The mixed-chemistry problem in planetary nebulae

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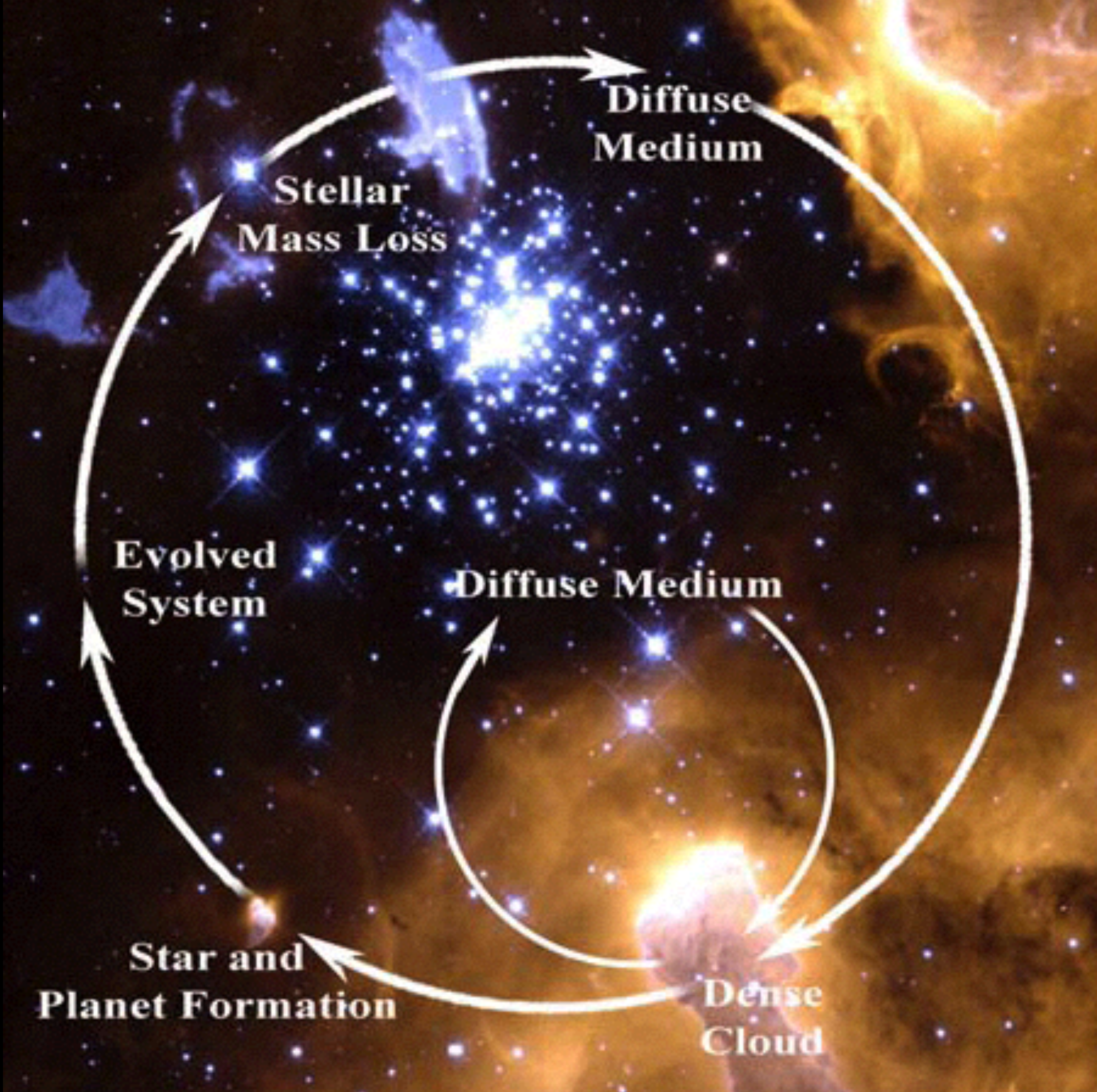
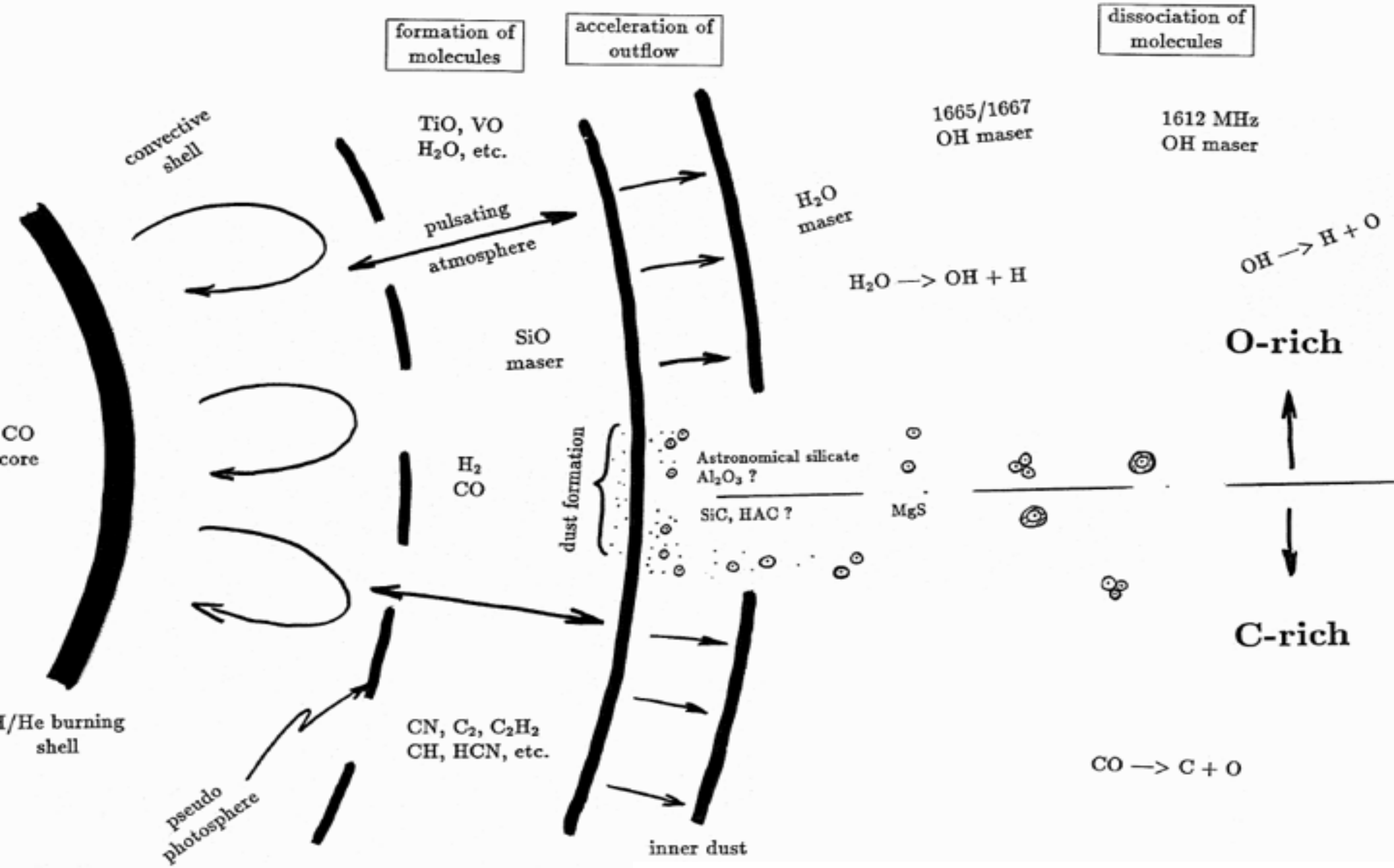
Dredge-up
Mass-loss

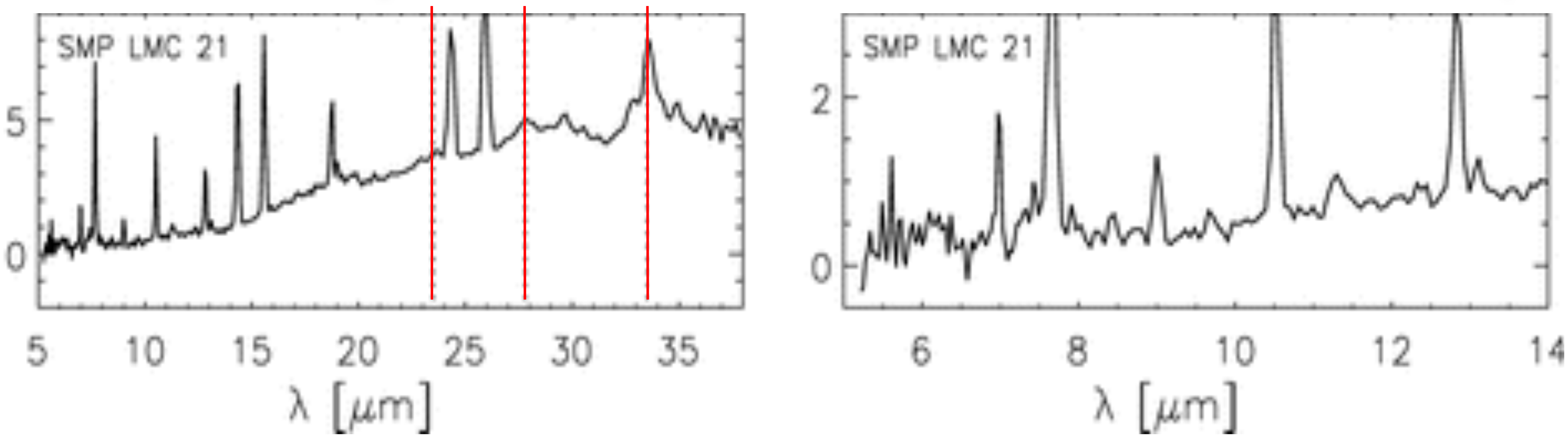




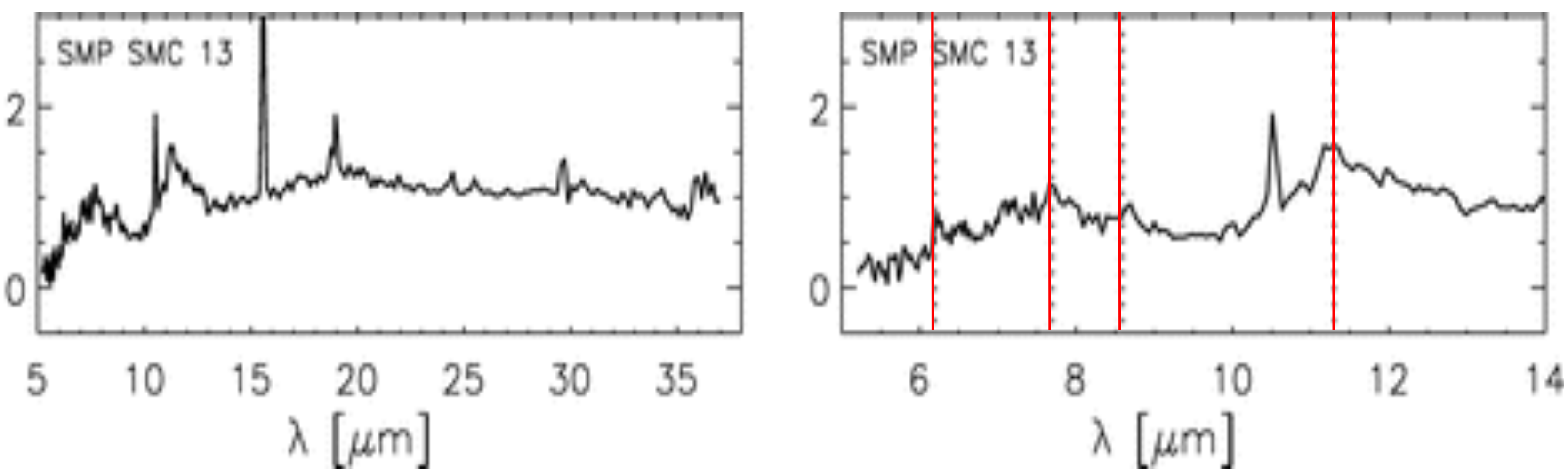
formation of molecules
acceleration of outflow
dissociation of molecules
convective shell
TiO, VO
H2O, etc.
1665/1667
OH maser
1612 MHz
OH maser
pulsating atmosphere
H2O maser
H2O —> OH + H
OH —> H + O
SiO maser
O-rich
CO core
H2
CO
dust formation
Astronomical silicate
Al2O3 ?
SiC, HAC ?
MgS
C-rich
H/He burning shell
CN, C2, C2H2
CH, HCN, etc.
CO —> C + O
pseudo photosphere
inner dust

This chemistry difference is reflected in the nebula, the molecular zone and the dust formation zone.

O-rich PNe – Crystalline silicate features - 23.5, 27.5 and 33.8μm

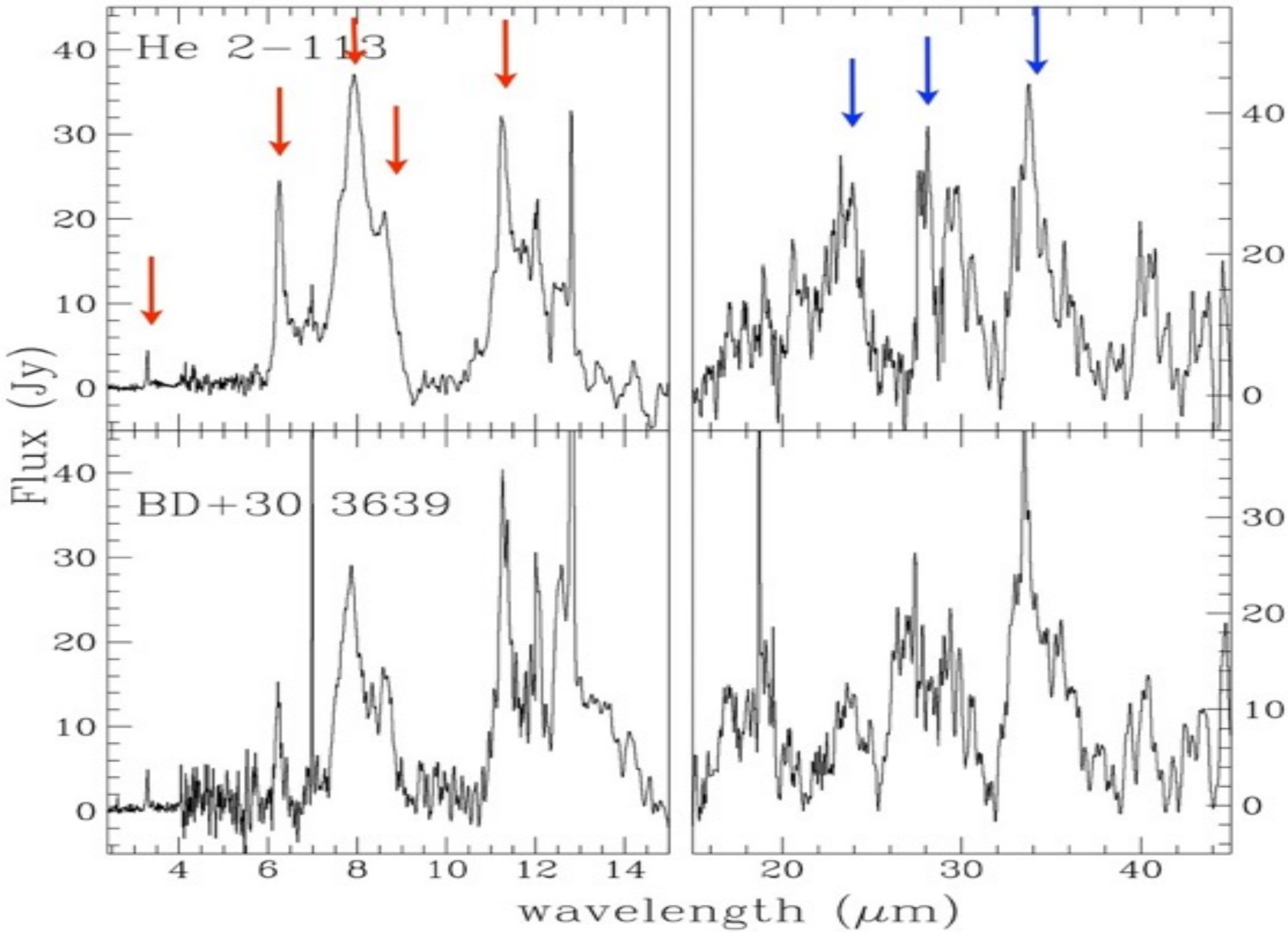


C-rich PNe - PAH bands - 6.2, 7.7, 8.6 and 11.3μm



Bernard-Salas et al. 2008

The mixed chemistry problem: O-rich and C-rich molecules and dust in the same PN



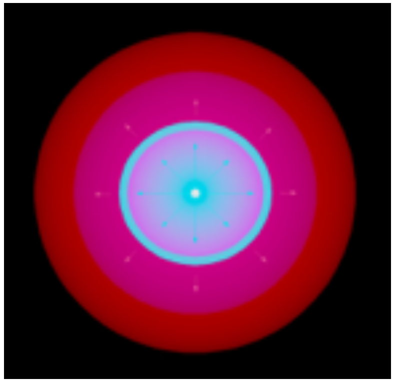
Zijlstra et al. 1991, Waters et al. 1998, Szczerba et al. 2001

Three scenarios to explain the mixed chemistry

Stars that experience a very late thermal pulse:

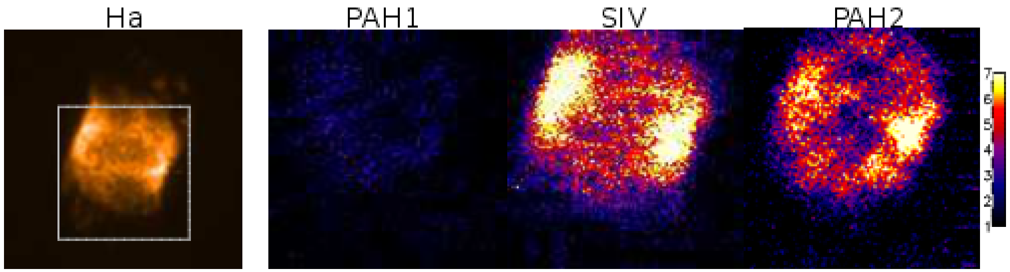
1. O-rich old stable disc and C-rich recent outflows.

2. O-rich old envelope and C-rich recent material in the inner.



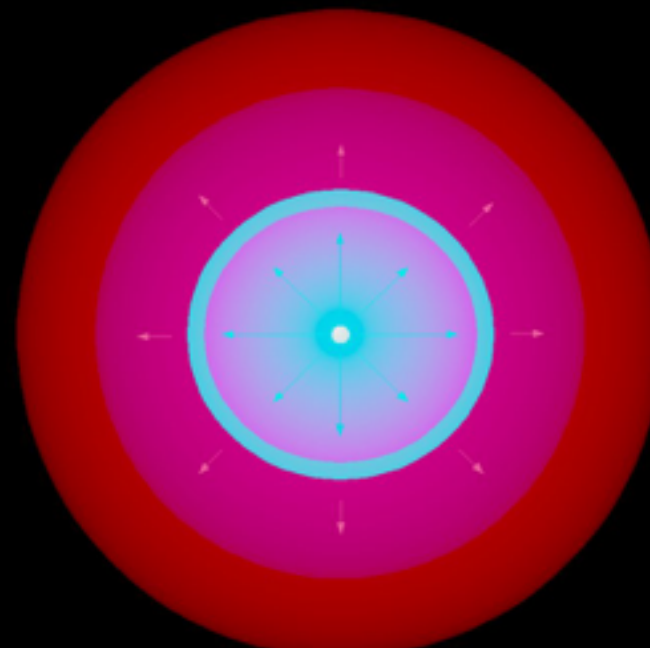
Stars that are O-rich:

3. CO photodissociation and PAHs formation in a disk or a torus.



Stars that experience a very late thermal pulse:

O-rich old stable disc and C-rich recent outflows vs
O-rich old envelope and C-rich recent material in the inner

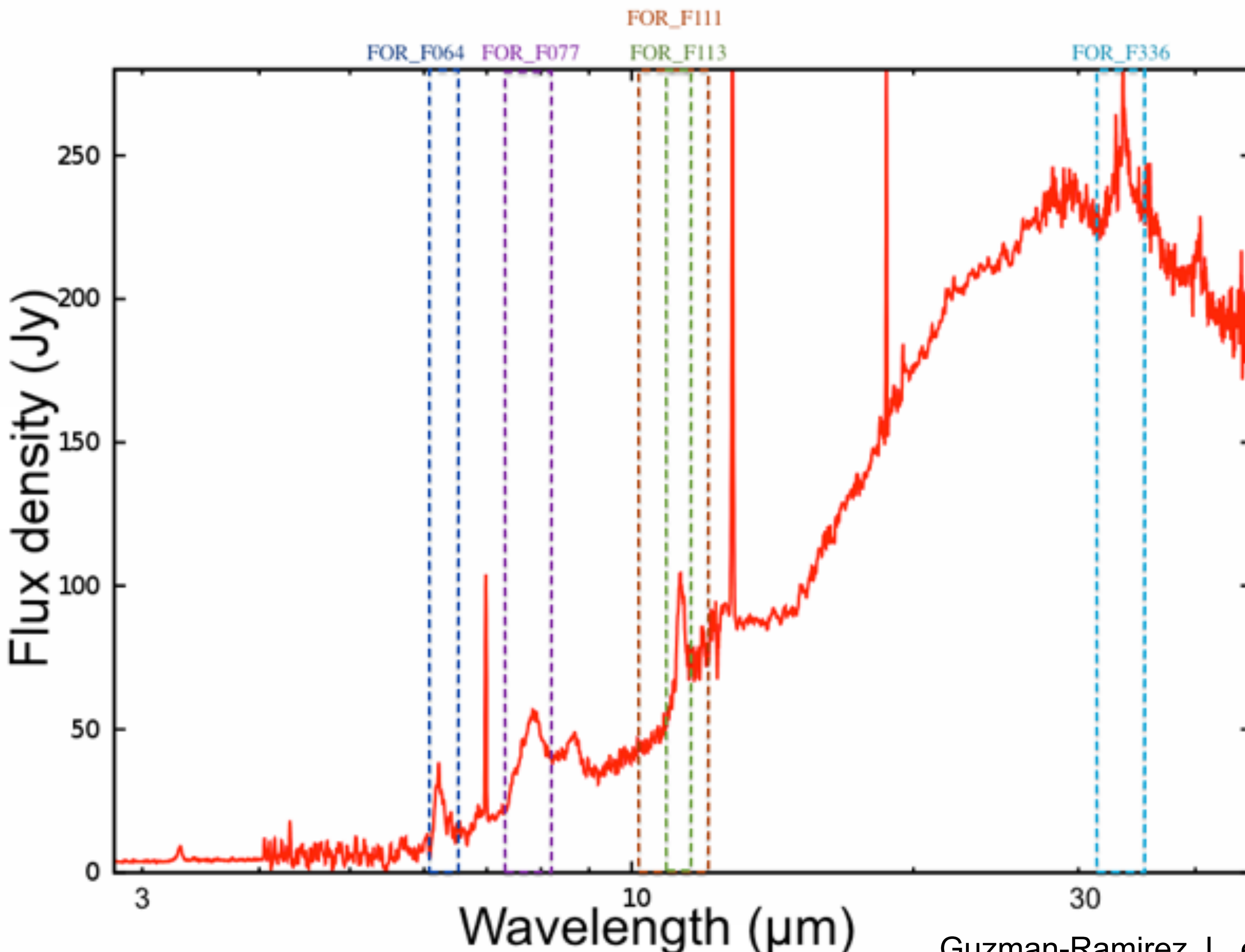


Testing the two scenarios that can produce mixed chemistry in PNe after a very late thermal pulse.

Waters et al., 1998 attributed it to a very late thermal pulse (VLTP)

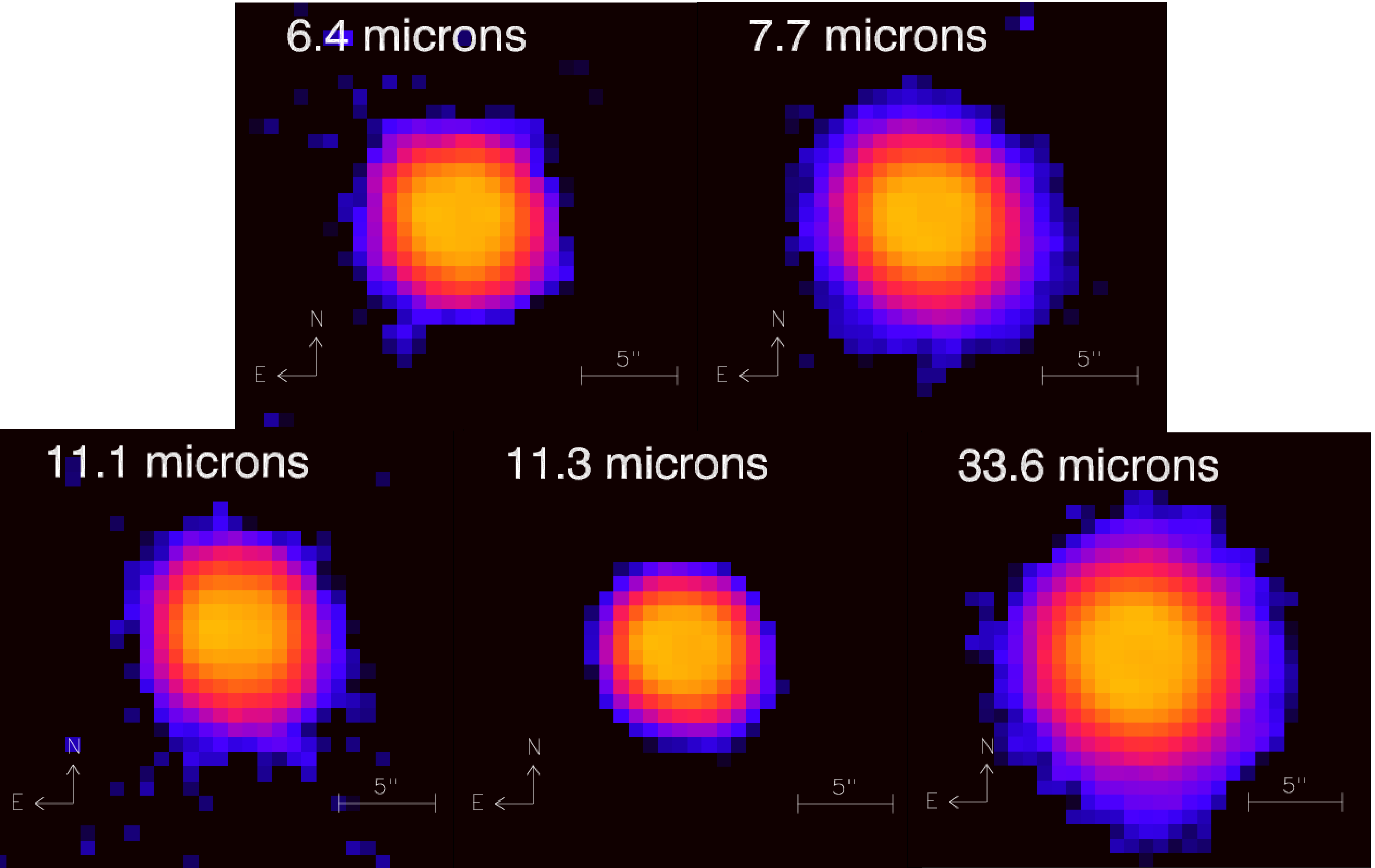
Testing the two scenarios that can produce mixed chemistry in PNe after a VLTP.

Testing the two scenarios that can produce mixed chemistry in PNe from the Galactic Disk after a very late thermal pulse.

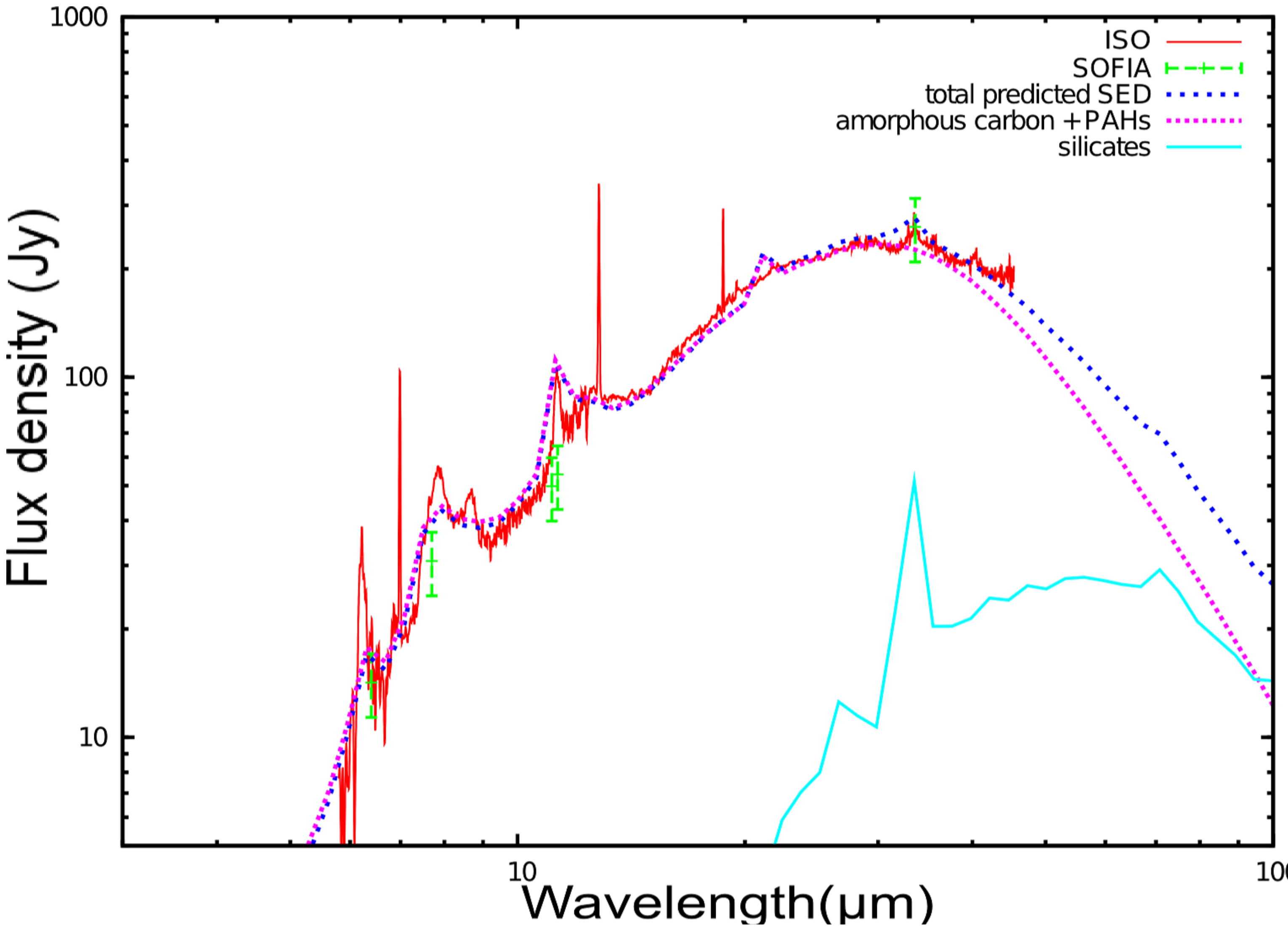


Guzman-Ramirez, L. et al., 2015

BD+30 3639 observations using FORCAST instrument on board of SOFIA



BD+30 3639 MOCASIN dust model

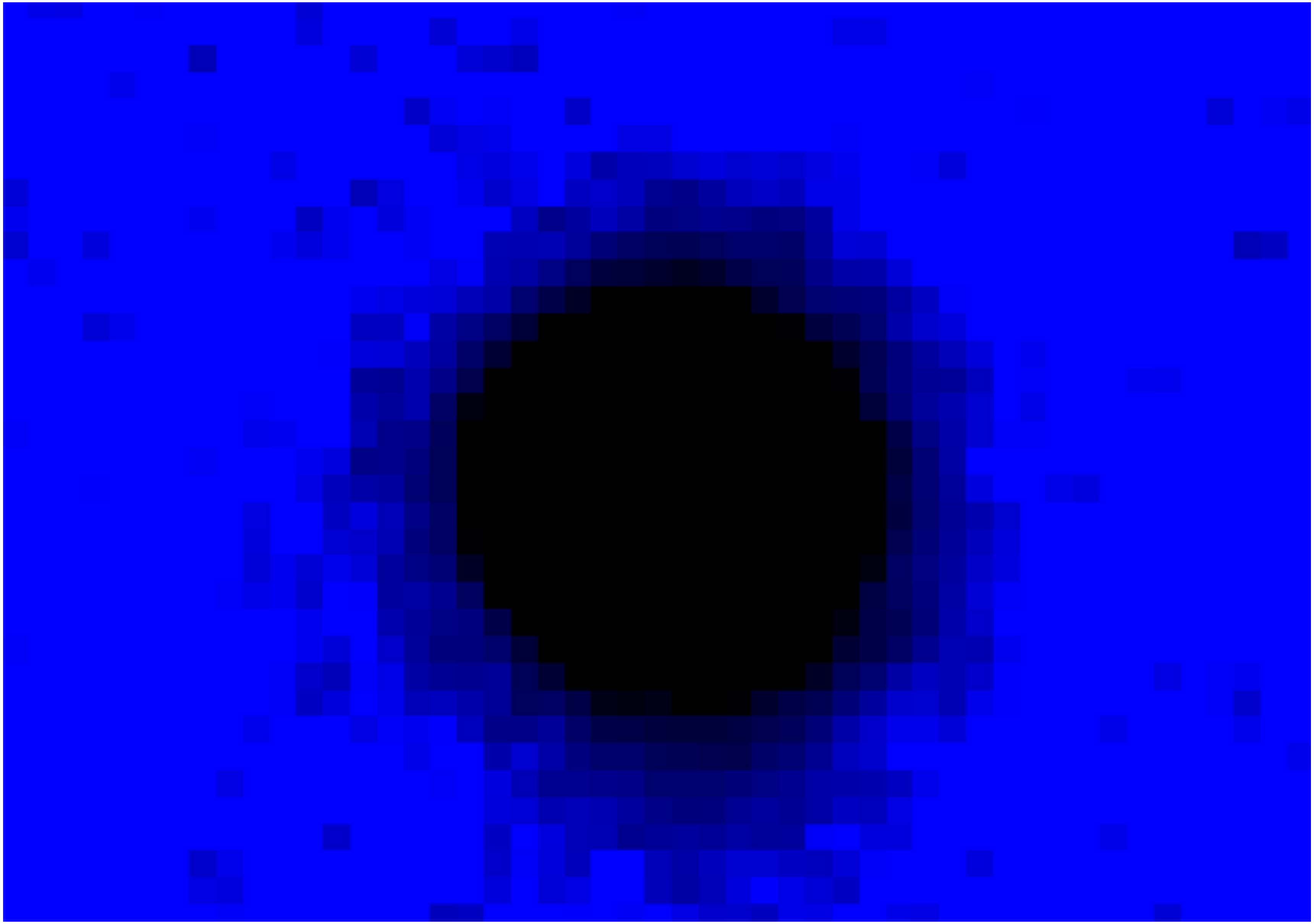


C shell 6.6×10^{-5} M_{o} mass-loss rate 2.4×10^{-8} M_{o}/yr

O shell 8.1×10^{-5} M_{o} mass-loss rate 5.4×10^{-8} M_{o}/yr

Guzman-Ramirez, L. et al., 2015

BD+30 3639 became a C-rich star only a few thousands of years ago



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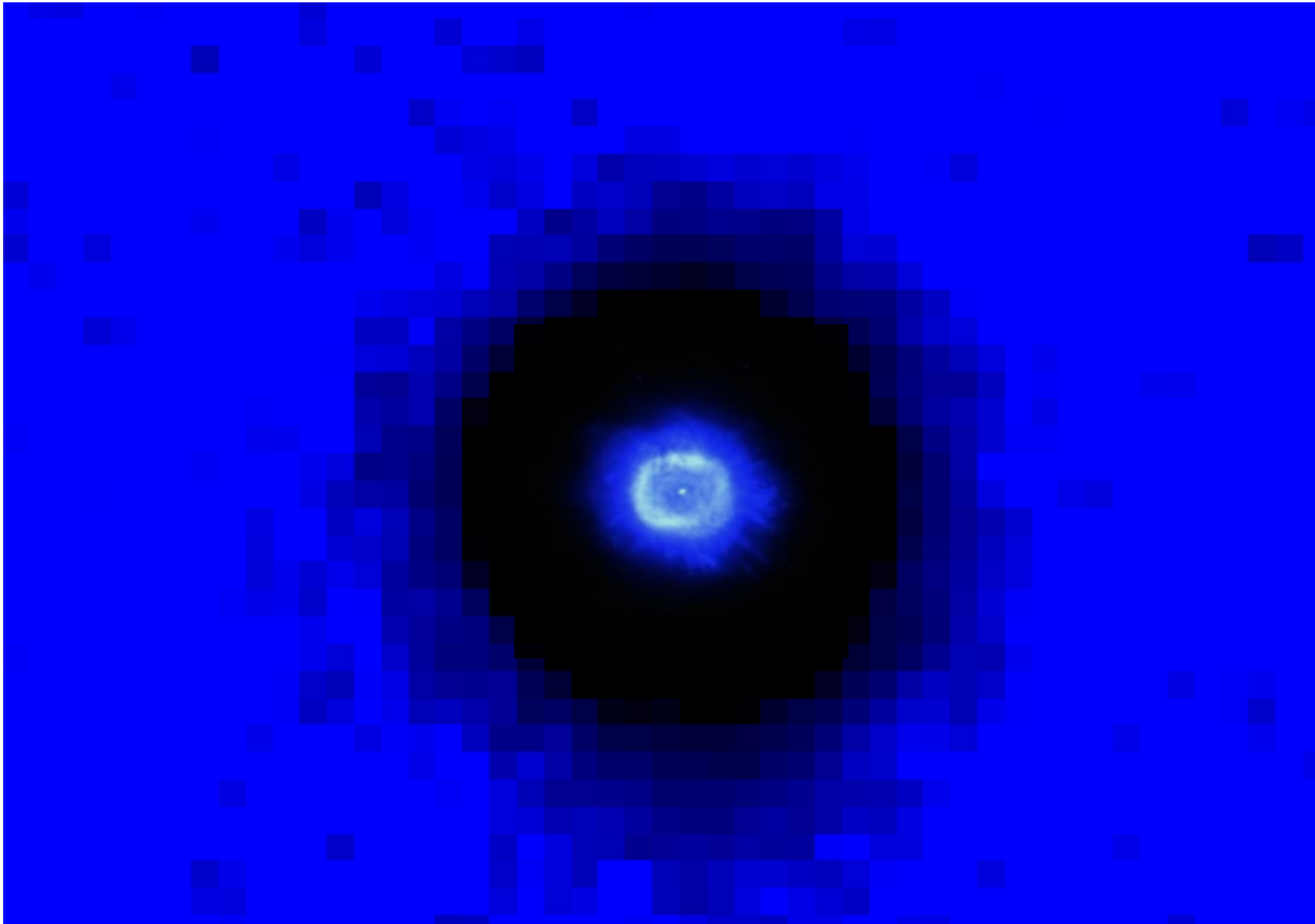
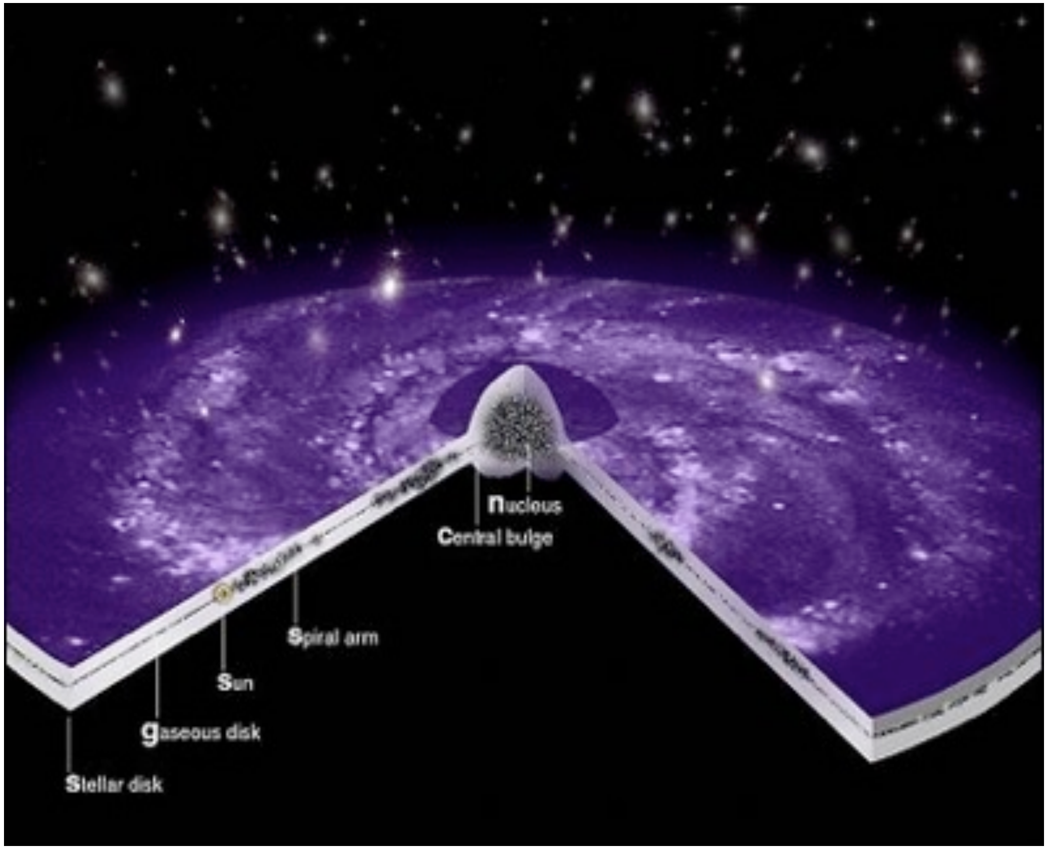
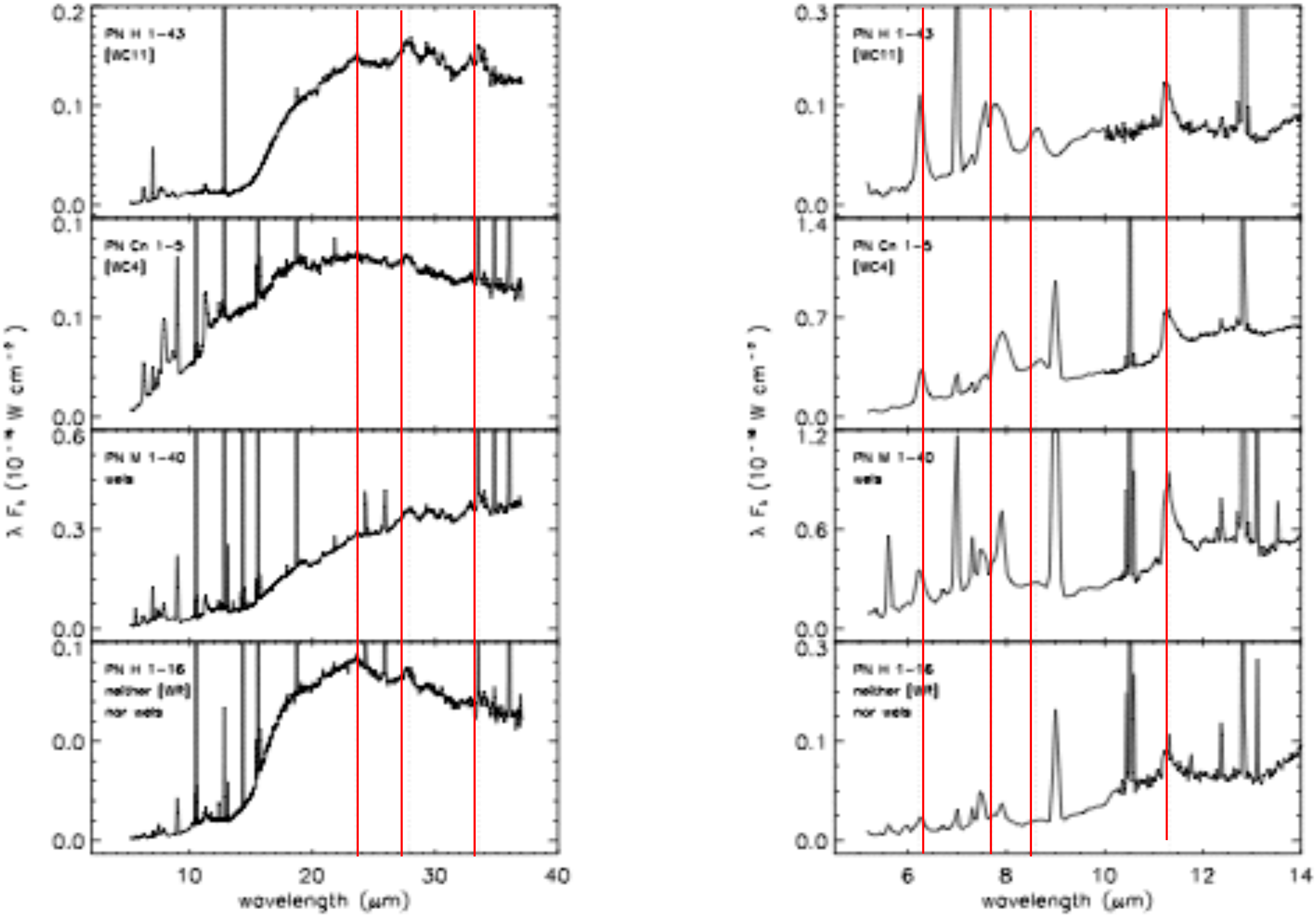


Low mass stars that never experienced a very late thermal pulse: CO photodissociation and PAHs formation in the dense environments os a disk or a torus.

Bulge Planetary Nebulae



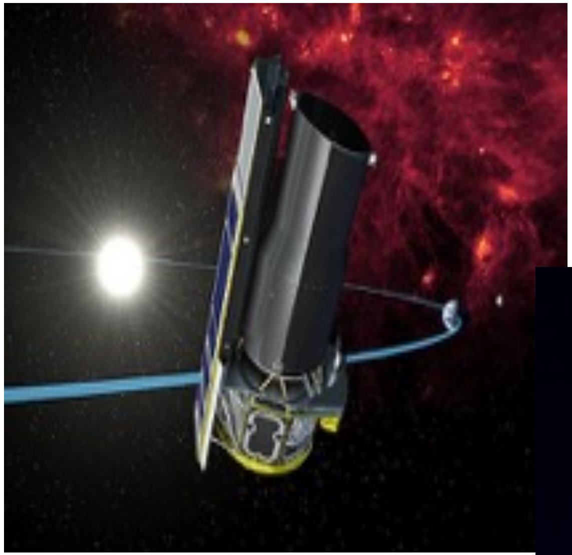
The mixed chemistry problem: Observed in PNe from the Galactic Bulge.



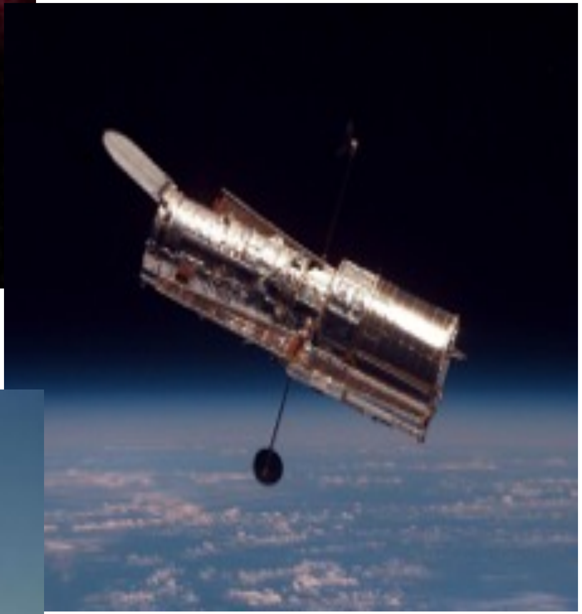
Gutenkunst et al. 2008, Perea-Calderon et al. 2009

Internal: PAHs from the nebula

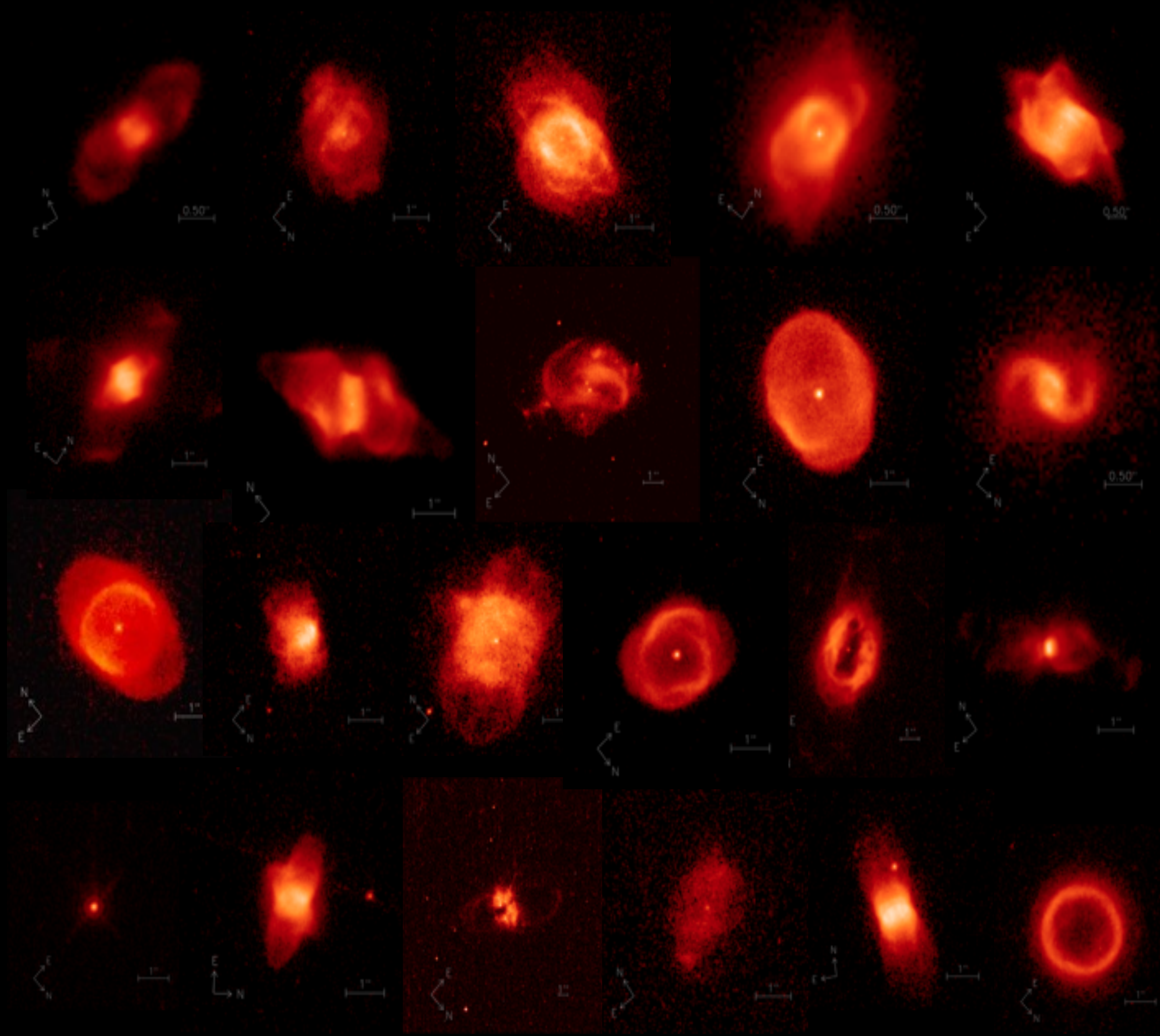
Spitzer archive - 40 PNe
IR (5.2 -37.2 μm)



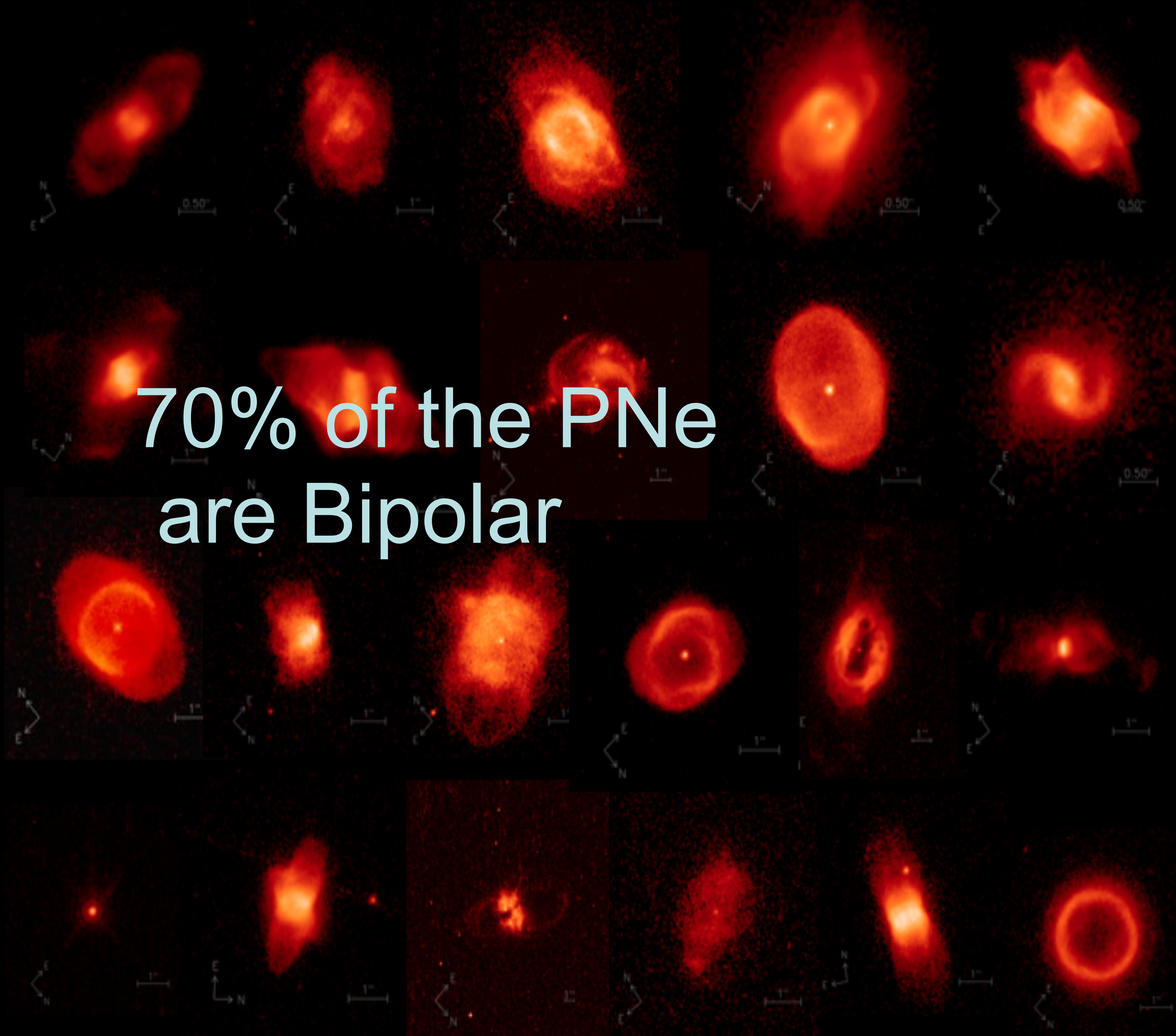
HST - 22 PNe
Visible - Hα image



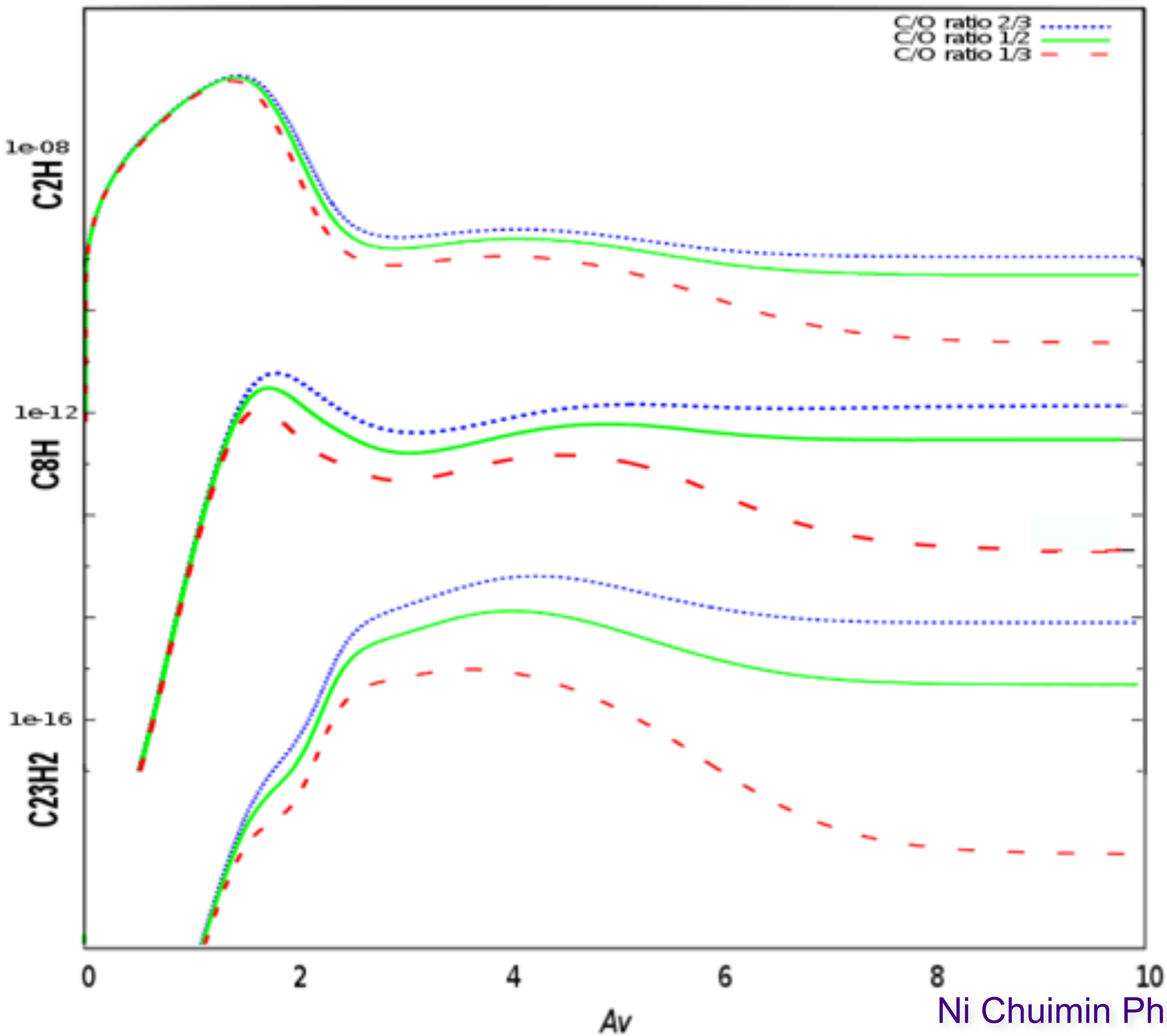
VLT - 22 PNe
Central Star spectrum UV (3300 - 6600 A)



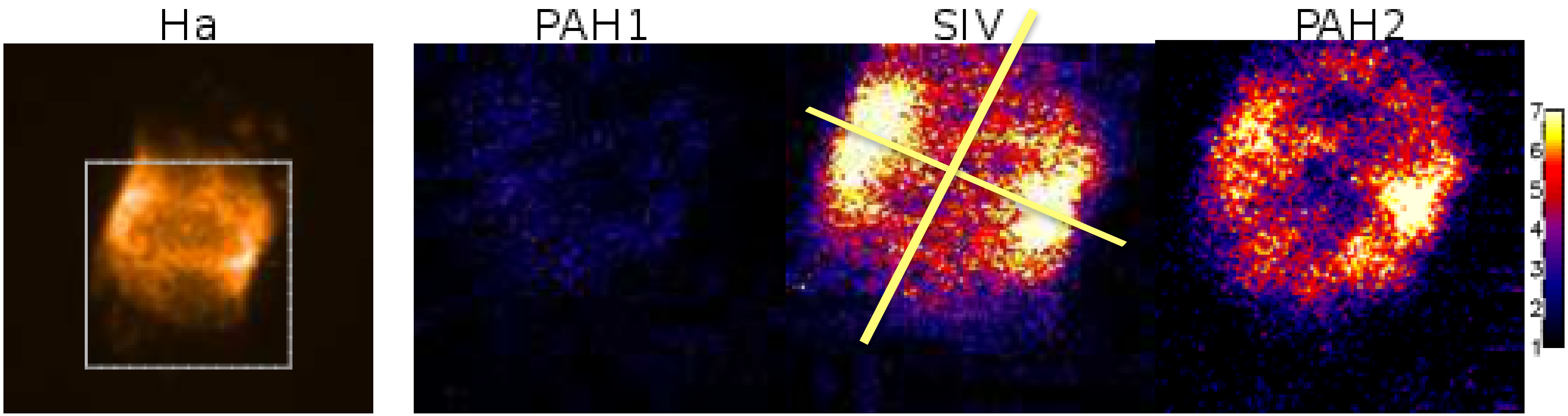
70% of the PNe are Bipolar



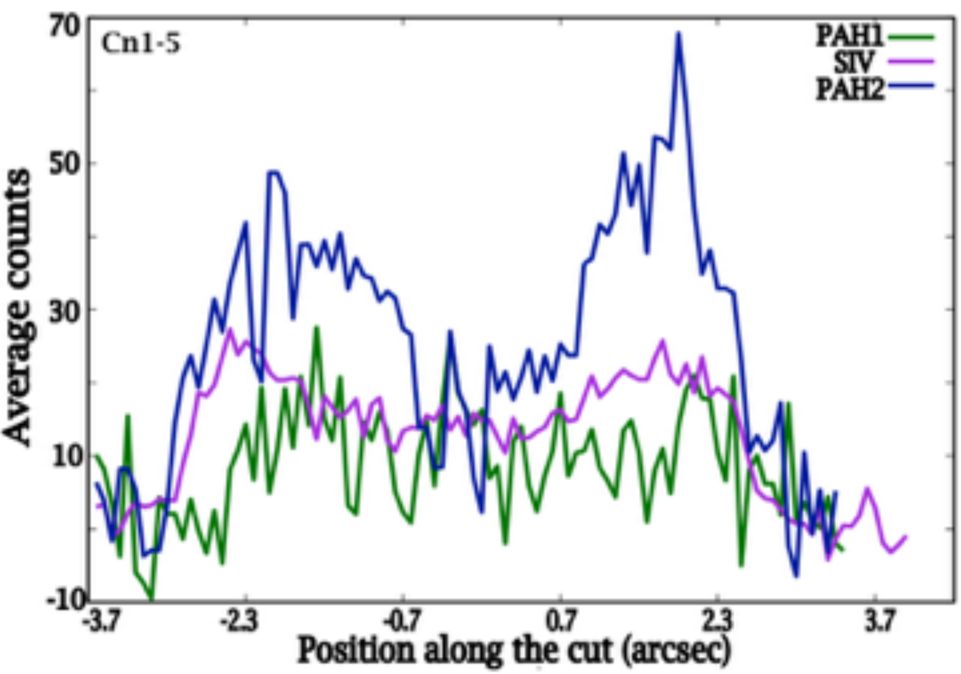
After CO photodissociation, is possible to form long C-chain molecules in an O-rich environment



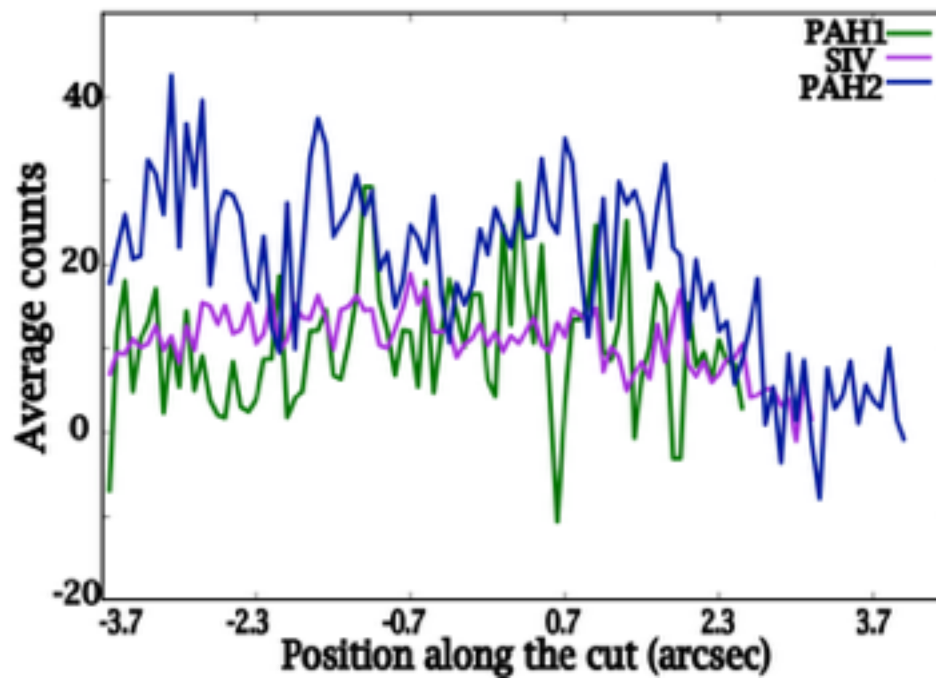
Ni Chuimin PhD thesis (2009)



Torus



Outflows



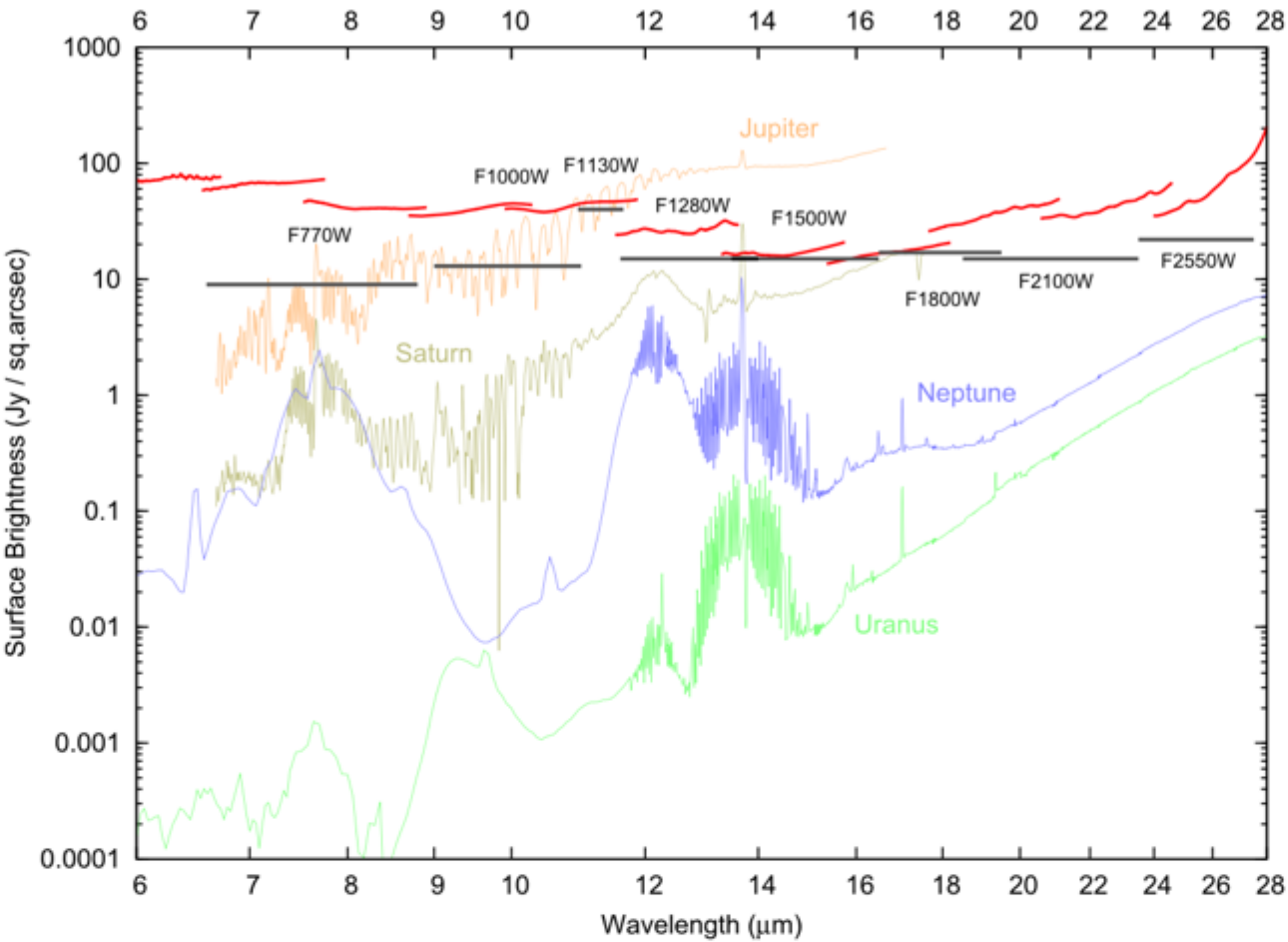
Guzman-Ramirez, L. et al., 2014

JWST Proposal

We will spatially resolve the PAHs in a selected sample of Galactic Disc (possibly very late thermal pulse objects) and Galactic Bulge objects (possibly low-mass) to solve the mixed-chemistry problem in planetary nebulae.

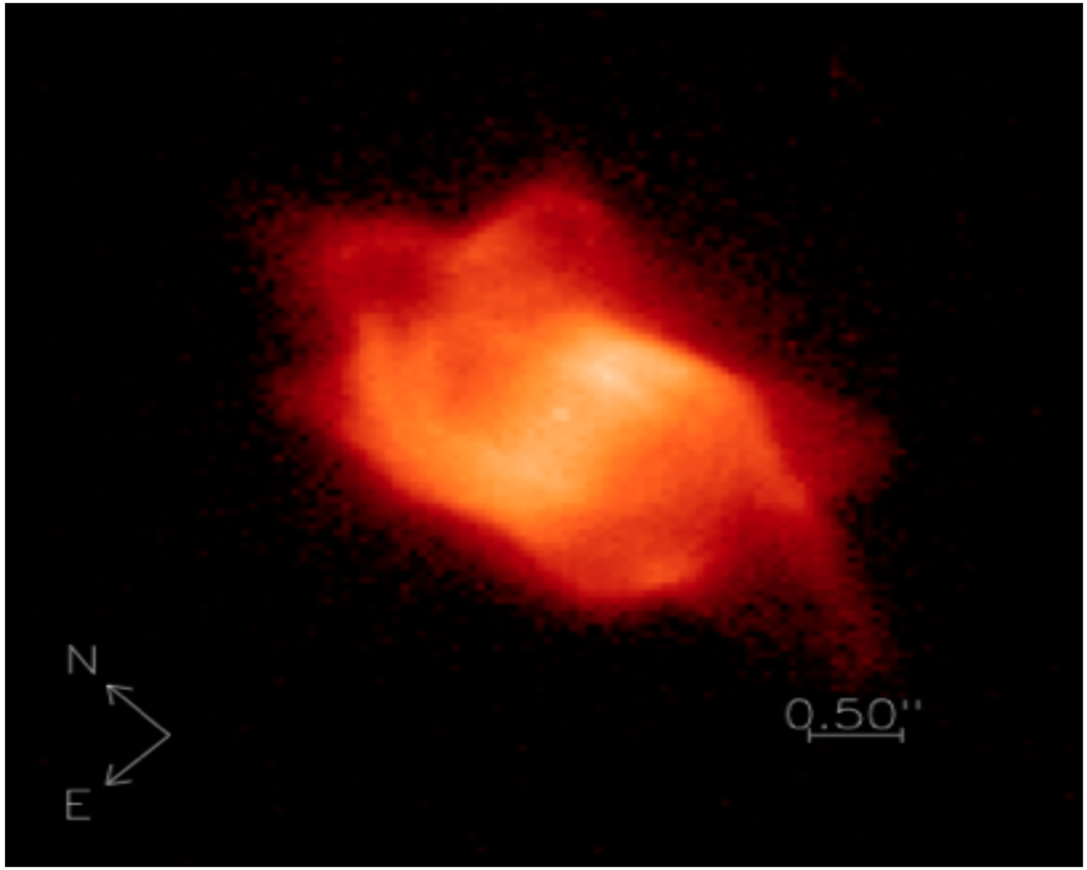
Observations using MIRI would give us 0.11” imaging resolution, to trace the PAHs in all the mixed-chemistry PNe.

MIRI/JWST



Surface Brightness (Jy / sq.arcsec)
Wavelength (µm)
1000
100
10
1
0.1
0.01
0.001
0.0001
6
7
8
9
10
12
14
16
18
20
22
24
26
28
Jupiter
Saturn
Neptune
Uranus
F770W
F1000W
F1130W
F1280W
F1500W
F1800W
F2100W
F2550W

JWST

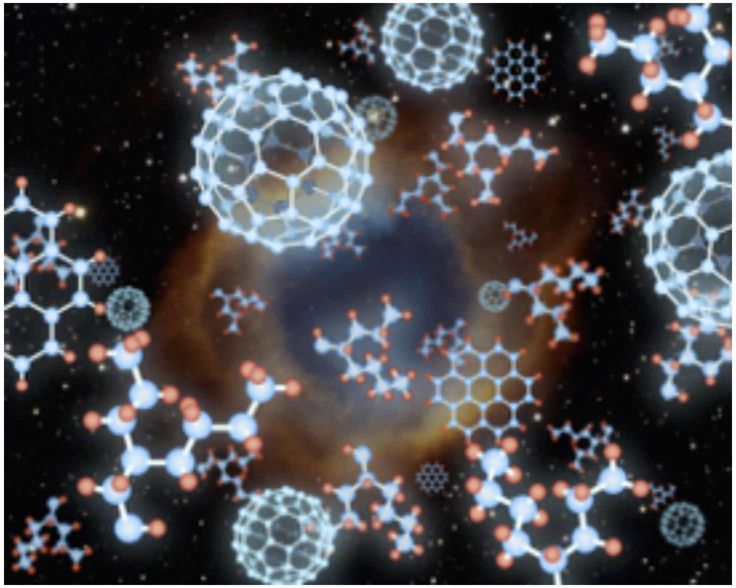


M1-31
size = 4.3sq.arcsec
Flux at 10um = 140mJy at 10μm
Using the PASP figure saturation limit is ~17 Jy/sq.arcsec

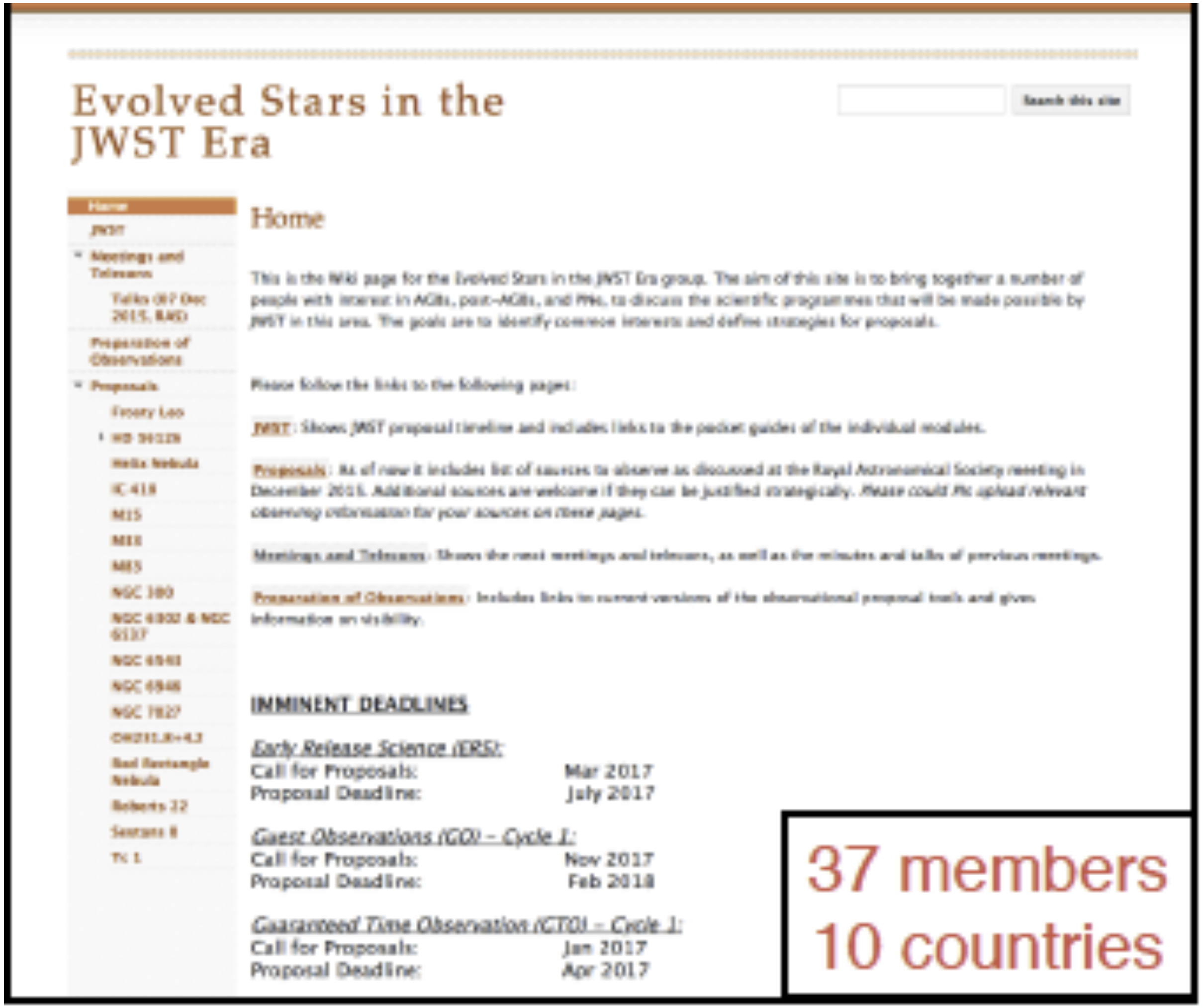
“Evolved Stars in the JWST Era” Working Group

What is the origin of the tremendous molecular diversity in circumstellar media?

How does AGB dust composition and production evolves over cosmic time?



https://sites.google.com/a/jwstevolvedstars.net/wiki/home



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