HST to JWST: Investigating Multiplicity in Orion

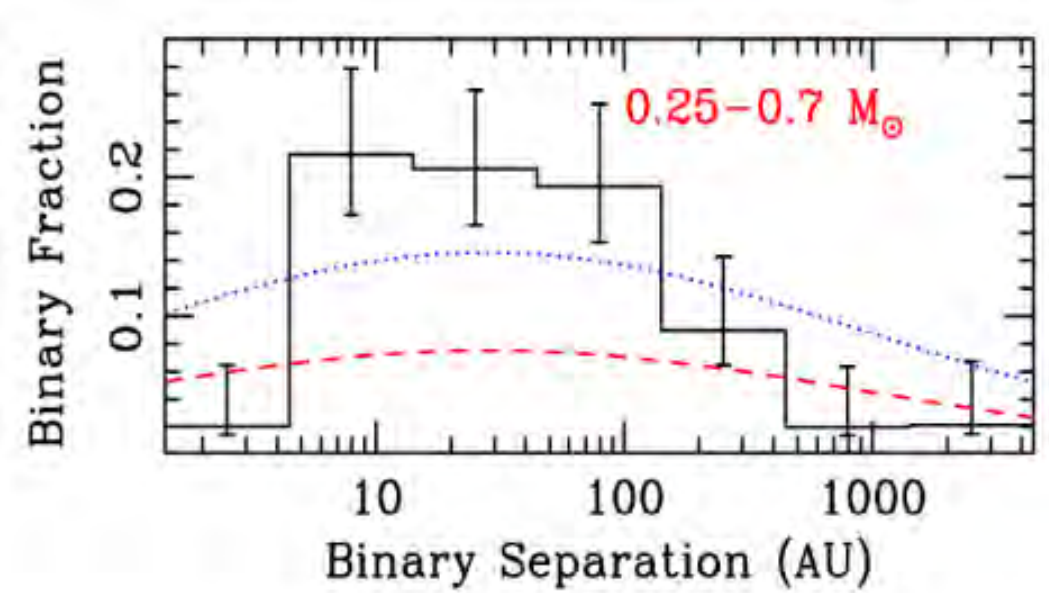
Matthew De Furio

University of Michigan

Collaborators: Michael Meyer (UM), Megan Reiter (UKATC), Alexandra Greenbaum (Draper Lab), Adam Kraus (U-Texas), Trent Dupuy (Gemini), and NIRCam Star and Planet Formation Team

A Long-Standing Puzzle

- Young, low-mass associations (e.g. Taurus) contain excess of binaries relative to Galactic Field
- Over q from 0-1 and a from 3 – 5000 AU for low-mass primaries: Companion Frequency in Taurus ~ 2x Field
- Do dynamics sculpt binary populations? (Kroupa 1995)
- What about high density regions?
  - Dynamical interactions more likely
  - Could affect fragmentation



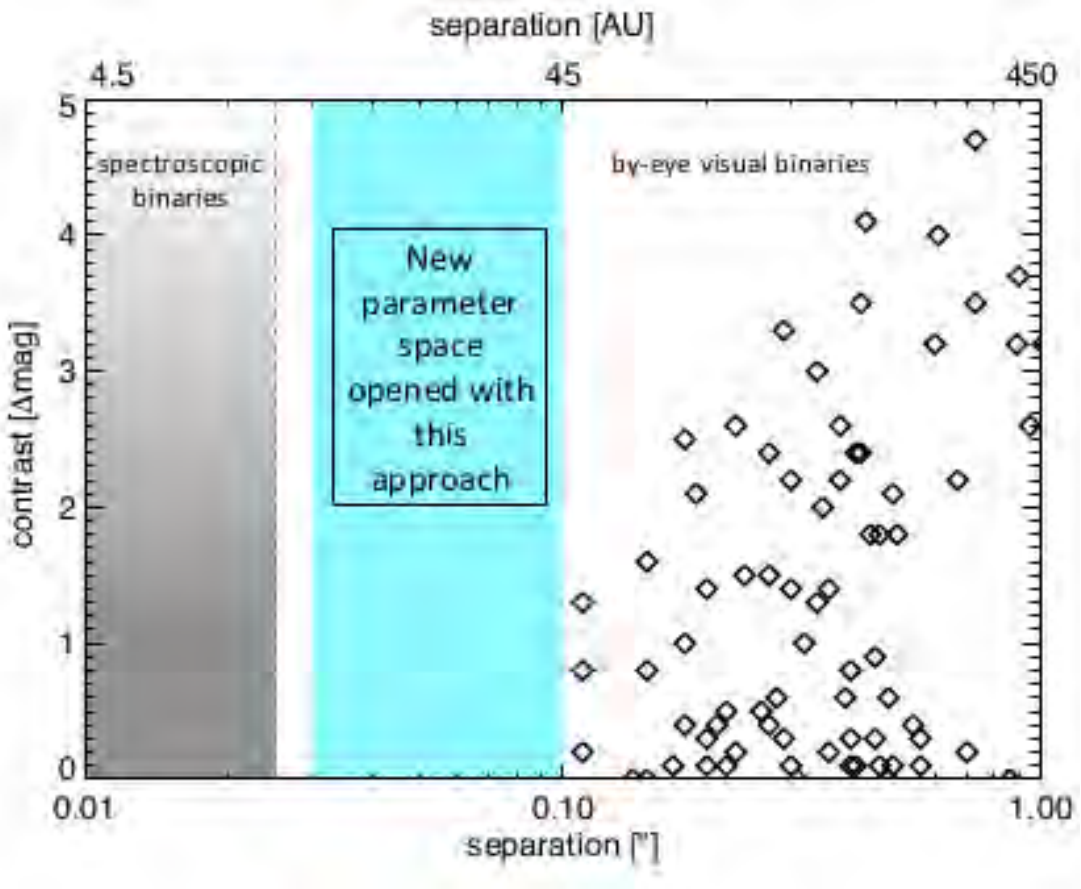
Red line is log-normal fit to Field from Duquennoy & Mayor 1991

Blue line is log-normal fit to Taurus from Kraus et al. 2011

Figure: Kraus et al. 2011

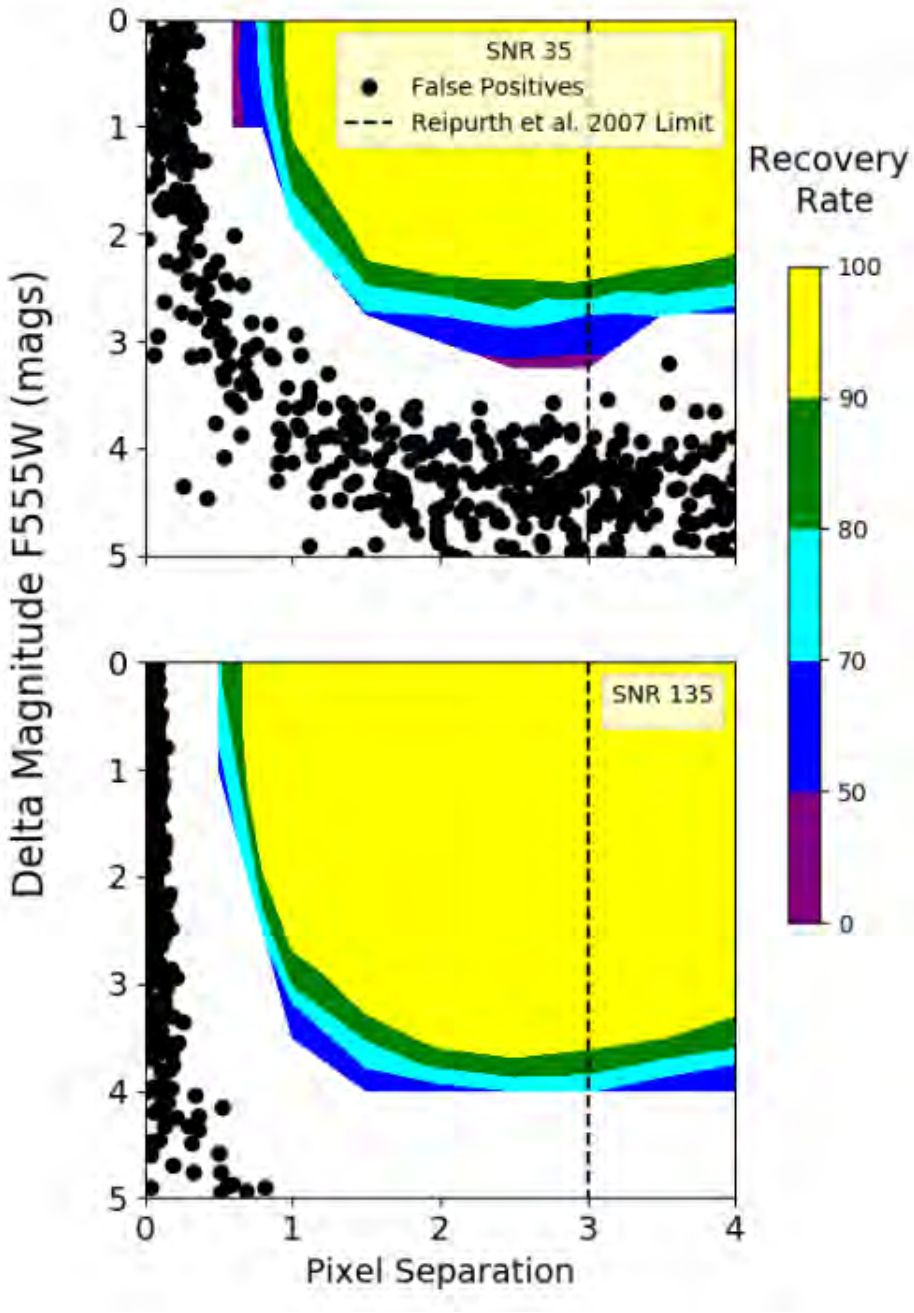
Studying M-star binaries in the ONC

- Past surveys identify binaries at a > 65 AU and a < 10 AU
- M-stars are important for dynamics because most in number and mass
- No large sample survey of M-star primaries exists
- HST Treasury Program on ONC (Robberto et al. 2013)
- Representative M-star sample from Da Rio et al. 2016 membership survey



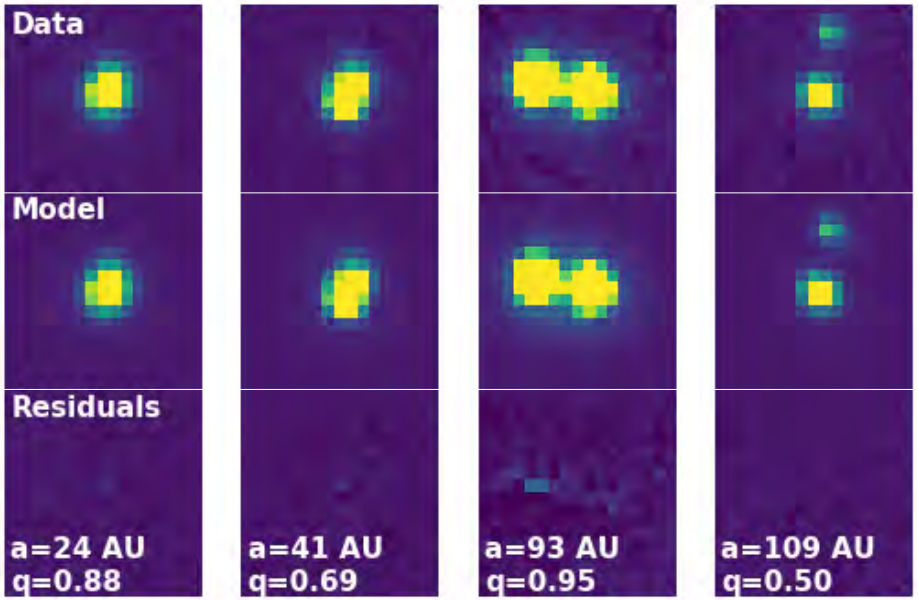
Finding Companions

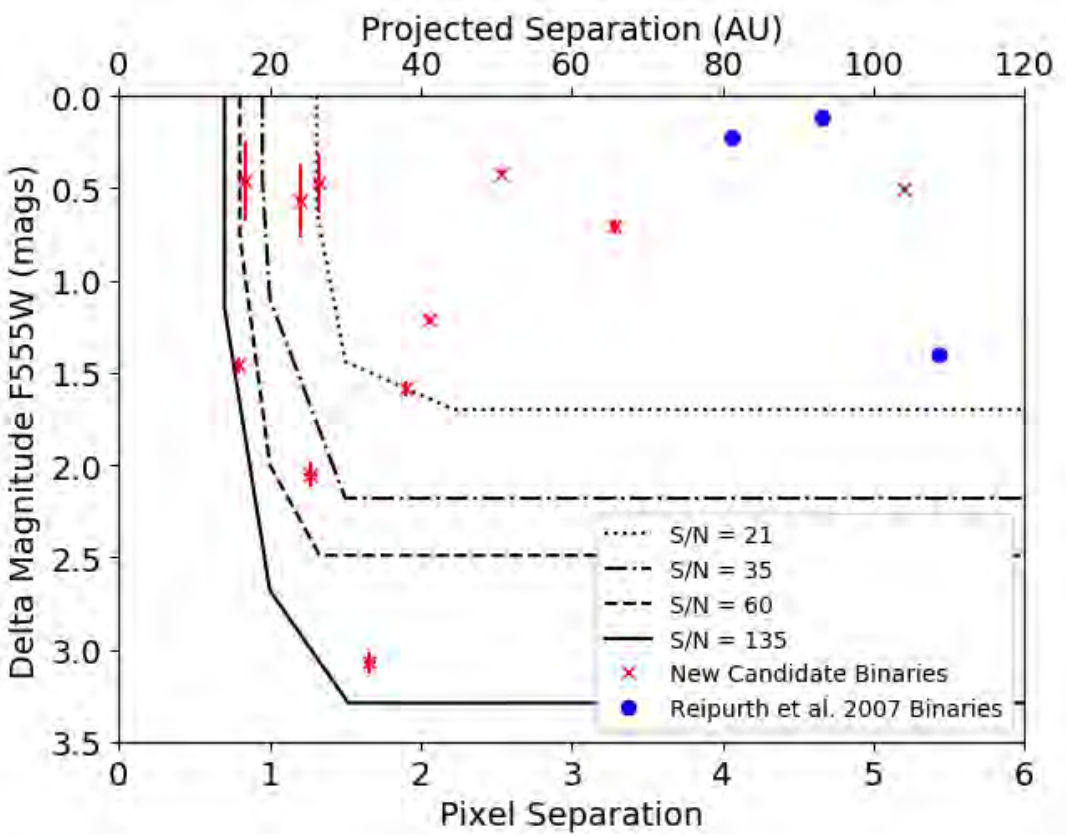
- Anderson & King 2006 developed position-dependent empirical PSFs for ACS
- We created a binary PSF-fitting algorithm
  - Artificial binaries test the sensitivity based on S/N, contrast, and separation
  - 90% recovery rate is detection threshold
  - False positives? Not an issue!
  - Result: 4x better resolution than previous wide-field surveys (e.g. Reipurth et al. 2007)



We Found 11 New Binaries

- 101 M-star sample
- 14 companions detected



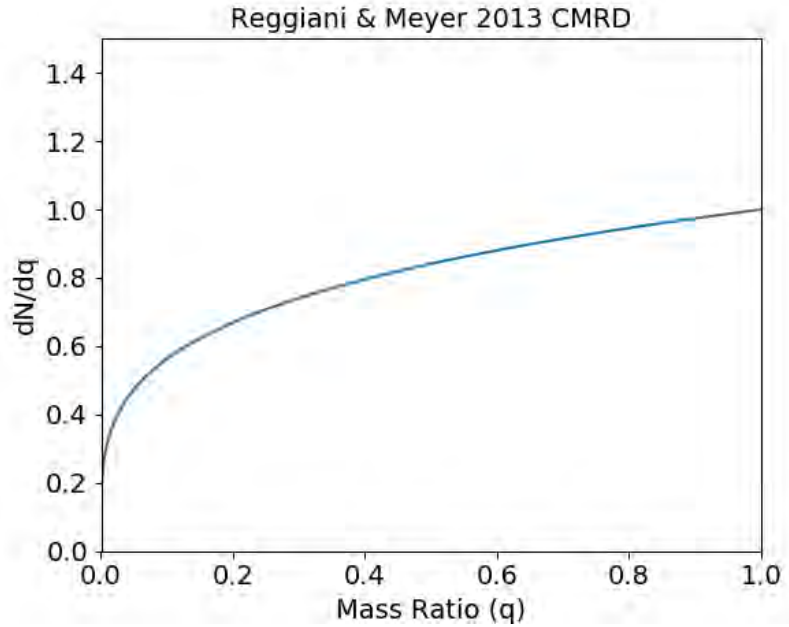


Calculating Galactic Field Companion Frequency

- Companion Mass Ratio Distribution (CMRD):

$$\frac{dN_1}{dq} \propto q^{\beta}$$

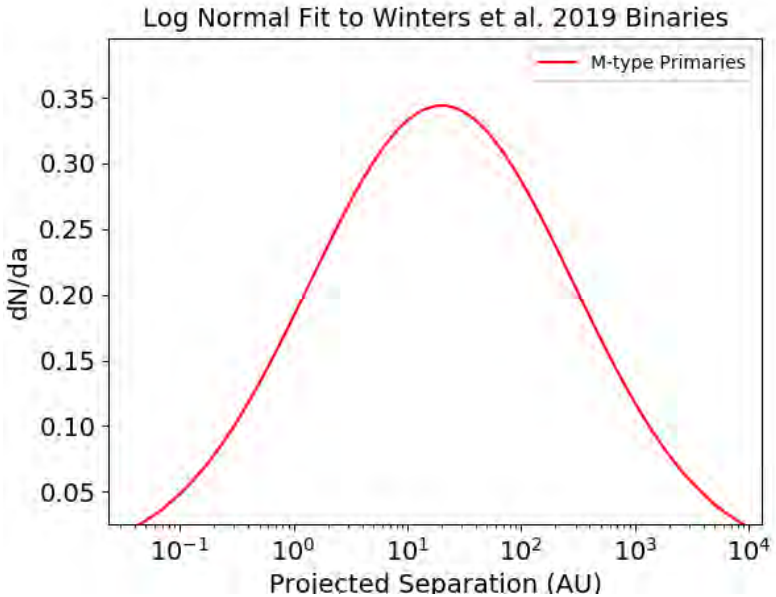
β = 0.25 ± 0.29
Reggiani & Meyer 2013



- Surface density distribution:

$$\frac{dN_2}{da} = \frac{1}{a} e^{-\frac{log(a)-log(\bar{a})}{2\sigma^2}}$$

ā = 20 AU, σ_{loga} = 1.16
Winters et al. 2019



- Expected Companion Frequency:

$$CF = C_n * \int_{q_1}^{q_2} \frac{dN_1}{dq} \int_{a_1}^{a_2} \frac{dN_2}{da}$$

Janson et al. 2012

Comparison to Galactic Field

- For low-mass stars, over common q of 0.6 - 1 and a of 30 - 160 AU
  - Field = 6.5 ± 3%, ONC = 8 ±4/2%
  - ONC to Field: 0.4σ (M_{prim} = 0.1 – 0.6 $M_{\odot}$)
  - ONC to Taurus: 1.3σ (M_{prim} = 0.25 – 0.6 $M_{\odot}$)

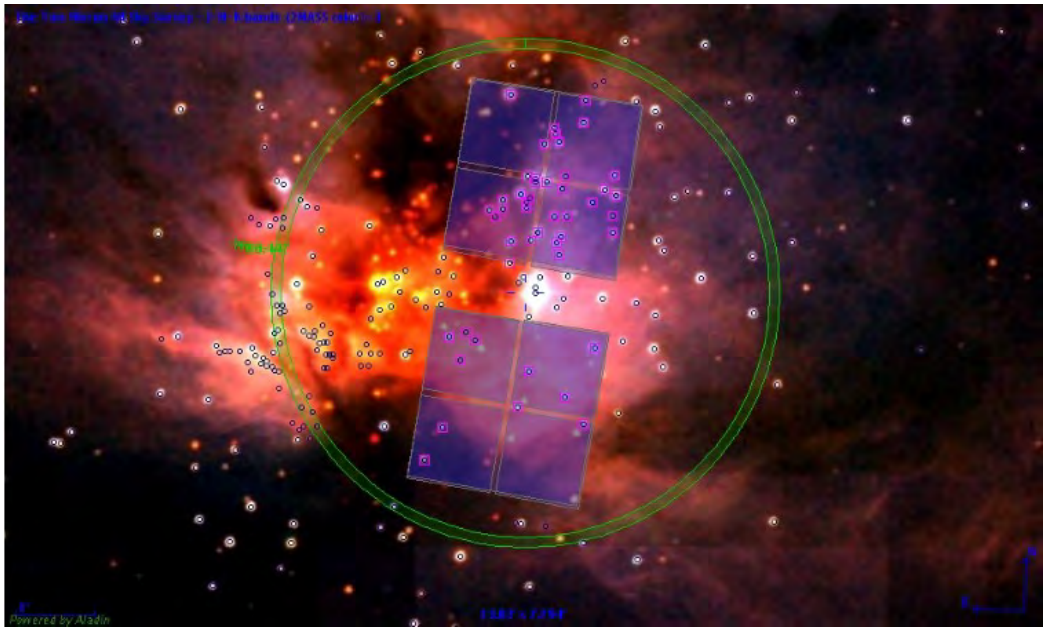
- Taurus to Field: 3.0σ over all q and 3-5000 AU for low-mass primaries

- No evidence for binary excess in ONC relative to the Field

- Further dynamical evolution of ONC not required to resemble the Field as theorized for young star clusters

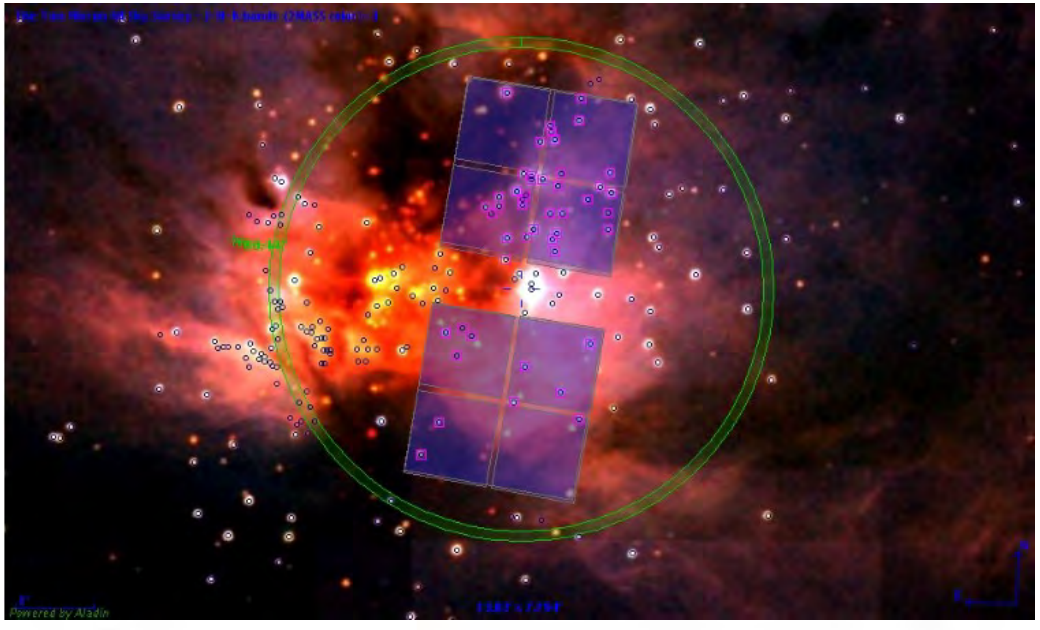
NIRCam GTO Imaging of NGC 2024

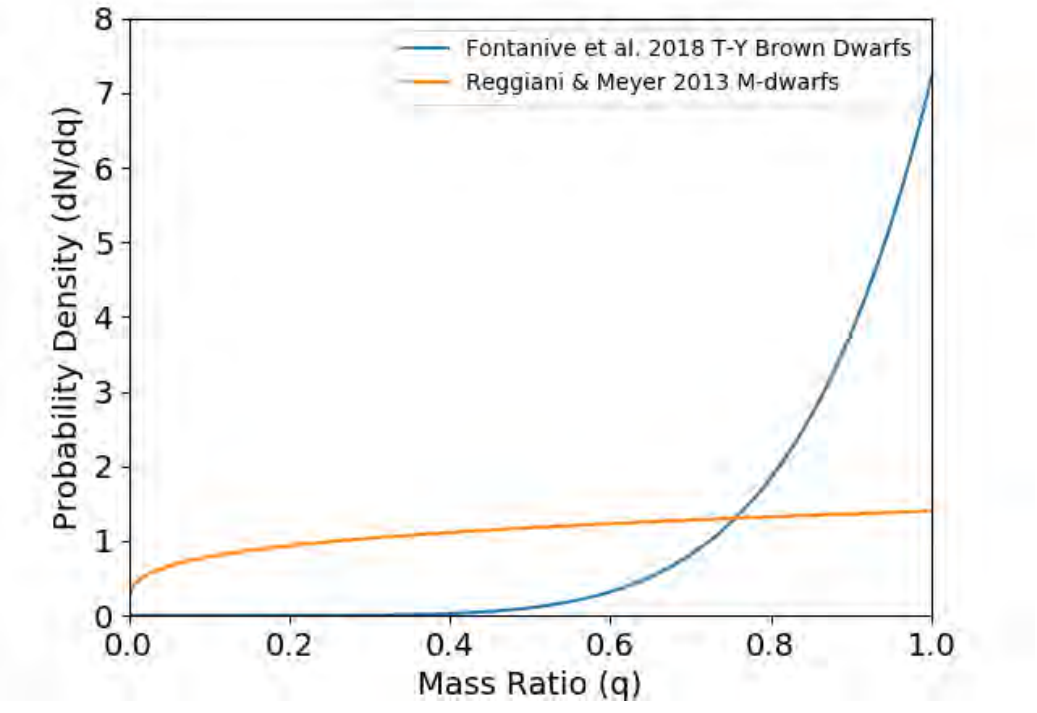
- 8 filters for 2.1 hr each
- Determine T_{eff}, log(g), and A_V, filter out Field stars
- Expect dozens of 2-20 M_J
- Follow-up with NIRSpec to confirm membership, T_{eff}, and abundances



Value of JWST in Star Clusters

- See deeper in A_v for more sources and probe diverse (central) regions of cloud core
- Extend companion studies to lower q
- Probe binary properties of brown dwarf primaries
- Is brown dwarf CMRD peaked at unity? Fontanive et al. 2018
- Is there a distinct formation process for BDs vs. stars?





Summary

- Empirical PSF-fitting can find companions at separations below the diffraction limit
- We identified 14 companions in the ONC
- ONC does not have an excess of binaries relative to the Field over q = 0.6 - 1.0 and a = 30 - 160 AU
- Plan to exploit technique on other SFRs
- JWST will reach lower primary mass, and wider range of q, exploring differences between BD and star formation