Origin of Phobos and Deimos in an accretion disk

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Abstract

Phobos, orbiting inside the synchronous orbit, is pulled in by the planetary tidal torque. It is set to fall into Mars on a timescale of tens of millions of years. But the moons are estimated to be at least 1 Gyr old, which prompts us to question how Phobos survived so long.

Two different formation mechanisms for the moons emerged. It has been proposed that both were captured asteroids (eg. Burns, 1992), with support from surface physical characteristics being similar to small low-albedo carbonaceous asteroids. However, the almost circular orbits are difficult to explain in this view. The alternative is that the moons were formed in a circum-Martian accretion disk, hence the almost circular orbits. An impact with a massive object would have spawned such a disk (Craddock, 2011). Analysis of this scenario has been performed for Saturn to account for the formation of its small irregularly shaped moons from the materials in its rings (Charnoz et al., 2010).

In a very recent study (Rosenblatt and Charnoz, 2012) the Martian system is studied for two scenarios. In the strong tide regime, accretion takes place near the Roche limit close to the planet. The orbit evolution of the moonlets is tied to the evolution of the accretion disk. Moonlets are subject to planetary tidal torque that draws them in, as well as tidal torque from the accretion disk that pushes them out. There are several problems in this regime. Both the disk and moonlets are expected to fall in after 200 Myr, much less than the estimated age of the two moons. Moonlets also do not end up as far out as Deimos is today. In the weak tide regime, accretion takes place further out, extending to beyond the orbit of Deimos. Moons formed through accreting disk material and mutual accretion of moonlets until they have swept up all the material within Hills radius of their orbit. The process is similar to formation of planets from planetesimals. With the right choice of initial disk density, this process is capable of producing moons of the right masses, as well as producing enough moonlets to account for the number of elongated craters. The problem with the survival time of Phobos persists, however.

Following this recent study, there are several things worth further investigation, such as having the accretion disk straddle the synchronous orbit initially; smoothing the transition in the direction of the tidal torque across the synchronous orbit; time evolution of some assumed properties of Mars such as its spin and dissipation.

References

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