

Semi-analytical model for close-in planet formation via giant collisions

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In the prevailing model of planet formation, planets gather near the central star with closely spaced orbits through orbital migration, undergoing subsequent orbital instability, giant collisions, and scatterings after the dissipation of the protoplanetary disc. Traditional N-body calculations, commonly used to simulate this process, are computationally expensive to generate sufficient planetary populations for statistical comparisons with observational data. A previous study introduced a semi-analytical model describing changes in planetary orbital elements due to giant impacts and scatterings, and has succeeded in reproducing statistical features seen in N-body simulations near 1 au around solar-mass stars. However, this model is not fully applicable to the close-in regions (around 0.1 au), where exoplanets are frequently discovered, because the collisional evolution is qualitatively different. This study presents a new semi-analytical model applicable to close-in orbits around stars of various masses, validated through comparison with N-body calculations. The model accurately reproduces final mass and orbital distributions within the range of 0.1–1 au around solar-mass stars and around 0.1 au around M dwarfs. By integrating this model with other planet-forming processes, a computationally low-cost planetary population synthesis model can be developed. Such a model holds significance for future statistical comparisons with exoplanet observations.

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