

The Dusty Side of Planetary Nebulae: a HerPlaNS View

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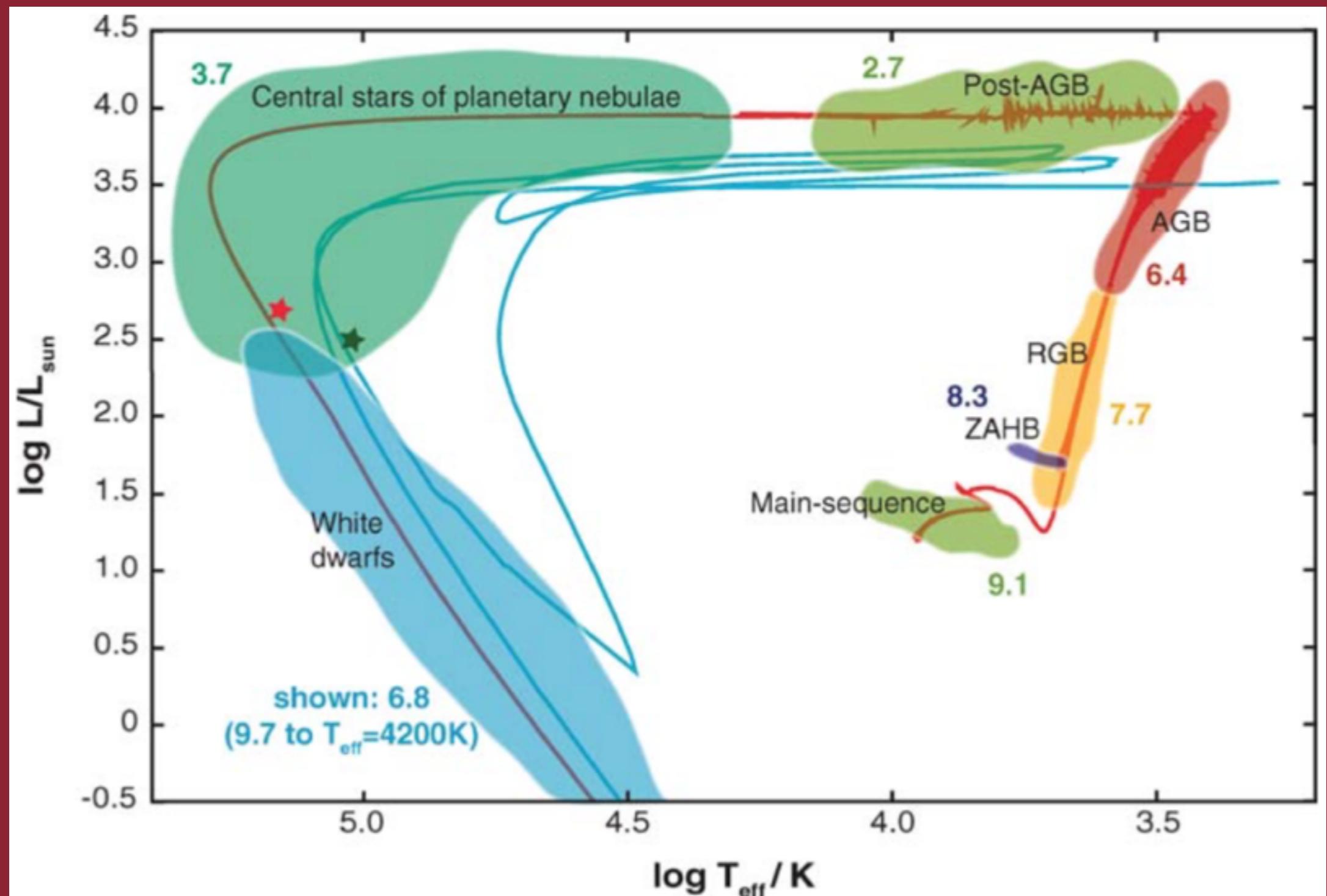
IAU TGF Fellow, Gemini-South

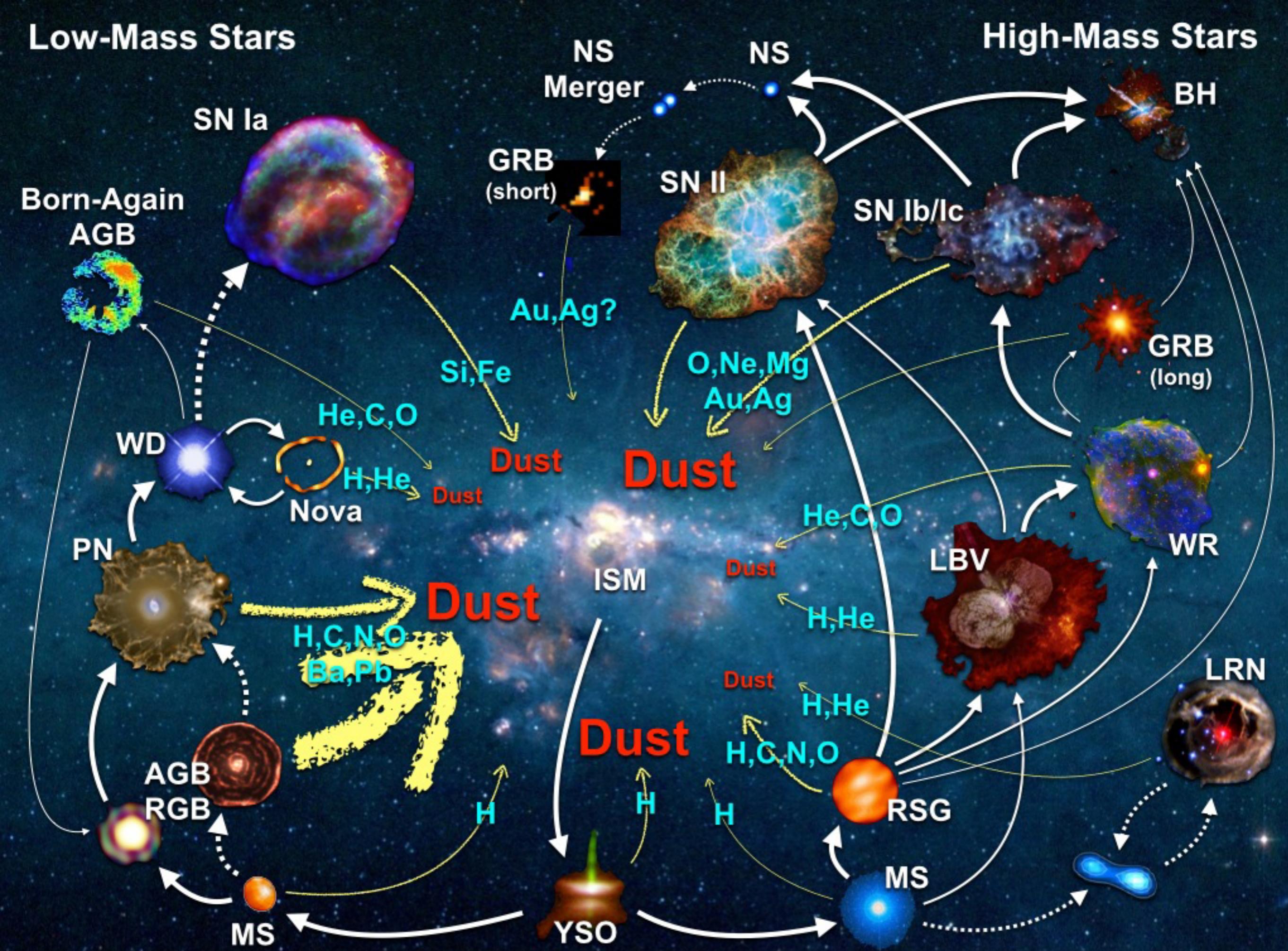
& The HerPlaNS team

PRCSA2015 @ HKU
Dec. 15, 2015



Planetary Nebulae (PNe)

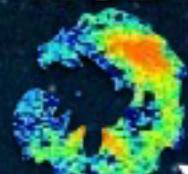




Low-Mass Stars



Born-Again AGB



WD

SN Ia

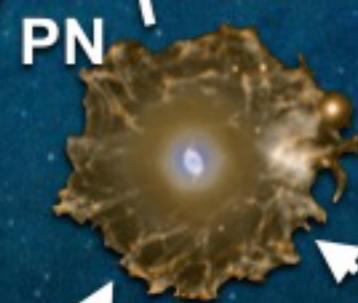
He,C,O

H,He

Si,Fe

Au,Ag?

Dust



PN

Dust

H,C,N,O

Ba,Pb

AGB
RGB

MS

YSO

NS
Merger

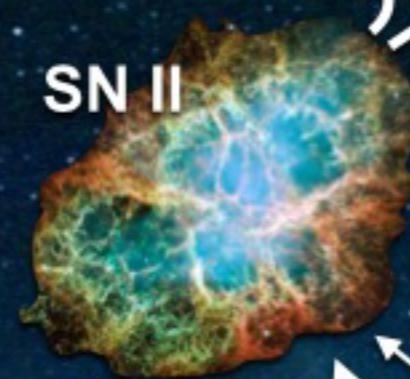
GRB
(short)

Dust

MS

YSO

High-Mass Stars



SN Ib/Ic



GRB
(long)



WR

LBV

Dust

He,C,O

H,He

Dust

H,He

H,C,N,O

RSG

LRN

MS

NS

Merger

GRB

(short)

SN II

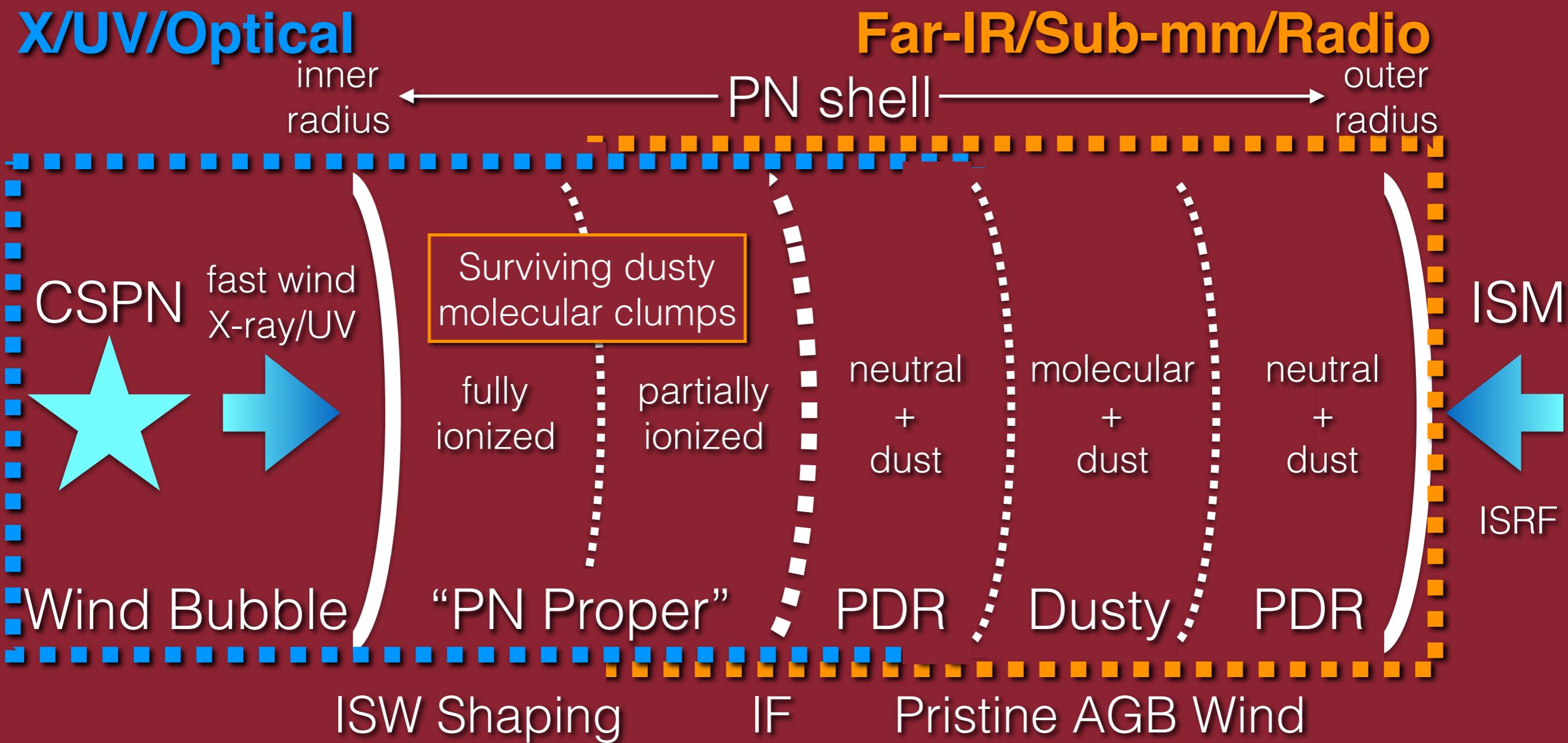
Au,Ag

O,Ne,Mg

Au,Ag

Dust

PN Dust Component



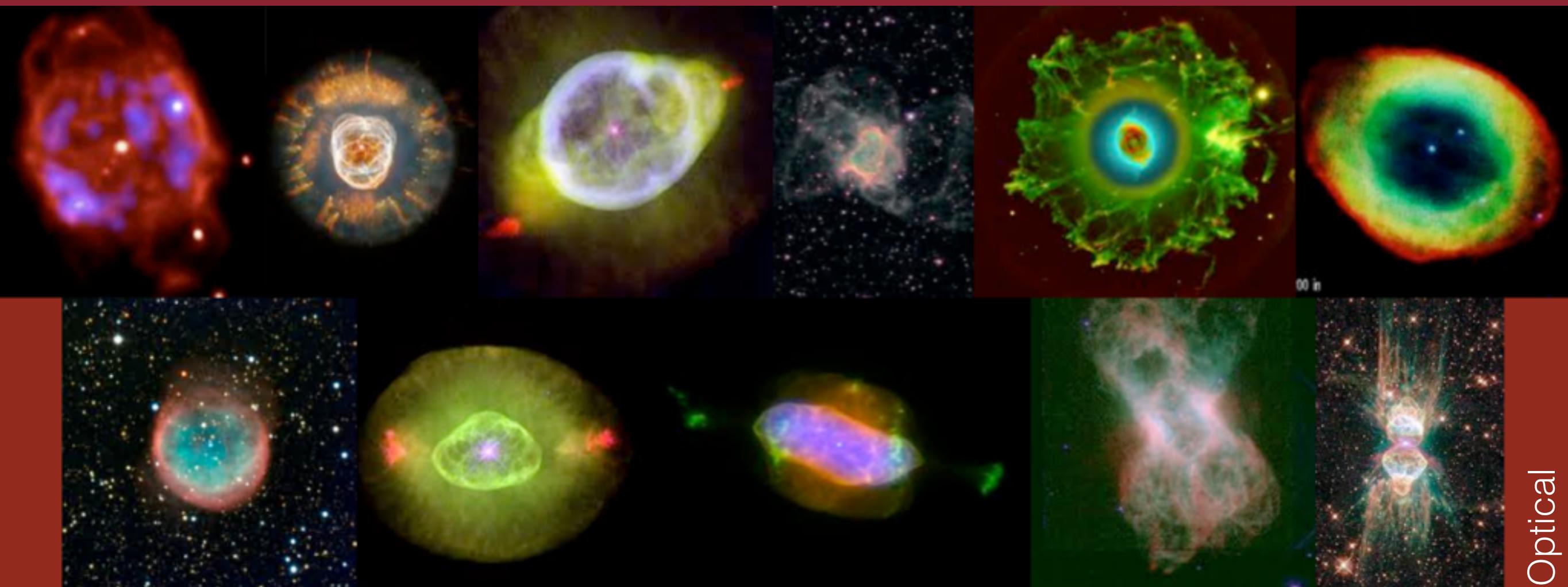
HerPlaNS

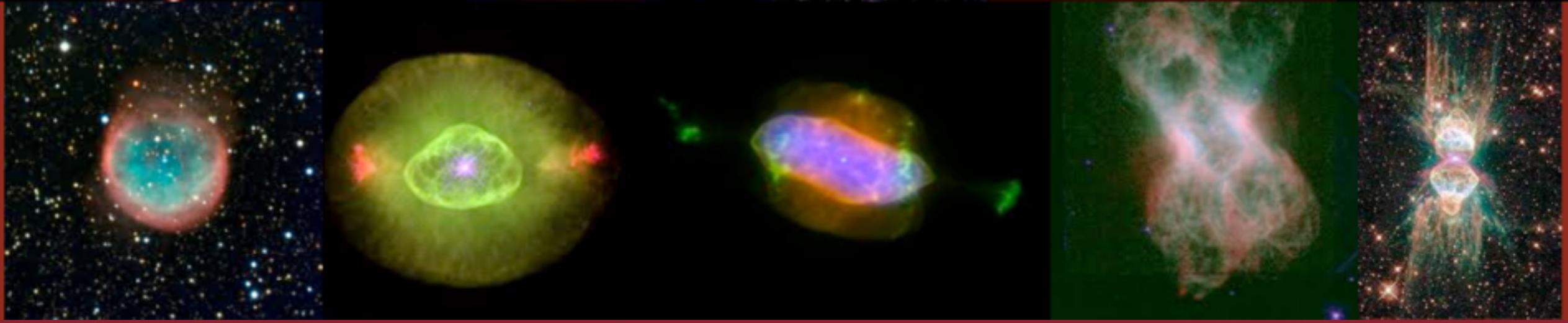
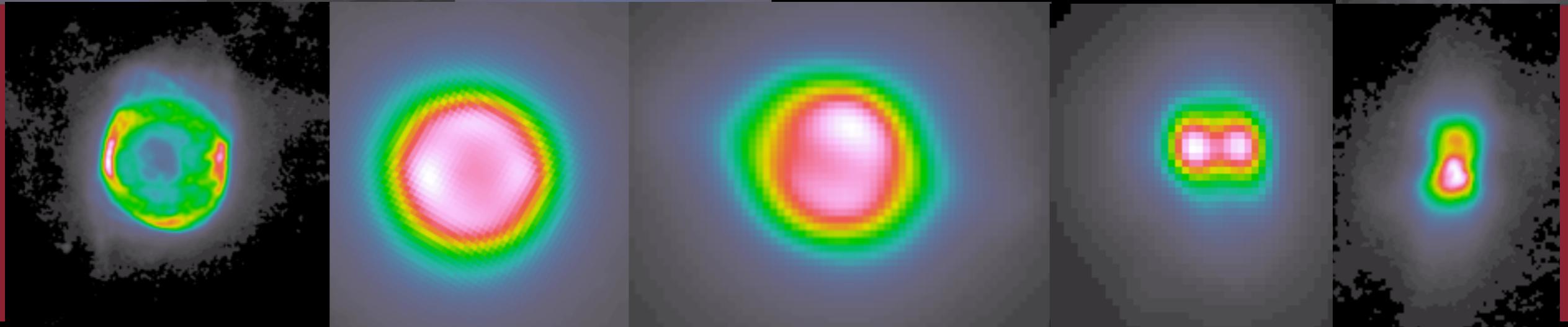
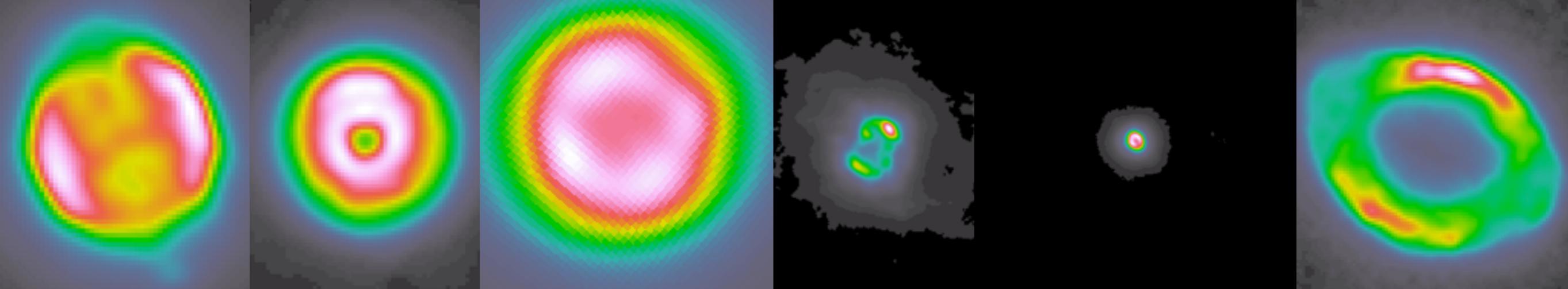
- Herschel Planetary Nebula Survey (Open Time 1)
- To learn spatial variations of
 - thermal dust continuum via broadband mapping @ 70, 100, 160, 250, 350, 500 μ m
 - T_{dust} , β distribution $\rightarrow M_{\text{dust}}$ distribution
 - far-IR ionic, atomic, and molecular line emission via multi-position spectroscopy @ 51-672 μ m
 - (T_e , N_e), abundance distribution $\rightarrow M_{\text{gas}}$ distribution
 - Spatially consistent gas-to-dust mass ratio distributions

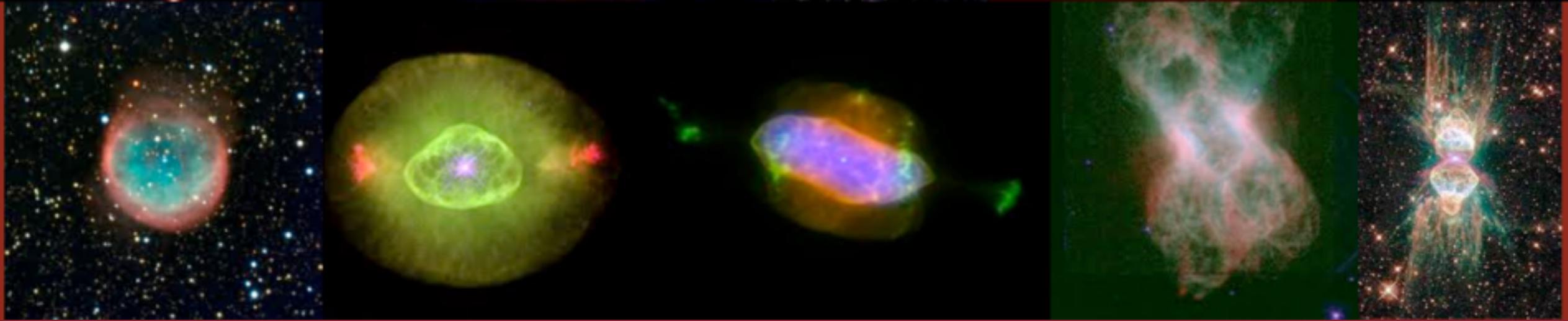
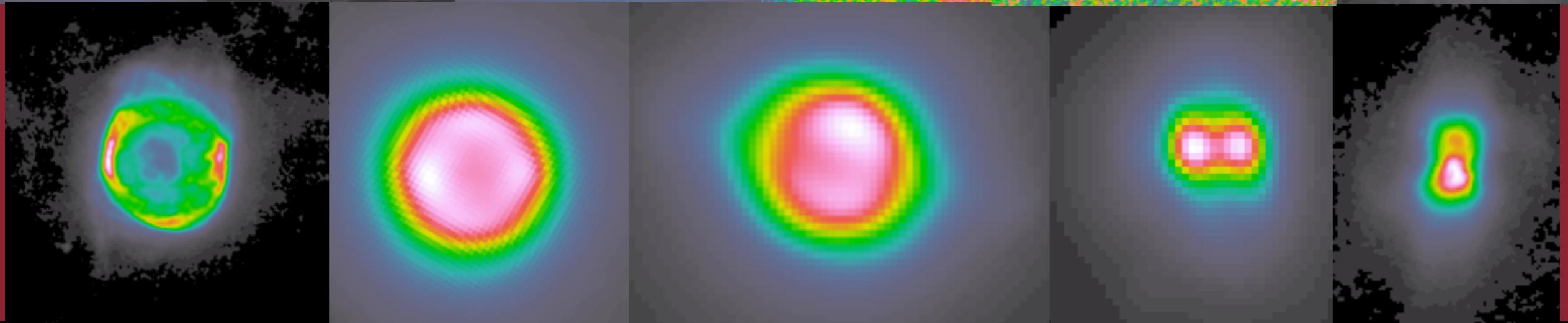
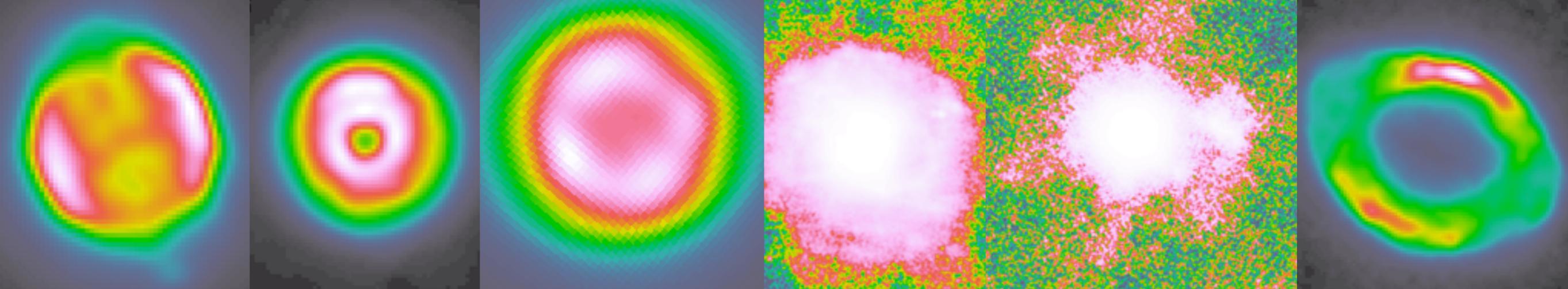
Ueta et al. 2014, A&A, 565, A36 (HerPlaNS I)
Aleman et al. 2014, A&A, 566, A79 (OH^+ discovery)
Ladjal et al. *in prep* (HerPlaNS II; this talk)

HerPlaNS Target PNe

- 11 High-Excitation PNe (with X-ray emission)
 - NGC 40, 2392, 3242, 6445, 6543, 6720, NGC 6781, 6826, 7009, 7026, Mz3

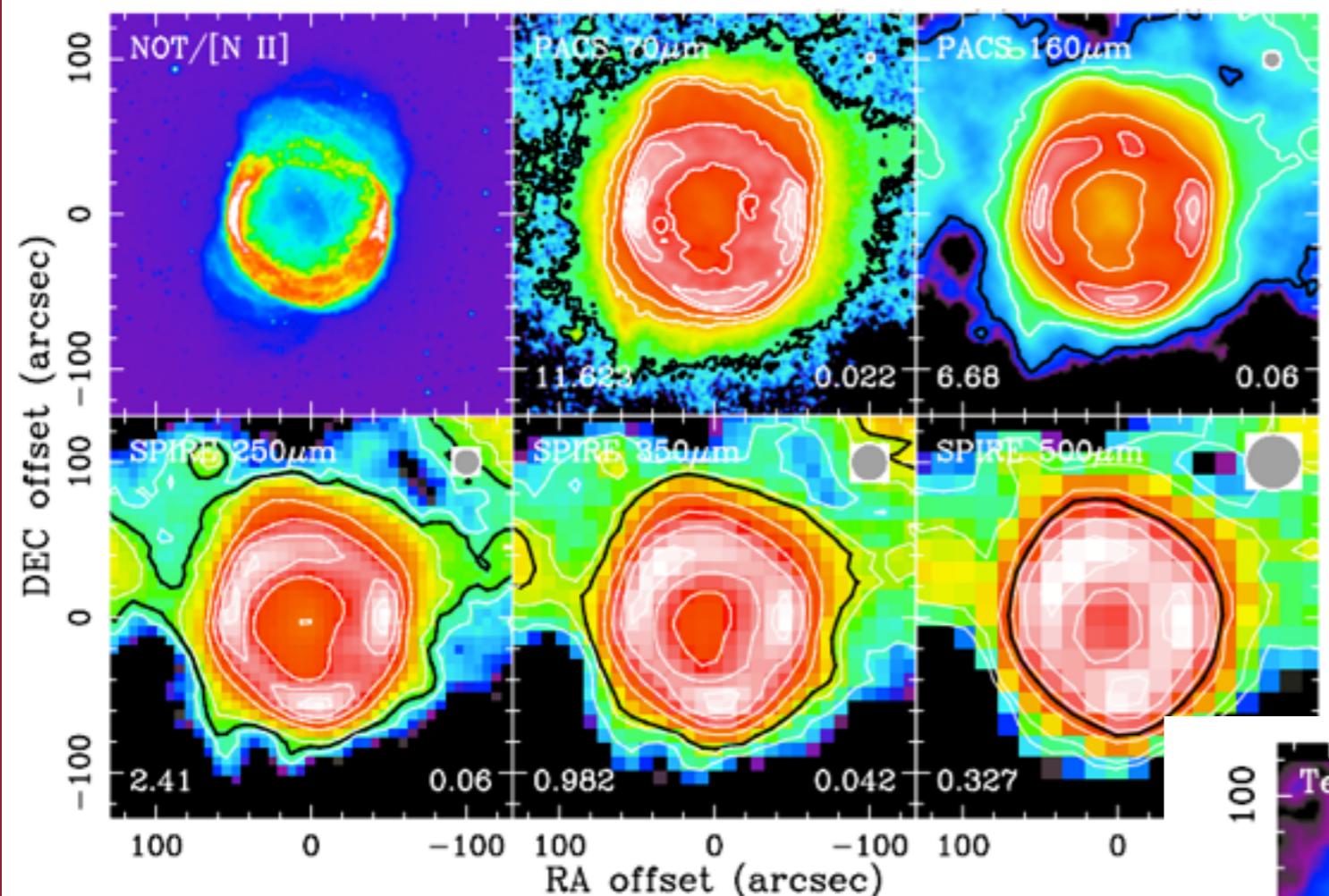






70 μ m

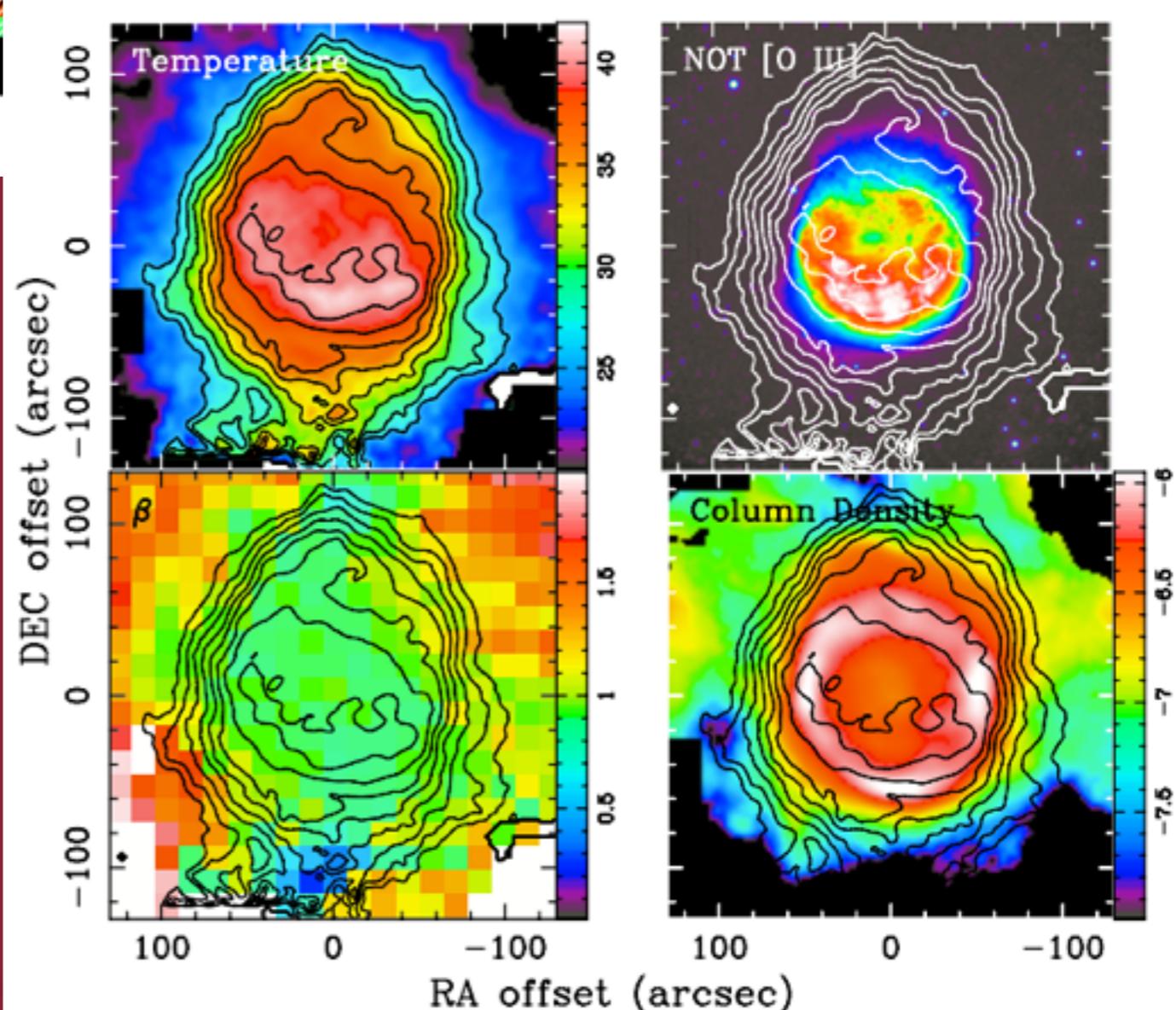
Optical

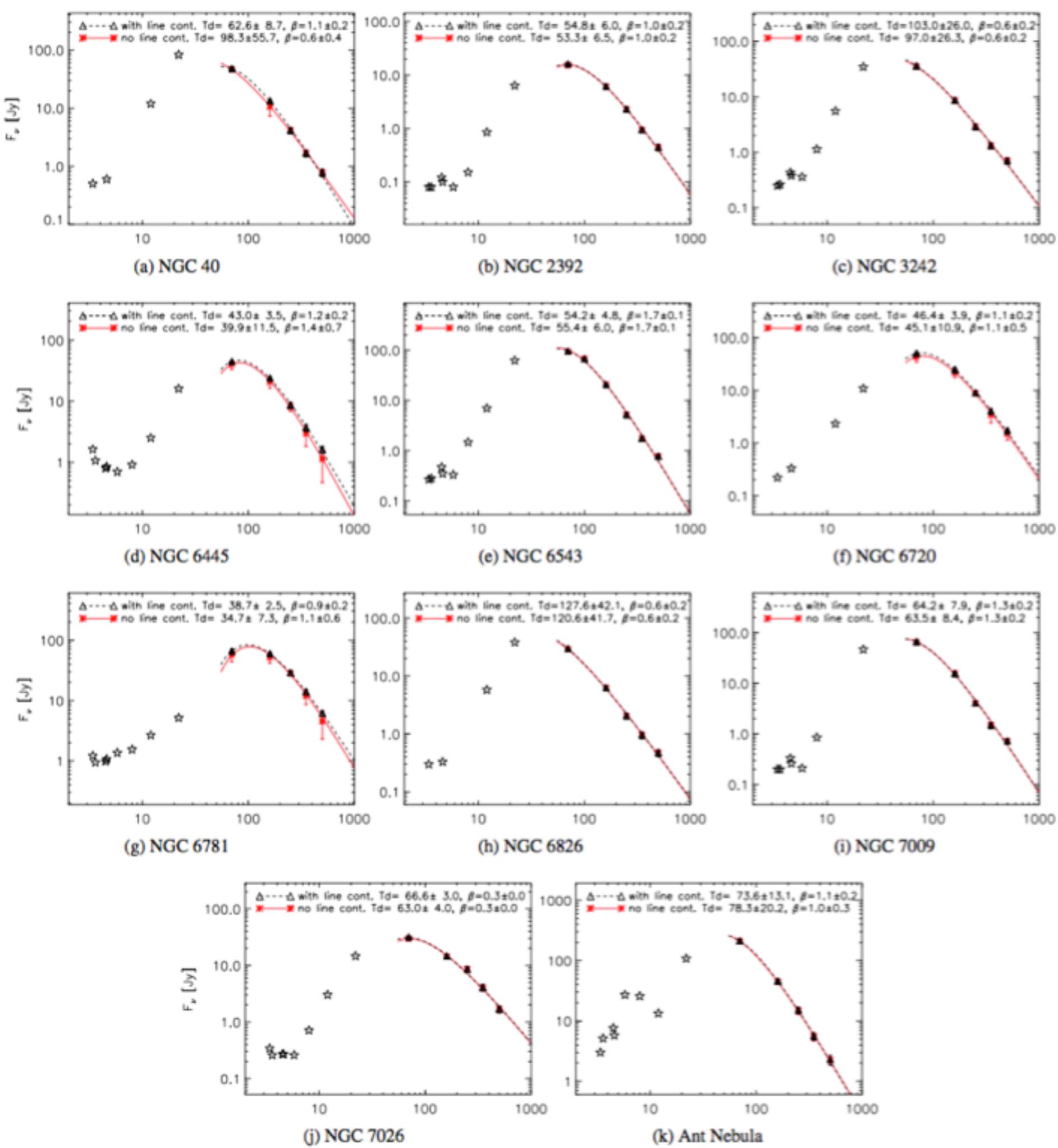


Modified BB fitting

$S_\nu \propto \lambda^{-\beta} B_\nu(T_{\text{dust}})$

- $T_{\text{dust}} = 26\text{-}40 \text{ K}$
- $\beta \sim 1.0$

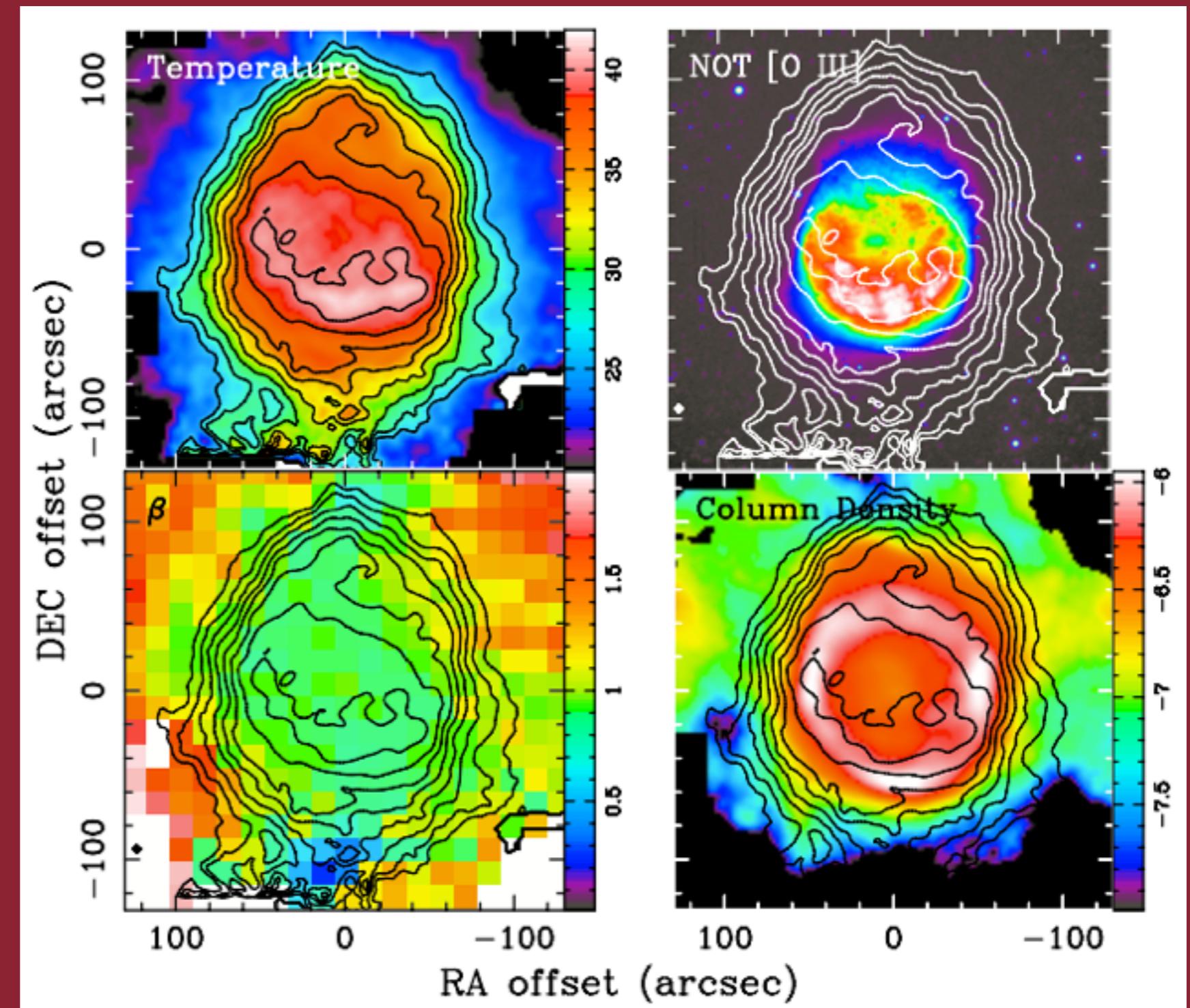




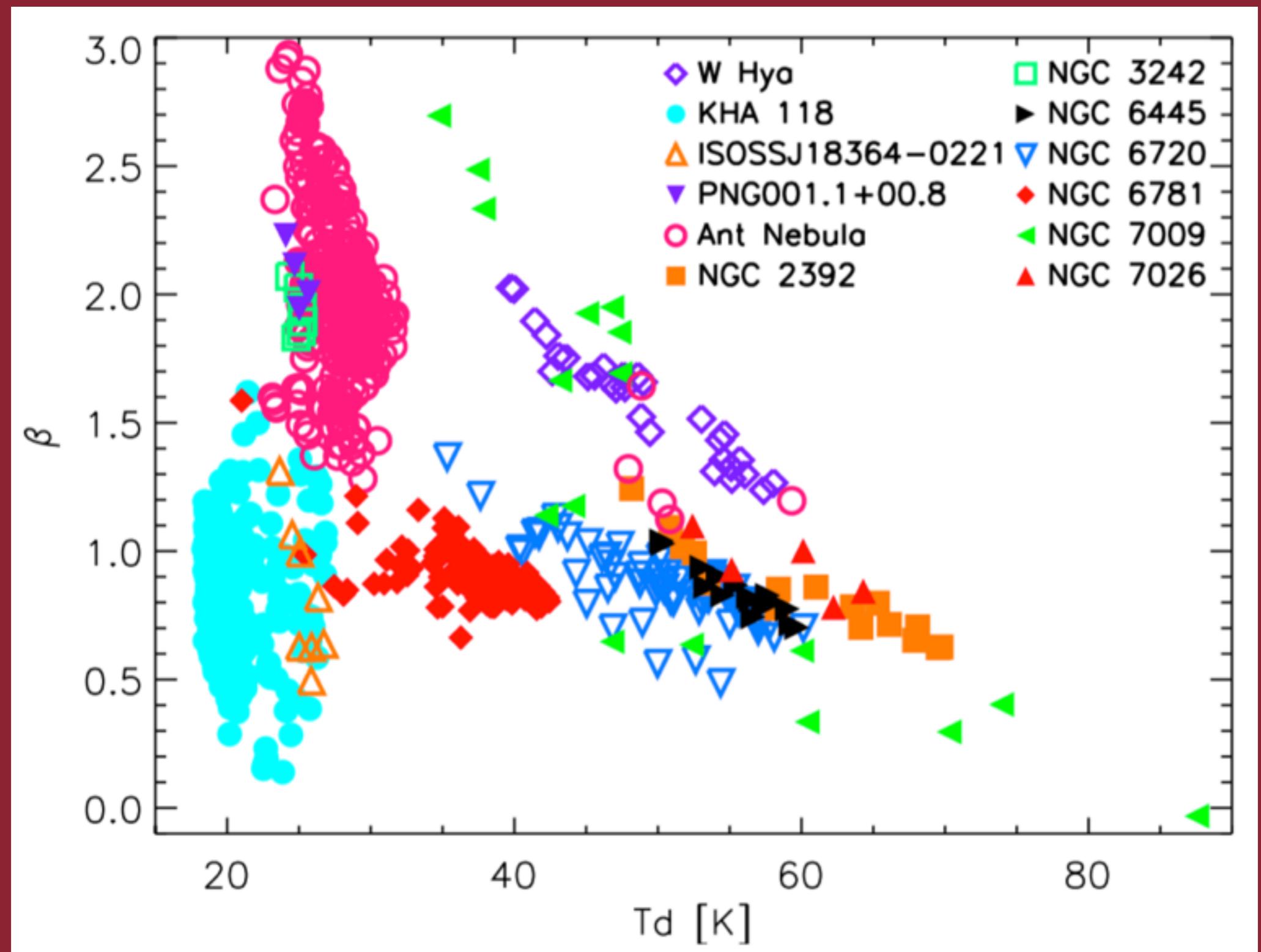
- $T_{\text{dust}} = 40\text{-}100 \text{ K}$
- $\beta \sim 1.0$
- No single T_{dust} fit for both mid-IR and far-IR
- Different T_{dust} regimes exist
- Significant amount of cold dust exists beyond PN proper

Spatially-Resolved β vs. T_{dust}

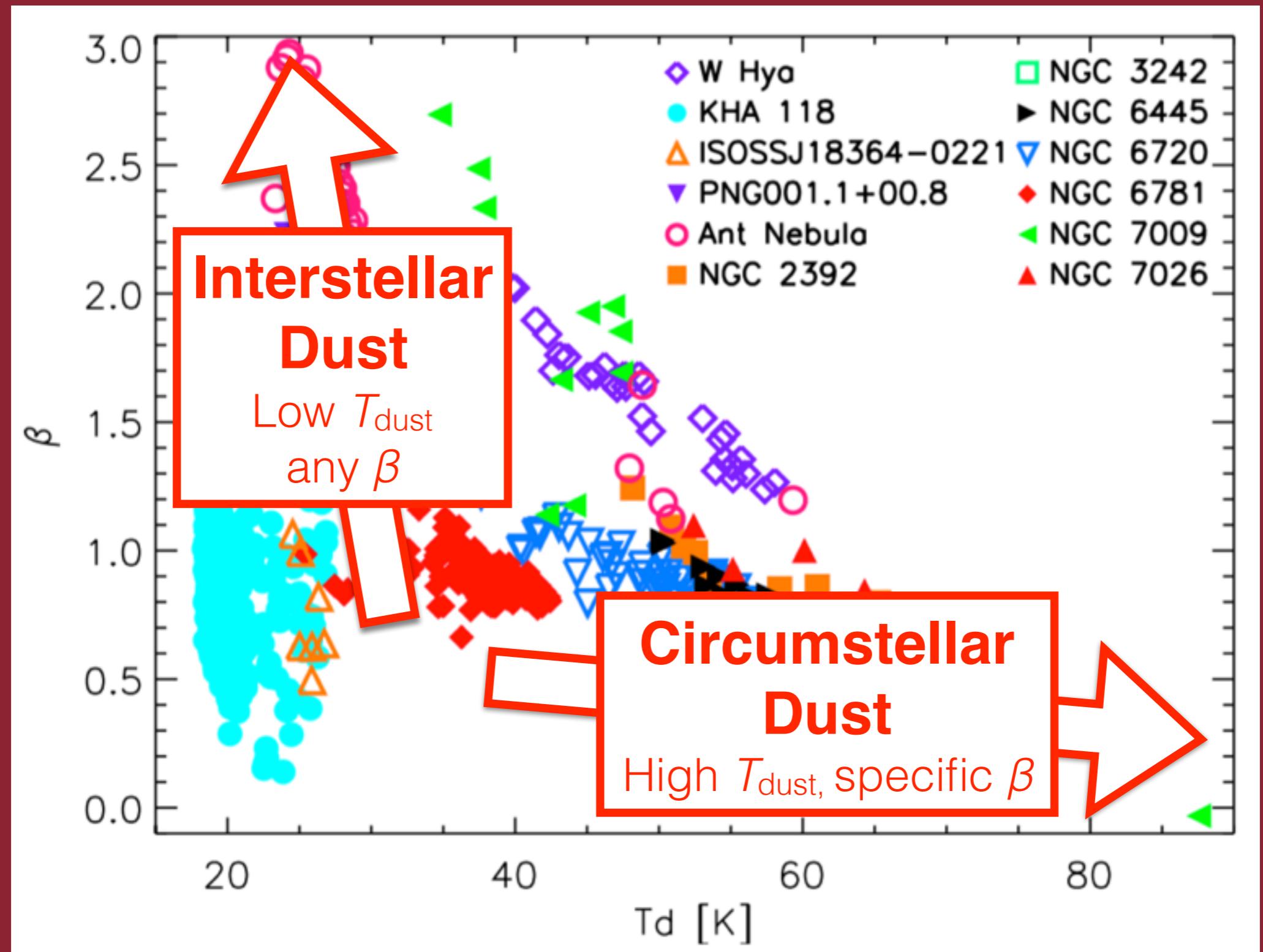
- $T_{\text{dust}} = 26\text{-}40 \text{ K}$
- $\beta \sim 1.0$



Spatially-Resolved β vs. T_{dust}



Spatially-Resolved β vs. T_{dust}



Summary

- The largest fraction of thermal IR dust emission from PNe arises in the far-IR
 - The coldest dust component in PNe due to ancient AGB wind cannot be ignored in the mass accounting and total energetics.
- Spatially-resolved β - T_{dust} relationship can separate the circumstellar and interstellar dust components
 - Circumstellar Dust: High T_{dust} , specific β
 - Interstellar Dust: Low T_{dust} , any β

HerPlaNS+

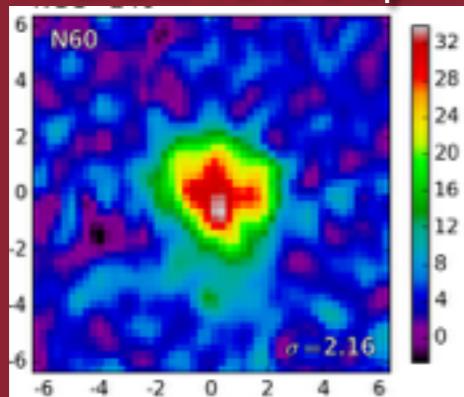


- Exhaustive Search in the Herschel Science Archive
 - ➔ ~200 targeted sources for broadband maps
 - ➔ ~40 targeted sources for gas line maps
 - ➔ many more serendipitous coverage cases
 - ➔ supported by NASA ADAP grant

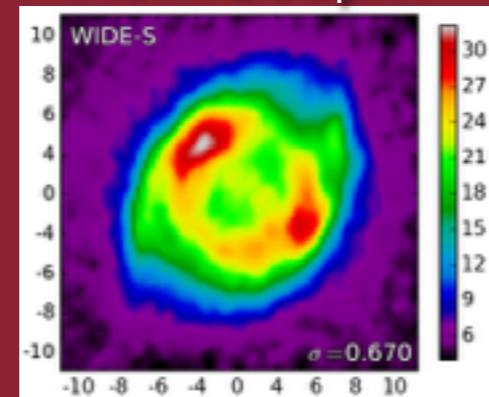
AKARI Far-IR All-Sky Survey Maps

- PN extraction from the AKARI far-IR all-sky survey map data with surface brightness correction
- Match with the Frew list of 2752 PNe
 - 145 consecutive 3-band detections
 - 334 consecutive 2-band detections
 - 409 other detections
- Cold dust mass catalog, etc

NGC246@60μm



Helix@90μm



Dumbbell@140μm

