

## X79a Galactic echoes

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*Gaia* has revealed a variety of substructures in the phase space of stars in the Solar neighborhood, including the vertical ‘Snail’ in  $(z, v_z)$  space. Such substructures are often interpreted as the incompletely phase-mixed response of the disc stars to a single perturbation, such as an impulsive encounter with a satellite galaxy. In this paper we consider the possibility that such structures contain manifestations of phase space *echoes*. First established in plasma physics in the 1960s, echoes arise when a collisionless system is perturbed *twice*: the macroscopic responses to both perturbations mix to small scales in phase space, whereupon they couple nonlinearly, producing a third macroscopic ‘echo’ response without the need for a third perturbation. We derive the galactic analogue of the plasma echo theory using angle-action variables and apply it to a one-dimensional model of vertical motion in the Milky Way. We verify the predicted echo behavior using idealized test particle simulations, both with and without the inclusion of diffusion through orbital scattering off molecular clouds. While we conclude that the *Gaia* Snail itself is unlikely a (pure) echo effect, the basic physics we uncover is sufficiently generic that we expect phase-space echoes to be common in disc galaxies.