Comparative Planetology between the Uranian and Saturnian Satellite Systems - Focus on Ariel

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Objectives

Revisit observations of *Voyager* in the Uranian system in the light of *Cassini-Huygens’* results

- Constrain planetary subnebula, satellites, and rings system origin
- Evaluate satellites’ potential for endogenic and geological activity
Uranian Satellite System

- Large population
- System architecture *almost* similar to Saturn’s
  - “small” < 200 km embedded in rings
  - “medium-sized” > 200 km diameter
  - No “large” satellite
  - Irregular satellites
- Relatively high albedo
- CO₂ ice, possibly ammonia hydrates
Daphnis in Keeler gap
Accretion in Rings?

Charnoz et al. (2011)

Porco et al. (2007)
Density (kg/m$^3$)

Ariel
Titania
Oberon

Distance to Planet (x Rp)
Configuration determined by tidal interaction with Saturn

Configuration determined by tidal interaction within the rings

Configuration determined by tidal interaction with Io

Distance to Planet (Rp)

Mass (kg)

Saturn

Jupiter
Configuration determined by tidal interaction with Saturn

Configuration determined by tidal interaction within the rings

Mimas

Miranda

Ariel

Titania

Umbriel

Oberon

Uranus

Saturn

Jupiter
Evidence for Activity?

“Blue” ring found in both systems
- Product of Enceladus’ outgassing activity
- Associated with Mab in Uranus’ system, but source if TBD

Evidence for past episode of activity in Uranus’ satellite?

Saturn’s and Uranus’ rings systems – both planets are scaled to the same size (Hammel 2006)
ENCELADUS
\[ \rho = 1607 \text{ kg/m}^3 \]
\[ X_s = 0.57 \]

MIRANDA
\[ \rho = 1201 \text{ kg/m}^3 \]
\[ X_s = 0.38 \]
\[ (dE/dt)_{\text{mir}} \sim (dE/dt)_{\text{enc}} \]

ARIEL
\[ \rho = 1665 \text{ kg/m}^3 \]
\[ X_s = 0.62 \]
\[ (dE/dt)_{\text{rad}} \sim 5 (dE/dt)_{\text{enc}} \]
Ariel

- Comparatively low crater density
  - Deficient in 100-km craters

- Extensional tectonics
  - Graben
  - Tilted blocks

- Cryovolcanic units
  - Convex valley floor units with marginal troughs 1-2 km deep (extend past ends of canyons)
  - Flows override craters
  - 100s m to kms thick

- Multiple stages of tectonism and volcanism are interleaved, causally related?
Castillo-Rogez and Lunine (2012)
Maximum Temperature

Does not include resonances

- Ariel
- Enceladus
- Miranda

Maximum Internal Temperature (K)

Water Melting Point

Ammonia Hydrate Peritectic

Time (My)
Preliminary Conclusions

• Uranus satellite system may have formed in the rings
  – Strong resemblance with Saturn system
  – Full model needs to be developed

• Ariel offers high potential for recent endogenic activity
  – Depends on detailed orbital evolution (resonances)
  – If Ariel formed from rings then could have had episodes of activity while migrating outward
Accretion in Rings

- Chunks of silicates accrete an ice shell
- Proto-moons migrate outward by tidal interaction with the rings
- Ice-dominated satellites formed at the ring outer edge (beyond Roche limit)
- Final silicate mass fraction is a function of chunk size and collision between rock-rich and ice-dominated proto-moons prior exit
Moonlets

Propeller near Encke gap

Daphnis in Keeler gap
Casillo-Rogez and Lunine, CUP, in press.
Titania

Rhea

Oberon

1500 km
Ariel, R = 579 km

best resolution ~300 m
triaxial shape consistent with hydrostatic equilibrium (581x578x578)
topographic features up to 4 km
# 27 Uranian Satellites

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<th>Satellite</th>
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Fig. 1 Moons of the giant planets. The (logarithmic) horizontal axis gives the relative distance from the planet. In contrast to the irregular satellites (empty dots), the regular satellites (solid dots) formed within circumplanetary gas and dust disks.
Ariel, R = 579 km

- best imaging 1.3 km/lp
- deficient in 100-km craters, comparatively low crater density
- possible population of degraded or buried ancient craters
- shallow – intrusive or extrusive cryovolcanism or relaxation?
- high-albedo ejecta (related to flow material?)