HST to JWST: Investigating Multiplicity in Orion

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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):
  \[
  \frac{dN_1}{dq} \propto q^\beta
  \]
  \[\beta = 0.25 \pm 0.29\]
  Reggiani & Meyer 2013

- Surface density distribution:
  \[
  \frac{dN_2}{da} = \frac{1}{a} e^{-\frac{\log(a) - \log(\bar{a})}{2\sigma^2}}
  \]
  \[\bar{a} = 20 \text{ AU}, \sigma_{\log a} = 1.16\]
  Winters et al. 2019

- Expected Companion Frequency:
  \[
  CF = C_n \times \int_{q_1}^{q_2} \frac{dN_1}{dq} \int_{a_1}^{a_2} \frac{dN_2}{da}
  \]
  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 \( (M_{\text{prim}} = 0.1 - 0.6 \, M_{\odot}) \)
  - ONC to Taurus: 1.3σ \( (M_{\text{prim}} = 0.25 - 0.6 \, M_{\odot}) \)

- 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
8 filters for 2.1 hr each

- Determine $T_{\text{eff}}$, log($g$), and $A_V$, filter out Field stars

- Expect dozens of 2-20 M$_J$

- Follow-up with NIRSpec to confirm membership, $T_{\text{eff}}$, 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