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Catch and release: Ejection and recapture of planetesimals and planets and their role in planet formation

The traditional view of planet formation often treats planetary systems as isolated environments. However, dynamical processes are highly stochastic, and the “release” of material—from planetesimals to fully-formed planets—is a common, if not dominant, outcome. Planet-planet scattering, for instance, is a chaotic “release” mechanism that can eject 40-80% of a system’s planets, populating the galaxy with a vast reservoir of free-floating planets (FFPs), or “rogue worlds”. This ejected population, however, is not merely lost. We explore the “catch” part of this cycle, demonstrating how rogue objects can be recaptured and play a fundamental role in the formation and evolution of new and existing planetary systems. First, we show that stars within dispersing clusters can efficiently “catch” FFPs, leading to the dynamical recapture of planets into stable, wide orbits, potentially explaining the origins of observed wide-orbit planets (and binaries). Second, the “catch” mechanism is even more profound in young systems. Protoplanetary disks, through gas-assisted capture, are exceptionally effective at trapping interstellar planetesimals. This process “seeds” nascent disks with km-sized planetesimals, suggesting planet formation is a galactically-linked process. This mechanism may also trigger an “epidemic” cascade: the “catch” of an external object can lead to “seeding” of planet formation in other systems and the ejection of many more planetesimals from those systems, which can then be captured and seed planet formation and so forth. This same gas-capture framework also provides the most efficient known channel for catalyzed lithopanspermia. Finally, this cycle extends to stellar graves. Dynamical exchange in evolved binaries represents a direct “catch and release” scenario, where a planet is “released” from one star only to be “caught” by its companion. The material captured in such events, or through mass transfer, can then form disks around white dwarfs, providing stable environments for the formation of “second-generation” planets.

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