Effects of water vapor on the evolution of an impact-generated disk around Mars

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The origins of the Martian moons, Phobos and Deimos, are still heavily debated. There are currently two leading theories surrounding their origin: giant impact or asteroid capture. While the asteroid capture theory can straightforwardly explain the moons’ observed spectral features, the giant impact theory can straightforwardly explain the moons’ orbital characteristics. However, it is extremely difficult to capture two objects into the orbits that the moons are currently in, and there is not enough tidal dissipation to move them into their current orbits [1]. Previous giant impact studies can create an impact-generated disk large enough to recreate the moons in their current positions [2,3,4,5], but this large disk also creates a massive moon within Phobos’ orbit, which later would need to fall back to Mars [1]. This study proposes the use of an impactor containing mostly water-ice because water would be key for forming Deimos beyond the synchronous orbit, as the viscous interaction between rock grains and vapor would help extend the impact-generated disk, which would also cause the inner disk to be accreted back to Mars before satellite formation [6,7].
Our previous study focused on using Smoothed Particle Hydrodynamics (SPH) simulations [8] to model the impact of Mars and an impactor of varying water ice-rock ratios. We showed that chondritic materials (the moons’ possible composition) within the impactor could survive impact due to the vaporization of the ice mantle so that they may subsequently form the moons. This study continues where the previous study left off: with the impact-generated disk directly after impact. The impact-generated disk consists of water-vapor and rock components from both Mars and the impactor. This study uses the 1-D viscous diffusion equation to solve for the evolution of this impact-generated disk. Because of the disk’s water-vapor component, the gaseous disk should expand, and, depending on the size of the rock grains, the rock grains should couple with the gas motion and expand, as well. This extension of the disk is pivotal to forming Deimos without the large disks of previous studies [2,3,4]. This study investigates the effect of particle size and ice mass in the disk on the timescale of disk spreading. Through this we show that enough mass is delivered to the orbits of Phobos and Deimos to subsequently accrete the moons we see today, and the mass closer to Mars is depleted enough to not form the transient moon of previous studies for certain water-ice compositions of the initial impactor.

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