Multiplicity of Northern bright O-type stars with optical long baseline interferometry

Results of the pilot survey

by Cyprien Lanthermann

Abstract: The study of the multiplicity of massive stars gives hints of their formation processes and their evolution path. Optical interferometry is mandatory to fulfill our knowledge on their multiplicity by probing the separation's gap between 1 and 50 mas.

We demonstrated the capability of the new interferometric instrument MIRC-X, located at the CHARA array, to study the multiplicity of O-type stars. With a large interferometric survey of Northern O-type stars multiplicity, we would be able to probe the full range of separation of more than 120 massive stars (H < 7.5).

To do so, we built a pilot survey of bright O-type stars (H < 6.5) observable with MIRC-X. We observed as many of these systems as we could. We systematically reduced the obtained data with the public reduction pipeline of the instrument. We analyzed the reduced data with CANDID, a software dedicated to the detection of companions in interferometric observables.

We observed 29 O-type star systems, including a couple of systems in average atmospheric conditions around a magnitude of H = 7.5.

Out of these 29 systems, we detected 17 companions in 15 different systems, resulting in a multiplicity fraction f_m = 15 / 29 = 0.52, and a companion fraction of f_c = 17 / 29 = 0.59. Those results are in agreement with the results of SMASH+ survey. We observed for the first time 10 of these detected companions.

This study concludes that a large survey on more than 120 Northern O-type stars is possible with MIRC-X.

1. Massive stars

- Short life-time
- Rare

⇒ Relatively **far** (2 kpc)

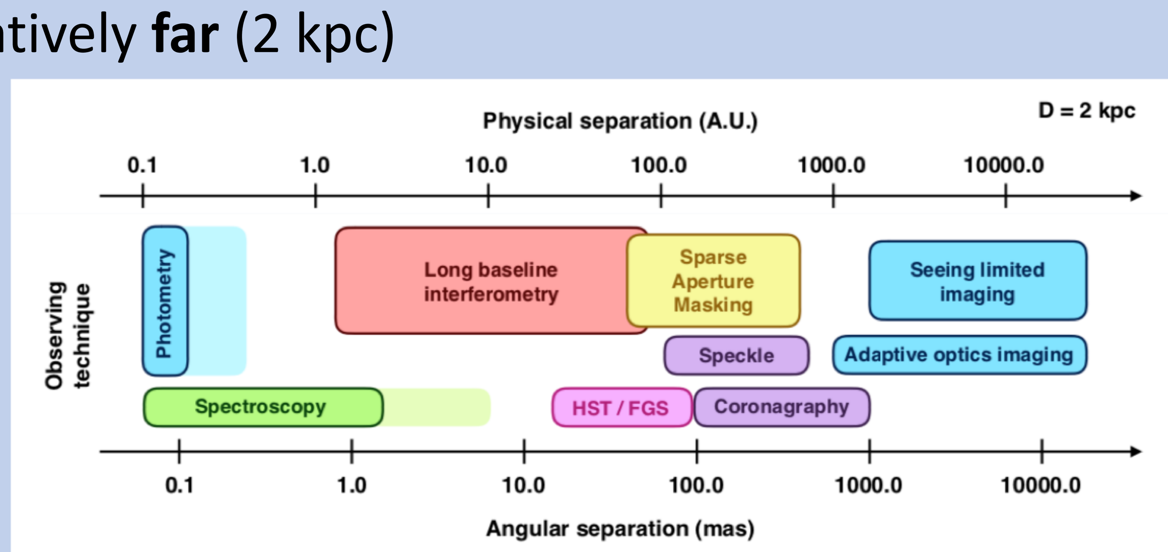

Figure 1: Representation of the different techniques necessary to study massive stars' multiplicity, with the corresponding physical (on top, for a typical distance of 2 kpc) and angular separation (bottom). Adapted from Sana, H. (2017)

Optical Long Baseline Interferometry necessary to fill the **1 -50 mas range** of separations.

SMASH+ already did it in the Southern hemisphere with VTLI

Goal: **double the statistics** with the Northern hemisphere with CHARA's new beam combiner **MIRC-X**

⇒ Pilot survey (H < 6.5) to prove the **possibility of a large survey** (> 100 O-type star systems, H < 7.5)

2. Pilot survey

29 O-type star's systems (DEC > -20 degrees, H < 6.5)

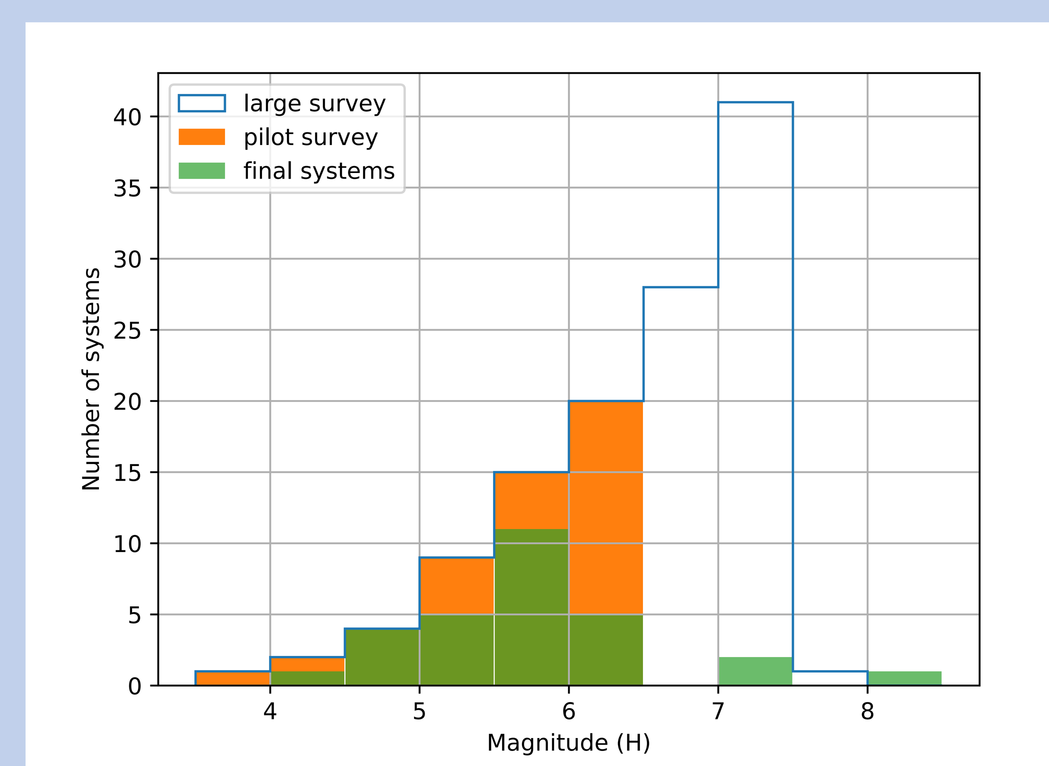

Figure 3: Histogram of the magnitude in H-band of the O-type star system in the large survey (blue), in the pilot survey (orange), and observed by the pilot survey (green). Lanthermann, C. et al (2022, in preparation)

- Focus on the brightest systems
- A few systems with typical magnitude for the large survey (testing limit magnitude)

⇒ Large survey **possible**

3. Statistics

- 17 detected companions in 15 different systems
- Multiplicity fraction f_m = 15 / 29 = **0.52**
- Companion fraction of f_c = 17 / 29 = 0.**59**
- **10** companions detected **for the first time**

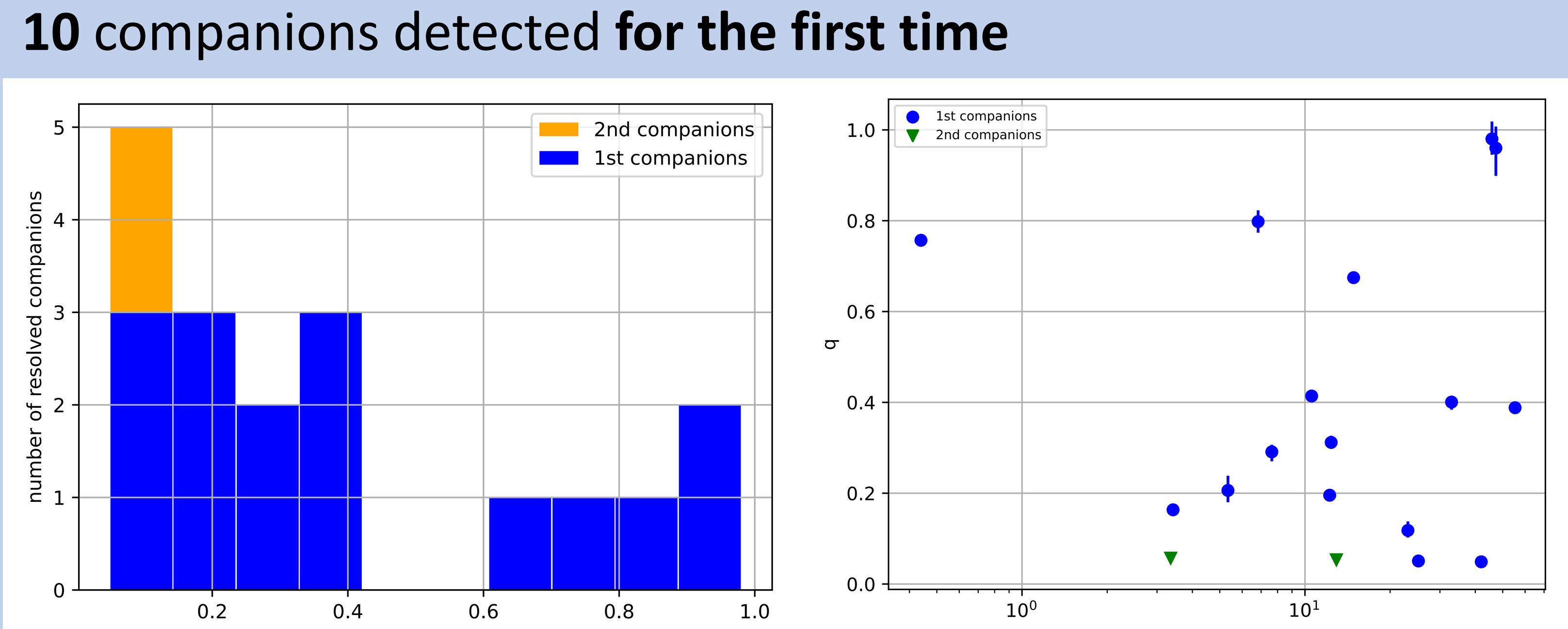

Figure 2: Left: Histogram of mass ratio (q). Right: Mass ratio as a function of the physical separation Lanthermann, C. et al (2022, in preparation)

- Mass ratio q not compatible with a uniform distribution
  - Power law? Bi-modal?
- No strong correlation between separation and q

⇒ **Statistics too low** to have strong conclusions

4. Long term follow-up

- **10** systems suitable for **long term** interferometric follow-up for dynamical **orbit** determination (period < 10 years)
- **5** systems could have dynamical orbit determine by **GAIA**

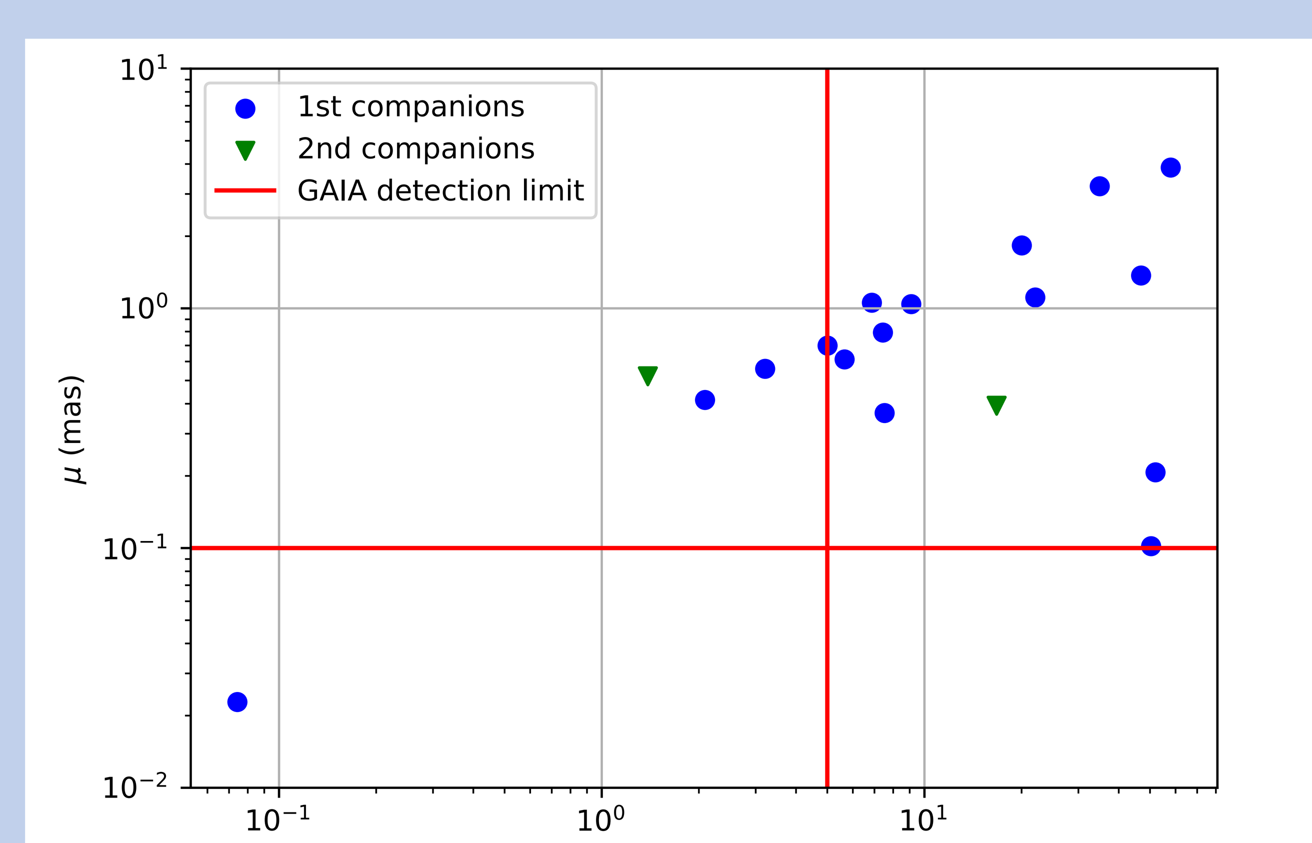

Figure 4: Estimated photocenter shift (μ, in mas) as a function of the estimated period. Lanthermann, C. et al (2022, in preparation)

Conclusions

- Large survey **(> 100** O-type stars) is **possible** with CHARA/MIRC-X (already on-going)
- f_m and f_c **consistent** with SMASH+ results
- Statistics **too low** to conclude on massive star formation => **large survey required**
- **GAIA DR3** should help determine **orbital parameters** for some of the detected multiple systems