The Origin of the Spectral Evolution in Young PNe

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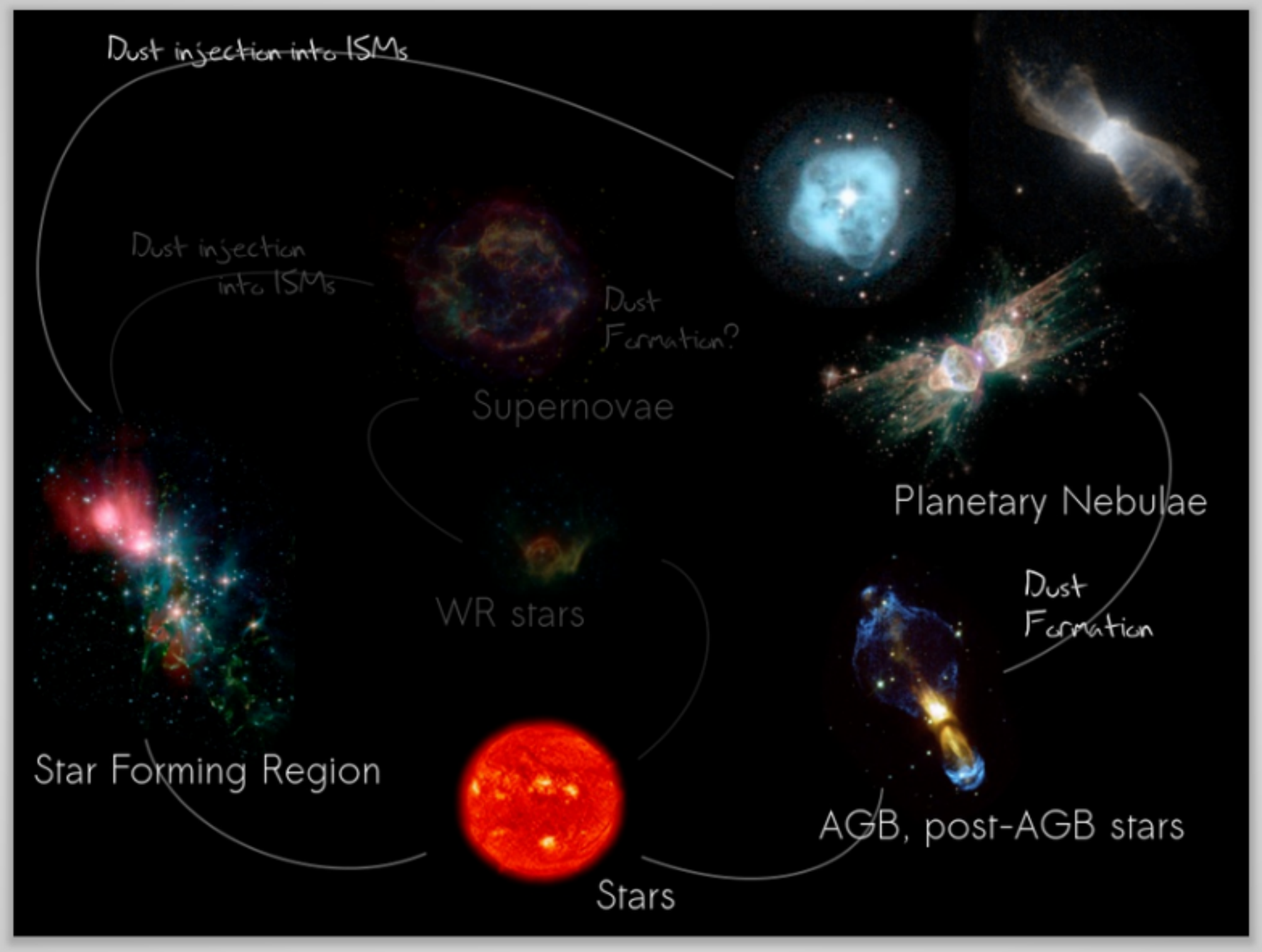
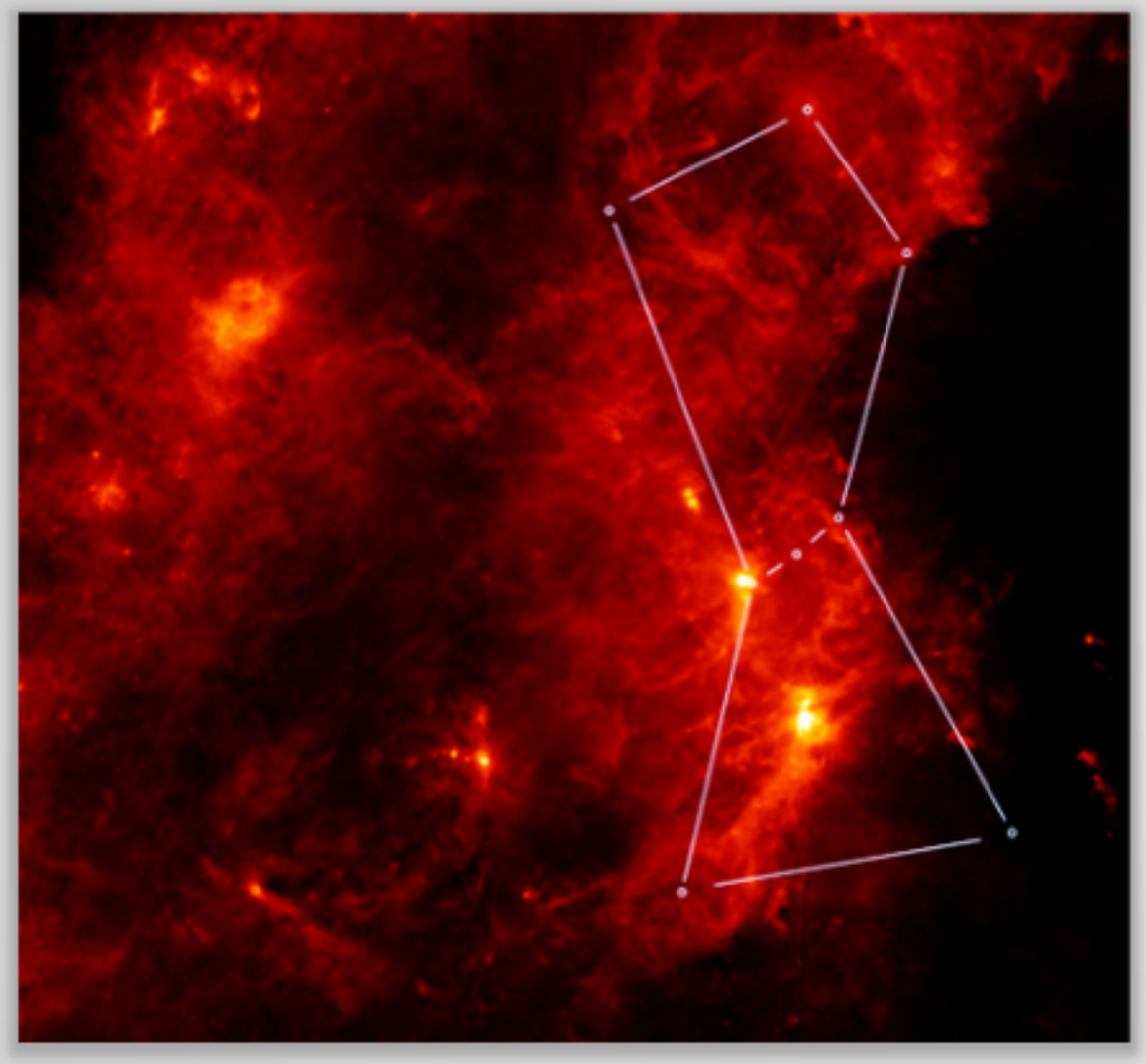
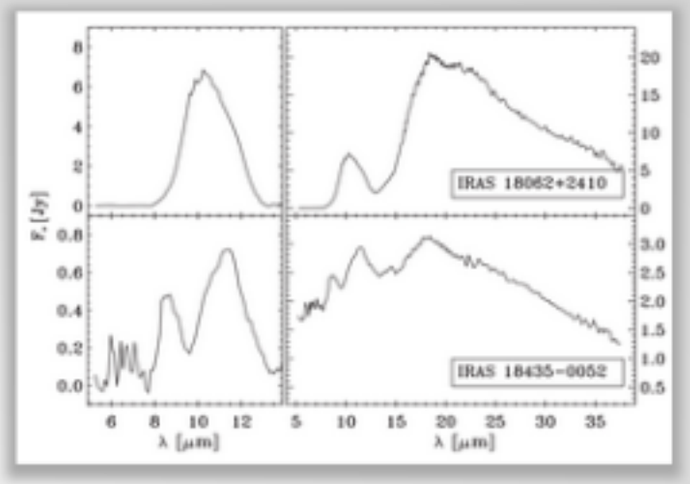


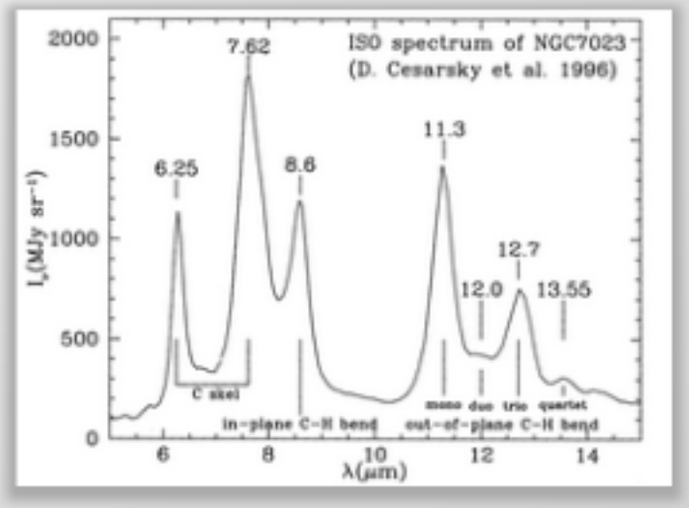
(Images from Archives of JPL/NASA)



(Orion Nebula in the FIR; Image from ISAS/JAXA)

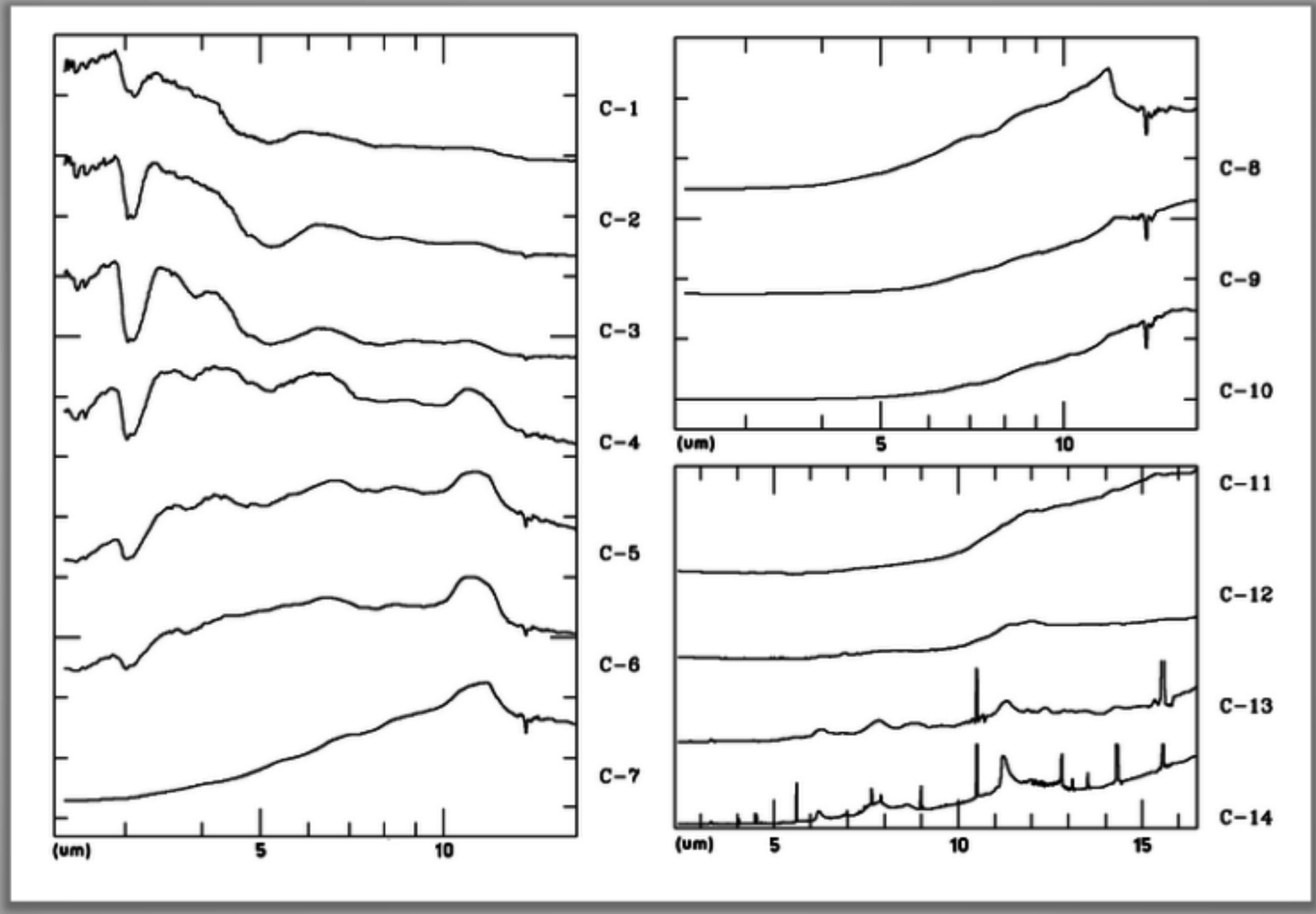


(Silicate; Cerrigone+, 2009)



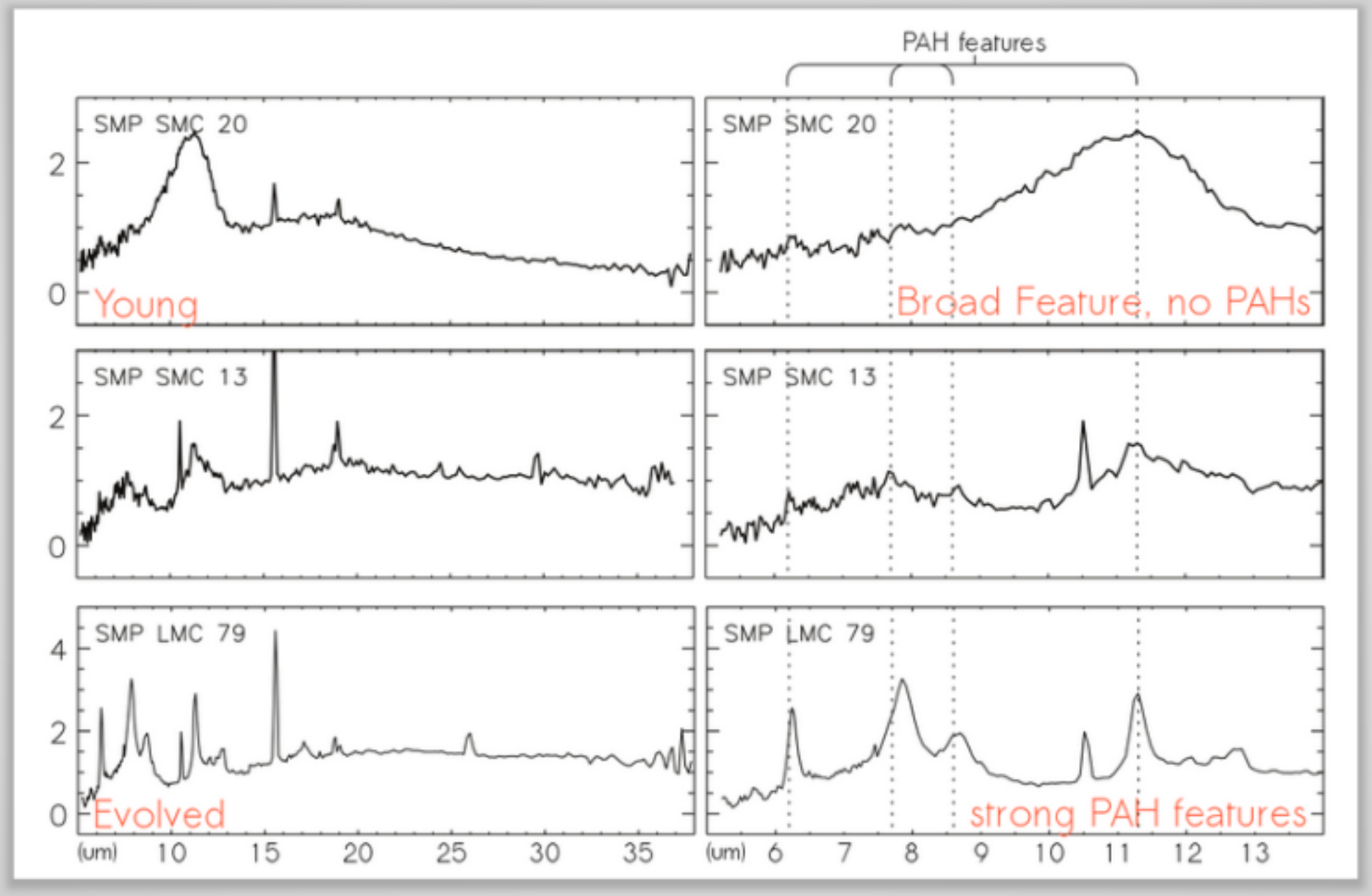
(PAHs; Cesarsky+, 1996)

MIR spectra of evolved stars



(ISO/SWS spectra of evolved stars; García-Lario+, 2003; edited)

Sequential Transition



(Spitzer/IRS spectra of PNe in the MCs; Stanghellini+, 2007; edited)

Questions

1. **Why** are the PAH feature weak or not detected in young PNe?

2. **Why** is the broad feature detected only in young PNe?

Our Goals

- check whether the transition is related to any dust processing or not
- propose a plausible scenario to account for the transition

Observations

PN G095.2+00.7 imaging/spectroscopy with the Subaru/COMICS

PN G095.2+00.7

C-rich, shell-like planetary nebula

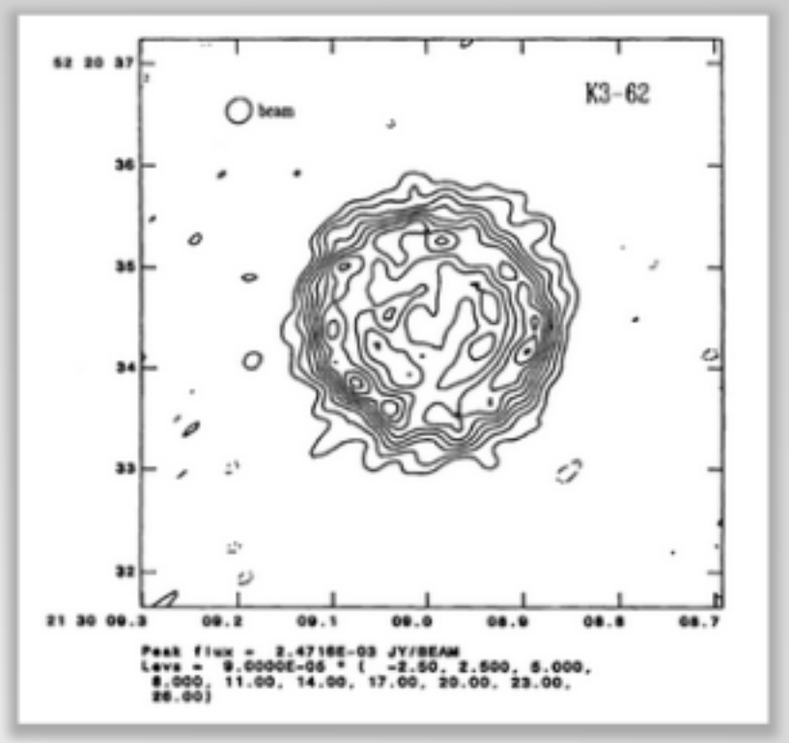
$T_{\rm eff} \simeq 58,000\,{\rm K}$ (Lumsden+ 2001)

$\theta = 1.3''$ (Aaquist & Kwok 1990)

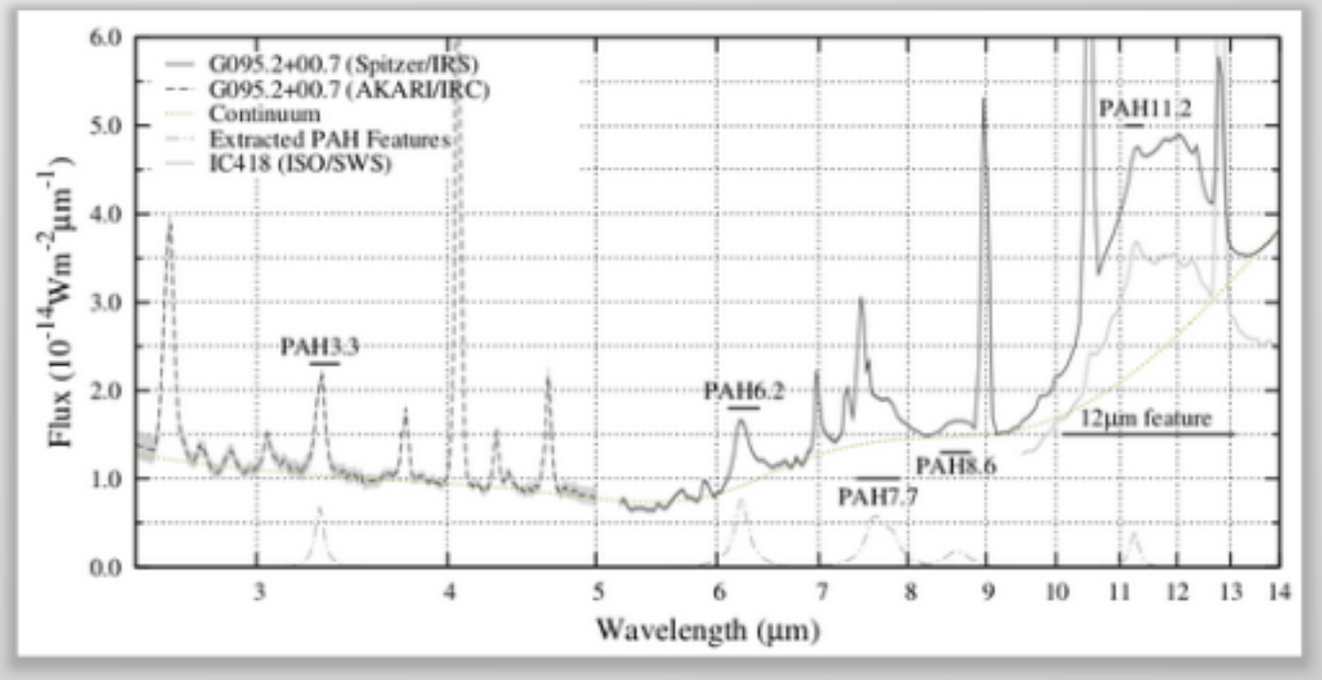
$d = 2.3\,{\rm Kpc}$ (Chan+ 1992)

IRAS color: $F_{25}/F_{60} \simeq 2.0$

Age: $t \simeq 900\,{\rm year}$ (radius/velocity)



(8.4GHz cont. in Kwok+, 1993)

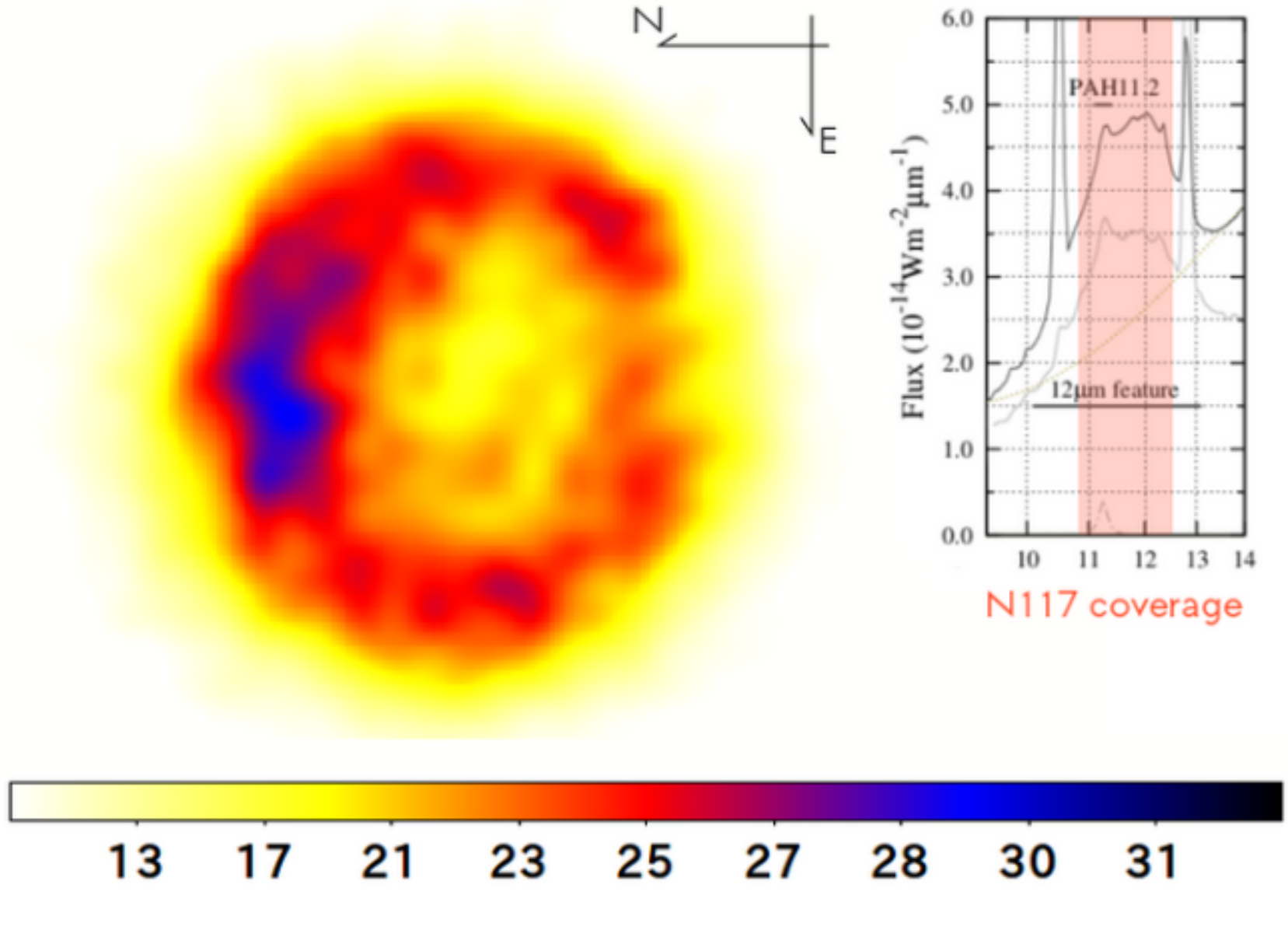


(AKARI & Spitzer spectra in Ohsawa+, 2012)

COMICS Observation

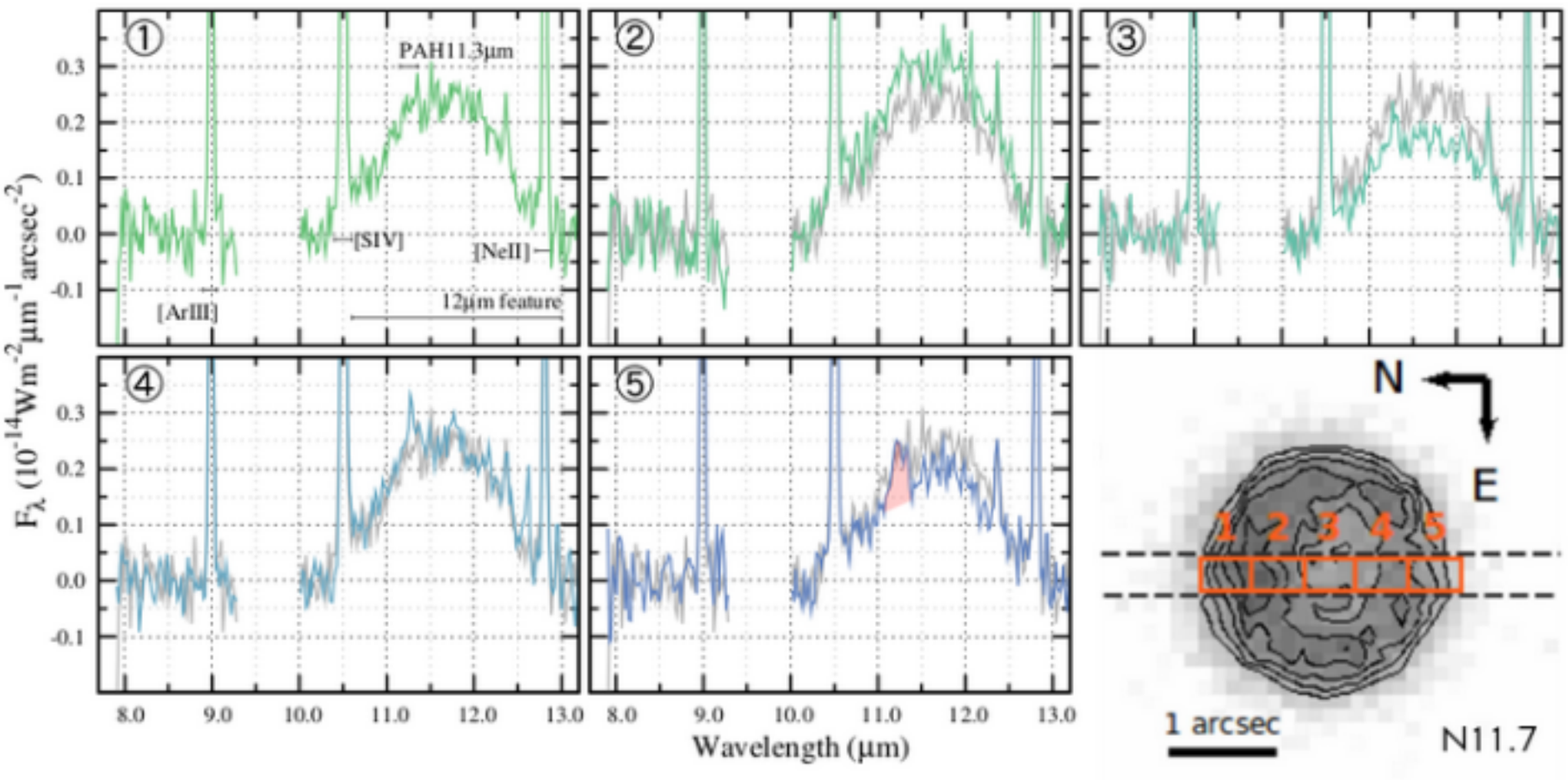
Observation	Imaging	Spectroscopy
Date	2011-08-31	2011-08-31
Grism/Filger	NL (R≈250)	N11.7 (R≈10)
Wavelengths	8.0-13.5μm	11.1-12.4μm
Slit Width	0.26″	—
Exp. Time	185s	600s
Standard	HD 197989 (K0 III)	

COMICS N11.7μm imaging



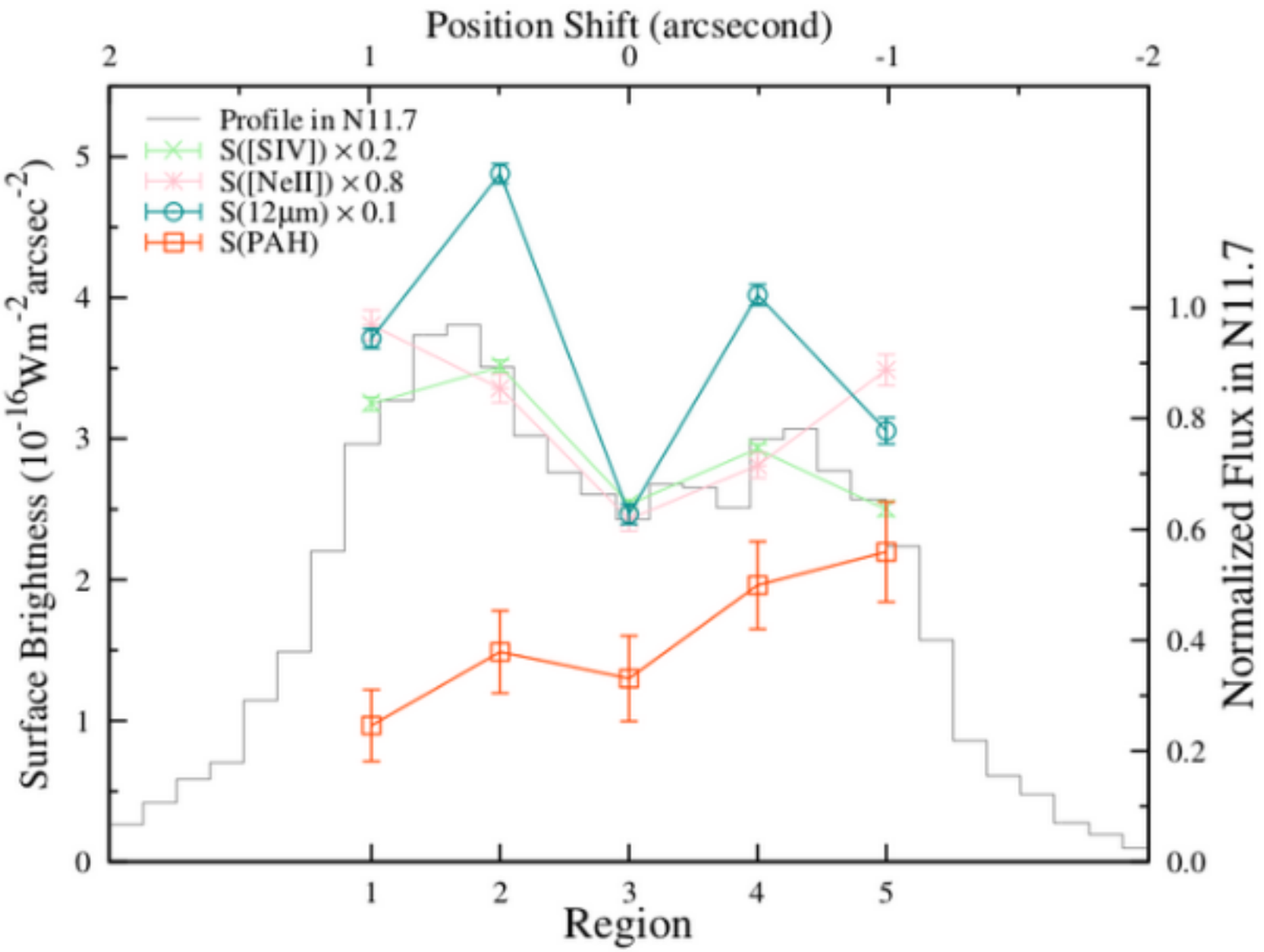
COMICS NL spectroscopy

The PAH emission detected in the southern part of the envelope



Distribution of spectral features

The PAH emission in the southe is **twice** as strong as in the north.



Excitation Mechanism of PAHs

PAHs are excitatd by absorption of a single UV photon.
The intensity of the PAH features are given as

$$I_{\mathrm{PAH}} \propto I_{\mathrm{UV}} \times N_{\mathrm{PAH}},$$

- I_{PAH}: in the south **twice** as strong as in the north
- N_{PAH}: the difference is assumed $\sim$ **10%**.

$\Rightarrow$ We estimated the difference in I_{UV}.

Extinction within the envelope

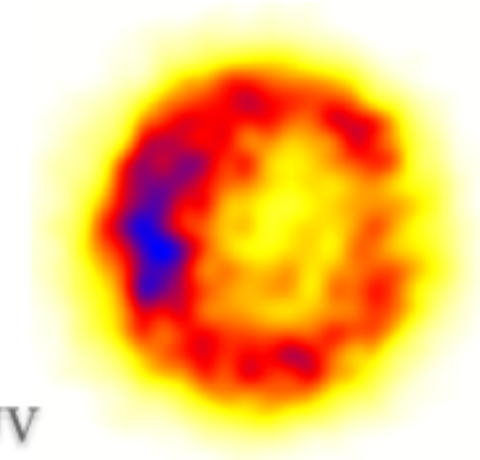
The difference in the N-band brightness is about 10%.
Assuming the optically thin condition in the mid-infrared,

Northern Part

$1.05 I_N$

$1.05 \tau_{\rm UV}$

$I_{\rm UV} \propto e^{-1.05\tau_{\rm UV}}$



Southern Part

$0.95 I_N$

$0.95 \tau_{\rm UV}$

$I_{\rm UV} \propto e^{-0.95\tau_{\rm UV}}$

The ratio of the UV intensity: $\frac{I_{\rm UV,S}}{I_{\rm UV,N}} \sim e^{0.1\tau_{\rm UV}}$.

Assuming $I_{\mathrm{PAH,S}}/I_{\mathrm{PAH,N}} = \exp(0.1\tau_{\mathrm{UV}})$,

$$\frac{I_{\mathrm{PAH,S}}}{I_{\mathrm{PAH,N}}} \simeq 2 \iff \tau_{\mathrm{UV}} \simeq 7.$$

According to the SDSS DR7 catalog (Abazajian+ 2009),

$$B\!-\!V \simeq 1.5 \iff \tau_{0.15\mu\mathrm{m}} \simeq 10.6.$$

assuming that $R_V = 3.1$, an extinction curve in Mathis (1990),
and interstellar extinction ($A_V \simeq 0.31$) in Dobashi (2011).

Summary: G095.2+00.7

- a N-band image and NL spectra with COMICS
- circumstellar dust in a spherical shell-like shape
- PAH emission significantly enhanced in the south
- possibly caused by the differnt UV intensity

Key Point:

Optically **thin** in the infrared, optically **thick** in the UV

We speculate that it is the case in young planetary nebulae.
We propose a simple scenario to account for the spectral transition.

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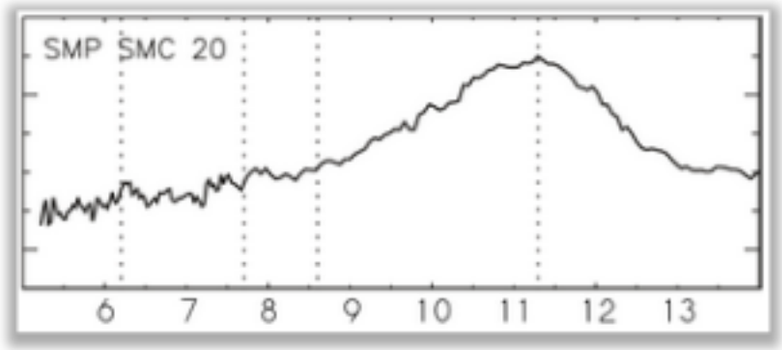
Young PNe: small & dense envelope

dense envelope ⇒ optically thick in the UV
small envelope ⇒ high dust temperature

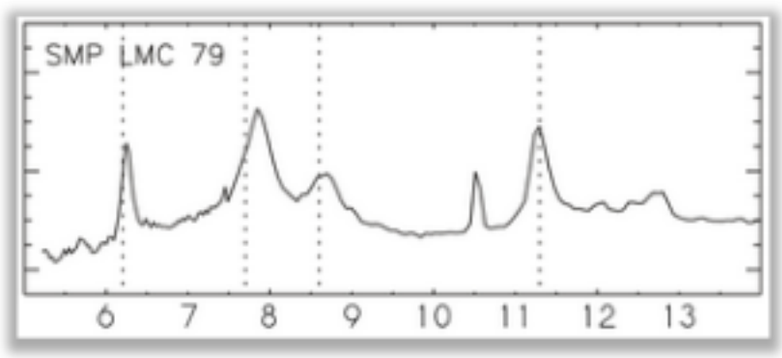


inefficient PAH excitation

hot dust feature in MIR

Evolved PNe: large & diffused envelope

diffuse envelope ⇒ optically thin in the UV
large envelope ⇒ low dust temperature



PAHs efficiently excited

no hot dust feature in MIR

shell expansion ⇒ the MIR spectral transition

Origin of Spectral Transition

sequential spectral transition:

- young PNe show no/weak PAH features
- evolved PNe do not show the MIR broad feature

the transition simply explained by expansion

- young PNe tends to have small and dense envelopes.
- evolved PNe have large and diffuse envelopes.
- do not require any dust processing to account for the transition