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Long-term evolution of tidal heating and surface temperature on extrasolar planets

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Increasing number of detected extrasolar planets provides a unique statistical set that may help us to improve our knowledge about planetary evolution. Indirect detection methods employed in search for exoplanets are most sensitive to objects orbiting close to their host star and this criterion gets particularly important in the case of low-mass terrestrial planets. Here, we focus on long-term orbital and thermal evolution of a single planet subjected to stellar tides. Our approach combines evaluation of surface temperature as well as numerical computation of tidal effects on planetary orbit and internal heating. By calculating the tidal evolution of the orbit [1], we analyze the effect of initial orbital parameters (eccentricity, semi-major axis and rotational frequency) on secular changes in surface temperature and tidal dissipation. The maximum surface temperature and temperature gradient is computed during the process and it evolves together with the semi-major axis, the eccentricity and the ratio of spin and orbital frequency. Significant increase in the surface temperature is observed when the planet encounters a spin-orbit resonance. We solve the heat diffusion equation numerically for both 1D and 3D geometry in a thin spherical shell corresponding to a subsurface layer (see e.g. [2]), where the upper boundary condition is given by energy equilibrium and is strongly non-linear in temperature due to Stefan-Boltzmann law. Additionally, we solve the viscoelastic response to the tidal loading during orbital evolution. Following the method of [3,4], the tidal heating is evaluated for Maxwell or Andrade rheology in the time domain. We study disturbing potential caused by the body's deformation, the time dependence of phase lag and time lag during one orbit and compare our results with traditionally used constant tidal lag models (e.g. [1,5]). The effect of a 3D internal structure on the disturbing potential is investigated as well. This study is our first step towards coupled orbital and thermal evolution of extrasolar planets.

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