PAHs and H_2 in the Ring Nebula

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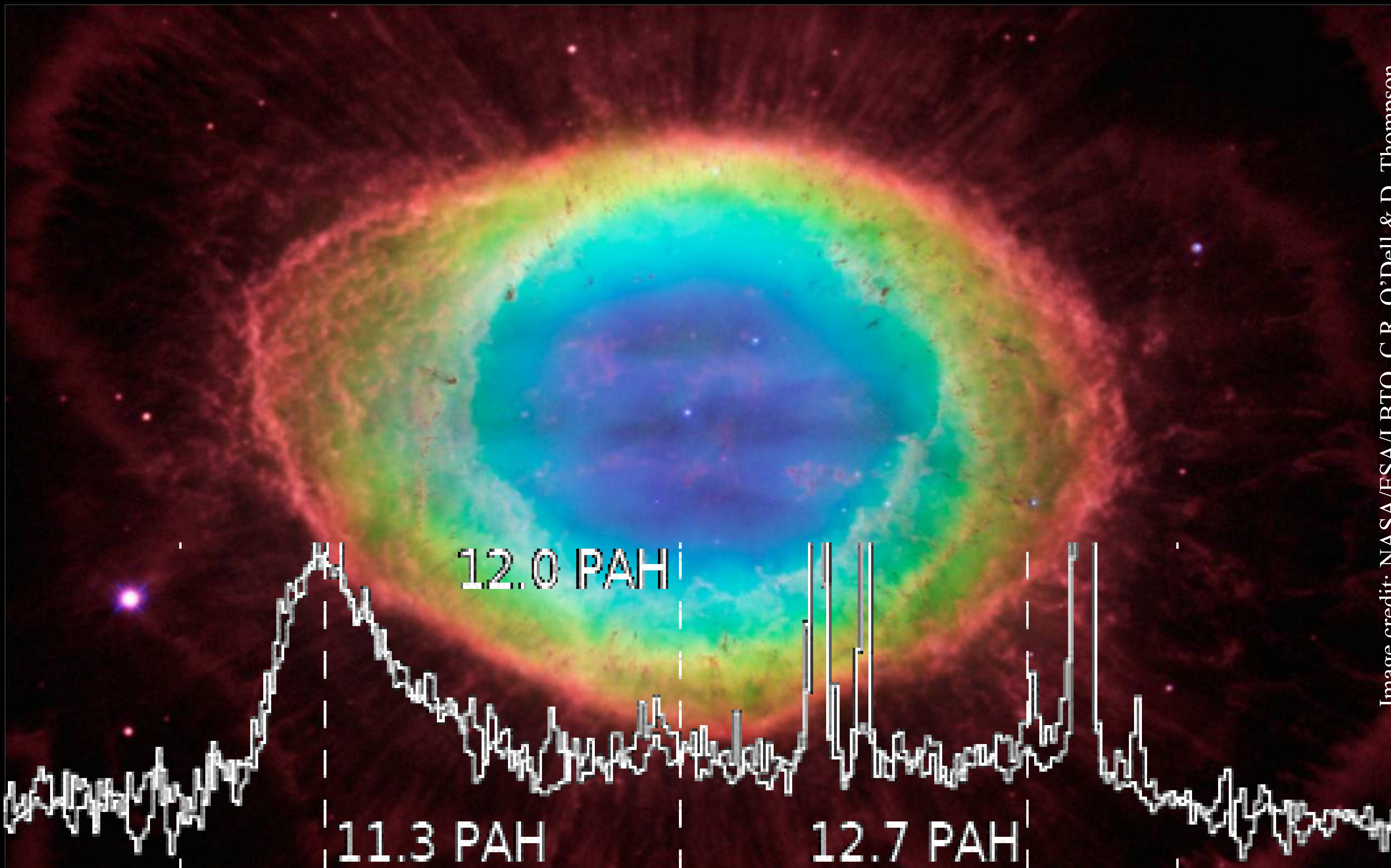


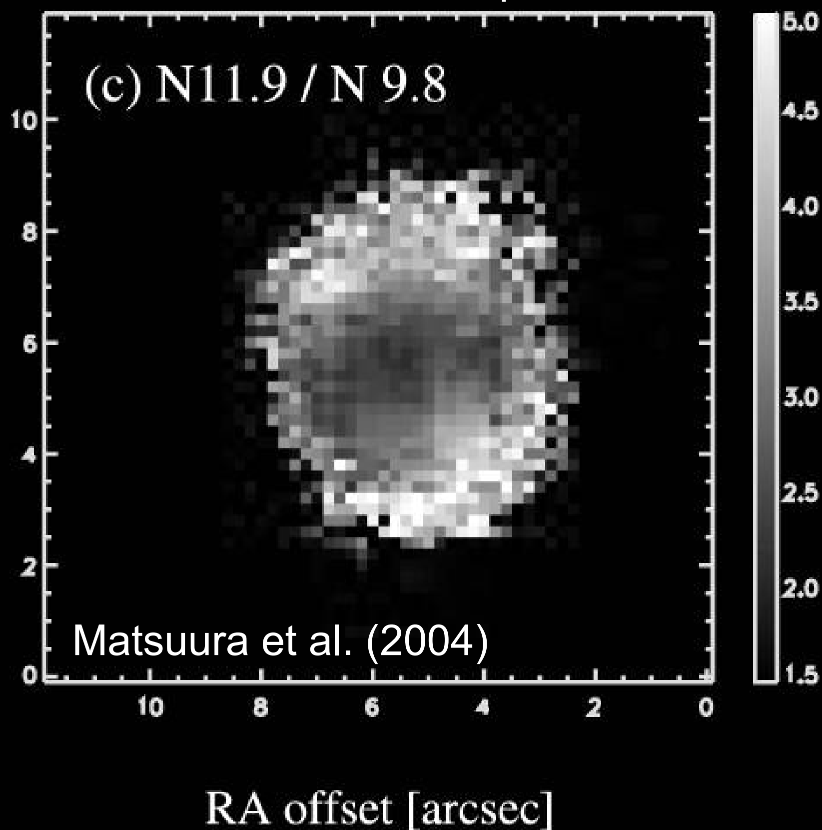
ArXiv:1511.08725 (Cox+2015)

ERC Synergy Grant #610256

Dual-dust chemistry – origin of PAHs in O-rich sources?

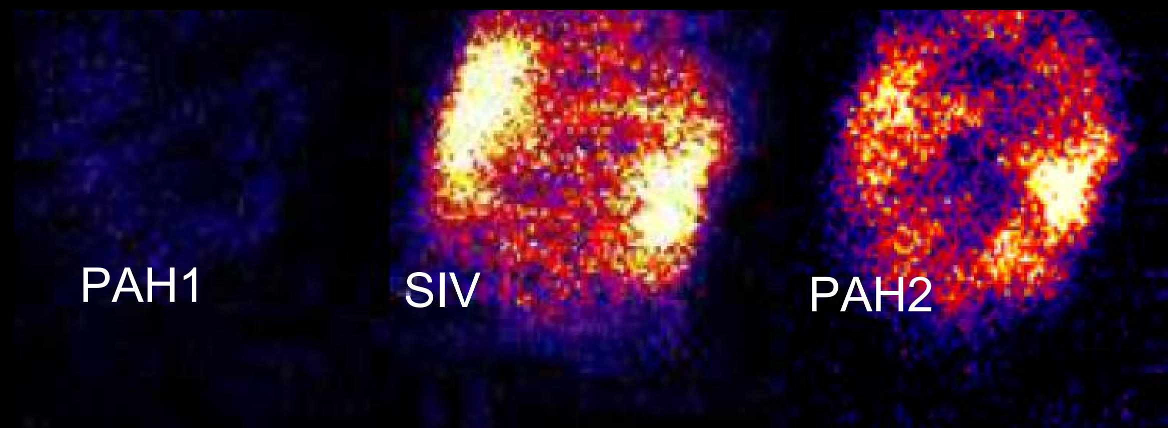
PAH formation mechanism(s) in O-rich and C-rich planetary nebulae?

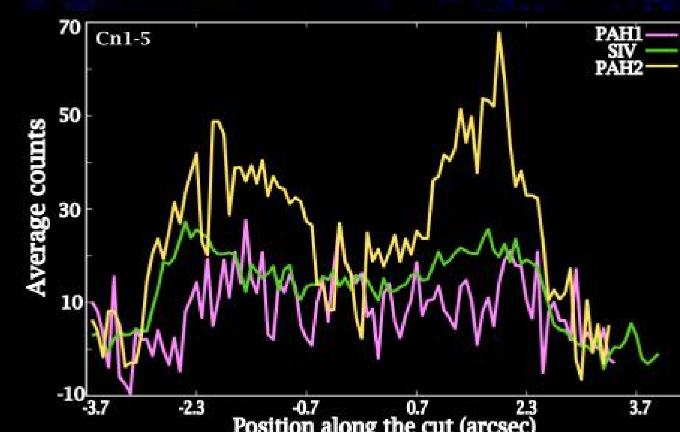
IRAS 16279-4757 post-AGB



PAH emission at 11.3 µm.
Crystalline silicate bands at ~20–40 µm.

PN Cn 1-5

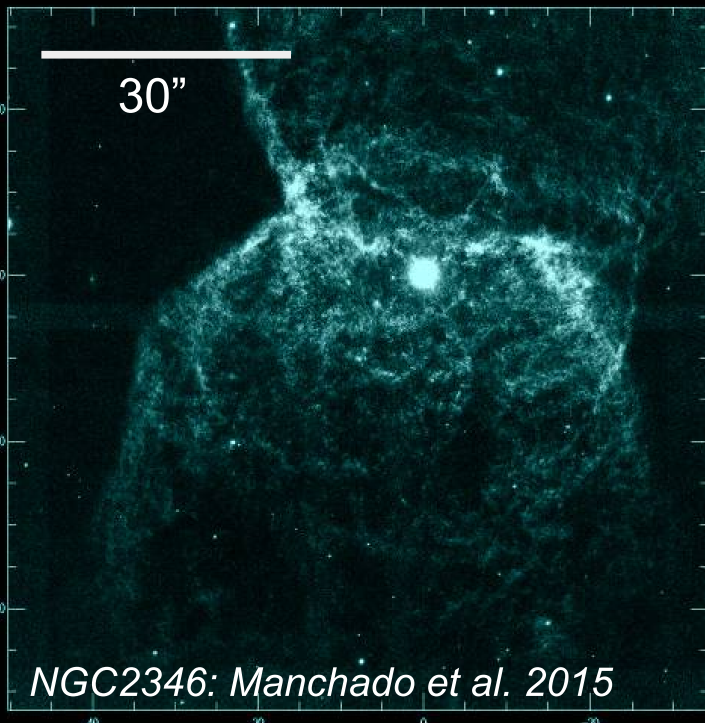




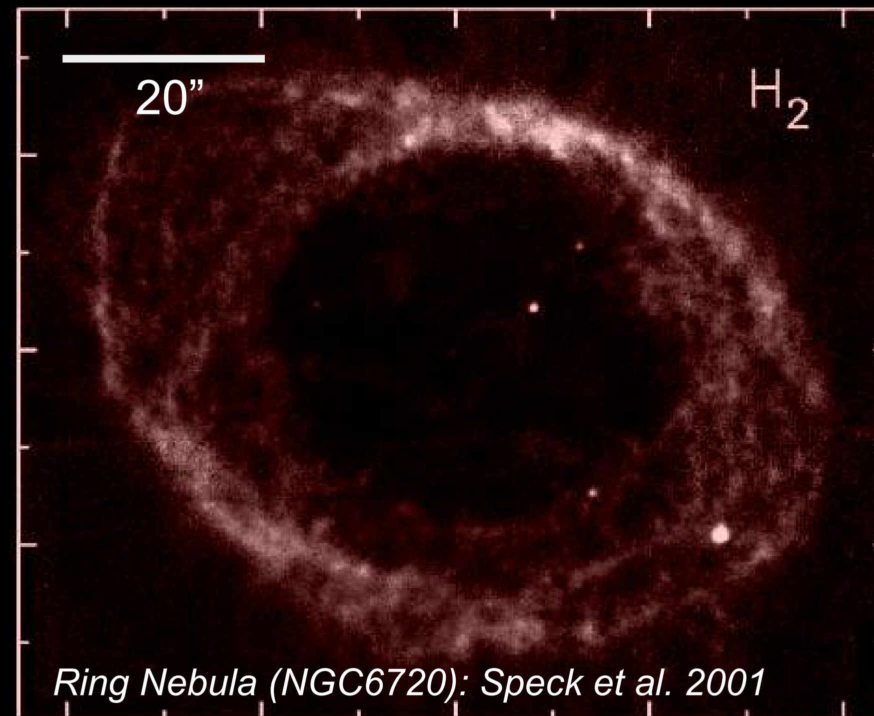
Mixed-chemistry ubiquitously seen in Galactic Bulge PNe (Guzman-Ramirez et al. 2011, 2014).

Dense H_2 clumps in PNe

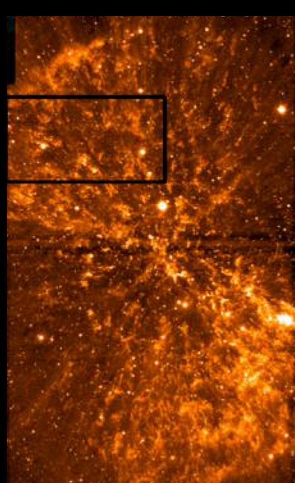
H_2 emission from PDRs associated with dense knots in ionized region

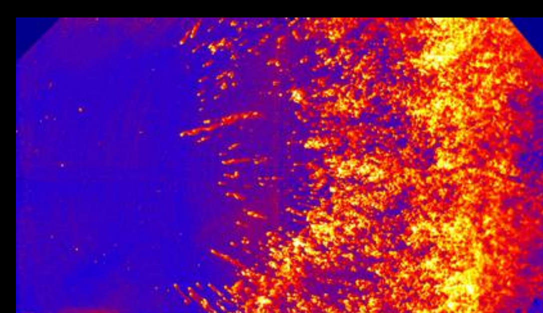


NGC2346: Manchado et al. 2015



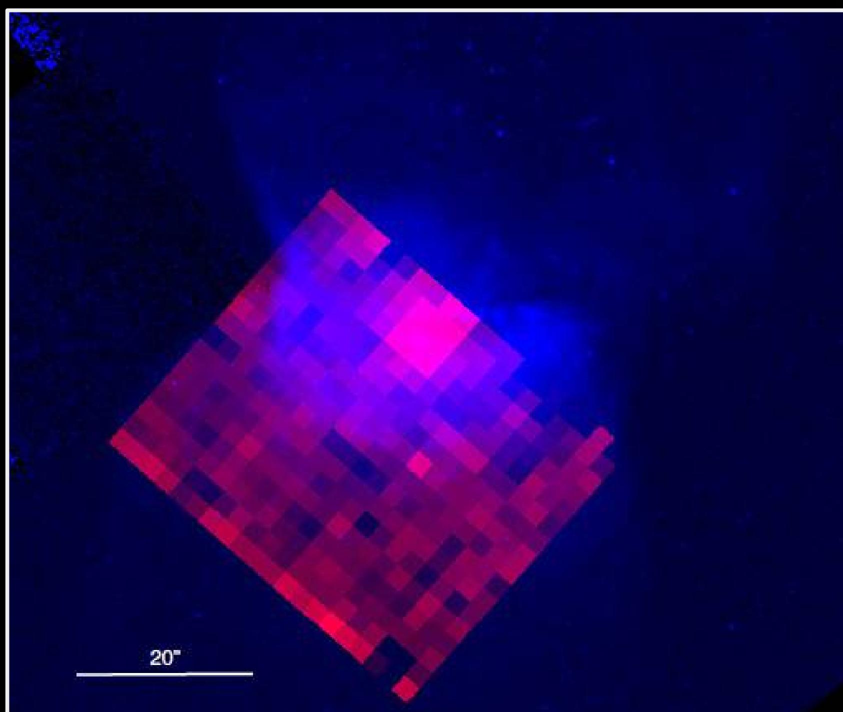
Ring Nebula (NGC6720): Speck et al. 2001


Dumbbell Nebula (NGC6853) Matsuura et al. (APN V)

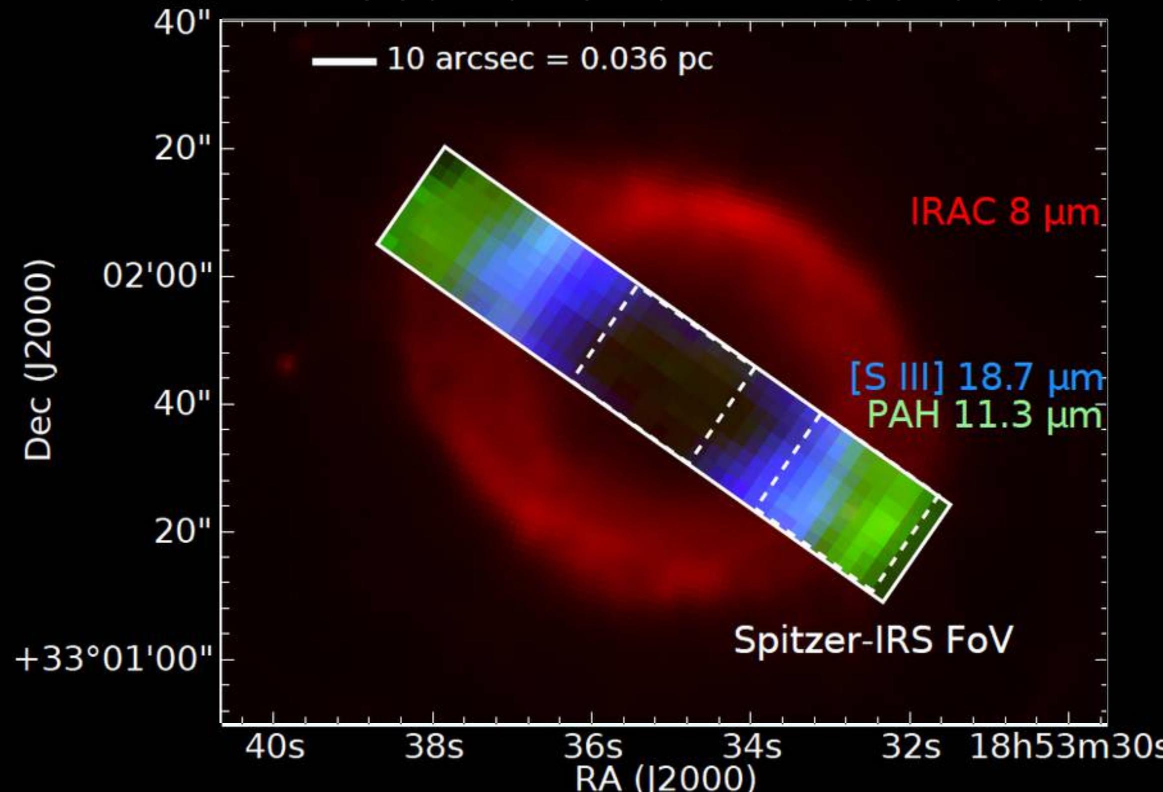

Helix Nebula (NGC7293) Matsuura et al. 2009

Spitzer-IRS SH Map observations of O-rich PNe

NGC2346 - O-rich PN – C/O~0.35

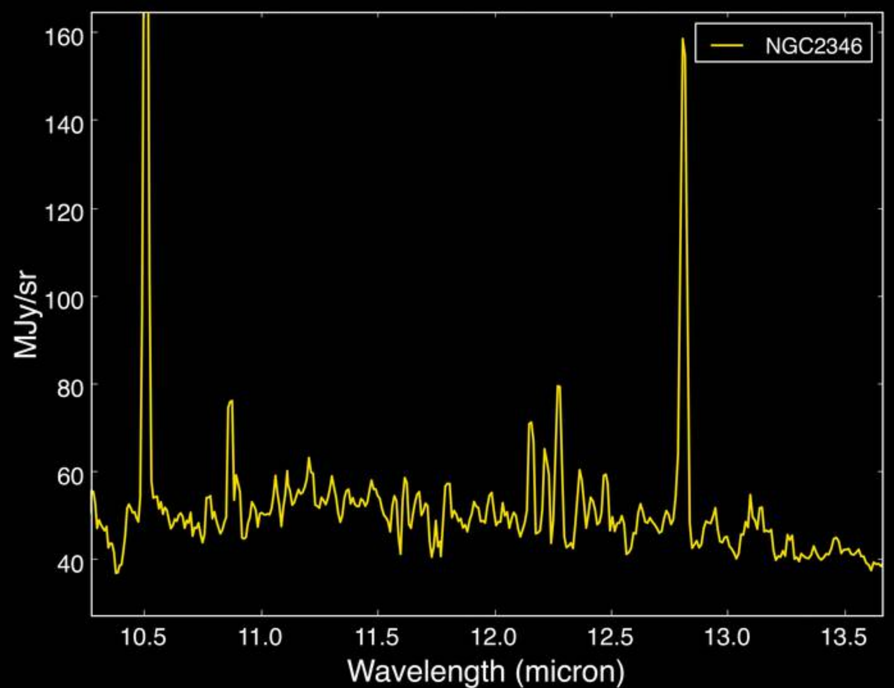


NGC6720 - O-rich PN – C/O~0.6-0.9



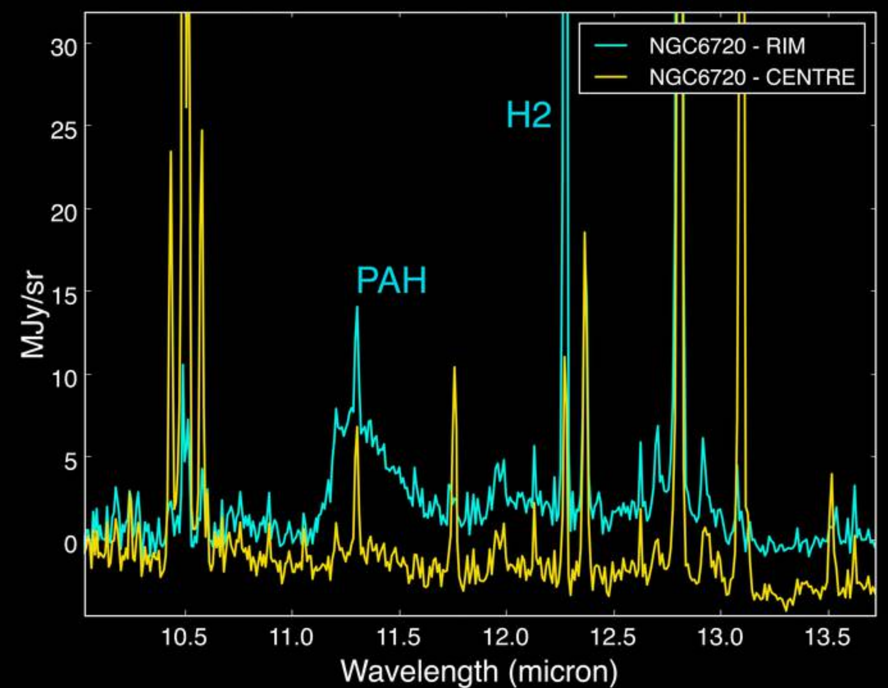
Mid-infrared spectroscopy of O-rich PNe

NGC2346 - O-rich PN – C/O~0.35



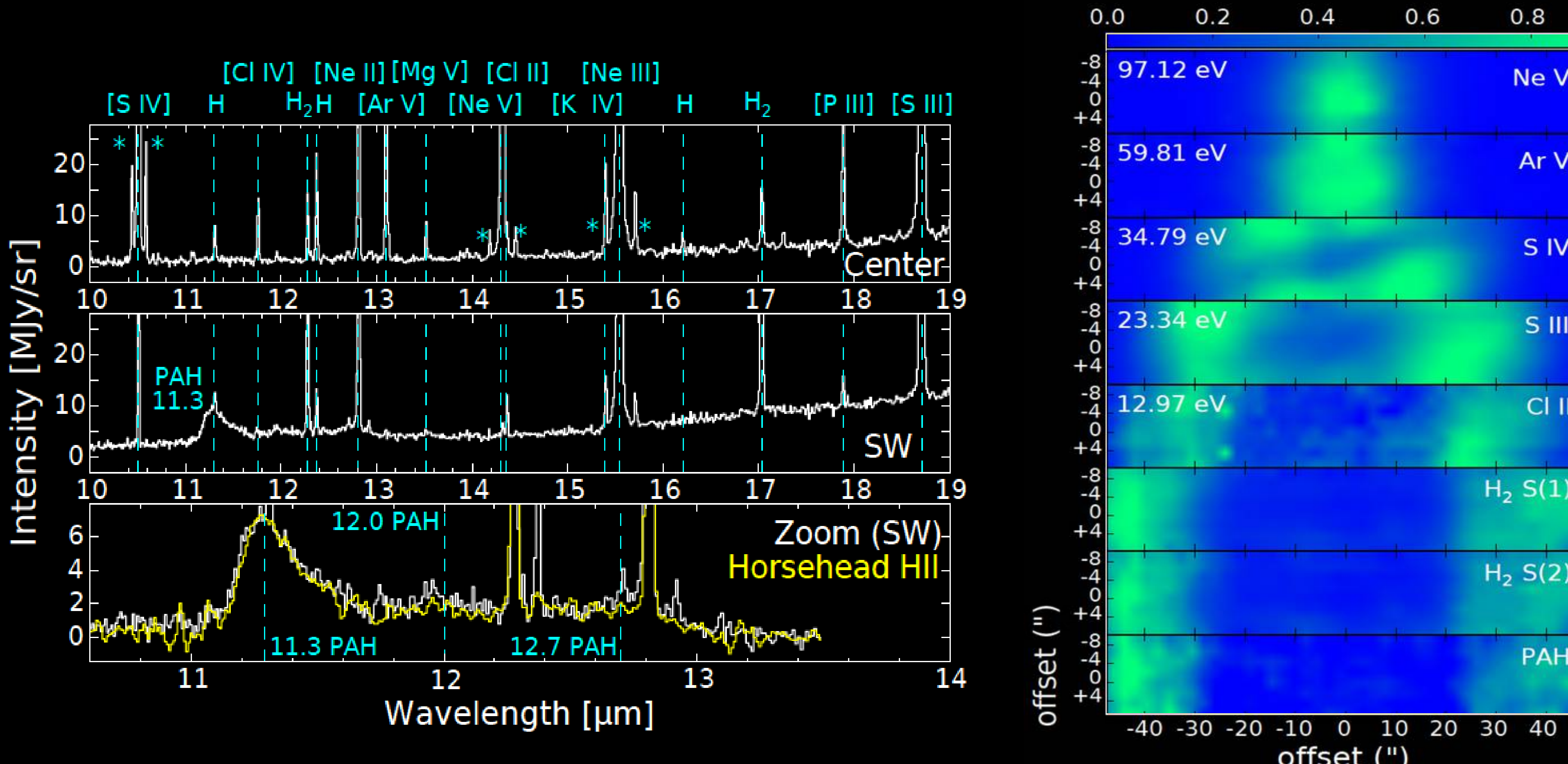
Spitzer IRS-SH 10 – 19 μm.

NGC6720 - O-rich PN – C/O~0.6-0.9



Spitzer IRS-SH 10 – 19 μm.

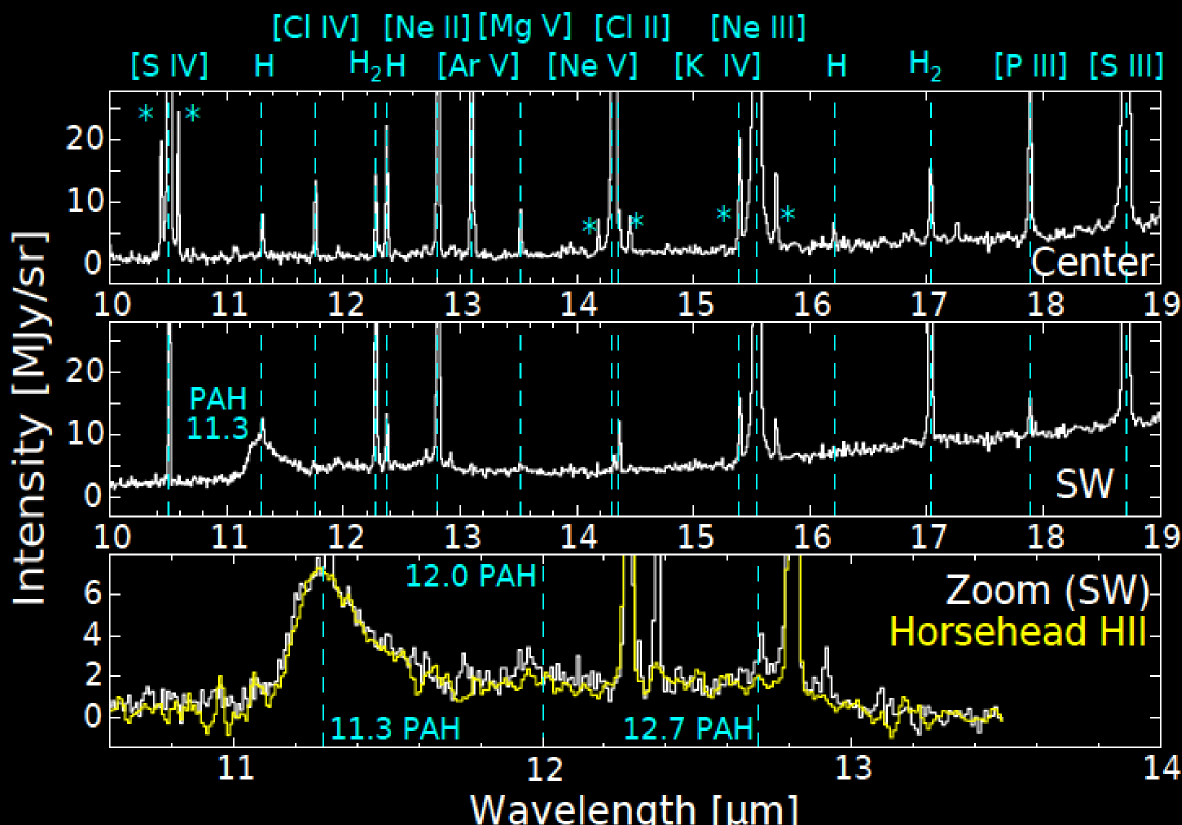
Mid-infrared PAH spectrum of NGC6720

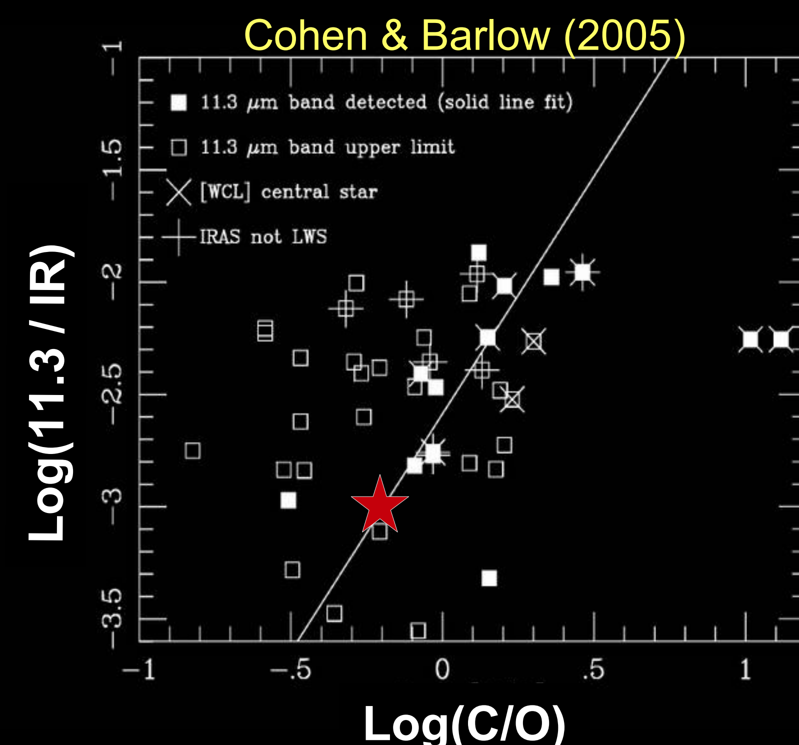


Hot CSPN T_* ~ 120.000 K

→ rich gas spectrum of ionized species

Mid-infrared PAH spectrum of NGC6720

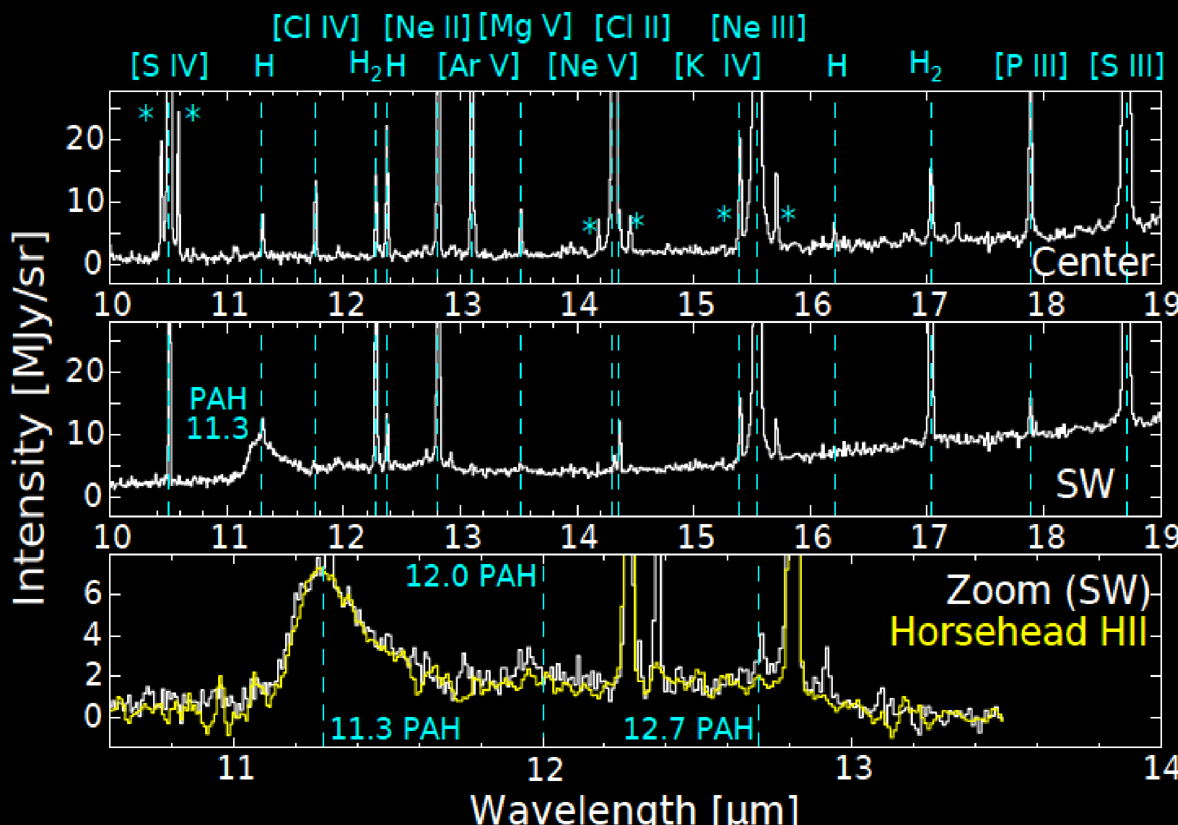


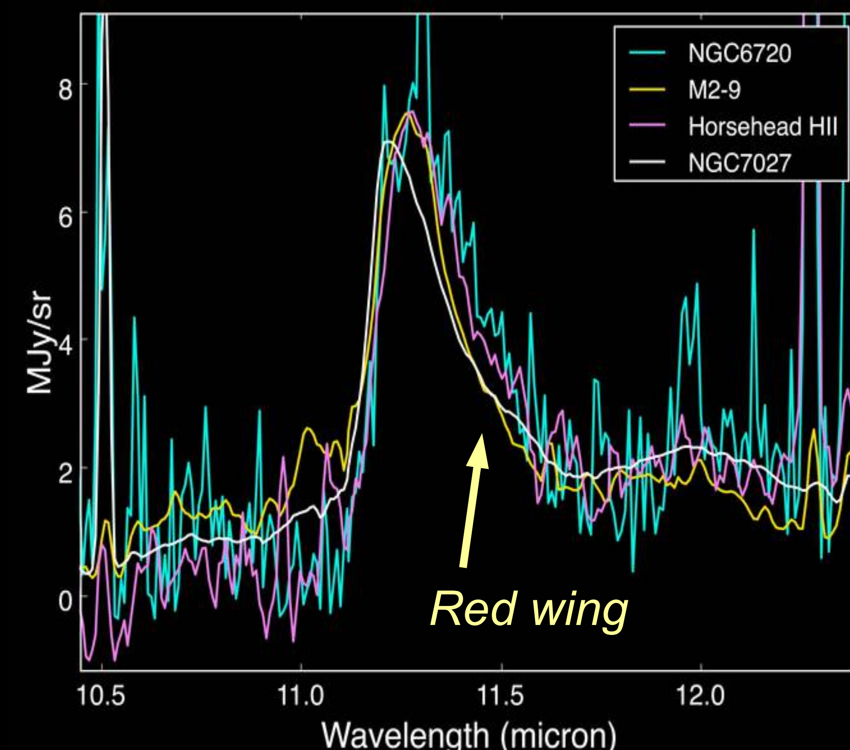


Mid-infrared PAH spectrum of NGC6720

11.3-12.0-12.7 PAH complex clearly revealed; but no PAH 6.2 & 7.7

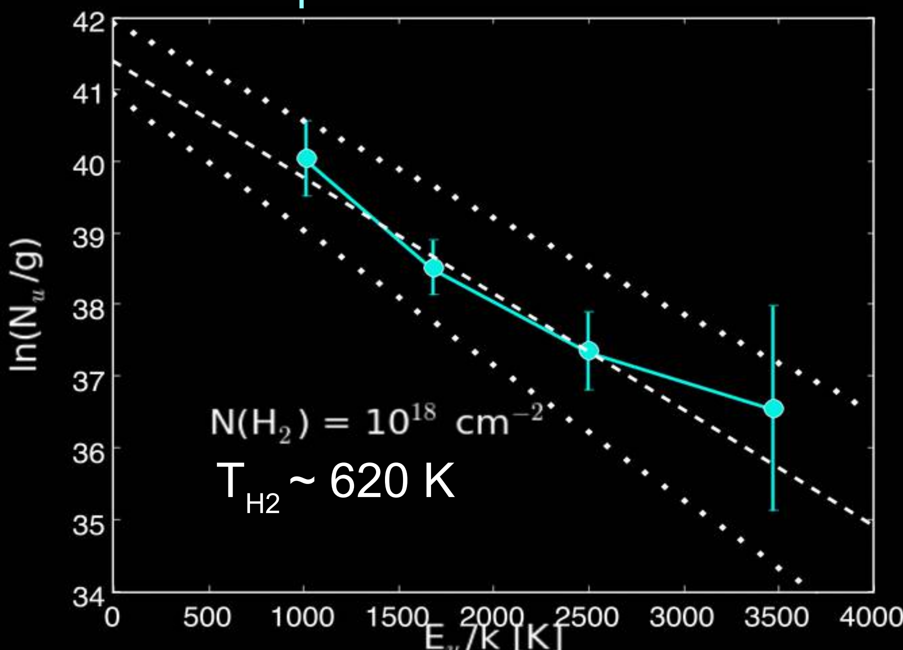
→ Resembles closely PAH spectrum of Horsehead HII region.



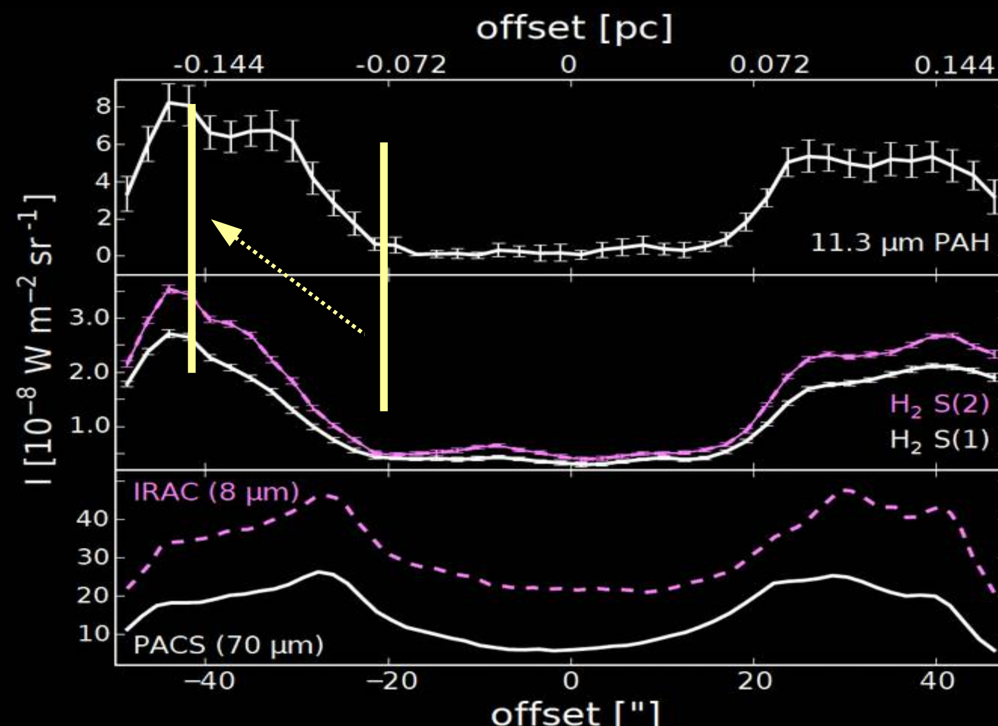


Physical conditions: densities & radiation field

Spitzer SH & SL



T_{H2} ~ 620 K



Density and temperature of H_2 v=1

$n_H > 10^4$ cm^{-3}
(pressure equilibrium at the ionization front)

PAH and H_2 at the PDR interface
→ *Stronger <u>H_2</u> due to <u>attenuation of UV</u> photons*
→ *Increasing <u>PAH</u> intensity due to <u>density</u> gradient*

UV photons attenuated by A_V~0.5 mag
over distance 0.07 pc → *mean* $n_H > 10^4$ cm^{-3}

Hydrocarbon photochemistry → PAHs?

PAH bottom-up formation scenario [Cernicharo 2004, Matsuura et al. 2004]
→ CO is dissociated → free C → hydrocarbons/PAHs.

Ring Nebula [Bachiller+1994, Sahai+2012, this work]

* $N(C) > 10 \times N(CO)$.
* Moderate radiation field ($G_0 \sim 200$)
* C, CO and H_2 have clumpy distribution.
* Knots with $n_H > 10^4\ cm^{-3}$

Carbon chemistry reactions such as:

$$C_2 + H_2 \rightarrow C_2H + H$$
$$C_2H + H_2 \rightarrow C_2H_2 + H$$
$$C^+ + H_2 \rightarrow CH^+ + H$$

have moderate activation energies, thus slow in cold ISM, but can become rapid enough to control C-bearing species at high T and n_{H2} prevailing in PDRs of (P)PN.

? How to get from small hydrocarbons to larger PAH molecules ?

? Impact of grains? Carbonaceous or silicates ?

Perspectives – exploring new grounds

Millimeter.

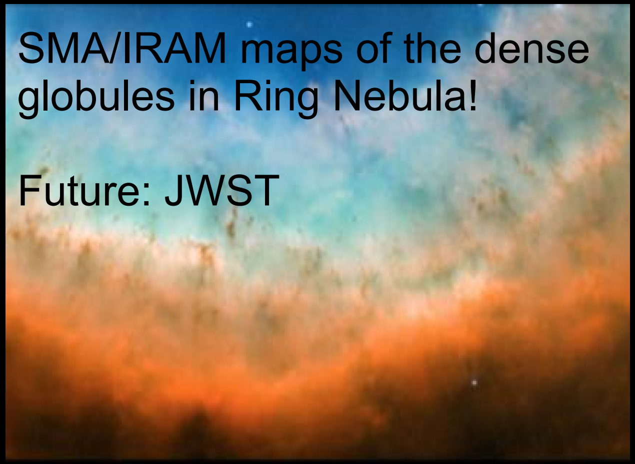
SMA Map CO and tracers of both oxygen-rich (SiO) and carbon-rich (HCN, CCH,SiC_2) chemistry in knots of NGC6720.

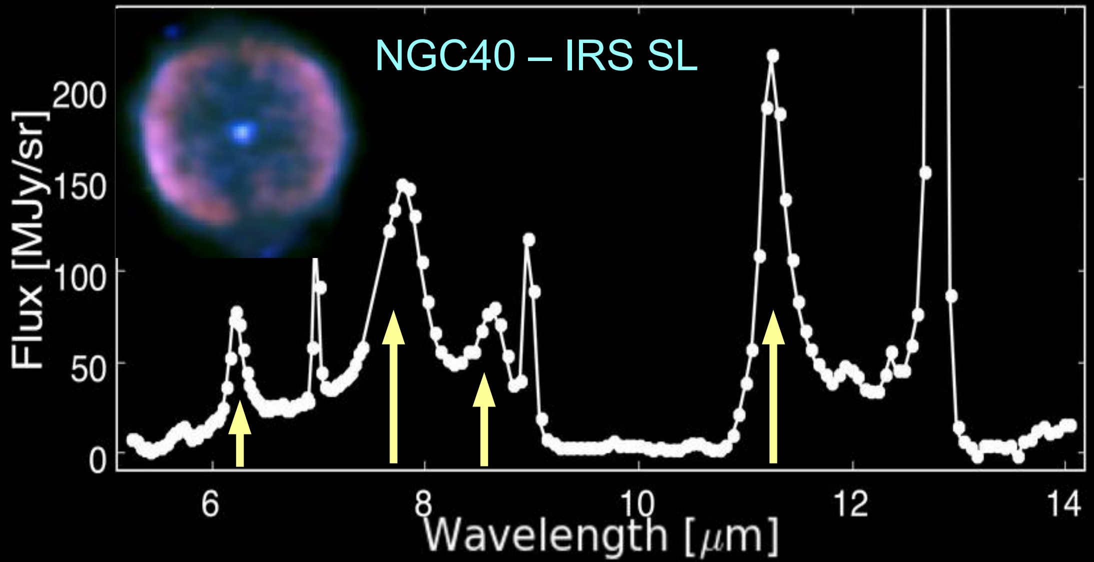
IRAM-30m zero-baselines for global view on chemistry.

Mid-infrared. :

JWST/NIRCam map distribution of H_2 and PAHs/eVSGs in extended PNe → Field-of-view is 130” x 130”.

JWST/MIRI mid-infrared spectroscopy of PAHs/hydrocarbons in <u>micro-PDRs</u> associated with dense knots in HII regions of PNe. → IFU (4”x8”) spectroscopy at R~1550-3250.





Theory:

Chemical modeling of knots → bottom-up formation of C-chains and PAHs?

Spitzer/IRS archive:

Other interesting sources to be analyzed E.g NGC40 (C-rich PN).