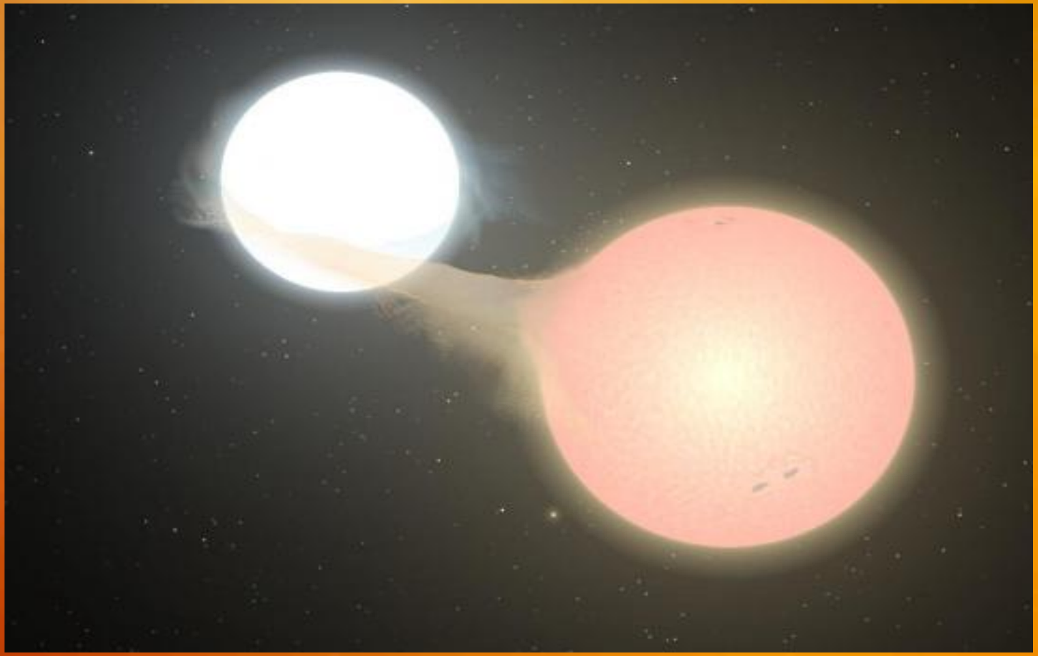
The binarity of young massive stars



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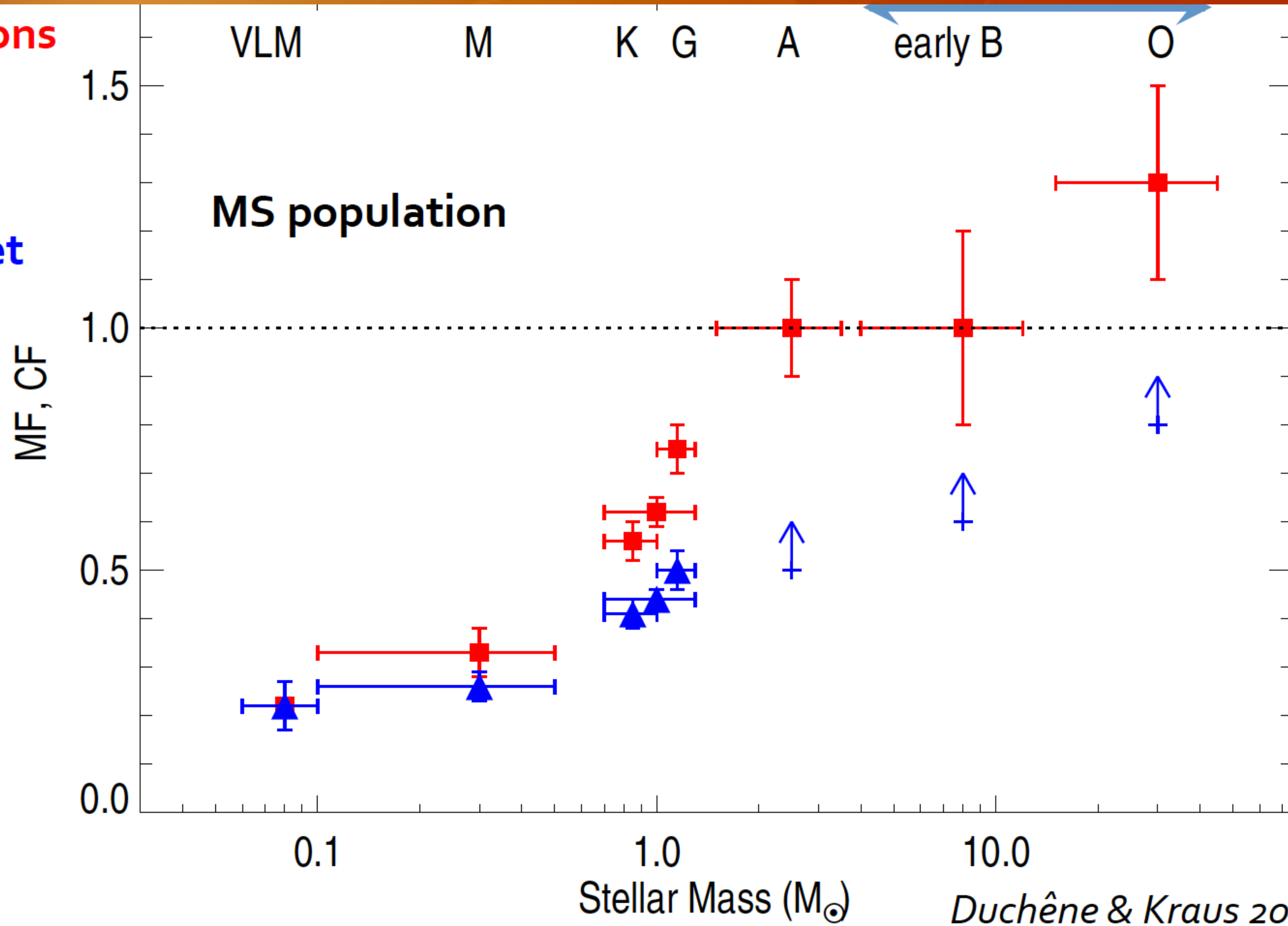
(ESO, Chile)

Multiplicity vs. Stellar Mass

# of companions per target

# of multiple system / target

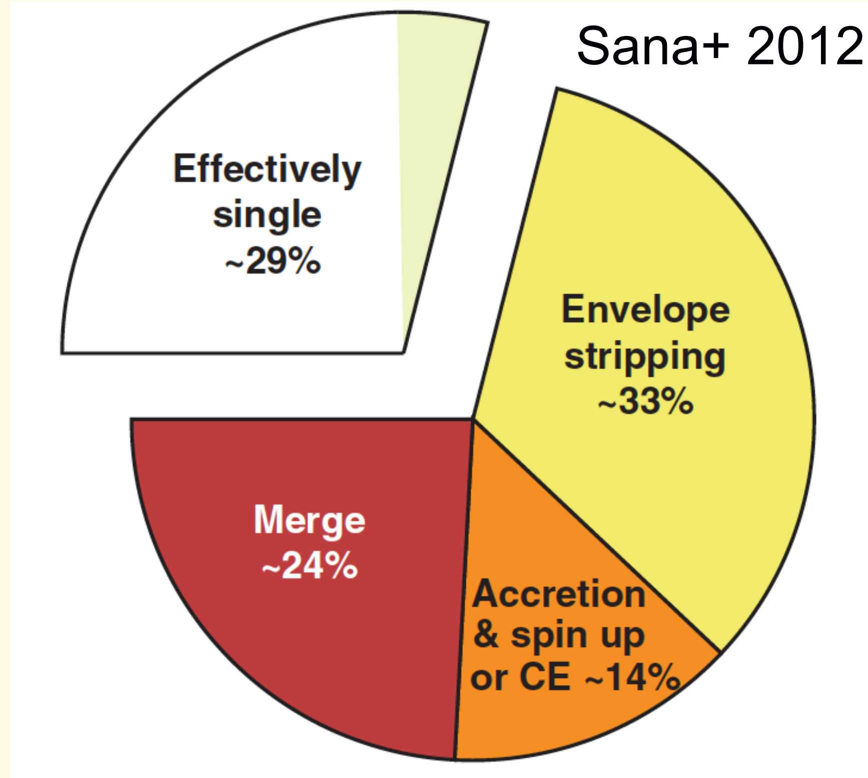


Duchêne & Kraus 2013

Why study (massive) binary stars?

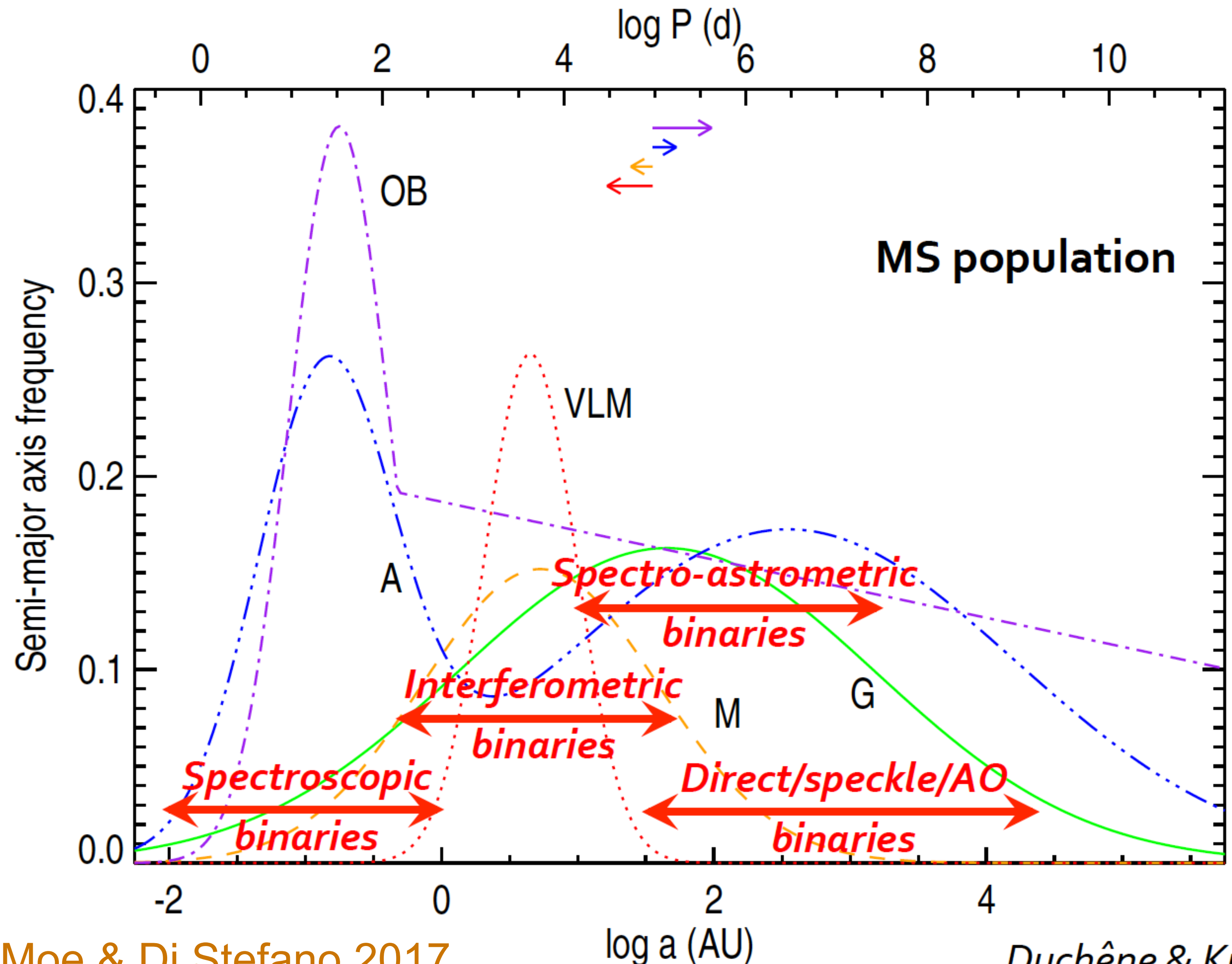
- Importance for stellar evolution
- Only “evolved” fractions known
- Need to go to young objects
- Formation mechanism & its details largely unknown :
  - capture,
  - (disk) fragmentation
  - (with added migration)

  (Krumholz+ 2009; Rosen+ 2016; Lund & Bonnell 2018; Meyer+2018, Poster Kuiper)



- Theory needs to be informed by observations of young stars
- This talk concentrates on the youngest, massive binaries

Need many complementary techniques to sample all separations



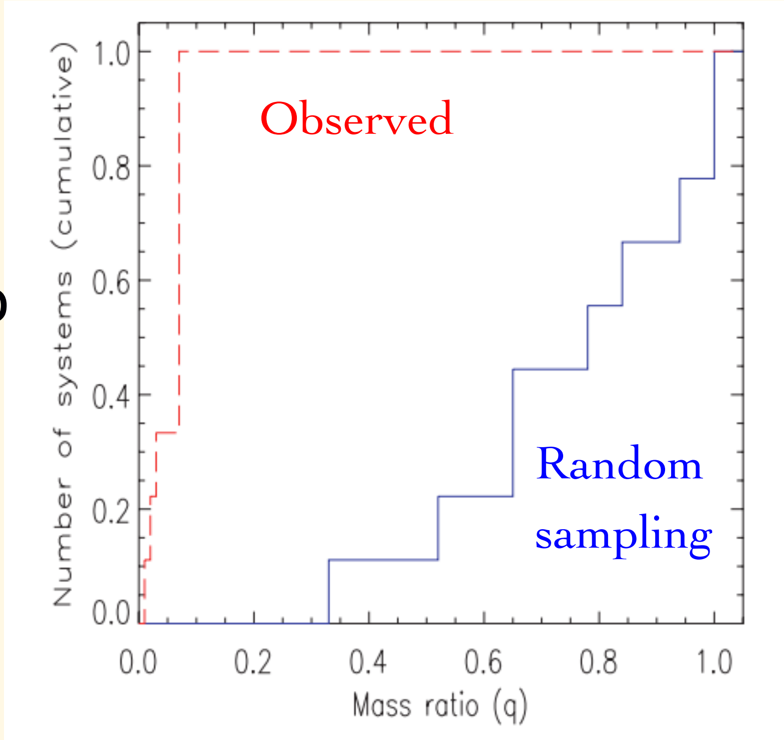
See also Moe & Di Stefano 2017

Duchêne & Kraus (2013)

Binary studies in massive pre-Main Sequence stars

Studies of most massive embedded Massive Young Stellar Objects limited to individual cases, eg. Kraus+ 2017's VLTI data reveal a 60 milli-arcsec/170 au massive binary

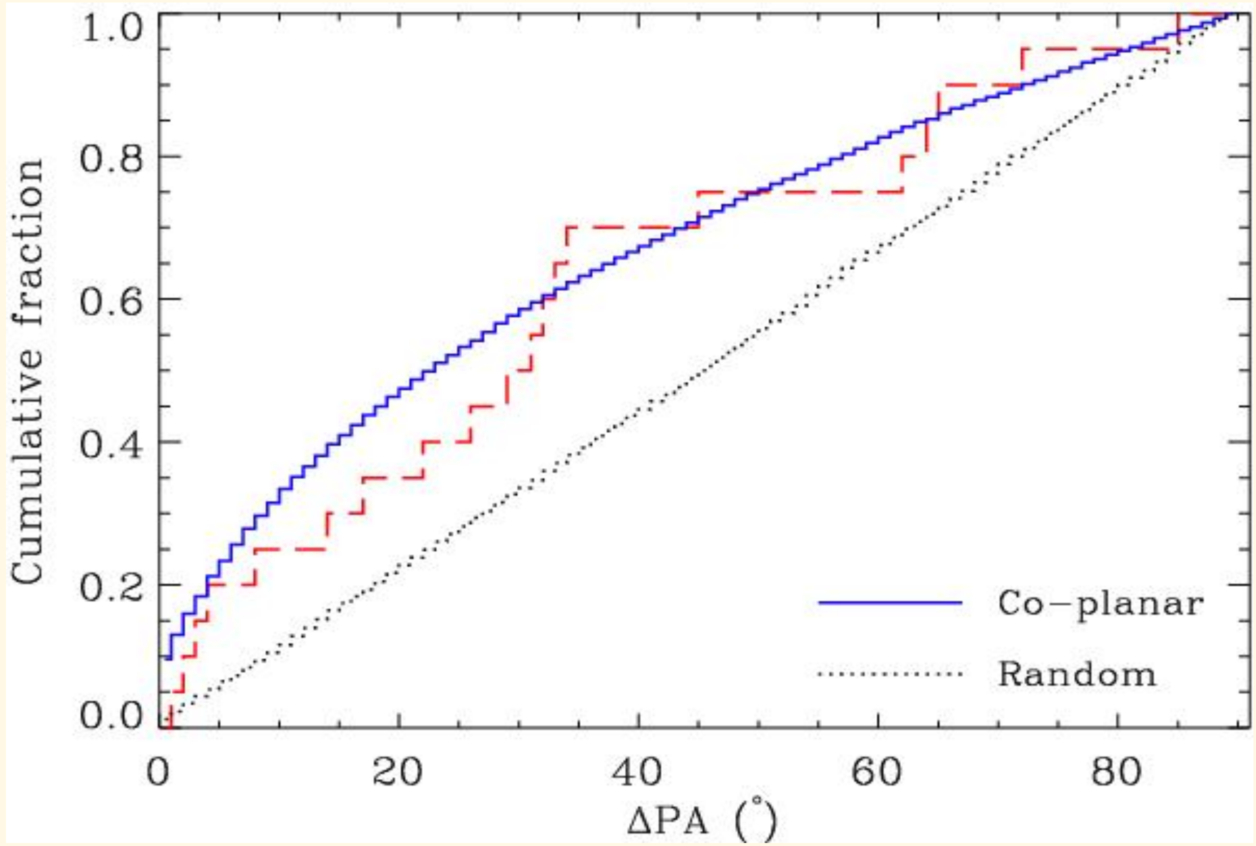
- Survey that comes closest in mass: 50 intermediate mass Herbig Ae/Be stars observed with spectro-astrometry (≈10s to 1000s au, Baines+ 2006).
- Total binary frequency of 74±6%
- Field star frequency smaller in probed regime



For 14 objects for which spectral types could be determined separately: Mass ratio close to 1, inconsistent with random sampling from IMF – Wheelwright+ 2010

Disk orientations vs. binary position angles:

Primary disks are co-planar with binary orbits



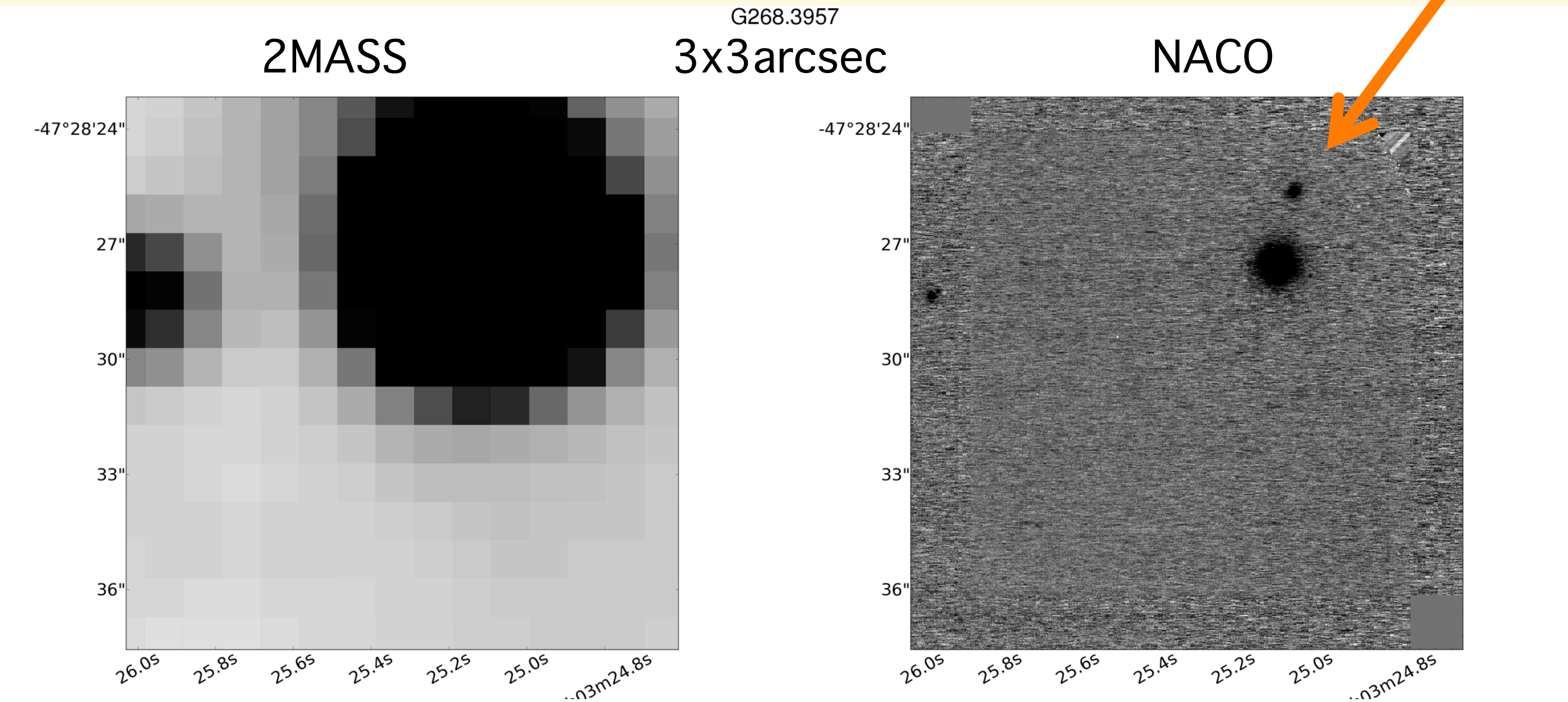
⟶ Disk fragmentation, not capture, is route to high mass stars/binaries

Wheelwright+ 2011

Going to even younger, more massive stars

From Leeds/RMS survey (Lumsden+ 2013) observed 32 MYSOs in 2015/16, masses in range 10-20 $M_{\odot}$

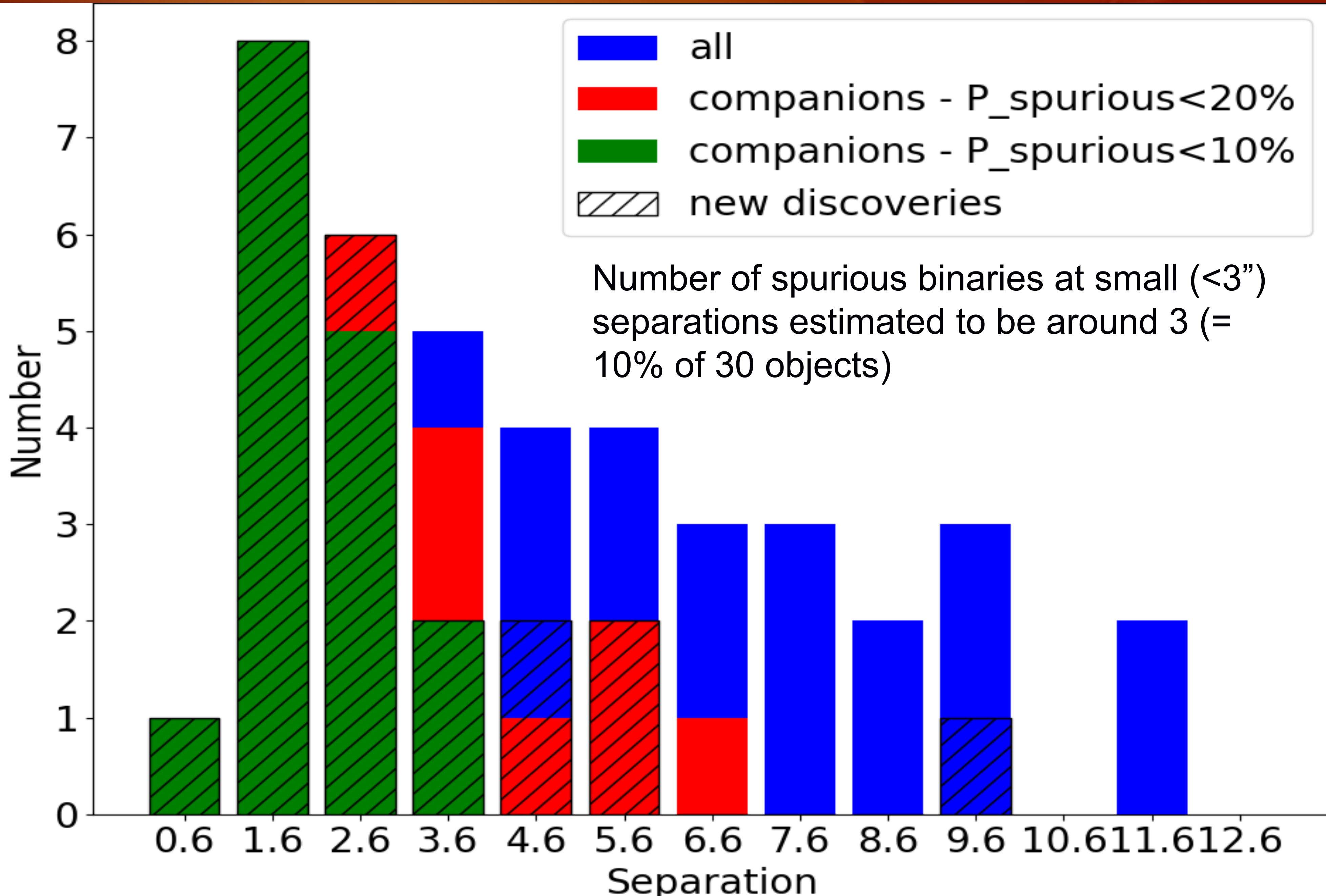
VLT/NACO *K*-band 0.1”, depth ~4-7 mags fainter than main target. Typical minimum observable separation 0.2-0.4”

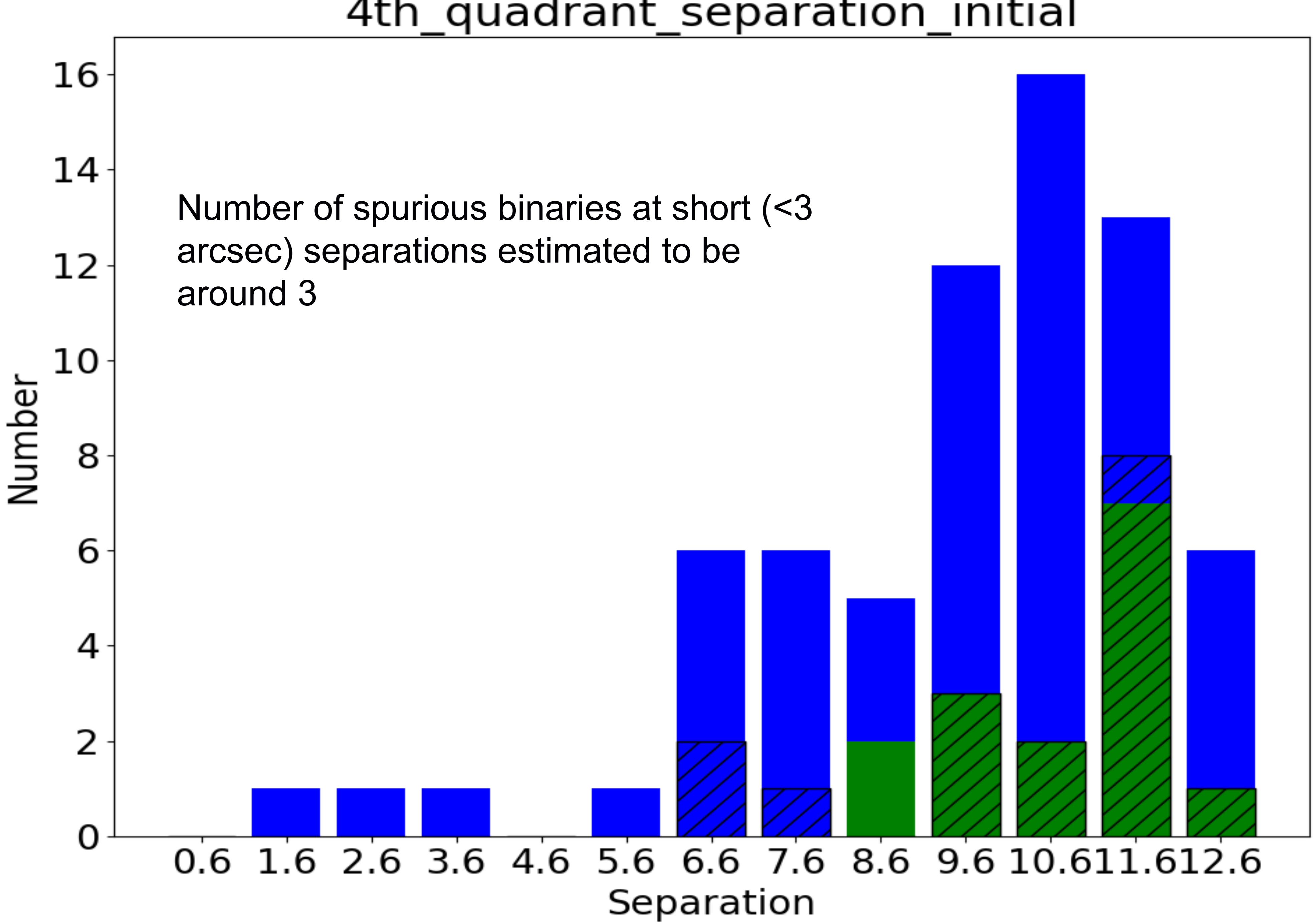


Pomohaci+ 2018 subm.

NB VISTA/UKIDDS saturated

Many sources in the fields:



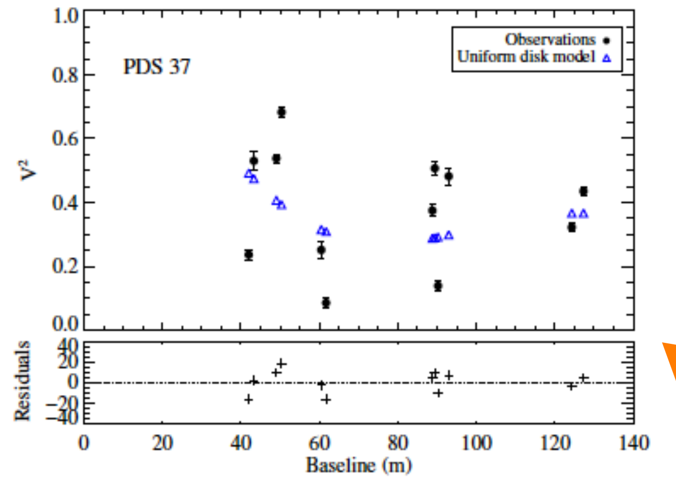

4th_quadrant_separation_initial
Number of spurious binaries at short (<3 arcsec) separations estimated to be around 3
Number
0
2
4
6
8
10
12
14
16
Separation
0.6
1.6
2.6
3.6
4.6
5.6
6.6
7.6
8.6
9.6
10.6
11.6
12.6

Results

Pomohaci+ 2018 submitted

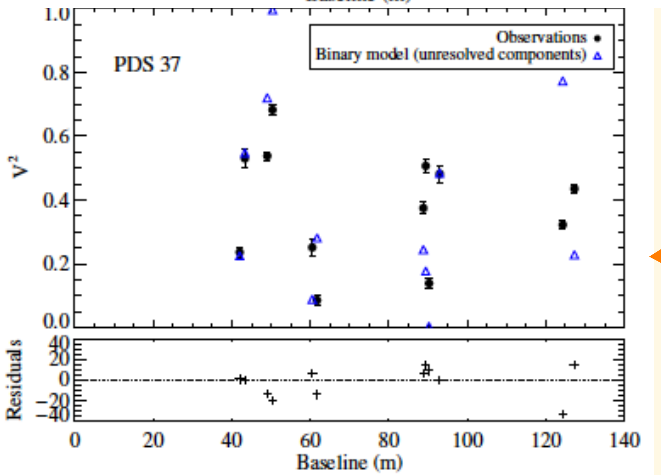
- Various tests indicate that newly discovered sources in frames are associated with MYSOs.
- Parameter space: separation range 500-8000 au, $\Delta K \approx 7$
- Binary fraction 31±8% ; Companion fraction 53±9%
- Based on distance, A_V and (single) *K*-band photometry, limits on companion masses determined. Highly uncertain, but consistent with $q>0.5$
- First steps taken, but is clear large binarity at 1000s au scale.
- ***Future :***
- Characterisation companions, multi-wavelength observations
- Probing smaller separations: VLTI / Gravity – some preliminary results on following slides

The highest resolutions: VLTI/Pionier data at *H*-band of 2 RMS MYSOs

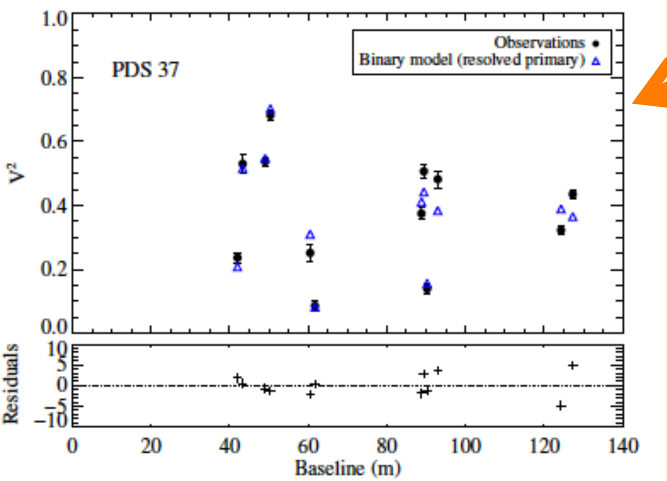


Sparse data, but probing at milli-arsec scales. PDS 37, Koumpia, Oudmaijer+ 2018 in prep.

Best fitting uniform single source + disk model to visibility data, 7 mas diameter.



Best fitting point source binary model



Best fitting binary model with a resolved primary object (disk).

Separations PDS 27 ≈12 mas (30 au).

PDS 37 ≈22-28 mas (42-54 au)

Consistent with RV data.

Conclusions

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- ★ Data on intermediate mass Herbig Ae/Be stars consistent with disk fragmentation
- ★ Data on Massive Young Stellar Objects only being collected now
- ★ Scales of 1000s au, binary fraction already of 30%, suggesting the 100% fraction in massive, more evolved stars, can be primordial
- ★ Both multiplicity and companion fraction higher than in comparable parameter space for low mass pre-MS objects and high mass MS stars
- ★ Limits on mass ratio indicate $q > 0.5$
- ★ Interferometry: reveals closest MYSO binaries known to date
- ★ Follow-up planned