## Gaia DR1 Evidence of Disrupting the Perseus Arm

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The origin of spiral arms in disk galaxies has been hotly debated since 1960s. There are two different theories of spiral arms in terms of lifetimes and rotational behaviour [1]. The quasi-stationary "density wave" theory characterises spirals as rigidly rotating, longlived wave patterns (i.e.,  $\gtrsim 1 \text{ Gyr}$ ) [2]. On the other hand, the "dynamic spiral" theory suggests spiral arms are differentially rotating, transient, recurrent patterns on a relatively short time scale (i.e.,  $\sim 100 \text{ Myr}$ ) [3].

In this study [4], we investigated kinematics of 77 Cepheid variables around the Perseus arm in the Milky Way galaxy, taking advantage of the accurately measured distances of Cepheids and the proper motions from Gaia Data Release 1. We found that both the Galactocentric radial ( $U_{pec}$ ) and rotation ( $V_{pec}$ ) velocities of these Cepheids are correlated with their distances from the locus of the Perseus arm (Fig. 1a), as the trailing side is rotating faster (Fig. 1c) and moving inward (Figs. 1b) compared to the leading side. We also found a negative vertex deviation for the Cepheids on the trailing side in contrast to the positive vertex deviation in the solar neighborhood (Fig. 1d).

We compared these observational trends with our *N*-body/hydrodynamics simulations based on a static density-wave spiral scenario and those based on a transient dynamic spiral scenario. Although our comparisons are limited to "qualitative" trends, they favor a conclusion that the Perseus arm is in the disruption phase of a transient arm. We will further test the disruption phase scenario of the Perseus arm with the future Gaia data releases, and compare more sophisticated simulations.

## References

- [1] Dobbs, C., Baba, J.: 2014, *PASA*, **31**, 35.
- [2] Lin, C. C., Shu, F. H.: 1964, ApJ, 140, 646.
- [3] Baba, J., et al.: 2013, *ApJ*, **763**, 46.
- [4] Baba, J., et al.: 2018, ApJL, 853, 23.



Figure 1: Comparison between the models and the observed kinematics of Cepheids in terms of correlations of  $d_{Per}-U_{pec}$  and  $d_{Per}-V_{pec}$  (panel a), mean  $U_{pec}$  (panel b), mean  $V_{pec}$  (panel c) and the vertex deviation (panel d). Horizontal shaded areas in black and red indicate the observed values. The model results are shown with the open symbols with error bars. Note that the left side of the panels shows the "Density Wave" model results for two different co-rotation (CR) radius values, whereas in the right side the "Dynamic Spiral" model results are presented as a function of time.