Lecture #10: Plan

• Terrestrial Planets
Mercury

- Heavily cratered
- Looks a little like the Moon!
Mercury

• **Density = 5.4 kg / liter**
  ~ Earth’s
  → Rocky mantle
  + iron/nickel core

• **Slow spin: 59 days**
  (orbital period = 88 days)

• **No satellites**

• **No atmosphere:**
  – $T_{day} = 800 \text{ F} / 700 \text{ K}$
  – $T_{night} = -280 \text{ F} / 100 \text{ K}$
Scarps

- Kilometer-tall cliffs that are the result of the shrinking of the planet as it cooled
Mercury

- \( R \sim 0.4 \, R_E \) → Heat loss more efficient than Earth’s

- \( M \sim 0.06 \, M_E \) → Less radioactive heating than Earth

- Cooler interior → No plate activity → Few volcanoes in the past
Mercury

• Few volcanoes
  → Virtually no gas production

• Low escape velocity
  → Gas escapes easily

+  

• Proximity to Sun
  → Any gas would be hot & escape easily

→ No Atmosphere!
Venus

- **Density** = 5.3 kg / liter  
  ≈ Earth’s
  → Rocky crust & mantle + iron/nickel core

- **Very thick atmosphere**
  - 96.5% CO$_2$
  - Clouds of sulfuric acid!
  - $T_{\text{surface}} = 900 \, \text{F} / 750 \, \text{K}$  
    (hot enough to melt lead!)

- **Slow & retrograde spin**
  - 243 Earth days
  - tilt of spin axis = 177°
  - Collision???
Venus

- $R \sim 0.95 \, R_E$
  - Heat retention
    - $\sim$ Earth’s

- $M \sim 0.8 \, M_E$
  - Radioactive heating
    - $\sim$ Earth’s

- Hot interior
  - $\rightarrow$ limited plate activity
  - $\rightarrow$ Many hot spots
  - $\rightarrow$ Many volcanoes
Venus

- Many volcanoes
  → Abundant gas (e.g., CO₂) production

- Escape velocity ~ Earth’s
  → Gas retention ability ~ Earth’s

→ Thick atmosphere!
  (100 x Earth’s atmospheric pressure!)
→ Very strong greenhouse effect
→ Water rain didn’t pick up CO₂ from atmosphere because Venus is too close to the Sun (H₂O is photodissociated)!
Images of Venus from Russian Venera spacecraft

- The spacecraft only lasted about an hour due to the extreme temperatures and pressure!
Recent radar map of Venus

- Surface of Venus seems to be relatively young
- Volcanic activity resurfaces the planet rapidly
- Few impact craters, due both to the thick atmosphere and volcanic activity
Congealed lava "pancake domes" at the eastern edge of the Alpha Regio Highlands.

Fractured plains in the Lakshmi region.

Approx. 37 km (about 23 miles)

20 km (about 12 miles)
Mars

• Density ~ 4 kg / liter
  — Rocky crust & mantle
  + iron/nickel core (?)

• Spin period & tilt ~ Earth’s
Moons of Mars

- Two moons: Phobos and Deimos.
- Both are very small (less than 20 km across) and are probably captured asteroids.
Mars

- $R \sim 0.5 \, R_E$
  - Heat loss is more efficient than Earth’s

- $M \sim 0.1 \, M_E$
  - Radioactive heating is less than Earth’s

- Moderately hot interior
  - Limited plate activity
  - Some volcanoes
Mars

- Some volcanoes
  → Some gas (e.g., CO₂) production

- Escape velocity lower than Earth’s
  → Gas retention ability < Earth’s
  → thinner atmosphere (95% CO₂, 3% N₂)
  → weaker greenhouse effect
  → \( T_{\text{average}} = -67 \text{ F} \) (\( T_{\text{day}} = 50 \text{ F} \))
  (strong seasonal changes due to tilt = 25.2°)
Polar Ice Caps

- CO$_2$ + H$_2$O ice
- Size of caps varies with seasons
Canyons

- Example: Valles Marineris
  - 5000 km long
  - 100 km wide
  - 10 km deep
  - Rift?
  - Plate activity?
Volcanoes

- Few but big!
- Olympus Mons — 25 km high!
Desert / Dunes with dust storms!
The Surface of Mars

- Currently a dry, dusty place
- Plains covered with rocks ranging from pebble-sized to boulder sized!
Channels

• Carved by liquid water billions of years ago!

→ Mars was once wet and warmer
Evidence for Water
Ice Floes?
Splash Craters

Approx. 20 km (about 12 miles) 

Material squished out by impact
Streaks: Liquid Water?
Where did H$_2$O of Mars go?

1. Impact of huge asteroid?
2. Slow loss of gas because of low escape velocity
   Lost gas was not replenished by volcanic activity
   → Greenhouse effect became weaker
   → Atmosphere and surface cooled
   → Loss of H$_2$O to surface & subsurface ice
Mercury
 diameter = 4,880 km

Venus
 diameter = 12,100 km

Earth
 diameter = 12,800 km

Moon
 diameter = 1,700 km

Mars
 diameter = 6,800 km
## Comparative Planetology

<table>
<thead>
<tr>
<th></th>
<th>Mercury</th>
<th>Venus</th>
<th>Earth</th>
<th>Mars</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distance (AU)</strong></td>
<td>0.4</td>
<td>0.7</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>Radius</strong></td>
<td>0.4</td>
<td>0.95</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>0.06</td>
<td>0.8</td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Density (kg/lit)</strong></td>
<td>5.4</td>
<td>5.3</td>
<td>5.5</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Volcanoes?</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Plate Activity</strong></td>
<td>none</td>
<td>some</td>
<td>much</td>
<td>little</td>
</tr>
</tbody>
</table>
Comparative Planetology

- **Mercury**
  - Surface temperature: $T_{\text{surface}} \approx 620 \text{ K (day)}$ (approx. 650°F) and $\approx 80 \text{ K (night)}$ (approx. -320°F)
  - $\text{CO}_2 = 96\%$, $\text{N}_2 = 3.5\%$

- **Venus**
  - Surface temperature: $T_{\text{surface}} \approx 750 \text{ K}$ (approx. 900°F)
  - Sulfuric acid clouds

- **Earth**
  - Surface temperature: $T_{\text{surface}} \approx 290 \text{ K}$ (approx. 60°F)
  - $\text{N}_2 = 78\%$, $\text{O}_2 = 21\%$
  - H$_2$O clouds

- **Moon**
  - Surface temperature: $T_{\text{surface}} \approx 390 \text{ K (day)}$ (approx. 240°F) and $\approx 120 \text{ K (night)}$ (approx. -240°F)
  - None

- **Mars**
  - Surface temperature: $T_{\text{surface}} \approx 210 \text{ K}$ (approx. -80°F)
  - Frozen CO$_2$ clouds
  - Frozen H$_2$O clouds

- **CO$_2$**
  - Mercury: 96% (approx. 1.7 atm)
  - Venus: 96% (approx. 93 atm)
  - Earth: 0.03% (approx. 0.002 atm)
  - Mars: 95% (approx. 0.01 atm)

- **N$_2$**
  - Mercury: 3.5% (approx. 0.005 atm)
  - Venus: 3.5% (approx. 0.03 atm)
  - Earth: 78% (approx. 1.02 atm)
  - Mars: 2.7% (approx. 0.03 atm)
## Comparative Planetology

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<thead>
<tr>
<th></th>
<th>Venus</th>
<th>Earth</th>
<th>Mars</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td>too hot</td>
<td>just right</td>
<td>too cold</td>
</tr>
<tr>
<td><strong>H₂O in atm?</strong></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>(evaporated &amp;</td>
<td>(frozen ice)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UV photodissociated)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Greenhouse Effect?</strong></td>
<td>Runaway!</td>
<td>Moderate</td>
<td>Weak</td>
</tr>
<tr>
<td></td>
<td>(too much CO₂)</td>
<td>(ok)</td>
<td>(too little)</td>
</tr>
<tr>
<td><strong>On Earth:</strong></td>
<td>(1) rain picks up CO₂ from atmosphere</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) plants also transform CO₂ → O₂</td>
<td></td>
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