Mercury, the Iron Planet
What We Will Learn Today

• What are planet Mercury’s features?
• How do we learn about planet interiors?
• Why do some planets have magnetic fields?
• How is Mercury unique in the solar system?
**Planet Mercury Details**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-major axis</td>
<td>0.4 AU</td>
</tr>
<tr>
<td>Size (radius)</td>
<td>$0.4 R_{\text{Earth}}$</td>
</tr>
<tr>
<td>Mass</td>
<td>0.055 $M_{\text{Earth}}$</td>
</tr>
<tr>
<td>Average density</td>
<td>5.43 g/cc</td>
</tr>
<tr>
<td>Composition</td>
<td>Rocks, metals</td>
</tr>
<tr>
<td>Average surface temperature</td>
<td>700 K (day), 100 K(night)</td>
</tr>
<tr>
<td>Moons</td>
<td>None</td>
</tr>
<tr>
<td>Orbital period</td>
<td>87.6 days</td>
</tr>
<tr>
<td>Rotation period (sidereal)</td>
<td>58.6 days</td>
</tr>
<tr>
<td>Axis tilt</td>
<td>$0^\circ$</td>
</tr>
<tr>
<td>Orbital inclination</td>
<td>$7.0^\circ$</td>
</tr>
<tr>
<td>Orbital eccentricity</td>
<td>0.206</td>
</tr>
</tbody>
</table>

From Earth, Mercury is never more than $28^\circ$ away from the Sun
The Interiors of Terrestrial Planets

**Core**: Highest density material, mostly metals, in the center

**Mantle**: Rocky material, moderate density, silicon, oxygen etc.

**Crust**: Thin outer layer, lowest density rock e.g. granite basalt

**Lithosphere**: Outer rigid layer (crust + part of mantle that floats on warmer, softer rock beneath)

- Thin lithosphere \(\Rightarrow\) increased volcanic activity
Mercury’s Internal Structure

- Internal structure related to size
  - Smaller planets have smaller cores
  - Smaller planets have thicker lithosphere
  - Smaller planets cool fast, convection stops
    - Geological activity comes to a halt
- Mercury has a relatively huge core
  - Explained by a giant impact after differentiation
  - Blew away much of the original crust
- Caloris basin
  - Global effect of the impact
  - Rings seen all the way around the planet
  - “Weird terrain”
    - Hilly region on the opposite side of the planet from Caoris basin
Formation of the Internal Structure

- Planet’s interior heats up
  - *Accretion*: Collapse of solar nebula remnants
  - *Differentiation*: Denser material sinks, lighter material floats; friction causes heating
  - *Radioactive decay*: *Fission* as opposed to *Fusion* in the Sun
    - $^{235}\text{U} + n \rightarrow ^{144}\text{Ba} + ^{90}\text{Kr} + 2n + $ energy
    - Remember radioactive dating?
Cooling of the Interiors

- **Convection**
  - Hotter material rises, cooler falls
  - Requires strong heating

- **Conduction**
  - Energy transferred between adjoining molecules

- **Radiation**
  - Energy lost to planet via infrared radiation

Fig 9.5
Clues to Internal Structure

- Two kinds of seismic waves
  - P-type (Primary)
    - Pressure or push waves
  - S-type (Secondary)
    - Shear or side-to-side
    - Can’t pass through liquids
- P waves seen on opposite side of the planet, S waves not seen
  - Implies a liquid code
- Internal structure clues
  - Precise studies of timing and location of seismic waves
  - Precise measurements of gravity point to mass distribution
  - Studying rocks come up to surface from beneath also offer clues
- Exploration
  - Mariner 10 orbited Mercury, took pictures
  - Messenger is on its way (launched August 3, 2004)
    - First flyby January 14, 2008, orbit 2011
Models of Far Away Planets

- Seismic activity measured only for the Earth and Moon
- For other planets, relate surface density to average density
  \[ \text{Volume}_{sphere} = \frac{4}{3} \pi R^3 \]
- Mercury’s surface density is much lower than its average density
  - Must have a large, dense core
Planets’ Magnetic Field

• Requirements for planetary magnetism
  – Conducting fluid in the core
  – Convection in the fluid
  – Moderately fast rotation

• Mercury has a detectable magnetic field
  – Bit surprising due to slow rotation
  – Large metallic core must be partly molten and have convection
Mercury’s Very Weak Atmosphere

• Almost non-existent atmosphere
  – Traces of Helium, Sodium, Oxygen
  – Geologically dead for most of history
    • No gases added to atmosphere
  – Proximity to the Sun heats up the day side
    • Speed of air molecules increases
  – Small gravity has low retaining power
  – Result: Atmosphere escapes into space
  – Thin wispy atmosphere extend out into space

• Dark sky with stars during broad daylight!
  – Sun is a bright ball in a dark sky
Unique Features of Mercury

- **3:2 orbit to rotation resonance**
  - Not 1:1 due to high eccentricity
  - 1 day per 2 years (176 Earth days)!

- **Most extreme temperature swing**
  - Daytime 425 °C, Nighttime -150°C
  - Coldest place in the solar system inside Saturn!

- **Oversized core, large impact**

- **Most heavily cratered planet**

- **The whole planet shrunk!**
  - Vertical cliffs seen, no stretch marks
    - 3 km high, 100s km long
  - Probably closed volcanic vents