Orbits and Masses of 152 companions from RV and Astrometry

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Motivation

The determination of dynamical masses for stars and their companions serves as a significant cornerstone in observational support for stellar evolutionary models. Using the 3D orbit and dynamical masses obtained from a combination of different observation methods, we will be able to spot precise location of substellar companions, and estimate their mass and therefore brightness. This will help us identify and select targets for future direct image study, saving a lot precious telescope time from blind searching.

Methodology

To obtain 3D orbits and dynamical masses for the list of systematically selected stars, we combine Radial velocity data (Keck/HIRES and ESO/HARPS) , absolute astrometry data (HGCA), and relative astrometry data (Gaia/WDS). We select HGCA stars with 5+σ acceleration ($\chi2 \geq 25$) to make sure astrometry adds significant constraints to orbit solutions. We select RV stars with more than 10 observations for an adequately resolved orbit, and with baseline longer than 10 years to comparable with the 25 years baseline of HGCA. Relative astrometry data is also applied if applicable. We then perform orbit fit for the stars in the final list, using an open source python package orvara. Among them, there are 134 two body fit and 9 three body fit, and adds up to 152 orbit solutions. The joint orbit fit, by virtue of two input data types, can measure orbits and masses of long period companions even without data that cover the full orbit.

Orit Fit results & Compare with Gaia DR3 data product

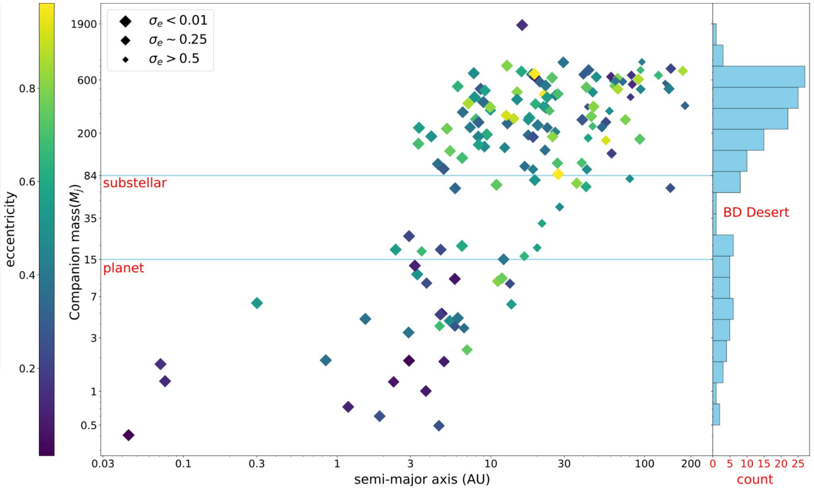

Figure 2. A full collection of 152 orbit solutions from this work. The left larger section plots companion mass as a function of semi-major axis, color coded by derived eccentricity of each companion. The marker size indicates uncertainty of derived eccentricity, where larger marker represents better constraint or smaller. The upper-left legend provides a couple examples of the marker size - uncertainty correlation. The right horizontal histogram plots companion occurrence rate as a function of mass. The lack of companion with the mass between ≈ 25 MJup to ≈ 65 MJup display a clear trend of BD desert.

Our results helps determine potential targets for direct imaging BD/exoplanets and can even pinpoint their relative position to host stars on the sky. Most of the host star here are M dwarfs, and this study significantly expands the number of nearby M dwarfs with well-determined dynamical masses.

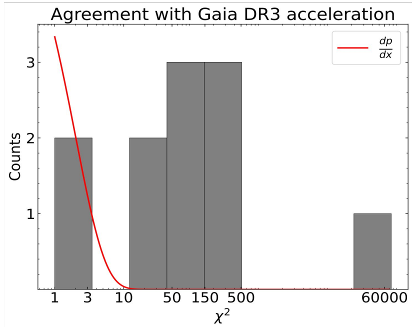

Figure 3. The histogram plots agreement between Gaia DR3 astrometric acceleration and result from this work. A probability density curve for 2 degrees of freedom is plotted in red for reference here. Only two results among eleven available comparisons lie within the red theoretical curve for agreement.

With the orbital posterior (MCMC chain), we use *htof* and the Gaia GOST scanning law to predict what Gaia DR3 should have reported for the right ascension and declination acceleration terms. At any given orbital draw, we calculate the reflex motion induced on the primary, sample that motion exactly according to the Gaia scanning law, and then fit a 7-parameter skypath *htof*, retaining the acceleration terms (the 6th and 7th parameters).

This offers some insights about the Gaia astrometric models.