

# Interstellar PAHs

- PAHs are everywhere
- PAH Identification
- PAHs in Star Forming Regions

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SWS PIs: Pierre Cox, Pjotr Roelfsema, Christoffel Waelkens, Rens Waters, Paul Wesselius.

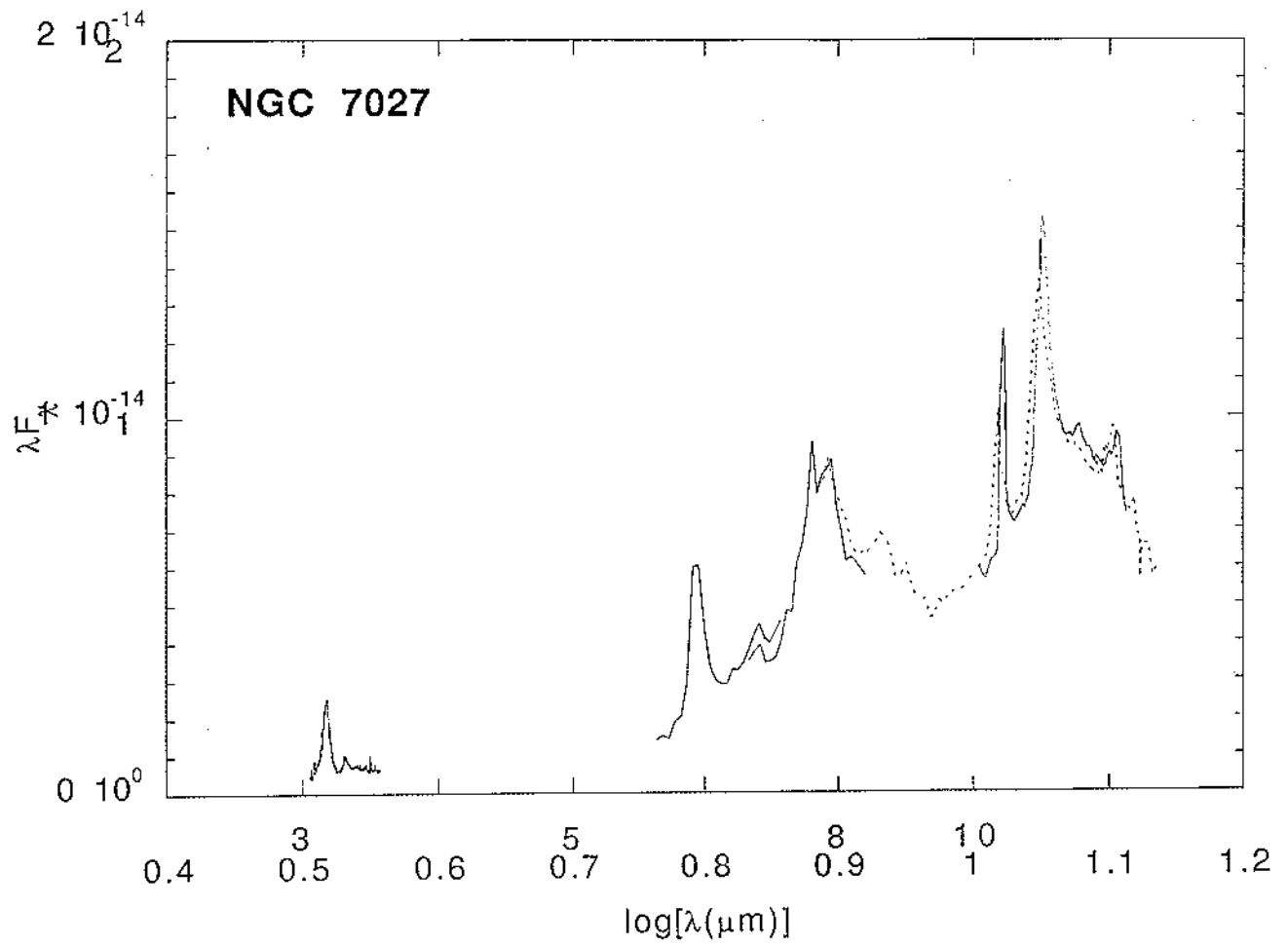
ISOCAM PIs: Christine Joblin

Laboratory: Max Bernstein, Doug Hudgins, Lou Allamandola

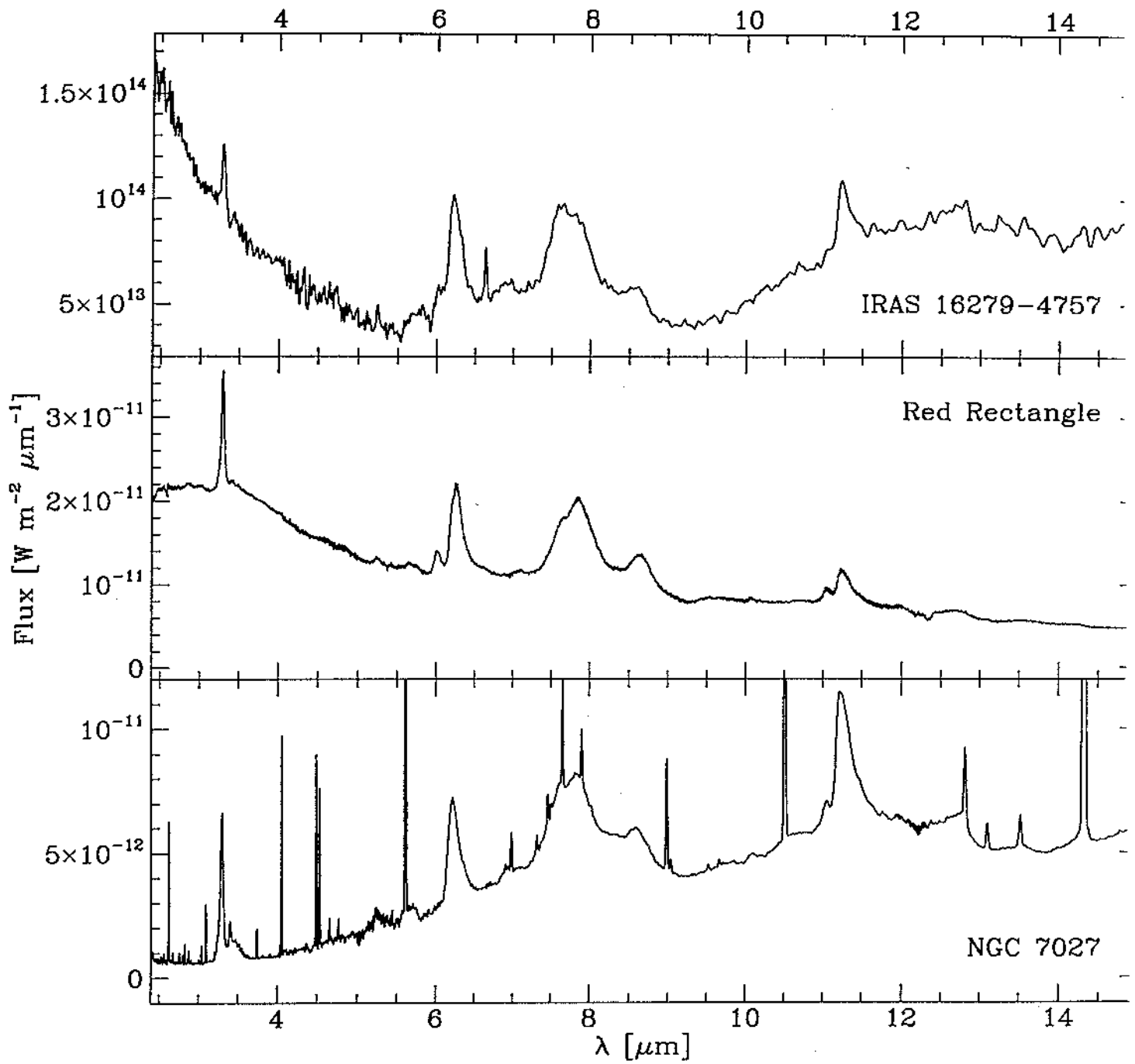
Modeling: Emma Bakes

Collaborators: Jean Chiar, Willem Schutte

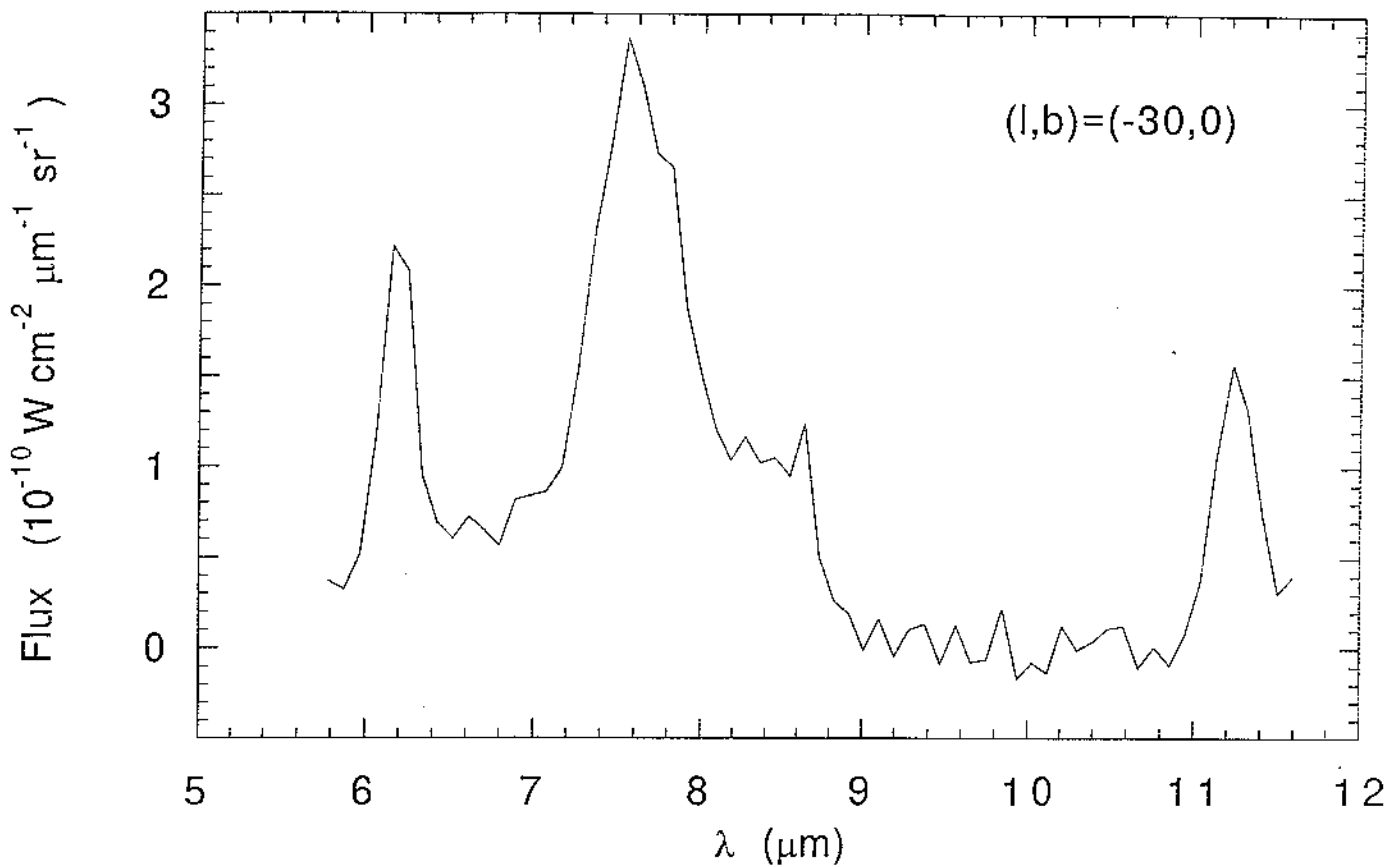
# The UIR bands: The early days



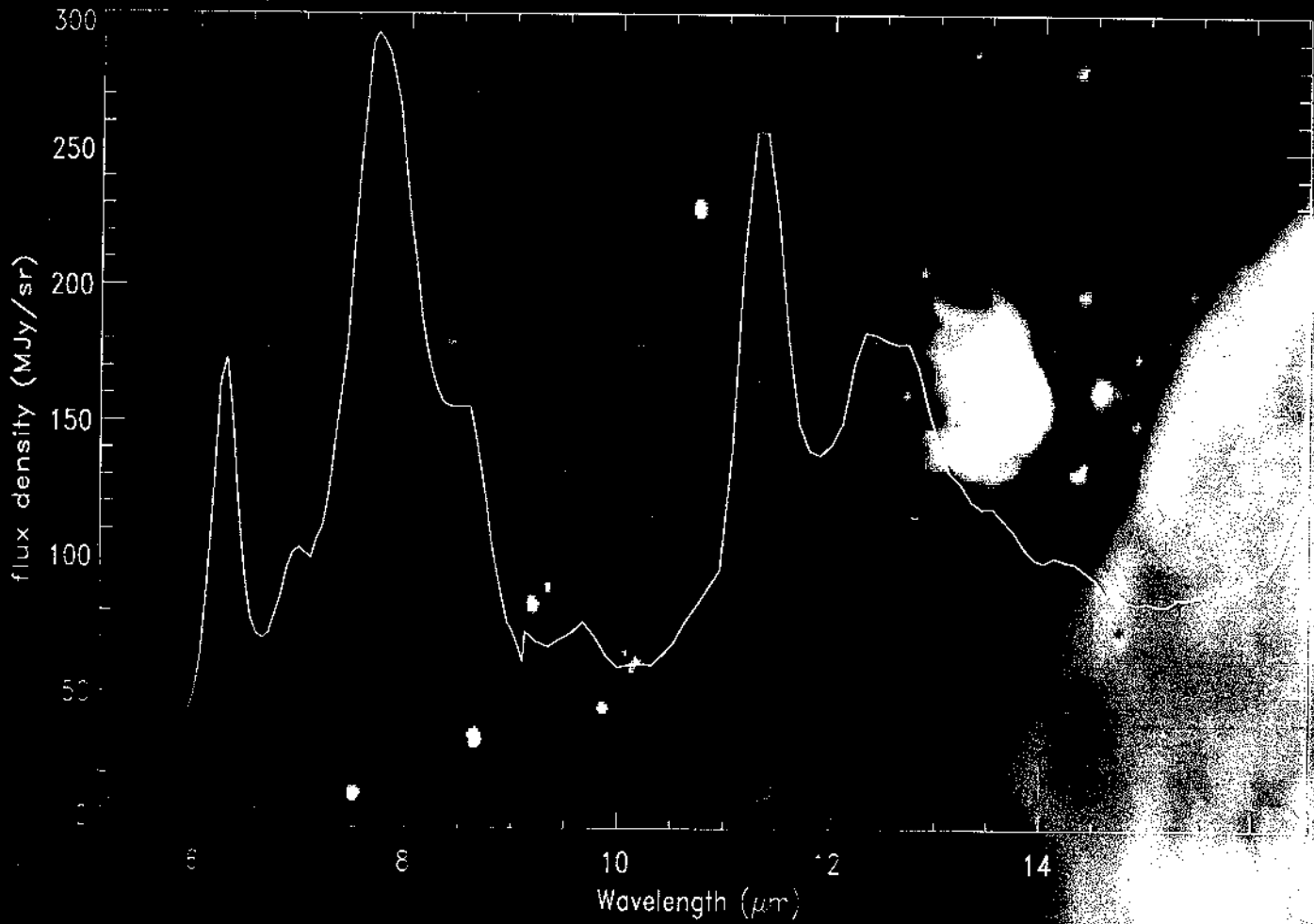
Gillett et al. 1973, ApJ, 183, 87  
Russell et al. 1977, ApJ, 217, L149  
Cohen et al. 1986, ApJ, 302, 737



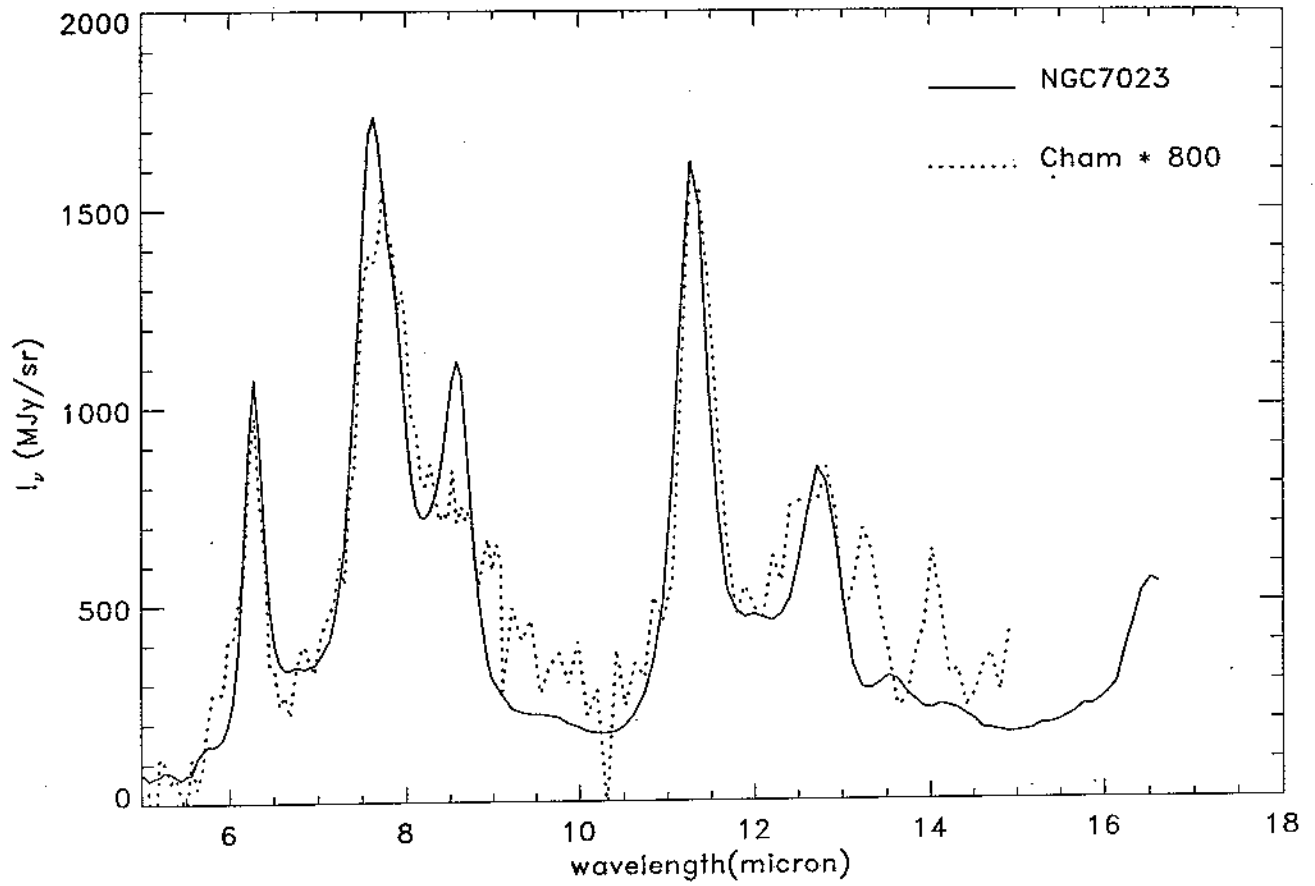
# The mid-IR Cirrus



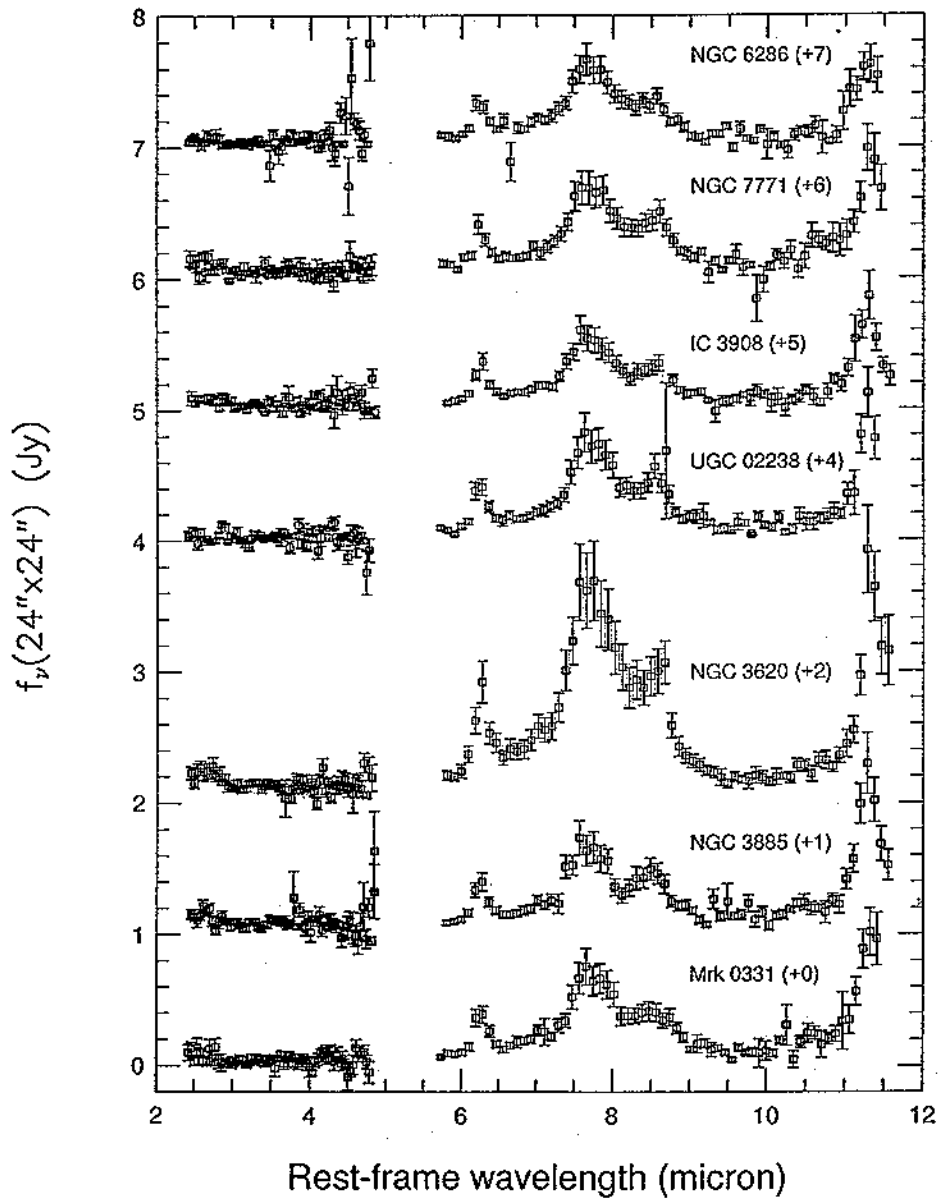
Mattila et al. 1996, A & A, 315, L353

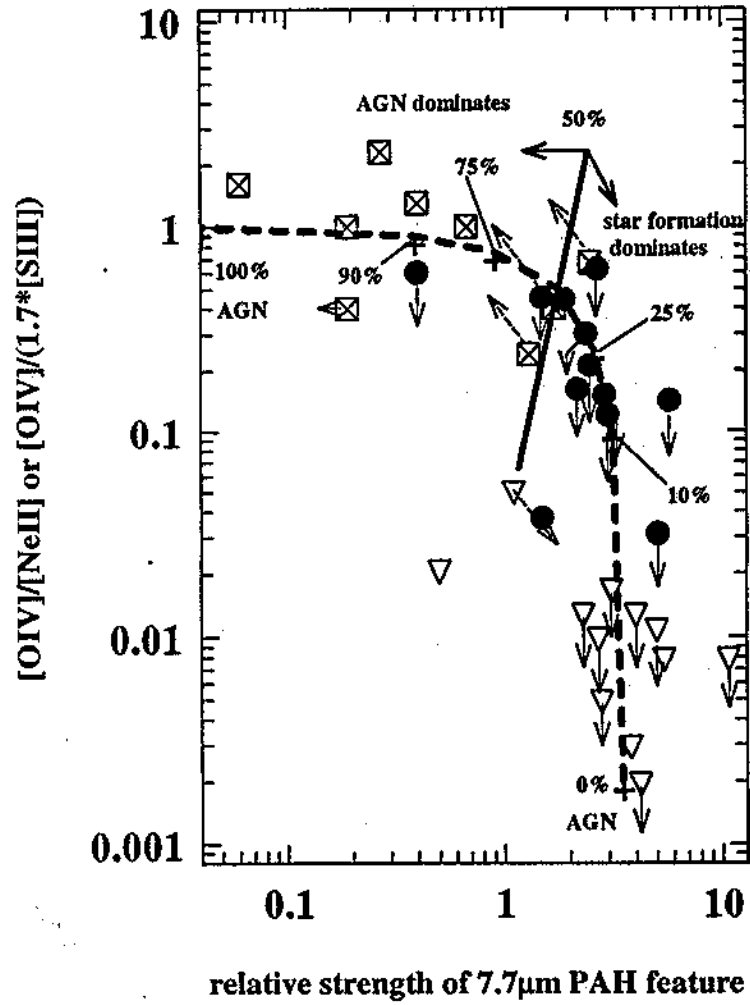
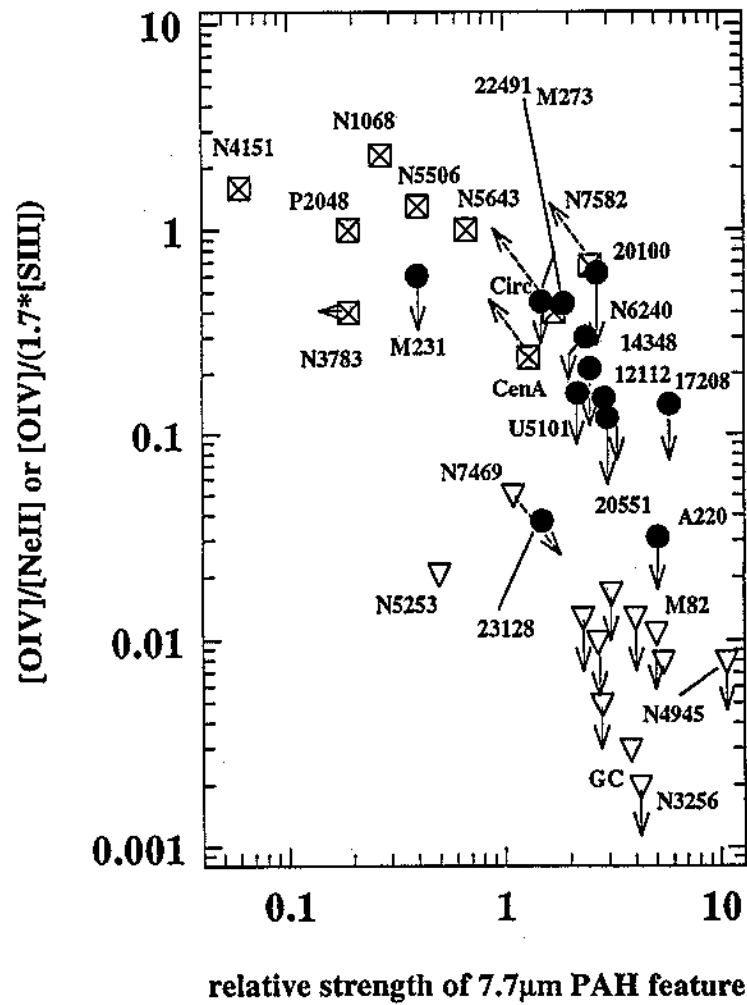


Dark cloud & reflection nebula



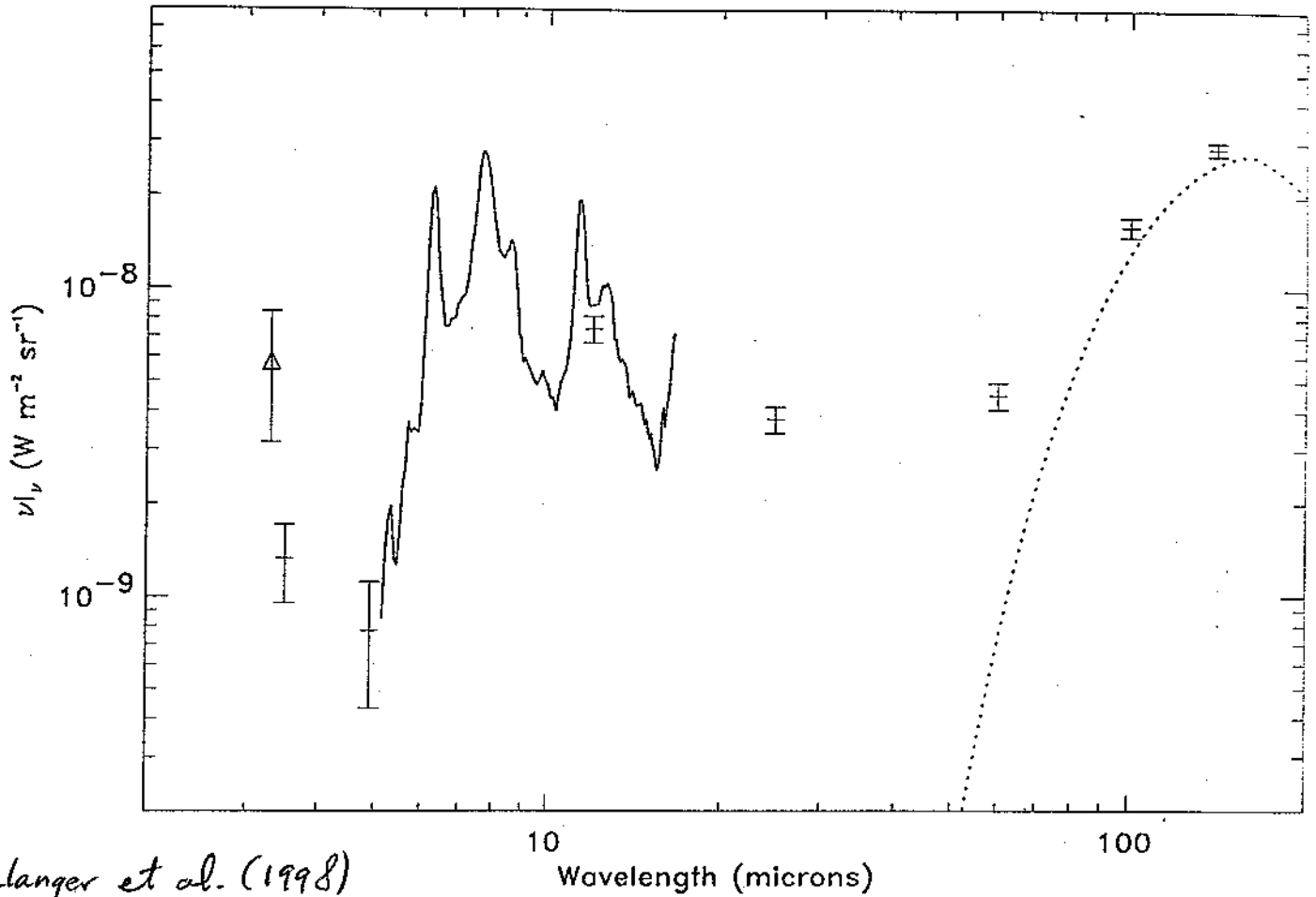
# The ISM in galaxies





Genzel et al. '99

## Molecular sized PAHs and the UIR bands



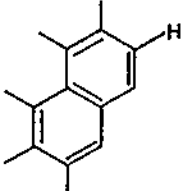
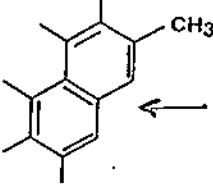
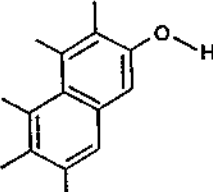
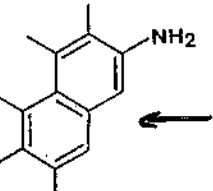
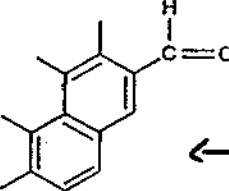
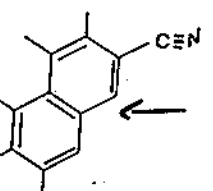
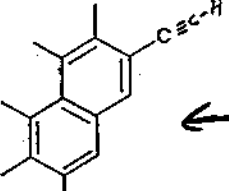
After Sellgren (1984), *ApJ*, 277, 623

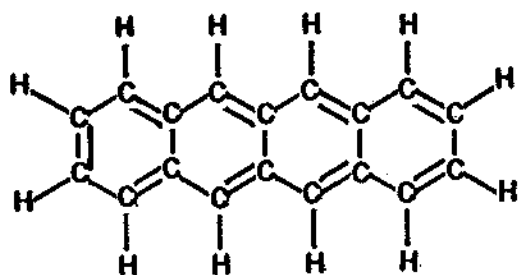
Observed Color Temperature:  $T_c \approx 650 \text{ K}$

Radiative Temperature:  $T_d = 15 [3000\text{\AA}/a]^{0.2} \text{ K}$

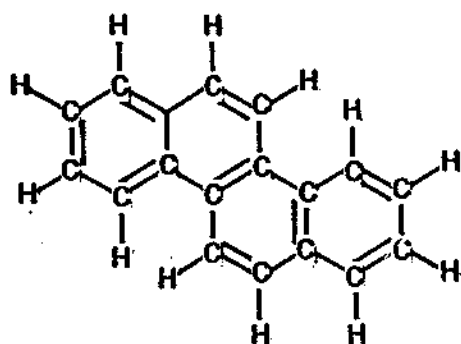
Single Photon Temperature:  $T_p = 1500 [E_{\text{uv}}(\text{eV})/N_c]^{0.47} \text{ K}$

# The overwhelming aromatic nature of the UIR bands

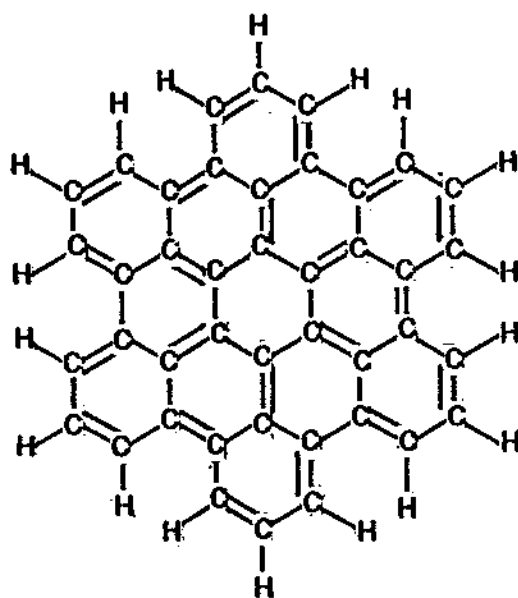
	Functional group	$\lambda$ ( $\mu\text{m}$ )	fraction
 <p>HYDROGEN</p>	aromatic H	3.3	1
 <p>METHYL</p>	aliphatic H	3.40	0.02
 <p>HYDROXYL</p>	OH	2.77	<0.002
 <p>AMINE</p>	NH <sub>2</sub>	2.88-2.95	<0.01
 <p>ALDEHYDIC</p>	HCO	5.9	0.006 (?)
 <p>C≡N</p>	nitrile	4.48	<0.01
 <p>C≡C-H</p>	acetylenic	3.03	<0.003



TETRACENE  $C_{18}H_{12}$

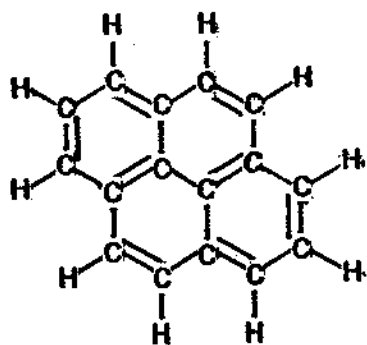


CHRYSENE  $C_{18}H_{12}$

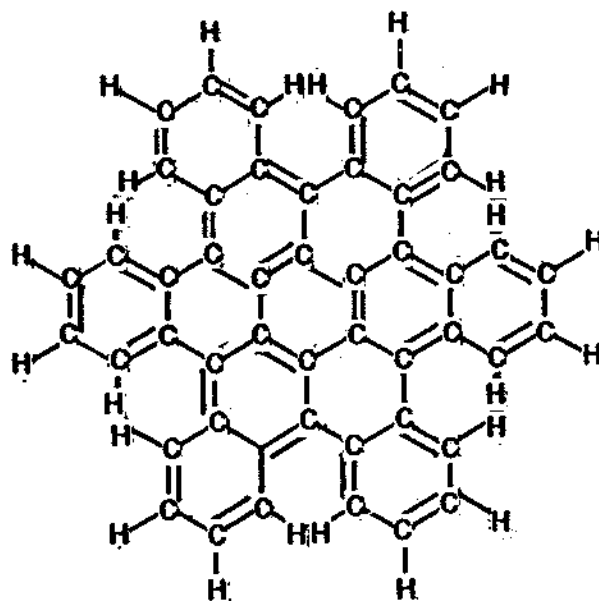


$C_{42}H_{18}$

HEXABENZOCORONENE A

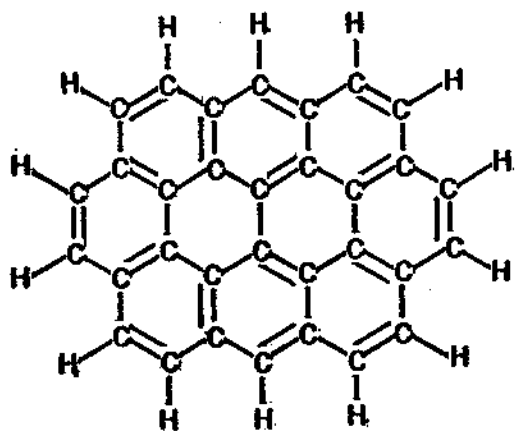


PYRENE  $C_{16}H_{10}$



HEXABENZOCORONENE B

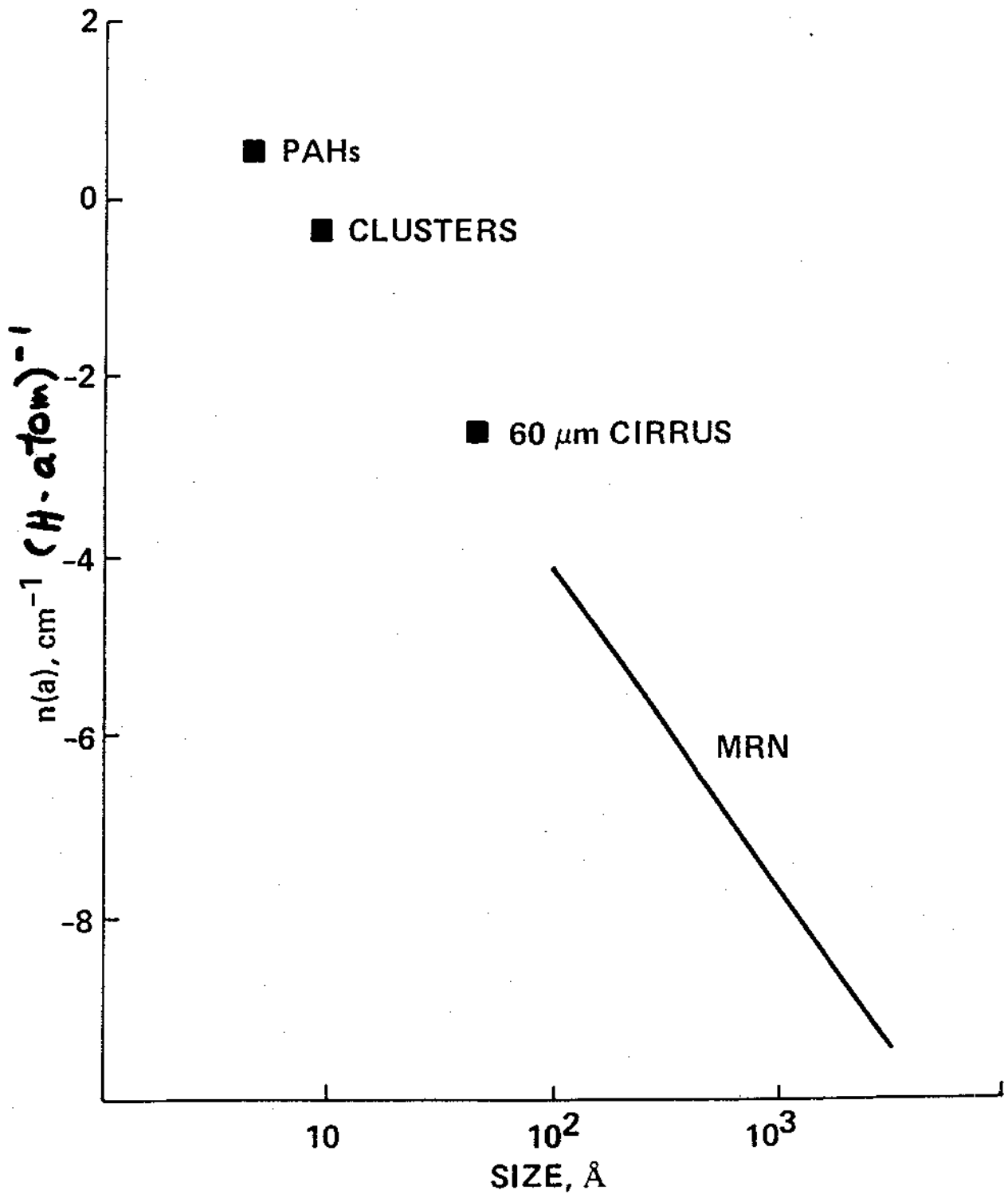
$C_{48}H_{24}$



OVALENE  $C_{32}H_{14}$

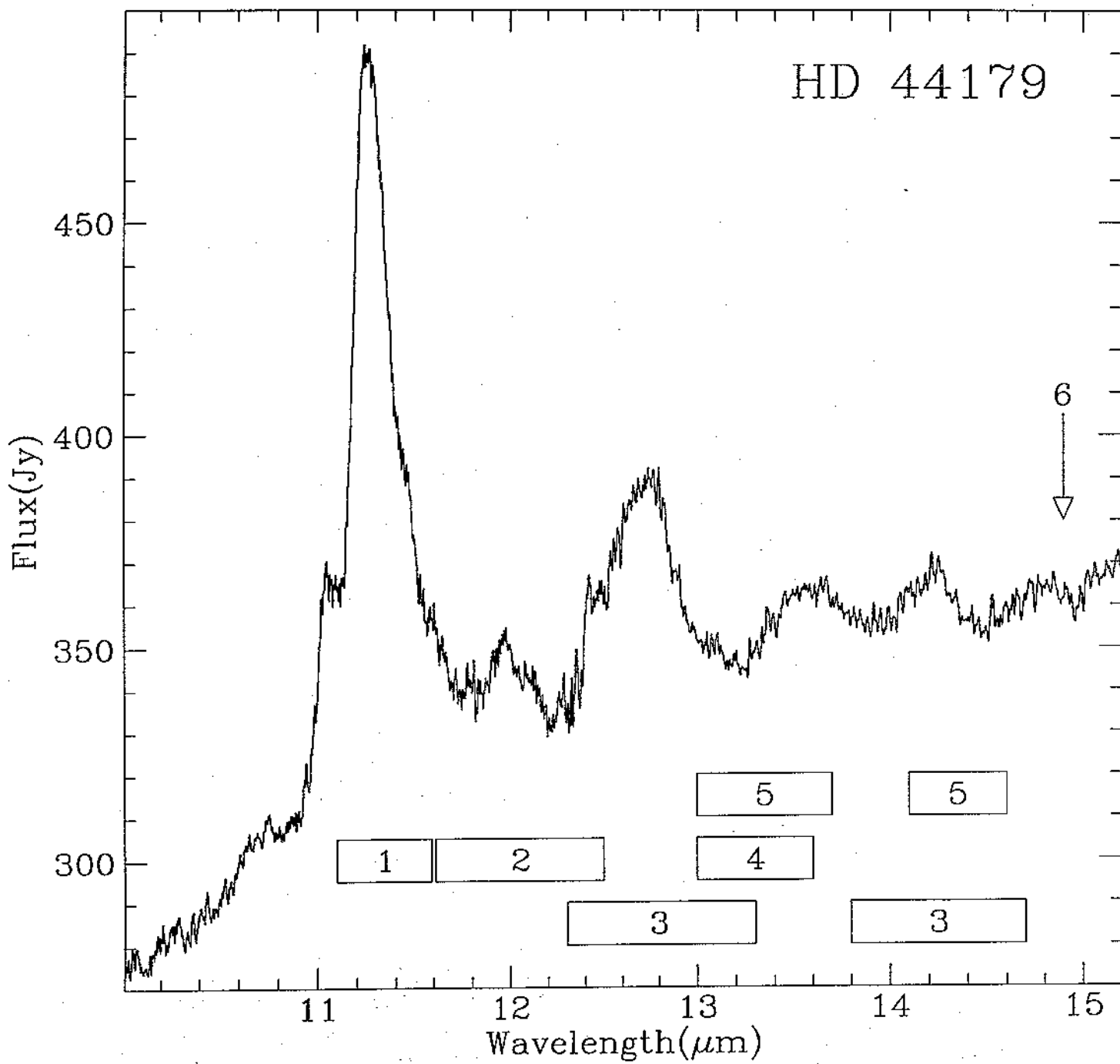
*Handwritten notes or signatures at the bottom right of the page.*

# THE INTERSTELLAR GRAIN SIZE DISTRIBUTION



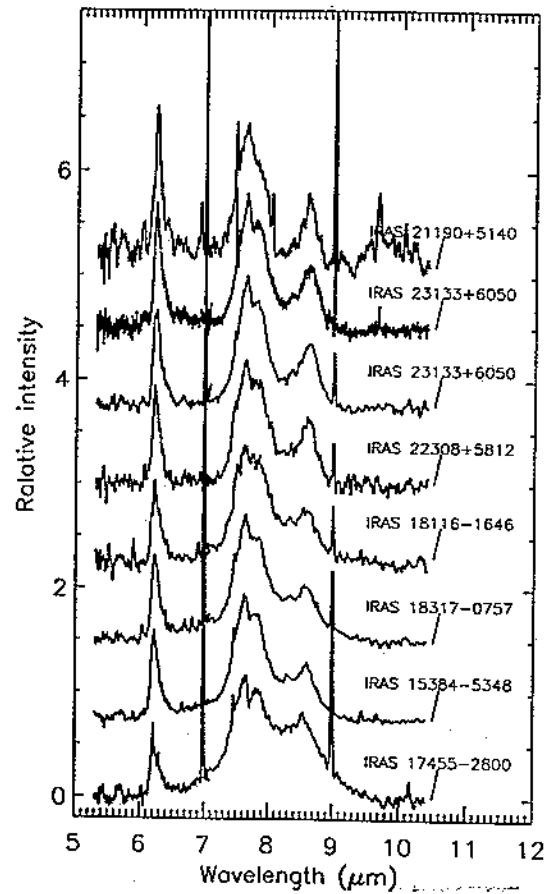
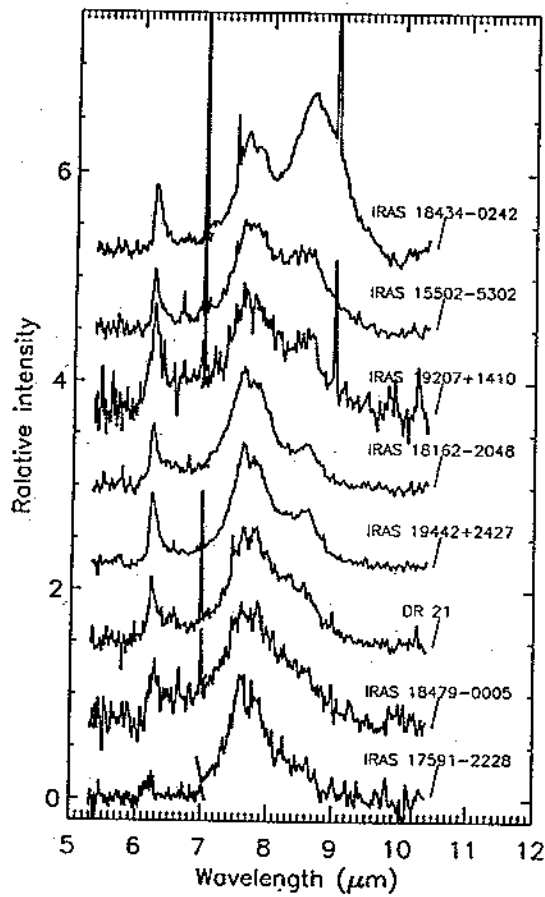
## **PAH Identification**

1. The 10-15  $\mu\text{m}$  CH out-of-plane bending modes
2. The 15-20  $\mu\text{m}$  in-plane and out-of-plane ring bending modes
3. Spectral variations
4. [Visible and UV electronic transitions]

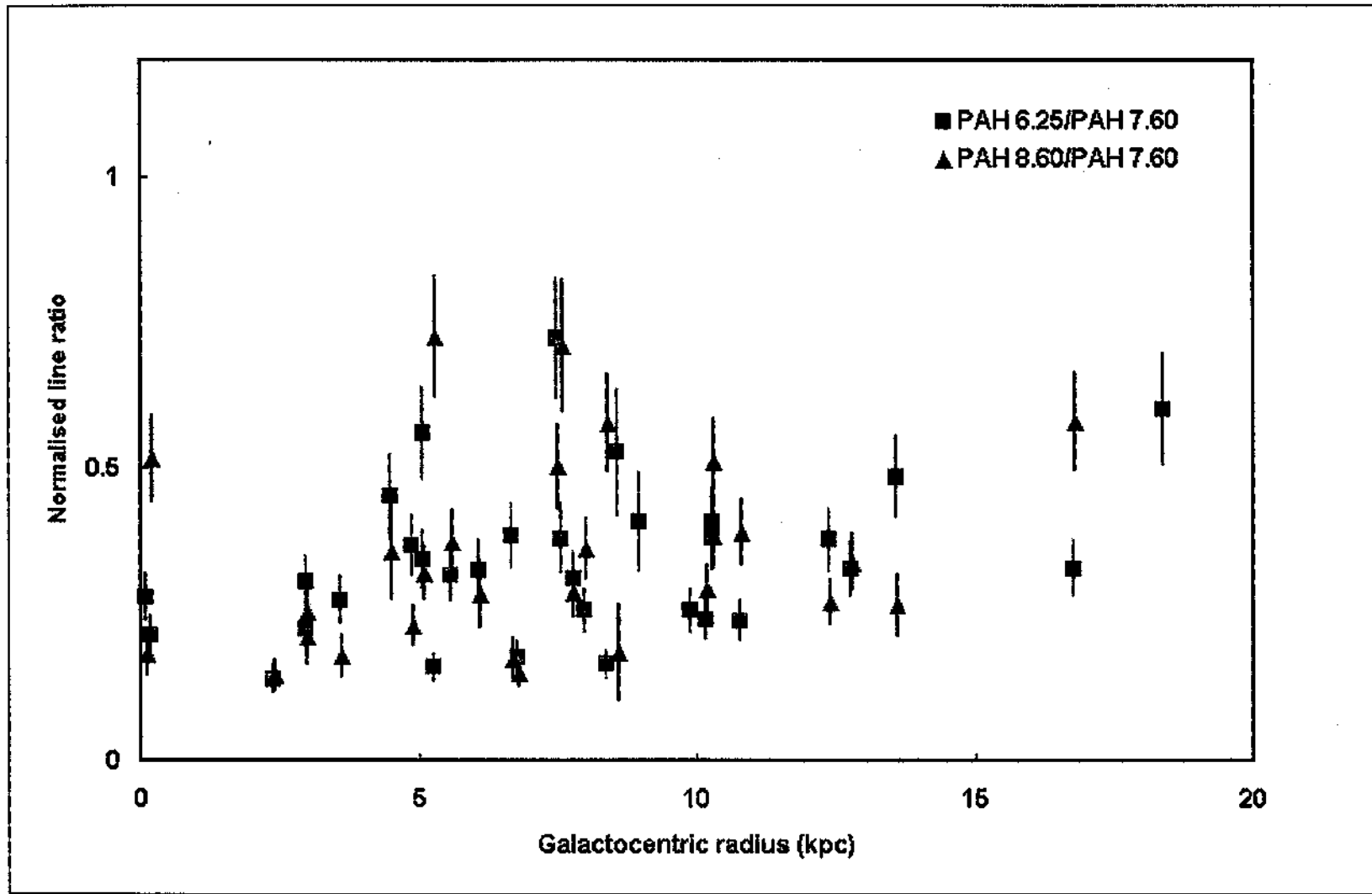


Hony et al '99

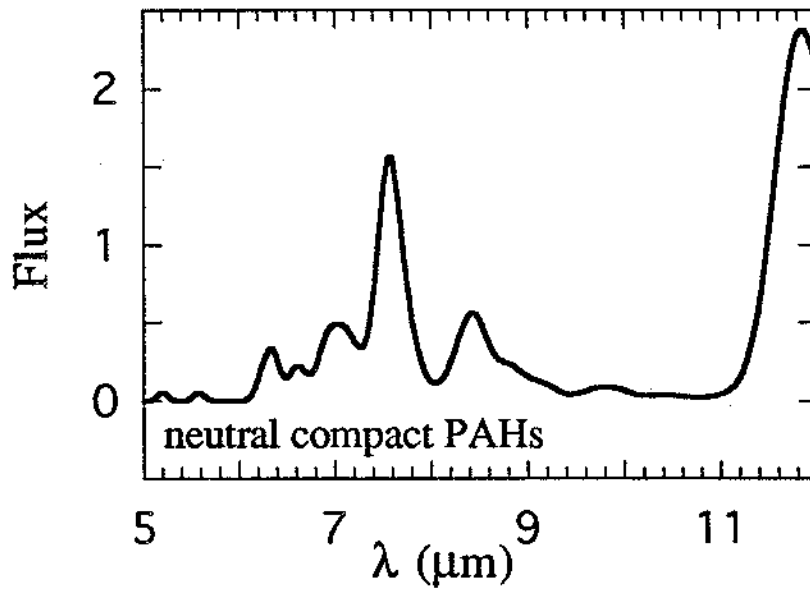
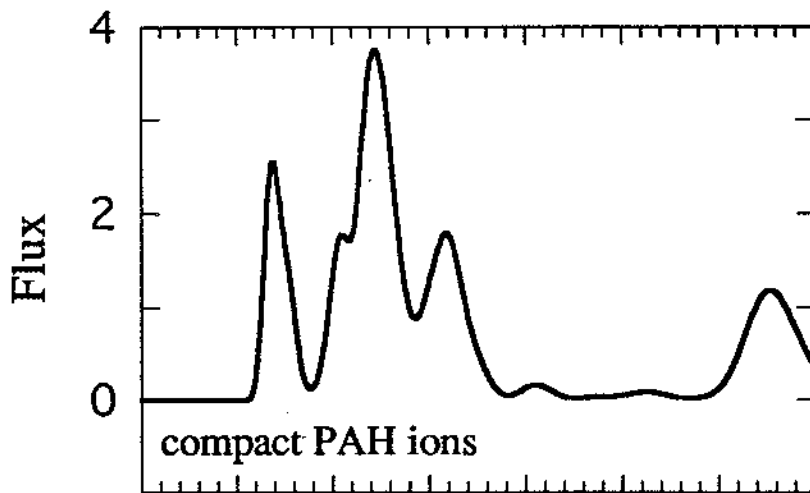
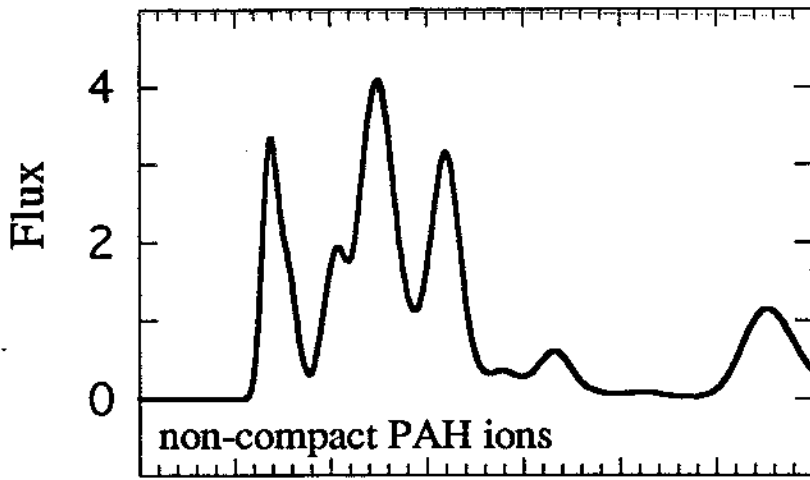
# PAH emission associated with compact HII regions



Roelfsema et al. 1996, A & A, 315, L289



Peter Roelfsema <pjotr@sron.rug.nl>  
SRON



Hudgins, Allamandola, Sandford

S106 7.7  $\mu\text{m}$  ISOCAM-cvf - Joblin et al.

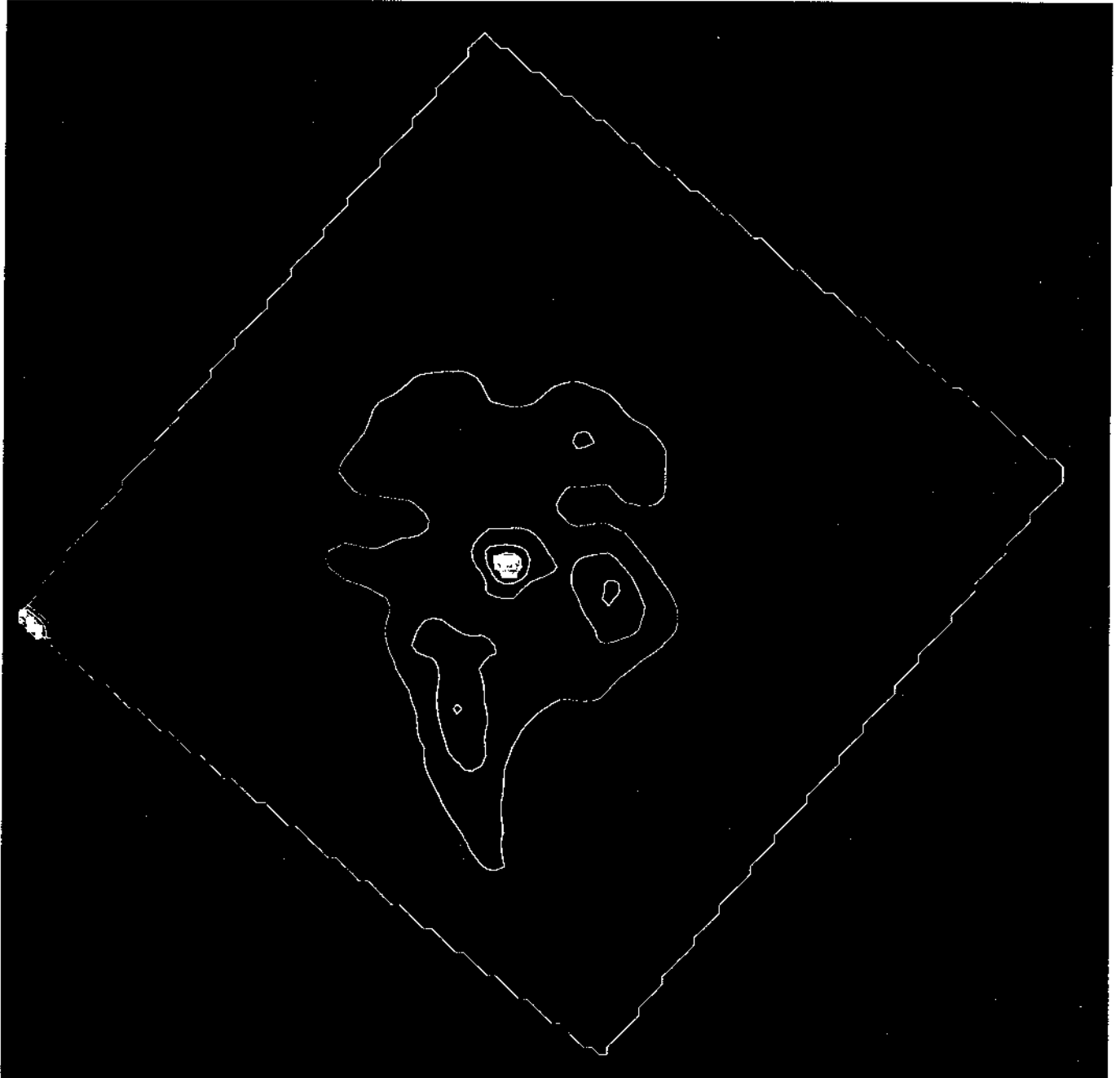
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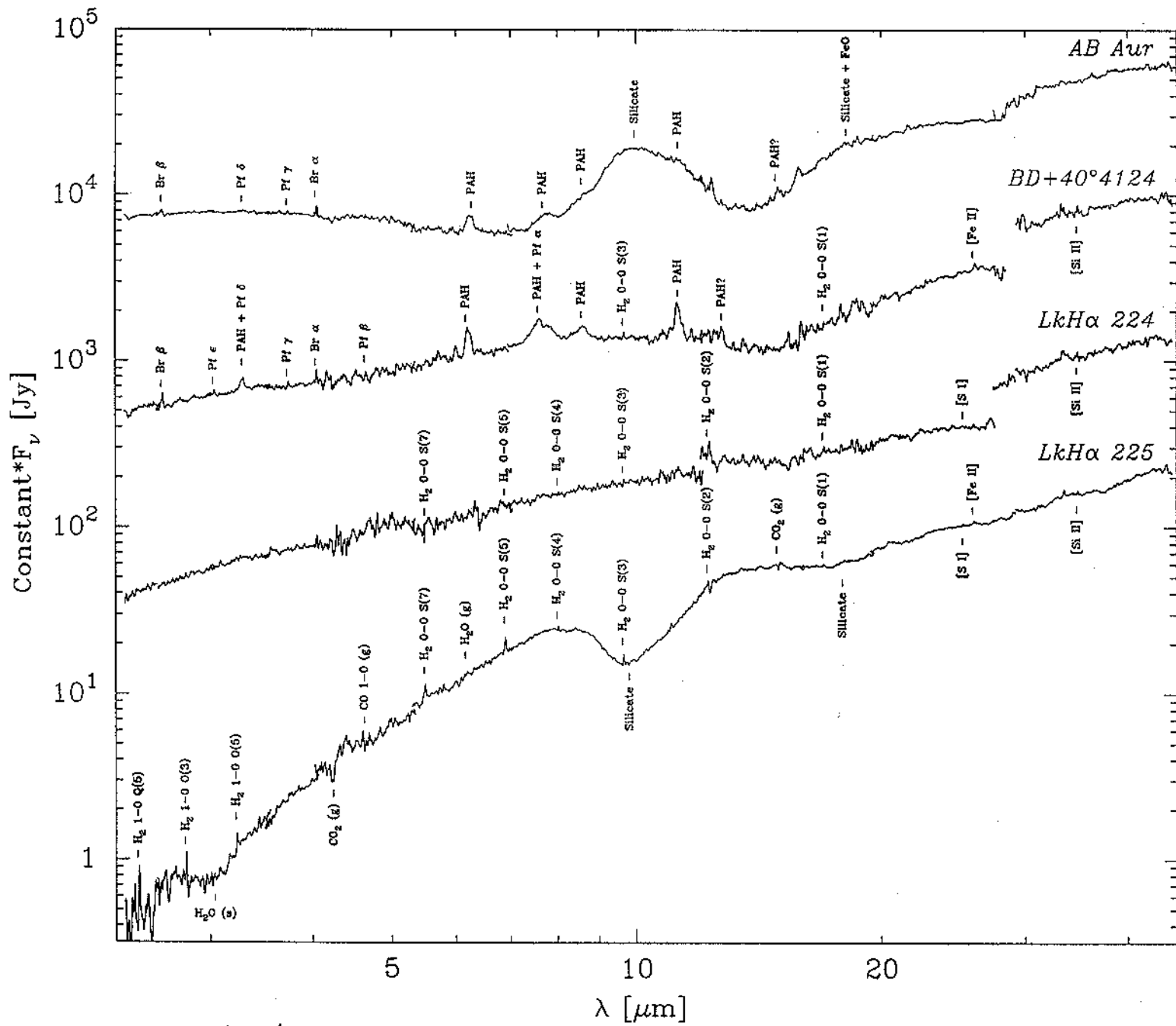
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20:27:31

20:27:26  
Ra (2000)



## **PAHs in Star Forming Regions**



Van Kerckhove et al. '99

## Summary

- 1) The UIR bands are observed in a wide variety of Sources:  
 Stars: Planetary Nebulae, post-AGB objects, Herbig AeBe stars.  
 ISM: HII regions, reflection nebulae, diffuse ISM  
 Galaxies: ISM of galaxies, Starburst regions, galactic nuclei
  
- 2) The UIR bands are carried by molecular sized PAHs (50 C atoms)

carrier	IR emission	$N_c$	a	f
			Å	ppm
PAHs	UIR bands	20-100	4-10	14
PAH-clusters	plateaus	100-1000	10-20	8
Very small grains	25 $\mu$ m cirrus	$10^3$ - $10^4$	20-30	7
small grains	60 $\mu$ m cirrus	$10^5$	50	16

- 3) There are few non-aromatic groups attached to these PAHs
  
- 4) Detailed spectral variations:
  - Family of related species
  - Photochemistry rules
  
- 5) SOFIA projects:
  - The Grand-PAH: Spectral variations within nebulae
  - PAHs and the star formation rate in galaxy
  - PAHs and the spectral evolution of class 0 --> III protostars
  - Absorption spectroscopy of PAHs