

Late stages of Stellar Evolution

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December 13, 2006, "ISO Legacy Colloquium", ESAC

Introduction

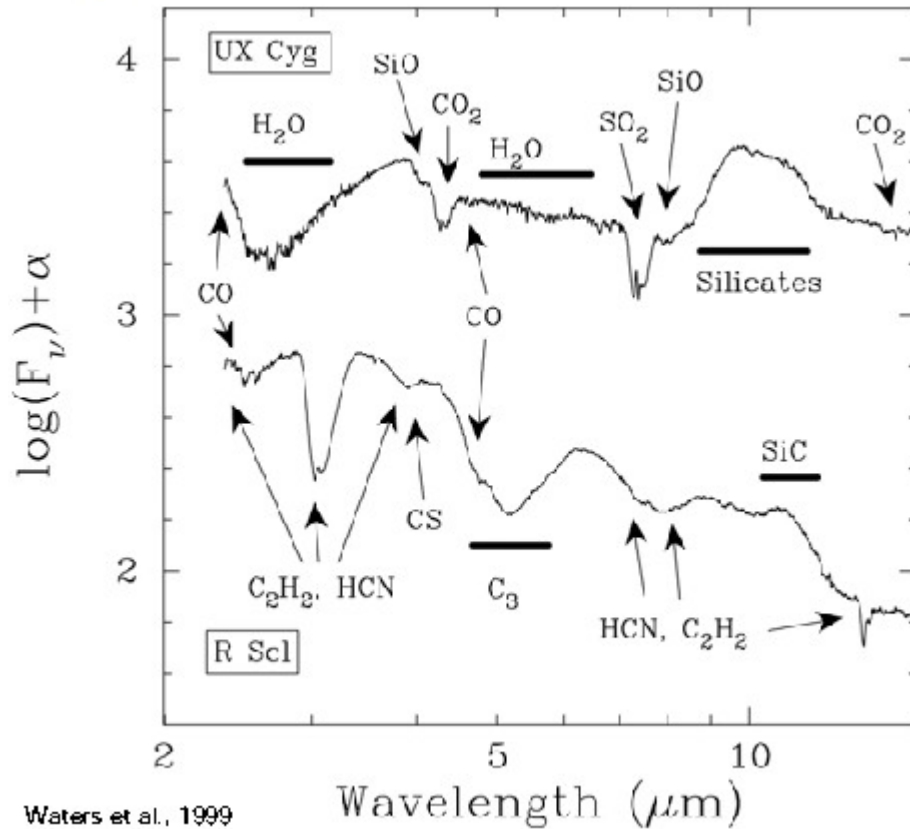
ISO has been tremendously important for evolved stars

- IRAS discovered many evolved stars with circumstellar shells

But ISO provided the higher sensitivity and spatial resolution to study stars in the inner regions of the Galaxy and in the MCs

- ISO's spectroscopy in the 2-200 μ m range allowed studies of molecular bands, dust features ...
- ISO observations of (post-) AGB, PNe

Asymptotic Giant Branch - Molecules

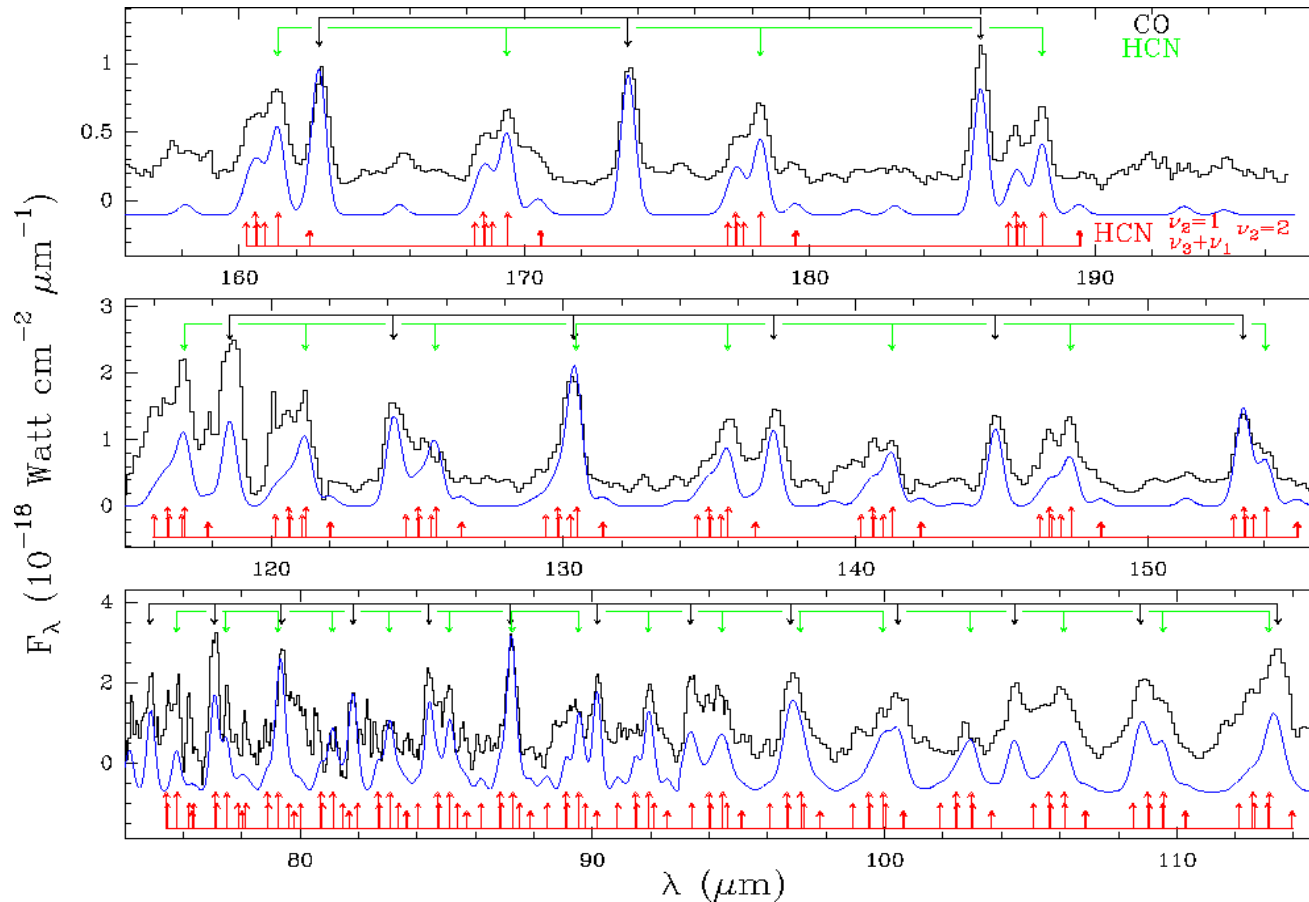


Waters et al., 1999

- Molecules in the stellar atmospheres...
- ... and beyond: in the extended atmosphere

Asymptotic Giant Branch - Molecules

- LWS spectrum of IRC+10216 (Cernicharo, et al. 1996)

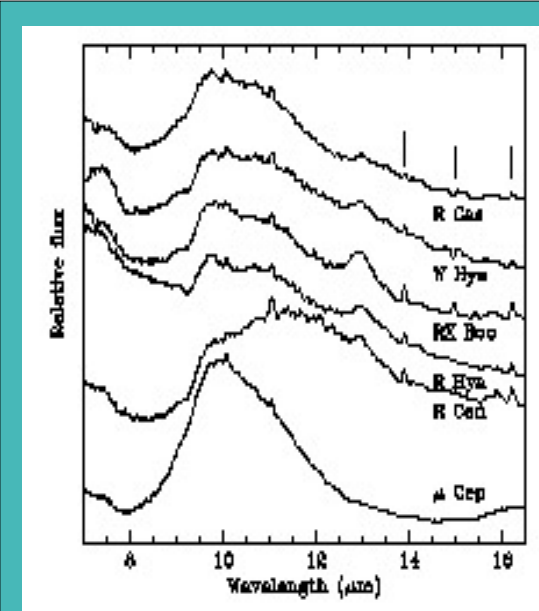


Asymptotic Giant Branch - Molecules

The extended atmosphere:

- CO and SiO absorption weaker than expected in early M giants
- Water vapour and CO₂ stronger than expected
- 750-1250K excitation temperature needed (Tsuji et al. 1997)

Many more molecular bands from the extended atmosphere were discovered (e.g. Cami et al. 2000)



CO₂ emission lines
<=> 13 μm feature
(Justtanont et al. 1998)

Asymptotic Giant Branch - dust

Many different dust species:

O-rich stars

- Oxides like Al_2O_3 ($11\mu\text{m}$) and MgFeO ($19.5\mu\text{m}$)

- $13\mu\text{m}$ feature, but of still unclear origin

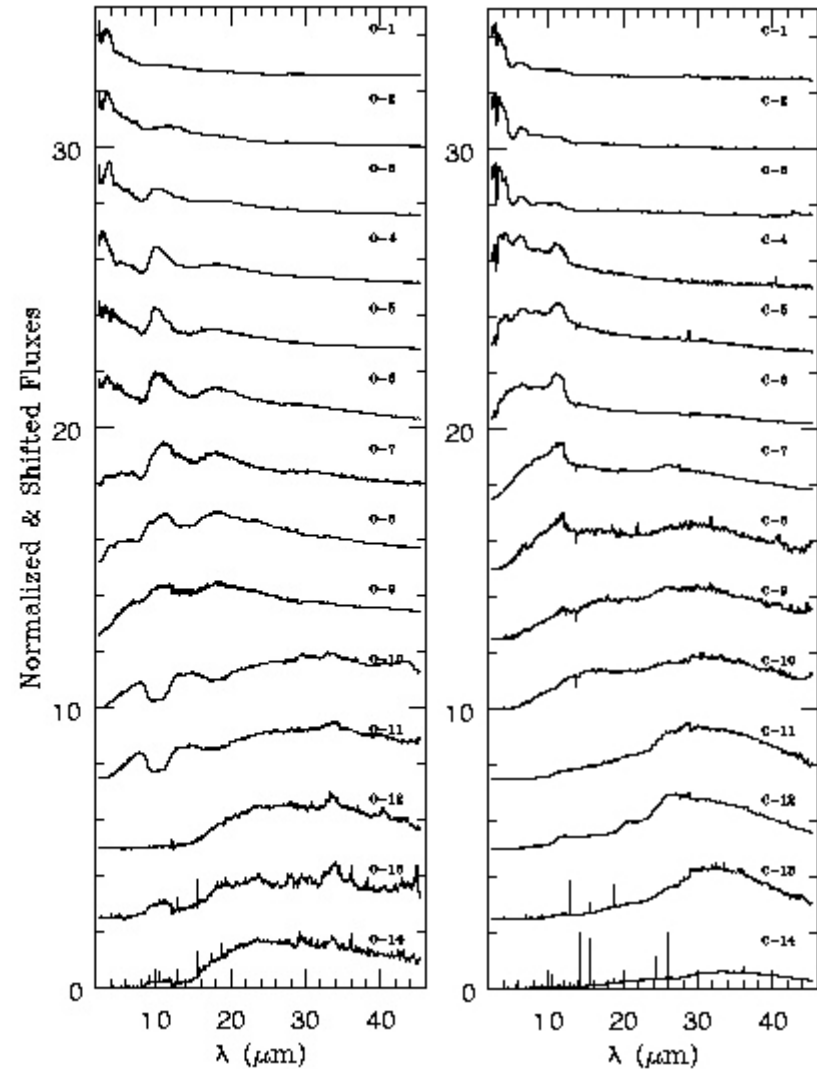
- amorphous / cristalline silicates

C-rich stars:

- amorphous carbon

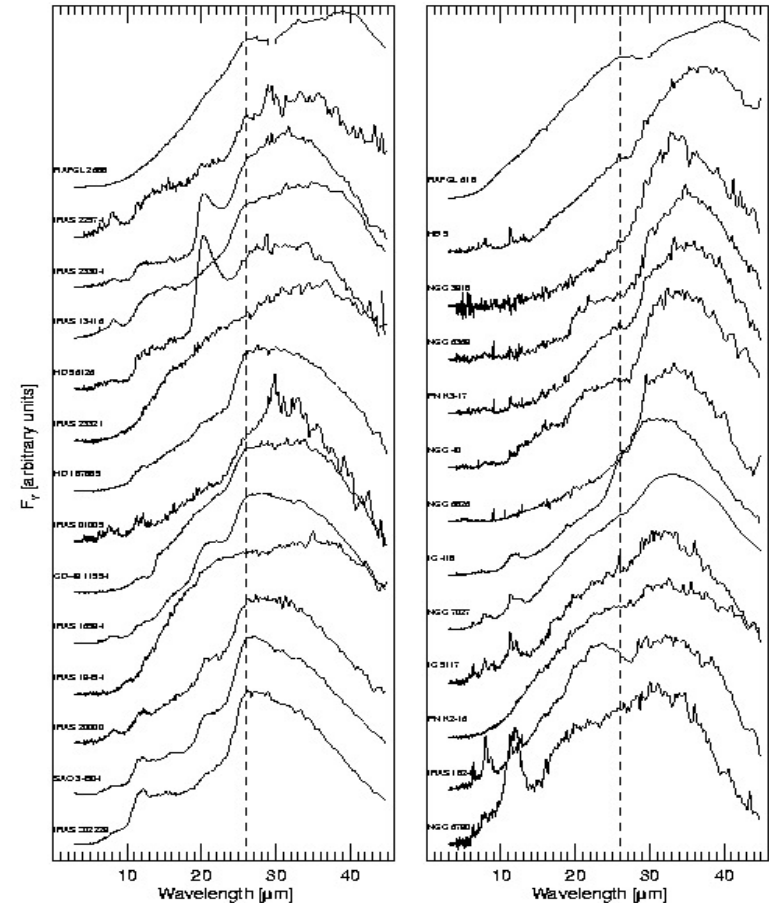
- SiC: $11.3\mu\text{m}$

- $30\mu\text{m}$: MgS

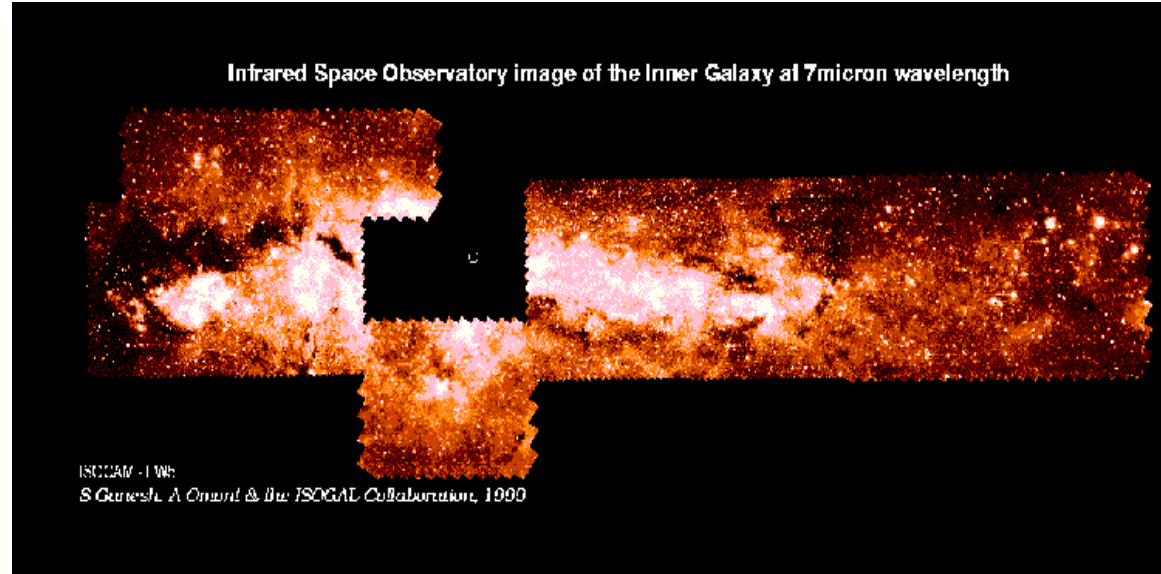
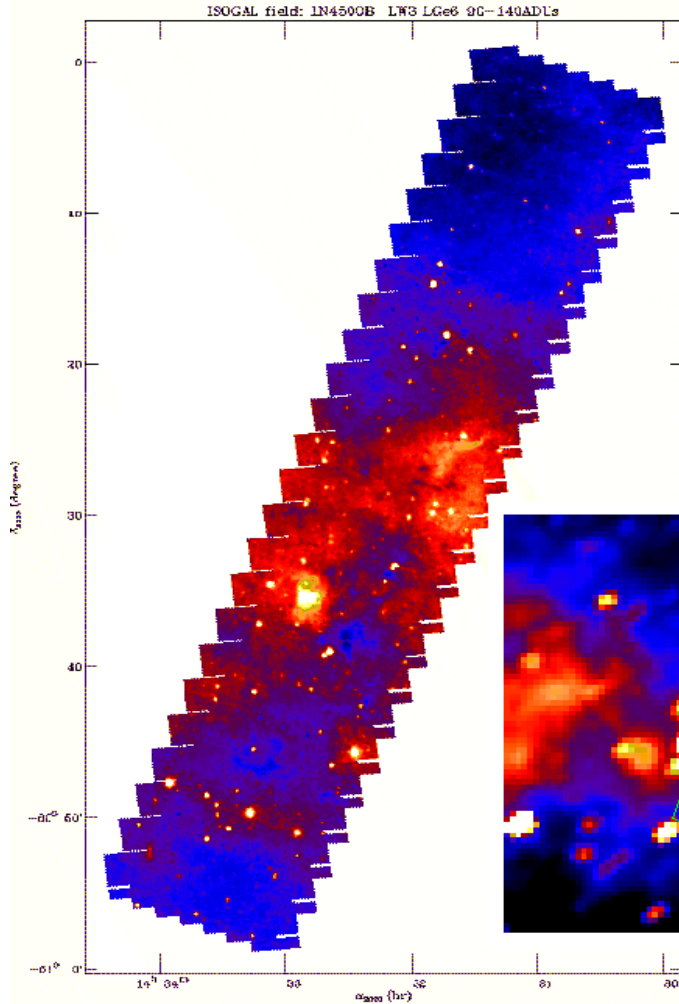


Asymptotic Giant Branch - Dust

- Identification of the $30\mu\text{m}$ feature in carbon-rich AGB, post-AGB and PNe: MgS
The variation in peak position \sim grain temperature
(Honey et al. 2002)
- Also useful in studying detached shells (Hony & Bouwman 2004).



ISOGAL survey

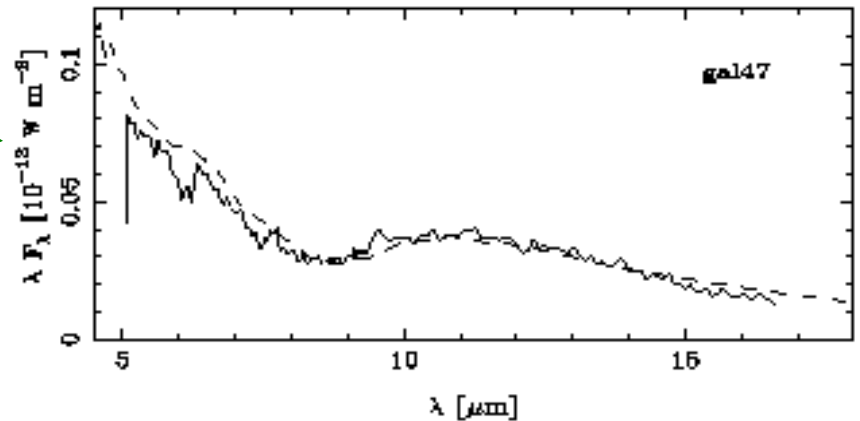
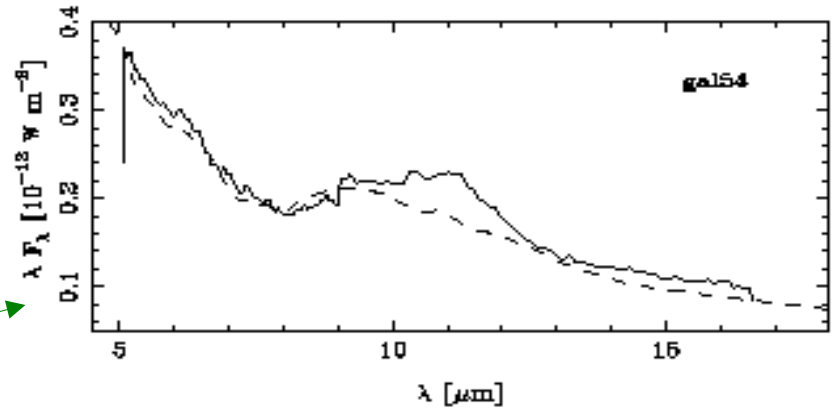
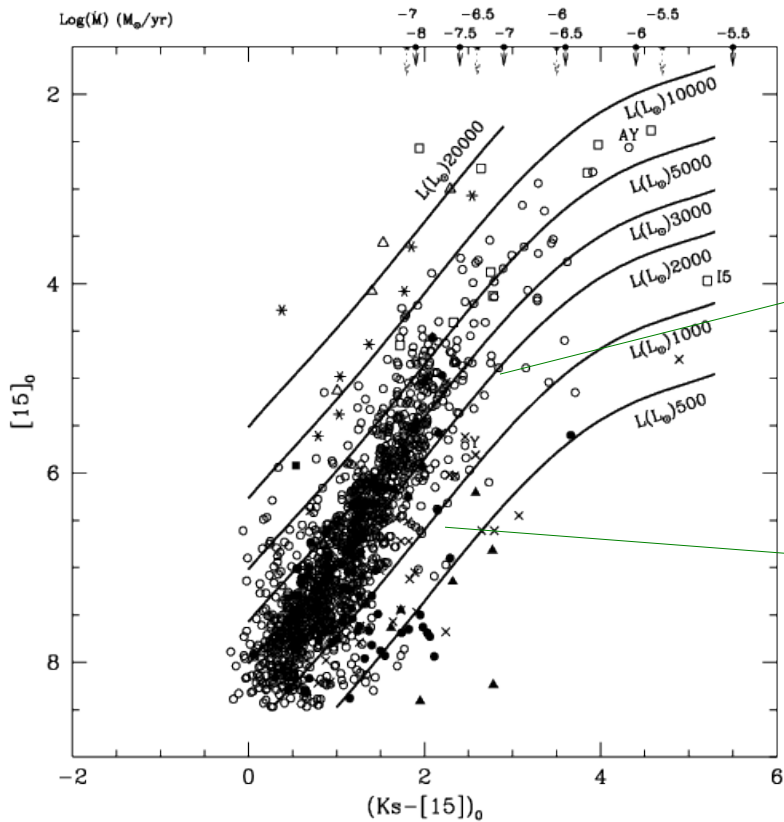


- I J K_s [7] & [15] catalogue (Omont et al. 2003)

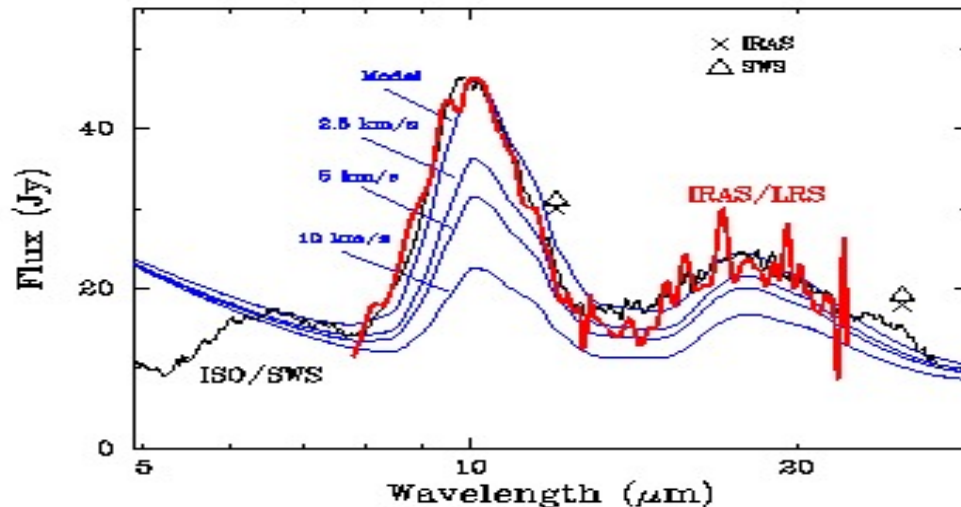
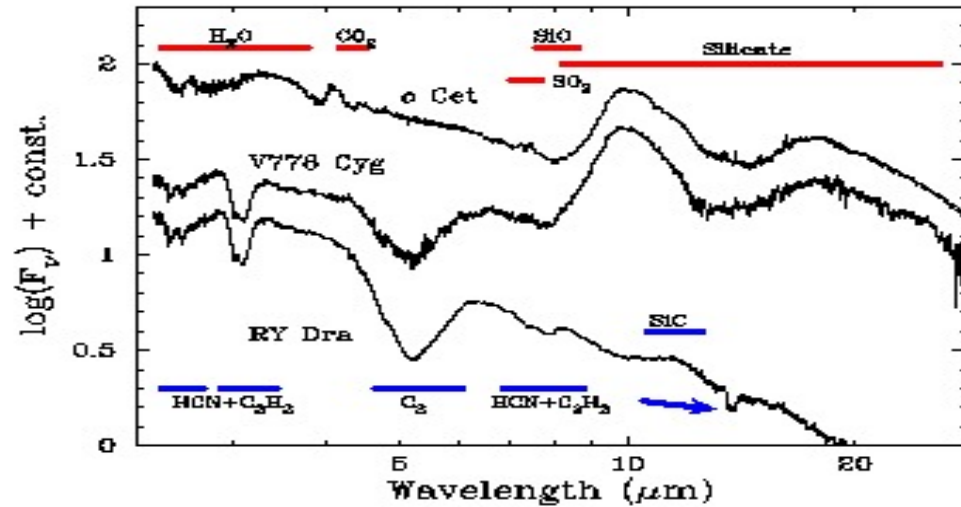
Asymptotic Giant Branch in the Bulge

Ojha et al. 2003

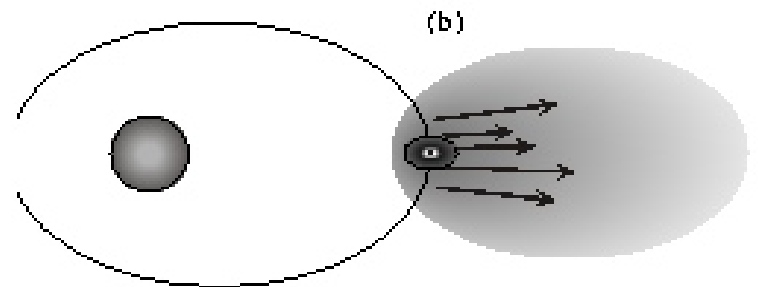
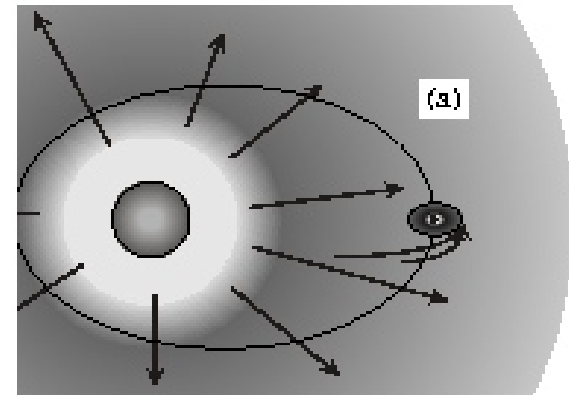
ISOCAM – CVF
(Blommaert et al. 2006)



AGB – Mixed Chemistry



Yamamura et al. (2000)

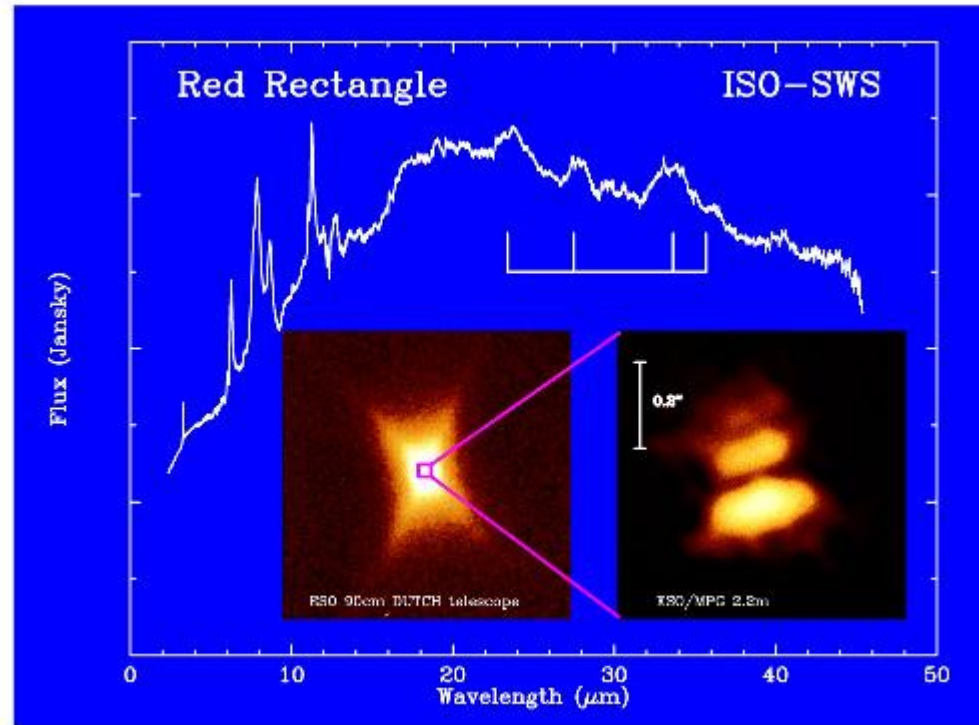
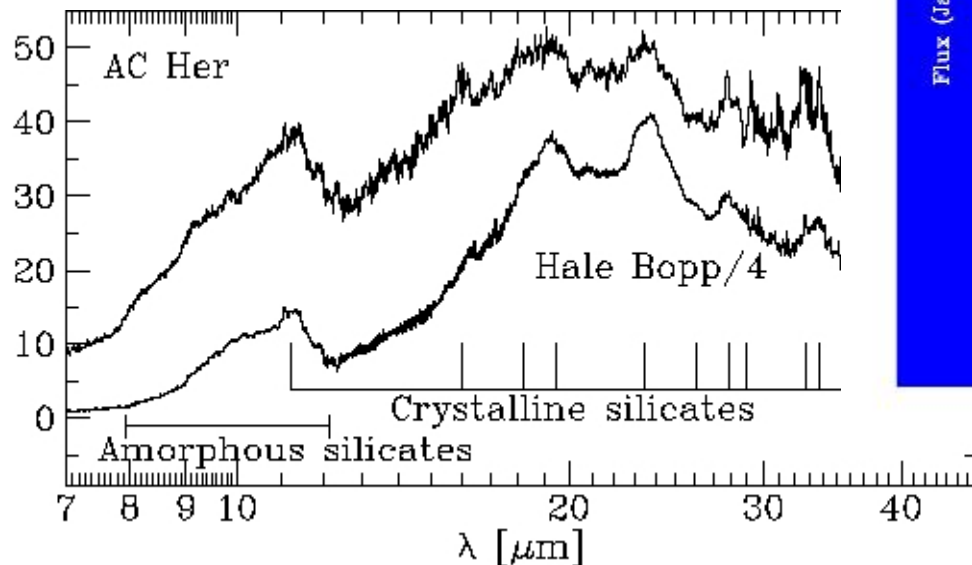


Post-AGB – binary stars

Crystalline silicates in a disk

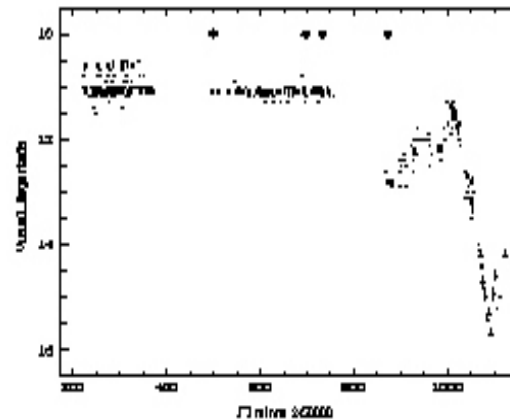
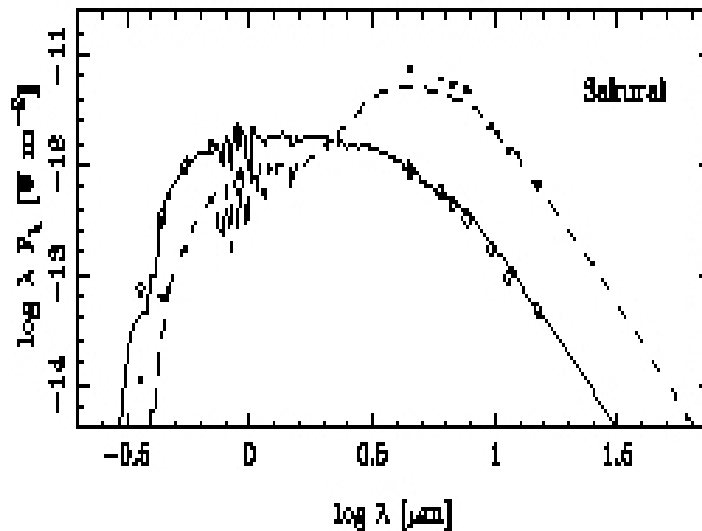
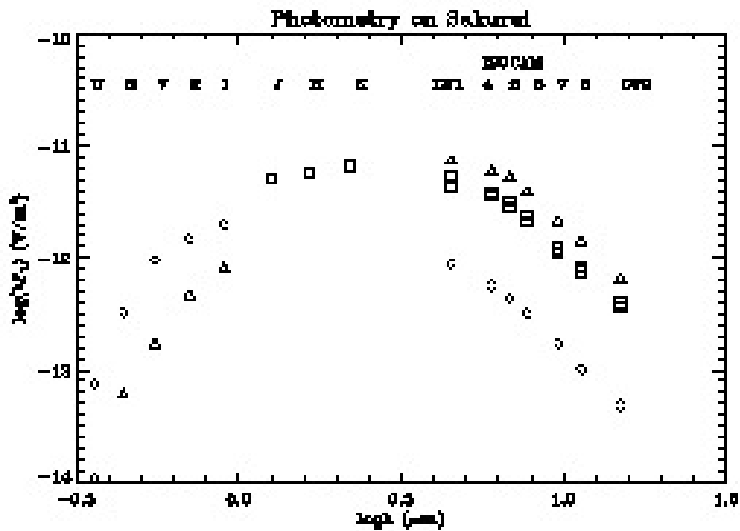
Waters et al. 1998

Molster et al. 1999



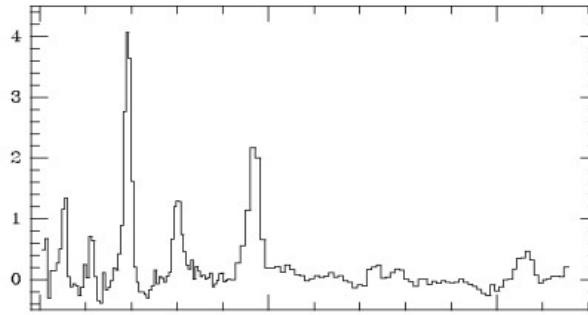
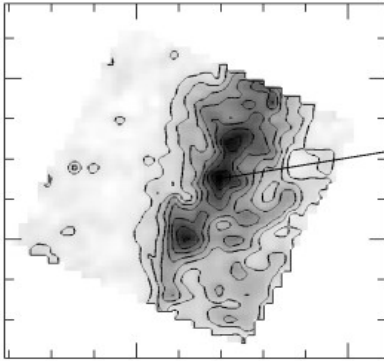
Sakurai's object

- Thermal Pulse after the AGB
- ISO monitoring project shows the presence of hot circumstellar dust (Kerber et al. 1999)

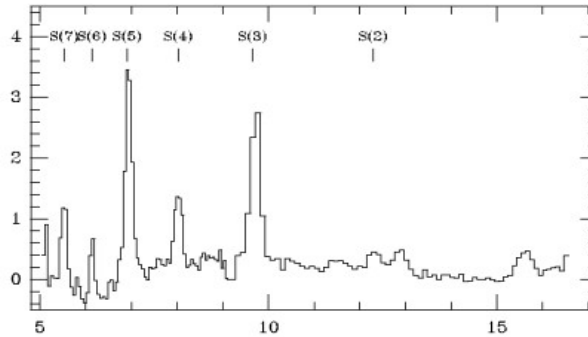
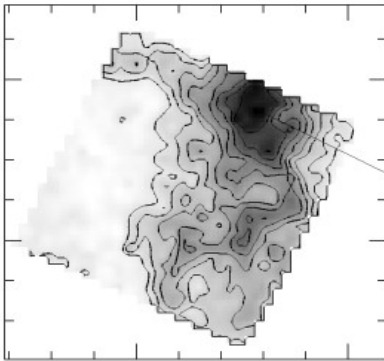


Planetary Nebulae

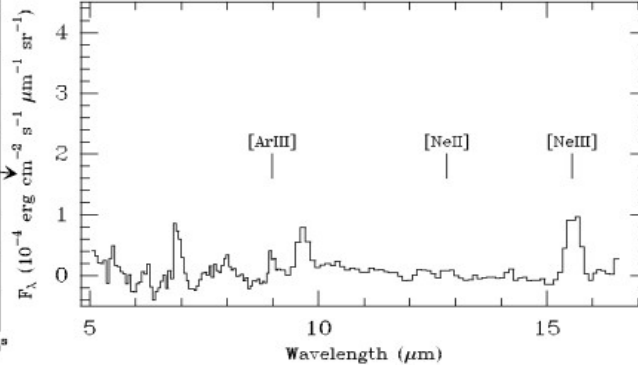
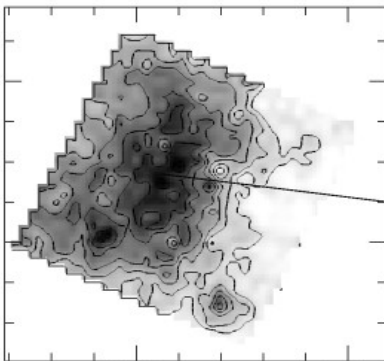
H₂ S(5) 8.91 μm



H₂ S(3) 9.66 μm



Ne[III] 15.55 μm



ISOCAM spectroscopic
imaging of the Helix
Nebula
(Cox et al. 1998)

