Simulation of Gaia DR4 epoch astrometry for binary systems

Binary systems provide a model-independent way to measure stellar masses, a way to test and constrain stellar evolution models. In addition, binaries provide direct distance measurements. Cepheids can benefit from both of these measurements, especially for calibrating the Period-Luminosity relation, playing a key role in the current tension in the Hubble constant. To simultaneously derive masses and distances, one needs a full orbital solution combining radial velocities (RV) of both components and relative astrometry, conditions that are hard to achieve.

On the other hand, the Gaia mission provides precise parallaxes that can, however, be biased by the nature of the observed systems, in particular unresolved binaries. If such a system includes a pulsating component (e.g., Cepheid, Mira, RR Lyrae), an additional photocentric motion is introduced through the variable-induced mover effect. The new extension in DR4, Gaia epoch astrometry, will allow us to apply better-suited models depending on the case, resulting in more precise parameters.

To prepare for DR4, we developed a python tool that simulates the epoch astrometry of such systems. We used this tool to simulate a total of eighteen well-studied systems, including simple binaries and systems containing Cepheids and AGB stars, in order to evaluate the influence of orbital motion and pulsation on Gaia parameter measurements.

We find that parallax and proper motion are mostly affected by orbital motion, while the VIM effect becomes significant only for large pulsation amplitudes. For parallax, the difference between a single-star model and binary models can reach a few sigma, which confirms previously reported discrepancies. For one system treated with a binary model in DR3, the simulations reproduce the Gaia solution. In addition, a new method to correct for proper motion anomalies shows consistency with Hipparcos-Gaia proper motions.

After the new release, these data can be used alongside optical interferometry, Gaia and ground-based RVs. This approach will allow precise mass and distance measurements for a large number of stellar systems, as it overcomes limitations associated with both methods.