

Interferometric monitoring of Evolved Stars

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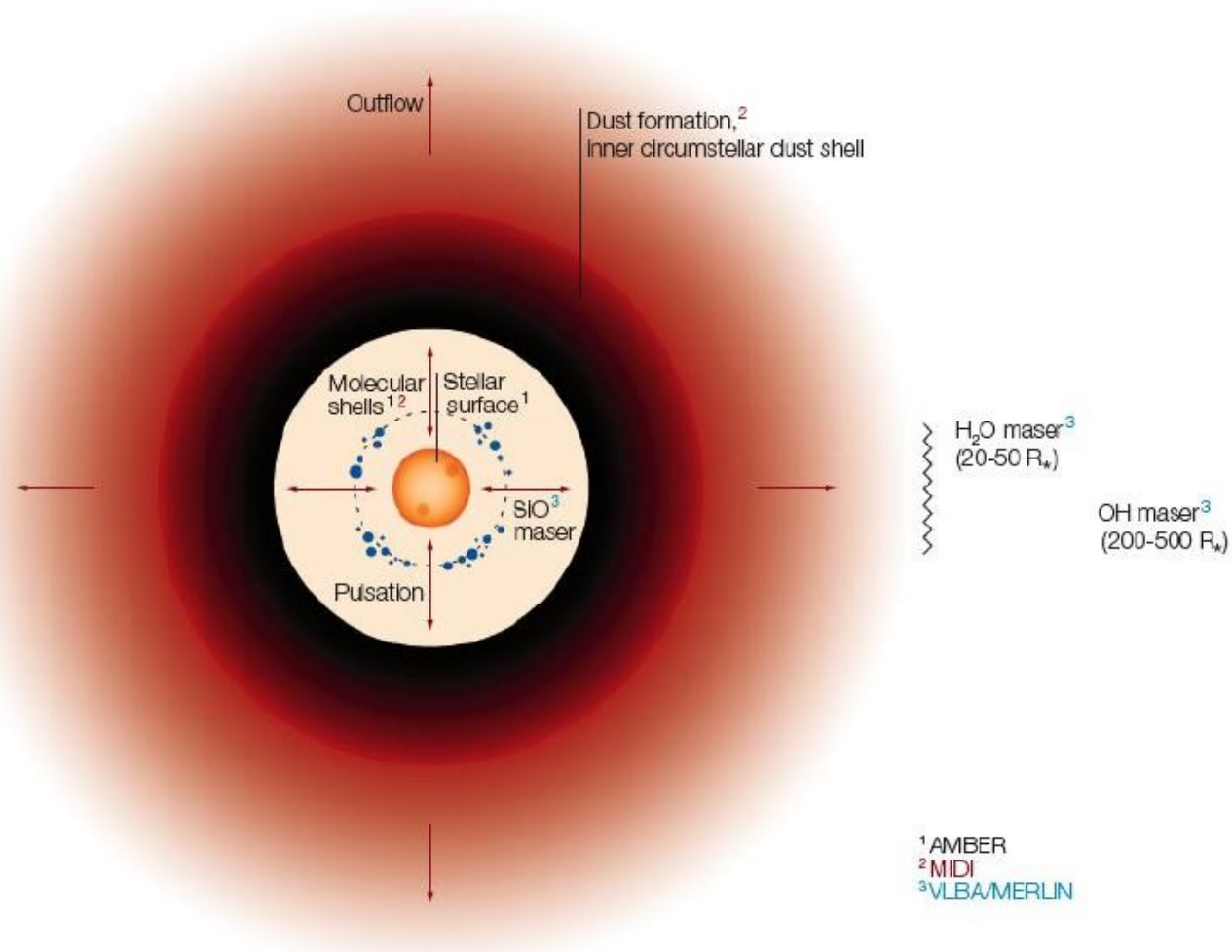
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The Origin and Fate of the Sun: Evolution of Solar-mass Stars Observed with High Angular Resolution

ESO Garching, March 2 - 5, 2010

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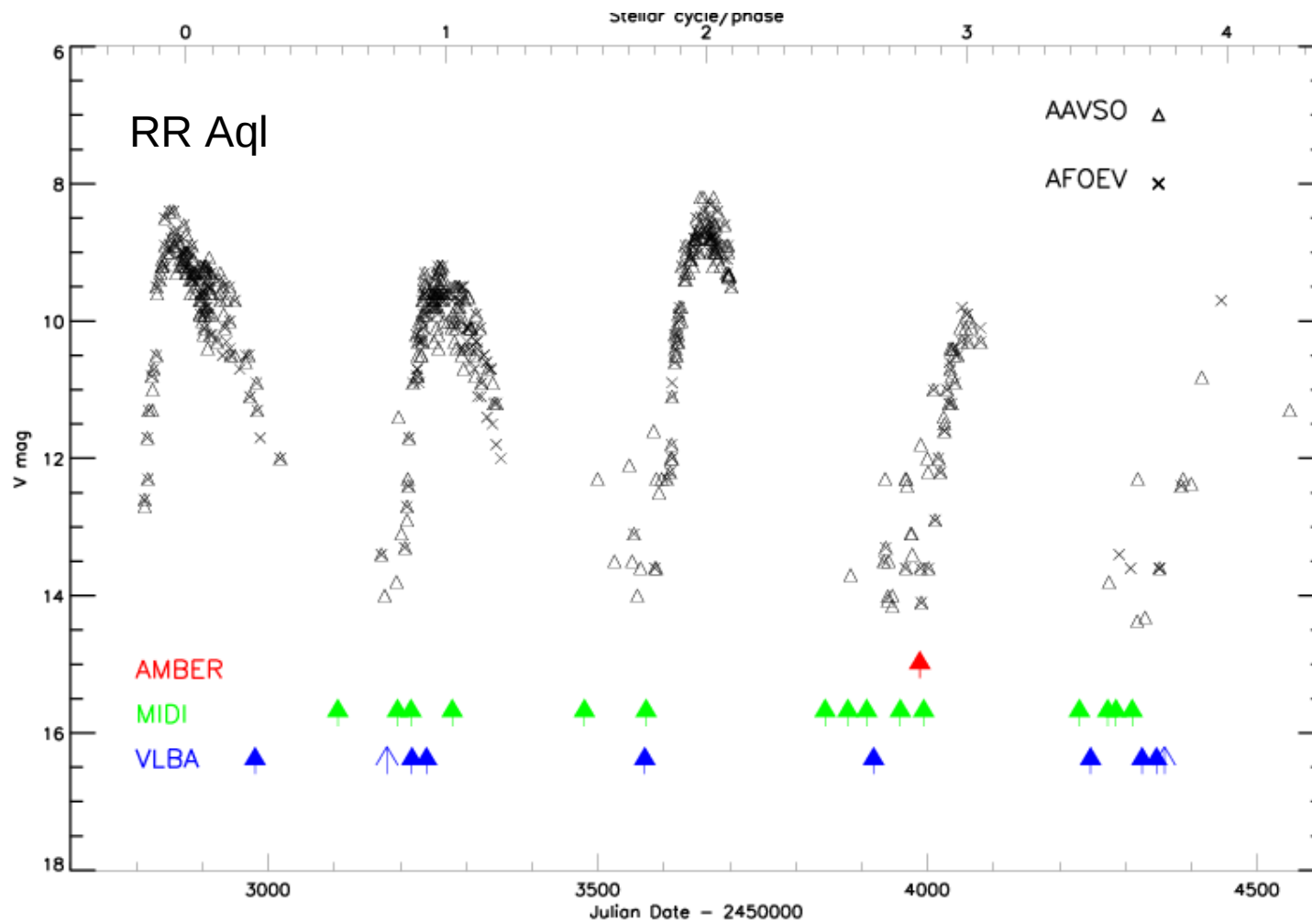
AMBER near-infrared interferometry (J, H, K band)

MIDI mid-infrared interferometry (N band)

VLBA radio interferometry (SiO, H₂O, OH)

M. Wittkowski

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Pulsation period 394.78 d

Spectral type M7

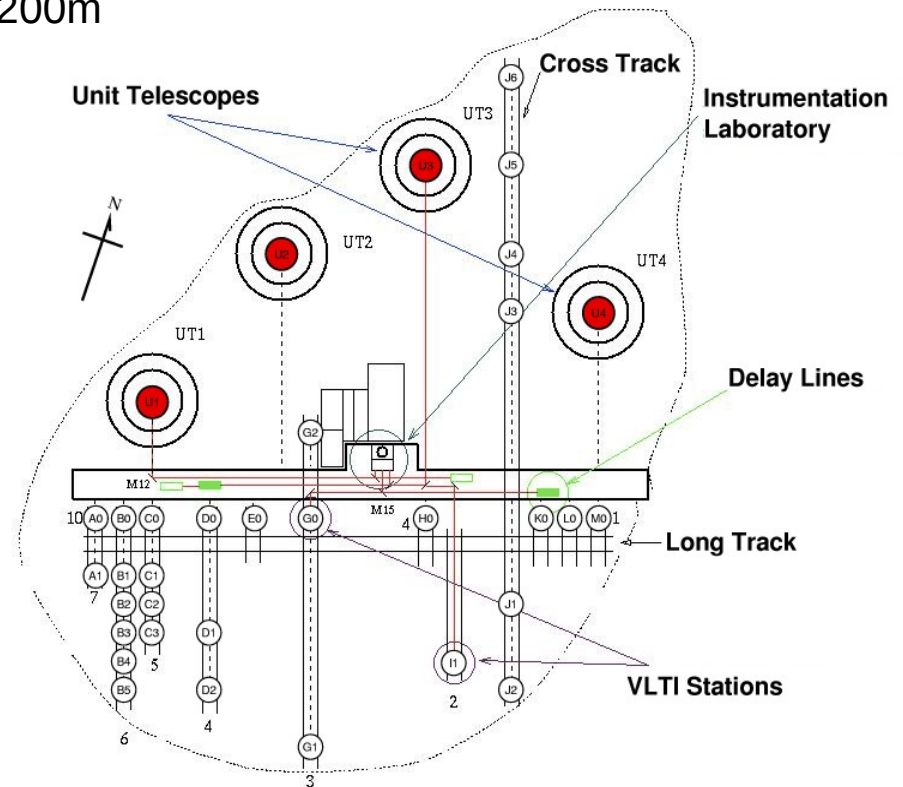
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VLTI – AMBER/MIDI Observations

Four 8.2 m Unit Telescopes. Baselines (UTs) up to 130m
Four 1.8 m Auxiliary Telescopes (Ats), baselines 8 – 200m

AMBER: Near-Infrared
K-band ($2.2 \mu\text{m}$), 3-way beam combiner
Spectral resolution $R=1500$ (medium resolutions)
(UTs)

MIDI: Mid-Infrared
N-band ($8\text{-}13 \mu\text{m}$) 2-way beam combiner.
Spectral resolution $R=30$ (PRISM), HIGH-SENS
(ATs, UTs)
Projected baseline varies: 10-130m



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data reduction

AMBER

Amdlib package (version 2.1) with the **yorick** interface
(provided by the *Amber consortium* by *Jean-Marie Mariotti Center*)

MIDI

MIA+EWS software package, version 1.6 (<http://www.strw.leidenuniv.nl/~koehler/MIDI>)

modeling

AMBER/MIDI (atmospheres + molecular layers)

Uniform disk, Gaussian model

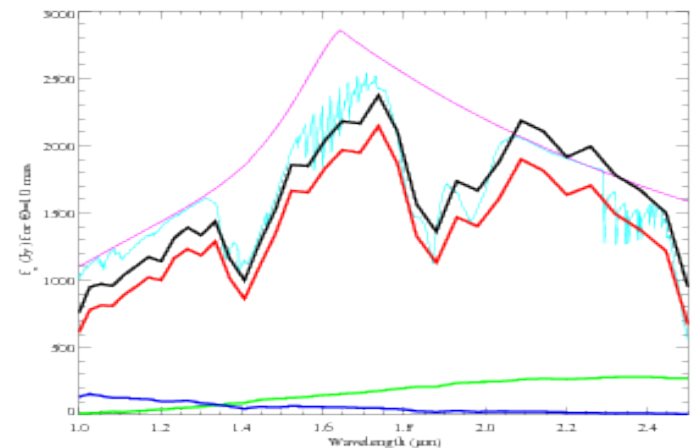
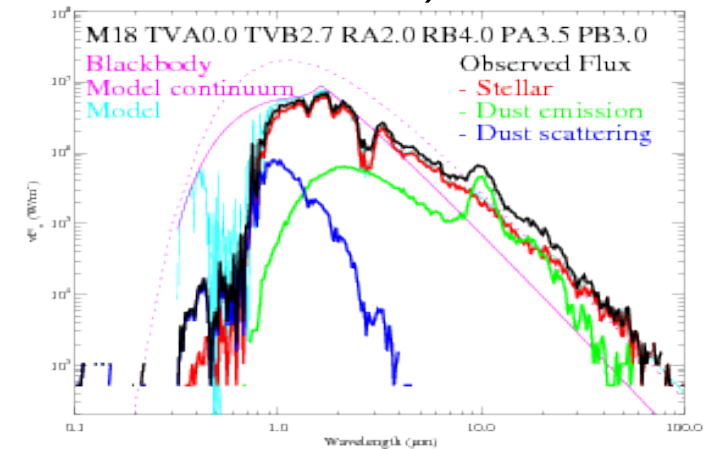
the complete self-excited dynamic atmosphere models

(P and M) of Mira stars by Scholz
(*Ireland et al. 2004 a,b*, *Woodruff et al. 2008*).

MIDI (dust shell)

The radiative transfer code **mcsim_mpi**
(Ohnaka et al. 2006a)

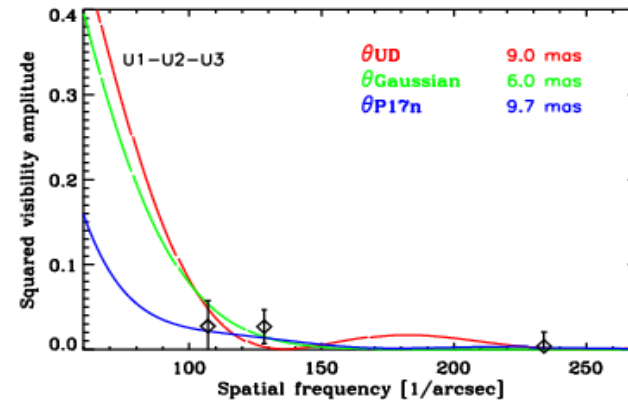
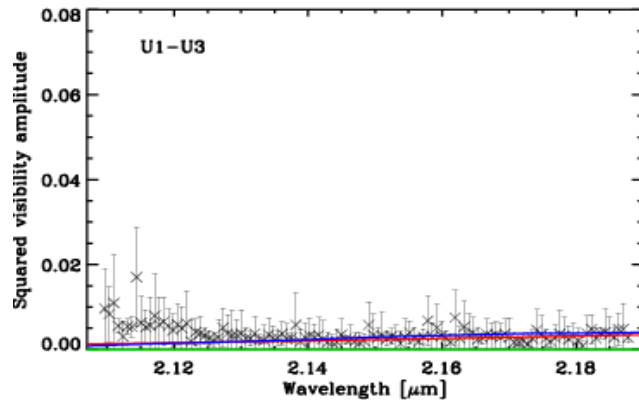
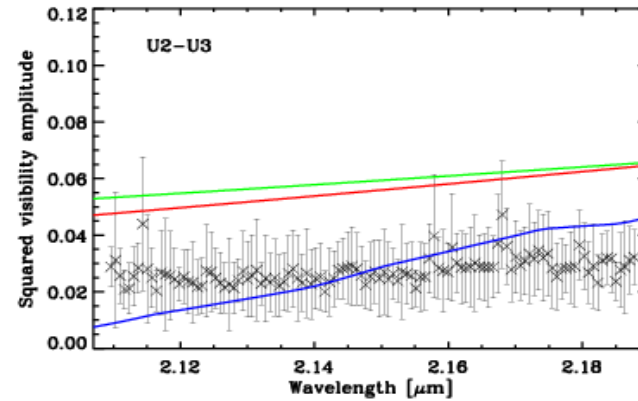
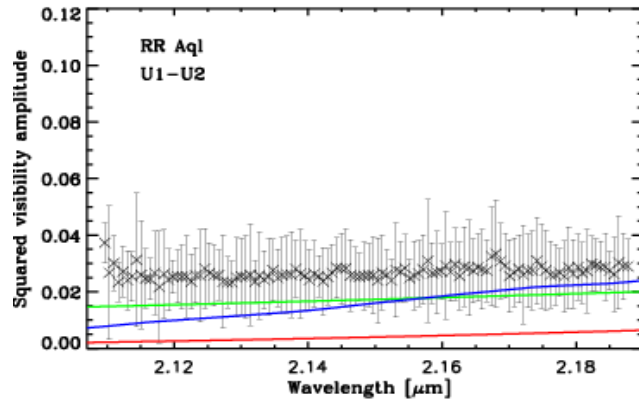
(Wittkowski et al. 2007)



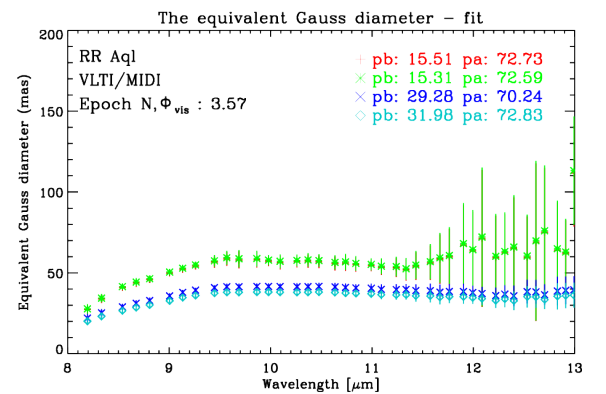
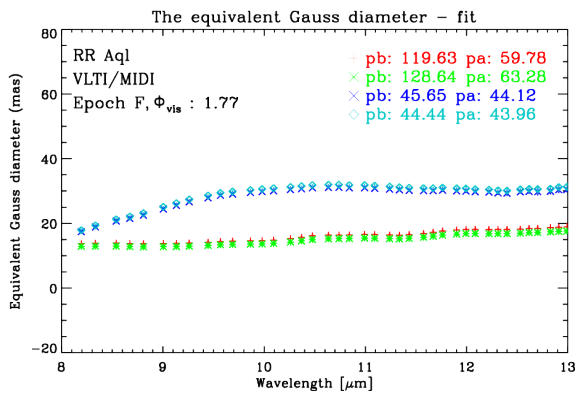
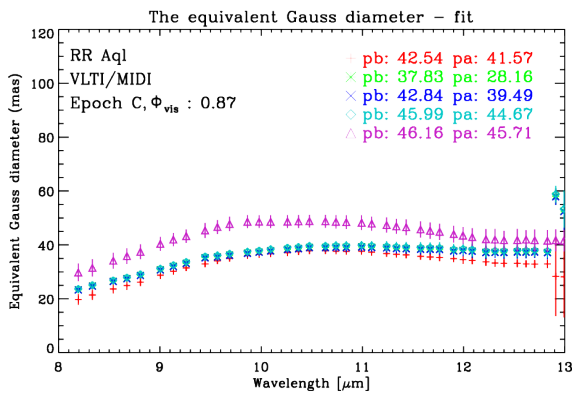
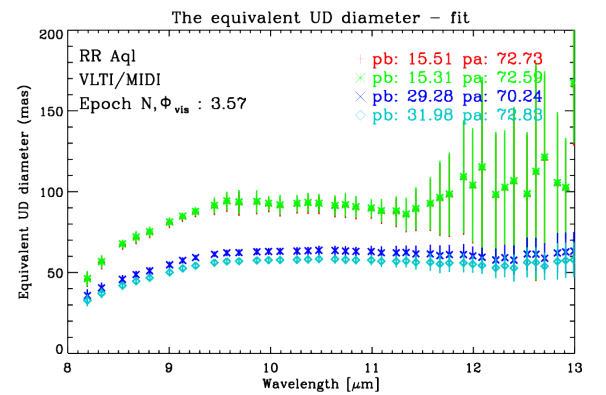
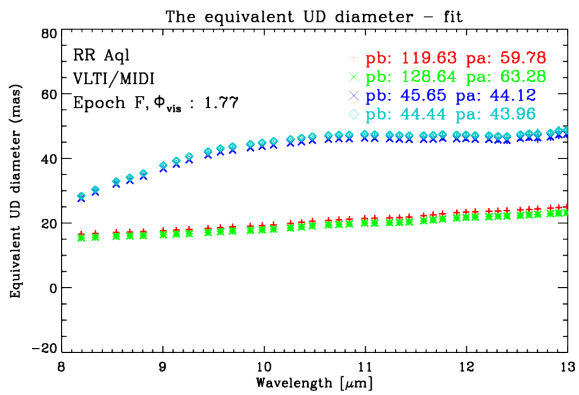
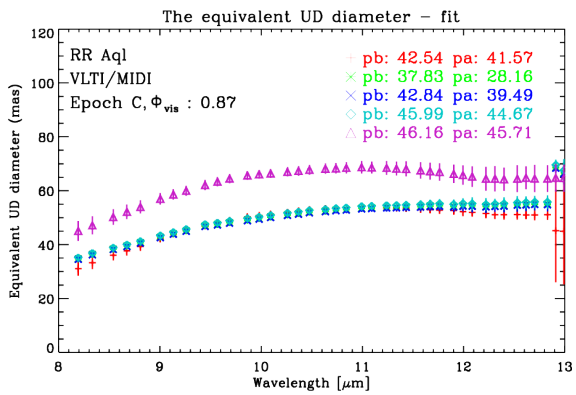
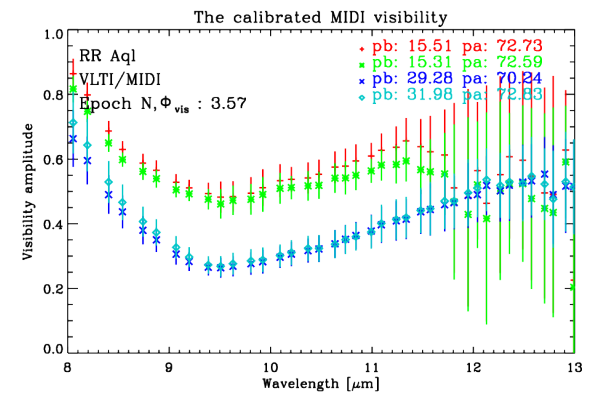
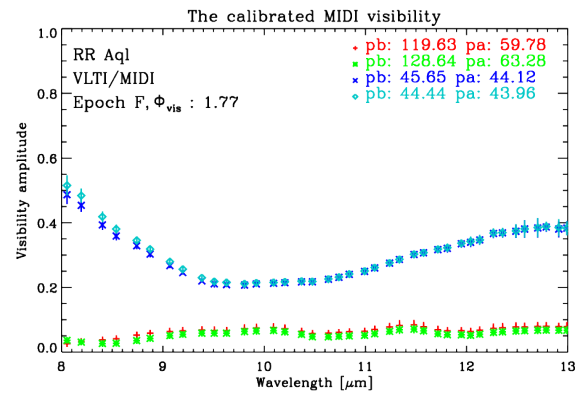
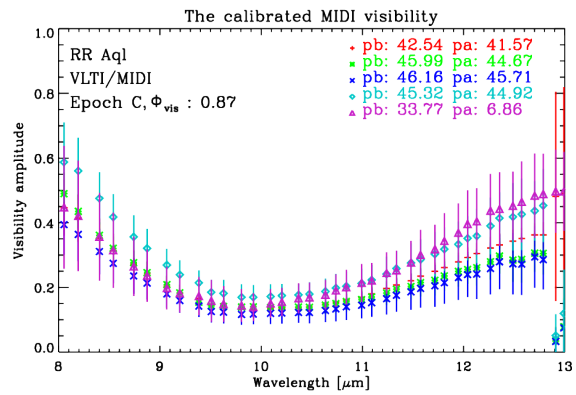
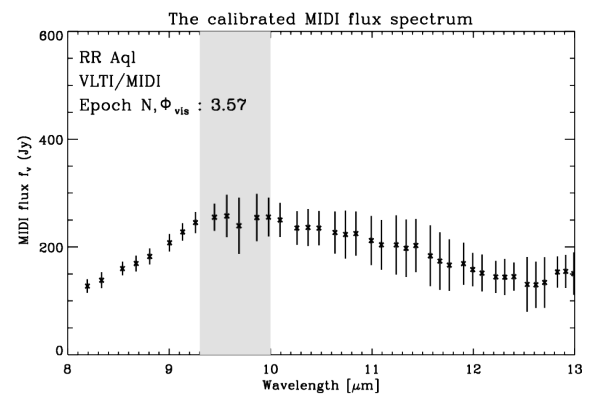
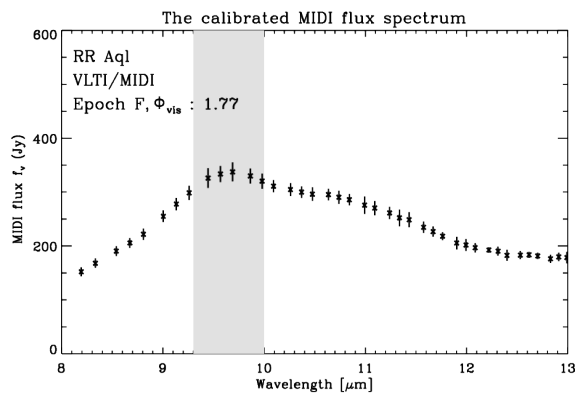
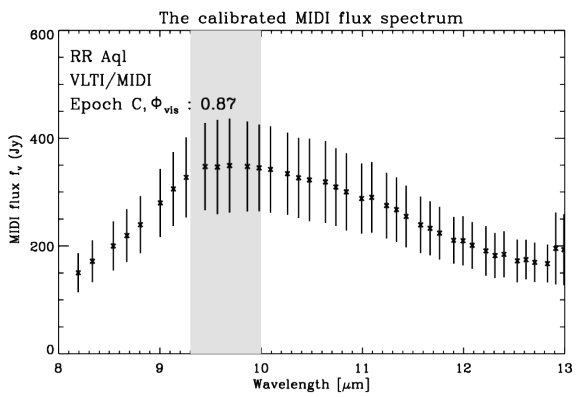
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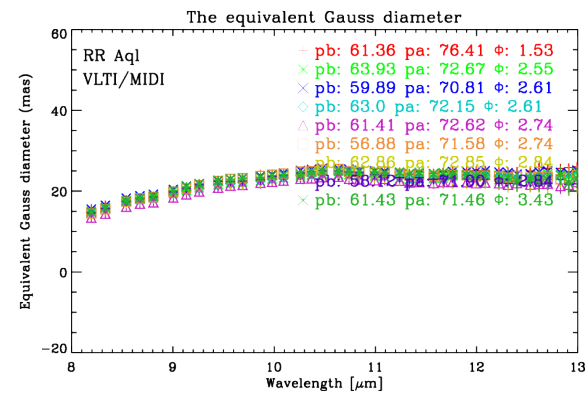
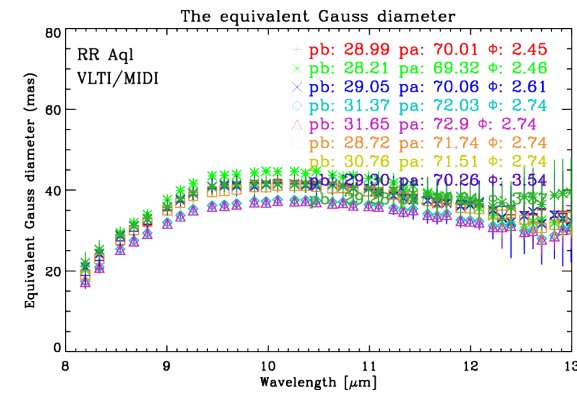
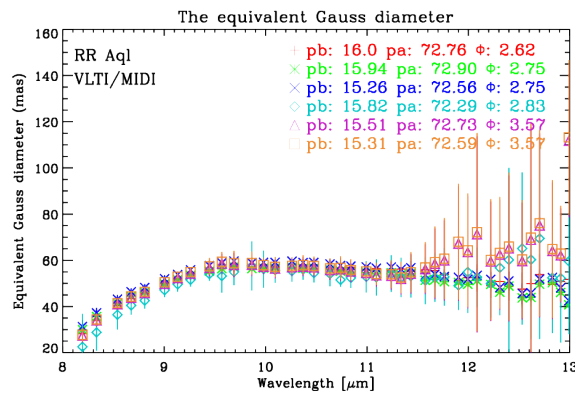
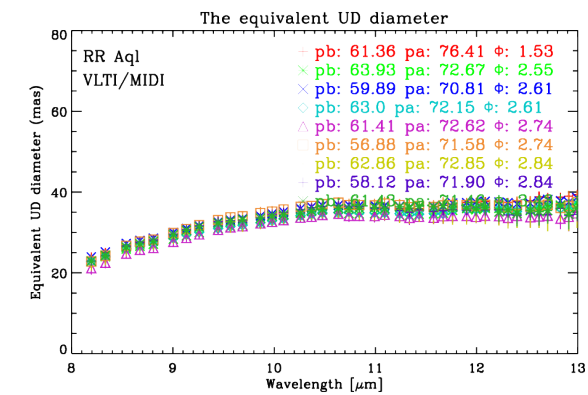
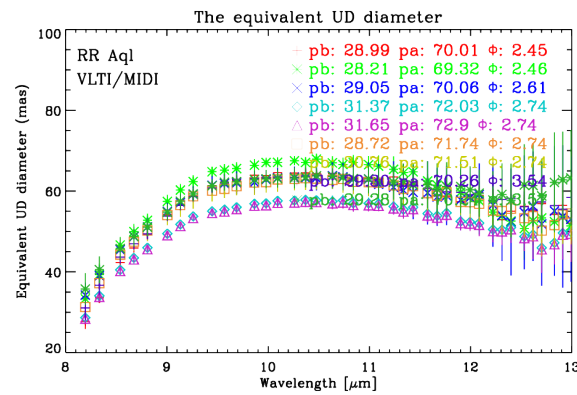
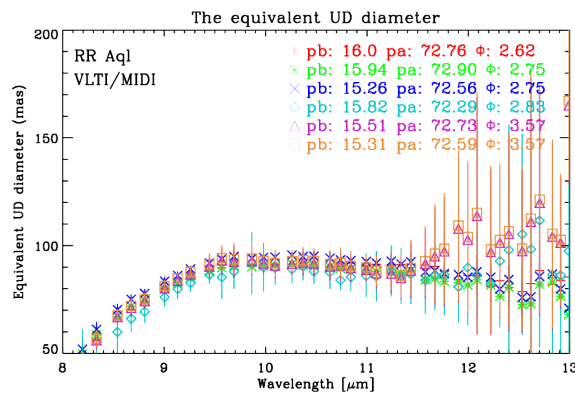
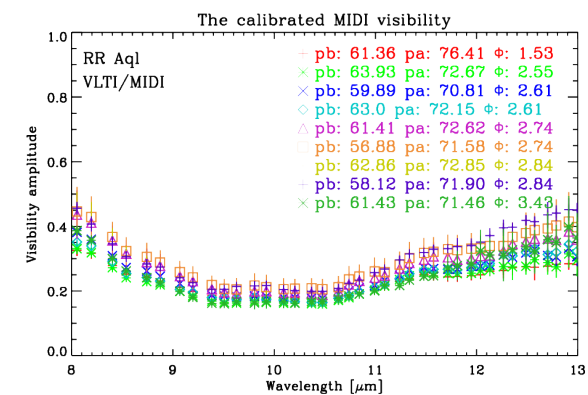
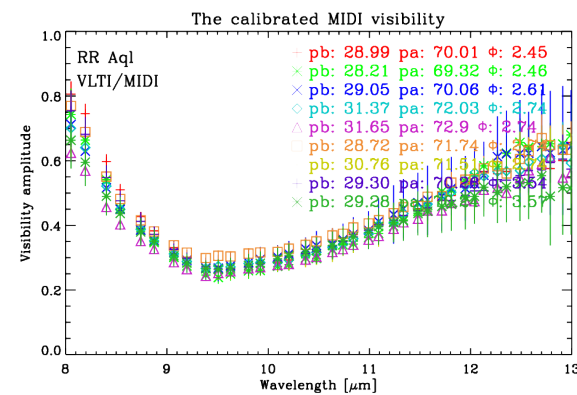
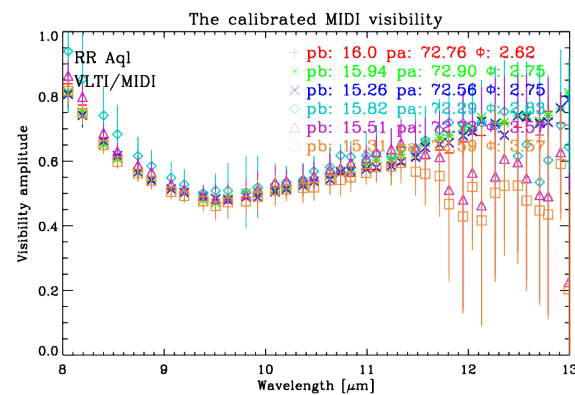
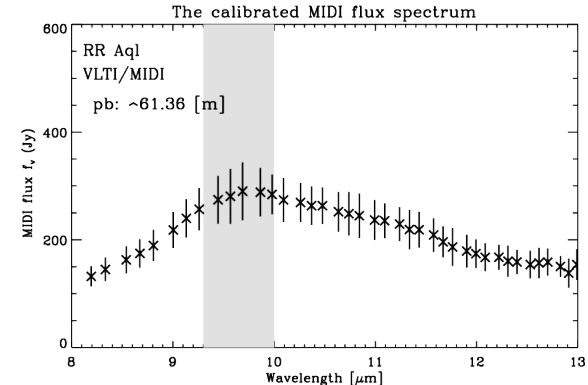
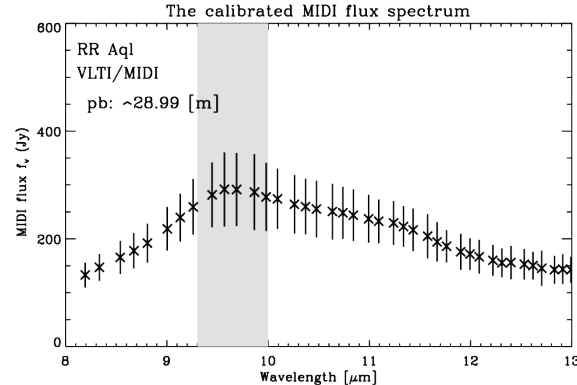
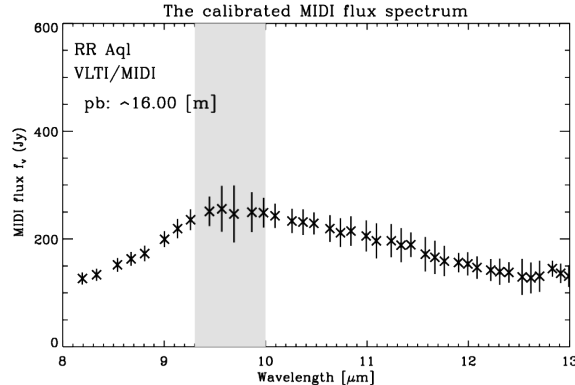
AMBER Observations

U1-U2-U3

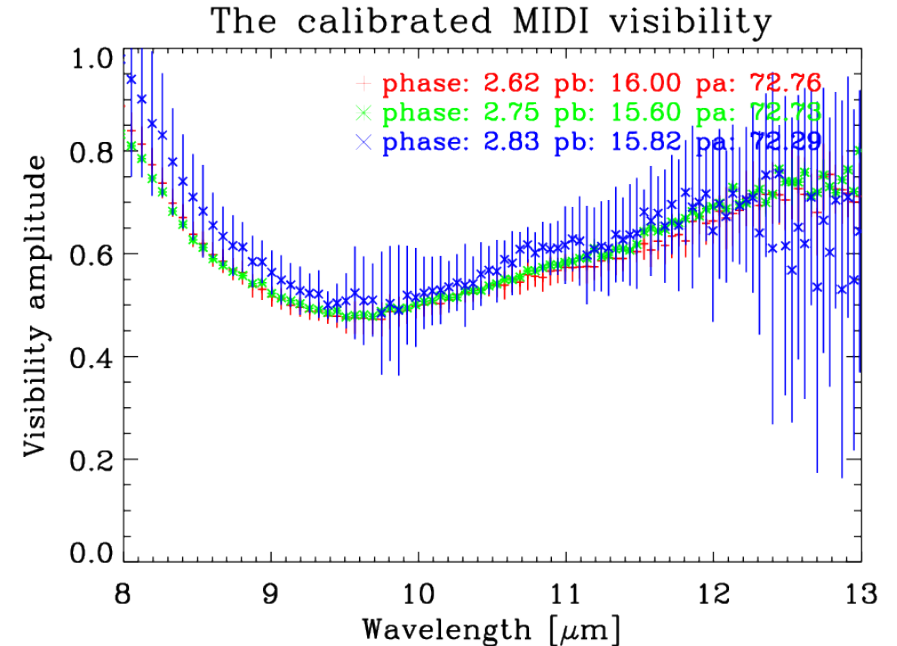
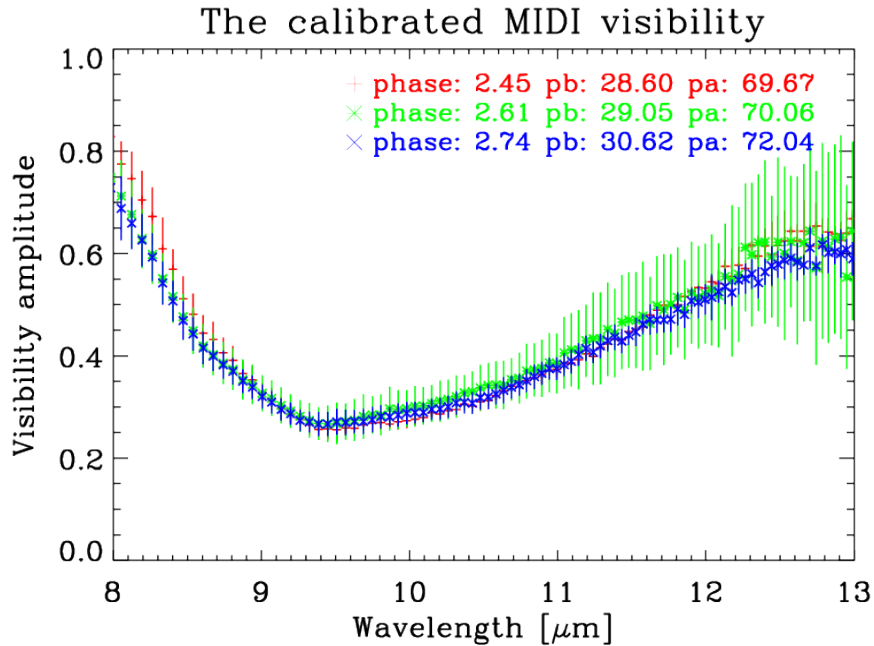


We estimate a continuum photospheric angular diameter of $\Theta_{\text{Phot}} = 9.9 \pm 2.4$ mas





Interferometric monitoring of Evolved Stars



pulsation phase : **2.45** **2.61** **2.74**

projected baseline : **28.60** **29.05** **30.62**

position angle : **69.67** **70.06** **72.04**

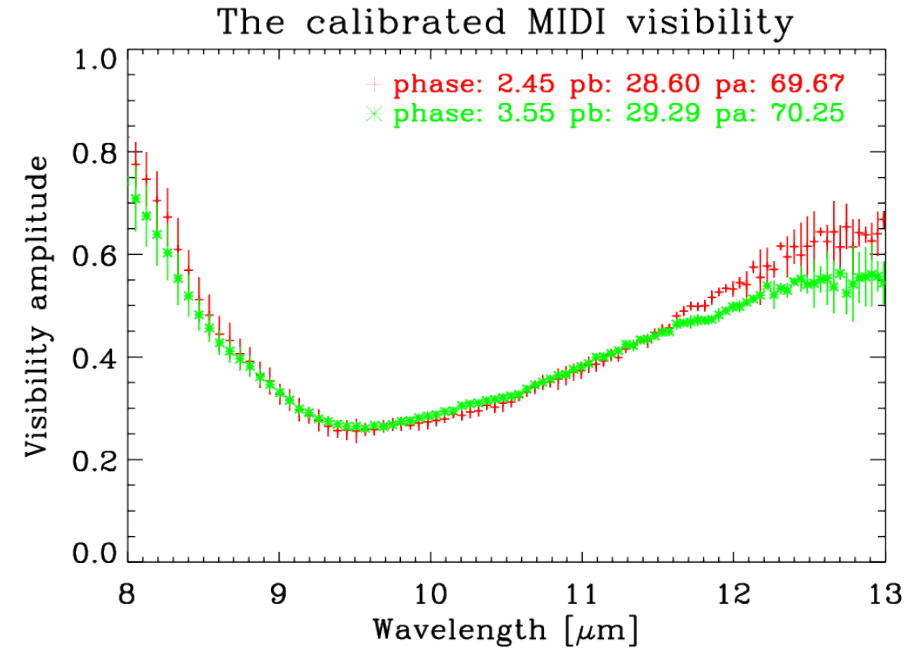
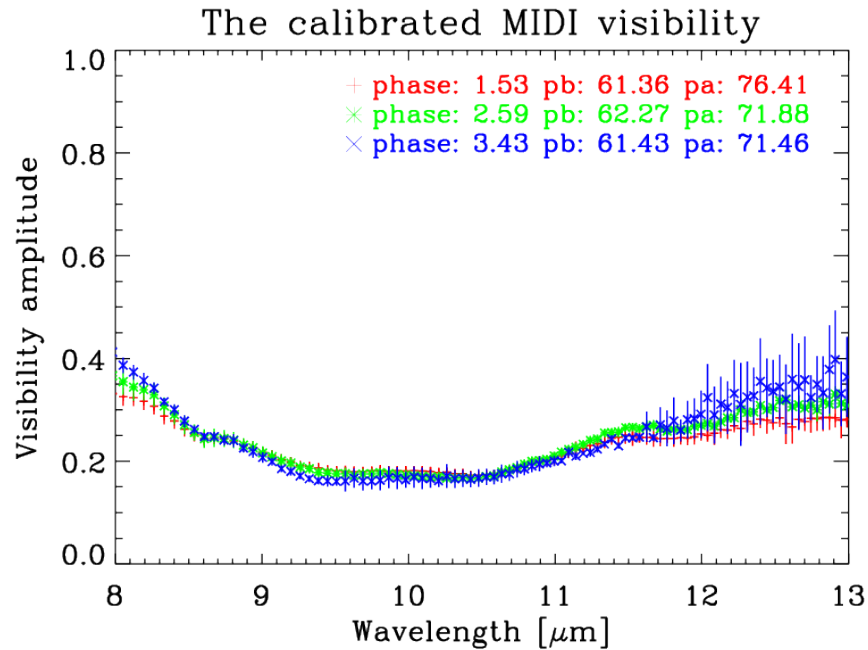
pulsation phase : **2.62** **2.75** **2.83**

projected baseline : **16.00** **15.60** **15.82**

position angle : **72.76** **72.78** **72.29**

→ NO intra-cycle visibility variations

Interferometric monitoring of Evolved Stars



pulsation phase : **1.53** **2.59** **3.43**

projected baseline : **61.36** **62.27** **61.43**

position angle : **76.41** **71.88** **71.46**

pulsation phase : **2.45** **3.55**

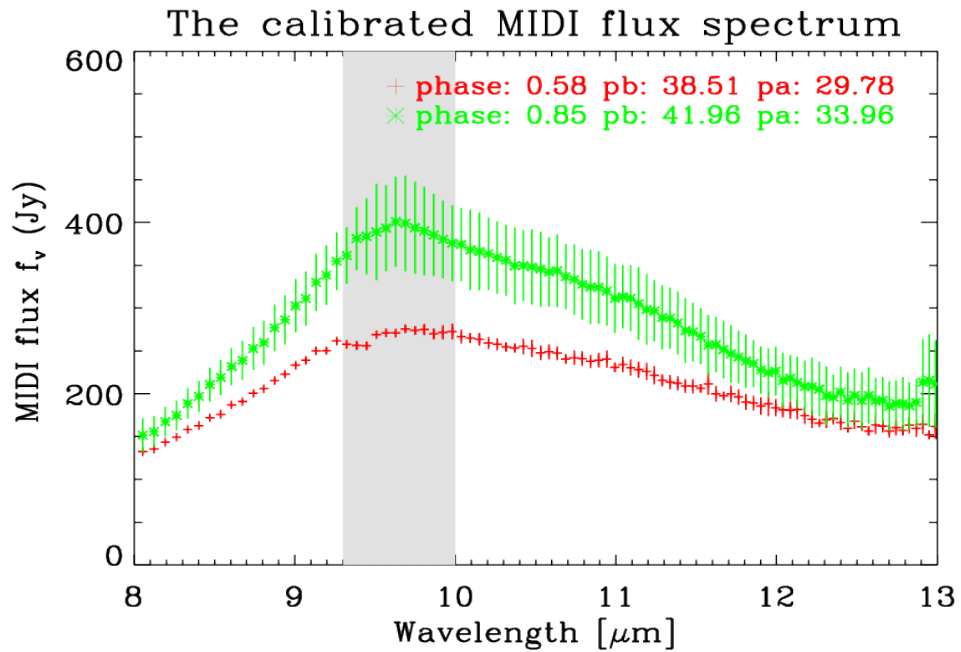
projected baseline : **28.60** **29.29**

position angle : **69.67** **70.25**

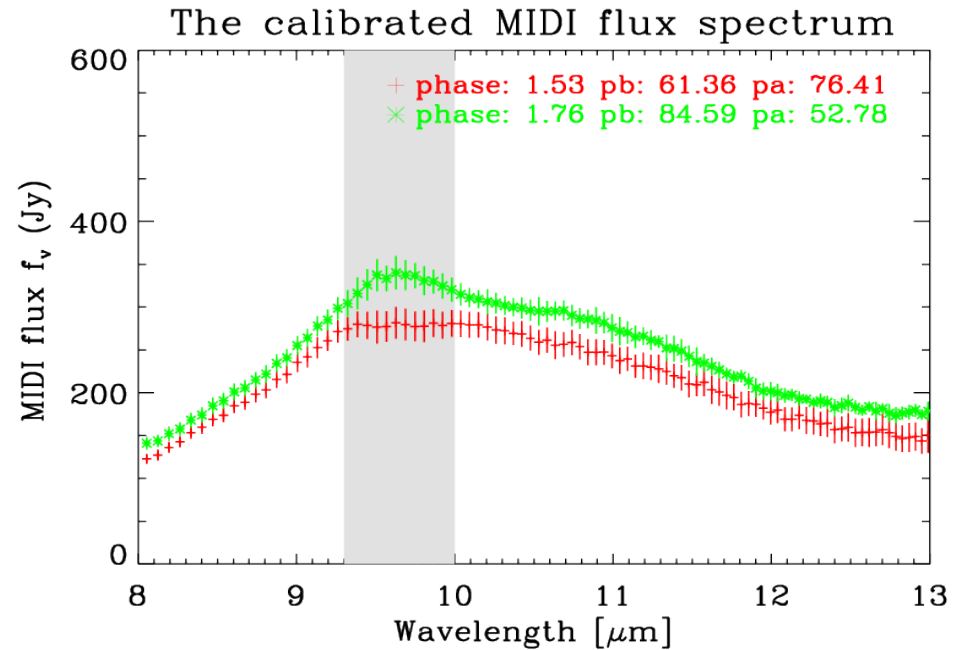
→ **NO cycle to cycle visibility variations**

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N-band flux → intra-cycle variations

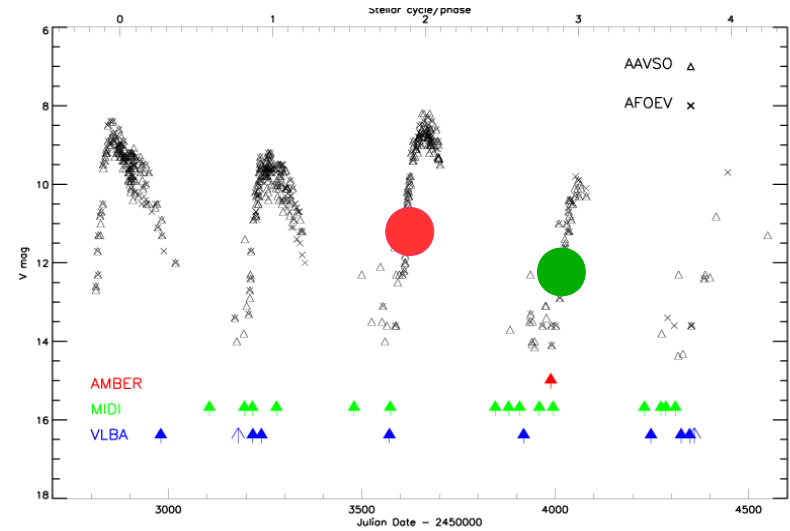
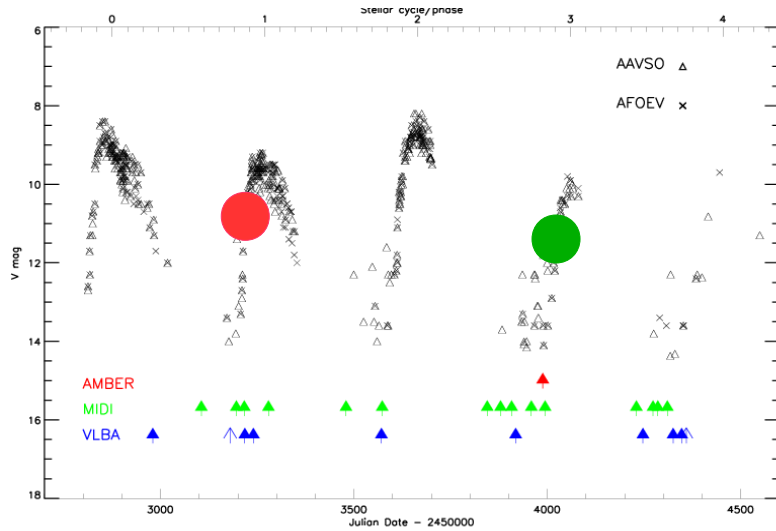


pulsation phase : **0.58** **0.85**



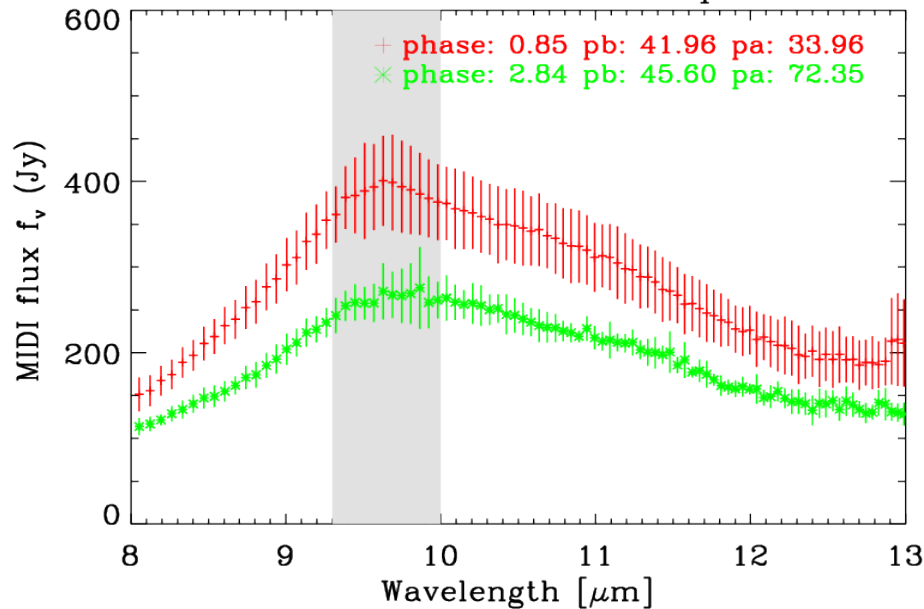
pulsation phase : **1.53** **1.76**

Interferometric monitoring of Evolved Stars



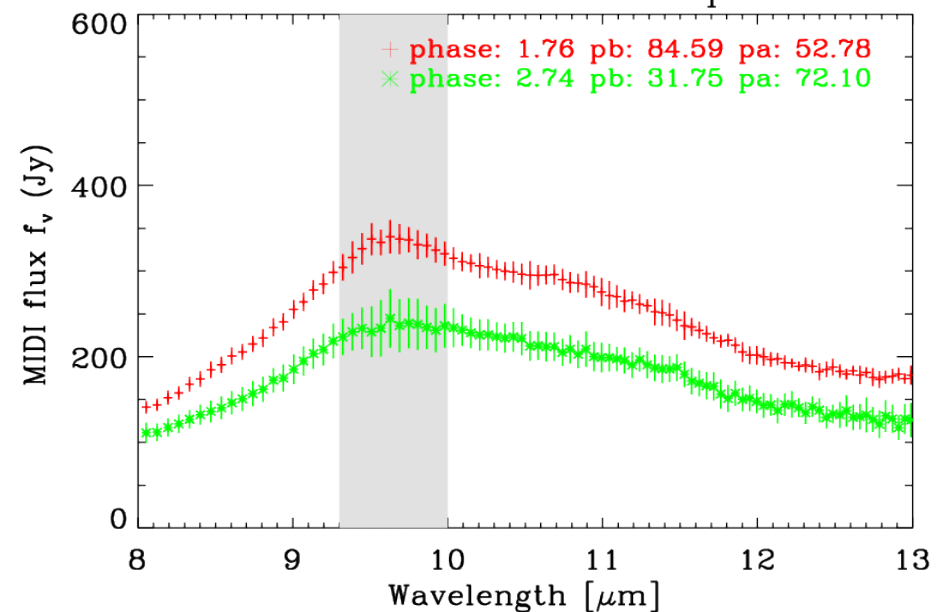
N-band flux → cycle to cycle variations

The calibrated MIDI flux spectrum



pulsation phase : **0.85** **2.84**

The calibrated MIDI flux spectrum



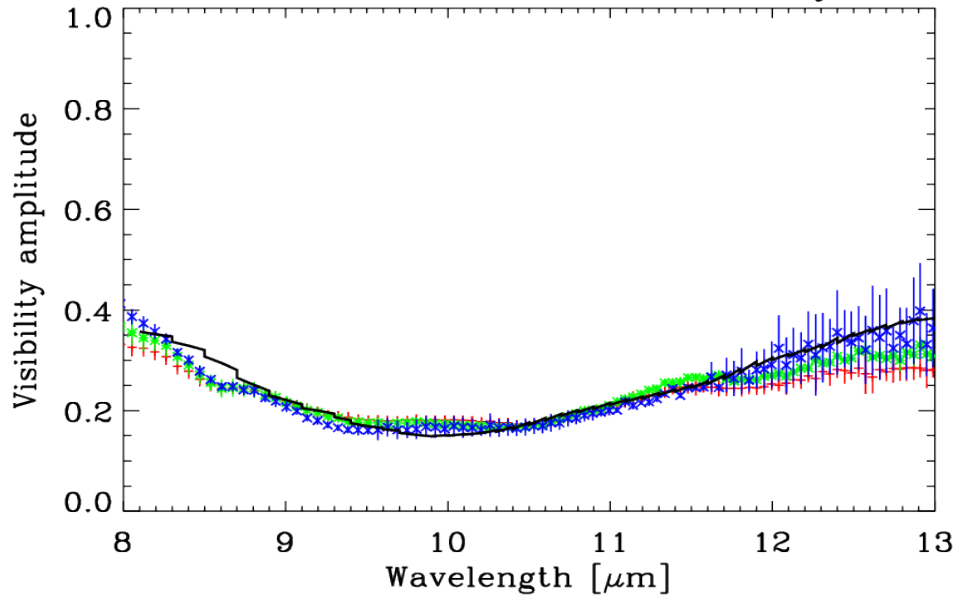
pulsation phase : **1.76** **2.74**

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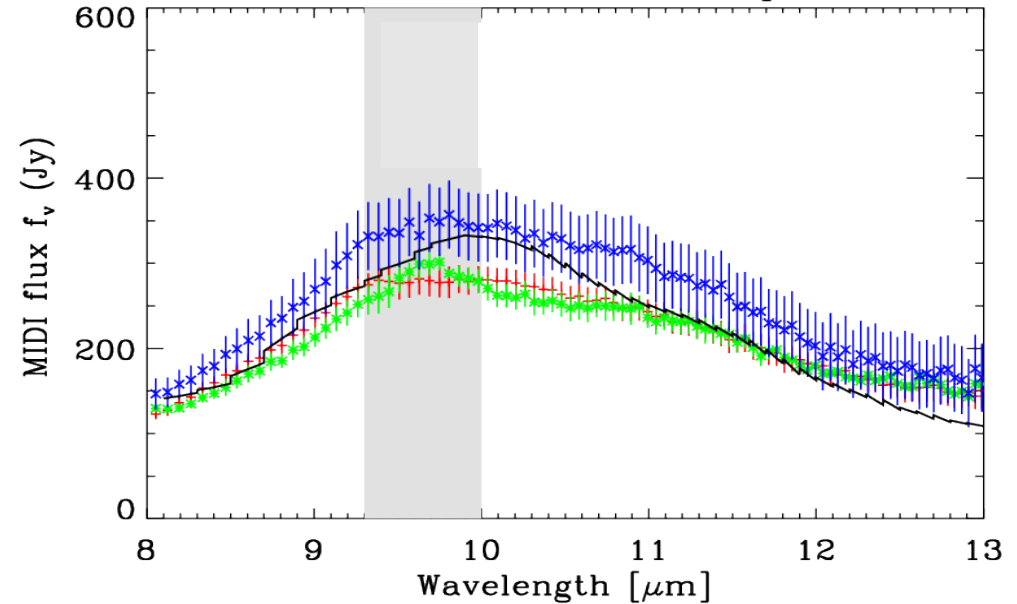
Modeling

dynamic model atmospheres + radiative transfer code

The calibrated MIDI visibility



The calibrated MIDI flux spectrum



Model parameters: specific Model (phase): M18
 optical depth of AL₂O₃ and silicates: 0.0; 7.5
 inner boundary radii in: 4.9
 density gradient p: 2.5

dust chemistry of RR Aql contains silicate grains alone (Lorenz-Martins & Pompeia, 2000)
→ can be confirmed by our study ? (work in progress)

Interferometric monitoring of Evolved Stars

Summary and Conclusions

long term study of Mira variable RR Aql

- NO intra-cycle visibility variations
- NO cycle to cycle visibility variations

X expectation

N-band photometry variations

Modeling : self excited dynamic model atmospheres + radiative transfer code

silicate grains alone ? (work in progress)

Interferometric monitoring of Evolved Stars

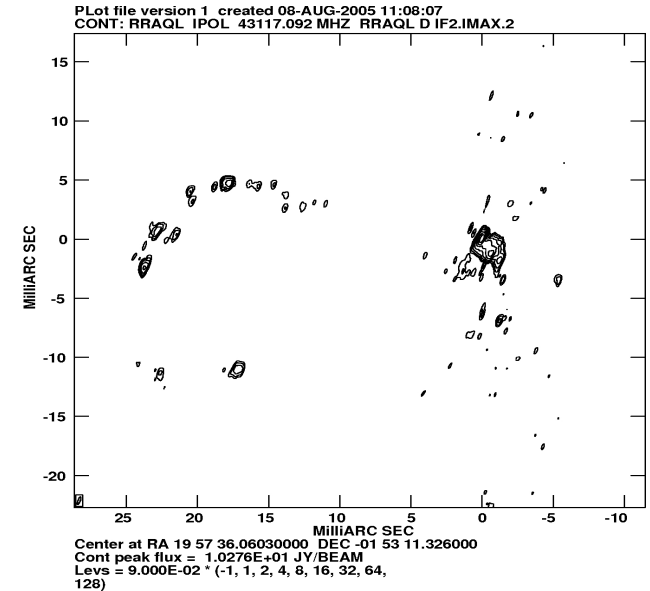
Future work / outstanding questions

- Comparison with VLBA observations
maser spots → spatial structure and kinematics

- Imaging (AMBER H-band + MIDI)

→ Asymmetries ?

Different scenarios of shaping processes AGB → pPNe, PNe



- Comparison with : Mira Variables: GX Mon
S Ori
Supergiant: AH SCO

