HYPERION: The Sponge Moon

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Hyperion & the Saturnian System

Saturn's Satellites

- Hyperion
- Titan
- Iapetus
- Phoebe
- Mimas
- Enceladus
- Tethys
- Dione
- Rhea
- Prometheus
- Janus
- Calypso
- Pan
- Atlas
- Pandora
- Epimetheus

All bodies are to scale except for Pan, Atlas, Telesto, Calypso, and Helene, whose sizes have been exaggerated by a factor of 5 to show rough topography.
Hyperion from the Ground

Bauer et al. 97

Saturn RPX

Mommery et al. 2000

R. H. Brown 85
Brightest regions are exposed water ice in the rim of the crater that dominates the hemisphere in view (Hendrix & Hansen, 2007).
Spectra of bright and dark regions

H$_2$O 2.42μm

CO$_2$
CO$_2$ on high- and low-albedo regions of Hyperion

Full spectrum with model, Cruikshank et al. 2007
Compositional maps of Hyperion

The low-albedo material on Hyperion (in the craters) appears to be the same as that on Saturn’s other satellite, Iapetus.
Origin of dark material?

The IR spectra show that Phoebe dark material is similar to lapetus dark material, but the visual spectra show that Hyperion and lapetus are more similar.

Hyperion Composition Map

Color code:

Blue = $\text{H}_2\text{O}$ band depth

Red = $\text{CO}_2$ band depth

Green = 2.42 $\mu$m band

Yellow = $\text{CO}_2 + 2.42 \mu$m

Magenta = $\text{H}_2\text{O} + \text{CO}_2$

Map by B. Dalton
CO$_2$ bands on Iapetus and Hyperion compared. The shift of the Hyperion’s CO$_2$ band center toward shorter wavelengths indicates that the CO$_2$ molecules are somehow combined with, or attached to, other materials (possibly water ice molecules).
Origin of the CO$_2$

- **Original** requires re-supply to surface
- Converted CO: CO $\leftrightarrow$ CO$_2$ (Moore, Hudson, et al.)
- Product of H$_2$O + carbonaceous material with UV
- Impact or shock-induced chemistry, e.g., H$_2$O + CH$_3$OH $\rightarrow$ CO$_2$  
  $\ldots$ (Naa Mvondo et al. 2007)

- Why is Hyperion’s CO$_2$ complexed (when CO$_2$ on other satellites is not)?
Ubiquitous CO2?

CO2 appears to be present on many outer Solar System surfaces including moons of Jupiter, Neptune & Uranus, and Saturn.

Callisto, Hibbitts et al. 00

Grundy et al. 03

Clark et al. 09
Hyperion, or what makes a space sponge?
Hyperion

Interesting because it has chaotic rotation, is the largest irregularly-shaped satellite seen to date, Voyager hinted at spotty albedo distribution.

Cassini made close flyby 26 September 2005, and Several passes <500000 km at other times.

Voyager views of Hyperion
Hyperion: the numbers

Because of chaotic and slow rotation, the generation of the shape model required stitching data from several encounter together.

Mean radius: $135 \pm 4$ km
Range of diameters: $195 - 349$ km
Mean density $540 \pm 50$ km m$^{-3}$
(mass from NAV and RSS teams)
Surface gravity $\sim 2$ cm s$^{-2}$
Spin found from observing "control" points
Hyperion: more numbers

Instantaneous spin pole solutions:

<table>
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<th>UTC range</th>
<th>RA</th>
<th>Dec</th>
<th>rate</th>
<th>SS lat</th>
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</table>

Rate: spin rate in degrees per day
SS lat = sub solar latitude: note drastic changes
Mean density of 540 kgm$^{-3}$, combined with probability of a lot of water ice, mean porosity is $>40\%$. If there are denser components, porosity is even higher.

Very small ring-related satellites have even lower densities.
The Sponge

Count obvious craters; then, what’s left?

Not much
Phoebe, Hyperion, Telesto at similar scale
Craters on Hyperion and Phoebe

Between 2-10 km, 2x craters on Hyperion as Phoebe.

>10 km Saturated

Small: more on Phoebe?
Little fill or erosion in old craters.
Little sublimation
Little ejecta fill
Role of porosity?

Housen and Holsapple, 2003 suggest
Less ejecta for porosities >30%;
and proportional $1/gD$

Very plausible,
if…

Effects of big impacts?
Geology

Central peaked crater?

Barely...
Hyperion

Sponge-like appearance from lots of 2-10 km craters with good rim preservation. No suncup role.
Scant evidence of ejecta, and some evidence for relative lack of ejecta.

Dark material concentrated by downslope motion and/or some sublimation

Porosity effects on craters?