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Interstellar objects follow the collapse of molecular clouds

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Interstellar objects (ISOs), the parent population of 1I/ʻOumuamua and 2I/Borisov, are abundant in the interstellar medium of the Milky Way. This means that the interstellar medium, including molecular cloud regions, has three components: gas, dust, and ISOs. From the observational constraints for the field density of ISOs drifting in the solar neighbourhood, we infer a typical molecular cloud of 10 pc diameter contains some $10^{18}$ ISOs. At typical sizes ranging from hundreds of metres to tens of km, ISOs are entirely decoupled from the gas dynamics in these molecular clouds. Here we address the question of whether ISOs can follow the collapse of molecular clouds. We perform low-resolution simulations of the collapse of molecular clouds containing initially static ISO populations toward the point where stars form. In this proof-of-principle study, we find that the interstellar objects definitely follow the collapse of the gas — and many become bound to the new-forming numerical approximations to future stars (sinks). At minimum, 40% of all sinks have one or more ISO test particles gravitationally bound to them for the initial ISO distributions tested here. This value corresponds to at least $10^{10}$ actual interstellar objects being bound after three initial free-fall times. We find that more massive sinks bind disproportionately large fractions of the initial ISO population, implying competitive capture of ISOs. Extrapolating to a solar-mass sink suggests binding of several Earth masses of ISOs, implying a novel dynamical mechanism for an eventual Oort cloud to potentially contain some smaller remnant fraction of pre-solar ISOs. Sinks can also be solitary, as their ISOs can become unbound again — particularly if sinks are ejected from the system. Emerging planetary systems will thus develop in remarkably varied environments, ranging from solitary to richly populated with bound ISOs.
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