The Companions to B and A Stars Snapshot (CBASS) Survey: Initial Detections of Low-Mass M Dwarf Companions to Young B and A Stars

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Introduction

- Here we present initial **second-epoch results** from a companion search for **brown dwarfs around B & A stars.**
- Brown dwarf companions around intermediate and high mass have not been discovered to the extent that planetary and stellar-mass companions have.
- **We determined the ages of the stars in our sample [1, 2]**, which allows us to **assign ages to any future confirmed brown dwarf companions. The median age of the sample is ~300 Myr (Figure 2).**
- The short lifetimes of high-mass B and A will allow us to:
  1) determine the properties of their brown dwarf companions **when they are young and bright**,
  2) refine and update BD **formation and evolution models**, and
  3) round out the **statistics of brown dwarf and giant planet companions to high-mass stars**.

Sample/Observations

- The sample: 1st-epoch observations of **212 B and A stars** over 4 nights using the **Keck Near InfraRed Camera 2 (NIRC2)**
  - Found 182 candidates around 77 targets
- We also took **2nd-epoch observations for 61/77 of the targets** to determine which candidates are bound

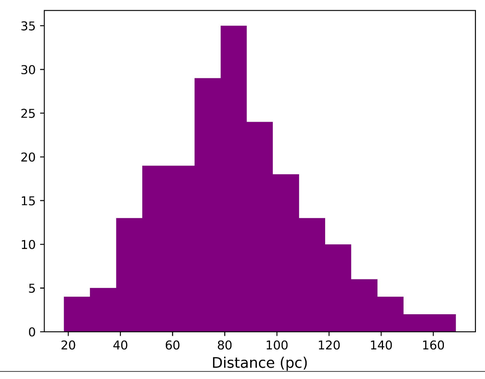

Figure 1. *Histogram of distances to our targets. All stars are within 175 pc, with stars closer to Earth being chosen deliberately.*

- **Observations were taken in the near-IR K- and Ks-bands with a 600mas coronagraphic spot**

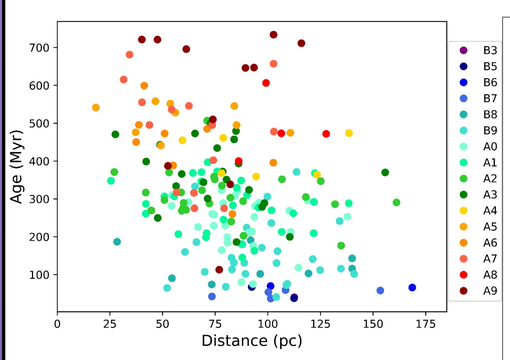

Figure 2. *Spectral types and ages as a function of distance for our targets. The median age and distance of the sample is ~300 Myr and ~85 pc.*

Results: Six New M-Dwarf Companions

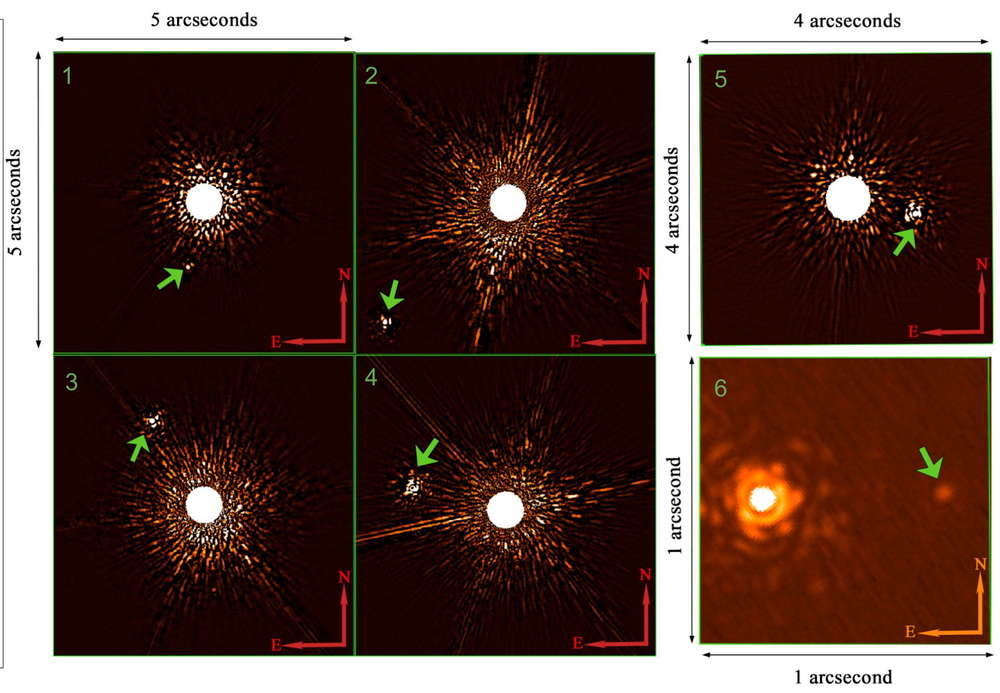

Figure 3. *Keck/NIRC2 K/K'–band images of the six new confirmed binary pairs. The companions in each pair were have mass estimates ranging from 86–821 Jupiter masses and the distances between the binary objects range from 20–300 AU. Note that Pair #6 was imaged without the 600mas coronagraphic spot due to the close separation of the binary.*

- From the 61 2nd-epoch observations of our targets, we have **discovered 6 bound M-dwarf companions (Fig. 3).**
- **Table 1** lists the separations and masses derived from the observations.
- These are some of the most extreme mass ratio stellar binary systems discovered.

Star/M Dwarf Pair	1st-Epoch Separation (")	2nd-Epoch Separation (")	ΔK (mag)	Mass (M_{Jup})
1	1.11	1.12	7.62	102
2	2.83	2.84	9.62	86
3	1.63	1.60	9.37	99
4	1.63	1.59	6.57	190
5	0.94	0.97	4.54	821
6	0.56	0.64	3.91	581

Table 1. *Details on the six newly discovered bound M-dwarfs.*

- Using the **BHAC15** evolutionary models for pre-main-sequence/main-sequence low-mass stars down to the hydrogen burning limit **[5]**, we determine posteriors for the companion masses based on their ages and magnitudes **(Fig. 4).**

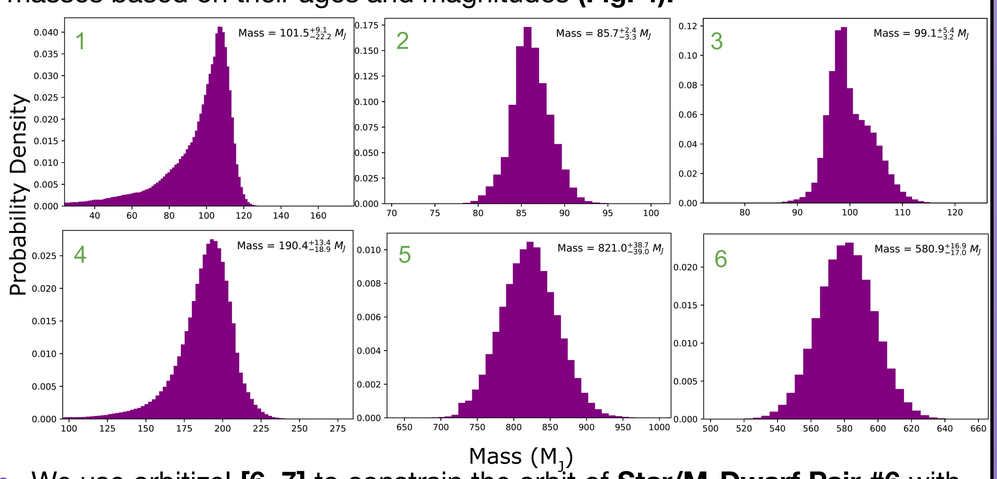

Figure 4. *Mass posteriors for each of the newly discovered M-dwarf companions. These were calculated by first randomly sampling age posteriors and Gaussian PDFs for parallax and K-band magnitude. The BHAC15 isochrones were then linearly interpolated for each sample.*

- We use orbitize! **[6, 7]** to constrain the orbit of **Star/M-Dwarf Pair #6** with the Markov-chain Monte Carlo orbit fitting algorithm. **Fig. 5 (right)** shows the spatial extent, separations and position angles for a sample of the calculated orbits. **Fig. 5 (left)** is a corner plot showing the semi-major axis, inclination, and total mass of the system with median values in blue.

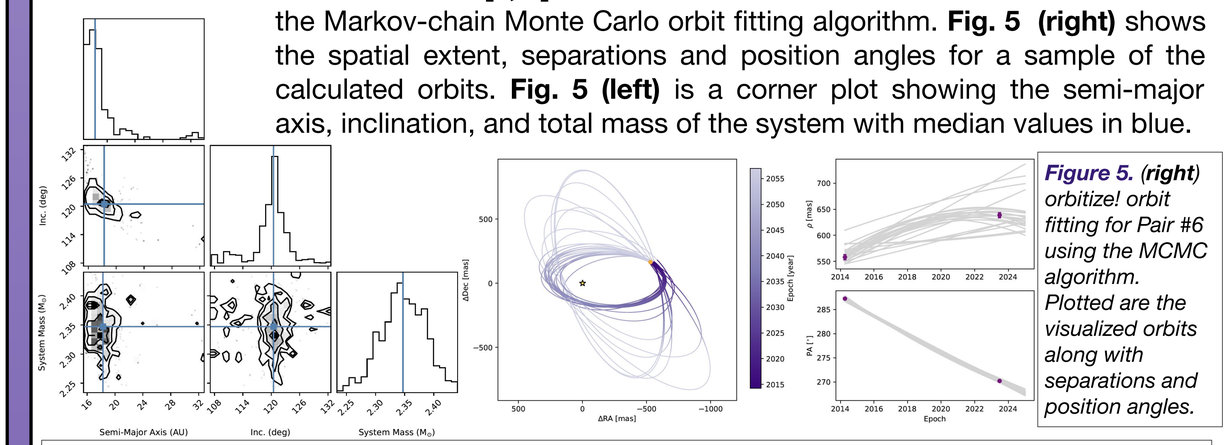

Figure 5. ***(right)*** *orbitize! orbit fitting for Pair #6 using the MCMC algorithm. Plotted are the visualized orbits along with separations and position angles.*

Figure 5. ***(left)*** *A corner plot showing the semi-major axis, inclination, and total system mass distributions from the MCMC orbitize! fit for Pair #6. The median values are semi-major axis = 18.3 AU, incl. = 120.5°, M_{Tot} = 2.347 $M_\odot$*

Future Work

- In the immediate future, we will finish **evaluating astrometry for the fainter candidates** that we already obtained 2nd-epoch observations for and determine if any are bound companions.
- We will also we also take observations of the 6 new bound M-dwarfs in other spectral bands (J+H+K) to **characterize spectral types** of the companions.
- **We will be obtaining 2nd-epoch observations for the remaining 16 targets** with candidates in the 2024A Keck observing semester.
- I am in the process of writing these results up for submission, with the goal of publication by the end of summer.

Stars Remaining to be Observed	Candidate Companions Remaining to be Evaluated
16	37

Table 2. *The number of remaining stars to be observed and candidate companions to be confirmed/rejected.*

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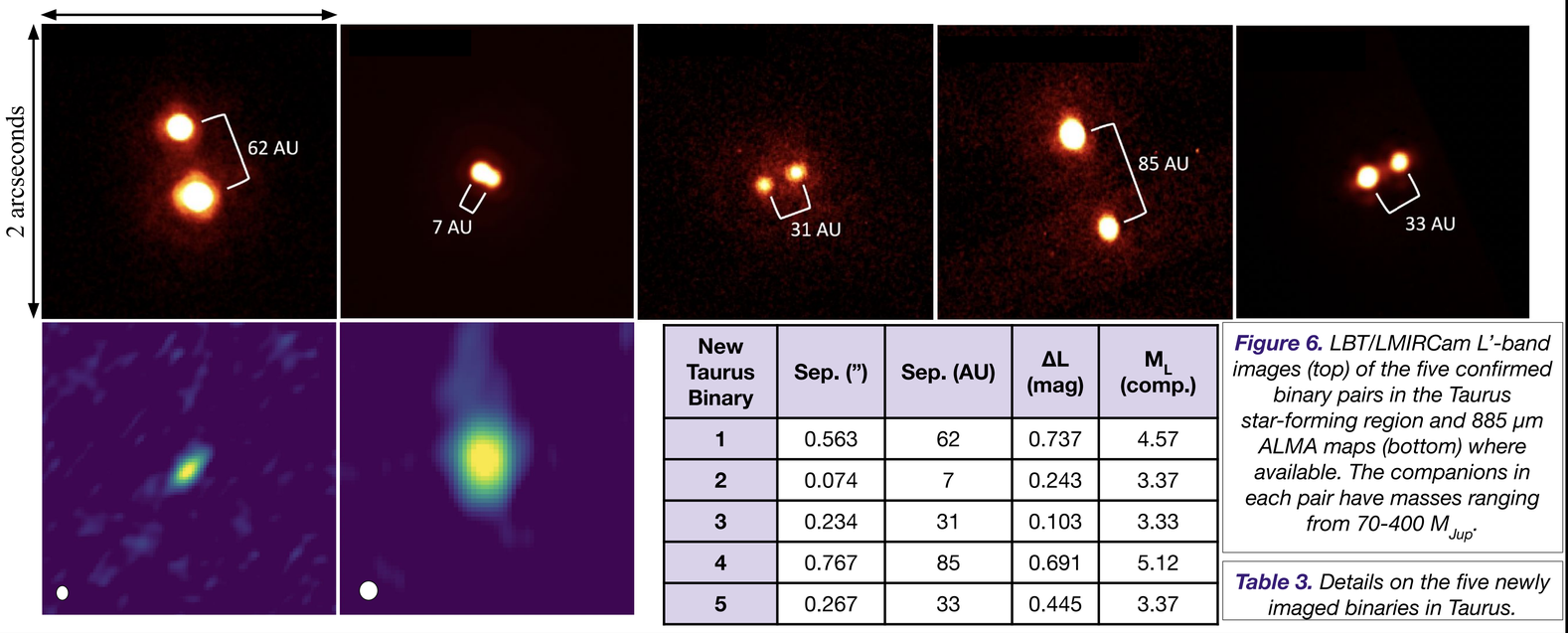
The Taurus Boundary of Stellar/Substellar Survey: New Low-Mass Binaries in Taurus

- The Taurus Boundary of Stellar/Substellar (TBOSS) Survey is a series of surveys searching for disks and companions around low-mass (M4–L0) objects in the Taurus star-forming region **[8, 9]**
- In contrast to CBASS, the goal of TBOSS is to find brown dwarfs and low-mass companions around low-mass hosts.
- Using the Large Binocular Telescope (LBT) and LMIRCam, we imaged 41 low-mass Taurus objects that lacked previous high-contrast imaging observations.
- From the sample of 41 targets, we have **discovered 5 bound low-mass companions (Fig. 6). 4/5 of these pairs are new discoveries, along with corresponding 885 μm ALMA maps where available.**
- **Table 3** lists the separations and magnitudes derived from the observations.
- I am in the process of determining mass estimates for the new companions, but initial comparison to models suggests one of the new companions is within the brown dwarf mass range.



New Taurus Binary	Sep. (")	Sep. (AU)	ΔL (mag)	M_L (comp.)
1	0.563	62	0.737	4.57
2	0.074	7	0.243	3.37
3	0.234	31	0.103	3.33
4	0.767	85	0.691	5.12
5	0.267	33	0.445	3.37

Figure 6. *LBT/LMIRCam L'-band images (top) of the five confirmed binary pairs in the Taurus star-forming region and 885 μm ALMA maps (bottom) where available. The companions in each pair have masses ranging from 70-400 M_{Jup}.*

Table 3. *Details on the five newly imaged binaries in Taurus.*