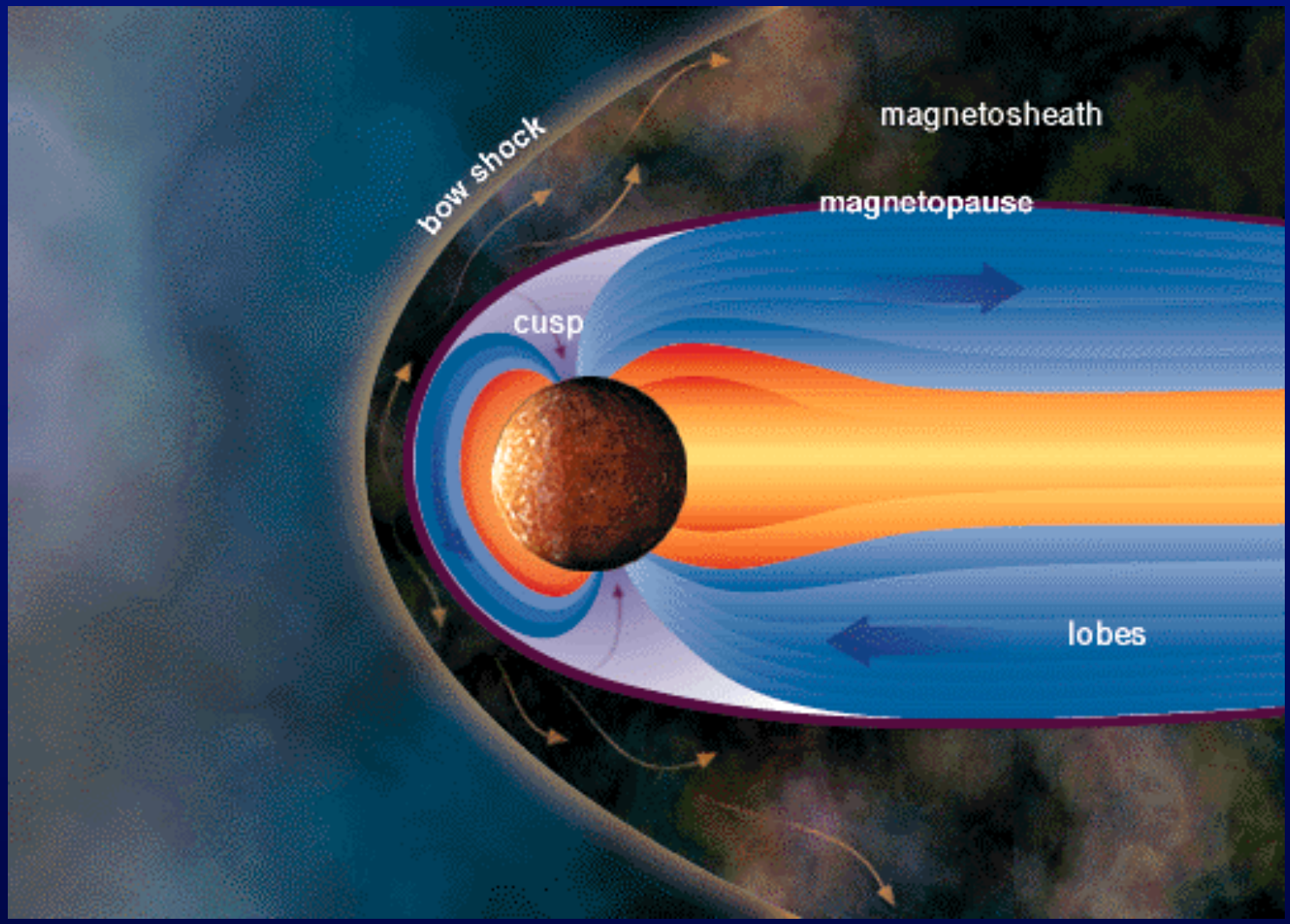
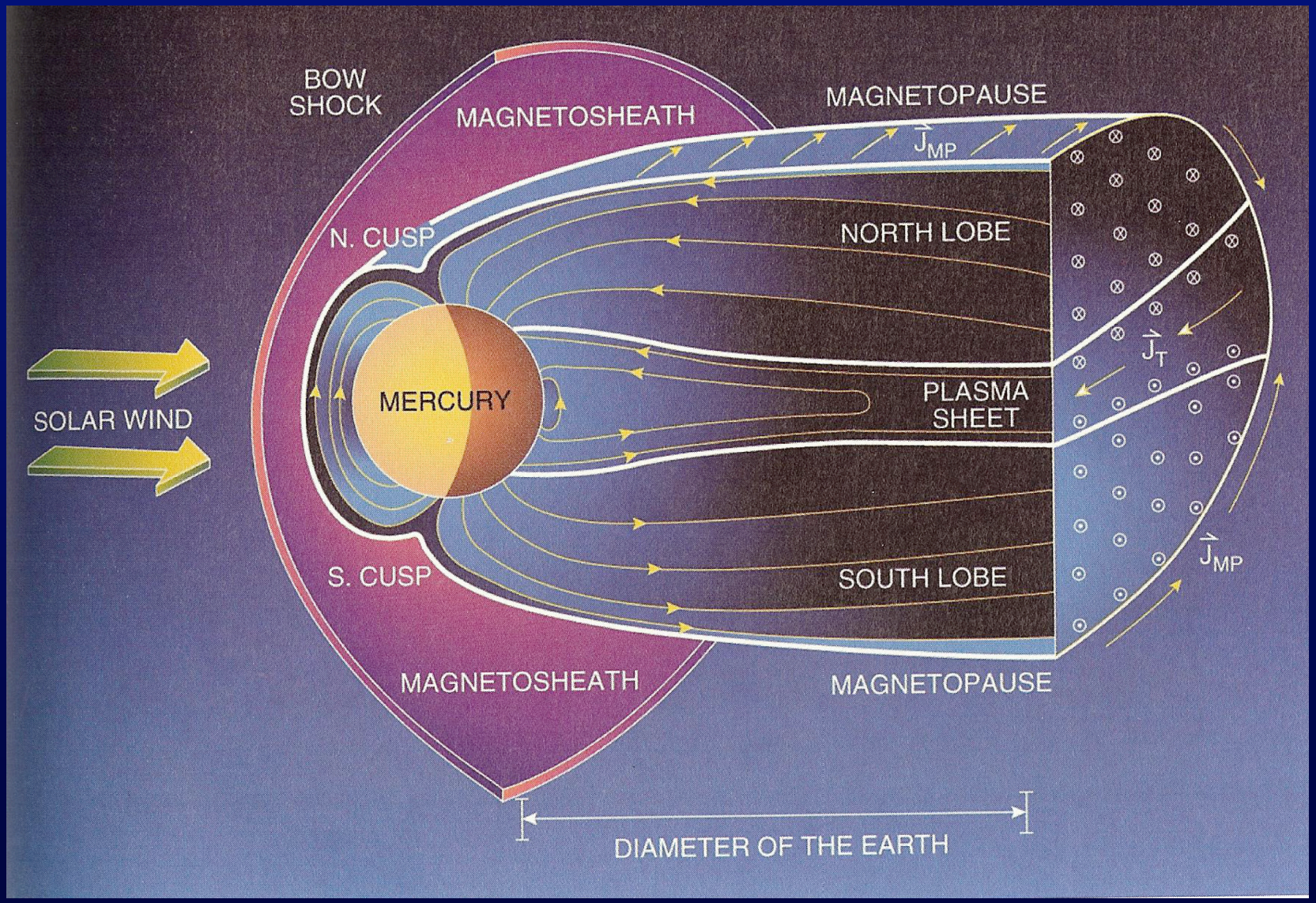



Image Courtesy of NASA

# Mercury's Magnetic Field

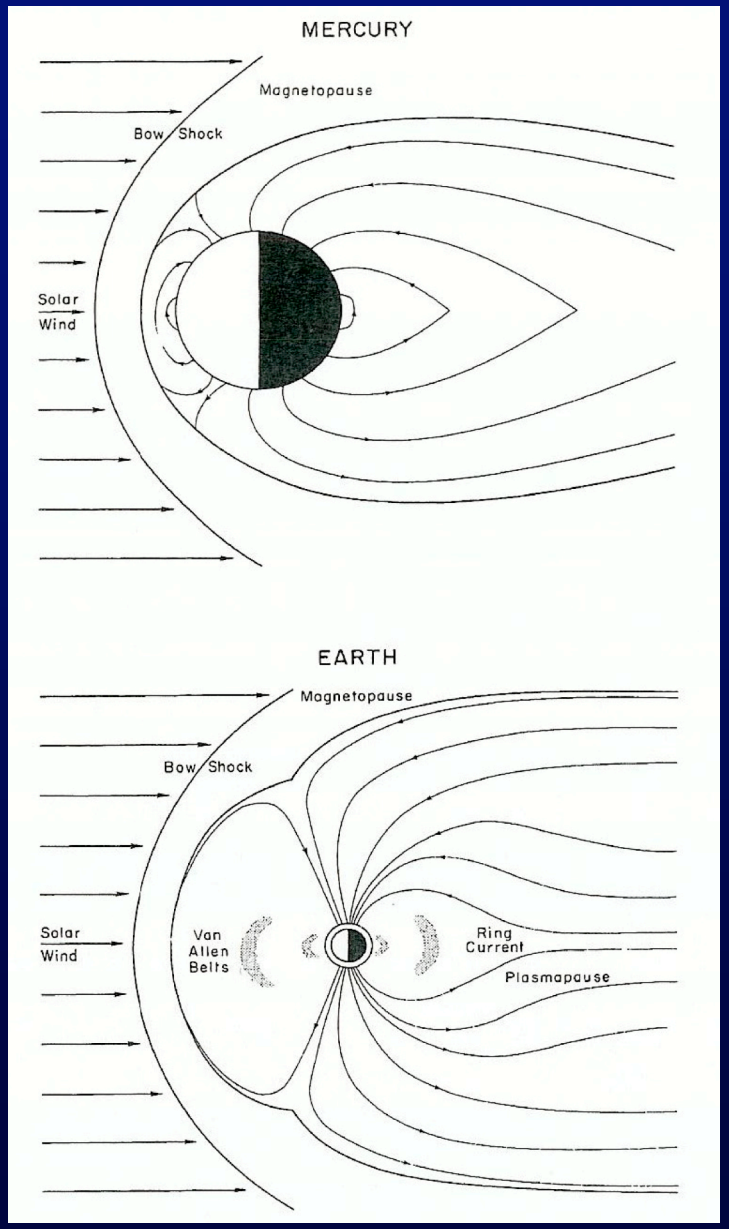
Kerri Donaldson Hanna

# Parts of a Magnetic Field



# Mariner 10 Observations

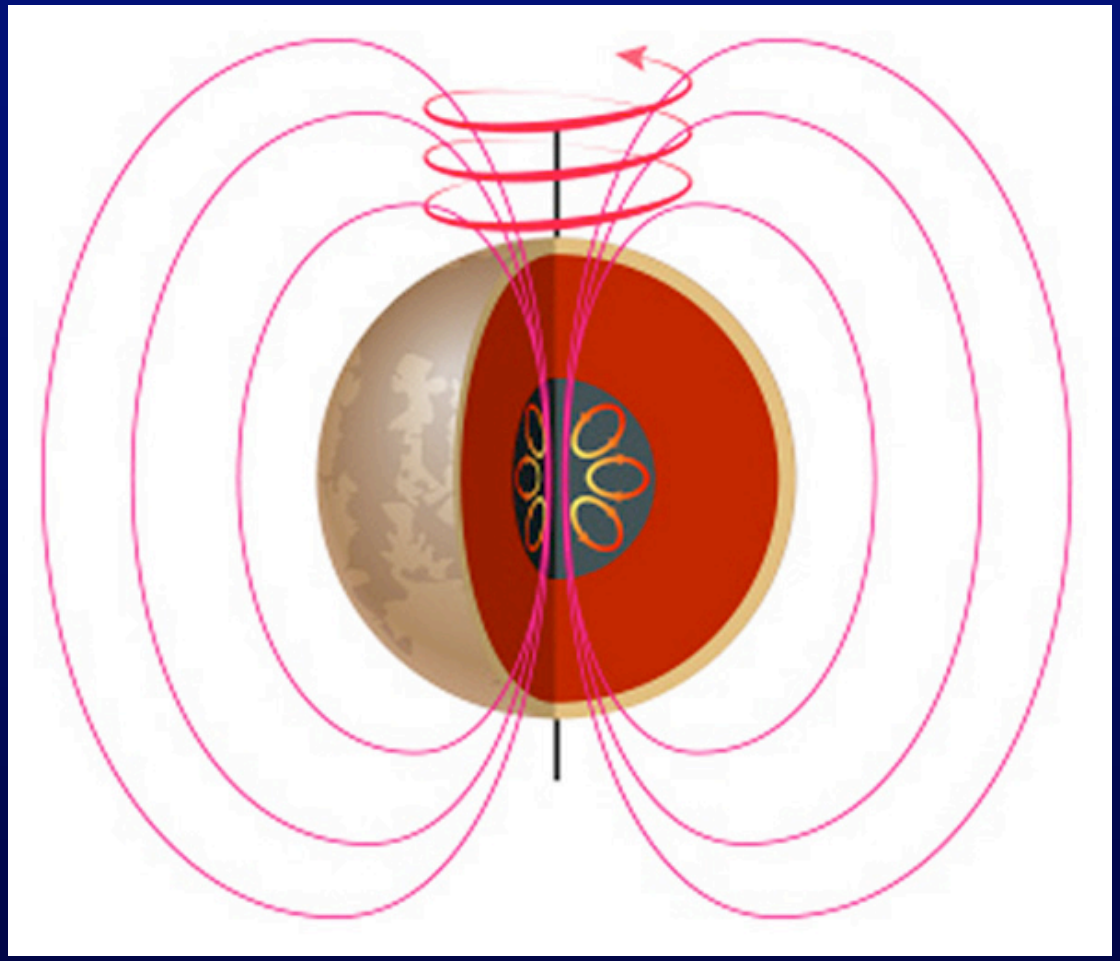
- Took measurements on the 1st and 3rd flyby ~43 minutes worth of data collected
- Signals measured the bow shock, and entrance and exit from the magnetopause
  - ➢ Has an Earth-like magnetosphere
- Magnetospheric cavity ~20 times smaller than the Earth's
- Field strength ~ 300 - 400 nT (T = Telsa the unit to measure magnetic intensity)
  - ➢ 1% of Earth's magnetic field strength
- Dipole field with the same polarity as Earth's present magnetic field



# Comparing to Earth's Magnetic Field

- Earth's magnetic field well-known
- Can build a model with Mariner 10 data and what we know about the Earth's magnetic field
  - Mercury fills a greater portion of its magnetosphere than the Earth
  - The cusp regions, where the field lines intersect the surface of the planet are probably at lower latitudes on Mercury than on the Earth
  - The magnetosphere probably fluctuates more rapidly and more often as a result of perturbations from the solar wind - I.e. flares and coronal mass ejections (CMEs)
- Mariner 10 results could be biased due to comparisons with Earth's model
- Still can't determine if field is a remanent field or generated by an active dynamo

# Magnetic Field via Active Dynamo



Courtesy of https://www.physast.uga.edu

For Active Dynamo Need:

1. Rapid planetary rotation to get conducting material moving about
2. Convection of an electrically conducting fluid in the liquid outer core

As conducting fluid flows across an existing magnetic field, electric currents are induced, which in turn creates or sustains a magnetic field

# Active Dynamo on Mercury?

- If Mercury's magnetic field is dipolar and there is a fluid outer core a physical mechanism to maintain high core temperatures is needed:
  1. provide more internal heat by adding more radioactive elements to the core such as uranium or thorium
  2. retain heat longer by reducing the thermal diffusivity of the mantle
  3. add light alloying element to lower the melting point of Fe
     - 3. is the most likely case with sulfur being the likely culprit, would only need 7% S for the entire core to be fluid at the present time
- Need further knowledge on the elemental surface composition

# Problems with an Active Dynamo on Mercury

- An Earth-like dynamo would be expected to produce a much stronger field than what is observed at Mercury
  - Two methods used to estimate magnetic field strength: energy balance and magnetostrophic balance
- Need to consider whether Mercury's dynamo operates in a thin- or thick-shell core geometry
  - Thin-shell - thin fluid shell surrounding a large solid inner core
  - Thick-shell - thicker fluid shell surrounding a smaller solid inner core
  - Sensitive function of core sulfur content and initial core temperatures
- ➢ Magnetic field measurements by MESSENGER should be able to distinguish between a thin- or thick-shell core geometry

# Remanent Field on Mercury?

- Remanent field could have been induced by a large external magnetic field (solar or nebular) or by an internal dynamo that existed earlier in the planet's evolution
- Remanent fields exist on Mars and the Moon
- Would require a thick layer of abundant magnetic minerals (possibly greater than 30 km deep)
- Magnetic minerals responsible for crustal magnetic remanence must be able to acquire and preserve magnetic fields
  - On the Moon it is metallic Fe, on Mars it is titanomagnetite, titanohematite, or pyrrhotite
- On Mercury pyrrhotite, iron sulfide, might be likely -- it could be a source of sulfur in the atmosphere and deposits in high-latitude cold craters with high radar backscatter signals

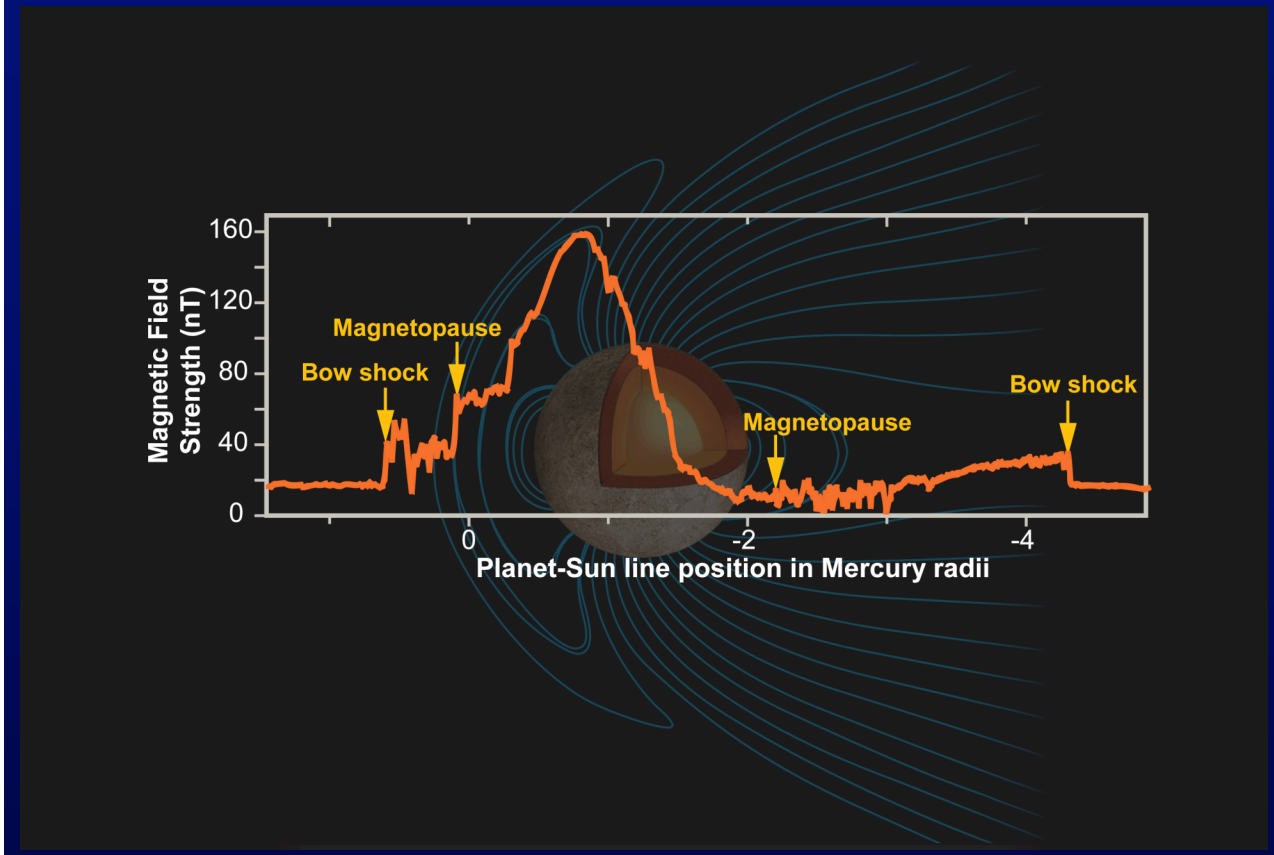
# Problems with a Remanent Magnetic Field on Mercury

- At first it wasn't believed that surface regions that had high enough remanent magnetization to explain the field strength measured existed
  - But on the Moon and on Mars localized regions have been measured to have several tens of nT up to 200 nT in field strength
- Not enough iron on Mercury's surface for magnetic minerals
  - However material could be buried
  - Or iron sulfides such as pyrrhotite could be the magnetic source material

# What could MESSENGER tell us?

- MESSENGER will be able to determine if field is due to an active dynamo, a remanent field or both
  - If magnetic field structure correlates with gravity data indicating topography at the core-mantle boundary -- likely dynamo
  - If it is a dynamo, could determine the thickness of the fluid outer core in relation to the size of the solidified inner core
  - If there is small-scale magnetic structure with a shallow source depth -- likely remanent field
  - If there is a remanent field, could determine what minerals are on the surface or buried that would preserve the remanent field

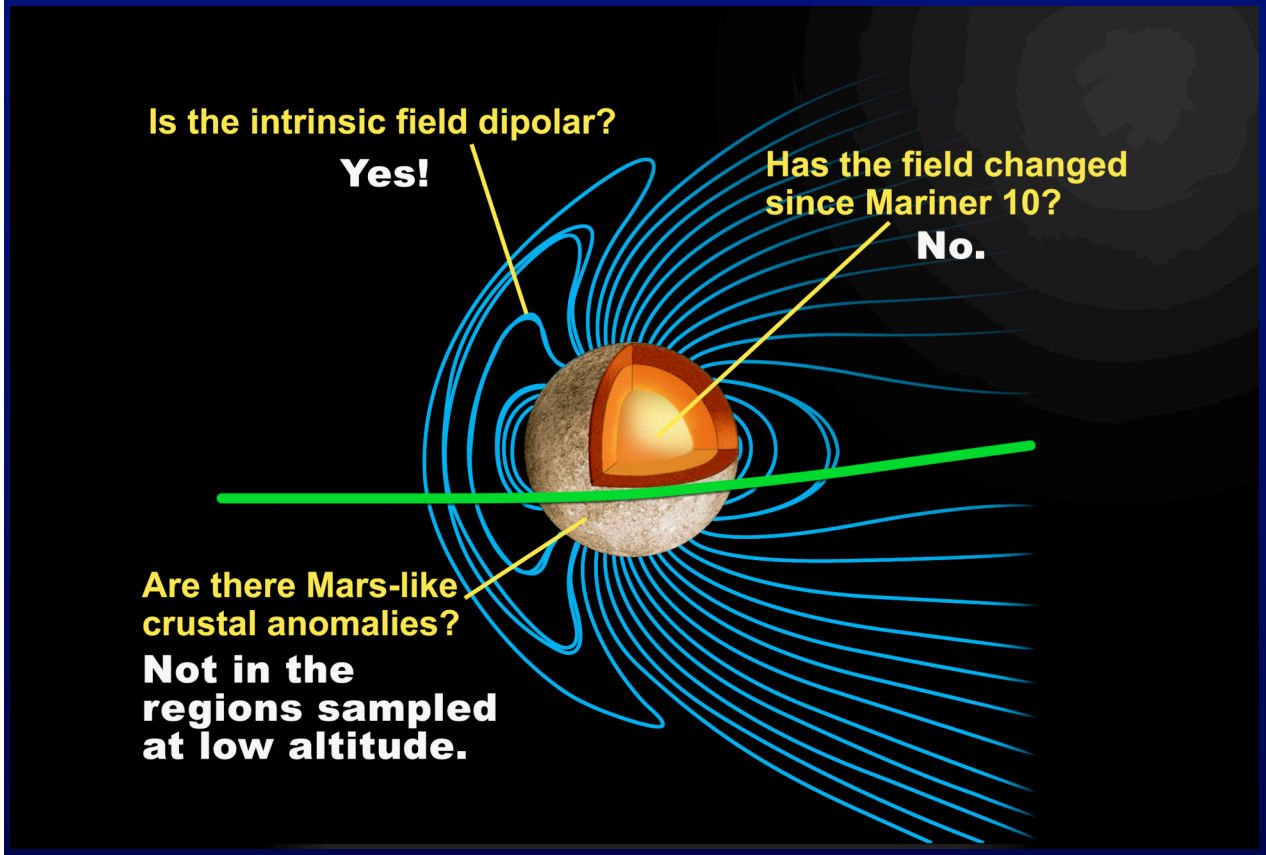
# MESSENGER 1st Flyby Results




Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

- MAG measured magnetic field strength
- MAG identified all boundary locations in the magnetosphere
- Found that Mercury's magnetosphere was a more quiescent system than observed by Mariner 10
- Results consistent with the FIPS and EPPS instruments

# MESSENGER 1st Flyby Results, Cont.




Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

- This is a simulated model not measured during flyby
- Measured during quiet solar conditions and equatorial pass
- Dipole field nearly aligned with planet's spin axis
- Field strength weaker by 1/3 than that measured by Mariner 10 - likely due to differences in trajectories
- Dipolar field consistent with an active dynamo
- Could not determine if magnetic crustal anomalies exist