Multi wavelength operations: SPICA, MIRC-X and MYSTIC

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(CHARA, MIRC-X/MYSTIC and SPICA collaborations)

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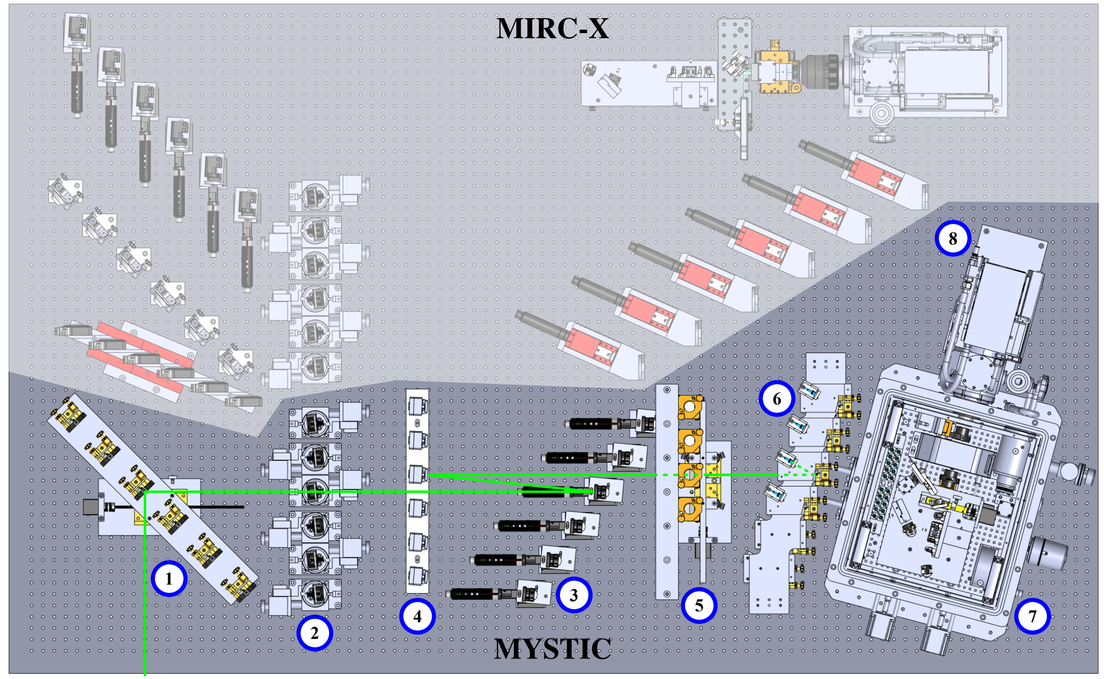
Advantages of the simultaneous operation

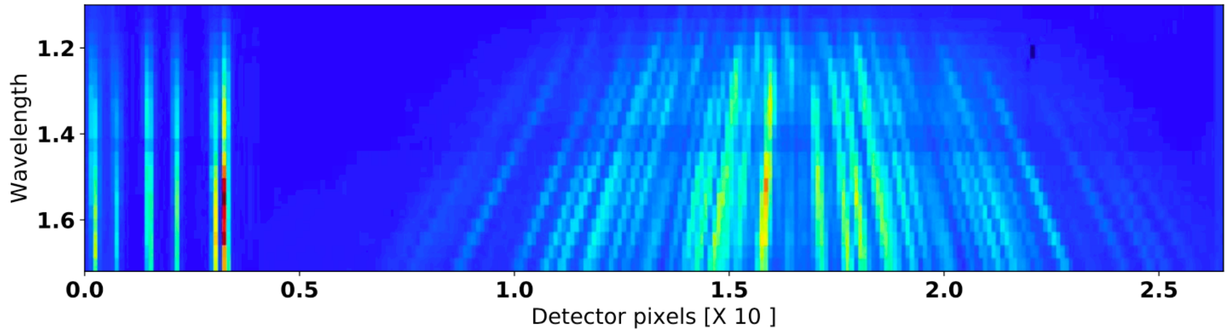
- Probe object properties in R, J, H and K-bands.
- Imaging of over-resolved objects up to 4 mas
- UV-coverage
- MIRC-X (J+H) and MYSTIC (K-band) ready to use

MIRC-X and MYSTIC in a nutshell

- MIRC-X and MYSTIC are six telescope all-in-one beam combiners similar to SPICA.
- MIRC-X works in J and H-bands (PI: S. Kraus)
- MYSTIC works in K-band (PI: J. D. Monnier)
- Spectral modes:

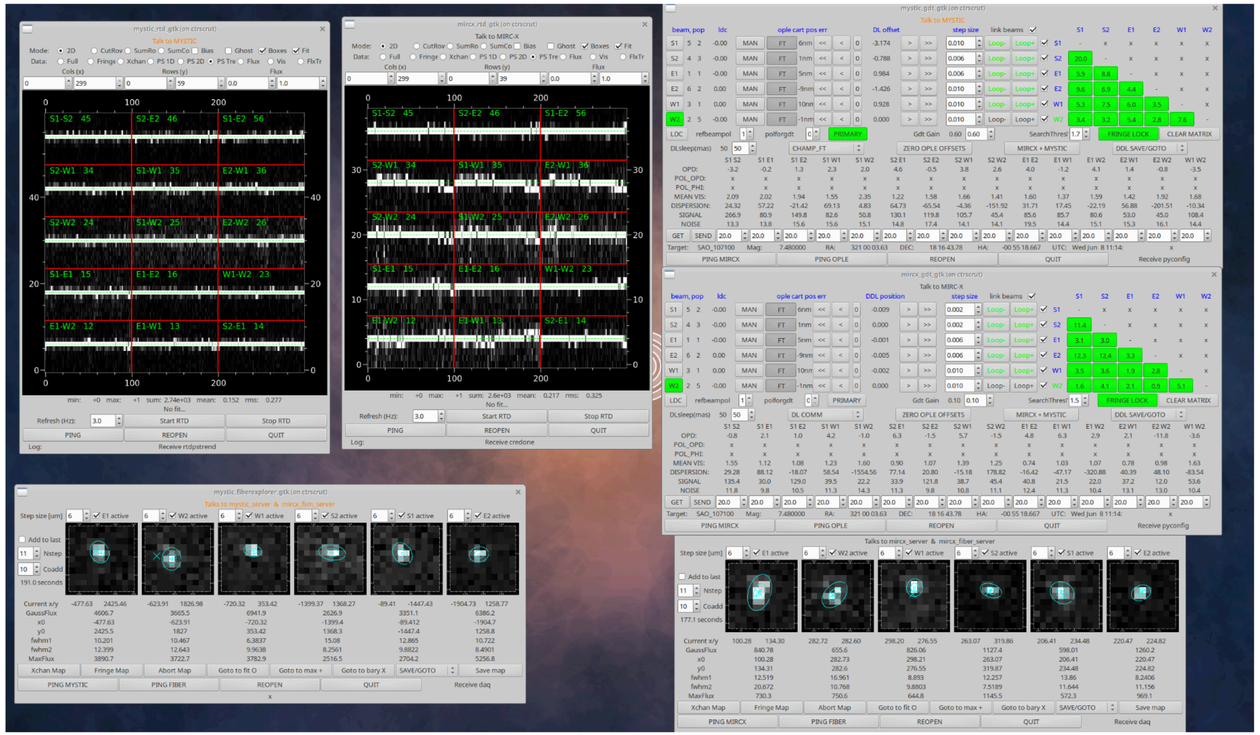
MIRC-X ($R = \frac{\lambda}{\delta\lambda}$)	MYSTIC (R)
20	20
50	49
102	99.5
198	278
1170	981
-	1724



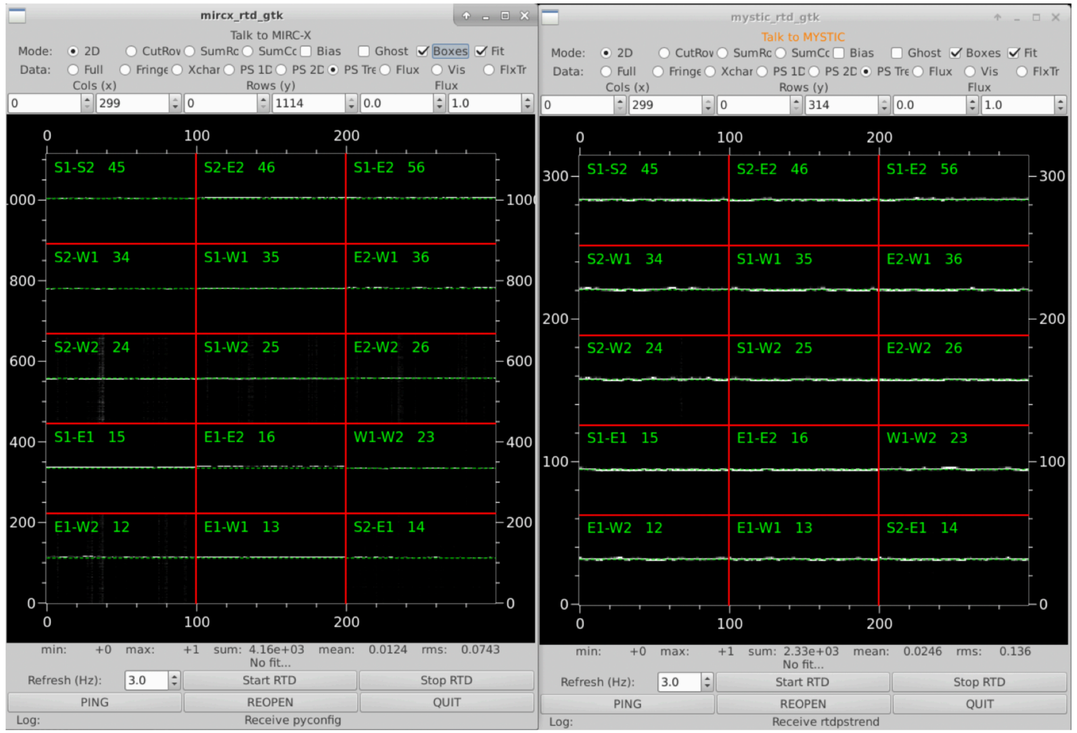


(Anugu+ 2020, Setterholm+ 2022)

Typical simultaneous observation of MIRC-X and MYSTIC

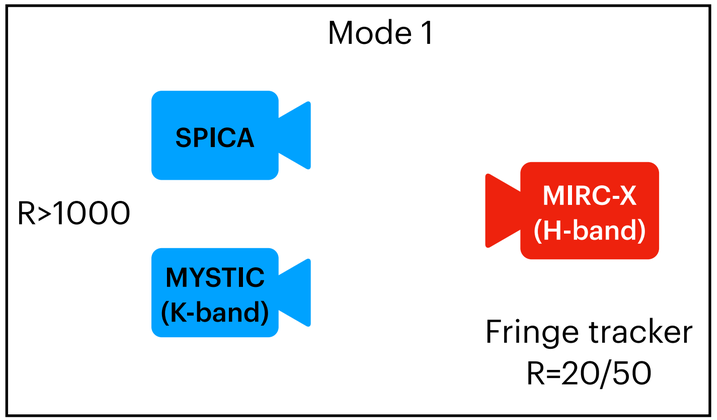


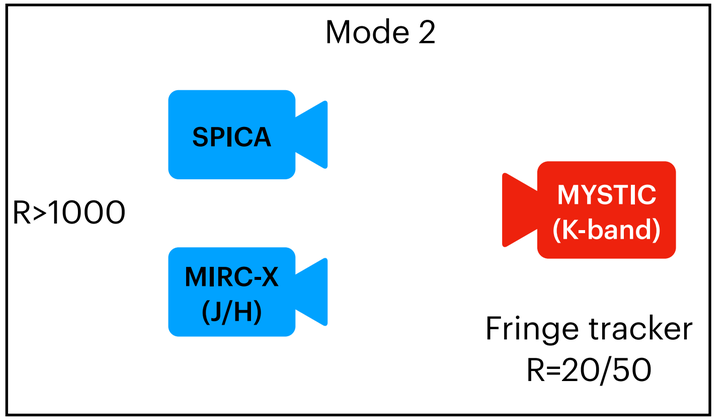
MIRC-X (R=50) and MYSTIC (R=50)



MIRC-X (R=1170) and MYSTIC (R=278)

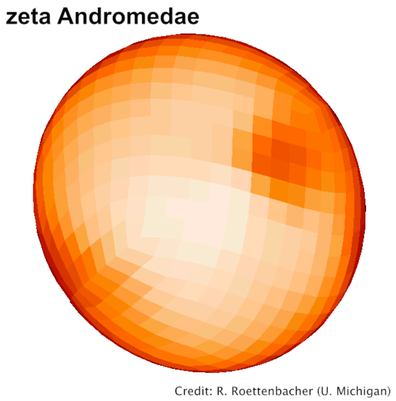
Simultaneous observing approach



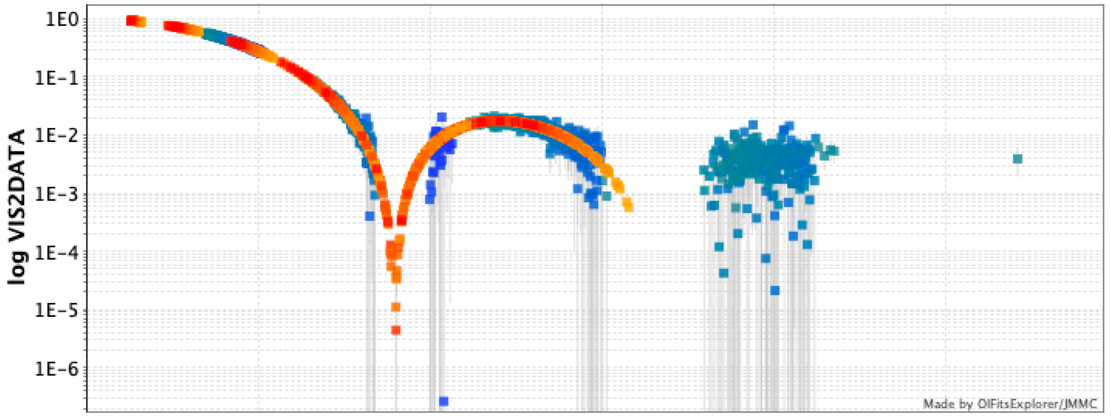


- All three instruments are cophased with STS (star simulator in the lab) before observations
- The observing modes are already validated and works routine at CHARA. So no additional work is required and ready to use.
- From high spectral resolution DATA measure spectral lines
- From low resolution fringe tracker DATA detect binaries

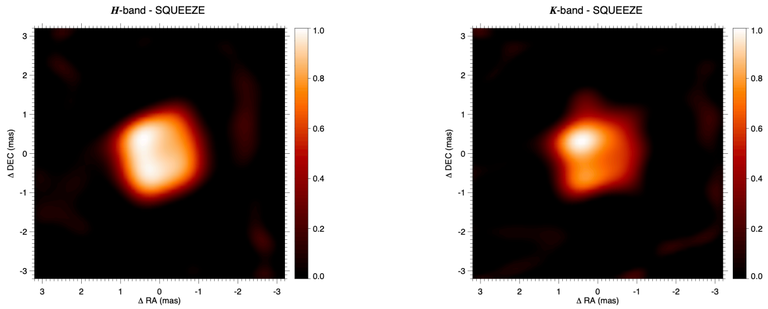
Science case 1: imaging surface of stars with R+H+K-band observations



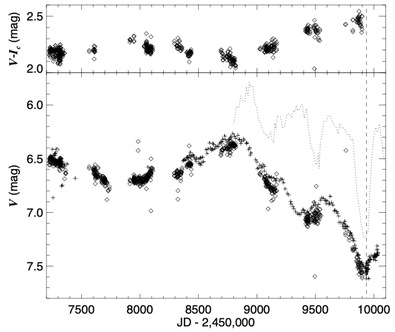
Credit: R. Roettenbacher (U. Michigan)



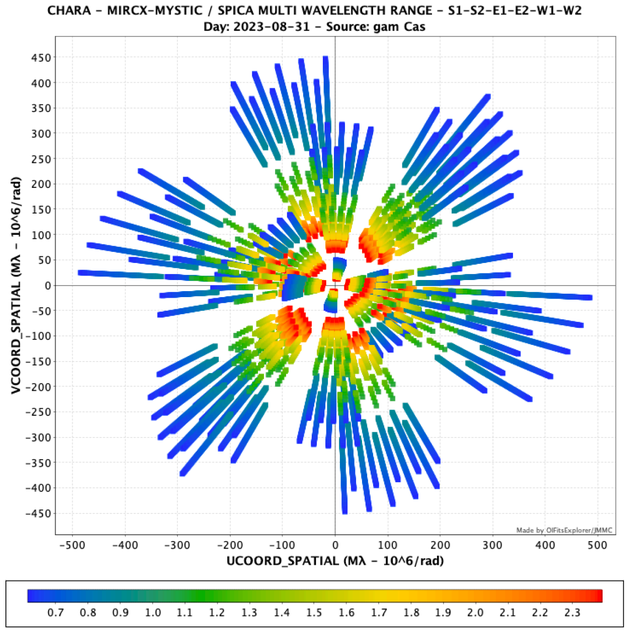
Simulated V^2
V^2<0.5 for 3 mas R-band
K-band red



RW Cep (submitted)
Red supergaint like Betelgeuse



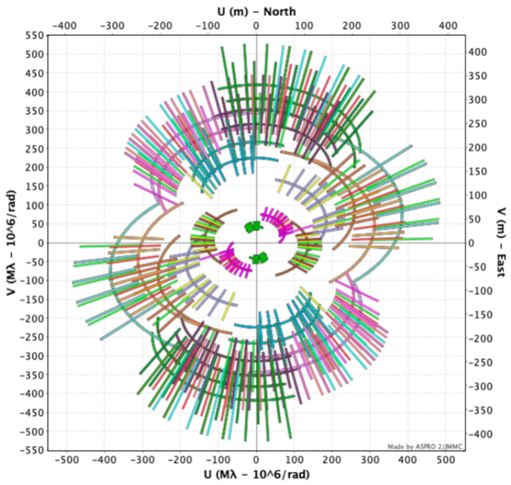
RW Cep, light curve



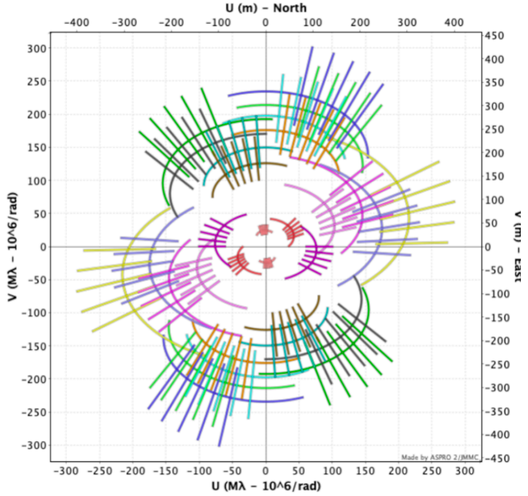
(U,V)-coverage R-K bands

UV -coverage again

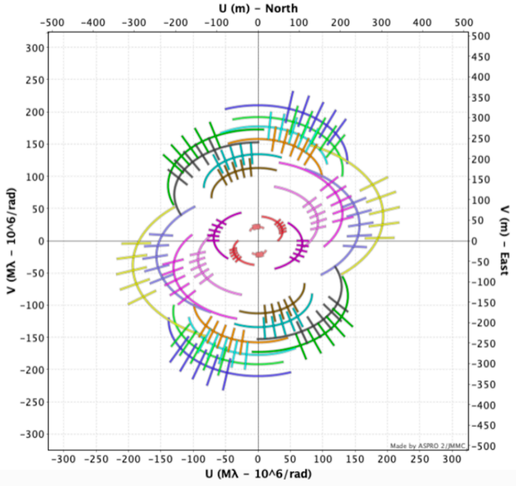
SPICA (R-band)



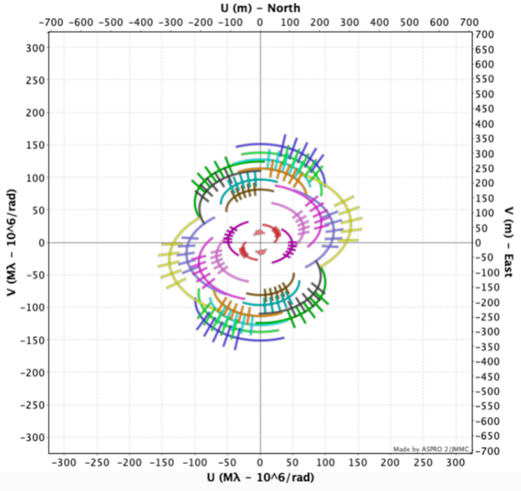
MIRC-X (J-band)



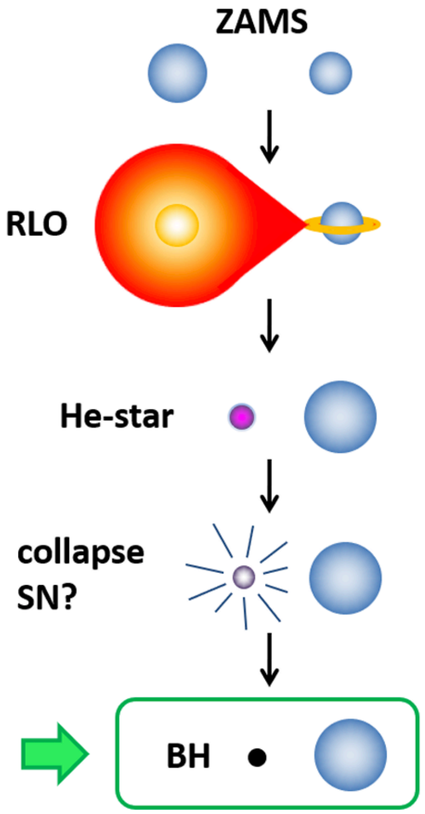
MIRC-X (H-band)



MIRC-X (K-band)

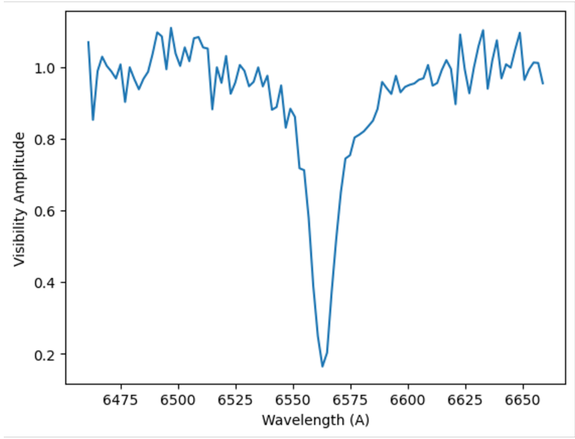


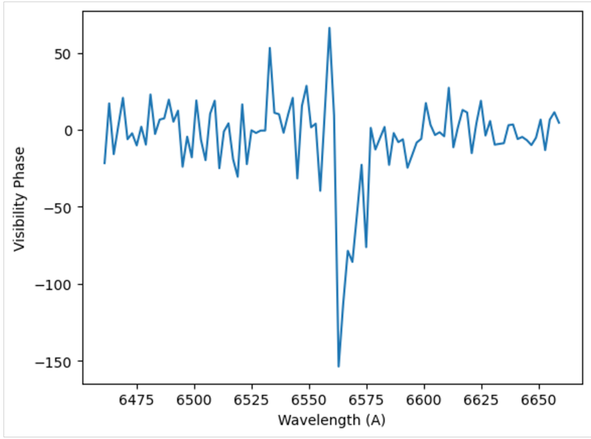
Science case 2: Spatial and Spectral imaging of Be stars



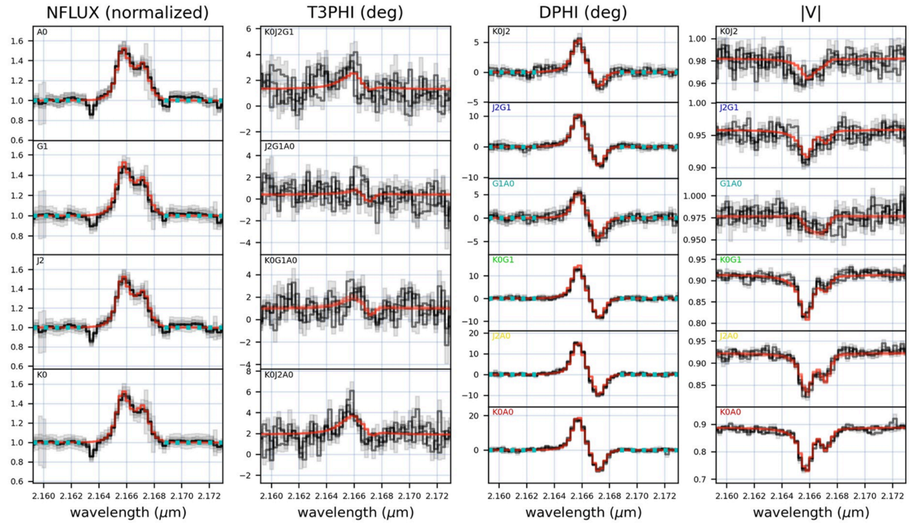
Langer+ 2020

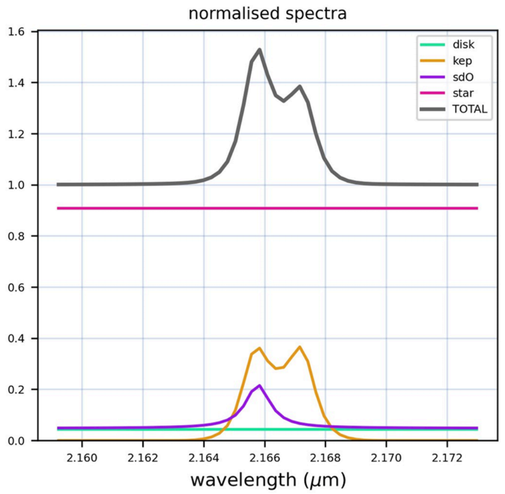
Building blocks of the system:
Inner binary and disk





H-alpha
From VEGA
Credit: Wysocki



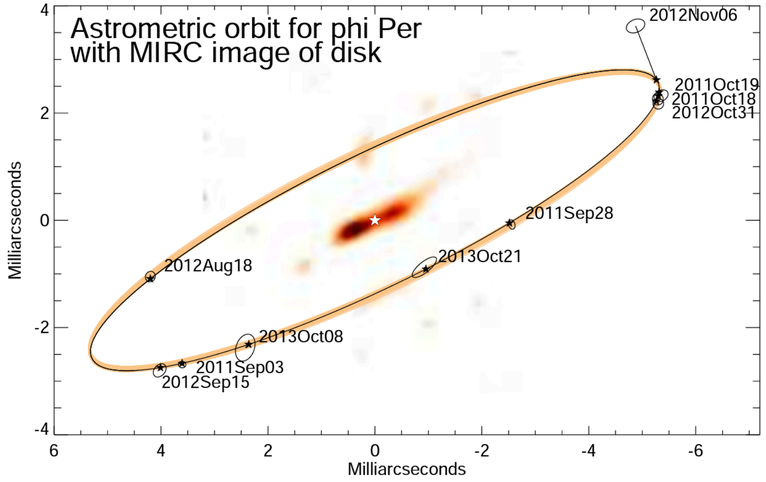


Bracket gamma, from GRAVITY, HR 2142, Credit: Klement

Binary detection in binaries and their orbits

HD	Name	Type	P [d]	ΔH [mag]	a" [mas]	a [AU]	M Be [Msun]	M sdO [Msun]
10516	ϕ Per	B1.5V:e-shell	126.7	4.6	5.9	1.1	9.6 ± 0.3	1.2 ± 0.2
41335	HR 2142	B3/5Vnne	80.9	3.8	1.9	1.0	18.0 ± 5.1	0.68 ± 0.13
109387	κ Dra	B6IIIe	61.5	4.5	3.4	0.5	3.65 ± 0.48	0.426 ± 0.043
161306	HD 161306	B3/5Vnne	99.3	3.9	1.8	0.8	6.316 ± 0.250	0.806 ± 0.086
183537	7 Vul	B5Vn	69.5	4.6	2.0	0.6	4.35 ± 0.20	0.485 ± 0.018
191610	28 Cyg	B2.5Ve	359.1	5.2	7.4	1.9	5.20 ± 1.16	1.98 ± 1.17
194335	V2119 Cyg	B2IIIe	63.1	4.1	1.8	0.7	8.42 ± 0.36	1.51 ± 0.30
200310	60 Cyg	B1Ve	147.6	4.8	3.0	1.1	7.93 ± 1.19	1.10 ± 0.24

Klement+ 2022



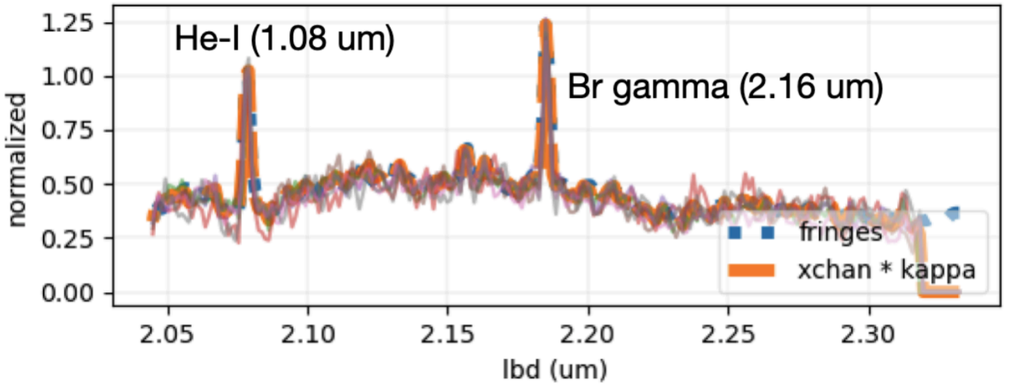
Mourard+ 2015

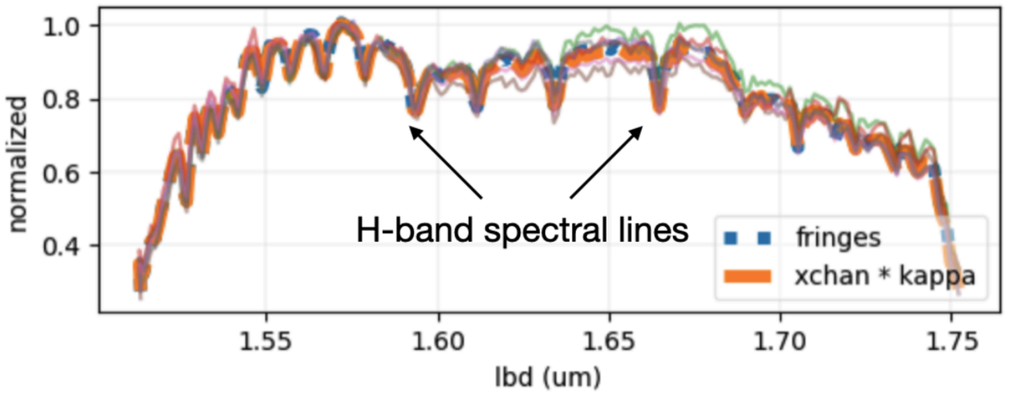
Dynamical masses for only a few systems so far, e.g., ϕ Per (Mourard+ 2015)

Followup of the above objects reveal orbits and their masses

Be stars from MIRC-X and MYSTIC observations

- We already observed 5 Be star targets with MIRC-X/MYSTIC, to measure spectral lines in H and K-band wavelengths
- Data reduction work in progress

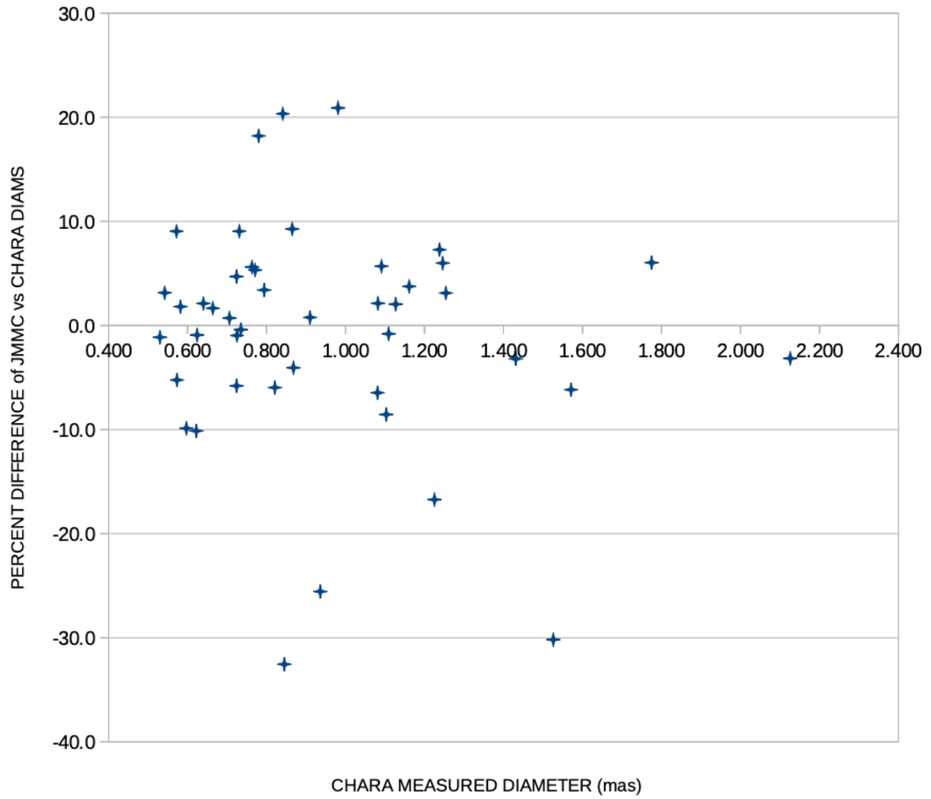




Science case 3: cross-verifying diameters measurements?

- For stars >0.5 mas: Simultaneous diameter measurement in R/H can help remove cross-instrument biases

- Can R/H-band visibilities 2x15, can help skip many CAl-SCI-CAL-SCI sequences by using baseline bootstrapping?



% diff diameters JMMC catalog vs directly measured from CHARA

Outliers from 10 – 30% are obviously an issue

MIRC-X vs MYSTIC (single night - 1-hour observation)

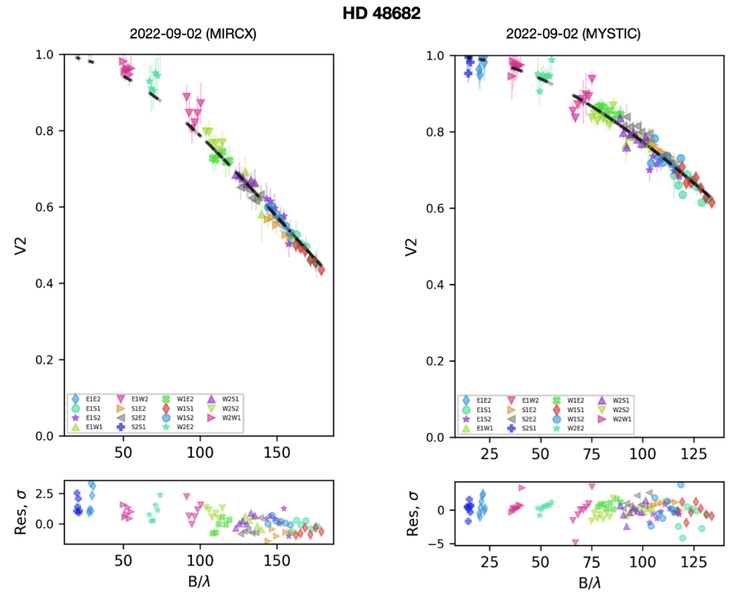


Figure 10. HD 48682 – Calibrated squared visibility and model fitting.

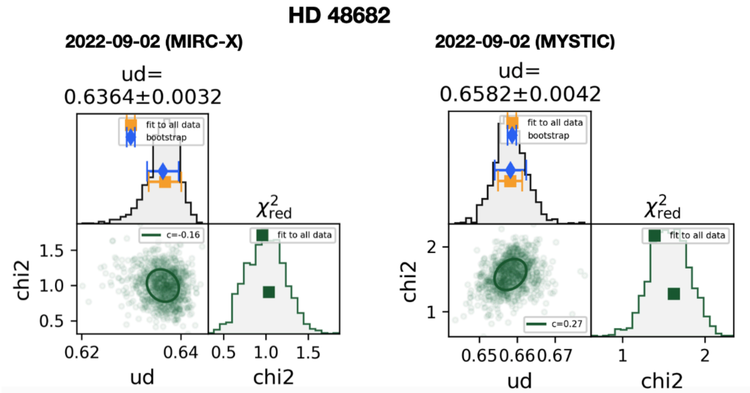


Figure 11. HD 48682 bootstrap fit uncertainities.

- MIRC-X and MYSTIC can measure diameters ~0.5mas
- Maybe those can be used to cross-check the diameter measurements

Case 3: Diameters in R + H-band

Down sides of data simultaneous collection:

- Simultaneous data collection means fringe tracker has to be stopped while taking BEAMS and BACKGROUNDs.
- The BACKGROUND can be taken during slewing.
- The Kappa flux (fringe/photometric channels), a measure of instrument polarization. Can be sufficient on a calibrator since same part of sky?

Data reduction process

- Data reduction can done two ways.
- Classical way of individual instrument, which is already implemented.
- Combined data by co-phasing fringe tracker (waterfall plot), which allows long exposures or blind fringe recording for faint targets

Summary

- Unexplored potential of simultaneous co-phasing observations from R-band to K-band.
- For imaging (ex. Star spots) it provides better coverage with 4x15 (R+J+H+K) baseline fringes.
- Simultaneous detection of binaries and spectral lines.
- The best part is ready to use.