Infrared interferometric imaging of the symbiotic Mira R Aquarii

Work in progress

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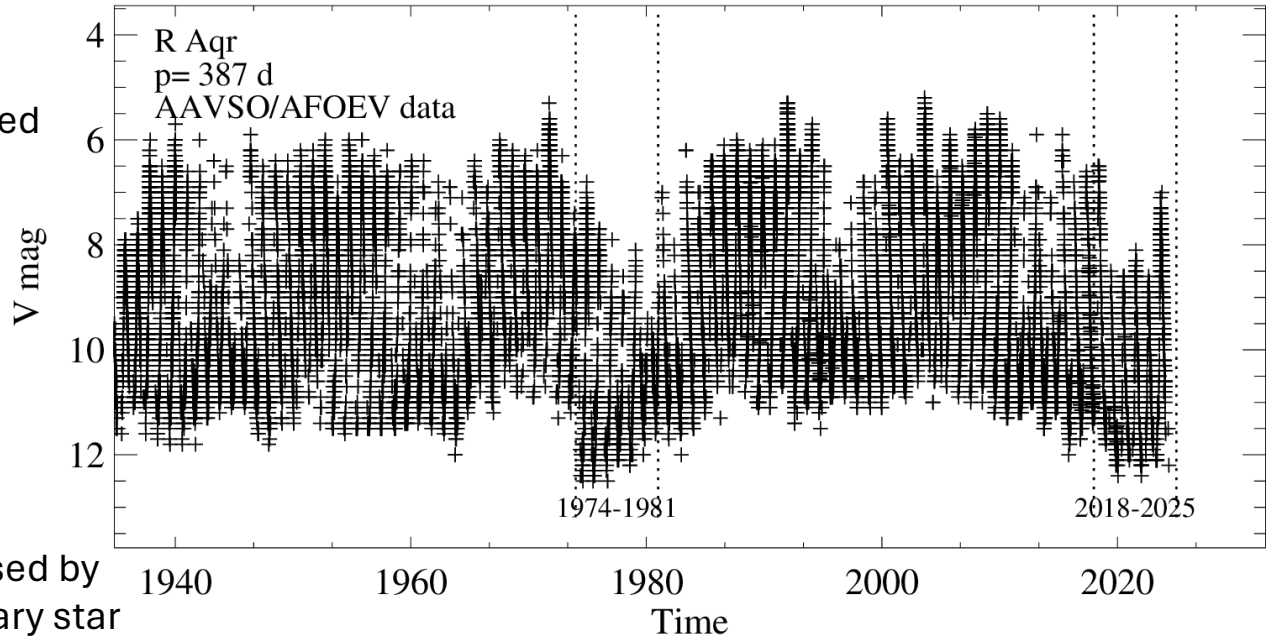
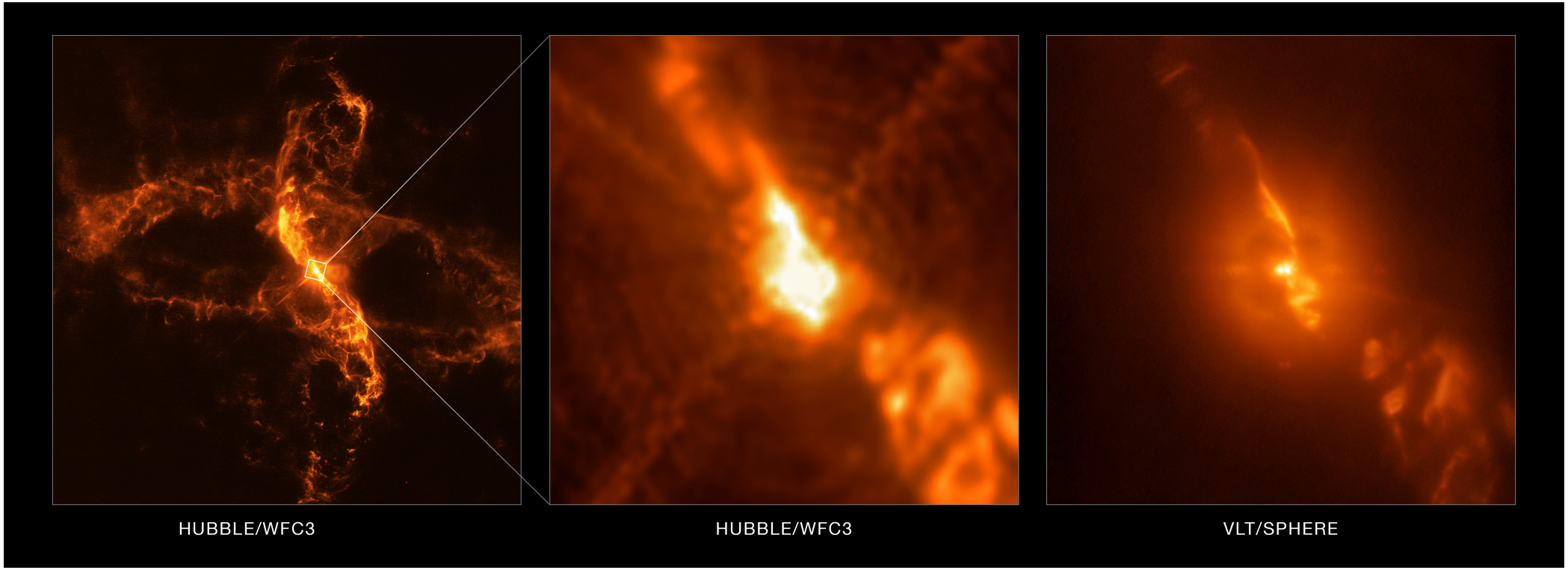
Picture:ESO/ M. Kornmesser

Symbiotic Mira R Aqr: Characteristics

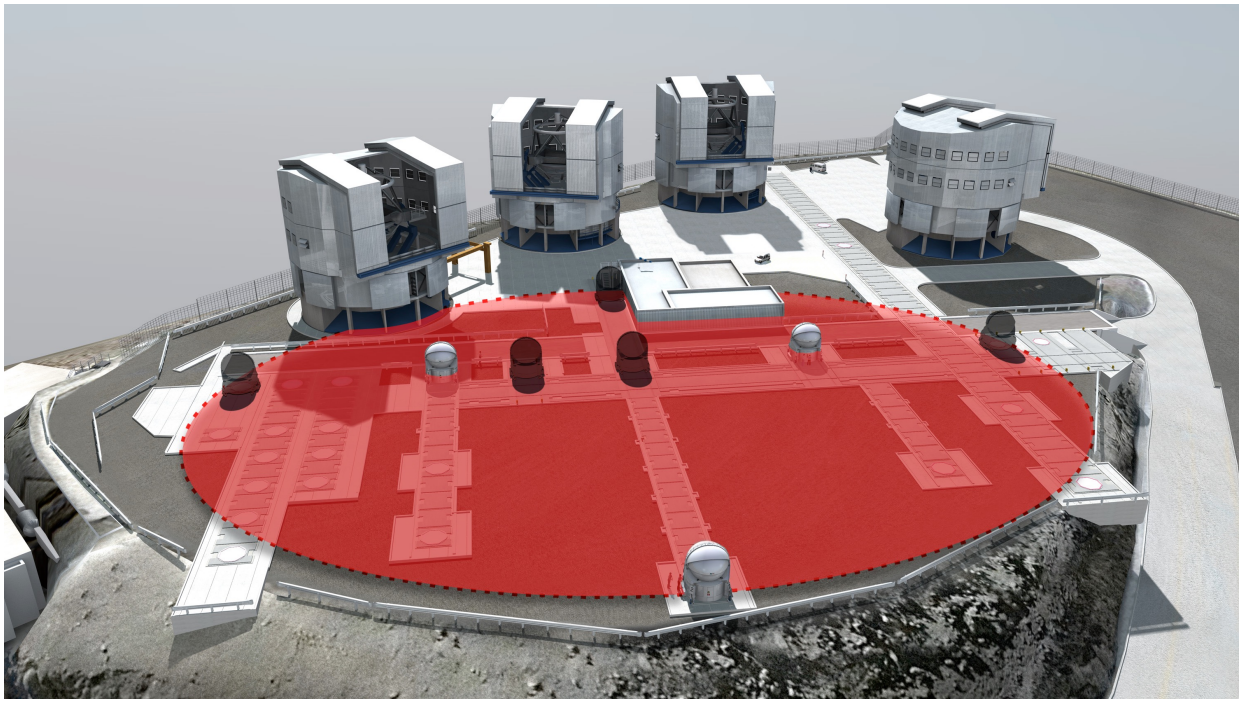


- Merrill 1921: bright nebular lines superposed on Md spectrum typical for LPVs
- Michalitsianos et al., 1980 :
  - Dense compact nebula, Warm chromosphere
  - Secondary identified as white dwarf
- Wallerstein &Greenstein 1980: Reddening 0.67 in (B-V), A_V ~ 2
- Willson et al. 1981: Mira component in the system being eclipsed by an extended gas cloud around the secondary star Orbital period 44 years, duration 8.5 yr (20% of period). Next eclipse: 2018-2026
- Hinkle et al. 1989: Orbit with 44yr period and high eccentricity (e=0.6). All mass loss Mira forced through the Roche lobe onto the accretion disk of the secondary.
- Gromadzki & Mikolajewska 2009 : Refined orbit, period 43.6 yr, e=0.25+-0.07, Mtot 1.6-2.5Msun, Mh (hot component)=0.6-1 Msun; Mg (giant)=1-1.5Msun; mass ration q=Mg/Mh=1.2-2.1.
- Min et al. 2014: Accurate parallax: 4.59 +- 0.24 mas, distance 218 +12/-11 pc



ESO/Schmid et al./NASA/ESA, https://www.eso.org/public/images/eso1840b/

VLTI: A virtual 200-meter telescope



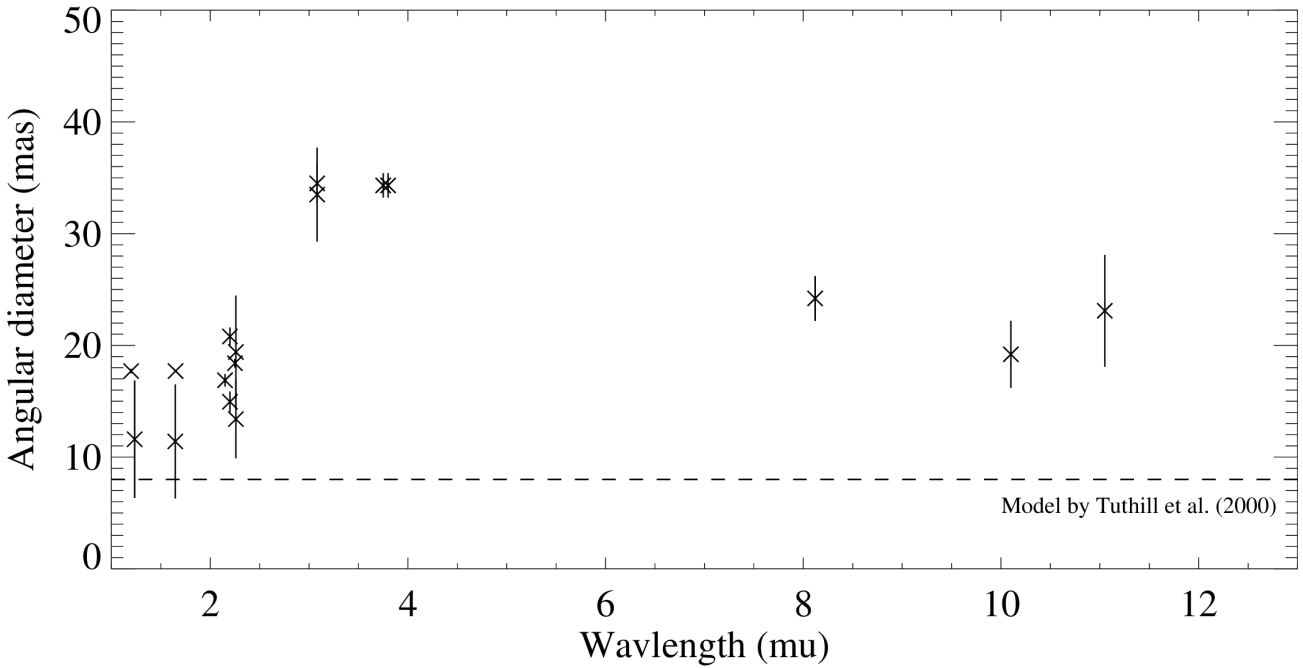
PIONIER:
H-band (1.5-1.7 mu), R~20
Angular resolution up to ~1.5 mas

GRAVITY:
K-band (1.9-2.4 mu) , R ~22, 500,4000
Angular resolution up to ~2.2 mas

MATISSE:
LM-bands (2.8-4.1 mu), R~30,500,1000,3500
Angular resolution up to ~4 mas

N band (8-13 mu), R~30,220
Angular resolution up to ~10 mas

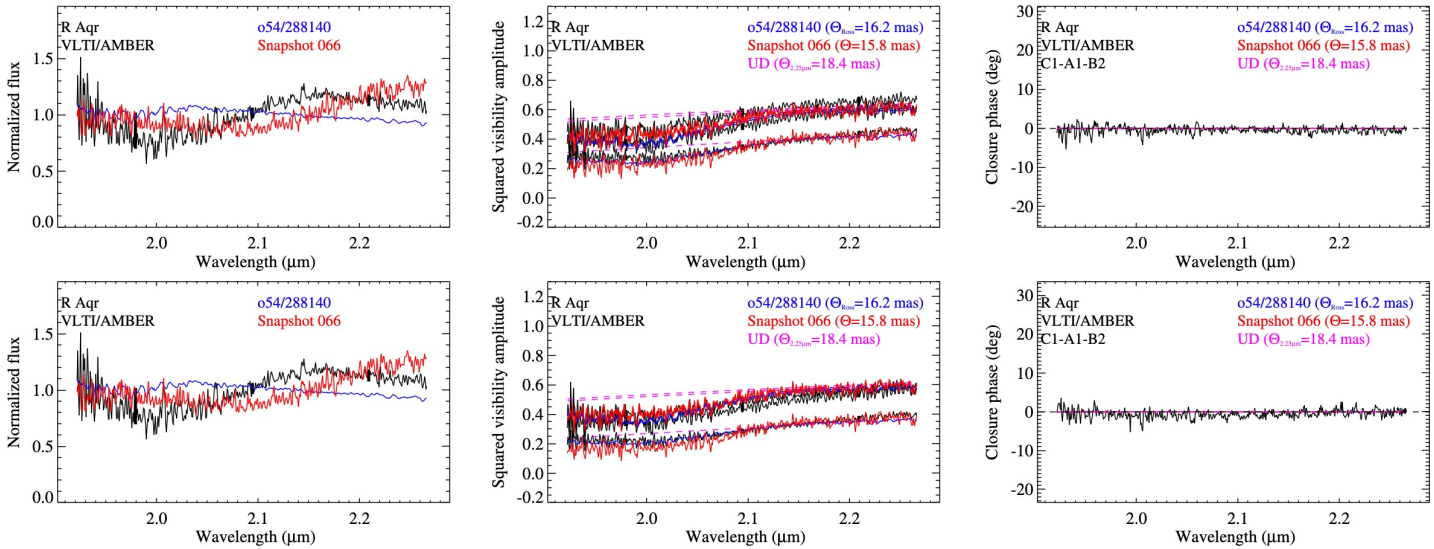
R Aqr angular diameters from the literature



- Near-continuum bands at 1.6 mu or 2.25 mu typically a good indicator of the photospheric diameter, while many other bands are contaminated by extended molecular layers (H_2O, CO, SiO)
- R Aqr: Larger than typical discrepancies between H and K near-continuum angular diameters

Van Belle et al. (1996), Tuthill et al. (2000), Chagnon et al. (2002), Mennesson et al. (2002), Millan-Gabet et al. (2005), Ragland et al. (2008), Zhao-Geisler et al. (2012), Wittkowski et al. (2016)

VLTI/AMBER interferometry of R Aqr (10/2012)



	o Cet	R Leo	R Aqr	R Cnc	X Hya	W Vel
Phase	0.1	0.6	0.6	0.3–0.5	0.7–0.9	0.9–1.1
$\Theta_{\rm UD}^{2.25\ \mu{\rm m}}$ (mas)[a]	28.5 ± 1.5	29.6 ± 1.3	18.4 ± 0.4	13.2 ± 0.3	6.0 ± 0.3	7.4 ± 0.2
$m_{\rm bol}$ (mag)[b]	1.04 ± 0.1	0.75 ± 0.1	2.37 ± 0.1	2.83 ± 0.4	4.00 ± 0.2	3.55 ± 0.2
Parallax (mas)	9.1 ± 1.4[c]	10.0 ± 1.5[c]	4.59 ± 0.24[d]	3.6 ± 0.5[c]	2.3 ± 0.3[c]	2.0 ± 0.3[c]
R ($R_\odot$)	340 ± 80	320 ± 70	431 ± 33	400 ± 70	280 ± 60	400 ± 80
$T_{\rm eff}$ (K)	2450 ± 120	2570 ± 120	2250 ± 76	2390 ± 260	2700 ± 195	2700 ± 160
log $L/L_\odot$	3.57 ± 0.27	3.60 ± 0.25	3.63 ± 0.12	3.66 ± 0.35	3.58 ± 0.28	3.88 ± 0.26

Wittkowski et al. 2016

New VLTI Observations of R Aqr

PIONIER

2019, July to August, Phase ~0.1

Imaging

GRAVITY

2016, October, Phase ~0.4

2018, August, Phase ~0.16

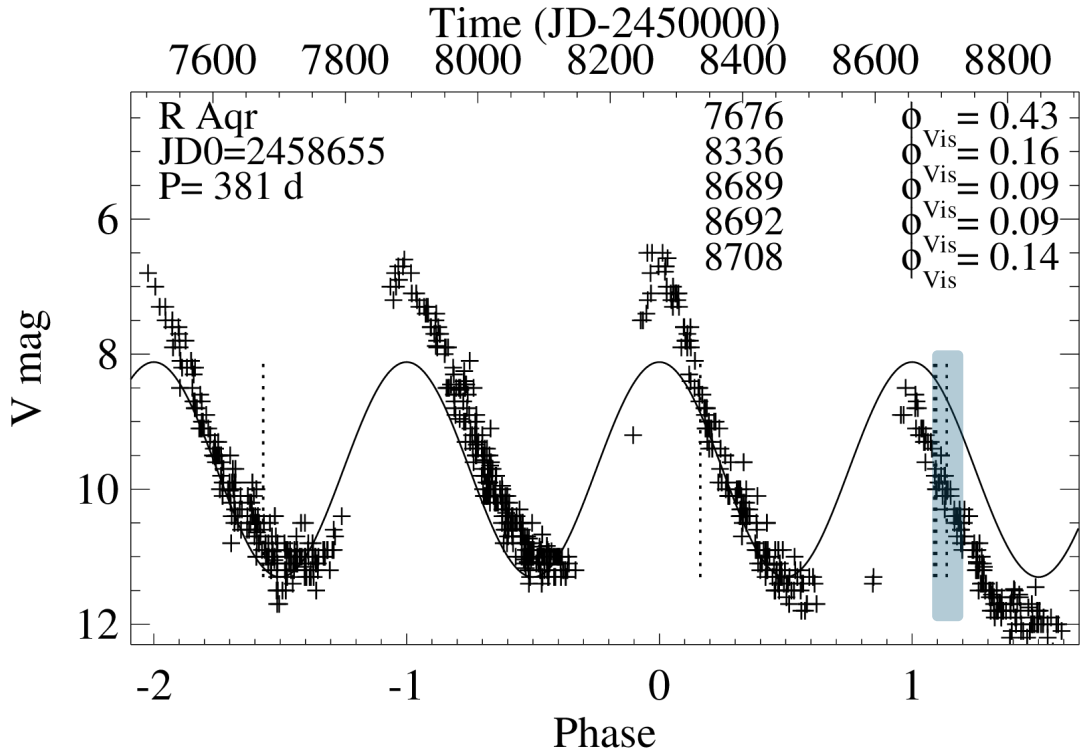
2019, August-September, Phase ~0.1-0.2

Snapshots

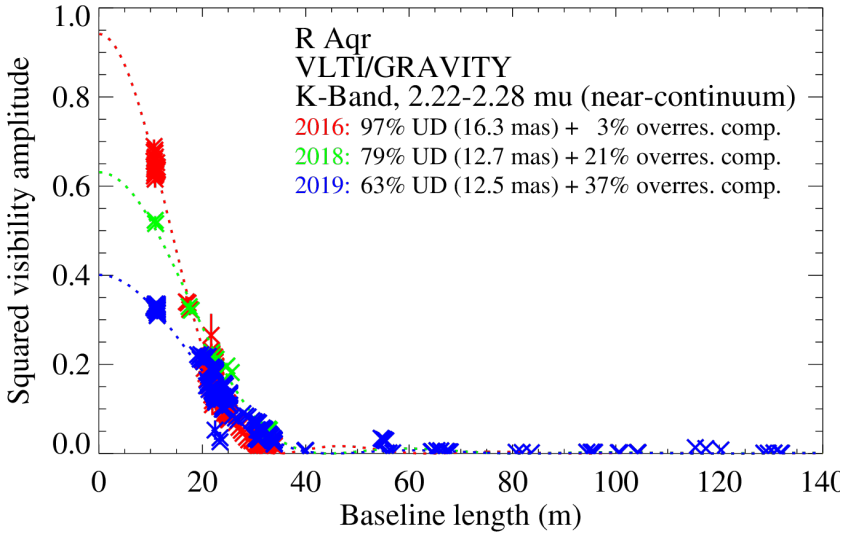
MATISSE:

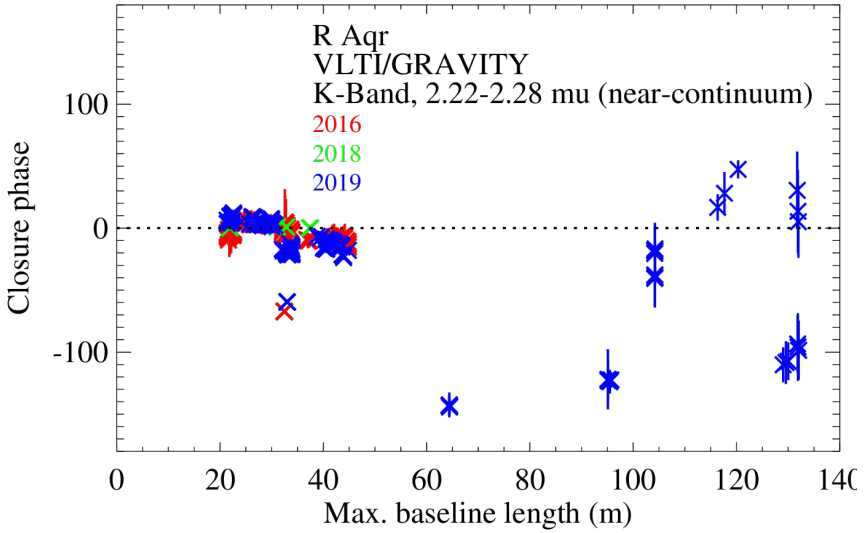
2019, July to August, Phase ~0.1

Imaging



GRAVITY (near-IR K-band) results





Increasing contribution by an uncorrelated background component in the FOV (~0.25 arcsec):

2016, before the suppression: 97% of the K-band continuum flux in the stellar (UD) component

2018, early in the suppression: 79% of the K-band continuum flux in the stellar (UD) component

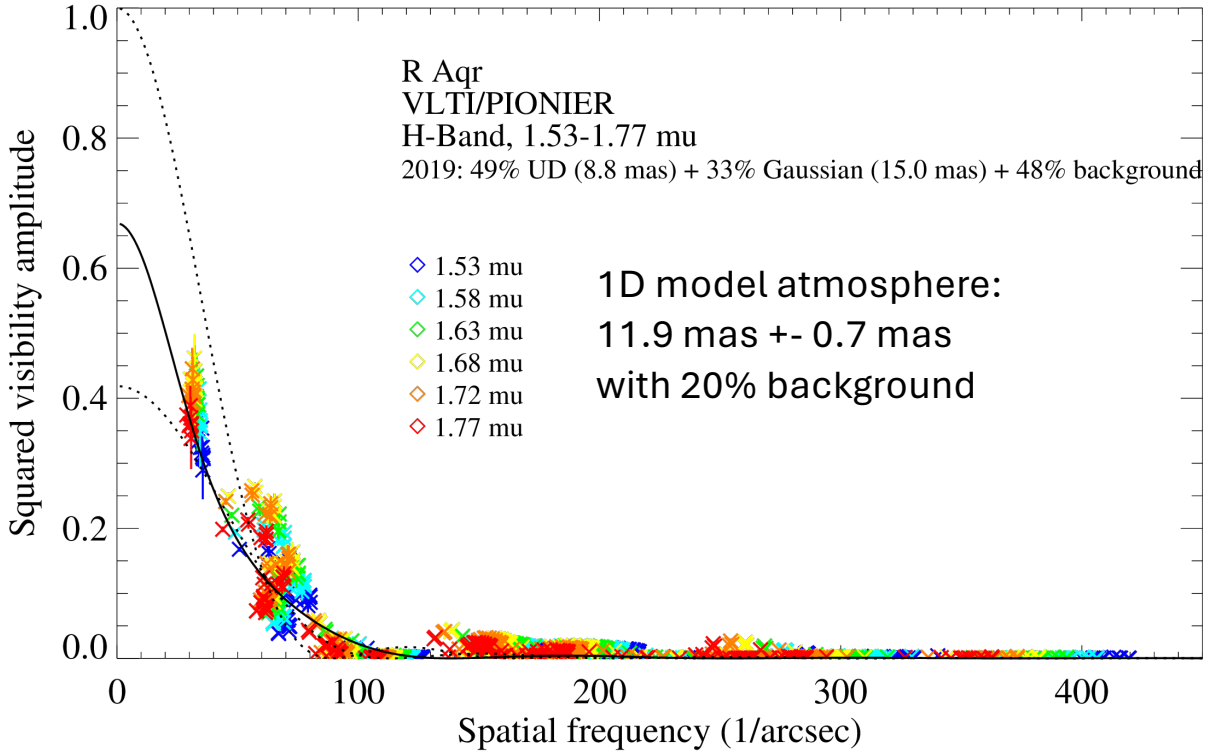
2019, in the suppression: 63% of the K-band contimuum flux in the stellar (UD) component

Continuum angular diameters in 2016 (phase 0.43), 2018 (0.16), 2019 (0.12):

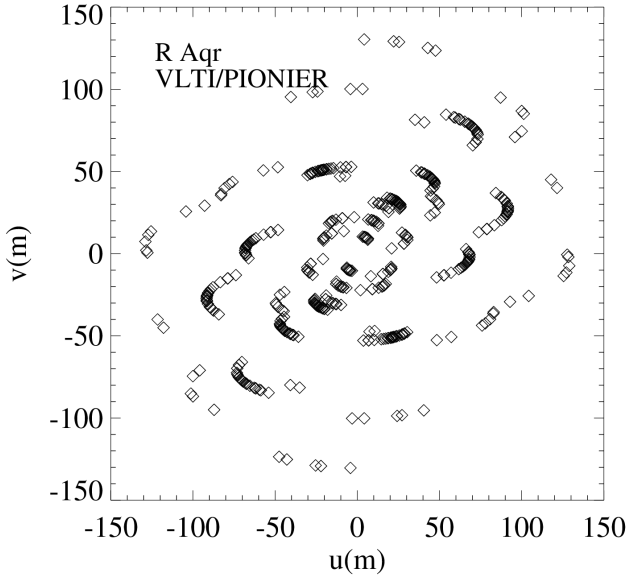
16.3 mas , 12.7 mas , 12.5 mas

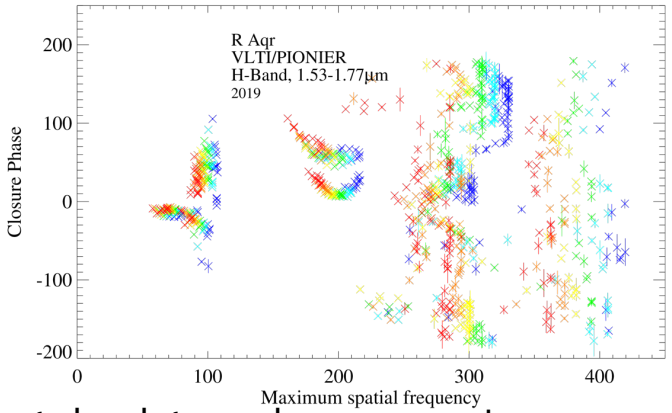
Pre-suppression epoch consistent with 2012 AMBER result (18.4 mas at phase 0.6).

PIONIER (near-IR H-band results



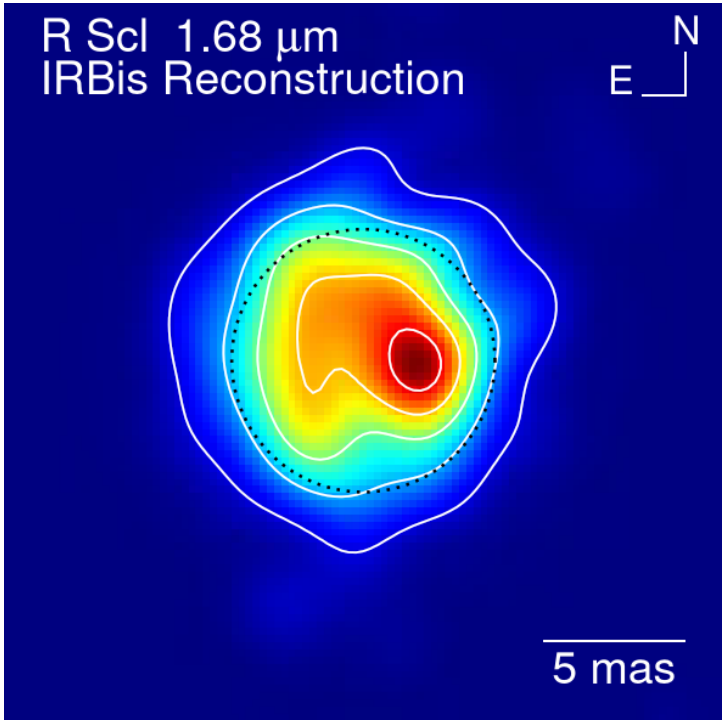
1D model atmosphere:
11.9 mas +- 0.7 mas
with 20% background

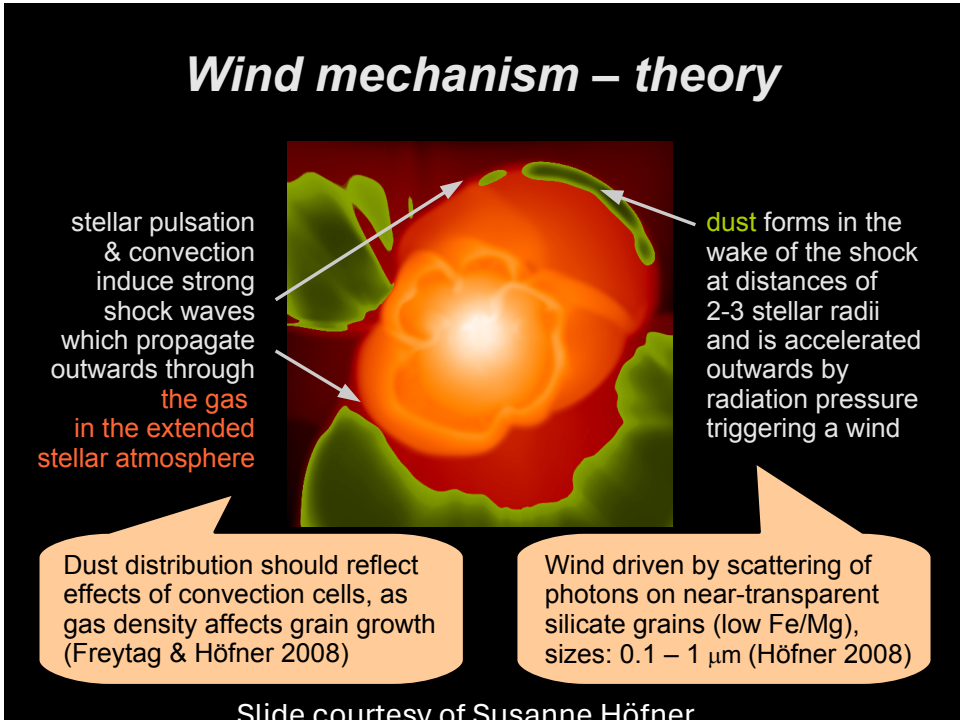




During the supression event in 2019:
20-50% of the H-band flux in the FOV (~0.2 arcsec) from an uncorrelated large background component.
Angular diameter lower than obtained from GRAVITY, and much lower than previous estimates.

Resembling the carbon star R Scl observed with PIONIER





Wittkowski et al. 2017

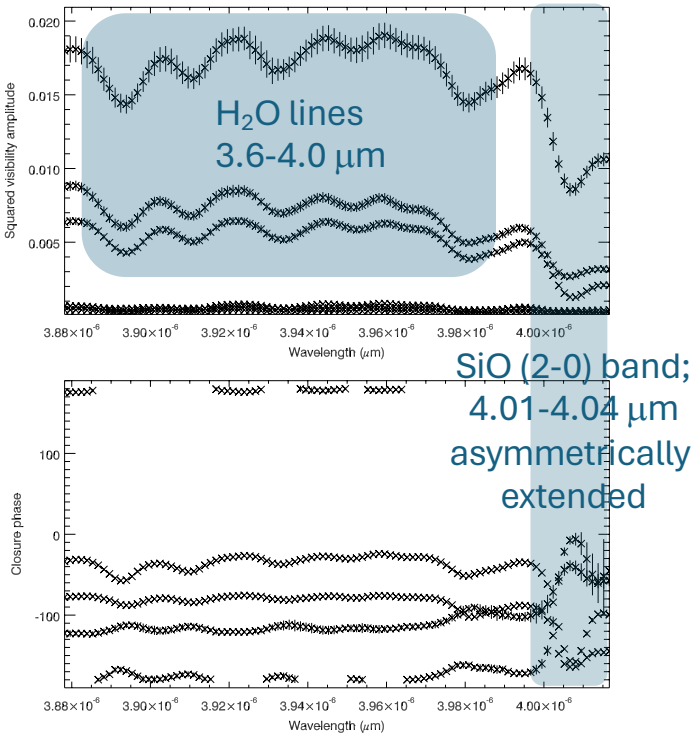
Interpretation of the image:

(1) Giant convection cells resulting in large-scale shock fronts, leading to clumpy molecule and dust formation.

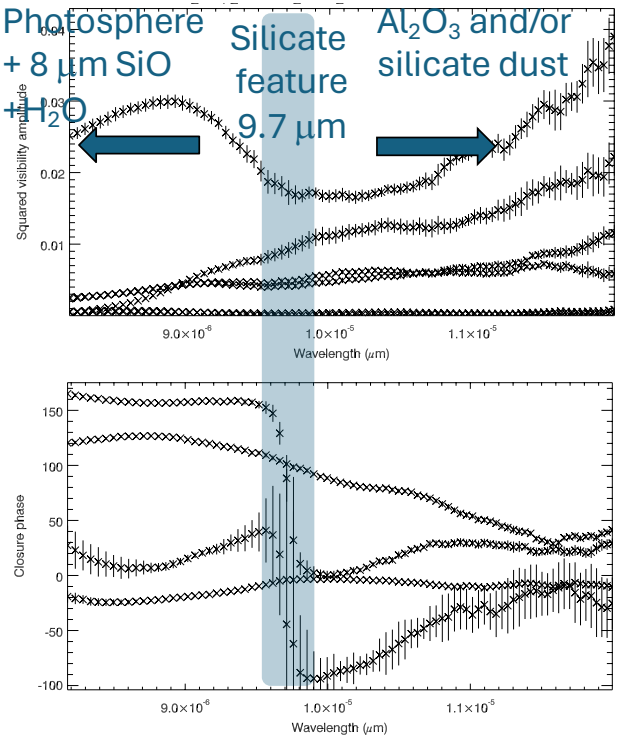
(2) Dust clumps (amC) at radii of 2-3 R_{star} seen against the photosphere

MATISSE (thermal IR LMN bands) results

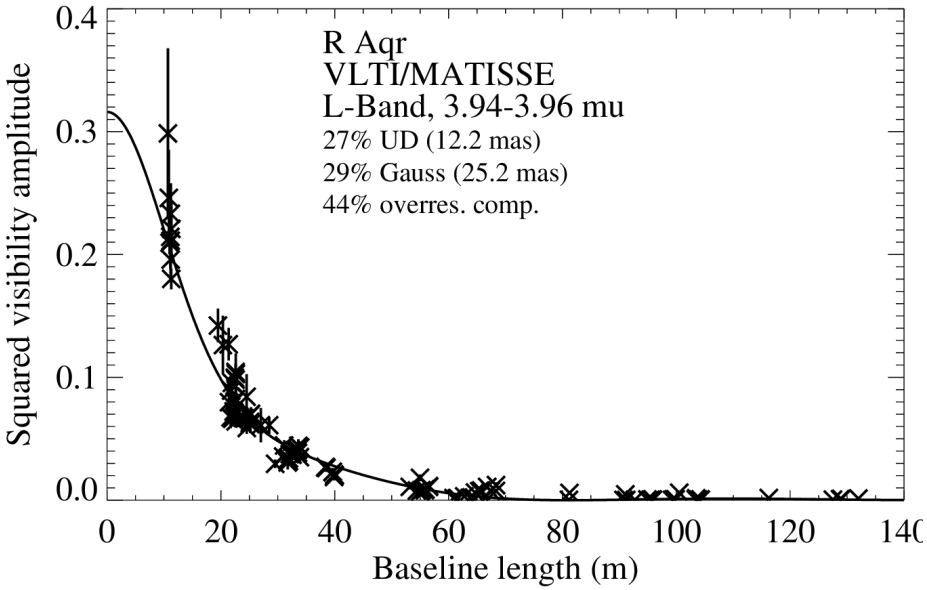
L-band medium spectral resolution, center 3.95μm

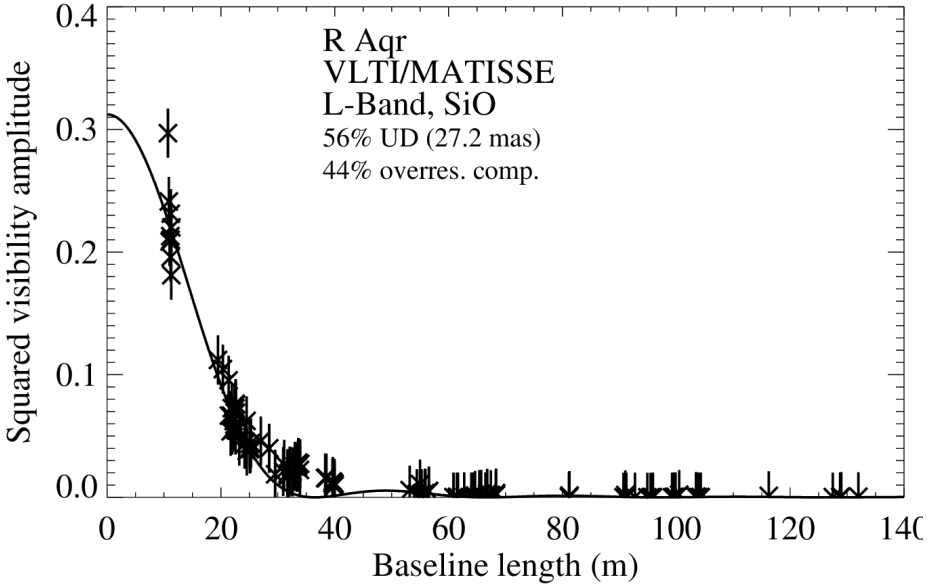


N-band low spectral resolution



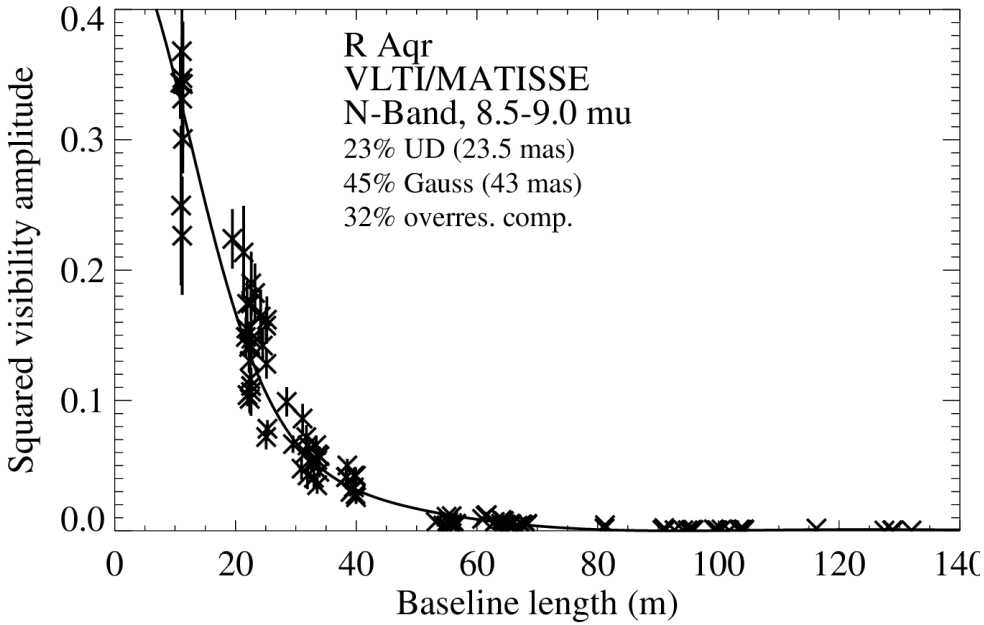
MATISSE L-band results

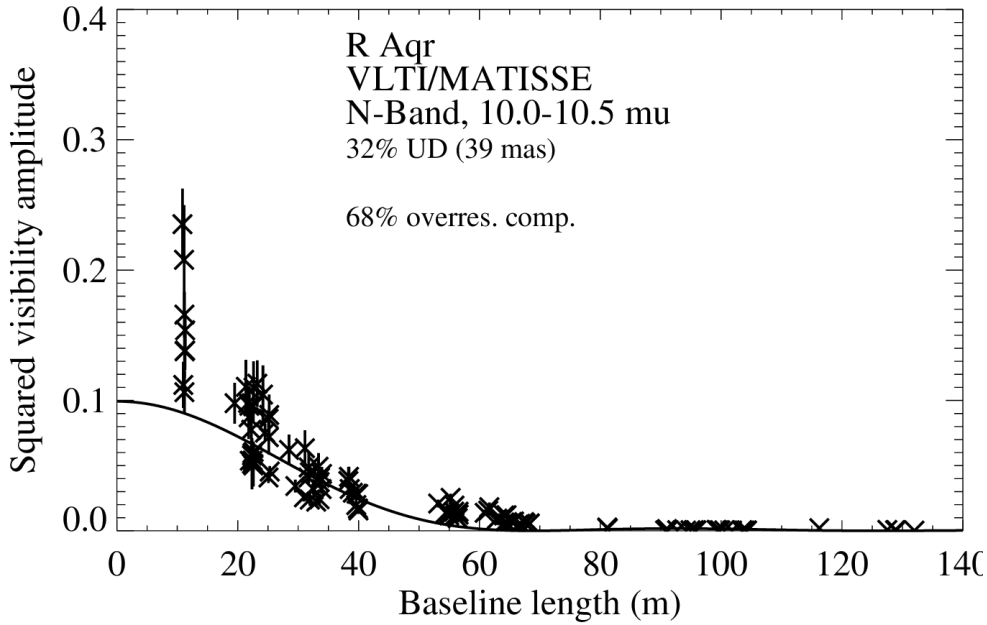




1D model atmosphere:
13.1 mas +- 0.2 mas
with 42% background flux

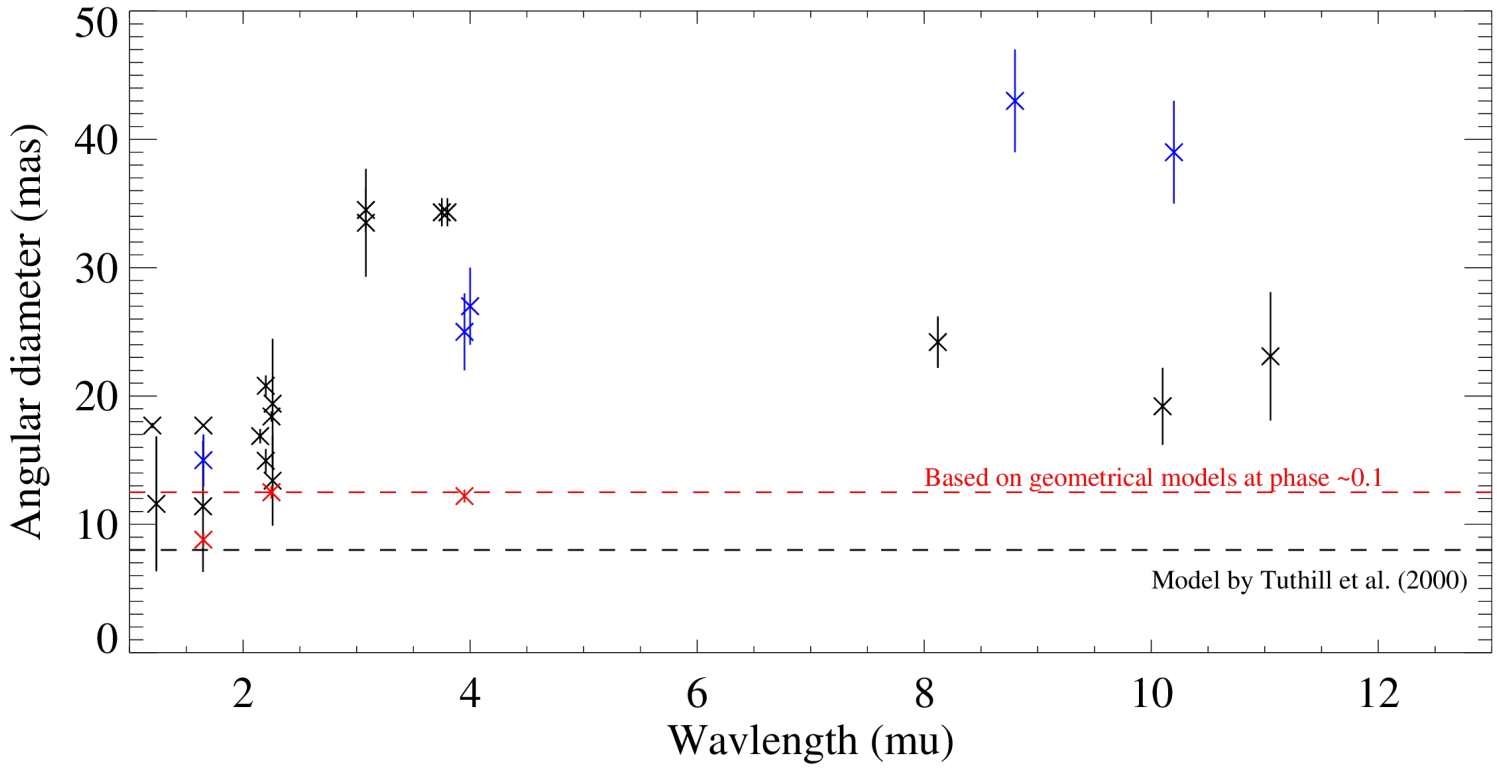
MATISSE N-band results





Resolved structure confined within Roche lobe diameter of ~40 mas

Summary of angular diameters



Angular diameter overestimated in the past?

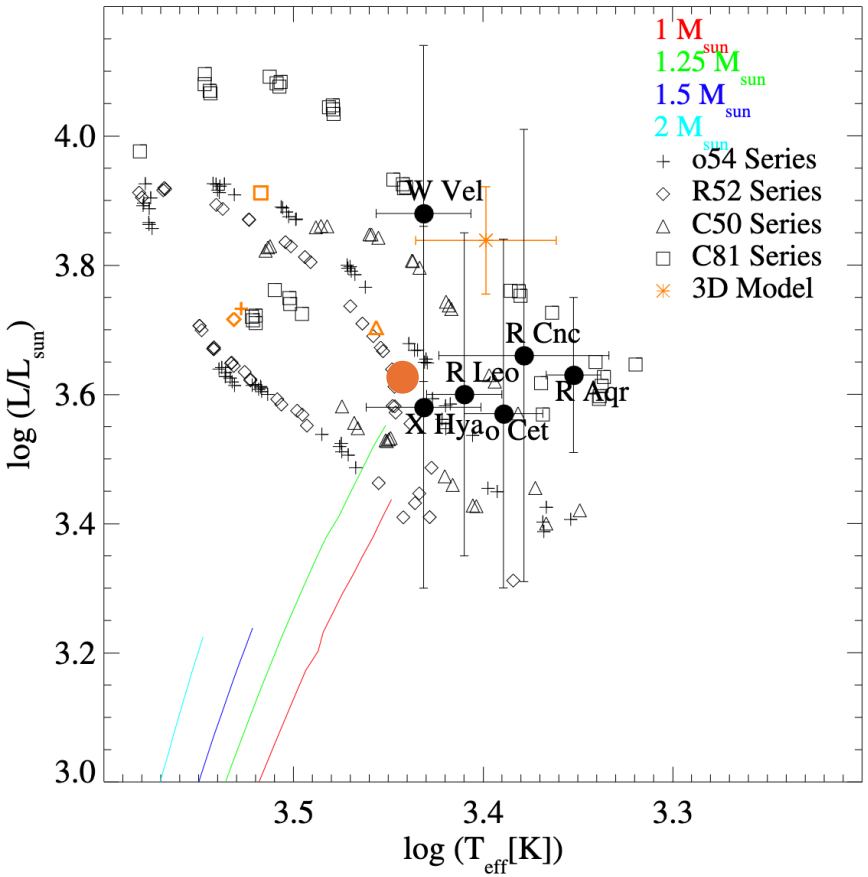


Figure from Wittkowski et al. 2016
based on an angular photospheric diameter of 18.4 +- 0.4 mas at phase 0.6.

Angular diameter of 12.5 +/- 0.5mas:

Radius: 431+-33 Rsun ➡ 293 +- 30 Rsun

Teff: 2250+-76 K. ➡ 2728 +- 120 K

log (Teff): 3.48. ➡ 3.44

Summary

- Increasing contribution from an uncorrelated large background flux contribution at 2.2 mu: 3% in 2016, 20% in 2018, 50% in 2019
- Spatially resolved images of the Mira component in the near-IR H and K bands and the thermal-IR L, M, N bands
- H-band image seen behind foreground extinction
- Untypically large discrepancies of measured angular diameters in near-continuum bands
  - Angular photospheric diameters may be overestimated
  - Unusually strong contribution from the CSE
- No indication of mass transfer in the current image reconstructions