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Vertical structures induced by embedded moonlets in Saturn's rings

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Abstract

Images of Saturn's rings, taken by the Cassini spacecraft near Saturn's equinox in 2009, show shadows cast by small moonlets embedded in Saturn's rings. Although the resolution of these images is not high enough to see these embedded moonlets directly, the s-shaped structures induced by these moonlets, called propellers, are observable. The shadows cast reveal information about the vertical structure of propellers and therefore about the embedded moonlets [5].

We extend the propeller model [4] into the vertical direction. We use the scattering operator concept [3, 4] to model the gravitational interaction of the embedded moonlet with the ring particles, taking place in a rather small region around the moonlet. Outside this region we describe the ring by hydrodynamic equations. We extend the hydrodynamic description [4] by taking the energy balance equation for the granular temperature $T = c^2/3$ into account, thus getting information about the downstream relaxation of vertical structures induced by the moonlet.

We find that the granular temperature decays exponentially to a local equilibrium value after a few orbits. After that the local equilibrium value changes with the surface mass density and hence with the diffusion timescale [4]. Because the evolution of the ratio of thermal speed components c_z/c_x after the gravitational interaction with the moonlet reaches the equilibrium value after a few collisions per particle [1, 2], we use this equilibrium value to estimate the scale height $H \propto c_z/\Omega$ of the ring. We compare our results of vertical heights and azimuthal lenghts of propellers (like Blériot and Earhart) with measurements taken from Cassini imaging data [5].

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