What can Triton's retrograde orbit tell us about how the Giant Planets (and others) were constructed?

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Of the 166 known satellites of the four Giant Planets (GPs) the outer ones have mixed prograde and retrograde motions but, of the 56 which orbit their planet at 4 Gm or less, Triton, the 7th largest moon in the solar system, is the only retrograde one and it does so at one-tenth of that distance. Many have considered the retrograde orbit of Triton to render it an 'outsider', so have invoked its entry from the outermost solar system. This betrays an oversight of the properties of the tidal capture mechanism of satellites. Forty years ago [1,2] it was pointed out that, from a population of tidally captured objects, those captured into retrograde orbits would spiral in to eventual coalescence with the central body, leaving the prograde ones in orbit, so this appeared to be the nature of the GPs' satellite population. Tidal capture offers a big capture cross-section but is a difficult process unless assisted by gas drag during the first pass, so the implication is that the nebula was present during this growth. This contribution addresses the question of how the GP interiors originally possessed this tidal propensity but then lost it, evidence of which is that Triton did not complete its inward spiral and is now observed only to be doing so extremely slowly. Both Triton's size and the empty gap between it and tiny, very eccentric Nereid, 16 times further out, and the even bigger gap outside that, suggest that Triton grew by mopping up its satellite brethren as it spiralled inward.

For the GPs originally to have had a tidal propensity rules out the ultra-low-viscosity liquid H models of their interiors. Instead, the predominantly silicate composition of their satellite capture population must surely be representative of the growth and composition of the deep (8 - 18?) earth-mass 'cores' of the GPs. The size range of those satellites, the evidence for their tidal capture, the consistent spin directions of the GPs and the remarkably low orbital eccentricities of the solar system planets (bar Mercury) conspire to rule out that the planets grew by impact accretion, and ended with post-nebula giant impacts. Those would have destroyed the low eccentricities, acquired during accretion in the gas-drag presence of the nebula. The >90^{O} tilt of the Uranian axis has been attributed to such a late impact, but acquisition of its closely equatorial satellite family and its corresponding planetary growth (from the coalescence of any retrograde ones) must have post-dated that. So quite a small body might have done the tilting, with the nebula then restoring its now-very-low orbital eccentricity.

In the absence of their massive gas and ice envelopes, the GP silicate 'cores' could well have have been interstitially molten, due to accretion and other heating, so would likely have had the required viscosity and tidal propensity. But the imposition of the envelopes has made them liquid and lose it, the moment of so doing being documented by the interruption of Triton's spiral motion. So the picture which emerges is that these envelopes were late-stage gravitational acquisitions during the final nebular clear-out from the system. Jupiter, by attracting the most, also had its rotation spun up the most. So our GPs are to be seen as two-stage planets and may not be representative of similar-appearing exoplanets. Here I will develop this picture in the frame of a two-stage scenario for planetary system formation [3,4].

Overall, the widespread signatures among the solar system planets of their growth by tidal capture may relegate accretion by random impact to the building of the bodies provided for capture, of which the asteroids and present satellite population appear to be the residual representatives.

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