Planetary Atmospheres II
Solar System Explorers 08

Describe one feature of a non-solar atmosphere in the Solar System that makes it different from EVERY other non-solar atmosphere. (no spectral features)

1.
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11.
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16.
17.
18.
19.
20.
Jupiter

STRATO/MESO: ~ 150K, temp balance heating of photochemical smog cooling by CH$_4$, C$_2$H$_2$, C$_2$H$_6$, 8-14 µm (BB at 150K peaks at 19 µm)

TROPO: multiple cloud layers we see convection
Saturn

similar to Jupiter, except
less convection ... weaker internal heat
colder by ~ 30K
He 12% (S) vs. 14% (J) vs. 16% (protosun)
C, N, S species enhanced by 2-3X
puffed out atm results in lower density
Jupiter vs. Saturn: pressure
Jupiter vs. Saturn: height

at 1 bar
$H_{\text{Jup}} = 24 \text{ km}$
$H_{\text{Sat}} = 47 \text{ km}$
Neptune and Uranus

significant cloud features
internal heat source

super bland!
no internal heat source

no NH$_3$ clouds (as seen on Jup and Sat)
CH$_4$, H$_2$S, and NH$_4$SH clouds instead

H + He only $\sim$10% mass of planet, unlike Jup and Sat at $\sim$90%
Wind Speeds
Jovian Atm Highlights

Jupiter

- enrichment of atmosphere by Io
- Galileo probe has visited

Saturn

- He rain has depleted He from outer layers
- Saturn has cooled faster than Jupiter

Uranus

- cold enough for CH$_4$ clouds to condense
- NH$_3$ condensed out/into NH$_4$SH clouds, so not observed

Neptune

- CH$_4$ trend continues … increases from Jup min to Nep max
- NH$_3$ condensed out/into NH$_4$SH clouds, so not observed

recall conditions in solar nebula …

CO preferred above 700 K, CH$_4$ preferred below 700 K, CH$_4$ ice below 80 K
N$_2$ preferred above 300 K, NH$_3$ preferred below 300 K, NH$_3$ ice below 150 K
Atmospheric Composition

GO THERE!

(GC)MS = (gas chromatograph) mass spectrograph
Earth, Moon, Venus, Mars, Jupiter, Titan
particularly good for He, Ne, Ar, N\textsubscript{2}

SPECTROSCOPY

line position … which gas?
line shape … how much? T? P? moving?

WHAT TO LOOK FOR, WHERE TO LOOK

excitation/de-excitation typically in ultraviolet or visible
vibration typically in infrared
rotation typically in radio
## Terrestrial Compositions

<table>
<thead>
<tr>
<th></th>
<th>Earth</th>
<th>Venus</th>
<th>Mars</th>
<th>Titan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>at least 1%</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{N}_2 )</td>
<td>78%</td>
<td>CO(_2) 97%</td>
<td>CO(_2) 95%</td>
<td>( \text{N}_2 ) 95%</td>
</tr>
<tr>
<td>( \text{O}_2 )</td>
<td>21%</td>
<td>N(_2) 3%</td>
<td>N(_2) 3%</td>
<td>( \text{CH}_4 ) 1-5%</td>
</tr>
<tr>
<td>( \text{H}_2\text{O} )</td>
<td>&lt; 3%</td>
<td>Ar 2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ar</td>
<td>1%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

|          |       |       |      |       |
| CO\(_2\) 400+ | SO\(_2\) 100 | O\(_2\) 1300 | H\(_2\) 4000 |   |
| Ne       | 18    | Ar 70 | CO 700 | C\(_2\)H\(_2\) 189 |
| O\(_3\) 10 | H\(_2\)O 30 | H\(_2\)O < 100 | C\(_2\)H\(_6\) 121 |
| He       | 5     | CO 20 | H\(_2\) 10 | CO 45 |
| CH\(_4\) 2 | He 12 | NO 3  | C\(_2\)H\(_4\) 40 |
| Kr       | 1     | O\(_2\) 10 | Ne 3 | Ar 28 |
| Ne       | 7     |       |      | C\(_3\)H\(_4\) 4 |
## Jovian Compositions

<table>
<thead>
<tr>
<th></th>
<th>Jupiter</th>
<th>Saturn</th>
<th>Uranus</th>
<th>Neptune</th>
</tr>
</thead>
<tbody>
<tr>
<td>H(_2)</td>
<td>86%</td>
<td>H(_2)</td>
<td>88%</td>
<td>H(_2)</td>
</tr>
<tr>
<td>He</td>
<td>14%</td>
<td>He</td>
<td>12%</td>
<td>He</td>
</tr>
<tr>
<td>CH(_4)</td>
<td>2%</td>
<td>CH(_4)</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>H(_2)O</td>
<td>&gt; 400</td>
<td>H(_2)O</td>
<td>?</td>
<td>H(_2)O</td>
</tr>
<tr>
<td>NH(_3)</td>
<td>700</td>
<td>NH(_3)</td>
<td>500</td>
<td>NH(_3)</td>
</tr>
<tr>
<td>H(_2)S</td>
<td>80</td>
<td>H(_2)S</td>
<td>460</td>
<td>H(_2)S</td>
</tr>
<tr>
<td>Ne</td>
<td>20</td>
<td>Ne</td>
<td>?</td>
<td>Ne</td>
</tr>
<tr>
<td>Ar</td>
<td>16</td>
<td>PH(_3)</td>
<td>7</td>
<td>C(_2)H(_6)</td>
</tr>
<tr>
<td>PH(_3)</td>
<td>5</td>
<td>C(_2)H(_6)</td>
<td>3</td>
<td>CO</td>
</tr>
</tbody>
</table>

- **at least 1%**
- **ppm**
Tenuous Atmospheres

temporary, due to

**sputtering** --- physical lifting off surface (but not \( v_{esc} \))
energetic particles from solar wind
energetic particles from nearby planet/magnetosphere
micrometeorite bombardment
… all 8 tenuous atmospheres

capture of solar wind … Mercury, Moon

volcanoes (Io … \( \text{SO}_2 \)) and/or **geysers** (Enceladus … \( \text{H}_2\text{O} \) … Triton … \( \text{N}_2 \))

sublimation of ices … Mars, Io, Triton, Pluto
Clouds

form on all planets where the temp drops below condensation point of gases in the atmosphere

1. non-equilibrium conditions in atm
2. absorption of incoming radiation can heat local atm
3. can alter surface heating pattern
4. can block outgoing infrared photons

theoretical for Jovians!

\[ \text{NH}_3 + \text{H}_2\text{S} \rightarrow \text{NH}_4\text{SH} \]

“solution cloud” = \( \text{H}_2\text{O}+\text{NH}_3+\text{H}_2\text{S} \)

**note trend:**

**further from Sun … colder**

**more cloud decks**

<table>
<thead>
<tr>
<th>Planet</th>
<th>Cloud Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venus</td>
<td>( \text{H}_2\text{SO}_4 ) (sulfuric acid) evaporates</td>
</tr>
<tr>
<td>Earth</td>
<td>( \text{H}_2\text{O} )</td>
</tr>
<tr>
<td>Mars</td>
<td>( \text{CO}_2 ) (high, 50 km) ( \text{H}_2\text{O} ) (low, 10 km)</td>
</tr>
<tr>
<td>Titan</td>
<td>hydrocarbon smog ( \text{CH}_4 ) below</td>
</tr>
<tr>
<td>Jupiter</td>
<td>( \text{NH}_3 ) ( \text{NH}_4\text{SH} ) ( \text{H}_2\text{O} ) “solution cloud”</td>
</tr>
<tr>
<td>Saturn</td>
<td>( \text{NH}_3 ) ( \text{NH}_4\text{SH} ) ( \text{H}_2\text{O} ) “solution cloud”</td>
</tr>
<tr>
<td>Neptune</td>
<td>( \text{CH}_4 ) ( \text{H}_2\text{S} ) ( \text{NH}_4\text{SH} ) ( \text{H}_2\text{O} ) “solution cloud”</td>
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