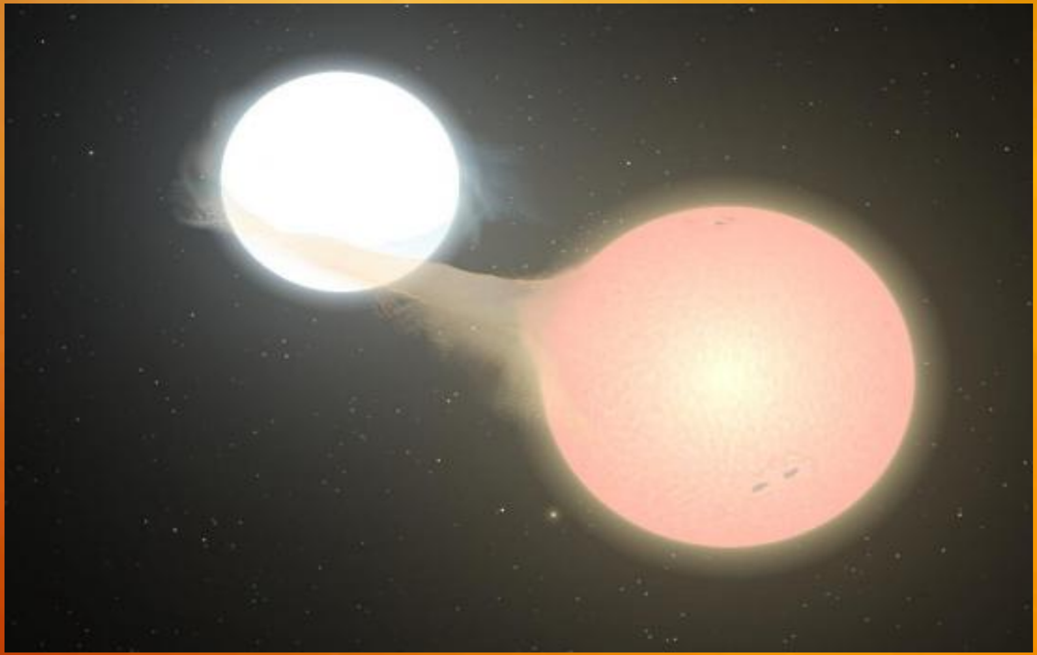
The binarity of young massive stars



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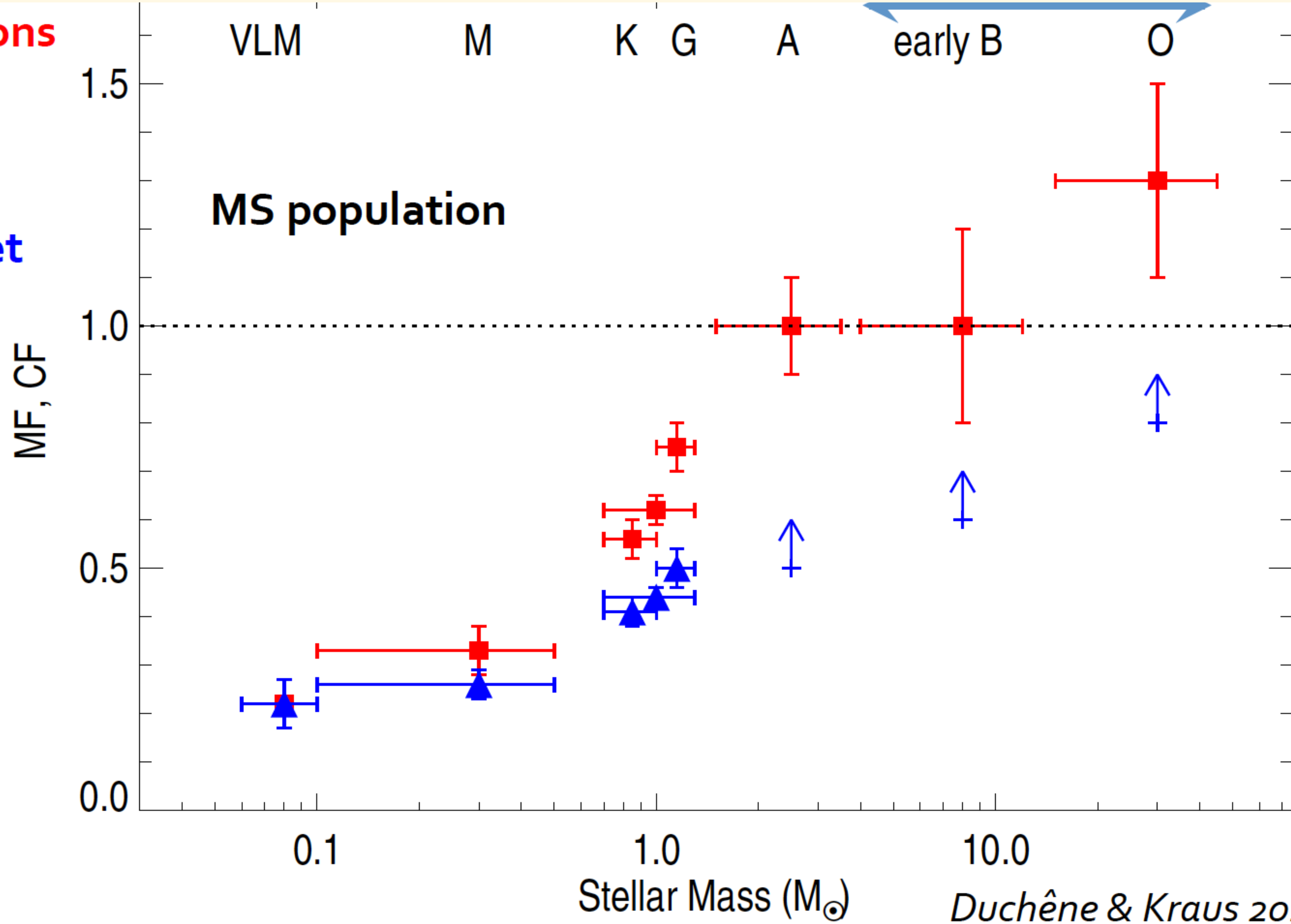
Deborah Baines
(Madrid, Spain)
Willem-Jan de Wit
(ESO, Chile)

Multiplicity vs. Stellar Mass (from Duchene 2014)

of companions per target

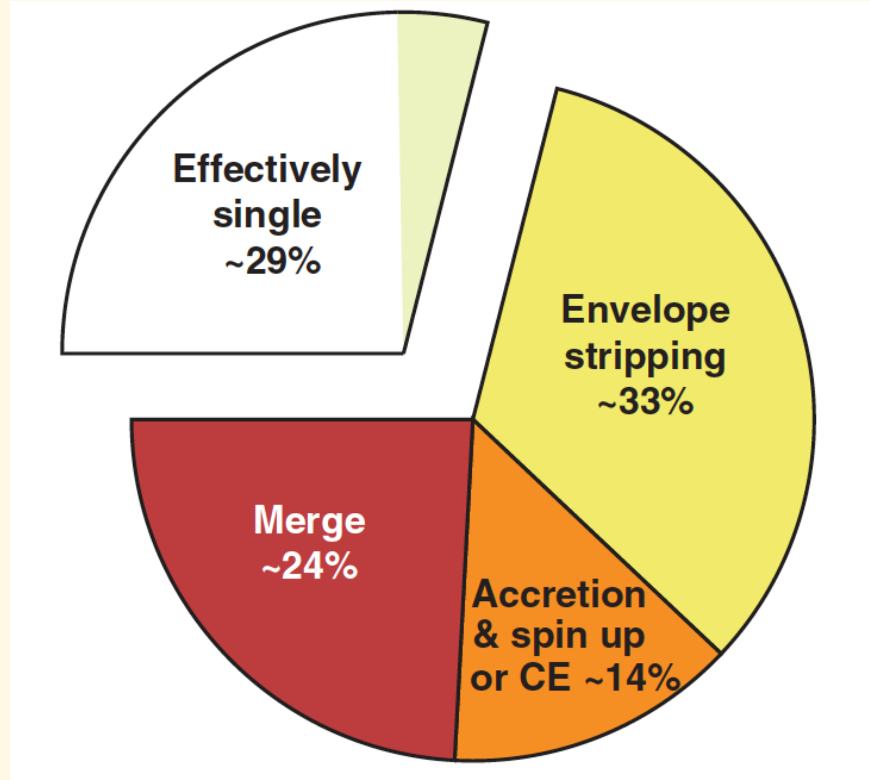
# of multiple system / target



Duchêne & Kraus 2013

Why study (massive) binary stars?

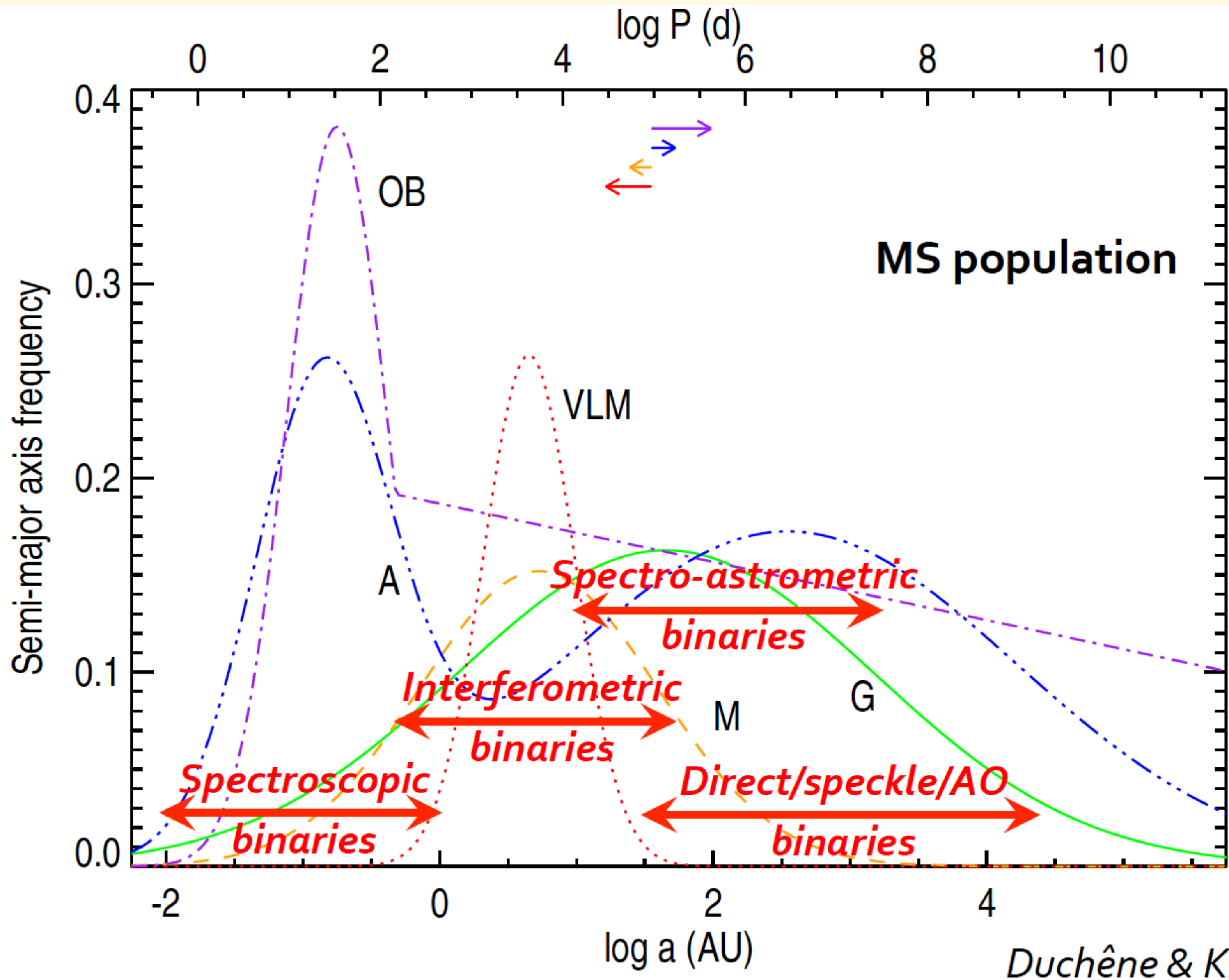
- Importance for stellar evolution
- Importance for clusters
- Only "evolved" fractions known
- Need to go to young objects
- Formation mechanism unknown :
  - capture,
  - disk fragmentation,
  - turbulent fragmentation



Sana+ 2012

- 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



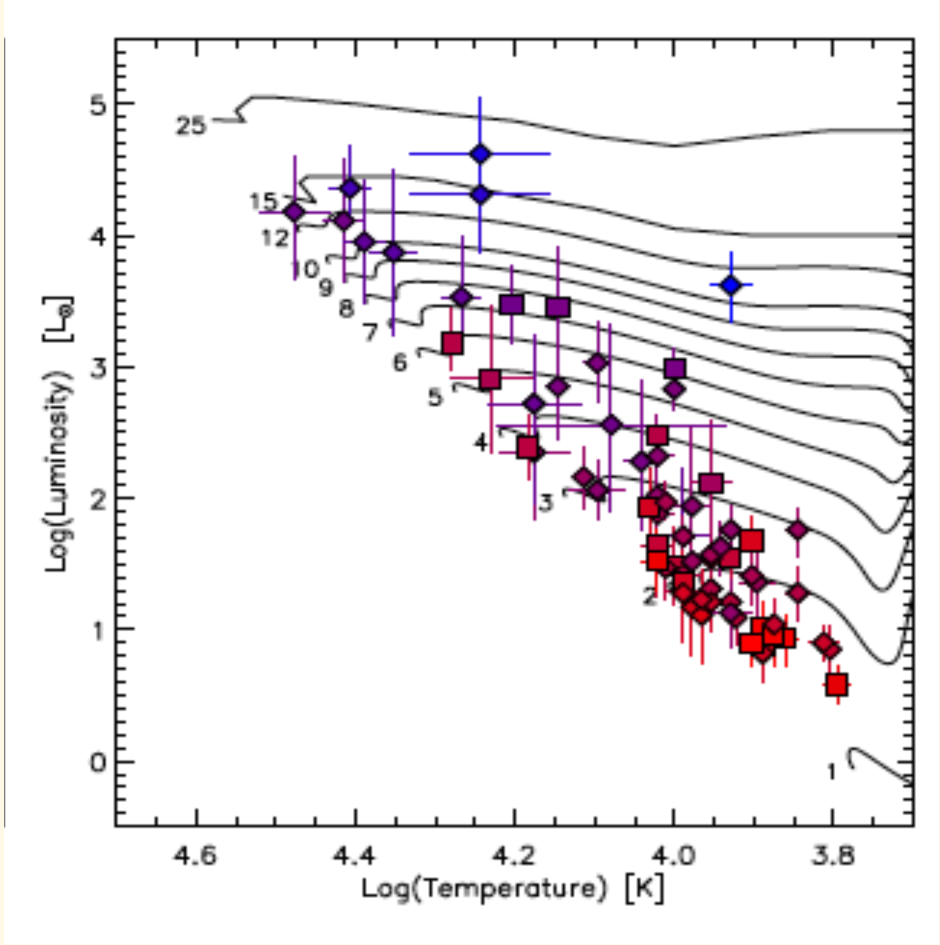
Duchêne & Kraus (2013)

Pre-main sequence stars

T Tauri stars : solar mass, magnetically controlled accretion, veiling, optically visible

Herbig Ae/Be stars : intermediate mass, accretion by infall, optically visible

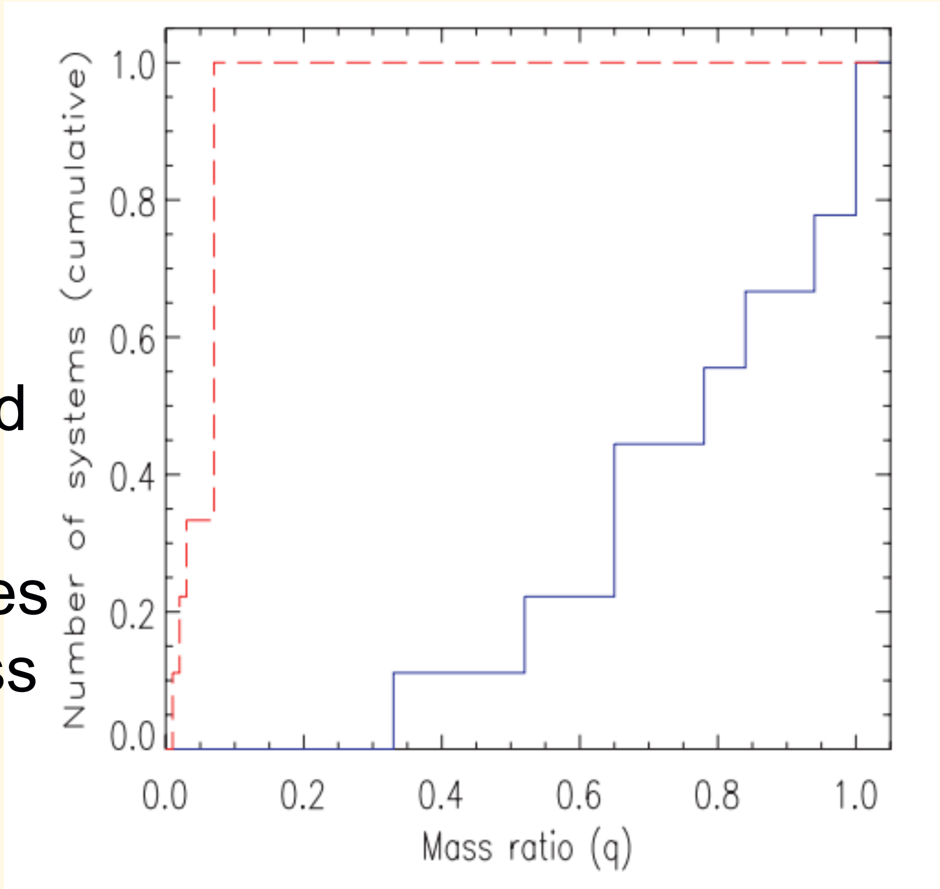
Massive Young Stellar Objects : massive, rare, elusive, obscured (Leeds RMS)



Fairlamb+ 2015

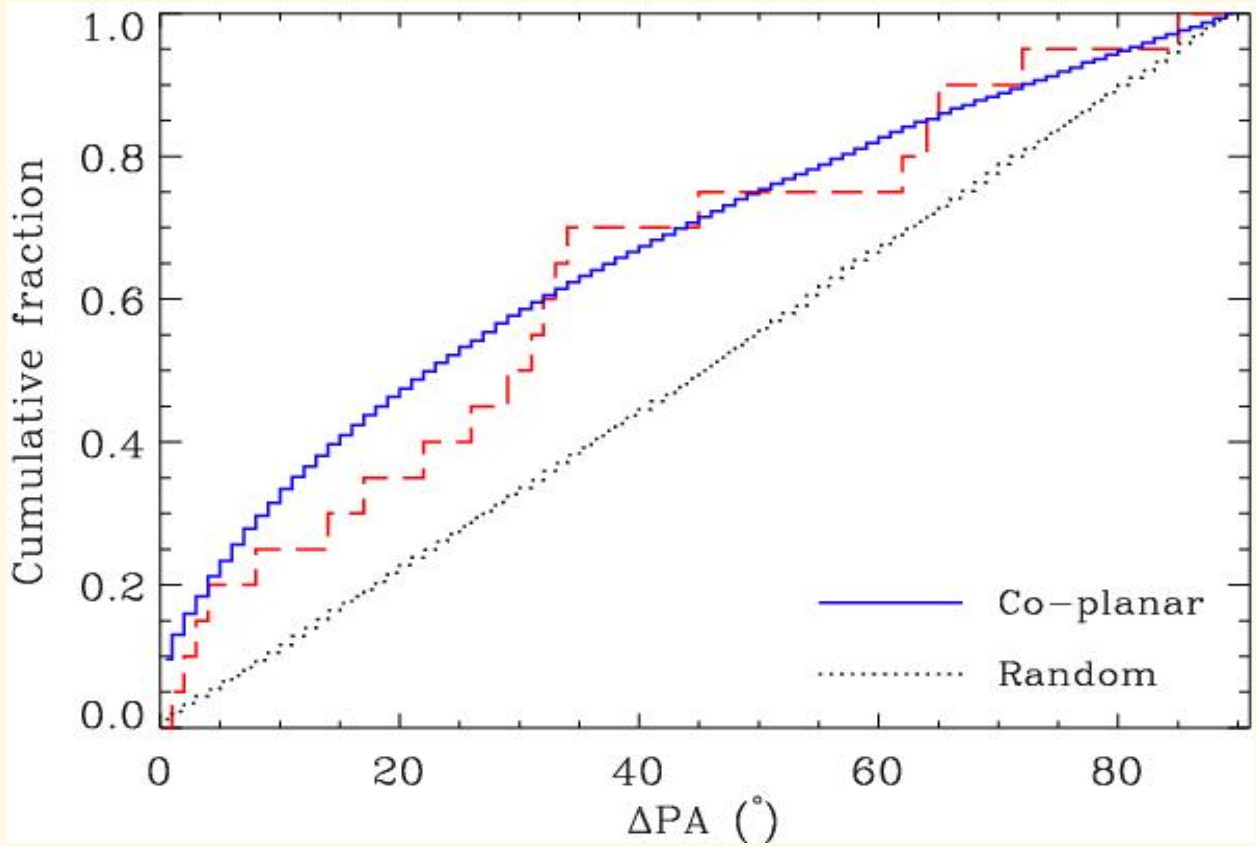
Herbig Ae/Be stars - Baines+ 2006, Wheelwright+ 2010

- 50 Herbig Ae/Be stars observed with spectro-astrometry 0.1 – 1.5” range (≈10s to 1000s au).
- 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



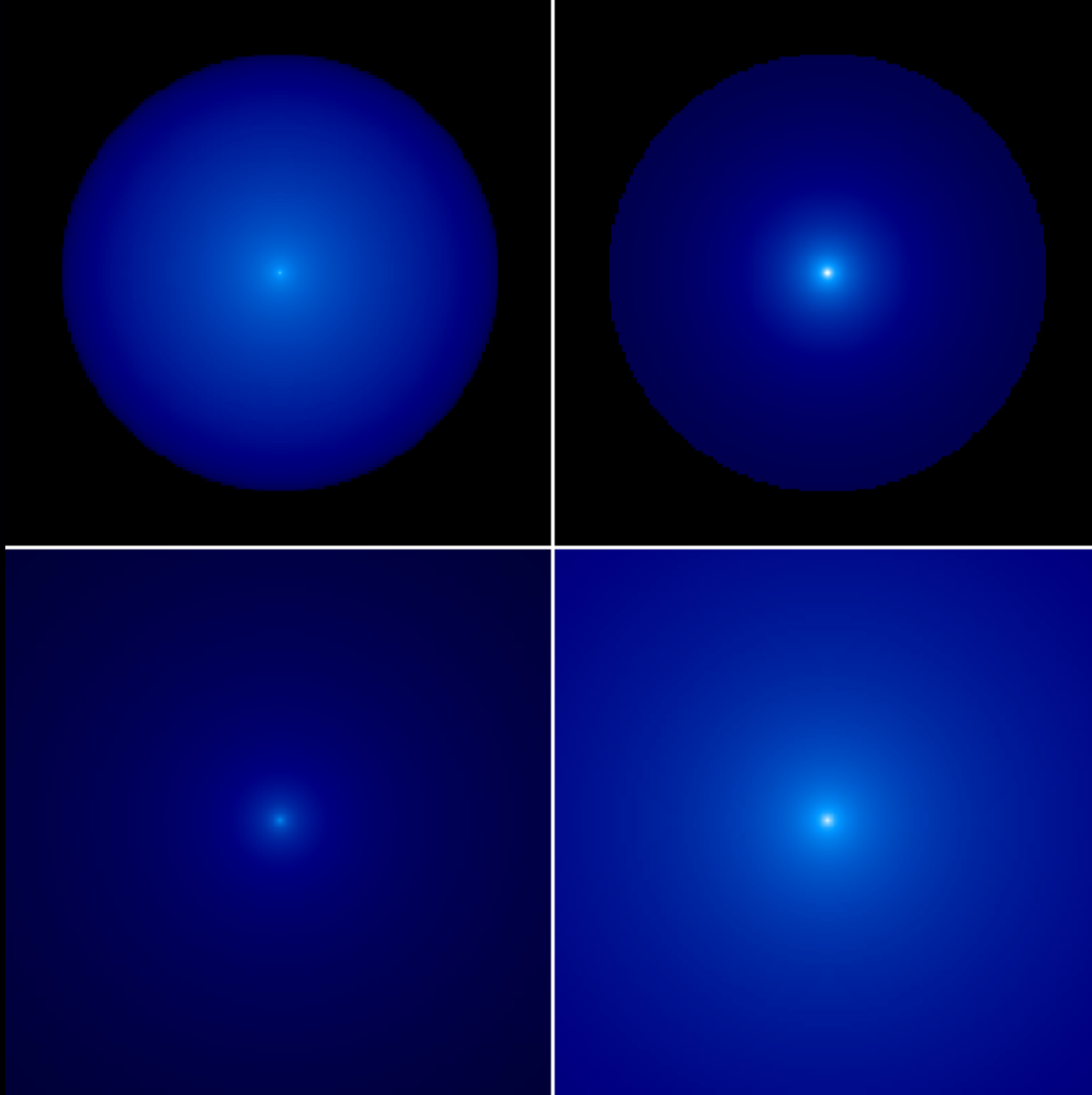
Disk orientations vs. binary position angles:

Primary disks are co-planar with binary orbits



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

Wheelwright et al 2011



Krumholz+
2009

Young binaries

Findings for Herbigs Ae/Be stars consistent with predictions simulations of disk fragmentation. Caveats: Herbigs not very massive stars, systems suffer post-fragmentation effects?

Moreover/however, Rosen, Krumholz, Klein et al. 2016:

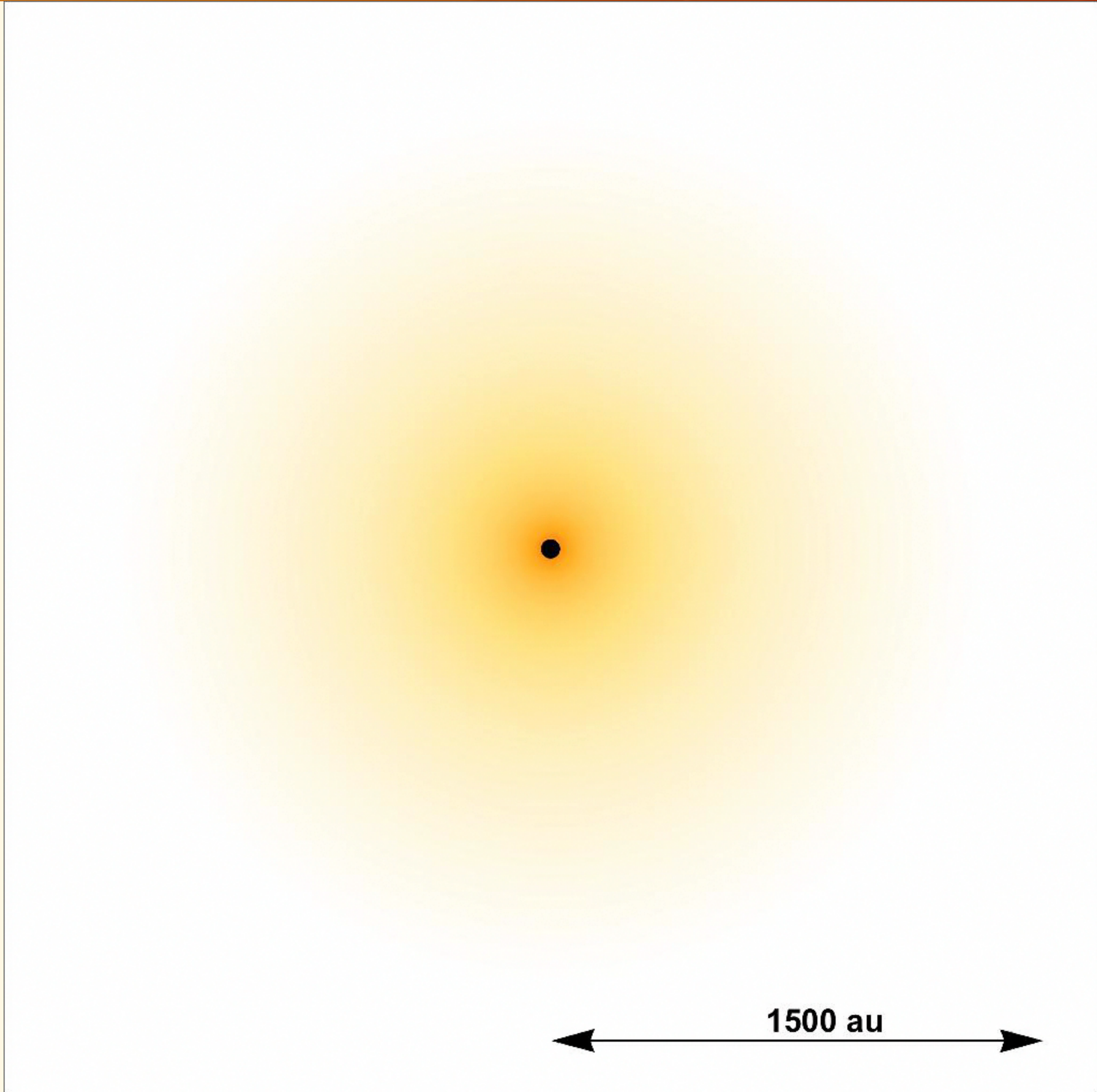
> merge sink particles. Since the fragmentation and resulting system multiplicity is sensitive to the numerics, we advise the reader that the fragmentation produced in our idealized numerical simulations and other simulations does not provide an adequate solution to the multiplicity of observed massive stars. Future work must include additional physics, such as magnetic fields and outflows, to further understand the observed multiplicity of massive stellar systems.

A new generation of models:

Latest simulations form binaries at large range of separations, down to smallest scales

Meyer, Kuiper+ 2017, submitted.

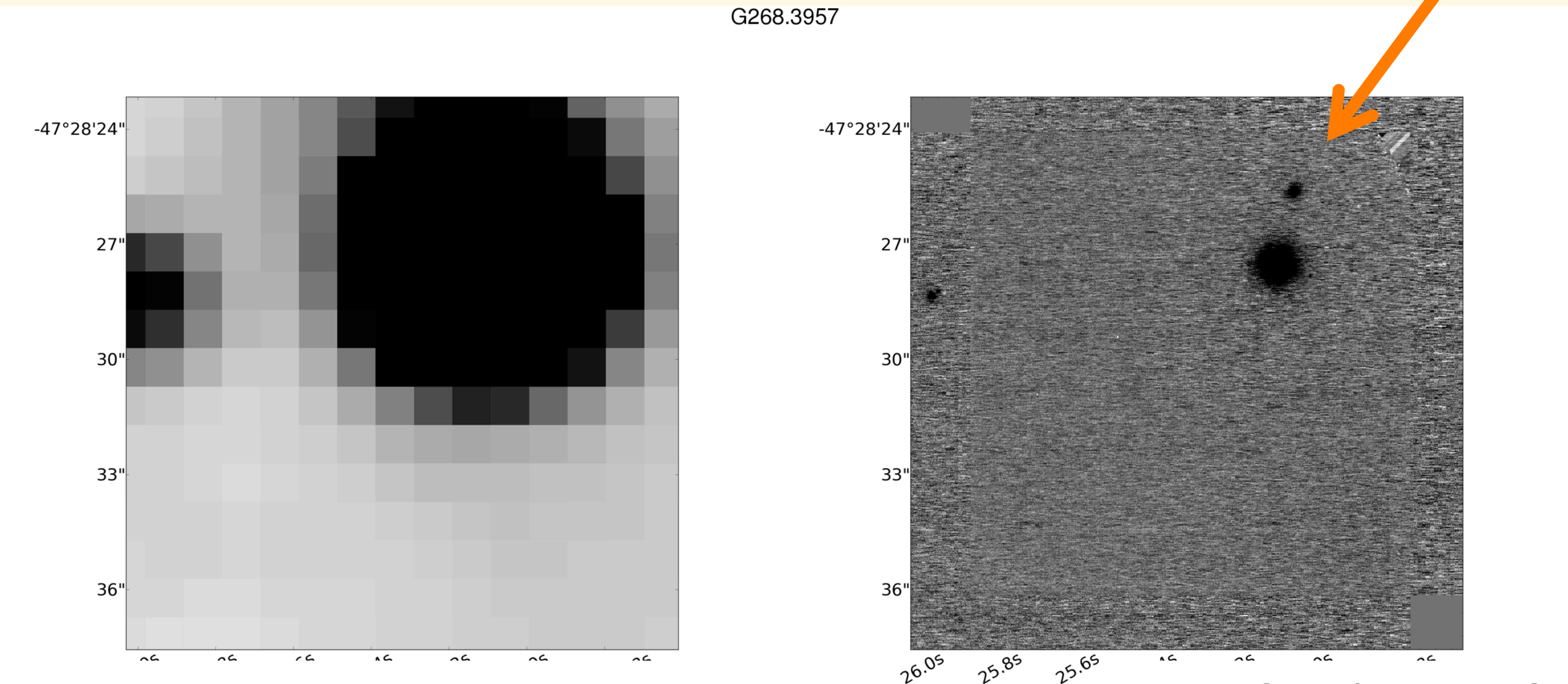
Also, Lund & Bonnell, 2017, submitted can form close primordial binaries, involving B-fields.



Going to even younger, more massive stars

- From Leeds/RMS survey observed 38 MYSOs
- VLT/NACO *K*-band 0.1”, depth – 4..6 mags fainter than main target. Typical minimum observable separation 0.2-0.4”

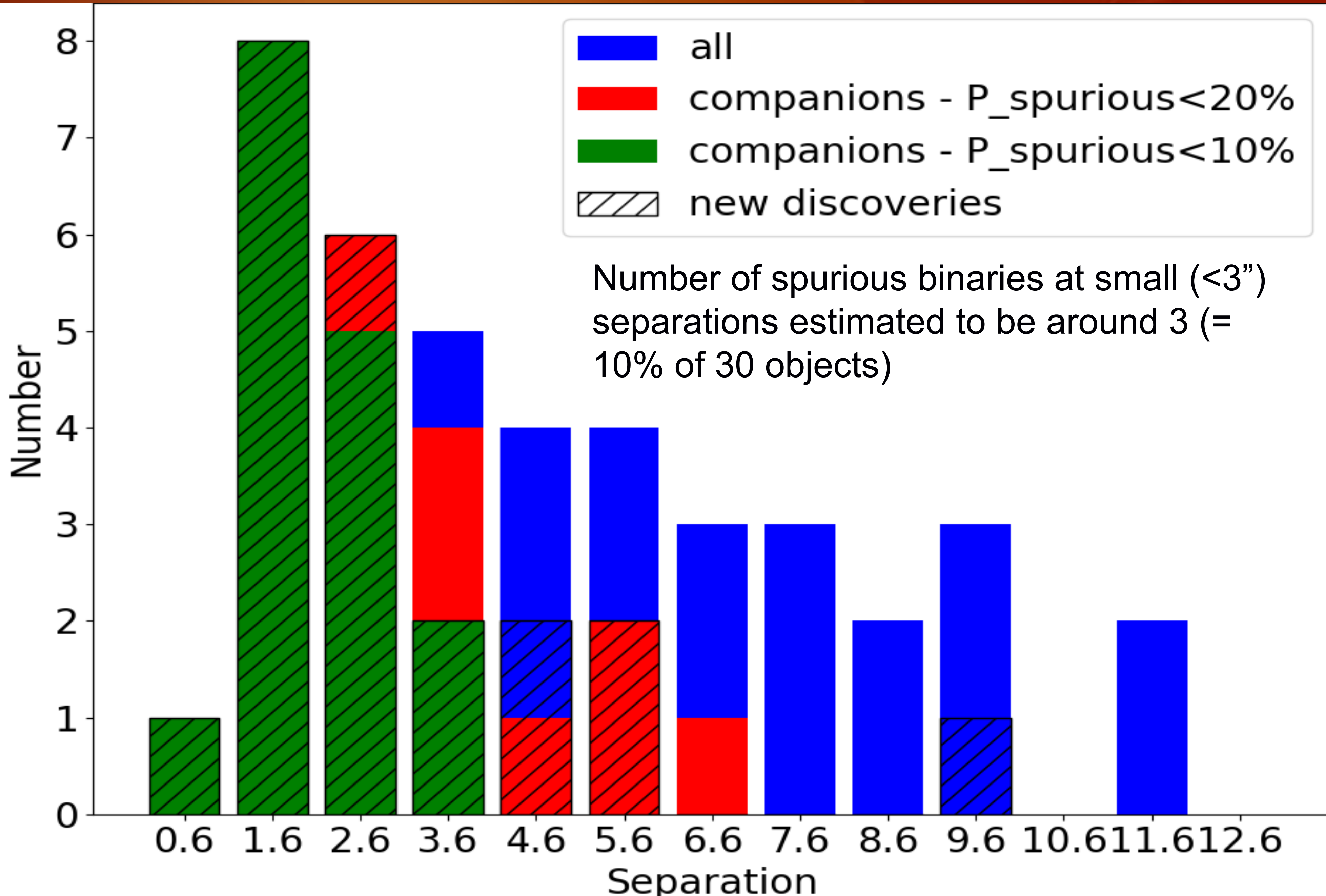
2MASS 3x3arcsec NACO



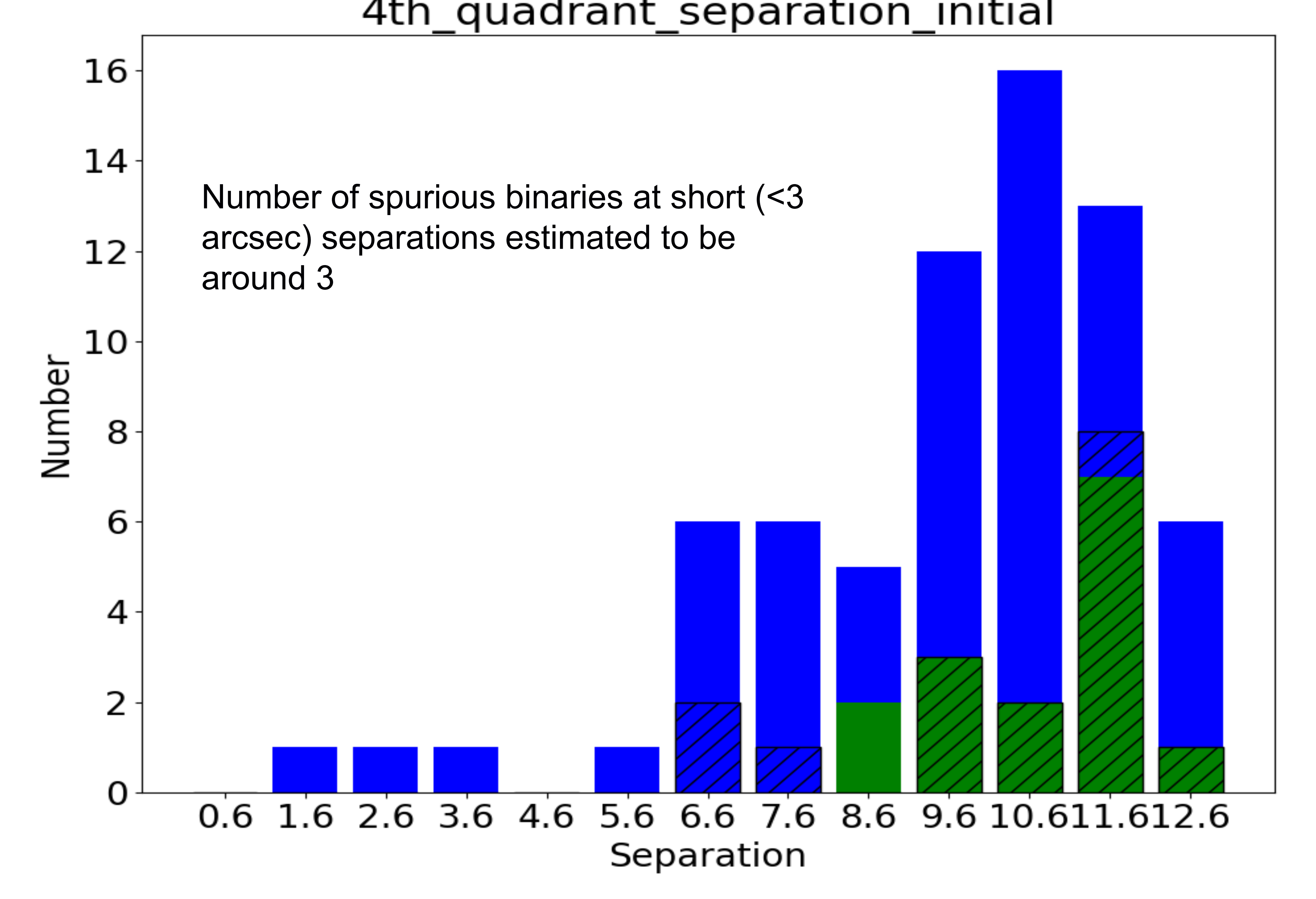
Latest results: Pomohaci 2017 in prep.

NB VISTA/UKIDDS saturated

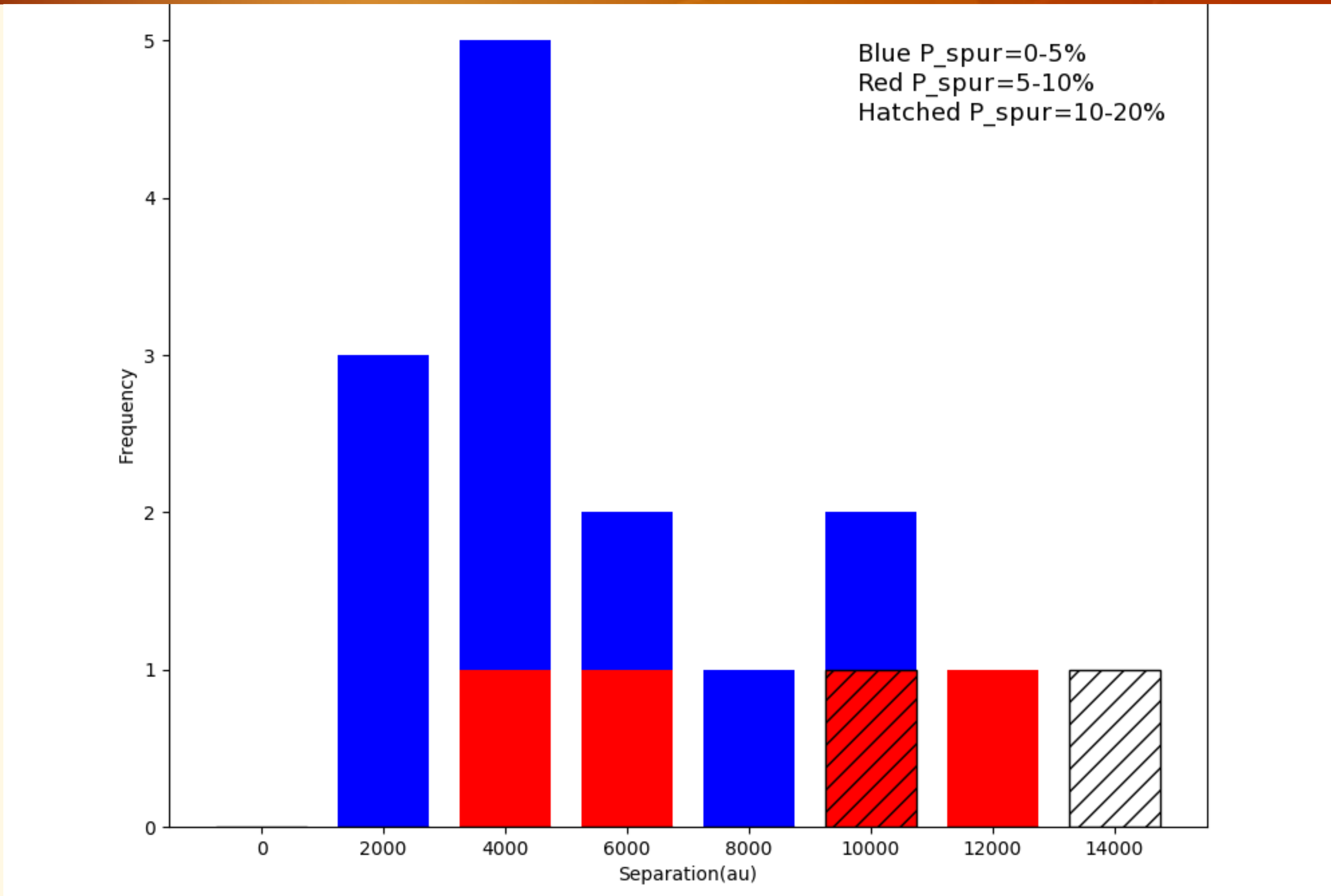
Many sources in the fields:

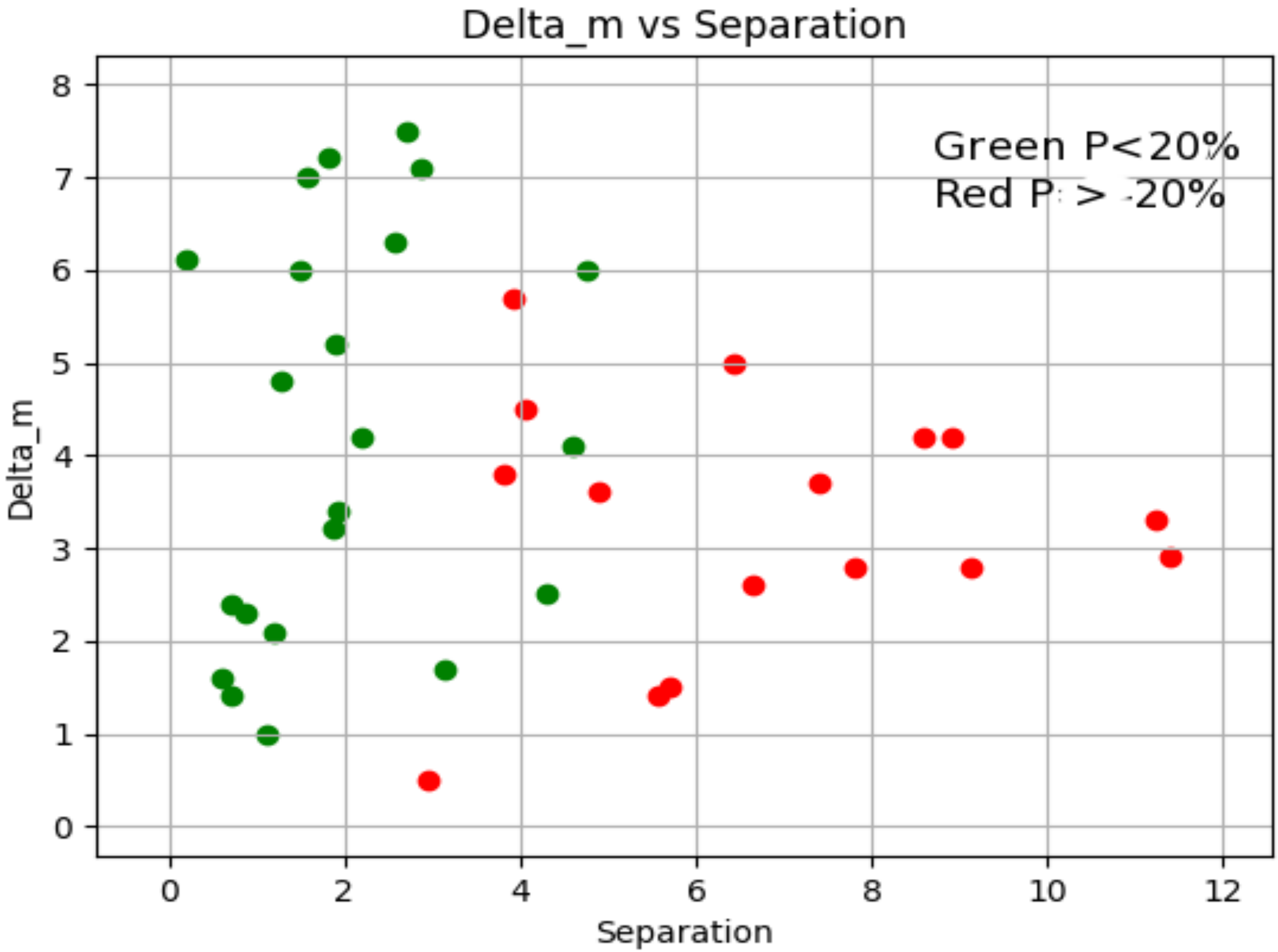


Number of spurious binaries at small (<3") separations estimated to be around 3 (= 10% of 30 objects)


4th_quadrant_separation_initial
Number of spurious binaries at short (<3 arcsec) separations estimated to be around 3
Number
Separation
0
2
4
6
8
10
12
14
16
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

Physical separations.




Delta_m vs Separation
Green P<20%
Red P > 20%
Delta_m
Separation
0
1
2
3
4
5
6
7
8
0
2
4
6
8
10
12

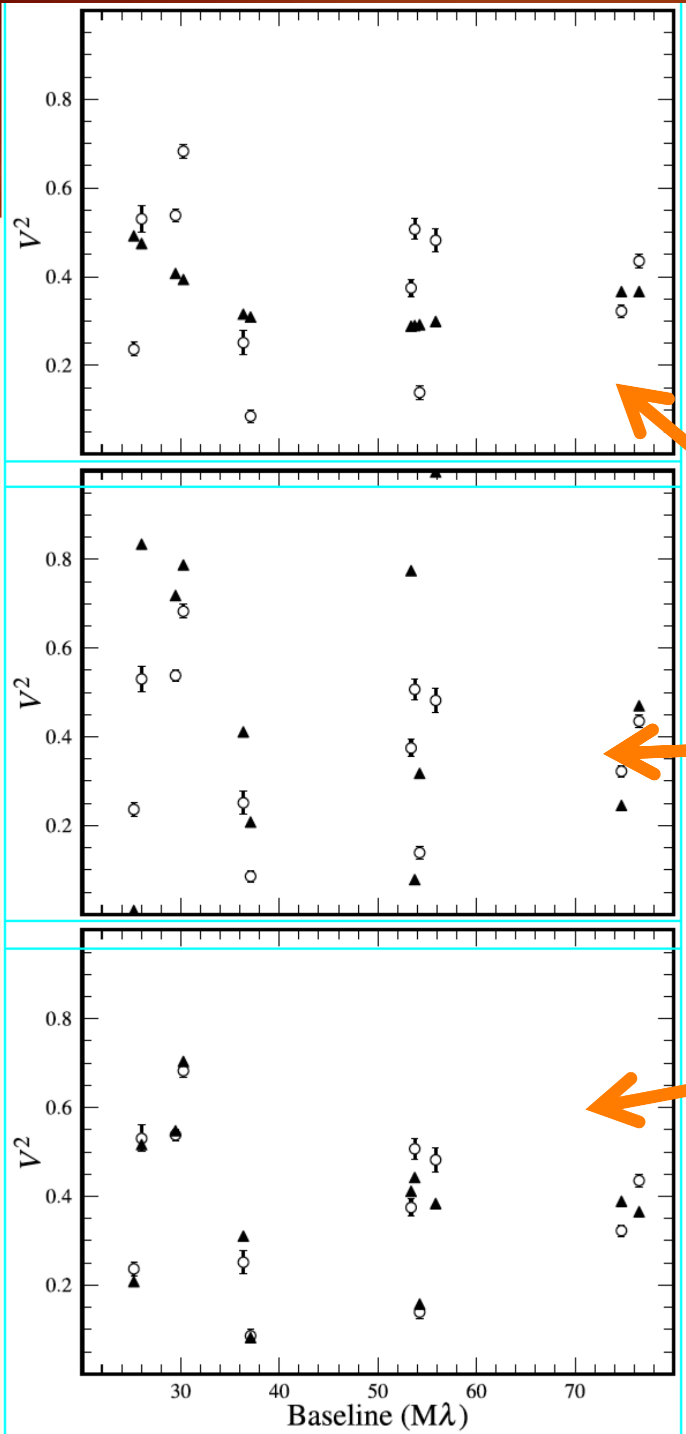
Results

Pomohaci PhD thesis 2017, in prep.

- Various tests indicate that newly discovered sources in frames are associated with MYSOs. Physical binary? Clusters?
- Binary fraction 50%
- Typical separation 3000 au
- Magnitude difference up to 7 magnitudes, attempts to determine mass ratio on-going
- Nature from colour-colour diagram
- Look for correlation binary PA and disk or outflow orientation

- First steps taken, but clear large binarity at 1000s au scale.
- Future : VLTI / Gravity

The highest resolutions: VLTI/Pionier data of RMS/MYSOs



Sparse data, but probing at milli-arsec scales! PDS 37, Ababakr, PhD thesis Leeds, 2016

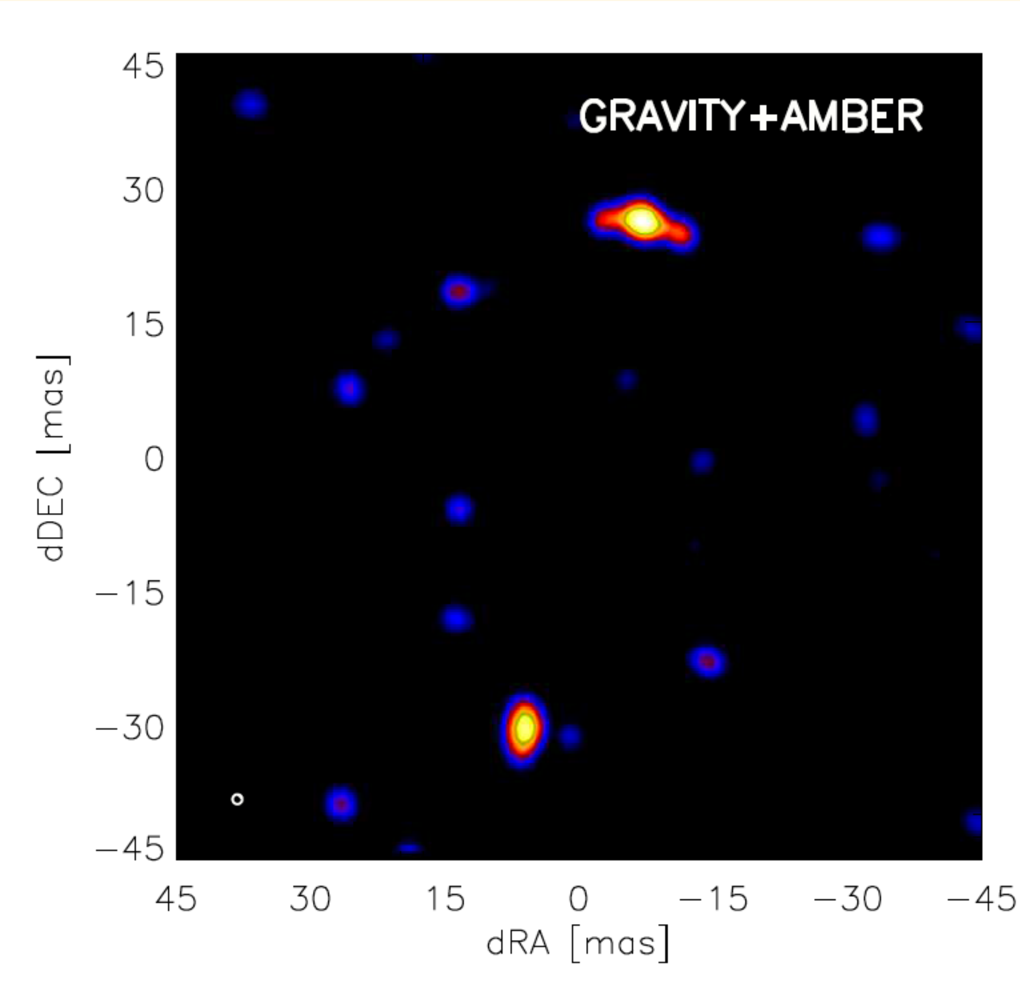
Best fitting uniform disk model to visibility data, 7 mas diameter.

Best fitting point source binary model

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

Separations PDS 37 : 23 mas. PDS 27 of order 110 mas.

VLTI/Gravity observations of an MYSO Kraus+ 2017



IRAS 17216-3801

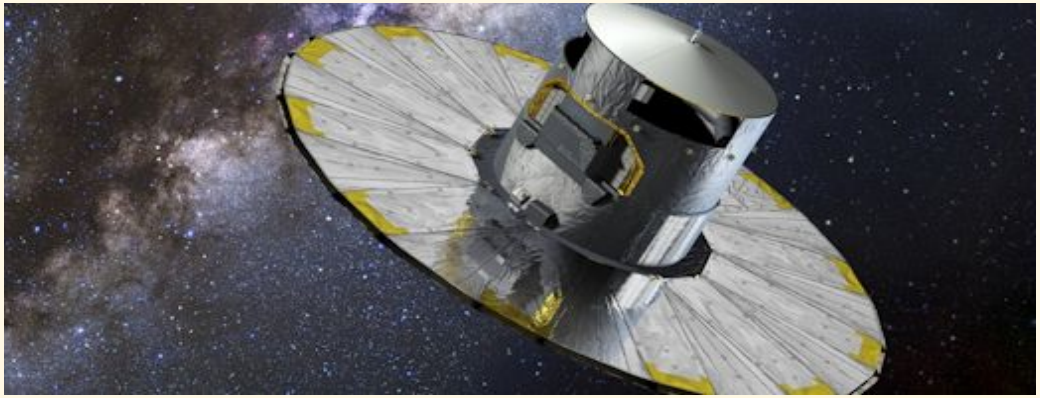
First massive binary young stellar object with resolved disks.

Separation 58 mas = 170 au

Masses 20 and 18 $M_\odot$

Disks misaligned (!)

GAIA and binaries



- GAIA satellite will provide fundamental information on a billion of stars
- Using HR diagrams, STARRY project will deliver new Herbig Ae/Be stars and their clusters
- STARRY will deliver “search and identify” tools and, if applicable, automatic cluster characterization.
- Extremely powerful for binary companions to Herbig Be’s
- Vioque and Perez (in prep.)

Conclusions

- Despite their importance for stellar evolution and cluster dynamics and evolution, the formation of massive binaries is not understood.

- Data on Herbig stars consistent with disk fragmentation
- Data on Massive Young Stellar Objects only being collected now

- Scales of 1000s au, binary fraction already of 50%, suggesting the 100% fraction in massive, more evolved stars, can be primordial.

- Latest, as yet unpublished theoretical work points to a large primordial close binary population.
- Provide initial constraints for cluster simulations

- Interferometry: reveals close binaries