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Orbital Evolution of the Mars-Phobos Tidal System

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NASA's InSight spacecraft successfully landed on Mars in November to place a set of instruments on the planet. The mission is planned to provide data about seismic activity, geodetic properties, and heat transport in Mars. In this context, we aim to study the tidal evolution of the Mars-Phobos system using constraints on the interior structure obtained from geodetic data.

By inverting tidal Love number (k 2), tidal quality factor (Q), mean mass, and mean moment of inertia, we constrain the internal structure of Mars in terms of parameters such as temperature, grain-size, composition, crustal thickness, core size, and state. We use several rheological models, i.e. Andrade, extended Burgers, Sundberg-Cooper, and power-law to compute the dissipative properties within Mars and calculate the global quality factor. We exploit the constraints imposed on the model parameters to build up density and seismic wave velocity profiles of the interior of Mars and use them in the calculations of the orbital properties of Mars-Phobos system.

We divide our study of the orbital evolution into two parts. In the first part, we consider the variations of the orbital properties from the present back to the point back in time when Phobos was at the synchronous radius of Mars. We compute the duration of this interval and study the interrelated variations of eccentricity of the orbit and semi-major axis of Phobos.

In the second part, we focus on the orbital evolution of the system from the present day until Phobos possibly reaches Mars' surface, i.e. we compute the remaining lifetime of Phobos. Since the higher degree effects become more important as the satellite gets closer to the planet, we account, in addition to the second degree, for the third degree effects in our calculations of the remaining lifetime. The dissipative properties of Mars change during the orbital evolution. We account for these changes by using the aforementioned rheological models and the constraints obtained for the frequency dependence of dissipation rate.