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Radial Wave in the Galactic Disk: New Clues to discriminate different Perturbations

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Decoding the key dynamical processes that shape the Galactic disk structure is crucial for reconstructing the Milky Way's evolution history. The second Gaia data release uncovers a new wave pattern in the L_Z-V_R space accompanied by a richness of phase space substructures, signifying the Galactic disk in dynamical disequilibrium. However, its formation mechanism remains elusive due to the complexity of involved perturbations and the challenges in disentangling their effects. Utilizing the latest Gaia DR3 data, we find that the wave systematically shifts towards lower L_Z for dynamically hotter stars. The amplitude of this phase shift between stars of different dynamical hotness increases with decreasing L_Z within the range of L_Z larger than 2000 km*kpc/s but stays approximately constant at a small value in the lower L_Z part of the wave. To investigate the role of different perturbations separately, we set up three test particle simulations in which a satellite galaxy, spiral, and bar act as the sole perturber by turn. The former trend is consistent with the waves induced by satellite impact, which we interpret in the context of a toy model of radial phase mixing. While corotating transient spiral arms do not produce a systematic phase shift pattern, a steadily rotating bar could generate a wave with phase alignment at higher L_Z extrema and phase shift at lower L_Z extrema at the locations of Lindblad resonances. Our results suggest that the formation of L_Z-V_R wave may arise from a complex interplay between internal and external perturbations. Moreover, the dependence of disk response on dynamical hotness could provide insights for discriminating between perturbations of different types.

Primary author: CAO, Chengye (Shanghai Jiao Tong University)

Co-author: Prof. LI, Zhao-Yu (Shanghai Jiao Tong University)

Presenter: CAO, Chengye (Shanghai Jiao Tong University)

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