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# Binary Formation from Three Initially Unbound Bodies

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We explore three-body binary formation (3BBF), the formation of a bound system via gravitational scattering of three initially unbound bodies (3UB), using direct numerical integrations. For the first time, we consider systems with unequal masses, as well as finite-size and post-Newtonian effects. Our analytically derived encounter rates and numerical scattering results reproduce the 3BBF rate predicted by Goodman & Hut (1993) for hard binaries in dense star clusters. We find that 3BBF occurs overwhelmingly through nonresonant encounters and that the two most massive bodies are never the most likely to bind. Instead, 3BBF favors pairing the two least massive bodies (for wide binaries) or the most plus least massive bodies (for hard binaries). 3BBF overwhelmingly favors wide binary formation with super-thermal eccentricities, perhaps helping to explain the eccentric wide binaries observed by Gaia. Hard binaries form much more rarely, but with a thermal eccentricity distribution. The semimajor axis distribution scales cumulatively as a3 for hard and slightly wider binaries. Though mergers are rare between black holes when including relativistic effects, direct collisions occur frequently
between main-sequence stars—more often than hard 3BBF. Yet, these collisions do not significantly suppress hard 3BBF at the low velocity dispersions typical of open or globular clusters. Energy dissipation through gravitational radiation leads to a small probability of a bound, hierarchical triple system forming directly from 3UB.

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