Special Physics Colloquium

EVOLUTION OF THE MOON
— UPDATE 2004

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Apollo 17 Astronaut, former US Senator & the only PhD trained geologist to walk on the moon

A first order understanding of the Origin and Evolution of the Moon and its implications in the history of the solar system has been continuously refined since the analysis of the first lunar samples collected by Neil Armstrong in 1969. Although there is much agreement within the lunar science community, several areas of significant debate still exist. The giant impact hypothesis for lunar origin, for example, is under serious attack due to its inability to explain the relatively undifferentiated nature of the lower mantle of the Moon. The hypothesis for a short, 100 million year cataclysm that produced most of the craters on the Moon appears to neglect sample bias as well as evidence for a more prolonged period of cratering in the inner solar system. These and other issues have significant implications relative to the history of the solar system as a whole and the Earth and Mars in particular.

1300 Sterling Hall • Monday, April 26, 2004 • 4:00 P.M.
Bit of Administration ....

- **Reading**
  - BSNV Chap. 13

- **Portfolios**
  - Due *Thursday, April 29*, because of possible TAA strike
    - Put in box outside 6522 Sterling
  - All 5 must be *securely* bound together, including ones already graded
  - Late portfolios will lose credit

- **Lab 3**
  - Due *Thursday, April 29*, because of possible TAA strike
    - Put in box outside 6522 Sterling
  - Problem 5, HW 1 is a good starting point for the lab questions
  - Note typo in Question 3 - “Jupiter” => “Saturn”
Jovian Rings

Saturn

Jupiter

Neptune

Uranus
Jovian Rings

- Saturn
Jovian Rings

• Saturn

70,000 km across …. 20 m thick!
Jovian Rings

- Saturn

**Velocity A** > **Velocity B**

Keplerian!

Earth
Jovian Rings

- Saturn

Snowflakes (few microns) to Boulders (10 m)
Jovian Rings

• Dynamics - Roche Limit

• Radius Inside Which Large Bodies Fragment Due to Tidal Forces (i.e., differences in gravitational forces)

\[ F_g = \frac{GM_2M_S}{1000^2} \quad 1.002 \times \text{Greater} \]

\[ F_g = \frac{GM_1M_S}{1001^2} \]
Jovian Rings

• Dynamics - Roche Limit

• Radius Inside Which Large Bodies Fragment Due to Tidal Forces (i.e., differences in gravitational forces)

Gravitational Force on Moon 1

\[ F_g = \frac{GM_1M_S}{2^2} \]

Gravitational Force on Moon 2

\[ F_g = \frac{GM_2M_S}{1^2} \]

4 x Greater!
Jovian Rings

- Dynamics - Roche Limit

- Radius Inside Which Large Bodies Fragment Due to Tidal Forces (i.e., differences in gravitational forces)

- Rings formed by ...

  - Moon entering within Roche limit?
  - Material originally inside Roche limit that never formed a moon?
  - Slow destruction of small moons within Roche limit by micrometeorites?
Jovian Rings

- Dynamics - Cassini Division - Tidal Resonance
  Suppose ....
Jovian Rings

- Dynamics - Cassini Division - Tidal Resonance

Suppose ....
Jovian Rings

- Dynamics - Cassini Division - Tidal Resonance
  - Orbital Period of Mimas is 2x Orbital Period of particles in Cassini’s Division
    “2 to 1 Resonance”
  - Repeated gravitational pulls clear gap at that orbit.
Jovian Rings

- Dynamics - Shepherd Satellites

100 km
Jovian Rings

- Dynamics - Shepherd Satellites

Saturn
Jovian Rings

- Dynamics - Shepherd Satellites
Jovian Rings

- Uranus and Neptune
Jovian Rings

- Uranus and Neptune - Weather
Jovian Rings

- Uranus and Neptune - Weather
Jovian Rings

- Uranus and Neptune - Interior Structure
Jovian Rings

- Uranus and Neptune - Rotation and Magnetic Fields
Jovian Rings

- Uranus and Neptune - Moons

Retrograde, inclined orbit - captured?

38 °K

[Image of Uranus with labeled features: cantaloupe terrain, wind streaks, frost deposits?]

[Diagram showing Neptune with TRITON orbit at 20° inclination]
Jovian Planets

• **Summary**

  • **Weather ("Atmospheric Dynamics")**
    • Driven by energy flows
      • Thermal from interior
        Residual heat from formation
        Ongoing contraction
    • Gravity (highs to lows)
    • Solar radiation
      • Rapid rotation + Coriolis leads to twisting motions

• **Magnetic fields**
  • Result from
    • Liquid metallic interiors
    • Rotation
    • Convection
Jovian Planets

• **Summary**

• **Giant Moons**
  • Ice and rock (from condensation sequence)
  • Dynamically active (due to tidal forces)
  • Atmospheres (Io, Titan, Triton)
  • Liquid oceans (Europa?, Titan?)
  • Life?
Asteroids, Comets, Meteors, and Pluto

As it contracts, the cloud heats, flattens, and spins faster, becoming a spinning disk of dust and gas. Large, diffuse interstellar gas cloud (solar nebula) contracts under gravity. Sun will be born in center. Planets will form in disk.

Hydrogen and helium remain gaseous, but other materials can condense into solid “seeds” for building planets.

Warm temperatures allow only metal/rock “seeds” to condense in inner solar system.

Cold temperatures allow “seeds” to contain abundant ice in outer solar system.

Solid “seeds” collide and stick together. Larger ones attract others with their gravity, growing bigger still.

Terrestrial planets are built from metal and rock.

The seeds of jovian planets grow large enough to attract hydrogen and helium gas, making them into giant, mostly gaseous planets; moons form in disks of dust and gas that surround the planets.

Solar wind blows remaining gas into interstellar space.

Terrestrial planets remain in inner solar system.

Jovian planets remain in outer solar system.

“Leftovers” from the formation process become asteroids (metal/rock) and comets (mostly ice).
Asteroids, Comets, Meteors, and Pluto

• Asteroids
Asteroids, Comets, Meteors, and Pluto

• Asteroids

QuickTime™ and a Cinepak decompressor are needed to see this picture.