Circumstellar dust and influence of the hot component in symbiotic Miras

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D-TYPE SYMBIOTICS

- well-detached binary system

(separation of the order >50 AU)

Mira component

Substantial near- and mid-infrared excess ⇒ **presence of dust**

SLOW NOVA ⇒ long lasting recovery phase (few decades):

RR Tel: outburst in 1944. (Mayall, 1949)
V1016 Cyg: outburst in 1964. (McCuskey, 1965)
HM Sge: outburst in 1975. (Dokuchaeva, 1976)

Pulsational periods:
RR Tel: 387 days (Feast+, 1983)
V1016 Cyg: 478 days (Munari, 1988)
HM Sge: 527 days (Yudin+, 1994)

Luminosities: 6000 – 11000 L_{Sun}

MODEL DEGENERACY:
Single vs. two dust shells (HM Sge)

Schild+ (2001):
TWO SHELL MODEL

T_{dust} = 1400 K 800 K

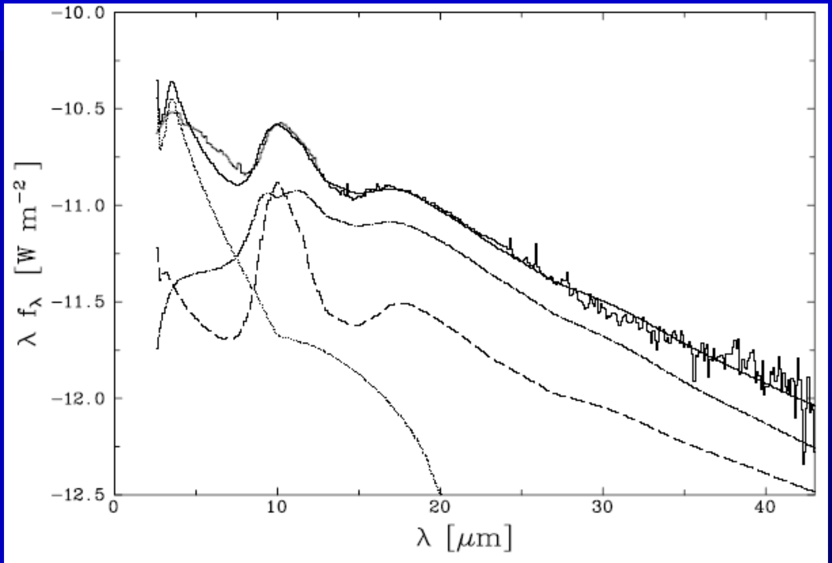
τ_V = 1.9 13

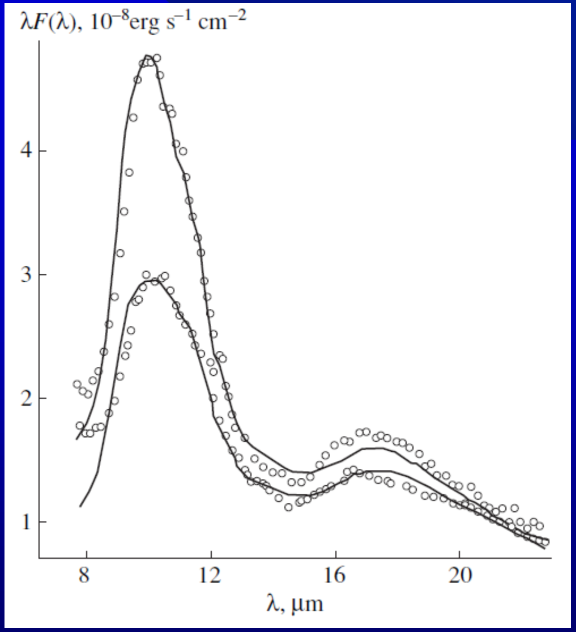
thick shell thin shell

Bogdanov & Taranova (2001):
SINGLE SHELL MODEL

700 – 900 K

10 – 13





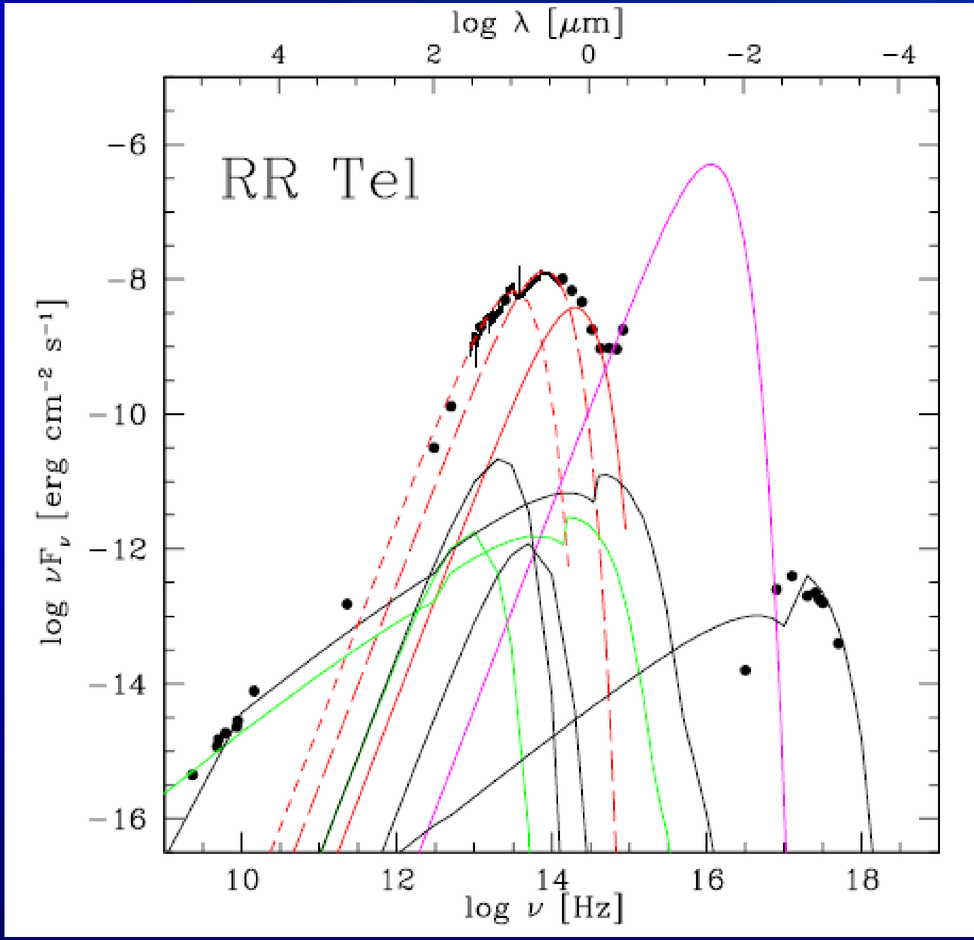
RECENT MODELS

Colliding wind model (Angeloni+, 2010):

- two dust shells: 400 K & 1000 K black body

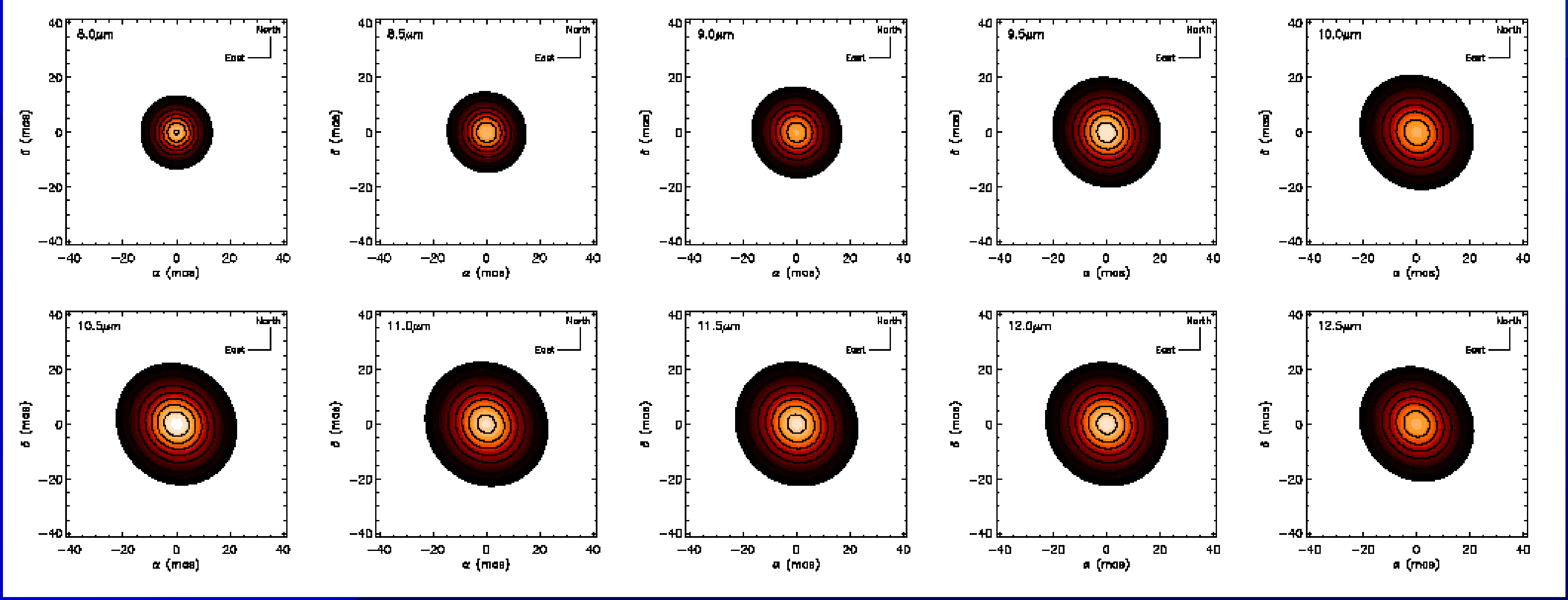
Black body shells:
Only part of the shell close to the shock front strongly emits

Problem ⇒ 10 μm feature is typical silicate feature, not black body emission!



RECENT MODELS: HM SGE

Sacuto & Chesneau (2009) – IR spectroscopy + inteferometry
Single-shell model
Sublimation dust temperature: T = 1600 K
Visual optical depth: 25
Density distribution: almost steady-state wind



OBSERVATIONS

Near IR JHKL observations from South African Astronomical Observatory and Crimean observatory

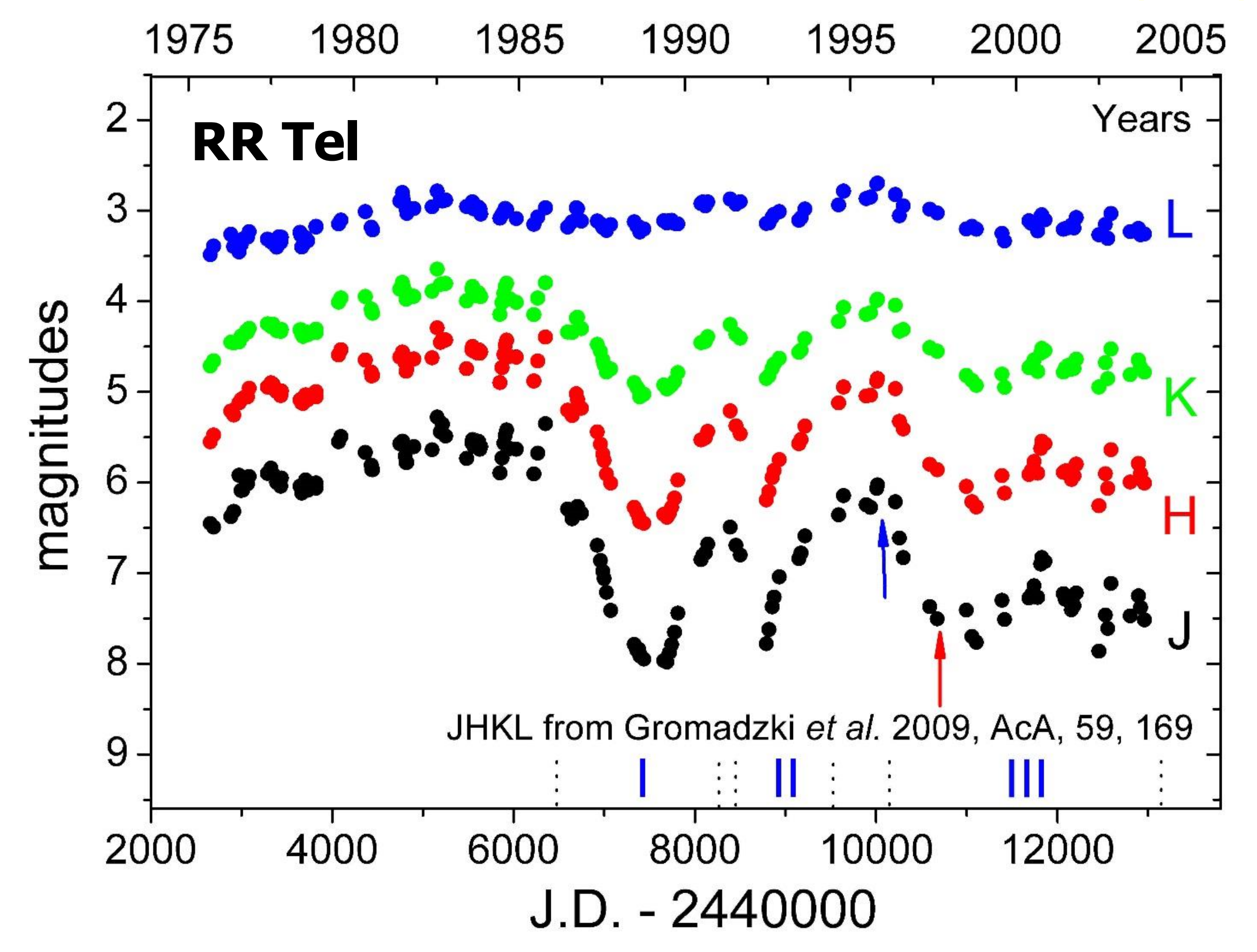
Time interval:
1975. – 2010.

12 symbiotic Miras

Light curve – **corrected** for Mira pulsations

Obscuration events
I. 1986 – 1991
II. 1991 – 1995
III. 1996 –

Jurkic & Kotnik-Karuza (2012)



SEARCH FOR PERIODICITY IN LIGHT CURVES

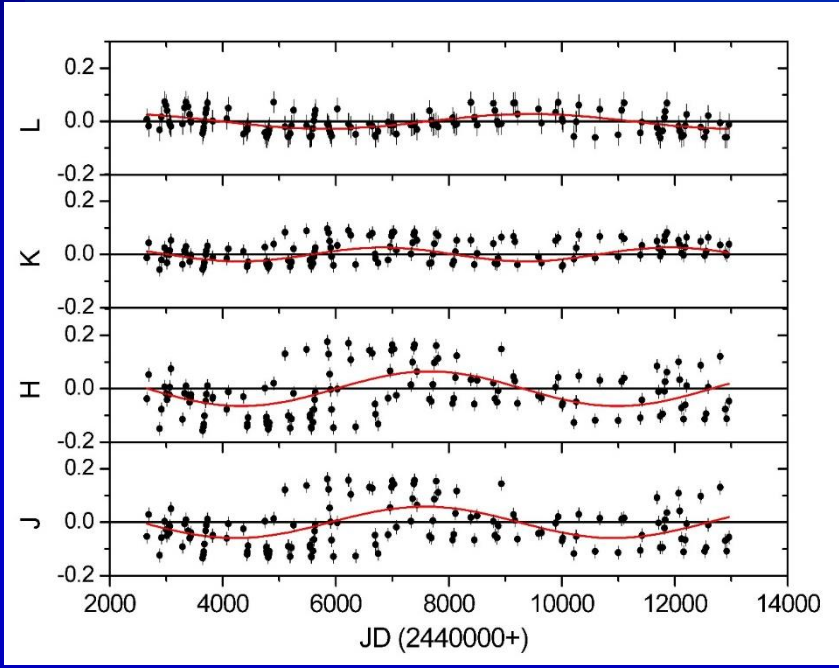
Long-term periods:

RR Tel 6800 d (18.5 yrs)

AS 210 7000 d (19 yrs)

V366 Car 6000 d (16.5 yrs)

HM Sge 9200 d (25 yrs)



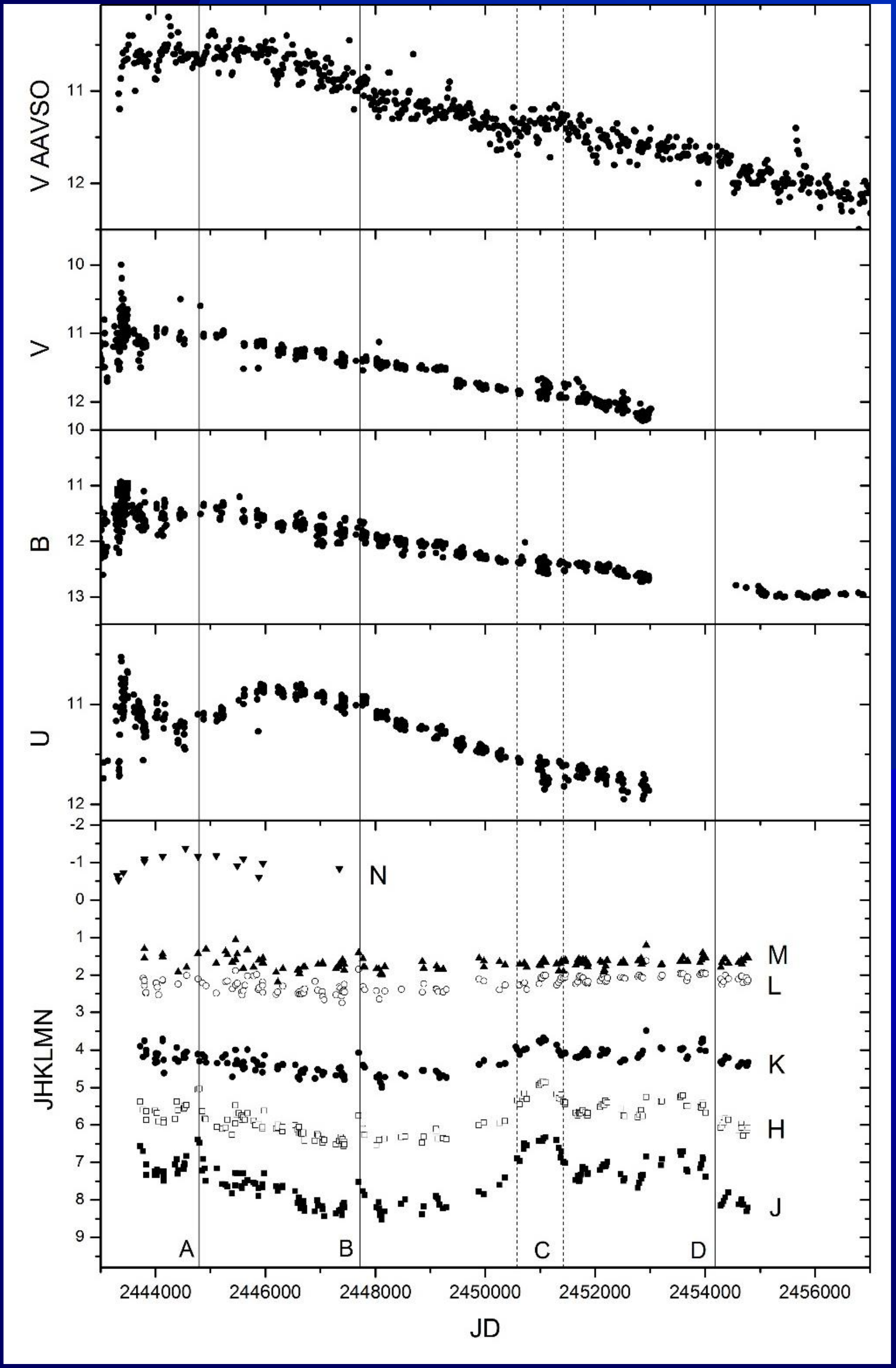
Jurkic & Kotnik-Karuza (2012)

- Phase dispersion minimization and Discrete Fourier Transforms
- orbit 8-10 AU from the Mira in RR Tel??
- dust at inner dust shell radius??

OBSERVATIONS

No major impact of nova eruption on dust!

Mechanism of dust shielding from UV radiation of hot component?

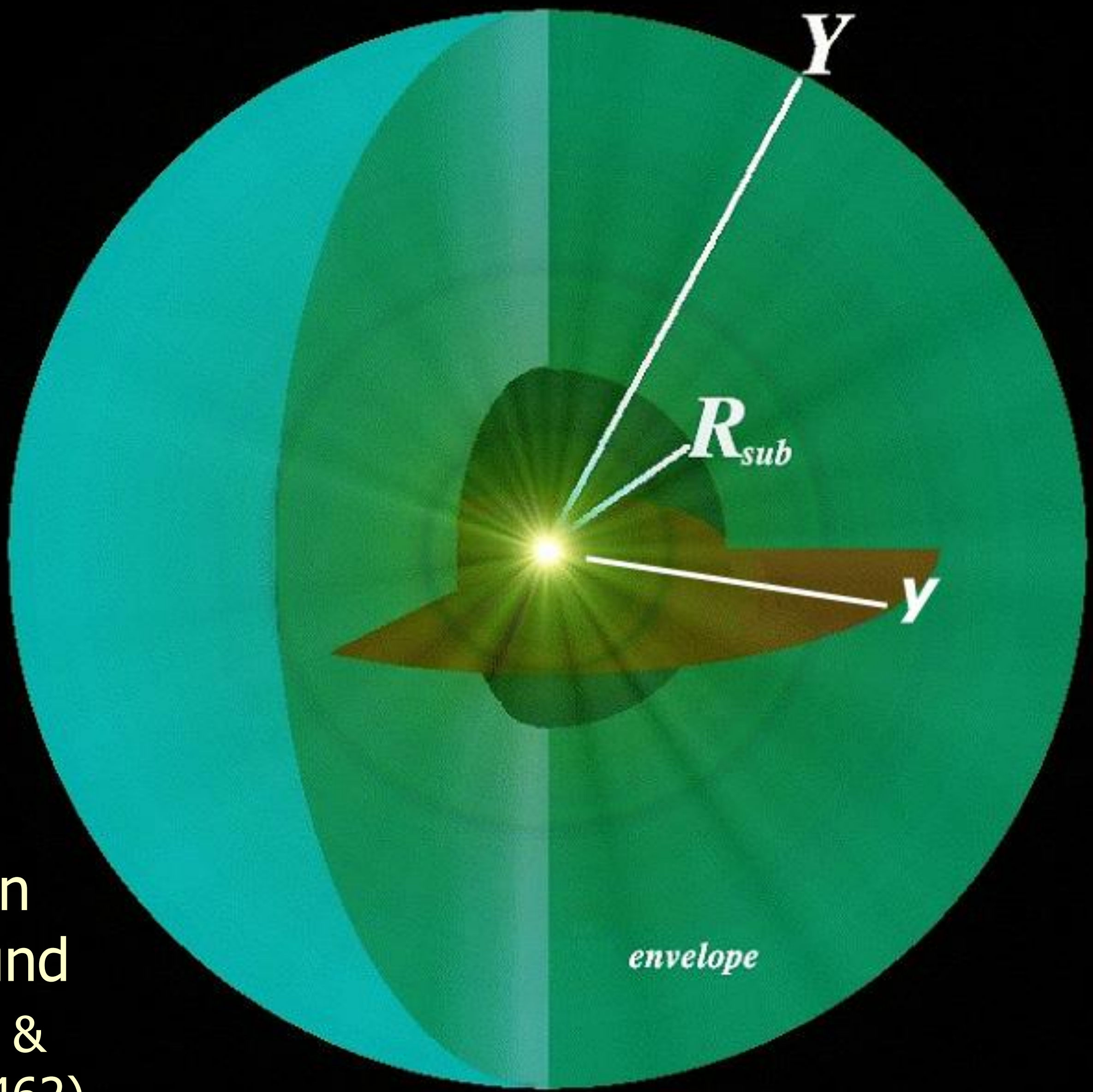


Jurkic & Kotnik-Karuza (2017)

DUSTY model (Miroshnichenko, Ivezić, Vinković, Elitzur)

DUSTY solves radiation transfer through dust environment:

- spherical or axial symmetry
- includes apsorption, scattering
  & emission
- succesfully used in dust envelopes around young stars (Vinković & Jurkić, 2007, ApJ, 658, 462)



Density distribution

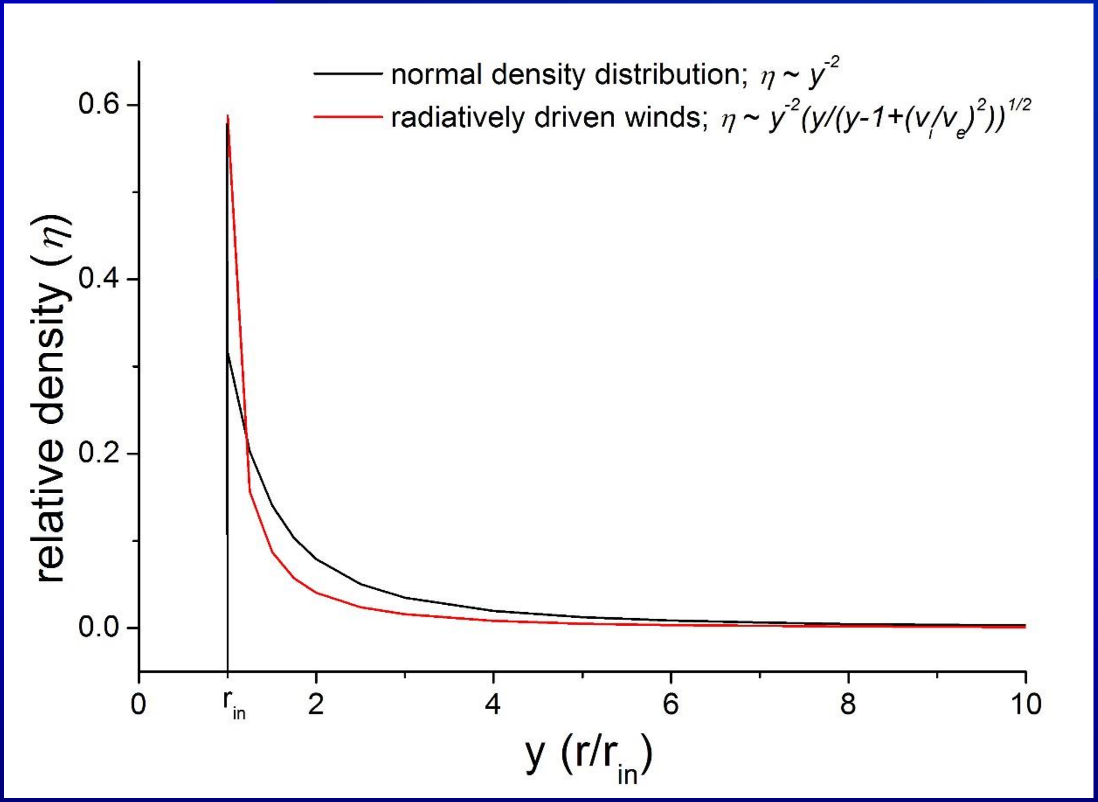
scale-free: relevant parameter – scaled radius *y*:

$$y = \frac{r}{r_{in}} \qquad \eta \propto \frac{1}{y^p}$$

r_{in} – inner dust shell radius (sublimation radius)
p – power index

Radiatively driven winds:

$$\eta \propto \frac{1}{y^2}\sqrt{\frac{y}{y-1+(v_i/v_e)^2}}$$



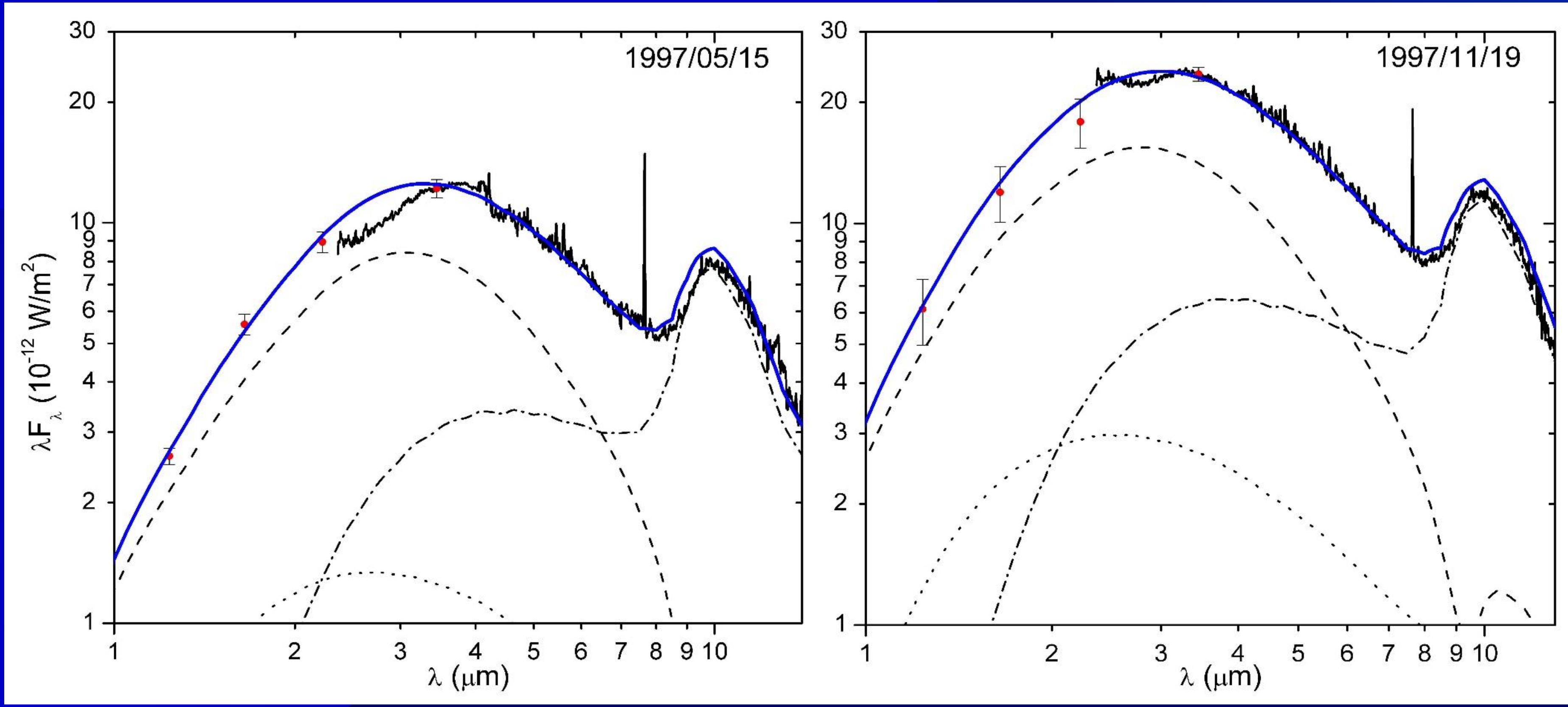
MRN grain size distribution (Mathis+, 1977)

RR TEL – OBSCURATION EVENT

Jurkic & Kotnik-Karuza (2017)

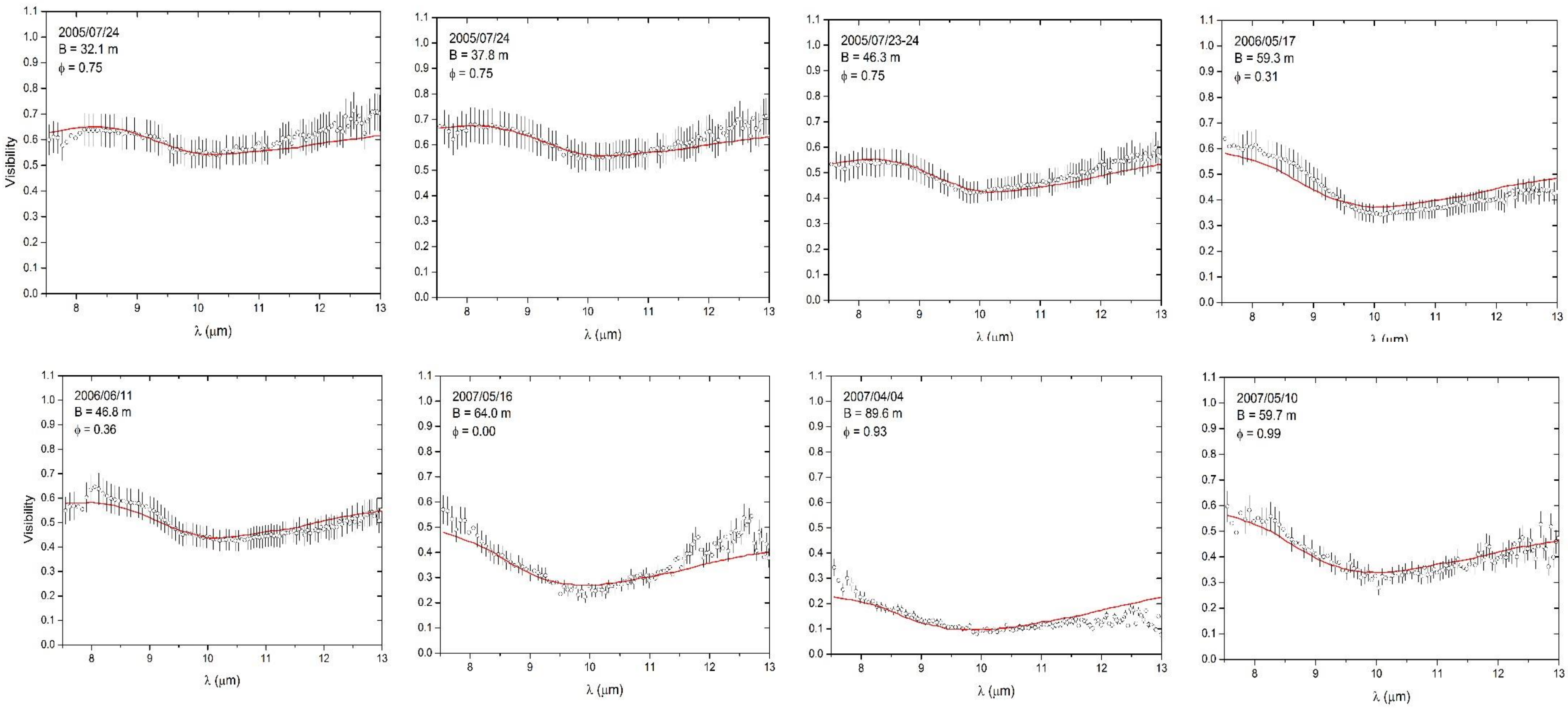
Parameter	RR Tel
T_{Mira} (K)	2350
T_{dust} (K)	1200 – 1350
a_{max} (μm)	4.0 – 4.7
τ_V	5.0 – 5.5
$\dot{M}$ (10^{-6} M_{Sun}/yr)	6 – 8

ISO SWS spectra + SAAO JHKL
Phase difference: 0.49 (188 days)



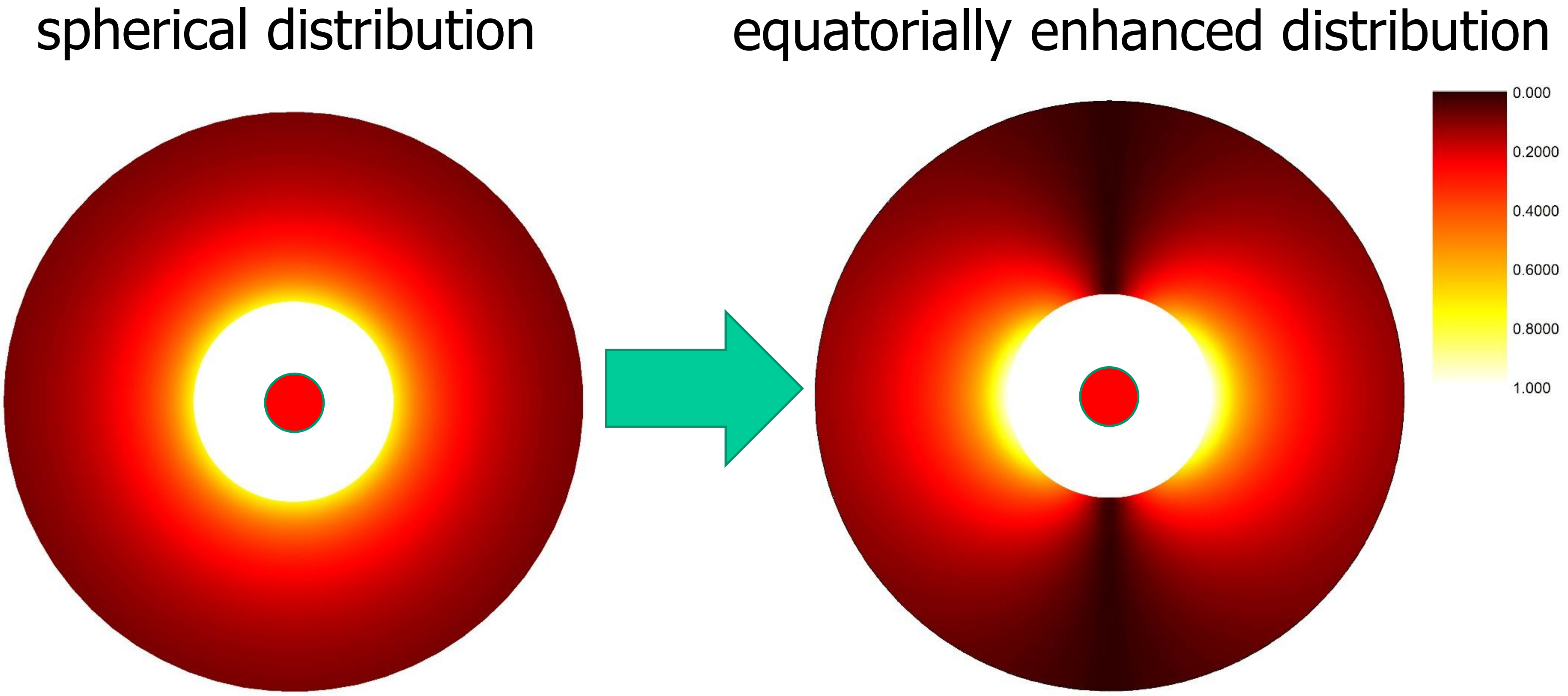
HM SGE: Interferometry

MIDI VLTI 8-13 μm (Sacuto & Chesenau 2009, Sacuto+ 2007)



RR TEL: OUTSIDE OBSCURATION

LELUYA code (Vinkovic, 2003; Balick+, 2012)
2D radiative transfer code, unstructured self-adaptive grid



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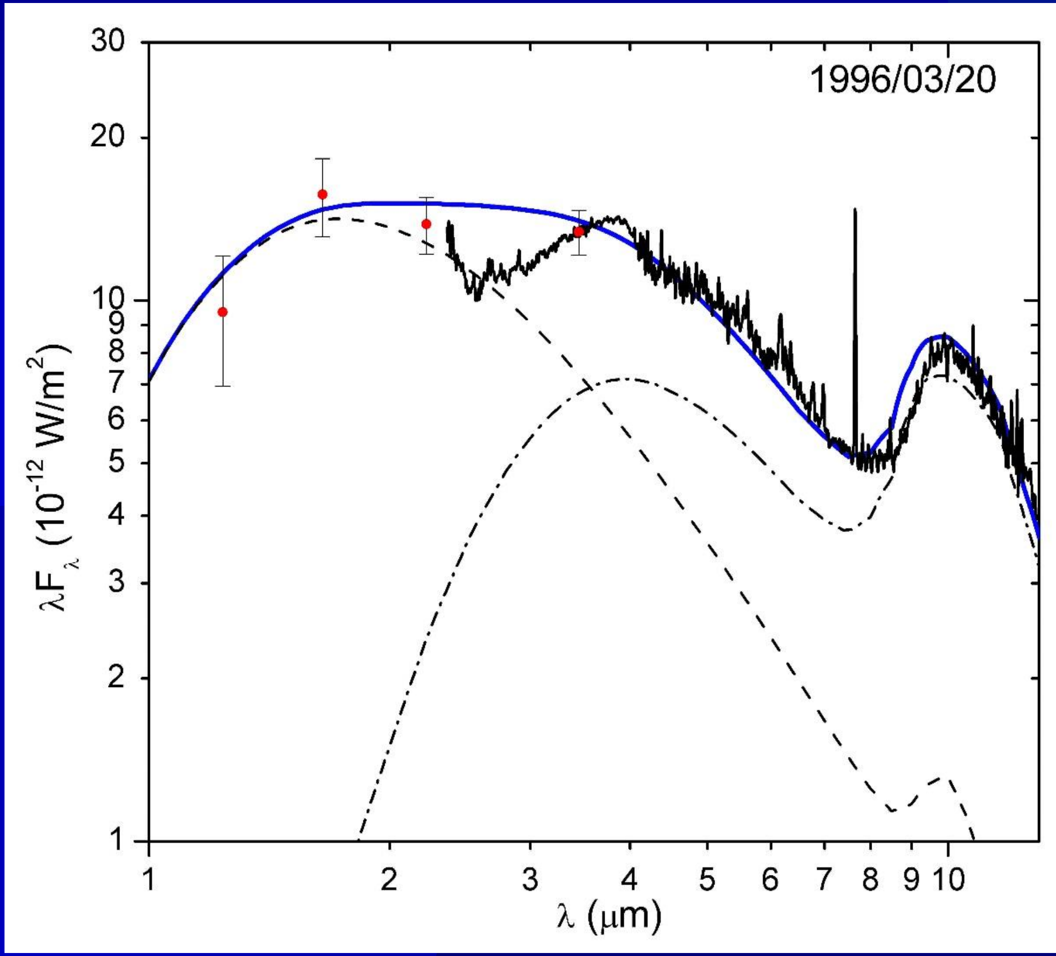
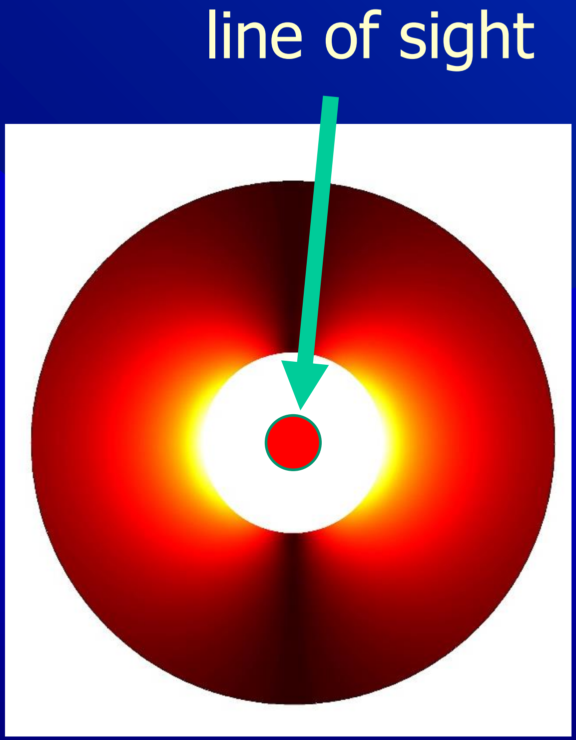
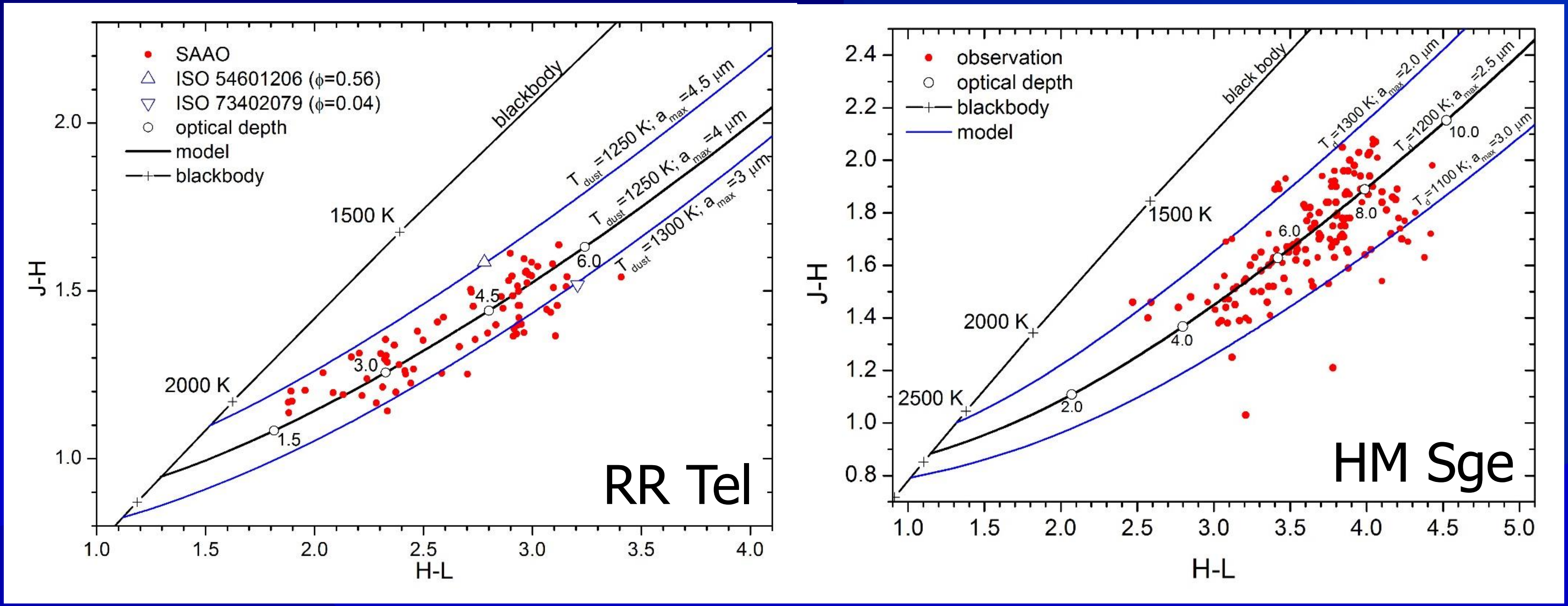




LONG-TERM DUST PROPERTIES

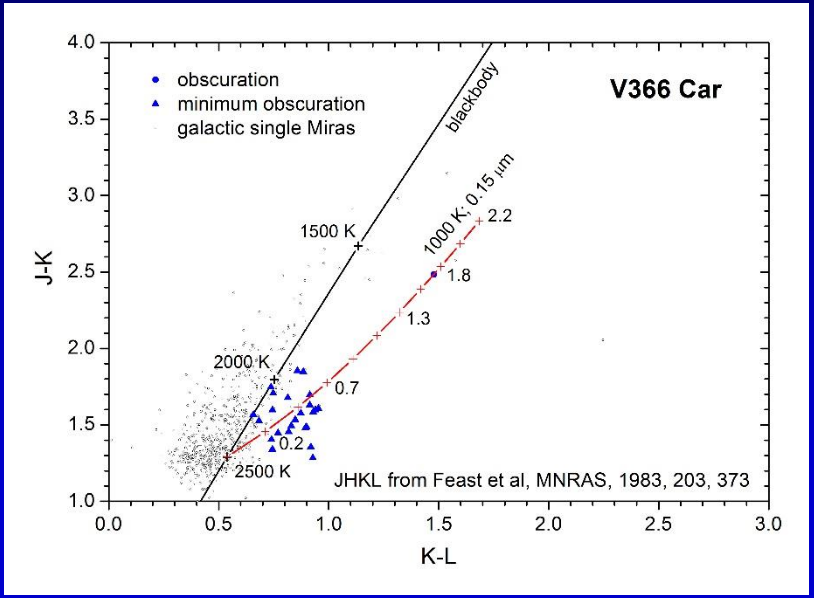


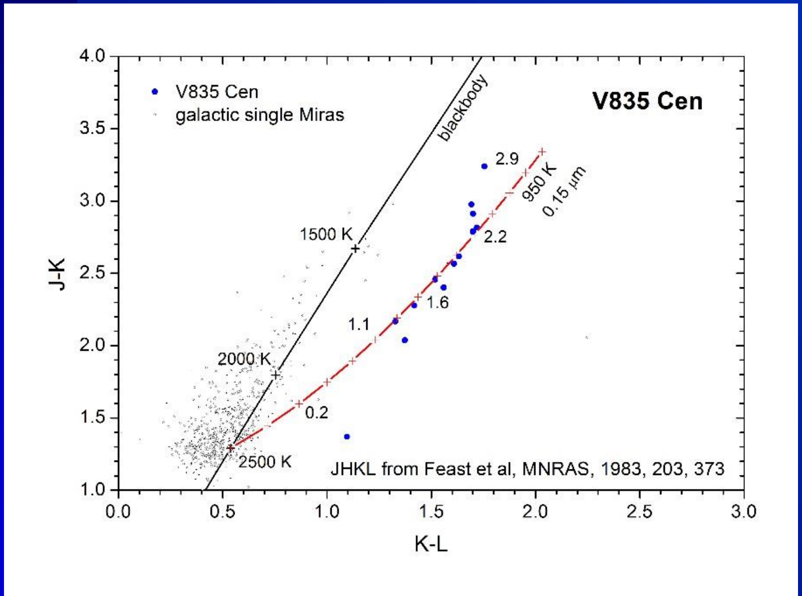
Jurkic & Kotnik-Karuza (2012, 2017)

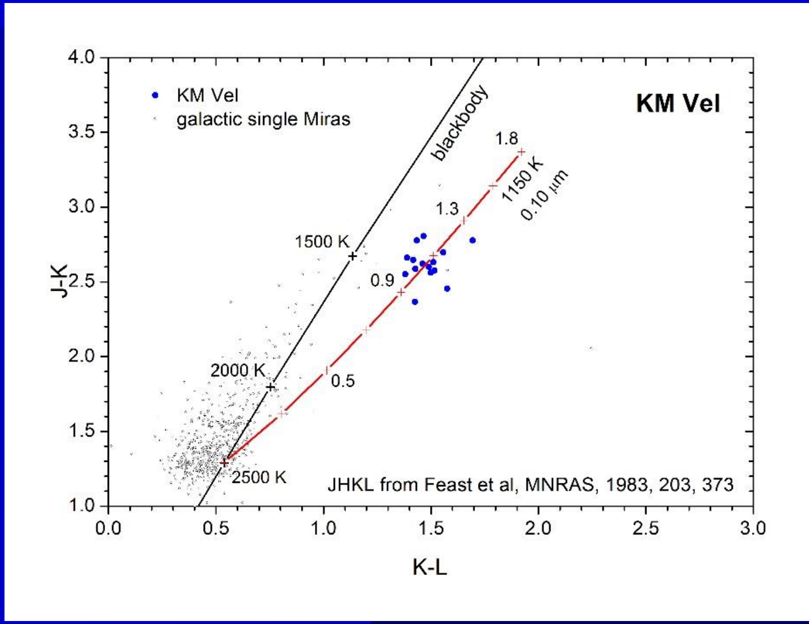
Obscurations in near-IR ⇒ explained by change in dust optical depth

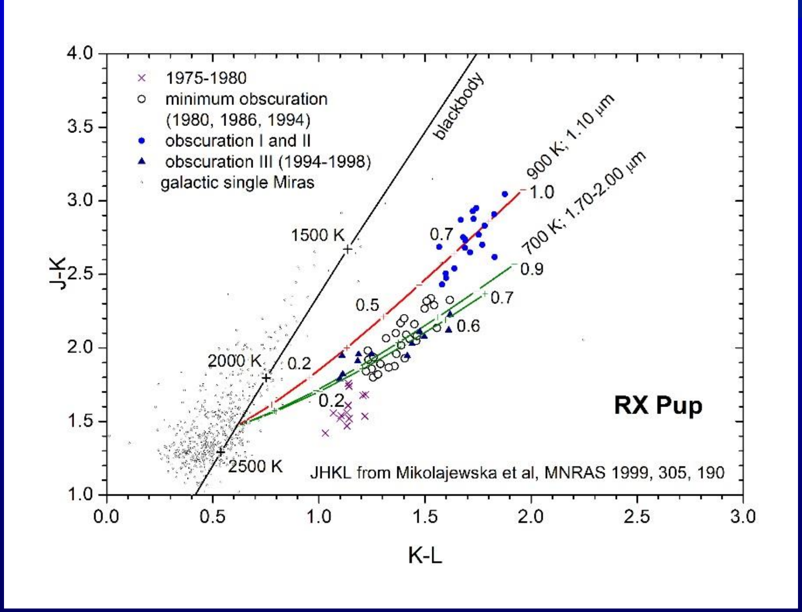
Dust optical depth changes in time ⇒ evolution of dust shell

LONG-TERM DUST PROPERTIES









DUST PROPERTIES

Symbiotic Mira	Luminosity (L_{Sun})	T_{cond} (K)	a_{max} (μm)	τ_V
BI Cru	4600	1200 – 1400	1 – 2	3.2 – 6.5
O Cet	6100	1100	0.15	0.4 – 3.4
KM Vel	7000	1150	0.1	8.3 – 12.6
R Aqr	7300	650	0.15	0.6 – 8.8
RR Tel	7400	1250	3.5	1.6 – 6.3
V835 Cen	7600	950	0.15	12 – 20
AS 210**	8000	1100 - 1300	0.5 – 1	1.5 – 5
V366 Car	8400	1000	0.15	15
V1016 Cyg	9200	1000 – 1200	1 – 4	2 – 6
SS73 38**	9200	900 – 1300	0.25 – 1	2.2 – 6.3
HM Sge	11000	1150	2.1	3.2 – 9.0
RX Pup	12000	700, 900	1.8, 1.1	2.5 – 7.5

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Grain growth in symbiotic novae? $\Rightarrow$ mass loss driven by radiation pressure on large grains

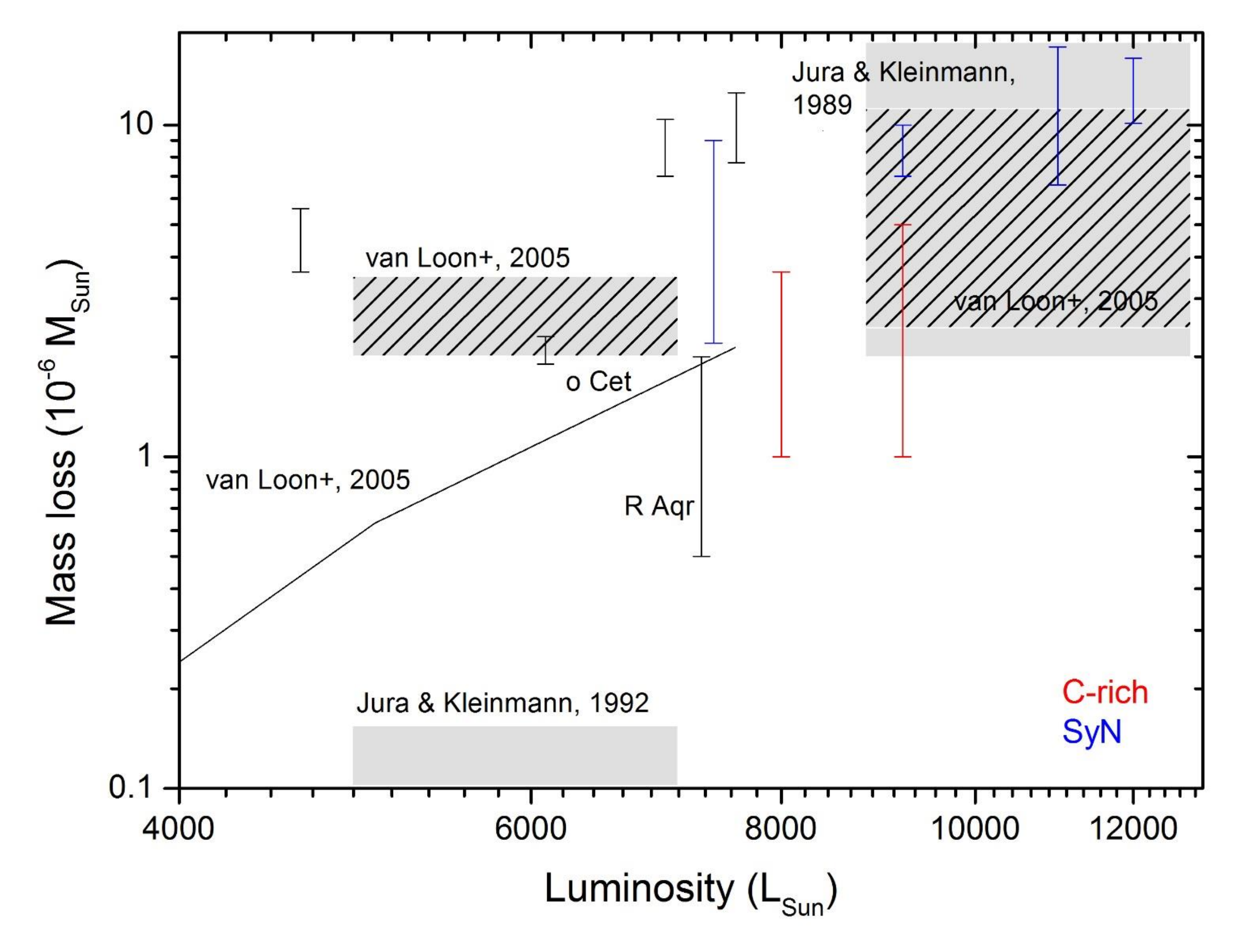
DUST PROPERTIES

Inner dust shell radius:
O-rich Miras: 3 – 7 R_*
C-rich Miras: 1.7, 2.3 R_*

- O-rich Miras condense dust **further** from the Mira component than C-rich Miras

- **Slower** (5-10 km/s) stellar wind in symbiotic Miras dominated by **smaller dust grains**
- **Faster** (15-30 km/s) stellar wind in symbiotic Miras dominated by **larger dust grains** $\rightarrow$ **Symbiotic Novae**

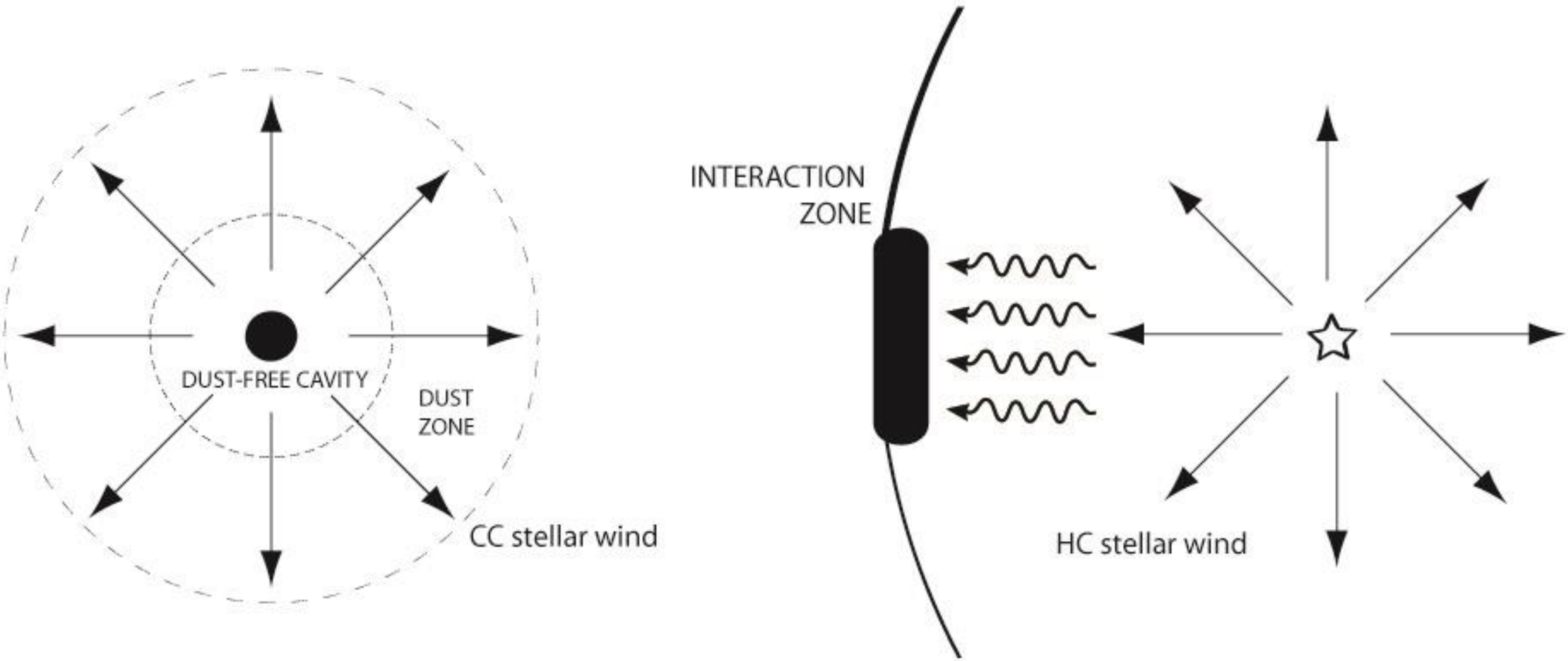
MASS LOSS



$L > 10\,000\ L_{Sun}$
In agreement with long-period single O-rich AGB stars (van Loon+, 2005)

$L < 10\,000\ L_{Sun}$
Higher than observed for single intermediate-period Miras (Jura & Kleinman, 1989, 1992)

INFLUENCE OF THE HOT COMPONENT



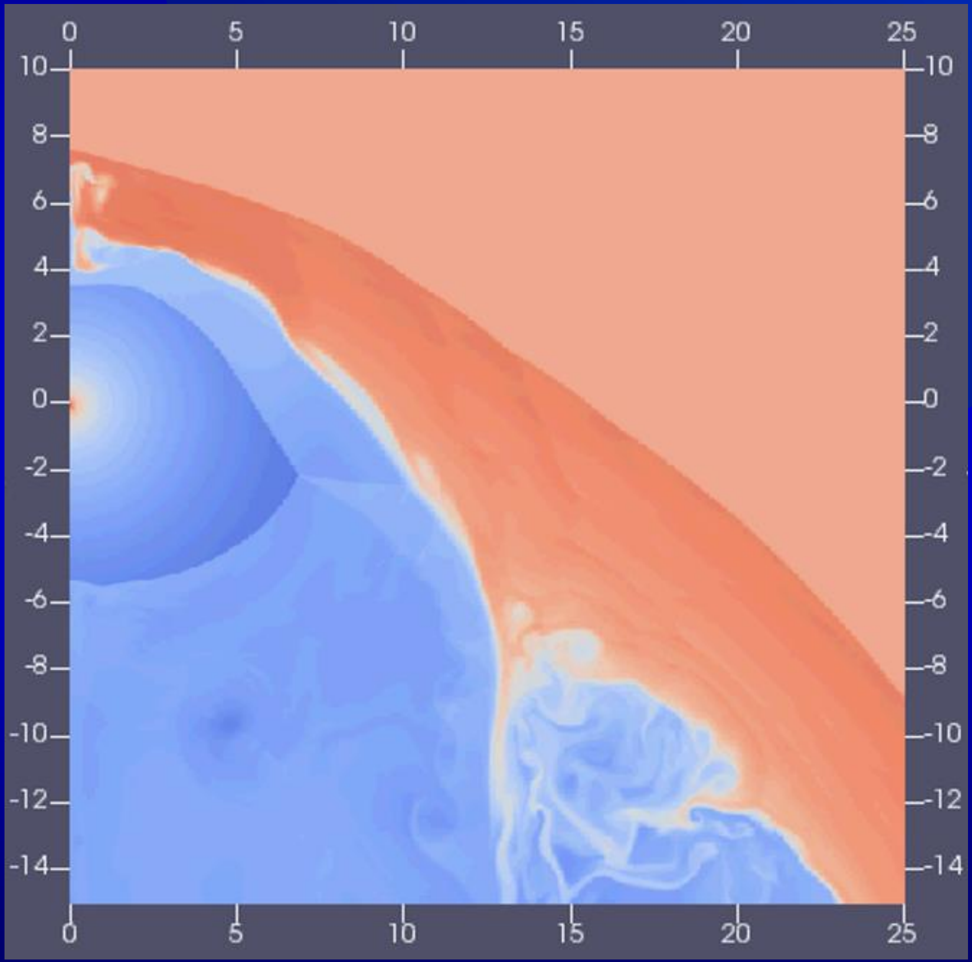
CLOUDY (Ferland+, 2013)

- Spectral synthesis photoionization code ⇒ calculates emission, absorption and continuum spectra
- Simulation of physical conditions in circumstellar matter: ionization, chemical and thermal state of matter, gas heating and cooling, molecular environment

INFLUENCE OF THE HOT COMPONENT

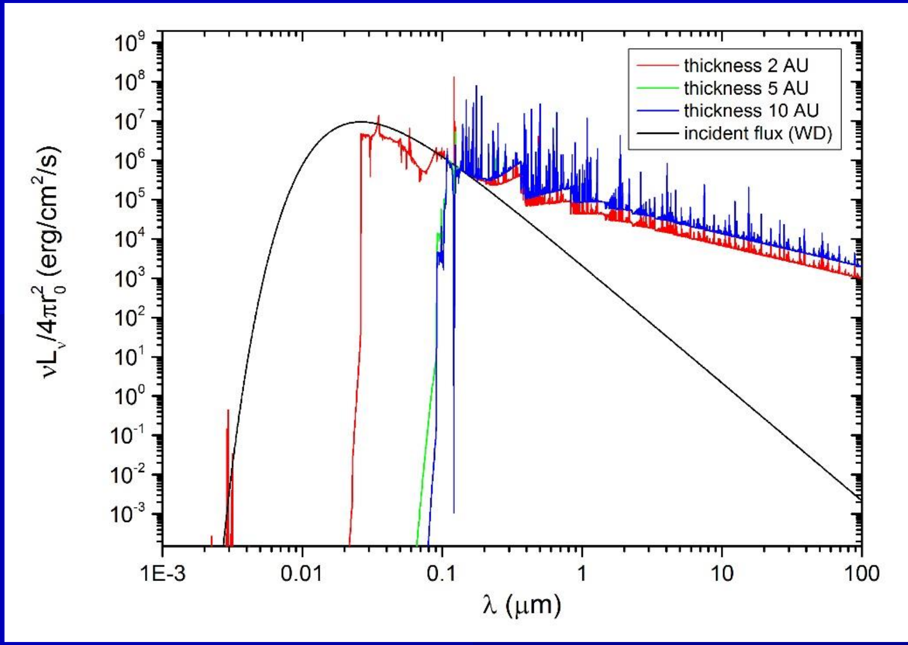
PLUTO (Mignone+, 2012)

- Numerical code for solving hydrodinamical equations
- Adaptive grid
- Collision of fast low density stellar wind from hot component with slow high density stellar wind from cold component



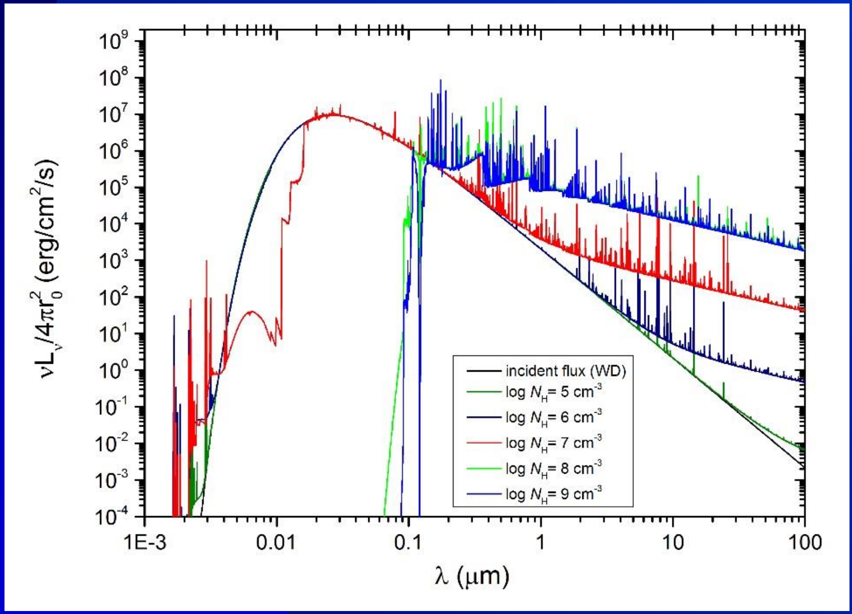
INFLUENCE OF THE HOT COMPONENT

log $N_H = 8\ cm^{-3}$

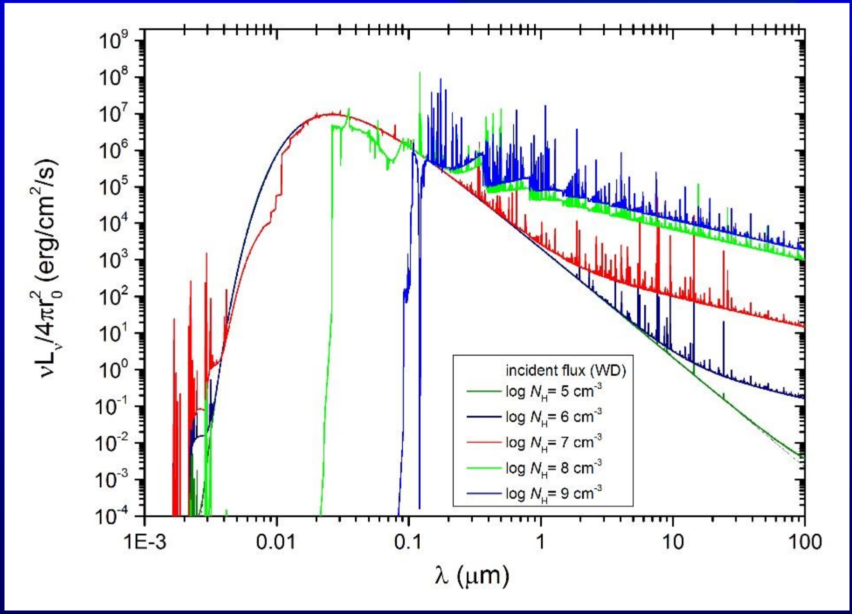


Jurkic & Kotnik-Karuza, in preparation

thickness of interaction region 5 AU

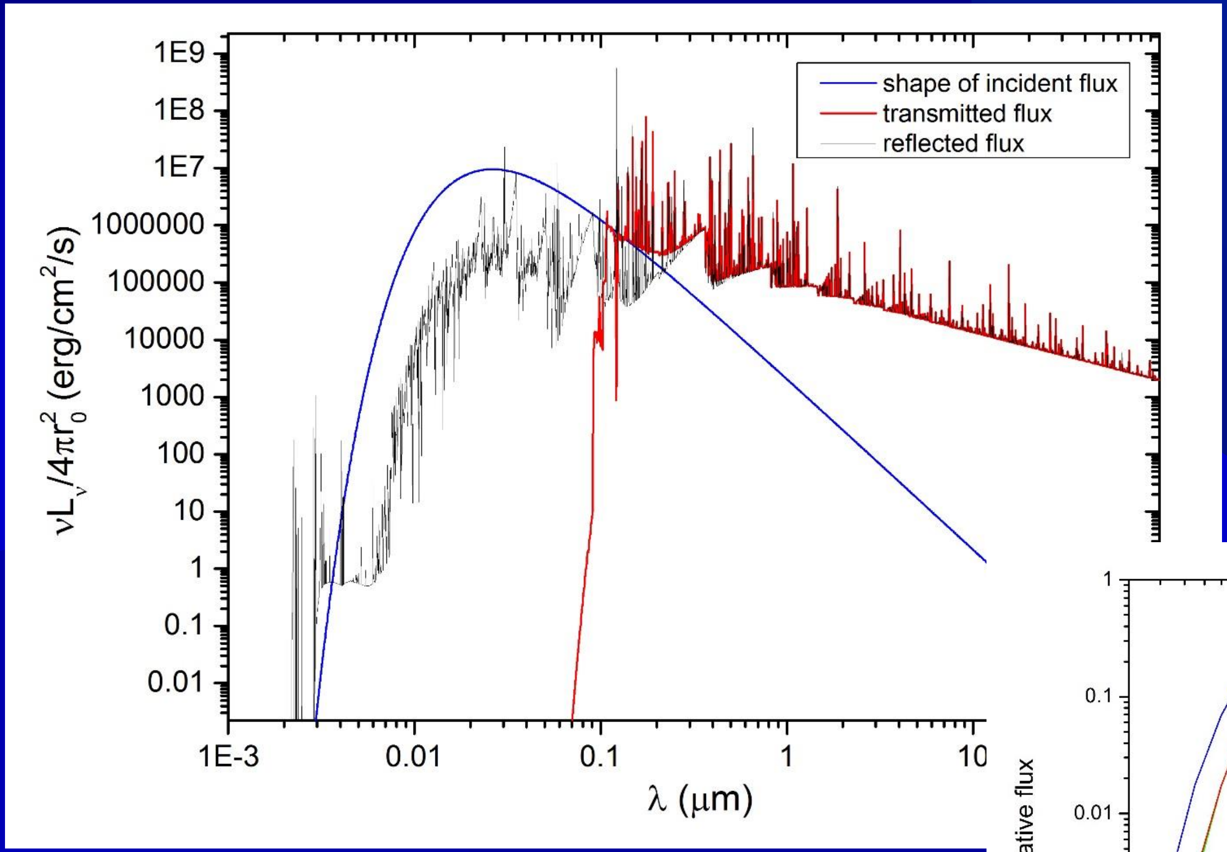


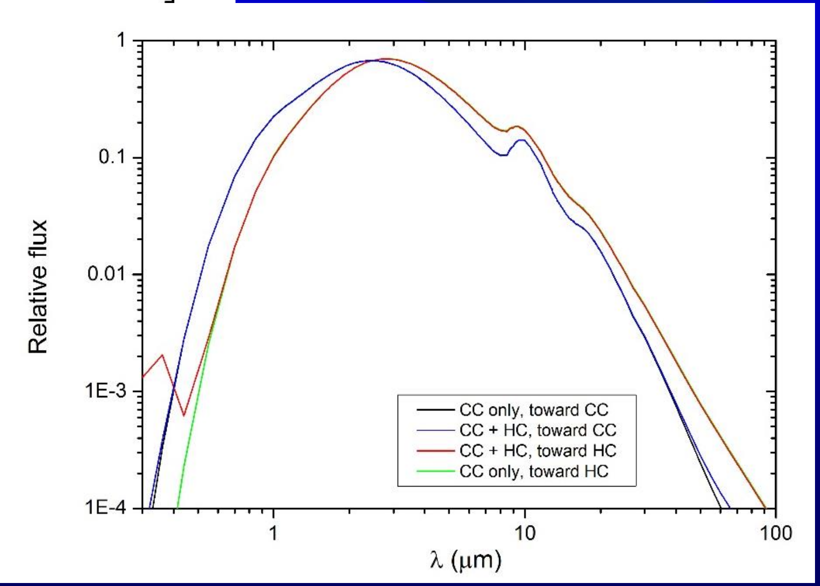
thickness of interaction region 2 AU



INFLUENCE OF THE HOT COMPONENT

log N_H = 8 cm^{-3}
thickness = 5 AU





SUMMARY

- Silicate/carbon dust shell around Mira can explain infrared observations of symbiotic Miras
  - → inner shell radius determined by the condensation temperature of ~1200 K
  - → density distribution enhanced by radiatively driven winds
- Obscuration events can be explained by change in dust optical depth
- Departure from spherical symmetry probably due to the presence of companion
- Long periodicity (~20 yrs): possibly connected with the dust at the inner shell radius
- Possible grain growth in symbiotic novae can increase stellar outflow driven by higher radiation pressure on larger grains
- Intermediate-period (lower luminosity) symbiotic Miras show higher mass loss than single Miras
- Long-period (higher luminosity) symbiotic Miras have mass loss is in agreement with longer period single O-rich AGBs
- Absence of significant dust destruction during and after nova outburst
- High-density gas region produced by collision between stellar winds can provide necessary shielding of dust from strong UV radiation

Thank you for your attention!

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