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Can The Spin Rates Of Irregular Satellites Provide Constraints To Their Formation Histories?

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Abstract

Irregular satellites are believed to have been captured from the circumstellar disk during planetary formation, and were once probably the most collisionally active population in the Solar System. The resulting orbital architectures at Jupiter and Saturn, especially the similarities between their largest moons Himalia and Phoebe, may provide clues to the origin of the systems. The spin-rates of several of Saturn's irregular satellites have been recently published; we are investigating whether the spin-rate distribution can significantly constrain their collisional histories. If Phoebe and Himalia share similar histories, then the satellites' spin-rates may indicate that Jupiter and Saturn captured different numbers of prograde and retrograde orbiting satellites.

1. Introduction

Most of the moons orbiting giant planets are irregular satellites. They move along distant eccentric and inclined orbits, with most orbiting retrograde, and, unlike their regular counterparts, are believed to have been captured from the circumstellar disk in the early Solar System. Over time, collisions have diminished their initial populations [1] and shaped their current orbital architectures. For example, Jupiter's prograde and retrograde irregular satellites are located in distinct regions with only two prograde orbiting moons, Carpo and Valetudo, transiting between them (Figure 1). As orbital velocities around the more massive Jupiter are faster, leading to more frequent and more violent collisions, it is no surprise that Saturn's satellite populations are more well mixed (Figure 2).

Retrograde orbiting satellites are stable farther away from the planet than prograde satellites [7], so it is unclear why there are fewer retrograde moons near the planet if the initial populations were random. Furthermore, Himalia and Phoebe, Jupiter's and Saturn's largest respective irregular satellites, follow nearly circular orbits closer to the central planet, yet one revolves prograde while the other retrograde. Saturn's prograde satellites also spin on average slower than the retrograde satellites. A connection between the formation histories of Phoebe and Himalia [5][6] and satellite spin distributions could provide more insight to the structure of the original satellite populations.

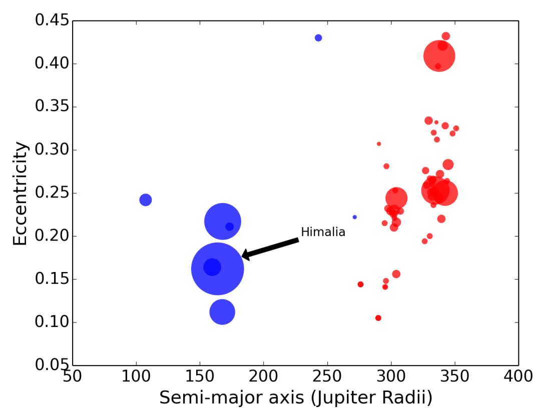

Figure 1: The eccentricities of Jupiter's irregular satellites verses their semi-major axes. The sizes of the circles represent their relatives sizes. Blue corresponds to prograde orbiting satellites, and red corresponds to retrograde orbiting satellites.

2 Saturn's Irregular Satellites' Spin Rates

The Cassini spacecraft has observed photometric lightcurves for 25 of Saturn's irregular satellites. Properties including shape, size, color, and rotation rates have been cataloged [2]. Saturn's prograde moons have average spin-rates (1.8 d^{-1}) that are significantly slower than its retrograde population (2.7 d^{-1}) to a 95% confidence level [3]. Break-ups from catastrophic collisions may yield smaller fast spinning objects, while multiple impacts striking randomly across the target's

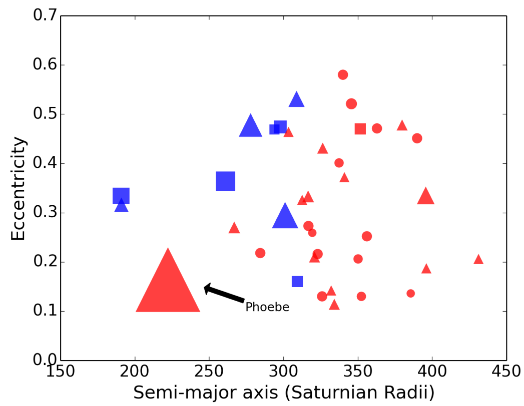

Figure 2: The eccentricities of Saturn's irregular satellites verses their semi-major axes. Those with unknown spin-rates are circles. Squares have slower than average spin-rates, while triangles indicate faster spins.

surface would result in slower spin-rates [4].

We have demonstrated that an object revolving in the same direction as a fixed background will result in minimal changes to its semi-major axis and a decrease to its eccentricity and inclination after multiple collisions. An object orbiting in the opposite direction will instead have its eccentricity and inclination increase by about the same amount after multiple collisions, but its semi-major axis will dramatically decrease [8]. Therefore, if Phoebe and Himalia were initially orbiting further away from the central planets, then a few head-on strikes would drive them closer inwards. This would need to be followed by multiple strikes from satellites orbiting in the same direction to shrink their eccentricities and inclinations. This would imply an initially more massive retrograde satellite population for Saturn, and a greater prograde satellite population for Jupiter.

This picture could be consistent with Saturn's irregular satellites' spin-rates. If the prograde orbiting moons collided with many smaller retrograde moons non-catastrophically, then they should be spinning systematically slower than their retrograde neighbors. Since Phoebe is also spinning relatively quickly, it may instead have experienced a few giant collisions from the larger prograde population. Finally, if Himalia's and Phoebe's orbits evolved similarly, then we would expect Jupiter's prograde satellites to also be spinning more slowly than its retrograde moons.

3 Summary

Recently published photometric data of Saturn's irregular satellites from the Cassini-Huygens mission cataloged their respective spin-rates and other physical properties. The distribution of satellite spin-rates may be a byproduct of their collisional history, which should also be reflected in their orbital architecture. The additional similarities between Phoebe and Himalia's orbital parameters may imply that Jupiter and Saturn started with different ratios of prograde and retrograde orbiting satellites. We are investigating this connection in greater detail and will report on our findings.

Acknowledgements

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