Making 13 sigma dynamical mass measurements for the components of the HD 104304 binary system using radial velocities and direct imaging.

Vighnesh Nagpal[1] and Sarah Blunt[2]

[1]University of California
[2]Department of Astronomy, California Institute of Technology

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Abstract

Combining direct imaging astrometry and long-baseline radial velocity (RV) measurements of stellar binaries can provide precise constraints on their 3D orbits and yield dynamical masses for both components. We applied the combination of these methods to study HD104304, a binary system with a decades-long orbit containing a G8IV subgiant and a recently-discovered M dwarf companion. Using radial velocities collected over a timespan of two decades by Keck/HIRES and astrometry calculated from adaptive optics images taken by Keck/NIRC2, we explored models to jointly fit the astrometric orbital motion and RV trend. Previous studies of this system (Howard & Fulton, 2016) were unable to distinguish between two and three body solutions using RVs alone. However, we are able to break this degeneracy by incorporating images into the fit. We make 13-sigma dynamical mass measurements of the primary and secondary, and find that a slightly eccentric solution (e=0.3) is required. However, the dynamical mass we measure for the primary (˜1.8 solar masses) is significantly higher than its well constrained spectroscopic mass of 1.02 solar masses. This hints at the need for a three-body solution to accurately model the observed trend in the HD 104304 system.

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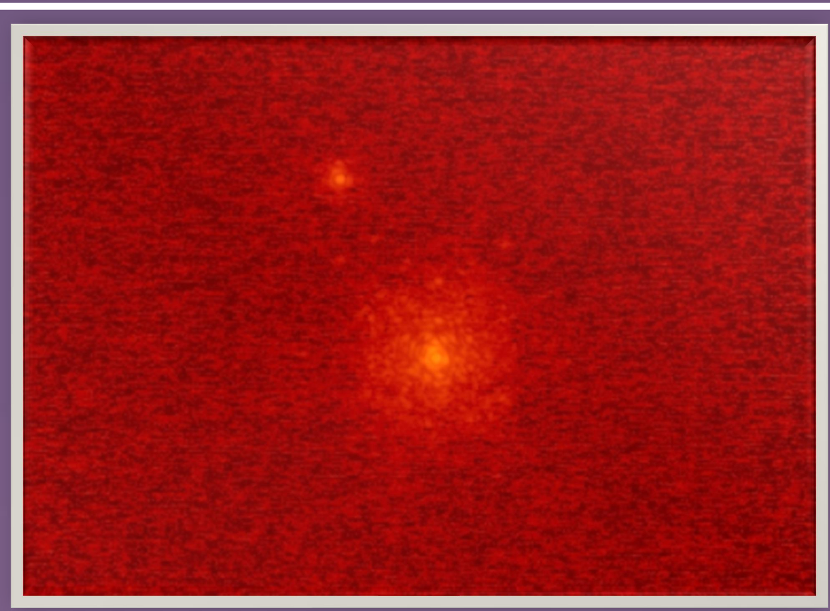
Vighnesh Nagpal[1,2], Sarah Blunt[3]

1. University of California, Berkeley
2. Lexington High School
3. Department of Astronomy, California Institute of Technology

vighneshnagpal@berkeley.edu

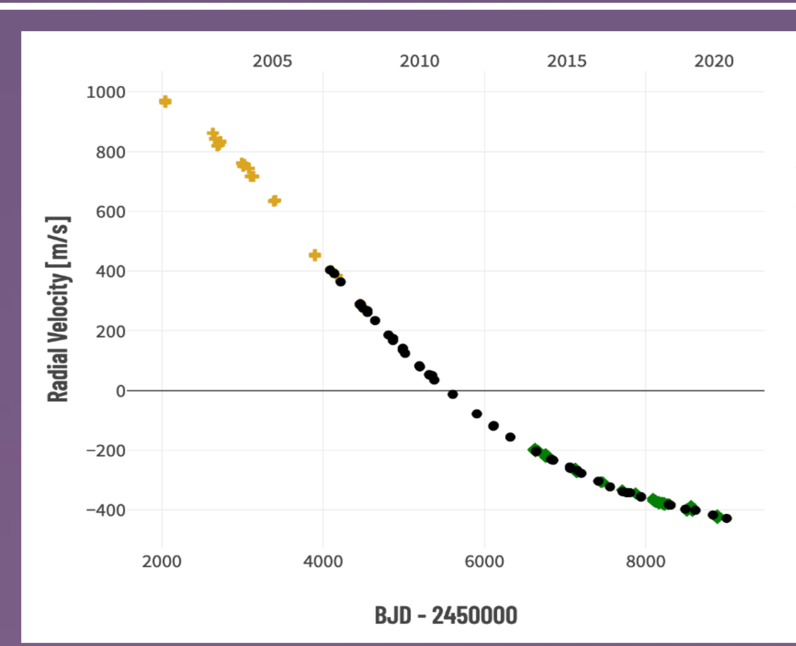
Introduction

HD 104304 is a binary system containing a GIV subgiant measuring 1.02 solar masses and a recently discovered M-dwarf companion with an orbital period of ~ 80 years and a colour-derived mass of ~ 0.21 solar masses



The system has a well studied radial velocity (RV) trend (Fig.2) with an observational baseline of ~20 years

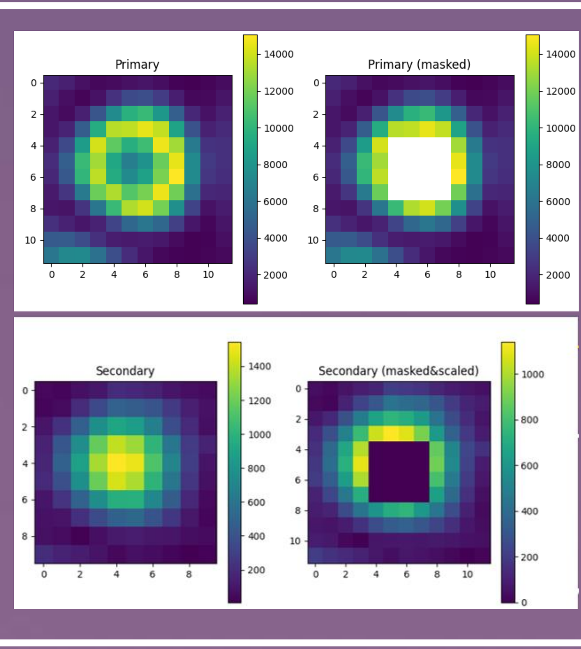
Previous analyses of the RV trend (Howard & Fulton, 2016) found that three body and two body models fit the data equally well.



Jointly using RVs and direct imaging can break the degeneracy between two and three body solutions!

Method

We use radial velocity measurements taken using Lick-HIRES-J and the Automated Planet Finder and astrometry derived from images taken by KECK-NIRC2 & VLT NACO (Schnupp et. al 2010)



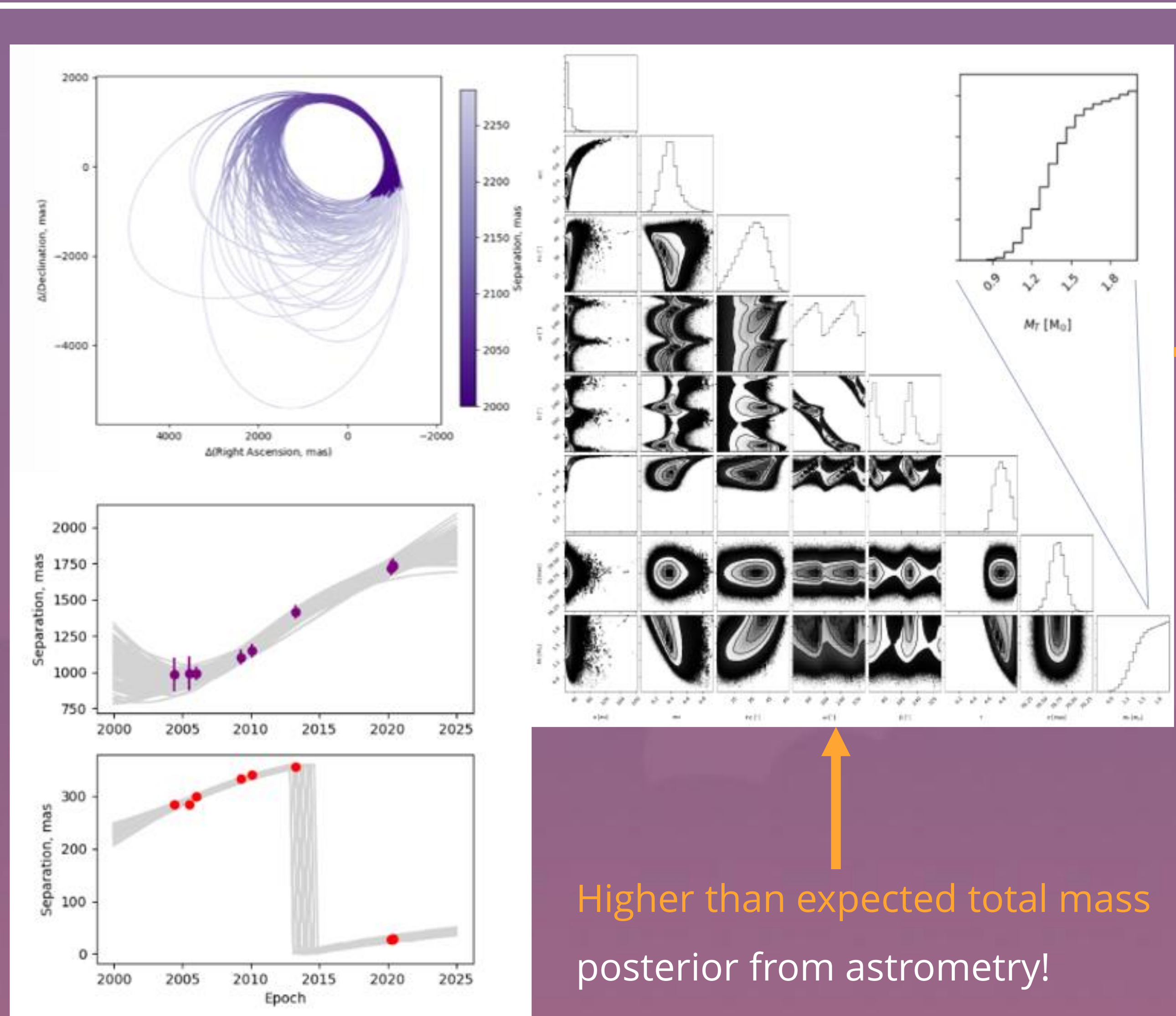
We then use the *orbitize!* API's (Blunt et. al 2020) implementation of the affine-invariant MCMC algorithm from *emcee* (Foreman-Mackey et. al) to conduct two orbit fits:
one using only astrometry and the other to a combined radial velocity and astrometric dataset.

orbitize!

Results

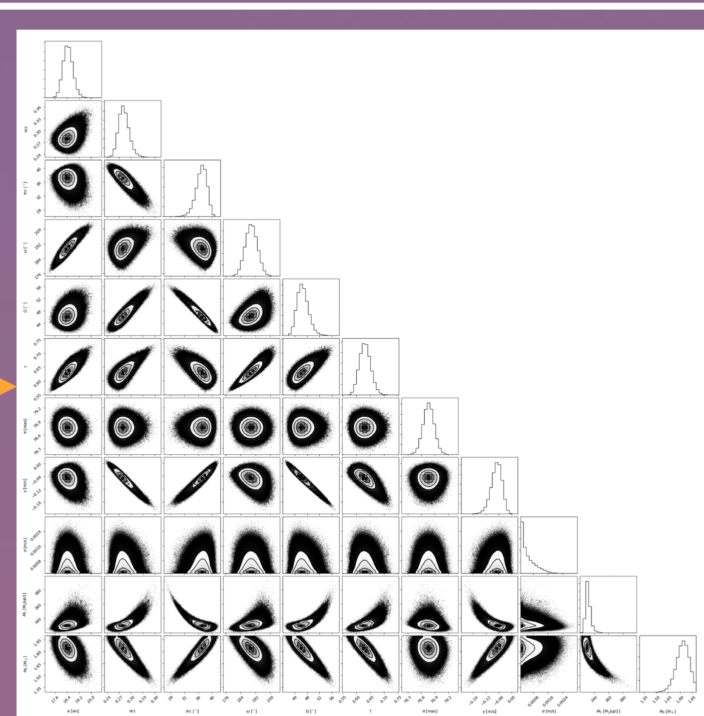
on-sky projections of permissible orbits

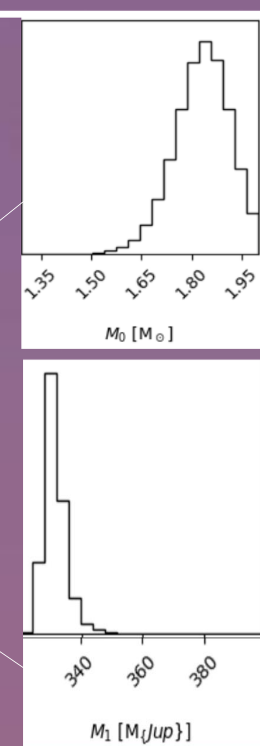
astrometric dataset overlaid on model predictions



Higher than expected total mass posterior from astrometry!

Joint RV+astrometry fit using *orbitize!*





The fit implies a primary mass of ~1.85 solar masses, a value significantly higher than HD 104304's spectroscopic mass of ~1.02 solar masses

We make 13 sigma dynamical mass measurements for the primary and the secondary

The mass distribution of HD 104304 B appears peaked around 330 Jupiter masses, or ~ 0.31 solar masses

For the primary, our analysis predicts a much larger dynamical mass than its well constrained spectroscopic mass.

This may be evidence pointing towards the need for a three-body model to accurately characterise the HD 104304 system.

Conclusions

- Through jointly fitting radial velocities and astrometry for the HD 104304 binary, we make astrometry, we make 13 sigma measurements of both components' dynamical masses
- The bias towards high dynamical masses in the joint fits' posteriors hint at the possible need for a three-body model to accurately fit the data.

Next Steps

- Investigating the source of the bias towards higher masses and exploring the feasibility of a three-body model
- Extracting more astrometry from raw data to incorporate into and better constrain the fit
- Investigating the impact of fitting in different bases on the posterior
- Looking into the relative information content provided by radial velocities and astrometry for binaries with periods of many decades.