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The changing orbits of "propeller" moons in Saturn's rings

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The orbits of disk-embedded moons in Saturn's rings have been tracked on a timescale of years, and a significant component of non-keplerian motion has been detected (Tiscareno et al. 2010, ApJL). This is the first time that an individual object has been tracked that does not orbit in empty space. The $\sim$1-km moons are not seen directly, but rather the propeller-shaped features they create by stirring up the disk around them. The deviation in longitude from constant angular velocity (i.e. circular orbit) is $\sim$0.2 degrees of longitude, with an instantaneous mean motion that is slightly faster than average from 2005 to 2007, slower than average from 2007 to 2009, and speeding up again in early 2009. The bi-directional character of the evolution eliminates simple models in which torque is applied only in one direction, but it is not clear whether the direction of the torque varies quasi-periodically or due to a deterministic oscillation. We will review theories for the non-keplerian motion of "propeller" moons, several of which have already been proposed by other authors, and will discuss the question of whether it is due to collisional and/or gravitational interaction with the disk, our direct observations of which may be applicable to future models of disk-embedded masses in proto-planetary disks and other astrophysical systems.