On the Lack of Commensurabilities in the Mean Motions of the Satellites of Uranus and the Resurfacing of Ariel

S. J. Peale (University of Califorina at Santa Barbara)

The lack of commensurabilities among the mean motions of the satellites of Uranus is investigated by determining the probabilities of capture into those orbital resonances which might have been encountered as the satellite orbits expand differentially from tidal torques. For the minimum value of the dissipation function of Uranus $Q_U \approx 6600$, the Miranda/Ariel pair would have passed through the 4/3, 3/2 and 5/3 commensurabilities but with no chance of capture into any of the orbital resonances and consequently no resulting constraints on the orbital evolution. Passage of Miranda through the inclination–type resonances in the wrong direction for capture is unlikely to account for the observed 4° inclination. In contrast the Ariel/Umbriel pair would have encountered the 2/1 commensurability with certain capture into either one or both of two eccentricity–type orbital resonances at 2/1 unless $e_A > 0.027$ and $e_U > 0.023$ as the resonances are approached. It is extremely unlikely that this pair could have avoided being trapped into these resonances if, in fact, they had been encountered. Certain capture of Ariel/Umbriel into eccentricity-type resonances at the 5/3 commensurability would require $e_A < 0.0040$ and $e_U < .0047$, so these resonances could have most likely been traversed. Certain capture of Miranda/Umbriel into the 3/1 eccentricity resonances involving Miranda's parameters would occur if $e_M < 0.0045$ for the simple e–type and $e_M < 0.0084$ for the mixed e–type, which would imply trapping Miranda/Umbriel into this resonance if it were encountered. A possible history for the satellite system would be to avoid traversal of those resonances into which capture was certain. With the potential Love number $k_{2U} = 0.104$ for Uranus, $Q_U \gtrsim 11{,}000$ would mean that Ariel/Umbriel did not encounter the 2/1 commensurability, $Q_U \gtrsim 39{,}000$ avoids the 3/1 Miranda/Umbriel commensurability, and $Q_U \gtrsim 100{,}000$ starts the Ariel/Umbriel outside the 5/3 commensurability leading to virtually no tidal expansion of the orbits at all. An alternative to this uninteresting history is investigated to evaluate the conditions necessary to allow sufficient tidal heating of Ariel for the observed resurfacing. The maximum tidal dissipaton in Ariel (assumed to be locked into the 2/1 eccentricity–type resonance with Umbriel) is determined as a function of Ariel's separation from Uranus. The tidal dissipation for the configuration corresponding to the last possible existence of the resonance is only comparable to a lunar like radiogenic source from the satellite core, but could be about 30 times larger than this value in the earliest past. Countless scenarios can be constructed which could lead to the resurfacing of Ariel in the 2/1 resonance, although the constraints may make them somewhat implausible. In any case, detailed thermal histories of Ariel are not warranted unless and until a supportable means of removing Ariel/Umbriel from the 2/1 resonance is found.