Sub-stellar Companions and Stellar Multiplicity in the Taurus Star-Forming Region

A High-Contrast Survey

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We have conducted a large, coherent survey for sub-stellar companions and stellar multiplicity of Taurus stars of all masses. It uses high-spatial resolution NIRI/Gemini North adaptive optics imaging in K-band, allowing us to detect companions as close as 0.07" out to 12" (corresponding to **~10 AU–1500 AU** at the distance of Taurus) with **masses down to ~1 M_{Jup}**.

We observed a sample of 73 stars in the Taurus-Auriga star-forming region, aiming to detect very low-mass companions to stars which were drawn from an **unbiased sample**. The final sample equally covers targets from the most massive Taurus members (> 3 $M_\odot$) to the lowest masses close to the sub-stellar limit.

From a total of 275 Taurus members[1], we randomly selected 10–15 in five equal logarithmic mass bins, respectively. The bins span the whole range of masses of Taurus stars between ~0.15 and ~4 $M_\odot$. *No other selection criteria were applied.*

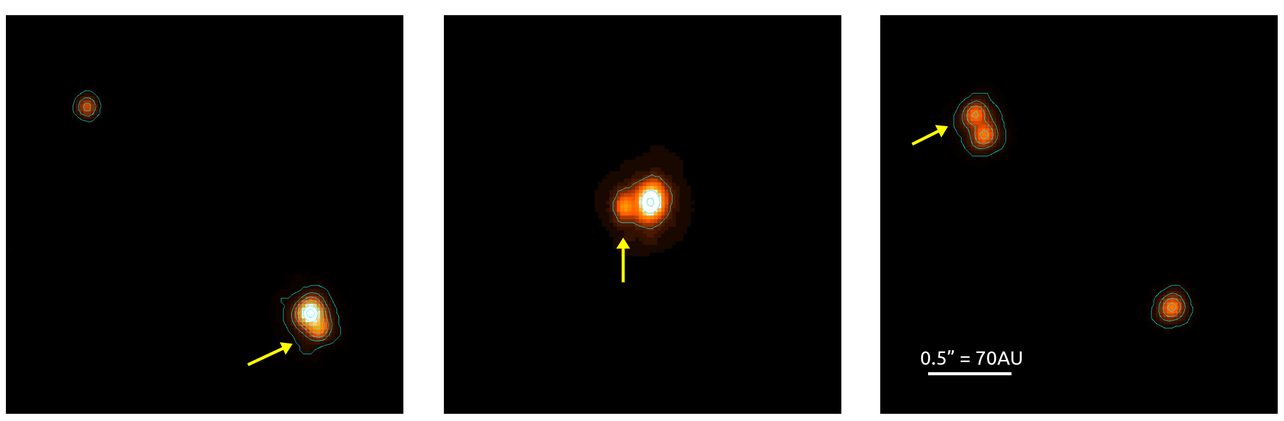

Fig. 1: NIRI/Gemini K-band images of three of the four newly discovered close-in companions.

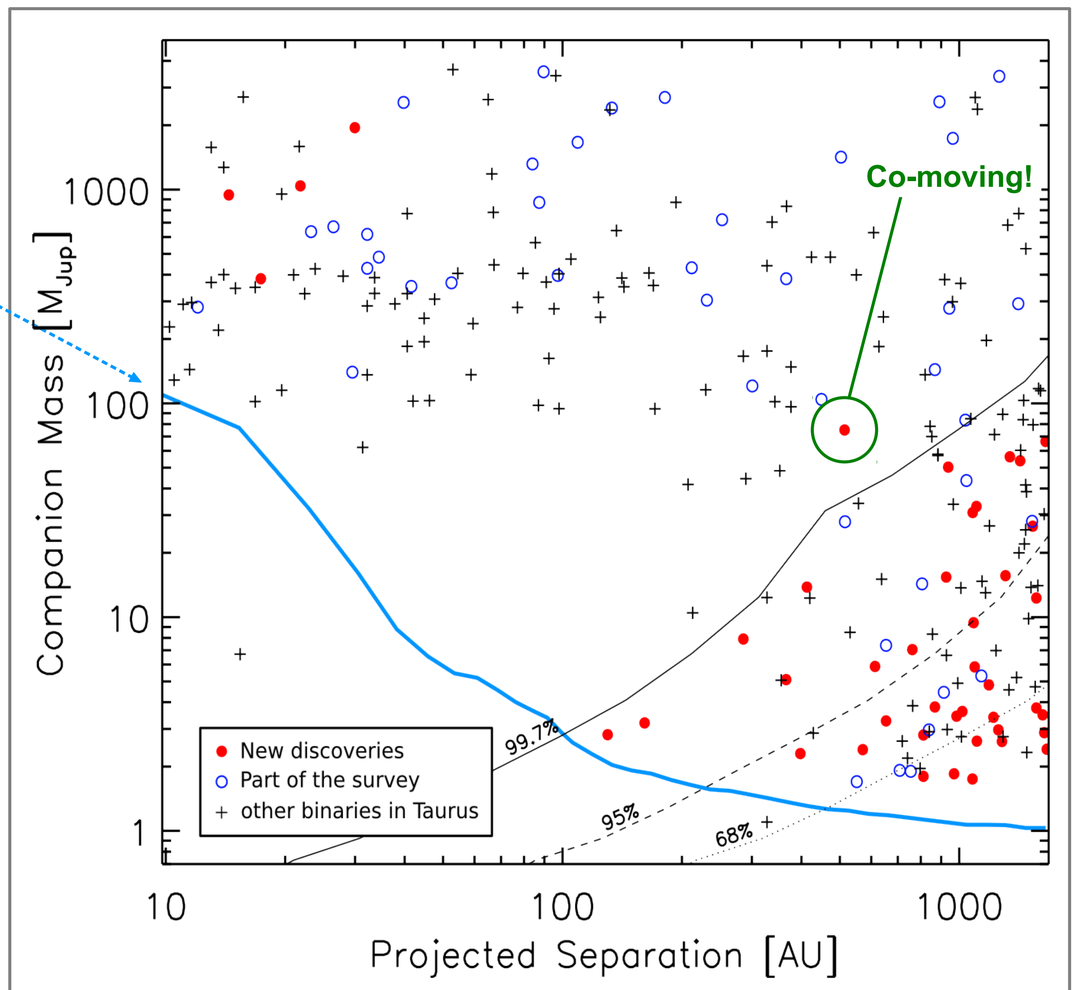

Fig. 2: Companion candidate masses as a function of projected orbital separation. The bold blue line marks our median 5σ detection limit. Companions above the thin black curves have a median probability of being physically bound to their host star of >99.7%, >95%, and >68% respectively.

We detected a total of 91 companions candidates to 48 stars. Out of these,

- → four previously unknown bona fide binary companions (**Figure 1**),
- → one co-moving ~75 M_{Jup} brown dwarf companion 400 AU from an F8 star, and
- → 22 additional faint companion candidates that, if they prove to be physically bound to their host stars, have masses **between 1 and 80 Jupiter masses**.

The findings are illustrated in Figure 2.

Preliminary results benefit from the survey's sensitivity to a large range of separations and primary masses. It allows us to explore aspects of the formation and evolution of stars at the age of Taurus (~1–2 Myr) in a wide parameter range:

- → The **multiplicity fraction** of Taurus was determined to be **47±8%** within our 90% completeness limits. This number accounts for the fact that many of our detections have a probability 0<P<1 that they are physically bound. This is slightly lower than previous findings[2].
- → **Higher order multiples**, i.e., systems with three or more components, were detected for **7–35%** of the sample. (Since we currently exclude possible wide tertiary companions outside the NIRI field of view, this is a lower limit)
- → We do not find a significant **correlation of multiplicity fraction with primary mass** (Figure 3)**.**

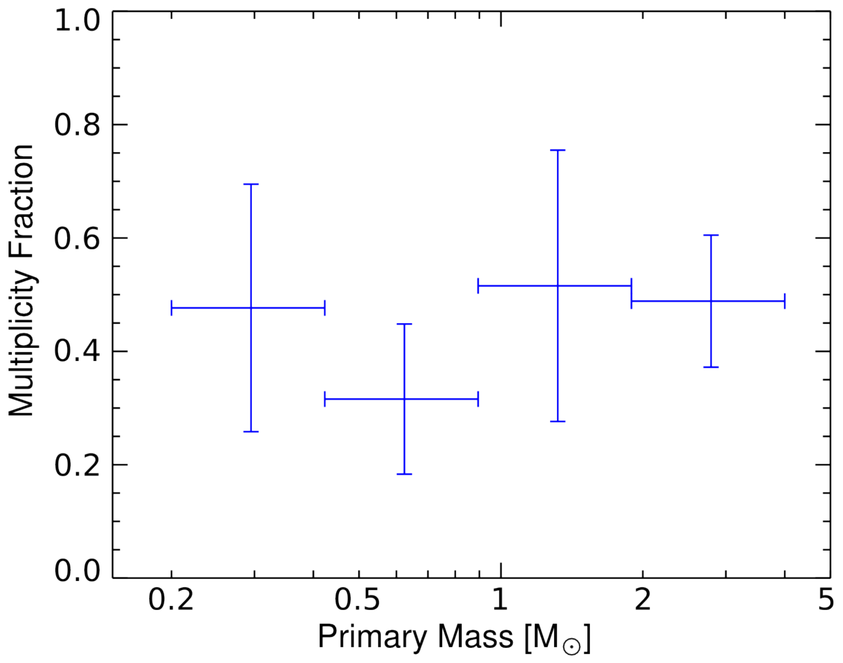

Fig. 3: Multiplicity fraction of Taurus companions as a function of primary mass. The calculations take into account individual probabilities that any of the companions may be a background star. The horizontal error bars show the bin sizes of the four individual measurements.

Analysis of this new data set is currently in progress. In addition to the above, the data will be used to discuss various aspects of multiple star formation, including the following:

- → **Mass ratios –** this survey extends the range of accessible mass ratios to q≈0.01 at separations ≥100 AU.
- → **Separation distribution –** Together with previous high-spatial resolution observations, e.g., using aperture mask interferometry[3], separations from a few tenth of an arcsecond to 12 arcseconds can be accessed with high sensitivity for companion masses in the planetary regime.

Future observations will be required to distinguish the newly discovered companion candidates with a high probability of being background objects (bottom right of Fig. 2) from physically attached companions. New imaging obervations are scheduled for late 2013 and all co-moving companion candidates will be followed-up with spectroscopic observations to confirm their brown dwarf or planetary nature.

REFERENCES:

[1] various sources (for a complete list see Daemgen et al. 2013, in prep.)

[2] Duchêne & Kraus 2013, ARA&A, 51

[3] Kraus et al. 2011, ApJ, 731, 8