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A full-lifetime planetary simulation: from stellar birth cluster evolution to planetary destruction around white dwarfs

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Escalating observations of exo-minor planets and their destroyed remnants both passing through the Solar system and within white dwarf planetary systems motivate an understanding of the orbital history and fate of exo-Kuiper belts and planetesimal discs. Here, we explore how the structure of a 40-1000 au annulus of planetesimals orbiting inside of a Solar system analogue that is itself initially embedded within a stellar cluster environment varies as the star evolves through all of its stellar phases. We attempt this computationally challenging link in four parts: (1) by performing stellar cluster simulations lasting 100 Myr, (2) by making assumptions about the subsequent quiescent 11 Gyr main-sequence evolution, (3) by performing simulations throughout the giant branch phases of evolution, and (4) by making assumptions about the belt's evolution during the white dwarf phase. Throughout these stages, we estimate the planetesimals' gravitational responses to analogues of the four Solar system giant planets, as well as to collisional grinding, Galactic tides, stellar flybys, and stellar radiation. We find that the imprint of stellar cluster dynamics on the architecture of ≥ 100 km-sized exo-Kuiper belt planetesimals is retained throughout all phases of stellar evolution unless violent gravitational instabilities are triggered either (1) amongst the giant planets, or (2) due to a close ($\ll 1000$ au) stellar flyby. In the absence of these instabilities, these minor planets simply double their semimajor axis while retaining their primordial post-cluster eccentricity and inclination distributions, with implications for the free-floating planetesimal population and metal-polluted white dwarfs.