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 $L_{\text{Sun}}$
**MODEL DEGENERACY:**
Single vs. two dust shells (HM Sge)

Schild+ (2001):

<table>
<thead>
<tr>
<th>Model</th>
<th>Temp 1</th>
<th>Temp 2</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWO SHELL MODEL</td>
<td>1400 K</td>
<td>800 K</td>
<td>thick</td>
</tr>
<tr>
<td>( T_{dust} )</td>
<td>700 K</td>
<td>900 K</td>
<td>thin</td>
</tr>
<tr>
<td>( \tau_v )</td>
<td>1.9</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

Bogdanov & Taranova (2001):

<table>
<thead>
<tr>
<th>Model</th>
<th>Temp Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SINGLE SHELL MODEL</td>
<td>700 – 900 K</td>
</tr>
<tr>
<td></td>
<td>10 – 13</td>
</tr>
</tbody>
</table>

\[ \lambda F(\lambda), 10^{-9} \text{erg s}^{-1} \text{cm}^{-2} \]

![Graph 1]

![Graph 2]
**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 \( \Rightarrow \) 10 \( \mu \)m feature is typical silicate feature, not black body emission!
RECENT MODELS: HM SGE

Sacuto & Chesneau (2009) – IR spectroscopy + interferometry
Single-shell model
Sublimation dust temperature: $T = 1600 \, \text{K}$
Visual optical depth: 25
Density distribution: almost steady-state wind
OBSERVATIONS

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


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)

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

Jurkic & Kotnik-Karuza (2012)
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 absorption, scattering & emission
Density distribution

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

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

$r_{in}$ – 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

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

<table>
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<tr>
<th>Parameter</th>
<th>RR Tel</th>
</tr>
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<tbody>
<tr>
<td>$T_{Mira}$ (K)</td>
<td>2350</td>
</tr>
<tr>
<td>$T_{dust}$ (K)</td>
<td>1200 – 1350</td>
</tr>
<tr>
<td>$a_{max}$ (µm)</td>
<td>4.0 – 4.7</td>
</tr>
<tr>
<td>$\tau_v$</td>
<td>5.0 – 5.5</td>
</tr>
<tr>
<td>$\dot{M}$ (10^-6 M(_{Sun}/yr))</td>
<td>6 – 8</td>
</tr>
</tbody>
</table>

Jurkic & Kotnik-Karuza (2017)
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

spherical distribution  
equatorially enhanced distribution
RR TEL: OUTSIDE OBSCURATION

1996/03/20

\[ \lambda F_\lambda \left(10^{-12} \, \text{W/m}^2\right) \]

\[ \lambda \, (\mu\text{m}) \]

line of sight
**LONG-TERM DUST PROPERTIES**

Obscurations in near-IR $\Rightarrow$ explained by change in dust optical depth
Dust optical depth changes in time $\Rightarrow$ evolution of dust shell

LONG-TERM DUST PROPERTIES
## DUST PROPERTIES

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<thead>
<tr>
<th>Symbiotic Mira</th>
<th>Luminosity ($L_{\text{Sun}}$)</th>
<th>$T_{\text{cond}}$ (K)</th>
<th>$a_{\text{max}}$ ($\mu$m)</th>
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<tbody>
<tr>
<td>BI Cru</td>
<td>4600</td>
<td>1200 – 1400</td>
<td>1 – 2</td>
<td>3.2 – 6.5</td>
</tr>
<tr>
<td>O Cet</td>
<td>6100</td>
<td>1100</td>
<td>0.15</td>
<td>0.4 – 3.4</td>
</tr>
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<td>KM Vel</td>
<td>7000</td>
<td>1150</td>
<td>0.15</td>
<td>8.3 – 12.6</td>
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<tr>
<td>R Aqr</td>
<td>7300</td>
<td>650</td>
<td>3.5</td>
<td>0.6 – 8.8</td>
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<td>V835 Cen</td>
<td>7600</td>
<td>950</td>
<td>12 – 20</td>
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<tr>
<td>AS 210**</td>
<td>8000</td>
<td>1100 - 1300</td>
<td>0.5 – 1</td>
<td>1.5 – 5</td>
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<tr>
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<td>1000</td>
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<td>15</td>
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<td>1000 – 1200</td>
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<td>SS73 38**</td>
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<td>3.2 – 9.0</td>
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<tr>
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Grain growth in symbiotic novae? ⇒ 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 → Symbiotic Novae
MASS LOSS

$L > 10000 L_{\odot}$
In agreement with long-period single O-rich AGB stars (van Loon+, 2005)

$L < 10000 L_{\odot}$
Higher than observed for single intermediate-period Miras (Jura & Kleinman, 1989, 1992)
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

\[ \log N_H = 8 \text{ cm}^{-3} \]

Jurkic & Kotnik-Karuza, in preparation
INFLUENCE OF THE HOT COMPONENT

\[ \log N_H = 8 \text{ cm}^{-3} \]

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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