

**TIDAL EVOLUTION OF PHOBOS: SATELLITE DESTRUCTION WHILE FALLING ONTO MARS.** G. Madeira<sup>1,2\*</sup> and S. Charnoz<sup>1</sup>, <sup>1</sup>Institut de Physique du Globe de Paris, CNRS, Université de Paris, F-75005 Paris, France (\*Email: madeira@ipgp.fr), <sup>2</sup>Orbital Dynamics and Planetology Group, FEG, UNESP, Ariberto Pereira da Cunha Avenue, 333, Guaratinguetá, 12516-410, Brazil.

**Introduction:** JAXA's Martian Moon eXploration (MMX) mission is expected to arrive on the Mars system in 2025 for a complete observational and geological study of the Martian system. The mission, which will also sample the moon Phobos, aiming to answer the main question: How did the martian moons, Phobos and Deimos, form? Formation models propose the formation of these moons in a debris disk generated in a giant impact of an exterior impactor with Mars [1,2,3,4,5]. In this scenario, the impact material settles into a disk almost completely within the Roche limit of Mars. The outwards viscous spreading of the disk material allows the formation of porous satellites at the planet's Roche limit. Thus, due to an intricate balance between outward migration caused by moon-disk interaction and inward migration caused by Martian tides, it is believed that an old population of satellites fell onto Mars [6], and that Phobos is the last surviving object of this old population. It was also proposed that there is rather a cycle of material close to Mars' Roche Limit, by which Phobos is periodically destroyed at the Roche limit, creating a temporary ring, and then reaccreted [7].

One important hypothesis in this model is that Phobos is disrupted in meter-sized particles, forming a temporary ring, from which new generations of satellite are accreted. However, it is uncertain if tides are really able to break a satellite in meter-sized particle. In addition whereas meter sized particles are not affected by tidal evolution, larger sized debris could tidally fall onto Mars rather than stay in orbit to form a ring.

So in this work, we elucidate about satellite disruption due to the tides and the fate of Phobos, using a mix of analytical models and numerical simulations. The classic Roche limit (a.k.a. fluid Roche limit) is obtained for a fluid object [9,10] so that solid objects will disrupt at an inner location, at the rigid Roche limit [11].

**Methods:** We numerically and analytically investigate the disruption of rubble-piles objects at the rigid limit Roche. For our analyses, we follow the analytical formulations given in [12,13,14]. The demise of the material produced in the disruption is also studied.

**Preliminary results and Discussion:** The location of the rigid Roche limit for a given object depends on its cohesion and strength [11]. For rubble-piles with a

few kilometres of radius, such as Phobos, we get that rigid Roche limit location also depends on its mass/radius. Assuming an erosive effect due to tidal dissipation, we obtain that Phobos would fall on Mars on longer timescales than those previously obtained in the literature [11]. This process affects the amount of material generated by the tidal action. The typical size of the material produced in the disruption is of great interest as it defines the viscosity of the disk and its spreading timescale. It defines whether Phobos is a recent satellite resulting from a series of cycles of material disruption and re-accumulation [7] or a much more older object [6,8]. Our results show that the lifetime of the particles is strongly affected by their radius, with kilometer-sized objects falling on Mars in some Myrs and dust material being removed from the system in thousand of years due to external forces.

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