Abstract

The phase spiral structure in the vertical position and velocity (z, v_z) plane of the Milky Way is one of the most important discoveries since the launch of the Gaia mission. Disc stars from the Gaia DR3 RVS sample are selected to explore the phase spiral as a function of position in the Galaxy. The data reveal a two-armed phase spiral pattern in the local $z - v_z$ plane inside the solar radius, which appears clearly when colour-coded by $< v_R > (z, v_z)$: this is characteristic of a breathing mode that can in principle be produced by in-plane non-axisymmetric perturbations. On the contrary, the phase spiral pattern becomes single armed when outside the solar radius. We use a steadily rotating central bar and 2-armed spiral arms as perturbation to perform particle test integrations, the pseudo stars get a prominent spiral pattern in the $< v_R >$ map in the x−y plane. Additionally, clear breathing mode evidence at a few km/s level can be seen in the $<v_z>$ map on the x−z plane, confirming that such breathing modes are non-negligible in the joint presence of a bar and spiral arms. However, no phase-spiral is perceptible in the (z, v_z) plane under this steady bar model. When an initial vertical perturbation is added to all pseudo stars, we find that one-armed phase spirals can clearly be seen 500 Myr after the perturbation and gradually disappear inside-out. Finally, we show how a toy model of a time-varying non-axisymmetric in-plane perturbation with varying amplitude and pattern speed can produce a strong two-armed phase-spiral. We conclude that a time-varying strong internal perturbation together with an external vertical perturbation could perhaps explain the transition between the two-armed and one-armed phase-spirals around the Solar radius.