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Active Satellites: Why are they active?

Torrence Johnson

Jet Propulsion Laboratory California Institute of Technology, Mail Stop 321 625, Pasadena, CA 91109, United States (torrence.v.johnson@jpl.nasa.gov, +1 818 393-3335)

When plans for spacecraft exploration of the outer solar system were developed in the early 1970's there were few indications that the satellites of the giant planets were the diverse and geologically interesting collection of worlds that we now know. Titan was known to have at least a thin atmosphere of methane, sodium emission had been detected from Io, and some satellites showed distinctive color and photometric characteristics. Cold, cratered icy spheres were expected to be the norm. Two lines of theoretical modeling suggested, however, that these objects might be considerably more active than previously envisioned: John Lewis' suggestion that radiogenic heat could have melted large icy satellites, particularly if ammonia or other 'anti-freeze' were present, and Stan Peale et al.'s demonstration that tidal heating might play a major role in heating Io. Over thirty years after these ideas were first advanced, melting of icy satellites and tidal heating remain the focus of most attempts to explain the characteristics of the active moons explored by Voyager, Galileo, and Cassini. Despite increasingly sophisticated modeling efforts, however, it has been difficult to explain satisfactorily the scale and range of activity observed – Io's emitted power remains hard to explain, plume activity on tiny Enceladus is difficult to reconcile with steady state power input, Titan's history is complex and it's interior structure still unknown, and the dynamical histories of the satellite systems are complex. Understanding these issues is one of the major challenges for the next generation of outer solar system exploration.