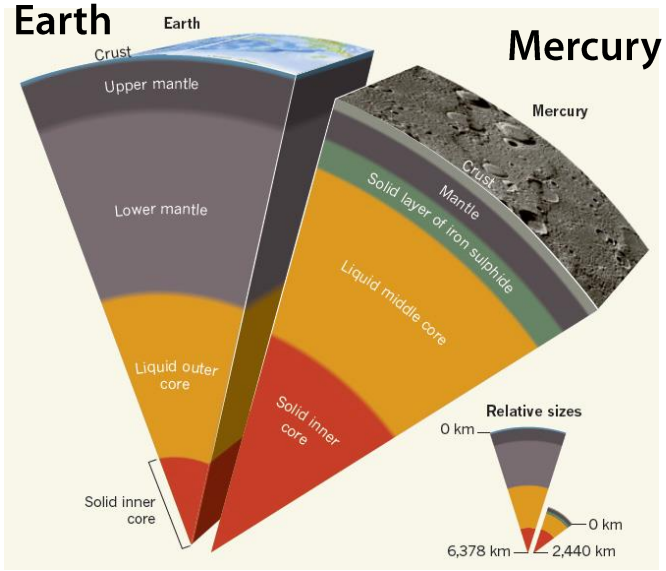
[*Vasavada et al.*, 1999]

Interior structure

- Gravity field and polar motion
  [e.g., *Smith et al.*, 2012]
  - Moment of inertia (MoI): C
  - MoI for the outer solid shell: C_m
  - Mantle is thin (~400 km)
- Surface temperature variation may affect the deep mantle thermal state

[*Smith et al.*, 2012]

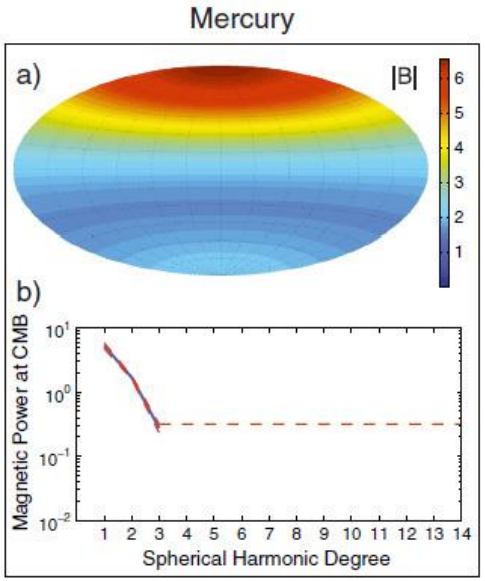


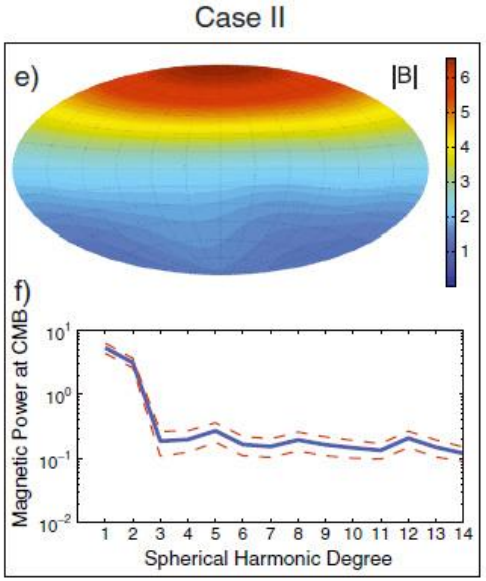


[Adapted from a figure from NASA/Johns Hopkins Univ. Appl. Phys. Lab./Carnegie Inst. Washington]

Magnetic field

- Observation [e.g., *Anderson et al.*, 2011]
  - North-south offset
- Dynamo simulation [*Cao et al.*, 2014]
  - Volumetric buoyancy
    - Breaks symmetry
    - Complex core solidification (iron snow?)
  - Latitude-dependent Core-Mantle Boundary (CMB) heat flow
    - Promotes and stabilizes asymmetric magnetic field

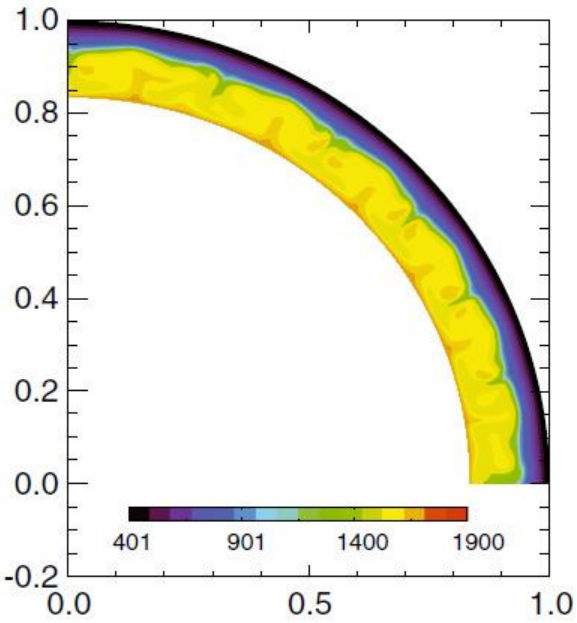




[*Cao et al.*, 2014]

Latitude-dependent thermal profile?

- Mantle convection simulation [*Michel et al.*, 2013]
  - Assumption
    - 2D axisymmetric
    - Latitude-dependent surface temp.
    - Latitude-independent basal temp.
  - Result
    - No significant variation in CMB heat flux is found

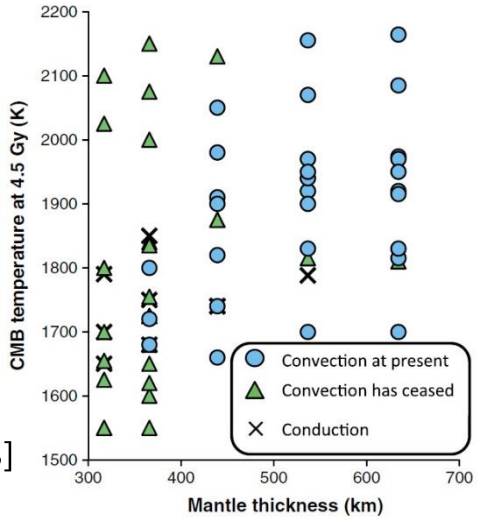


[Adapted from *Michel et al.*, 2013]

- Further studies are needed under different calculation conditions

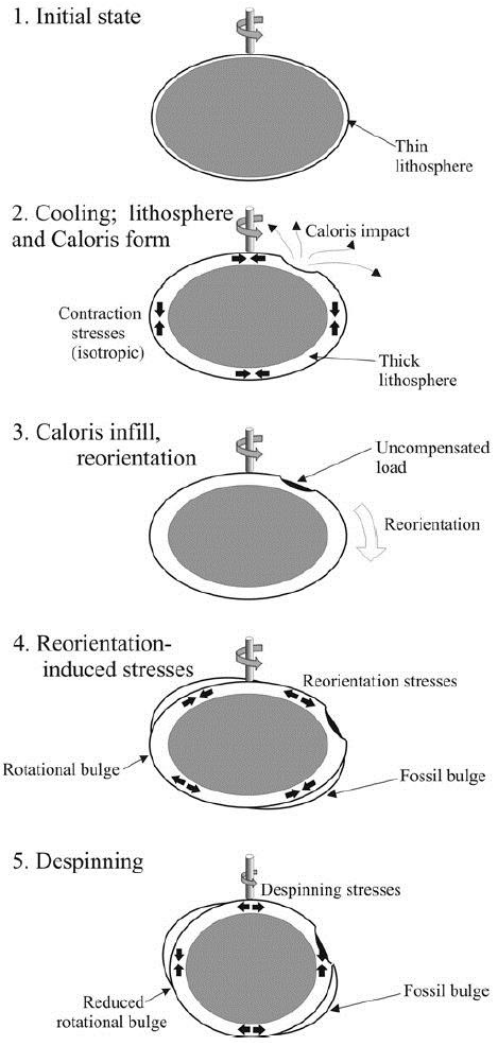
Evolution of Mercury

- Convection stops
  - Currently conductive?



[*Michel et al.*, 2013]

- Reorientation [e.g., *Matsuyama & Nimmo*, 2009]
  - The Caloris impact basin may change the rotational axis



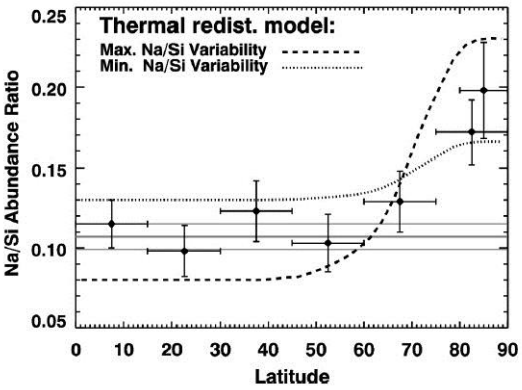
[*Matsuyama & Nimmo*, 2009]

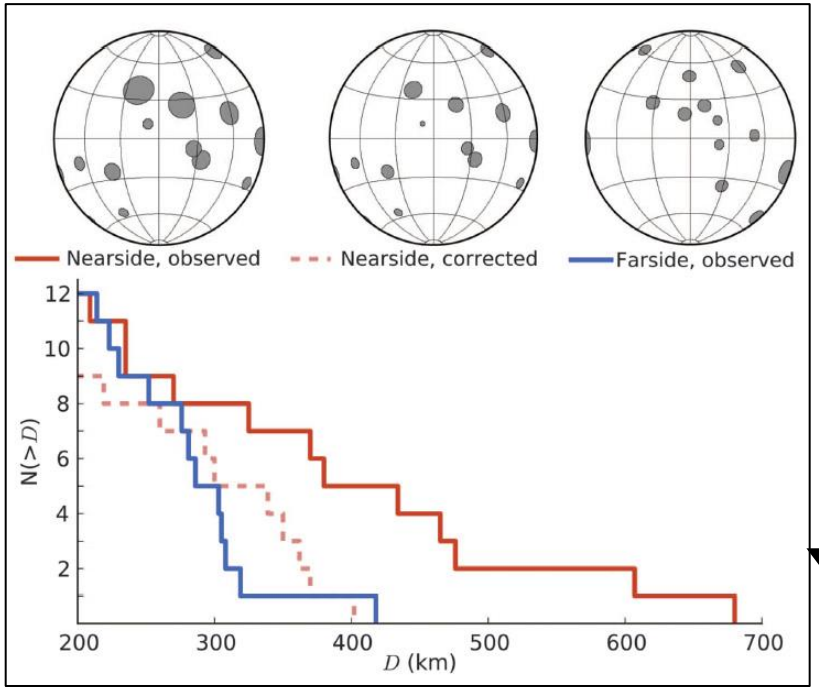
- N-S offset of the magnetic field may be a "recent" structure

Surface manifestation

- Elemental composition
  - May record thermal condition
- Size of impact basins
  - Hotter interior -> larger diameter [*Miljković et al.*, 2014]

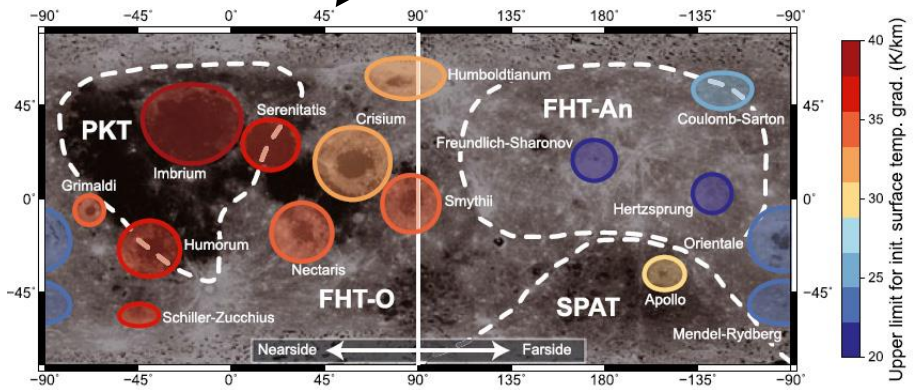
[*Peplowski et al.*, 2014]





Lunar impact basin formation study
[*Miljković et al.*, 2014]

Lunar thermal evolution study
[*Kamata et al.*, 2013]



Strategy

1. **Constrain CMB thermal conditions** that maintain asymmetric magnetic field
2. **Find thermal evolution scenarios** that are consistent with above constraints
3. **Examine various data** from *MESSENGER* and from *Bepi-Colombo*
   - North-south symmetry
   - North-south asymmetry

Summary

- North - south symmetry
  - Surface temperature
- North - south asymmetry
  - Magnetic field
- These facts imply a latitudinally heterogeneous evolution of Mercury
- Different kinds of high resolution data by *MESSENGER* & *Bepi - Colombo* are anticipated

Image Credit: NASA/Johns Hopkins Univ. Appl. Phys. Lab./Carnegie Inst. Washington