

Density Wave Structure in Protostellar Disks and Planetary Migration.

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The prolific discovery of extra solar planets over the past two decades clearly indicate that they commonly accompany solar-type stars, their structure are rich in variety, and their dynamical properties are diverse and complex. These observational advancements have also led to the construction of a new paradigm that planets migrate extensively throughout different stages of their assemblage from micron-size grains to Jupiter-like gas giants. During their initial growth, meter-size planetesimals are subjected to gas drag, undergo orbital decay to accumulate outside a magnetospheric cavity in their natal disks. When these building blocks collide and merge into protoplanetary embryos, they excite density waves and induce angular momentum transfer in the disk. An imbalance between corotation, inner and outer Lindblad resonances induces embryos to migrate outwards in the inner, viscously-heated regions, inward in the outer, irradiated regions of the disk, and to stall at their common border. The accumulation of embryos at this trapping radius leads to further growth through coagulation into super Earths. These super Earths migrate towards their host stars as the trapping radius contracts during the disk depletion. Their migration is stalled outside the disk's magnetospheric cavity. In relatively massive disks, super Earths evolve into cores with sufficient mass to efficiently accrete the disk gas before it is severely depleted. The intense perturbations of these massive planets excite nonlinear density waves and lead to the formation of gaps and the termination of the planets' gas accretion. They also scatter nearby embryos and induce them to evolve into additional cores of second-generation gas giants. We briefly review how these processes may account for the origin of some observed multiple super-Earth and gas giant systems. It is also possible to construct a unified model to account for the observational properties of protostellar disks in terms of this planetary migration scenario. We present images of disks due to the irradiation of stellar light on their 3D wave structure near the orbits of the embedded gas giant planets. Some ALMA images such as gaps and arcs in classical disks can be reproduced. Follow-up observations may be useful to provide verification of and diagnostics on the spiral structure of density waves. The migration and trapping of super Earths may also manifest the breaks in the spectral energy distribution in transitional disks especially in those with ongoing gas accretion.