mparison of various failure criteria indicates that tile (metallic) bodies fail by shear, but that internal ction supresses shear slippage in brittle (non-etallic) objects. Brittle bodies fail by tensional racture originating at the center or on the surface, depending on size and strength. The initial crack propagates immediately, but the body is not severed unless self-gravitational binding is also overcome. Afterwards the two halves drift apart and break up into a handful of large pieces plus smaller debris. Fragments of a disrupted satellite can interact further, while pieces of a "stray" may remain captured in eccentric orbits.

02.10

Tidal Evolution of the Uranian Satellites

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The major satellites of Uranus have encountered a number of low-order mean-motion resonances if the specific dissipation function (Q) of Uranus is small enough. The most recently encountered of these resonances would have been the 5:3 resonance involving Ariel and Umbriel ($Q < 100{,}000$), the 3:1 resonance involving Miranda and Umbriel ($Q < 39{,}000$), and the 5:3 resonance involving Miranda and Ariel ($Q < 12{,}000$). There is a significant chaotic zone associated with each of these resonances. Due to the presence of these chaotic zones, the standard theory describing passage through orbital resonances is not applicable. There are significant changes in the mechanism for and probability of escape from the resonances. In all cases, the maximum eccentricities attained by the satellites during passage through resonance are higher than the values prior to encountering the resonance. In particular, the eccentricity of Miranda can increase by up to a factor of 10 during passage through the 3:1 resonance with Umbriel, with a high probability of escape from the resonance.

02.11-T

Warming of Miranda During Chaotic Rotation

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Miranda appears to have had an active geologic history. The low temperature ($< 100^oK$) precludes mobilization of water ice. However, chaotic rotation may once have provided the conditions for heating and softening the supporting material. There are two criteria for chaotic rotation to occur. First, $(B-A)/C$ must be greater than ~ 0.1 (e.g., elongation 5%). Second, the orbit must be eccentric.

A non-synchronously rotating satellite is heated tidally at the rate $dE/dt = 3GM^2(n/a)(k_2/Q)(r/a)^5$ where M is the mass of the planet and n, a, k_2, Q, and r are the satellite's mean motion, orbital semi-major axis, Love number, dissipation parameter, and radius, respectively. This rate is $1/e^2$ faster than for synchronous rotation. For Miranda, $dE/dt \sim 6x10^{18}$ erg/sec, about 10^4 times greater than the radiogenic heating rate, if $k_2/Q \sim 5x10^{-5}$. This energy must come out of the satellite's orbit, and to conserve angular momentum e must plunge to zero in $t \sim 10^8 e_o{}^2$yr. Total energy dissipated is independent of k_2/Q, but strongly dependent upon e_o. In Miranda it would have been $2x10^{32}$erg for $e_o \sim 0.1$, giving an internal temperature rise $\sim 200^oK$. The skin temperature would remain low. Thermal models show the relatively cool upper 25 km has relaxation times such that topography of length scale ~ 20 km or less are preserved, while the global non-hydrostatic figure that initially permitted chaotic rotation relaxes away well before the satellite cools (< 100 Myr).

Our assumed value for e_o is comparable to Miranda's present orbital inclination. With e_o a few times smaller, heating of Miranda would have been considerably less. In that case, the presence of impurities such as methane or ammonia would permit equivalent softening with less heat.

It is possible that some of the other icy satellites comparable in size to Miranda experienced similar chaotic rotation. Repeating the above calculation for Saturn's inner satellites and for the other satellites of Uranus shows significant heating to be possible.

02.12

The Neptune-Triton System: Orbital Evolution Due to Planetary and Satellite Tides

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Early attempts (T. McCord, *Astron. J.* 71, 585 [1966]) to model the tidal evolution of the Neptune-Triton system neglected tides raised on Triton in the belief that Triton's low orbital eccentricity renders the effects of these tides negligible. More recent work (A. Szeto, Ph.D. Thesis, Australian National University [1981]) has suggested that the high orbital inclination of Triton leads to "inclination tides" on the satellite that are powerful enough to dominate orbital evolution due to tides raised on Neptune by several orders of magnitude. However, these results failed to take into account the likely Cassini state for Triton's spin axis, which should presently lie very close (obliquity $\sim 0.3°$) to Triton's orbit normal. It is this small obliquity, rather than the $\sim 159°$ inclination of the satellite's orbit plane to Neptune's equator, which is relevant for the calculation of inclination tides on Triton.

Beginning with a mutually-consistent set of Neptune parameters (flattening, period, and J_2), we examine tidal evolution in the Neptune-Triton system for plausible numerical ranges of Q_N and Q_T, and for different dissipation-frequency relationships. Proper account of Triton's Cassini obliquity is taken at each iteration in the system's orbital evolution. It is found that in semimajor axis evolution, tides raised on Neptune currently dominate those on Triton by several orders of magnitude. For $Q_N=10^4$, Triton will impact Neptune in $\sim 3.6\times10^9$ *yrs*. However, it is uncertain which body's tides dominate evolution in eccentricity and inclination: different plausible choices for either Q_N and Q_T or the dissipation-frequency relationship shift the dominant tidal effect from one body to the other. The effects of such differing choices for the long-term past and future dynamical evolution of the system are explored.

02.13

Plasma Bombardment Profiles and Modification of Reflectance Spectra of the Icy Satellites*

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Recent advances in the description of the spatial distribution of plasma bombardment of the icy satellites (e.g., Clark et. al. 1983; Johnson et al. 1987) have warranted new laboratory measurements of the reflectance of water ice (O'Shaughnessy et al. 1987) and realistic bombardment profiles for the plasma ions (Pospieszalska and Johnson 1987). Here we combine the laboratory results and modelling efforts in order to describe aspects of the spatial modifications of the visible reflectance spectra of the icy satellites of Jupiter, Saturn and Uranus. This involves changes in the reflectance of ice (brightening at longer wavelengths, darkening at shorter wavelengths), and adsorption due to implanted species.

Clark, R.N. et al. (1983) Icarus
Johnson, R.E. et al. (1987) Icarus submitted
O'Shaughnessy, D. et al. (1987) Ap. J. submitted
Pospieszalska, M. and Johnson, R.E. (1987) Icarus submitted

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