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The Enrichment of Giant Exoplanets: Migarion and Planetesimal Capture

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Abstract

Giant exoplanets are found to be highly enriched in heavy elements [1, 2]. The origin of this enrichment, however, is not well-understood. Thorngren et. al. 2016 [2] statistically investigated the composition of warm-Jupiters and found that some warm-Jupiters contain several hundreds Earth-mass heavy elements, and that heavier warm-Jupiter consist of more heavy elements. While several Earth-mass heavy elements can be captured during the gas accretion phase of gas giant planets through the accretion of planetesimals [3, 4, 5], the extremely large amount of heavy elements is still unexplained.

We investigate the possibility of heavy-element enrichment in giant exoplanets due to planetary migration and planetesimal capture using numerical methods. During the migration process, the protoplanet interacts with many planetesimals and can captures some of them [6, 7]. We perform orbital integration of a central star, a migrating protoplanet and planetesimals. In this study, planetesimals are treated as test particles. If a planetesimal collides to the surface of the protoplanet or loses the escape energy from the protoplanet's gravity, we consider the planetesimal to be captured by the protoplanet. We perform the orbital evolution calculation until the protoplanet reaches 0.5 AU, and determine the amount of heavy elements captured during the planetary migration. Our study includes various protoplanet masses, planetesimals sizes, migration timescales and initial locations of the protoplanet.

It is found that a resonant trapping of mean motion resonances inhibits planetesimals to enter the feeding zone of the migrating protoplanet. However, the combined effect of planetary migration and aerodynamic gas drag from the circumstellar disk pushes the trapped planetesimals into the planet's feeding zone. By the end of the migration process, we find that the protoplanet can capture up to a few hundreds Earth-mass planetesimals in metal-rich disks. It is also found that the amount of captured planetesimals increases with the migration distance. We suggest that the highly enriched warm-Jupiters must have captured planetesimals and migrated to their current locations, and that the observed correlation between the heavy-element-mass and the planet's mass is linked to the migration distance of the planet and the disk's metallicity.

References

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