

The Icy Origins of the Martian Moons

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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. Asteroid capture mainly explains the moons' asteroid-like shape, C-asteroid-like albedo, and low porosity (~15% for Phobos; suggesting hydrated carbonaceous material) but cannot explain the moons' low orbital inclination and near-circular orbital eccentricity (Rosenblatt, 2011). The giant impact scenario explains the orbital characteristics of the moons but cannot rectify their spectral observations, composition, or density (Rosenblatt, 2011). However, it is extremely difficult to capture two objects into the orbits that the moons are currently in, especially since their possible internal structure does not provide enough tidal dissipation to account for their current orbits. In addition, the moons possibly have high porosities that may have caused them to break apart during capture and accrete to Mars (Rosenblatt, 2011). Previous giant impact studies can create an impact-generated disk large enough to recreate the moons in their current positions, but this large disk also creates many massive moons within Phobos' orbit, which later would need to fall back to Mars (Craddock, 2011; Rosenblatt and Charnoz, 2012; Citron et al., 2015). Currently, we have not seen definitive evidence for these moons on the Martian surface (Citron et al., 2015); therefore, it is important, along with reproducing the compositional characteristics, to understand how the moons can be formed without this extra mass.

These studies mostly use an impactor that is an undifferentiated basalt body of high mass, but this study proposes that the extra disk mass could be abolished by an impactor containing mostly ice, allowing some mass to vaporize on impact and escape the system (Ida et al., 2020). The moons' compositions, density, and possible porosity can result by adding ice to the system, as the vaporization of water will also help to protect carbonaceous materials that partly form the moons from being altered during impact.

For this study, Smoothed Particle Hydrodynamic (SPH) simulations of giant impacts with impactors of varying ice content were performed to create an impact-generated disk massive enough to form both Phobos and Deimos. We use the Tillotson Equations of State to model both iron-rock Mars and the water-ice impactor. Using previous studies as a framework, we start with an impactor ~3% the mass of Mars, $\sim 10^4$ SPH particles, impacting at an angle of 45 degrees. From the SPH simulation data, we use the particle density to understand the post-impact mass of the planet. Then, to determine the disk and escaped mass, we examine whether the particle's velocity exceeds escape velocity of the planet, and if not, whether it is a disk particle if its distance from the center of mass (semi-major axis) is greater than the planet's radius. This process is iterated until the change in the number of disk particles is within ~5%. This yields the final post-impact parameters (mass, position, velocity, etc.) of the planet, disk, and escape particles.

Keywords: Phobos, Deimos, Mars, Giant impact, Water-ice, SPH