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Planet Migration Induced by Gravitational Instabilities

The study of gravitational instabilities (GIs) and their effects in protoplanetary disks has been an area of active research for over a decade. Although some studies have indicated that GIs cannot form gas giant planets directly, it is clear that they can have a significant effect on a protoplanetary disk. In this dissertation I present several areas where GIs may play a key role in the evolution of a protoplanetary disk. These studies are carried out using three dimensional numerical simulations. I have carried out and analyzed nearly twenty simulations with varying initial conditions, resolutions, and physical effects. Although all indications from these simulations are that GIs cannot form gas giant planets directly at radii smaller than 40 AU, they have shown that GIs can have a dramatic effect on protoplanetary disk structure and planets embedded in a protoplanetary disk.

I present several key results including: the effects of a varied initial surface density profile, azimuthal resolution, the amplitude of the initial random perturbation, and the adiabatic index used on the onset, strength and general evolution of GIs in protoplanetary disks. Additionally, I present results on studies of the interaction of the instabilities with the central star when it is allowed to move freely in response to the action of the GIs. Finally, I present several results regarding the interaction of embedded massive planets and GI active disks. I find that the presence of massive planets can have a dramatic effect on the evolution of GIs in an active disk, and the GIs can also dramatically effect them migration of the embedded planet. In fact, the action of the GIs may planets to migrate outward, contrary to the standard theory of the planet migration in laminar disks.

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