Silicate Dust in D-type Symbiotic Stars: an ISO overview

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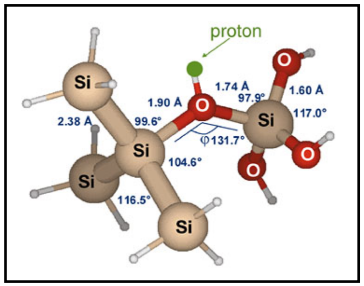
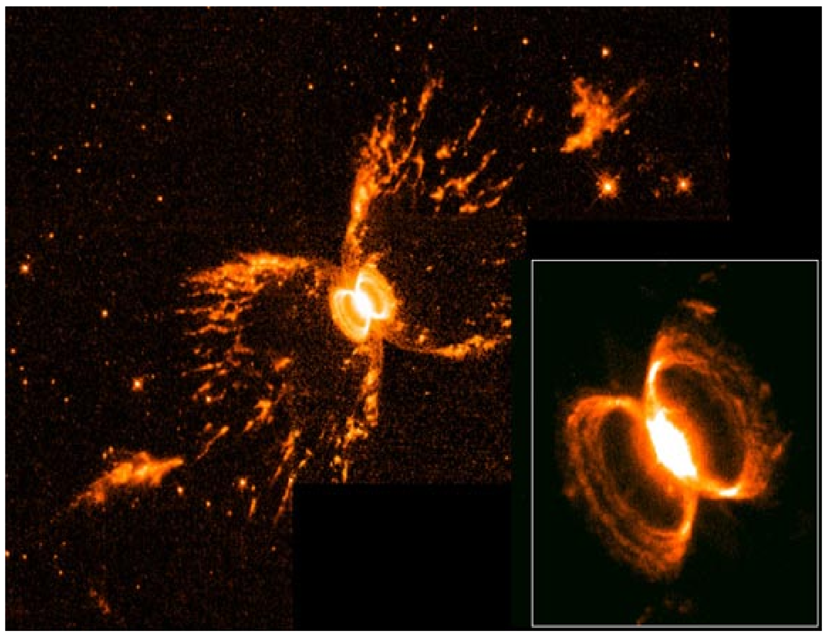
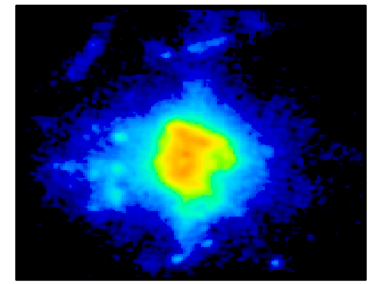
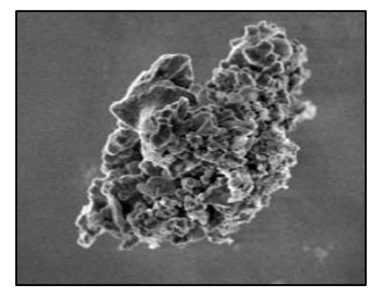
AJ, 2007 - 134, 205









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Rodolfo Angeloni
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Outline

1. Introduction
2. The ISO Sample
3. Silicate Dust Bands
4. Dust and Gas Conditions in the Ionized Nebulæ
5. Concluding Remarks

! - *Works in progress* - !

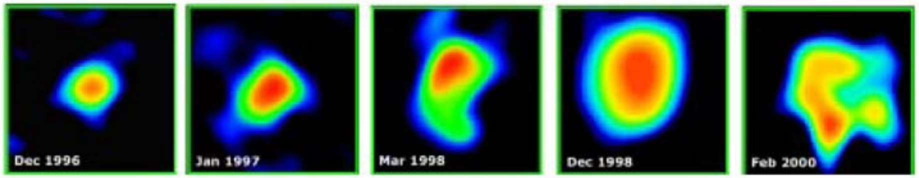
1. Introduction

Symbiotic Stars as Colliding-Wind Binary Systems

Symbiotic systems are **interacting binaries**

composed by a hot star; a cool giant star;

and different gas and dust nebulae.

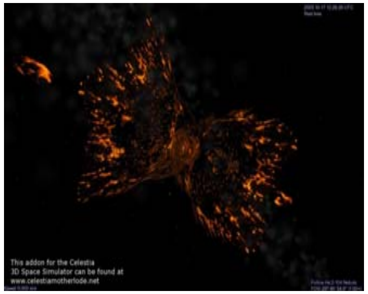


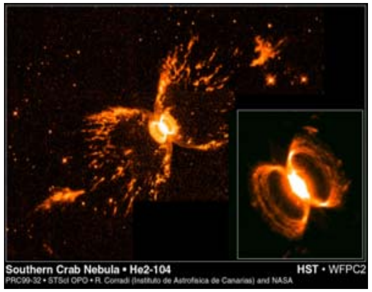
Theoretical models (e.g. Girard & Willson 1987, Kenny & Taylor 2005)
and observations (e.g. Nussbaumer et al. 1995, Schmid 1999, Bisikalo et al. 2006)

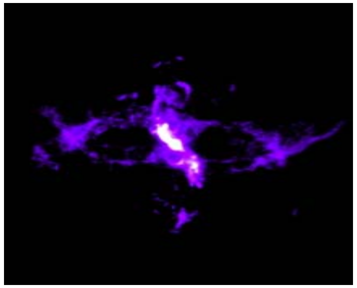
have unquestionably shown that actually both the hot and cool stars

lose mass through <u>stellar winds which collide</u>

within and outside the system, creating a complex network of wakes and shock fronts (Corradi et al. 1999, Nussbaumer 2000)

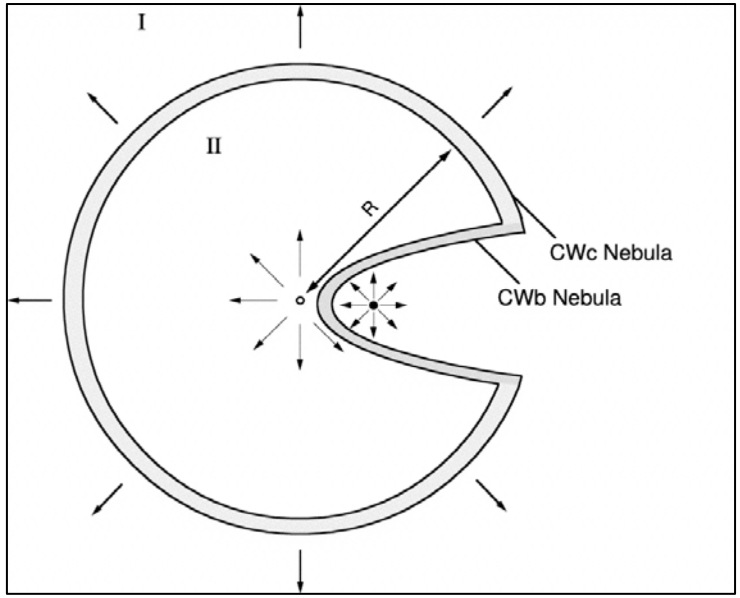


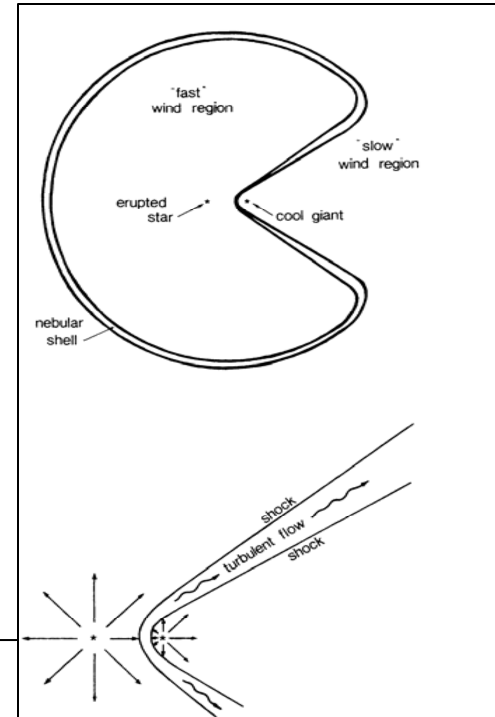




Colliding-winds

Kenny & Taylor (2005)



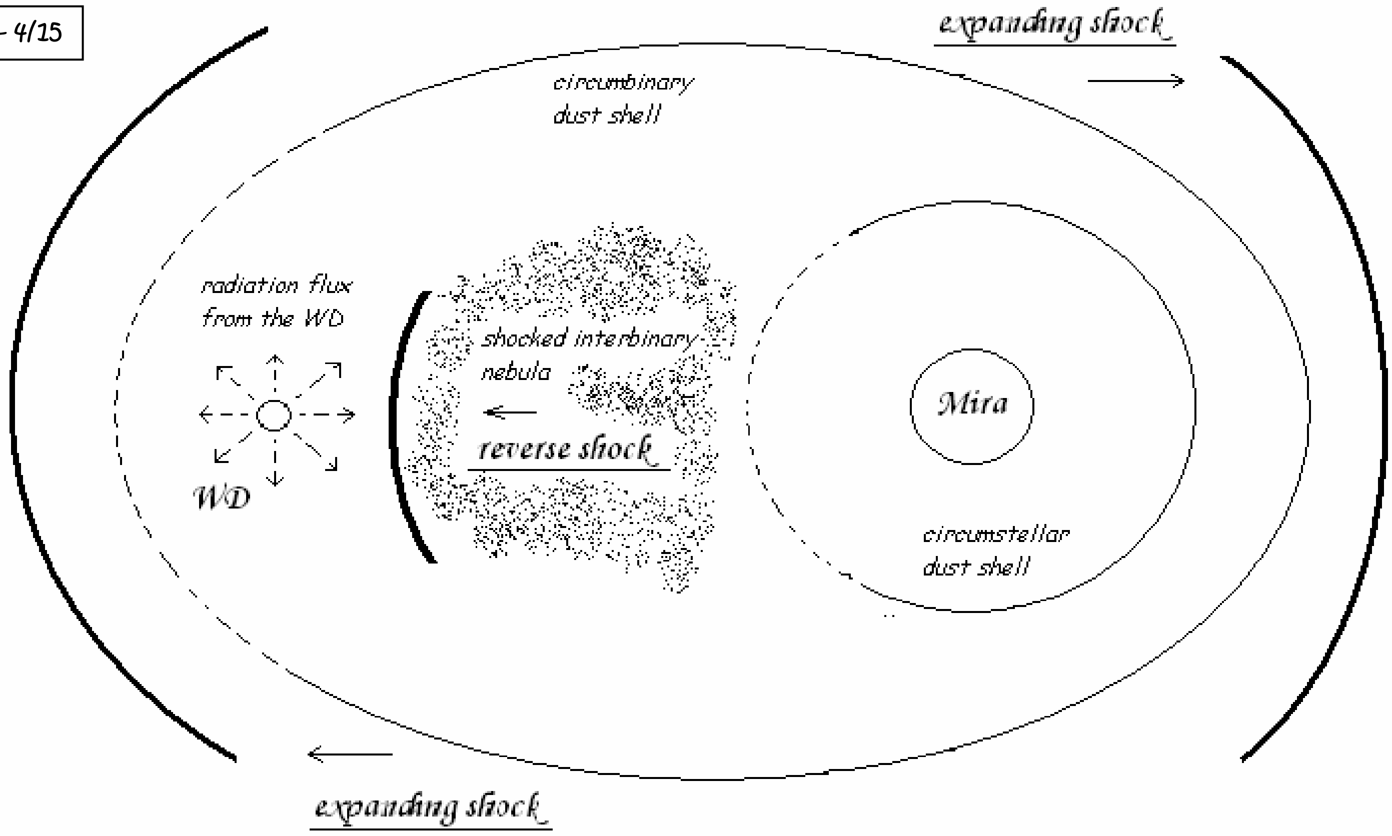


"Concentric" CW (CWc)

a low-velocity wind overtaken from the inside by a higher velocity wind from the same effective source.

"Binary" CW (CWb)

two stellar winds from binary companions coming into direct contact.



With Nussbaumer et al. (1995, 2000), we would rather refer to

- ***head-on shock***, located between the stars and facing the WD
- ***head-on-back shocks***, expanding *outwards* the system

From this scenario two different types of models derive...

• Reverse-shock model

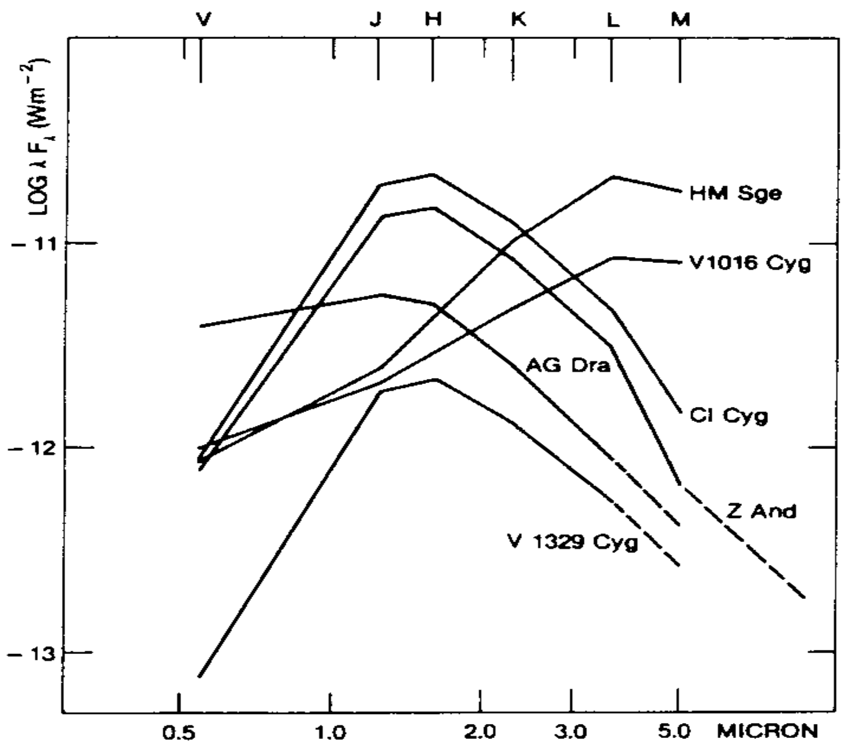
The photoionizing flux from the WD reaches the shock front edge of the nebula: very *high densities* and a *high ionization parameter*.

• Expanding-shock model

The photoionizing flux from the WD reaches the edge of the nebula opposite to the shock front: *lower densities* and a *low ionization parameter*.

Webster & Allen 1975

- S-type - NIR continuum dominated by *the cool star*
- D-type - NIR continuum dominated by *dust*



D-type

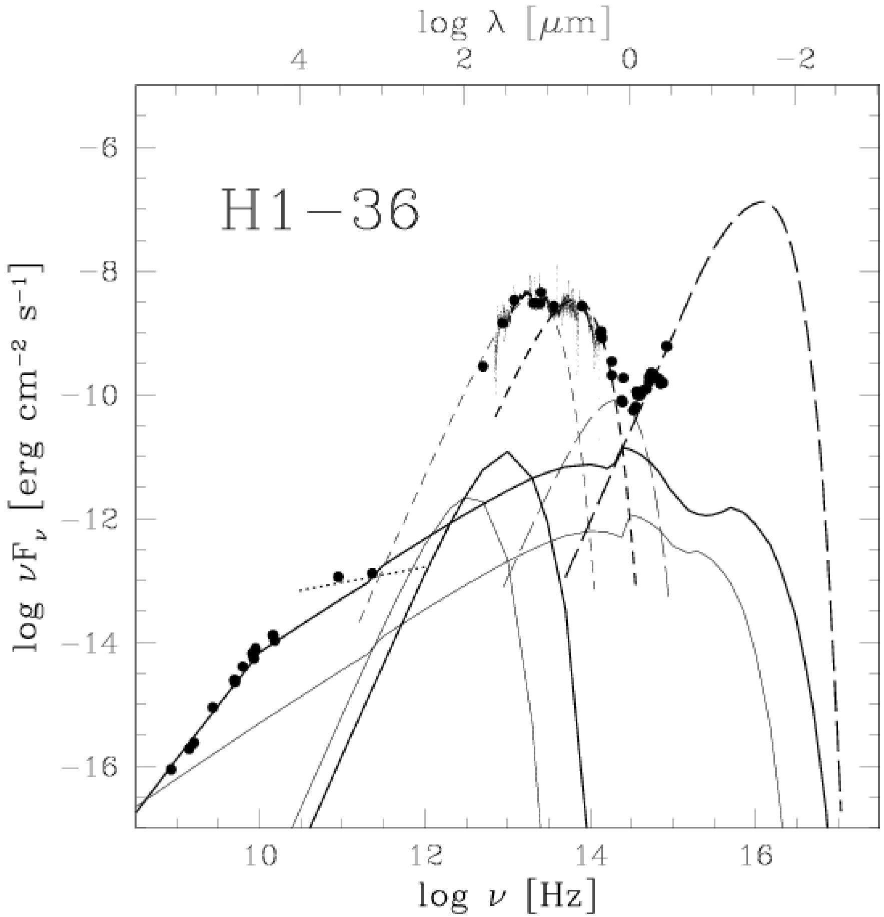
- Cool component: *MIRA*
- Electron density $n_e = 10^6 - 10^7\ cm^{-3}$
- [OIII]λλ4959+5007/Hβ >*1*
- Dust temperature *Td* ≈ *800°-1000° K*
- Large orbital period (even hundreds of years)

D-type

IR continuum

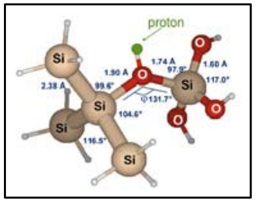
Several "dust temperatures" to reproduce the continuum SED

(Anandarao et al. 1988, Schmid et al. 1999, Angeloni et al. – *accepted for publication in A&A*)



Intermezzo

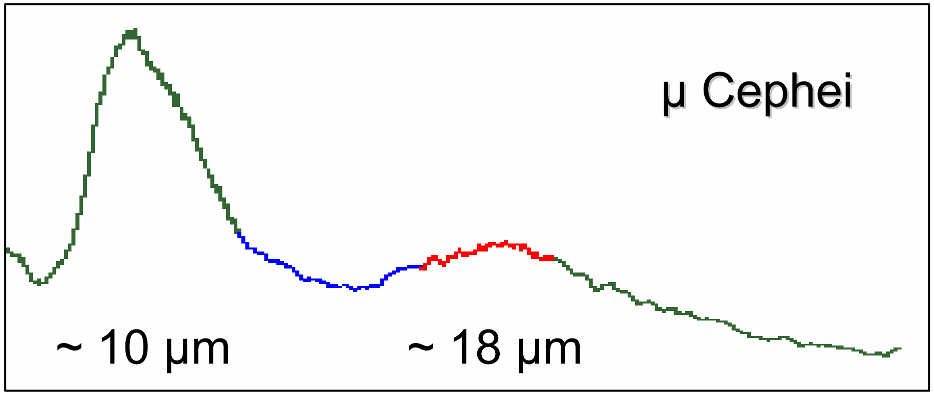
about dust spectroscopy, i.e. dust composition,
in Galactic environments

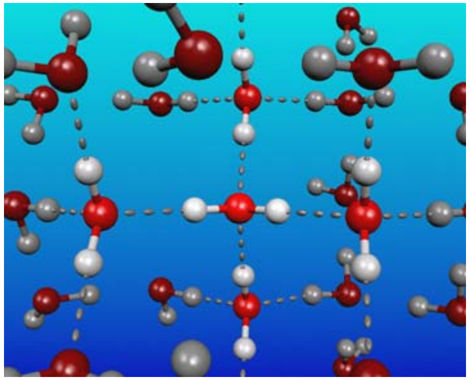


Amorphous silicates

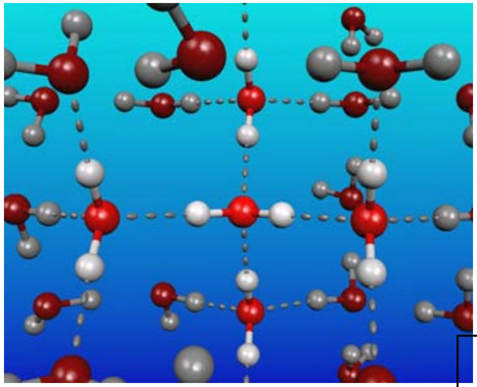
Smooth, broad bands in the spectra of some late-type stars and then in a wider variety of galactic environments were recognized since the last 60's …

10 μm ⇒ Si-O *stretching* mode





18 μm ⇒ O-Si-O *bending* mode



The band profiles show a strong dependence on the environment conditions

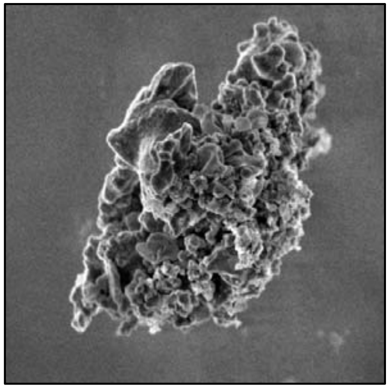
Pégourié & Papoular (1985) – Bowey & Adamson (2002)

Several studies have been investigating the possibility to derive information about the relative age of silicate from the band strenght ratio – Nuth & Hecht (1990)

and to interpret the 10 μm and 18 μm silicate profiles in terms of *mixed* crystalline and amorphous structures – Kemper et al. (2001) – Tamanai et al. (2006)

Before the *Infrared Space Observatory* (ISO) satellite opened the mid- and far-infrared range for high-resolution spectroscopy

1. It was generally assumed that cosmic dust was of *amorphous* structure



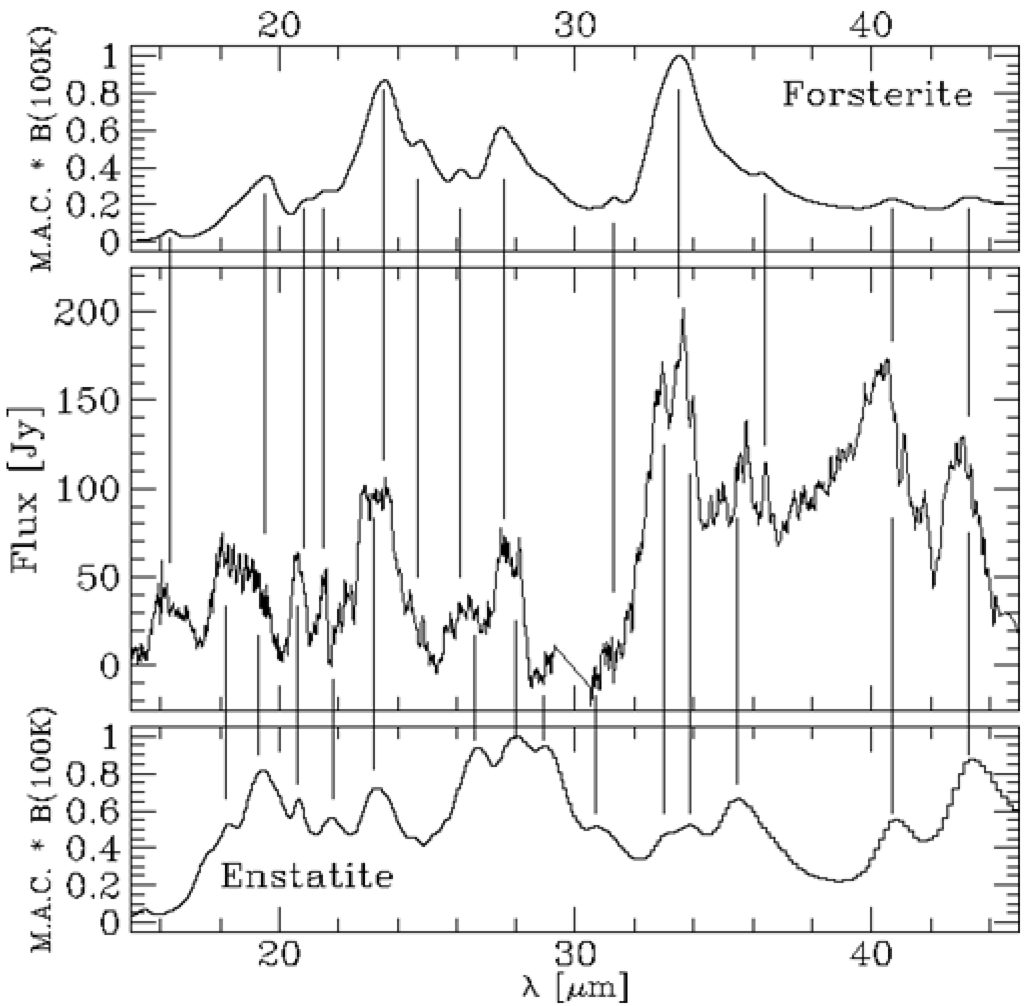
2. It was believed that the C/O photospheric ratio determined *invariably* the dust grain composition

C/O<1	→	*O-rich* dust (e.g. silicates)
C/O>1	→	*C-rich* dust (e.g. PAHs)

"Steps toward interstellar silicate mineralogy IV. The crystalline revolution"

C. Jäger, F.J. Molster, J. Dorschner, Th. Henning, H. Mutschke, L.B.F.M. Waters

A&A 1998 - 339, 904



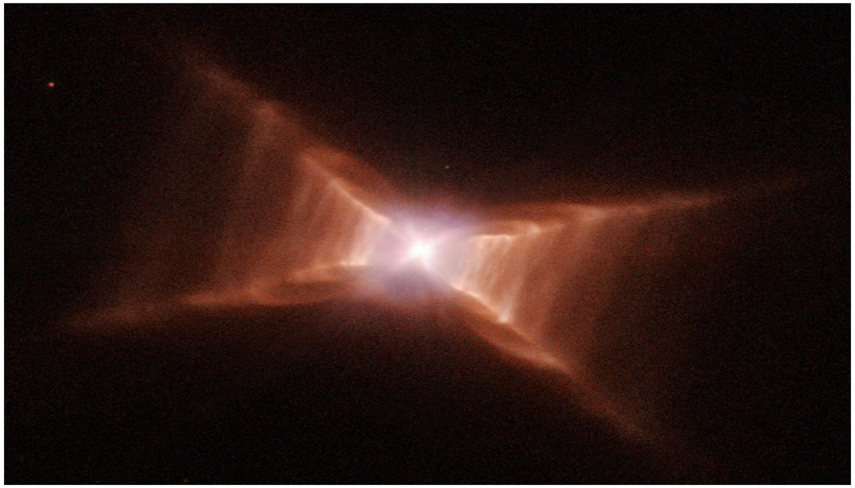
ISO-SWS spectrum of AFGL 4106

Mixed dust chemistry

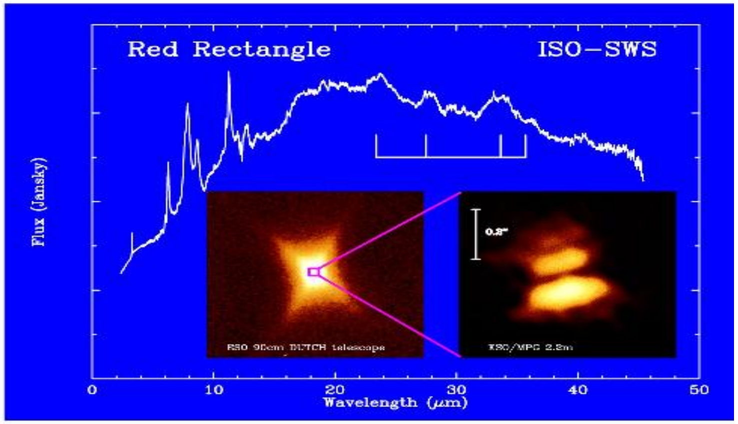
i.e. both *PAH* bands and *crystalline silicate* features

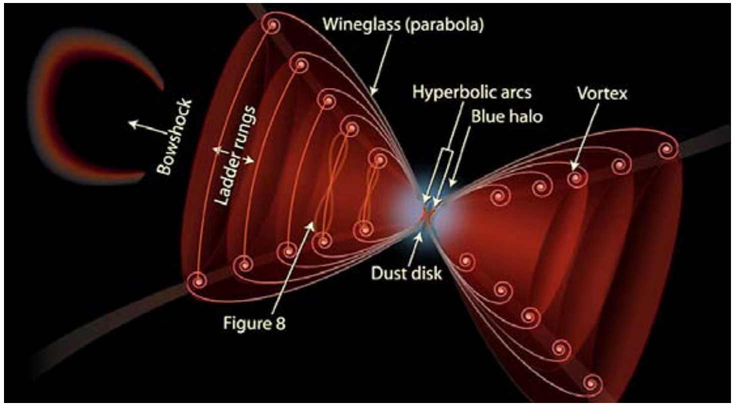
the "prototype"

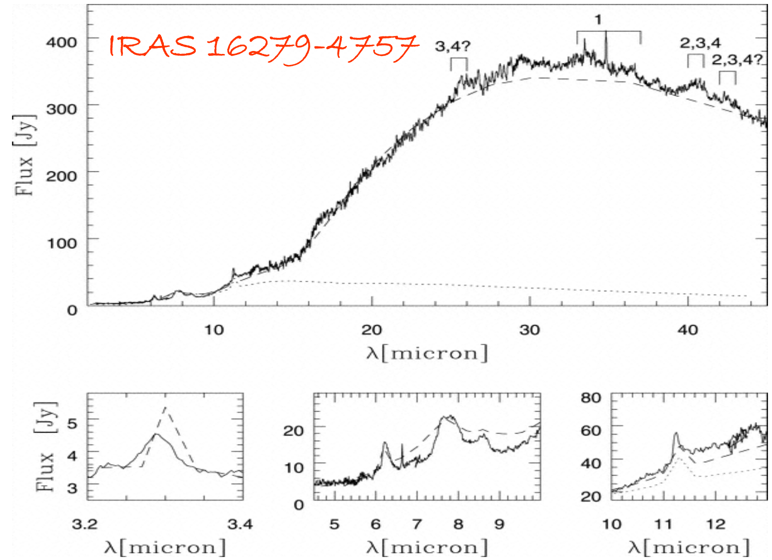
Red Rectangle (HD44179)



Waters et al. 1998, Nature 391 - 868





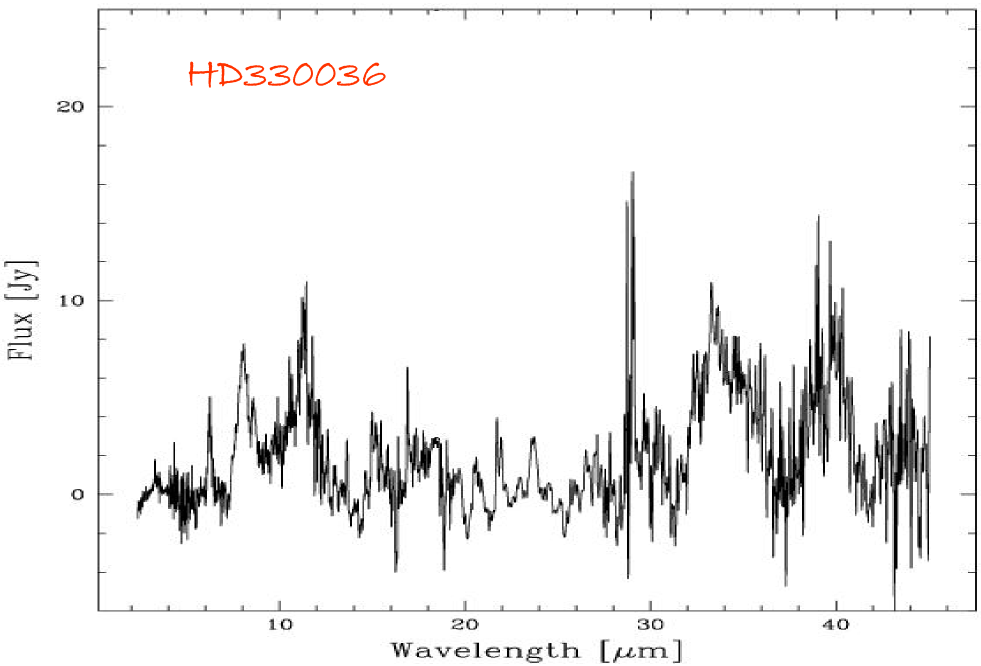


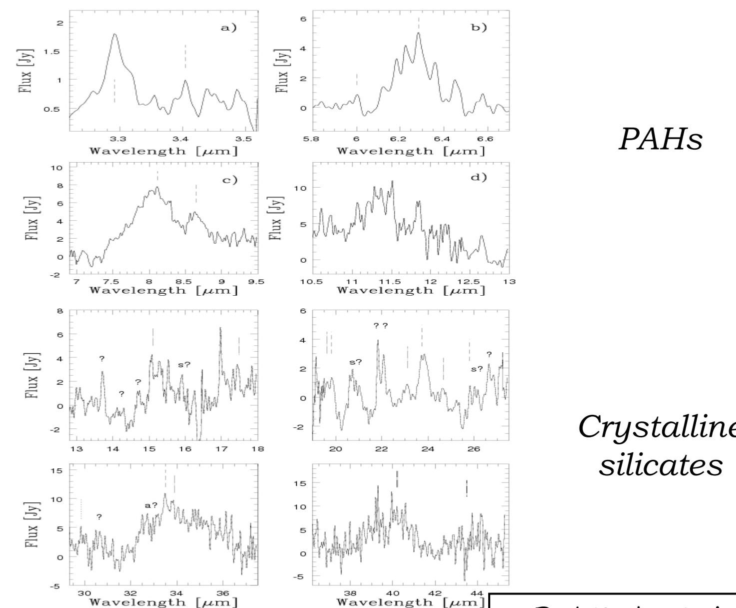
IRAS 16279-4757 – post AGB star

Matsuura et al. 2004, ApJ 604, 791

HD330036 – D' type SS

Angeloni et al. 2007, A&A, accepted for publication

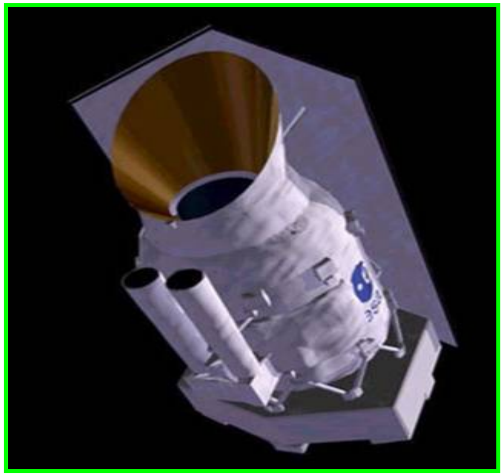


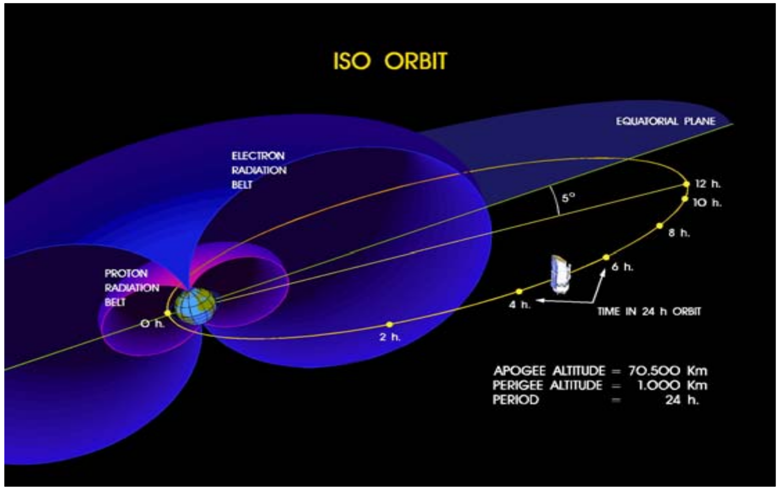


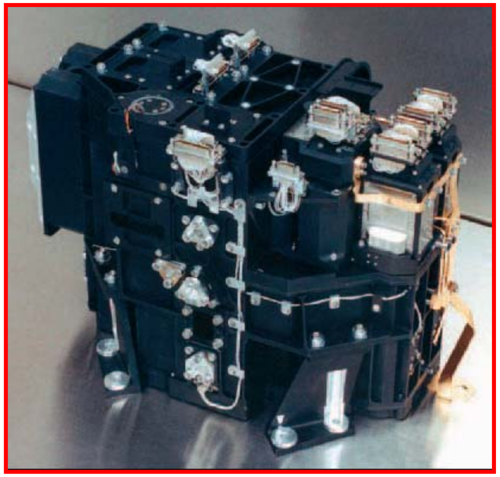
2. The ISO Sample

The Short Wavelength Spectrometer (SWS) Spectra

ISO/SWS Spectra







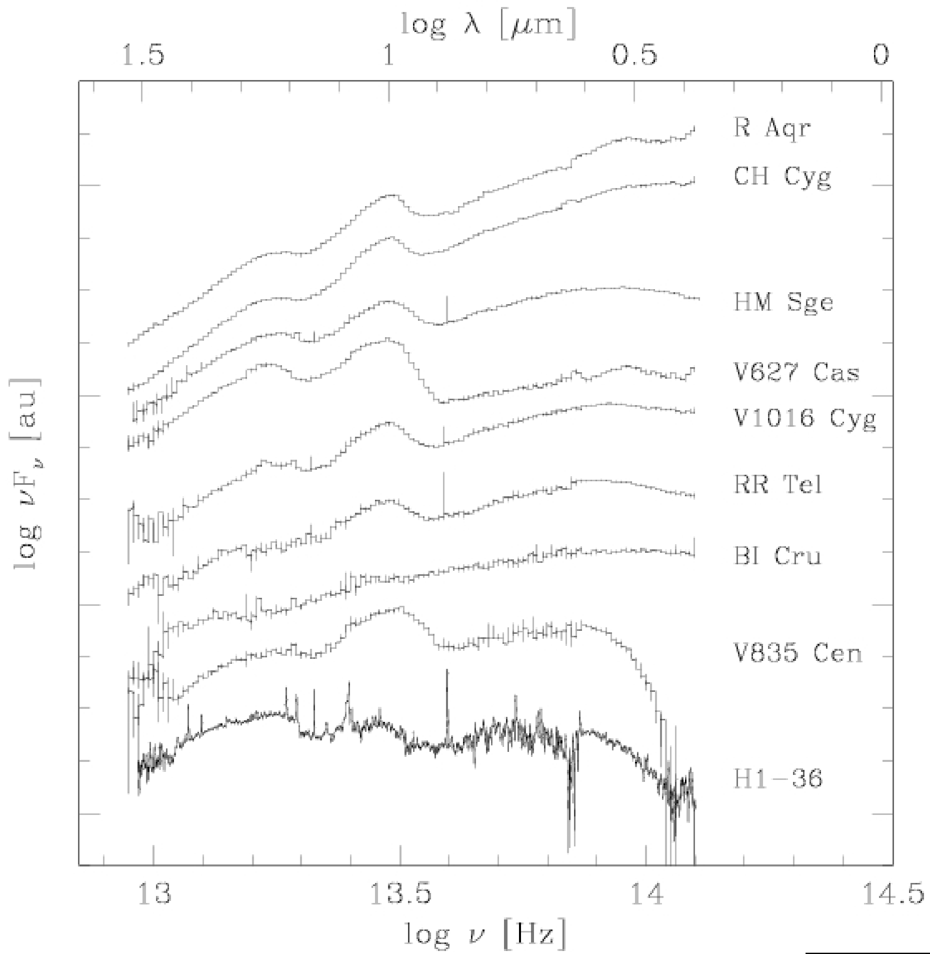
SWS wavelength range: 2.38 – 45.2 **μ**m

The spectra come from the
"Uniform database of SWS 2.4-45.4 μm spectra"
within the Highly Processed Data Products (HPDP) section of the ISO Archive.

The Sample

Selected by cross-checking the Belczynski et al. (2000) atlas of SSs with the *ISO Archive.**

R Aqr	**(RAq)**
CH Cyg**	**(CH)**
V627 Cas	**(V6)**
HM Sge	**(HM)**
V1016 Cyg	**(V1)**
RR Tel	**(RR)**
BI Cru	**(BI)**
V835 Cen	**(V8)**
H1-36	**(H1)**

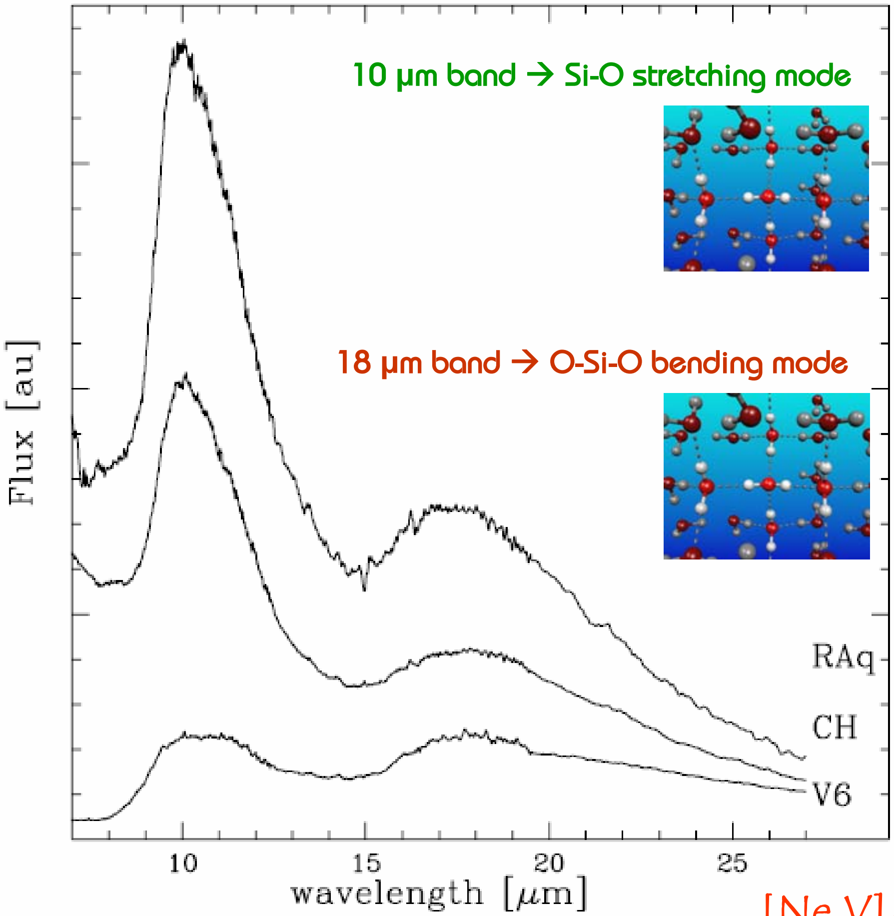


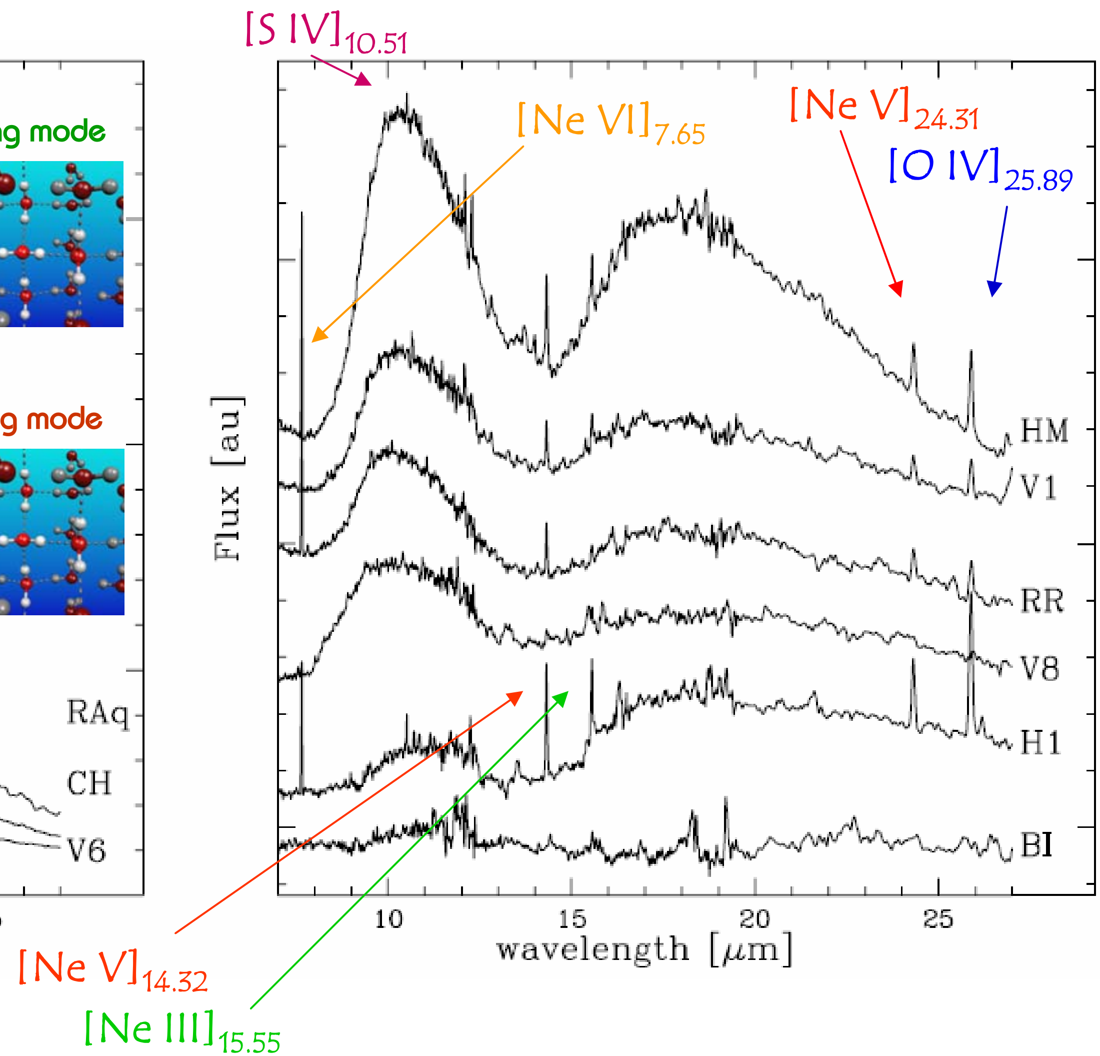
* http://www.iso.esac.esa.int/ida/index.html

** classified as S-type

3. Silicate Dust Bands

The 7-27 μm region of the *ISO SWS* spectra

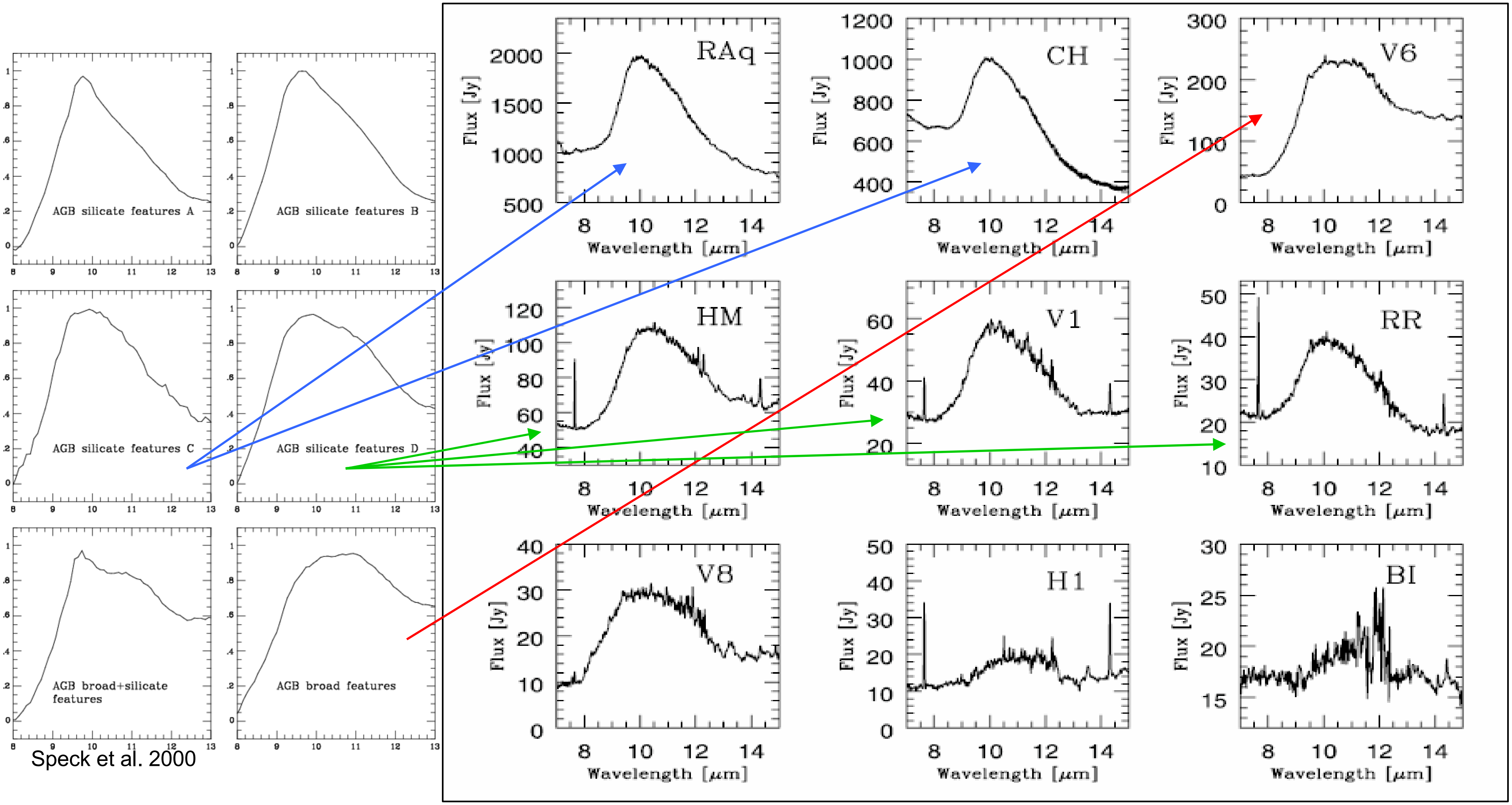




…as well as [Ar VI]$_{4.53}$, [Mg V]$_{5.61}$, [Si VII]$_{6.49}$, [Fe VII]$_{9.53}$, [S IV]$_{10.51}$, [Ne II]$_{12.81}$…

The ~10 μm Silicate Band

the profiles



Speck et al. 2000

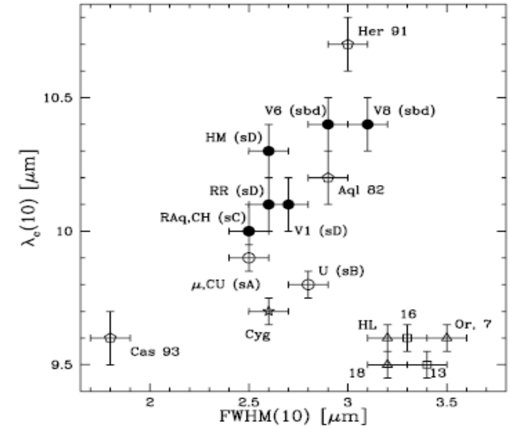
• [illegible]

The ~10 μm Silicate Band

effect of environment on the profile

TABLE 1
THE λ_c AND FWHM OF THE SILICATE PROFILES

Object	$\lambda_c(10)$	FWHM(10)	$\lambda_c(18)$
Symbiotic			
R Aqr	10.0 ± 0.1	2.5 ± 0.1	17.5 ± 0.2
CH Cyg	10.0 ± 0.1	2.5 ± 0.1	17.6 ± 0.2
V627 Cas	10.4 ± 0.1	2.9 ± 0.1	18.2 ± 0.2
HM Sge	10.3 ± 0.1	2.6 ± 0.1	17.9 ± 0.2
V1016 Cyg	10.1 ± 0.1	2.7 ± 0.1	17.9 ± 0.2
RR Tel	10.1 ± 0.1	2.6 ± 0.1	18.1 ± 0.2
V835 Cen	10.4 ± 0.1	3.1 ± 0.1	18.3 ± 0.2
Novae			
Aql 82	10.2 ± 0.1	2.9 ± 0.1	...
Her 91	10.7 ± 0.1	3.0 ± 0.1	...
Cas 93	9.6 ± 0.1	1.8 ± 0.1	...
Circumstellar			
μ Cep	9.9 ± 0.05	2.5 ± 0.1	...
CU Cep	9.9 ± 0.05	2.5 ± 0.1	...
U Aur	9.8 ± 0.05	2.8 ± 0.1	...
Diffuse Medium			
Cyg OB2 no. 12	9.7 ± 0.05	2.6 ± 0.1	...
YSOs, Orion Trapezium, and TMCs			
HL Tau	9.6 ± 0.05	3.2 ± 0.1	...
Orion Trap.	9.6 ± 0.05	3.5 ± 0.1	...
Taurus-Elias 7	9.6 ± 0.05	3.5 ± 0.1	...
Taurus-Elias 13	9.5 ± 0.05	3.4 ± 0.1	...
Taurus-Elias 16	9.6 ± 0.05	3.3 ± 0.1	...
Taurus-Elias 18	9.5 ± 0.05	3.2 ± 0.1	...



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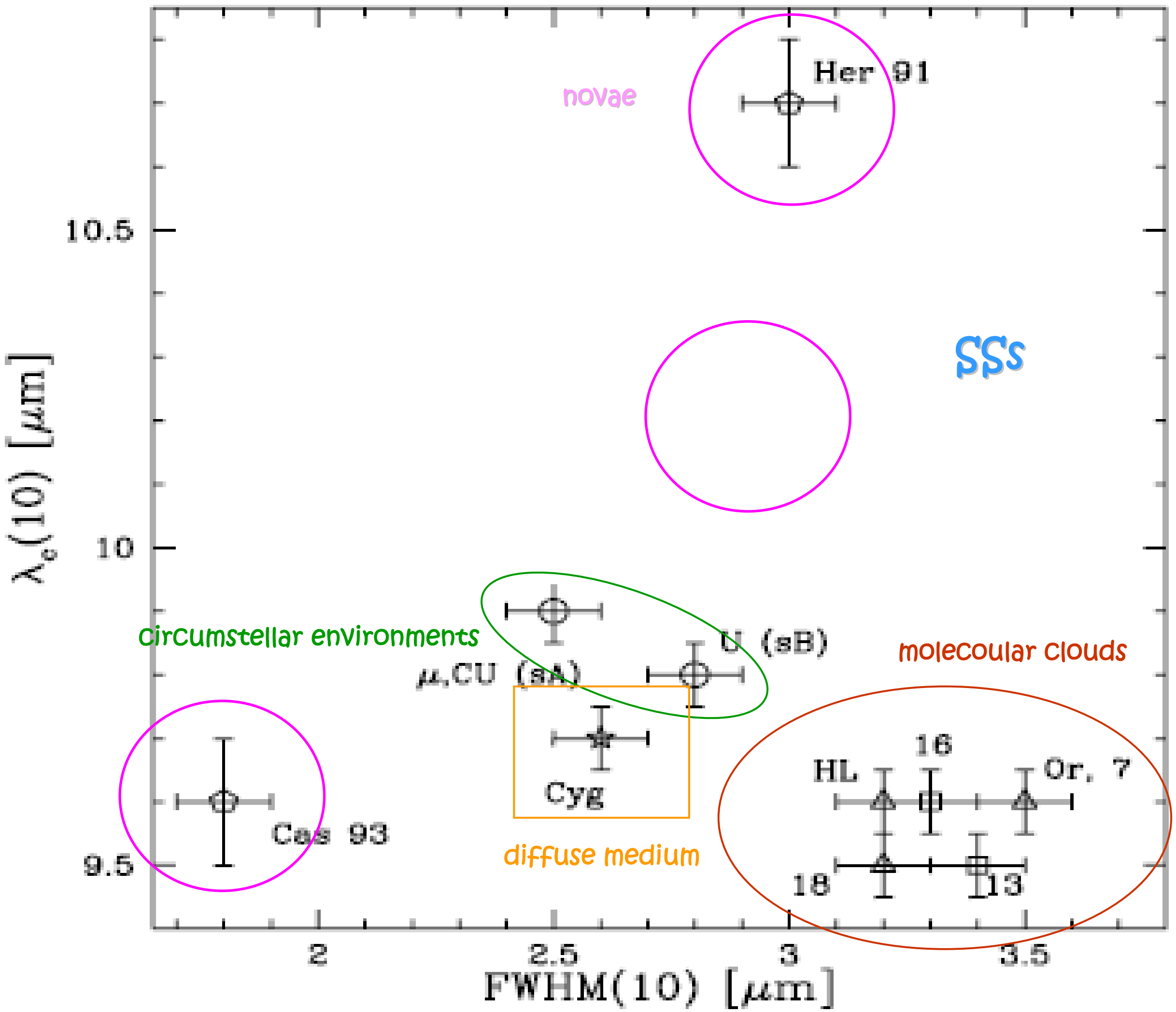
The ~10 μm Silicate Band

effect of environment on the profile



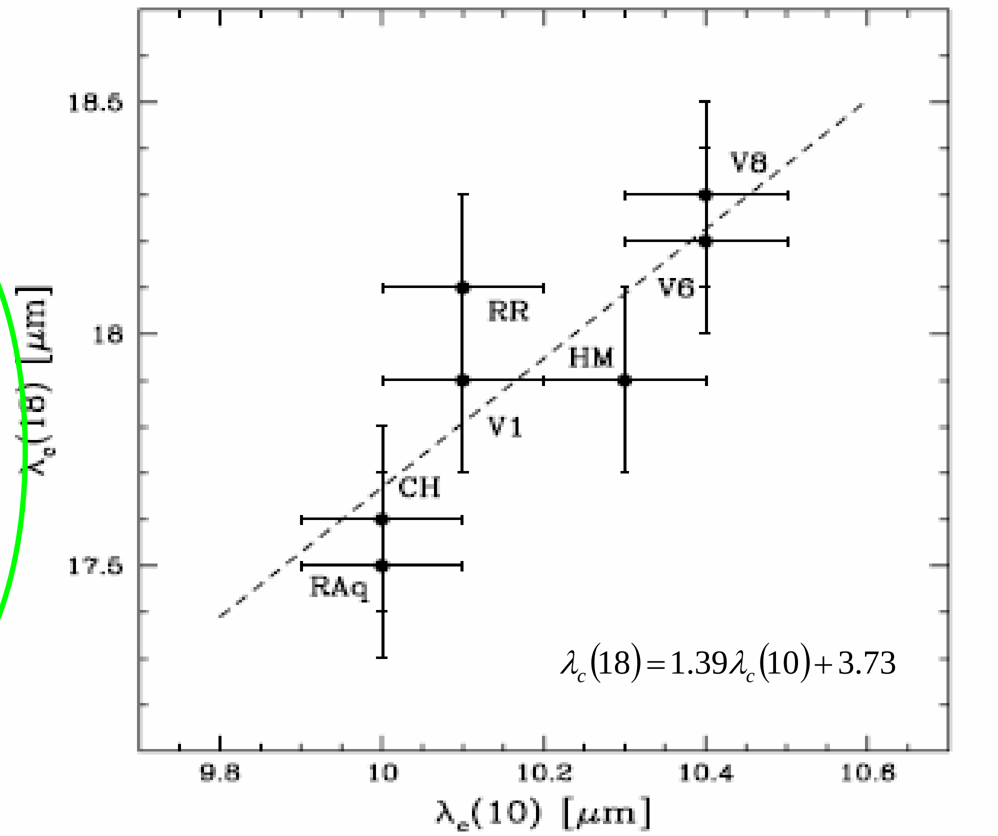
The ~18 μm Silicate Band

peak wavelength correlation

TABLE 1

THE λ_c AND FWHM OF THE SILICATE PROFILES

Object	$\lambda_c(10)$	FWHM(10)	$\lambda_c(18)$
	Symbiotic		
R Aqr	10.0 ± 0.1	2.5 ± 0.1	17.5 ± 0.2
CH Cyg	10.0 ± 0.1	2.5 ± 0.1	17.6 ± 0.2
V627 Cas	10.4 ± 0.1	[illegible]	18.2 ± 0.2
HM Sge	10.3 ± 0.1	2.6 ± 0.1	17.9 ± 0.2
V1016 Cyg	10.1 ± 0.1	2.7 ± 0.1	17.9 ± 0.2
RR Tel	10.1 ± 0.1	2.6 ± 0.1	18.1 ± 0.2
V835 Cen	10.4 ± 0.1	3.1 ± 0.1	18.3 ± 0.2



4. Dust and Gas Conditions in the Ionized Nebulae

The shocked nebulae

IR Emission Lines

TABLE 4

THE BRIGHTEST Ne EMISSION LINES VISIBLE ON TOP OF THE CONTINUUM

Object	[Ne v] 14.32	[Ne III] 15.55	[Ne v] 24.31
R Aqr	...	...	...
CH Cyg	...	...	...
V627 Cas	...	...	...
HM Sge[a]	0.13	0.08	0.06
V1016 Cyg	<0.3	<0.1	<0.2
RR Tel	<0.2	<0.05	<0.1
BI Cru	...	...	...
V835 Cen	<0.05	...	...
H1-36	<0.5	<0.2	<0.15

NOTE.—Normalized to [Ne VI] emission line at 7.65 μm.
[a] Adapted from Schild et al. (2001).

TABLE 5

FWHM (μm) OF THE BRIGHTEST ATOMIC EMISSION LINES

Object	[Ne VI] 7.65	[Ne v] 14.32	[Ne III] 15.55	[Ne v] 24.31	[O IV] 25.89
R Aqr	...	...	...	...	...
CH Cyg	...	...	...	...	...
V627 Cas	...	...	...	...	...
HM Sge	0.03	0.06	0.06	0.11	0.10
V1016 Cyg	0.03	0.05	0.05	0.11	0.11
RR Tel	0.03	0.06	0.06	0.09	0.10
BI Cru	...	...	...	...	...
V835 Cen	0.03	0.06	...	...	...
H1-36	0.03	0.05	0.06	0.10	0.11

HM Sge: a test-case

the SUMA model

in agreement with a $T_{plasma} \sim 10^{6.6}$ K deduced from X-ray observations (Muerset et al. 1997)

TABLE 2

EMISSION LINES NORMALIZED TO [Ne VI] 7.65 μm IN THE SWS SPECTRUM OF HM Sge

λ (μm)	ID	Ionization Potential (eV)	FWHM (μm)	Observed[a]	Model[b]
4.53.......	[Ar VI]	91.01	0.01	0.09	0.09
5.61.......	[Mg V]	141.27	0.04	0.19	0.18
6.49.......	[Si VII]	246.52	0.03	<0.07	0.07
7.65.......	[Ne VI][c]	157.93	0.03	1	1
9.53.......	[Fe VII]	124.98	0.04	0.05	0.05
10.51......	[S IV]	47.22	0.04	0.04	0.04
12.81......	[Ne II]	40.96	0.07	<0.07	0.001
14.32......	[Ne V]	126.21	0.06	0.13	0.12
15.55......	[Ne III]	63.45	0.06	0.08	0.08
24.31......	[Ne V]	126.21	0.11	0.06	0.04
25.89......	[O IV]	77.41	0.10	0.09	0.08

[a] Adapted from Schild et al. (2001).

[b] Input parameters are $V_s = 500$ km s^{-1}; $n_0 = 5 \times 10^5$ cm^{-3}; $B_0 = 10^{-3}$ G; $d/g = 4 \times 10^{-5}$ (by mass); $a_{gr} = 1$, 0.5, and 0.2 μm; $D = 1.74 \times 10^{14}$ cm; $T_{gas} = 1.85 \times 10^4$ K; $T_* = 1.6 \times 10^5$ K; and $U = 1$.

[c] Absolute flux $(74 \pm 0.6) \times 10^{-12}$ ergs cm^{-2} s^{-1}.

T_{gas} is high enough across the whole nebula to prevent recombination…

HM Sge: a test-case

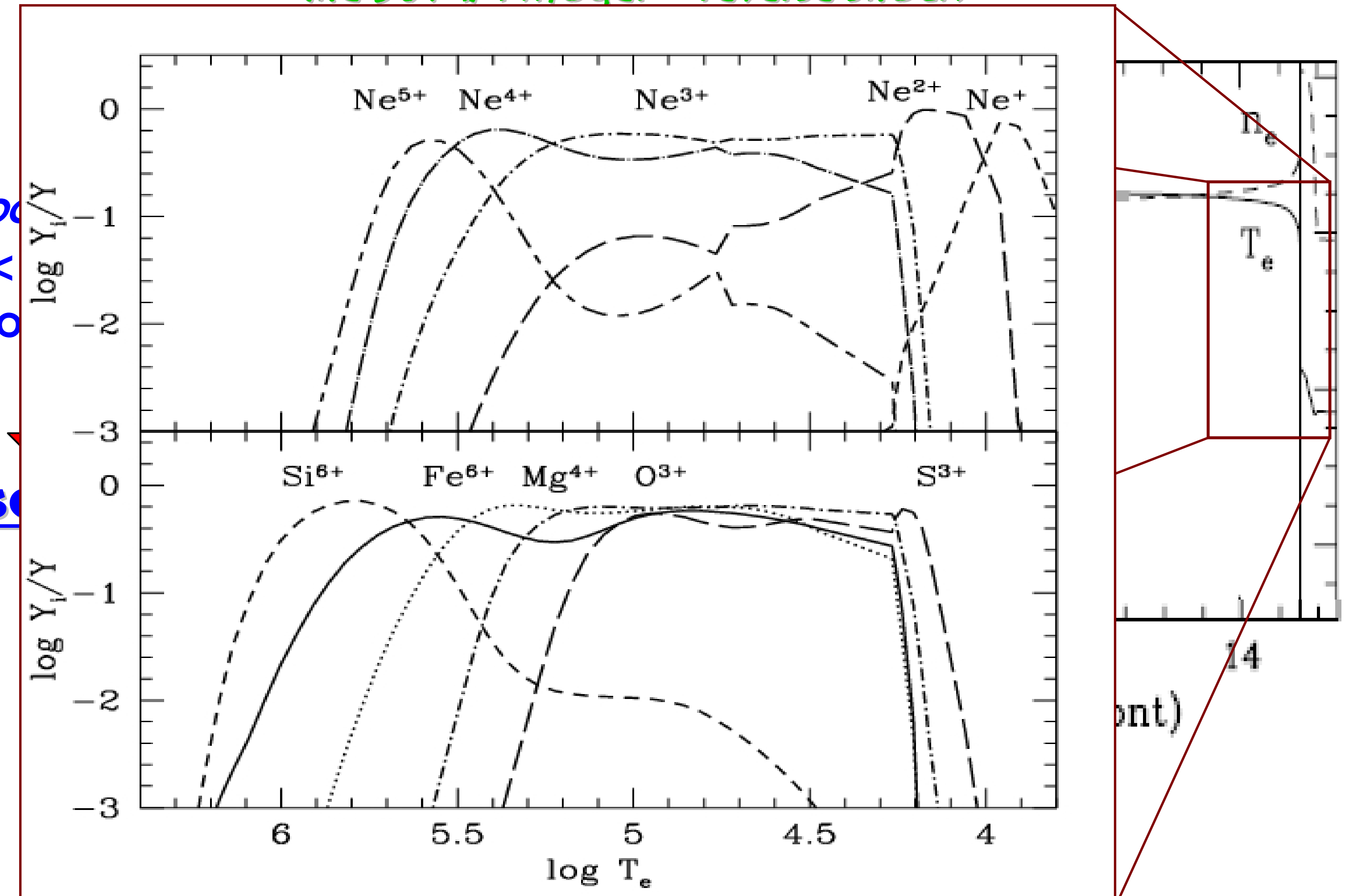
the SUMA model – *reverse shock*

· *Matter-bo*

· D<

· High sho

Reverse



*D - geometric thickness of the nebula ~ 1.74 x 10^{14} cm

R_{bin} – binary separation ~ 3 x 10^{14} cm (Richards et al. 1999)

HM Sge: a test-case

the element abundances

Grain Formation Processes

i.e. depletion

TABLE 3

The Comparison of Relative Abundances for HM Sge

Element	Model	NV90	Solar
He/H	0.11	0.10	0.085
O/H	1.5×10^{-3}	1.0×10^{-3}	6.6×10^{-4}
Ne/H	4.0×10^{-4}	4.0×10^{-4}	8.3×10^{-5}
Mg/H	1.5×10^{-5}	1.0×10^{-4}	2.6×10^{-5}
Si/H	8.0×10^{-6}	2.0×10^{-4}	3.3×10^{-5}
S/H	3.6×10^{-5}	1.0×10^{-4}	1.6×10^{-5}
Ar/H	6.3×10^{-6}	6.0×10^{-6}	6.3×10^{-6}
Fe/H	6.0×10^{-6}	3.0×10^{-5}	4.0×10^{-5}

Note.—NV90: Nussbaumer & Vogel (1990).

Depleted

Higher than solar: contribution of WD wind to the nebula?

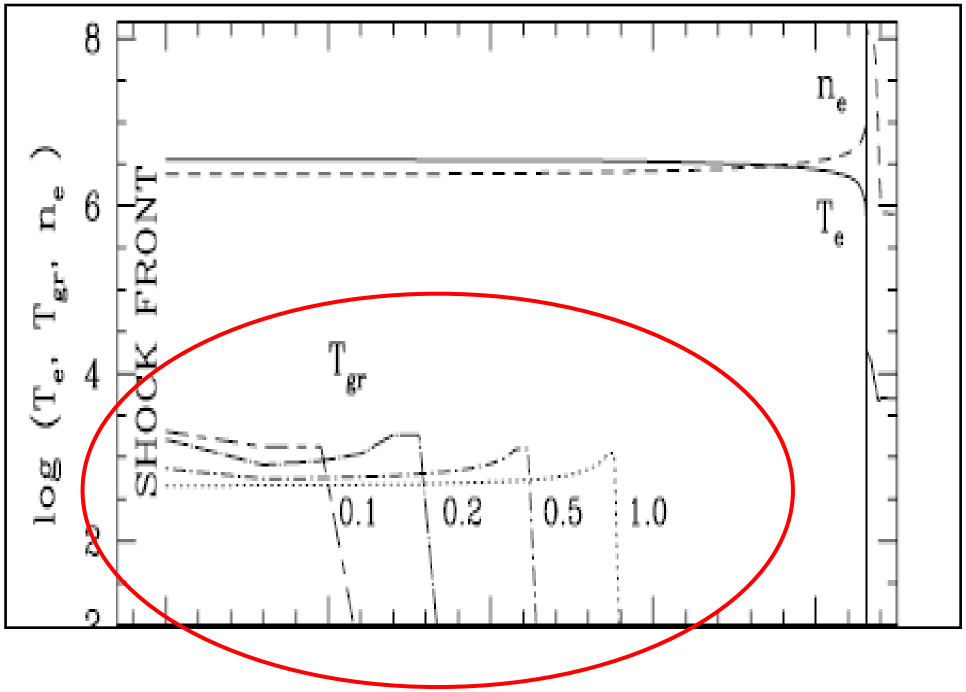
Nussbaumer & Vogel 1990; Weidemann 2003

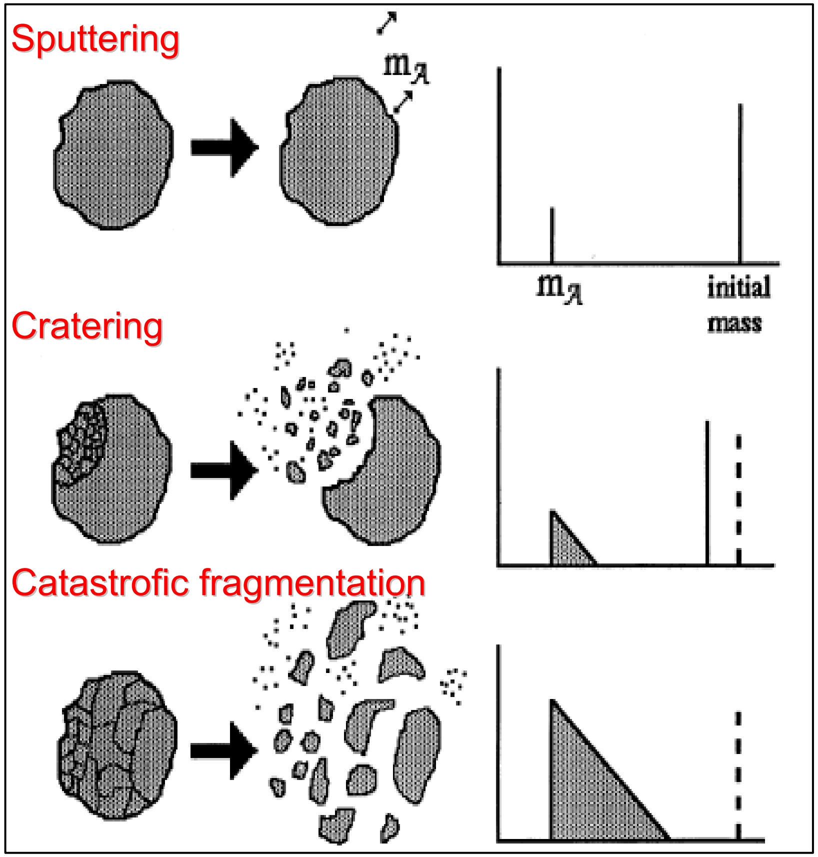
HM Sge: a test-case

the element abundances

Grain Destruction Processes

i.e. sputtering





HM Sge: a test-case

the element abundances

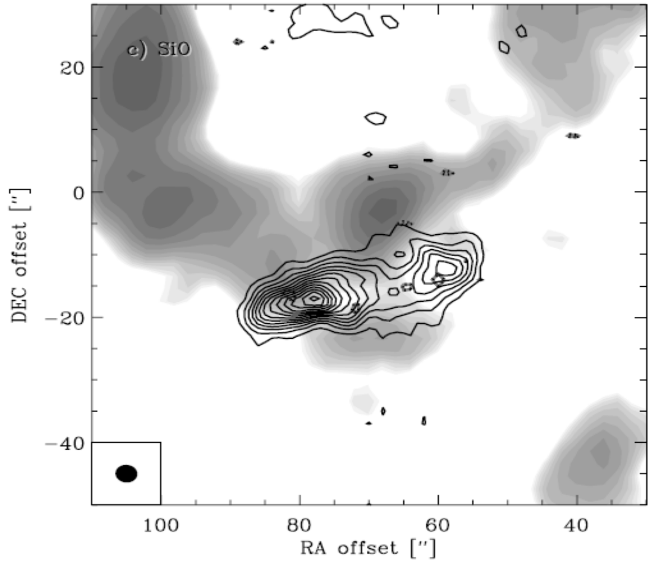
Grain Formation *vs* Grain Destruction Processes

Molecular chemistry?

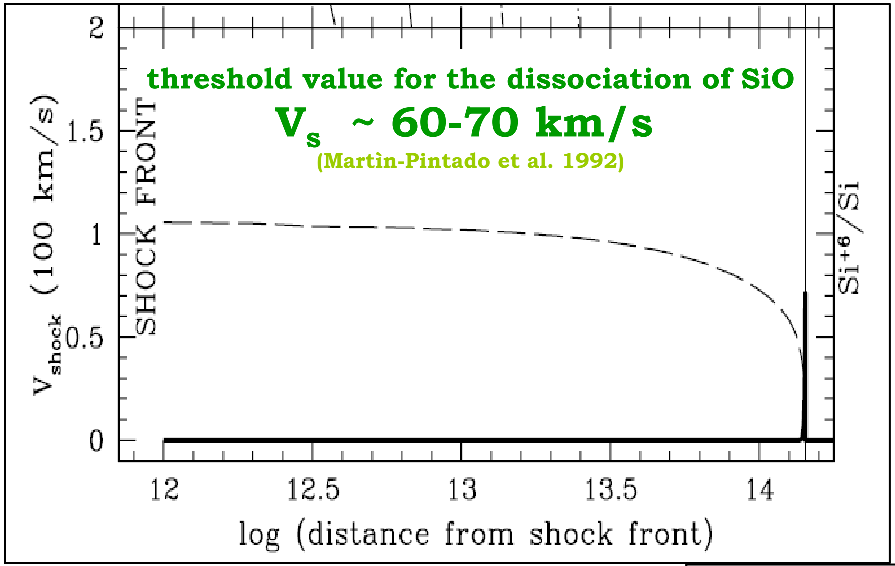
Shocks are expected to develop dust grains in molecular gas:
fast shocks can destroy the grain cores, liberating refractory elements

SiO molecula as tracer of shocked gas

both in YSOs (Martìn-Pintado et al. 1992) and in galaxies (Garcìa-Burillo et al. 2001, Usero et al. 2006)

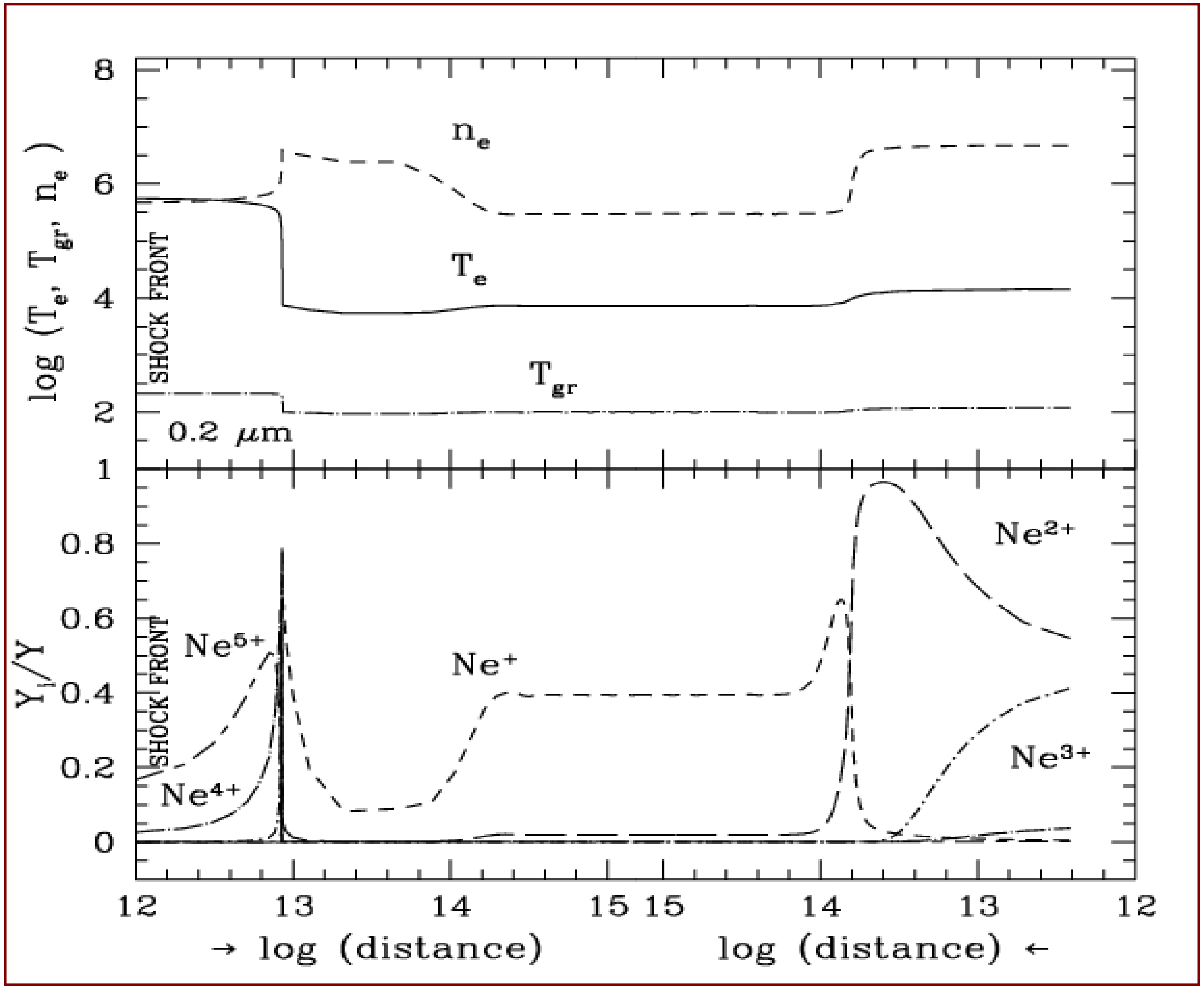


Jørgensen et al. 2004, A&A 415-1021



HM Sge: a test-case

the SUMA model – *expanding shock*



shock front

photoionizing radiation

5. Concluding Remarks

The analysis of unexploited ISO spectra allowed to constrain the emitting properties of coupled dust-gas particles

- **Strong amorphous silicate emission in 7 out of 9 objects**

  10 μm silicate dust profiles in SSs suggest hard reprocessing of grains.

- **Correlation between the λ_c of the 10 and 18 μm dust bands**

  to be verified and constrained on a larger sample of objects and Galactic environments.

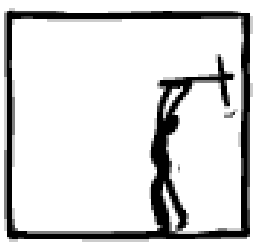
- **Sputtering processes efficiently at work in the inner nebulae**

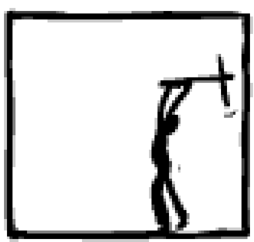
  The signature of dust chemical disturbance due to symbiotic activity should be looked for in the outer, expanding, circumbinary shells where the environmental conditions for grain processing and even crystallization might be achieved.

- **Enhanced abundance of SiO moleculae (reliable shock tracers)?**

  It may explain both the unusual depletion values and the high sputtering efficiency; SSs may be promising targets for mm observations.

! - Works in progress - !





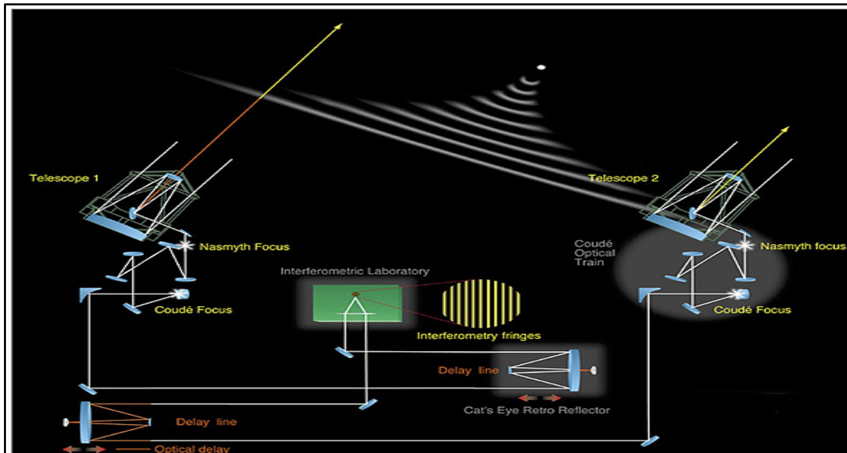
Rodolfo Angeloni
May 2007 - SNA

VLTI/MIDI Observations of HD330036

M. D'Onofrio, P. Rafanelli, R. Angeloni, M. Contini, S. Ligori, S. Ciroi, M. Orio

The VLT Array on the Paranal Mountain

ESO PR Photo 14a/00 (24 May 2000)

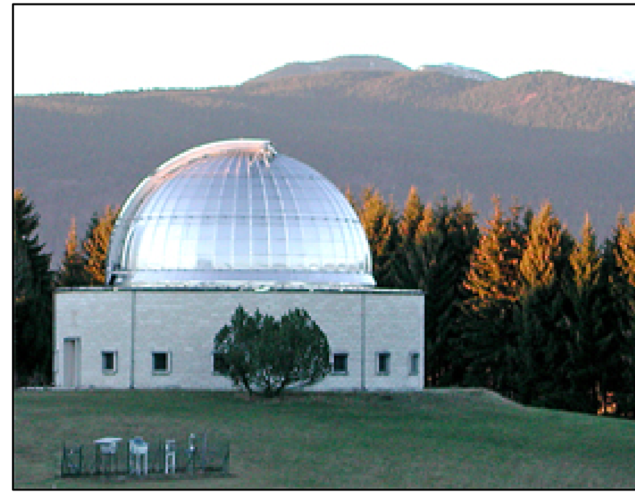


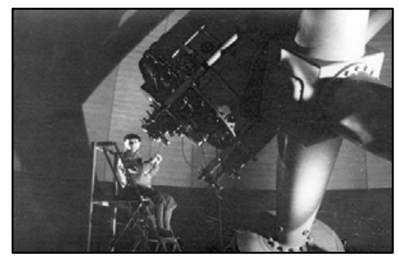
Overview of the VLT Interferometer

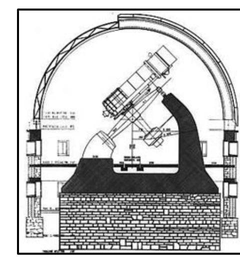
ESO PR Photo 10c/01 (18 March 2001)

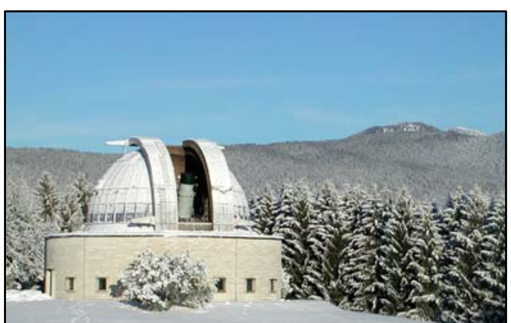
AMOS

Asiago Monitoring Of (suspected) Symbiotics









"Galileo" – 122cm telescope

http://dipastro.pd.astro.it/inglese/observatory/telescopio_en.html

http://dipastro.pd.astro.it/inglese/observatory/osservatorio_en.html

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