# Evolved Star Science with SPICA

## 晩期型星にまつわるSPICAサイエンス

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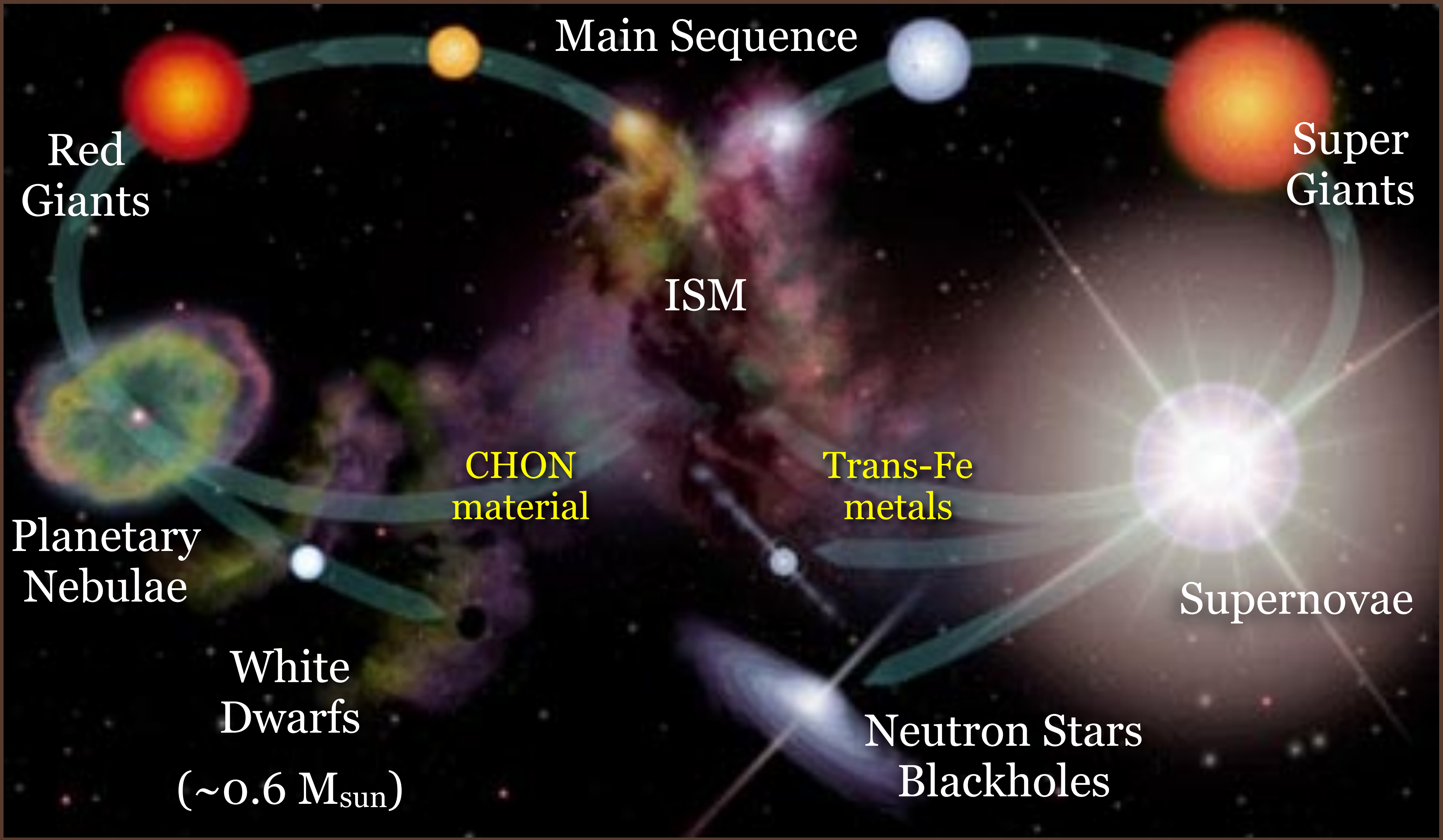
# Goals of Evolved Star Science

Low Mass Stars (<8M$_{sun}$) High Mass Stars (>8M$_{sun}$)



# Goals of Evolved Star Science

1. Understand physical and chemical yields of the mass loss ejecta into the ISM
2. Understand physics and chemistry of mass loss processes
3. Understand physics and chemistry of the Wind-ISM interaction
4. Understand the development of the complex shell structures

# Methods

- Determine the surface brightness variations and relate them to physical and chemical conditions as functions of radius/time

$$\text{e.g. } I_\nu(r) \rightarrow \rho(r) \rightarrow \dot{M}(t)$$

- Obtain statistically robust results by collecting a sufficiently large sample

# Recent Highlights

- AKARI MLHES MP (PI: Yamamura, Izumiura)
  - 144 AGB/post-AGB/PN/RSG
  - FIS broad-band thermal dust mapping (4 band)

(Ueta et al. 2008, 2010; Izumiura et al. 2011; ...)

- Spitzer GTO/MIRIAD (PI: Speck)/MLHES (PI: Ueta)
  - dozen evolved stars/4 AGB/27 AGB
  - MIPS broad-band thermal dust mapping

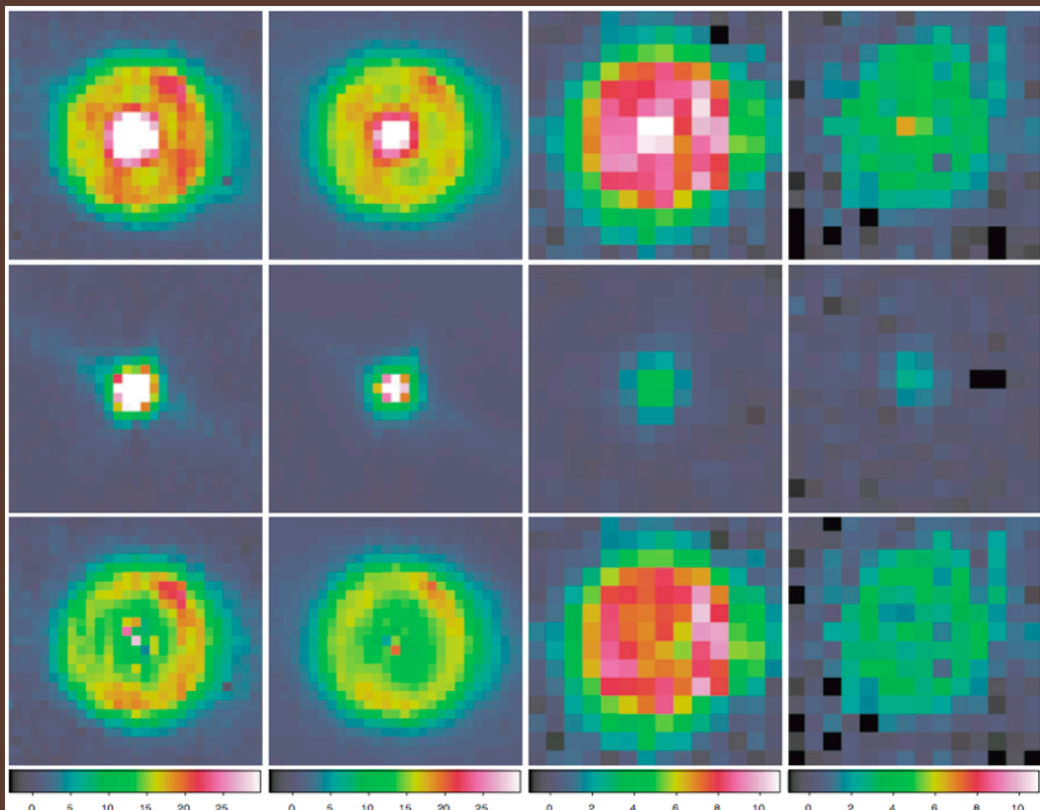
(Ueta 2006, 2008; Ueta et al. 2006; Geise et al. 2010; ...)

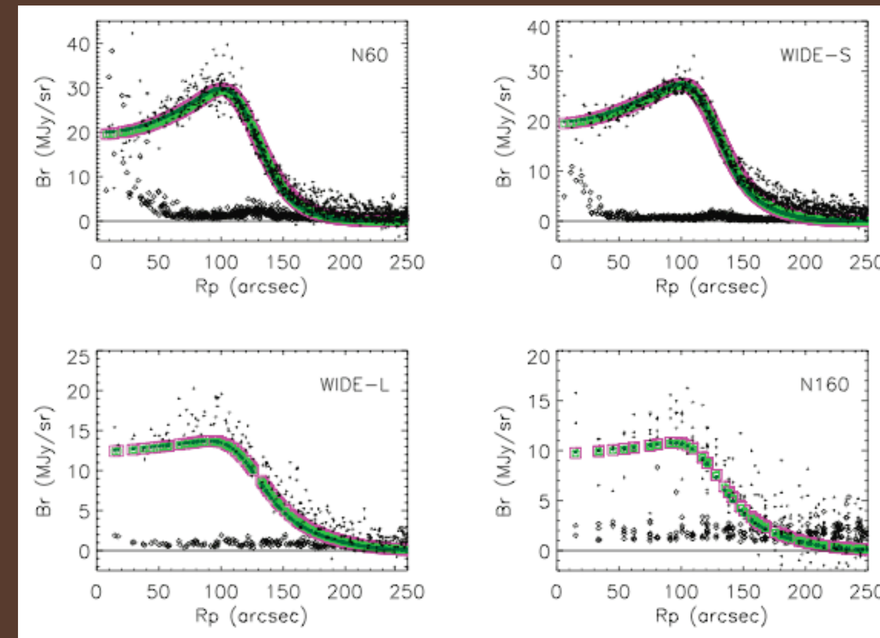
- Herschel MESS GTKP (PI: Groenewegen)
  - ~90 AGB/post-AGB/PN/RSG/SNR/WR
  - PACS/SPIRE broad-band thermal dust mapping (5 bands)
  - PACS/SPIRE pointed spectroscopy

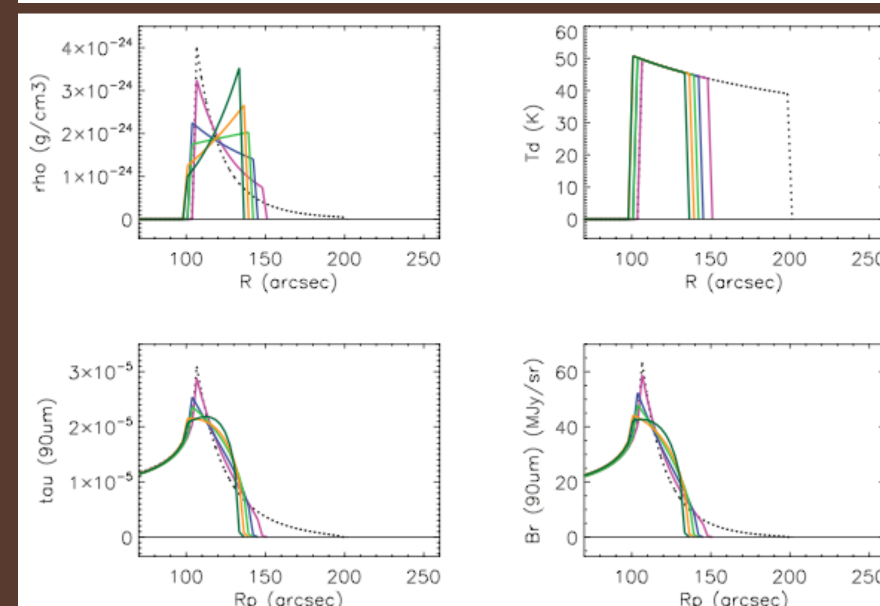
(Kerschbaum et al. 2010; Ladjal et al. 2010; Decin et al. 2010; van Hoof et al. 2010; Groenewegen et al. 2011; ...)

# AKARI MLHES

U Hya (Izumiura et al. 2011)




100” radius detached shell detected @ 1 MJy/sr

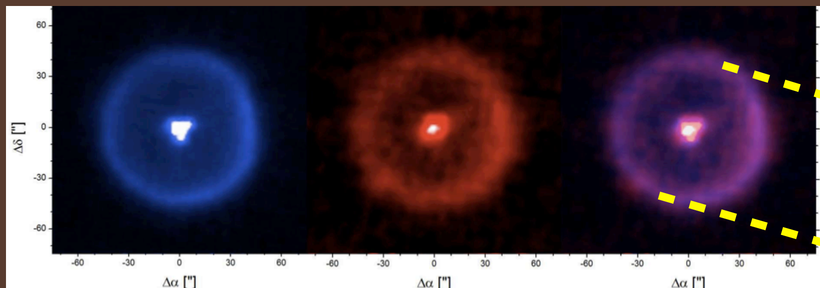
Shell thickness smaller than AKARI resolution

→ Shell origin inconclusive from RT fitting

→ Higher spatial resolution needed

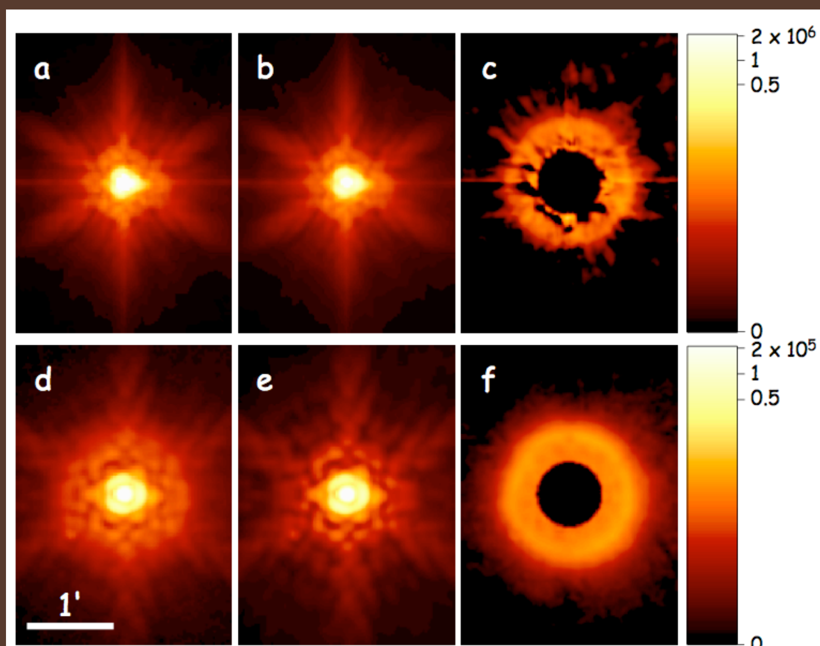
# Herschel MESS

PACS 70/160μm (Kerschbaum et al. 2010)



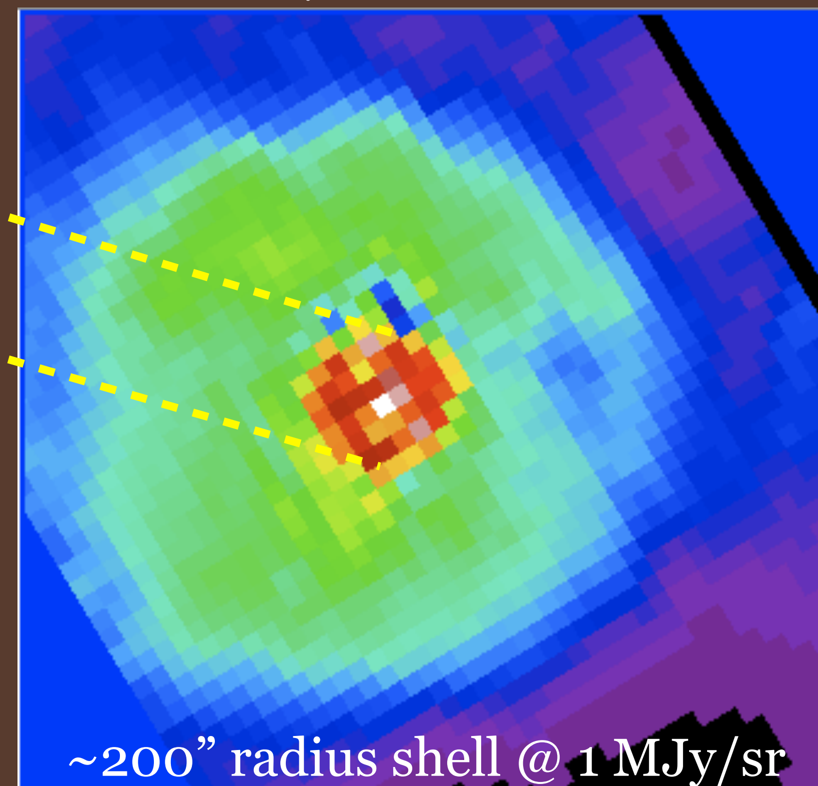

40” radius detached shell @ a few MJy/sr

AKARI IRC 15/24 μm (Arimatsu et al. submitted)




This makes good use of MCI as well!

AKARI FIS 90μm




(Not detected by Herschel!)

Spatial resolution should be well enough

→ Sensitivity is not sufficient to detect the rim

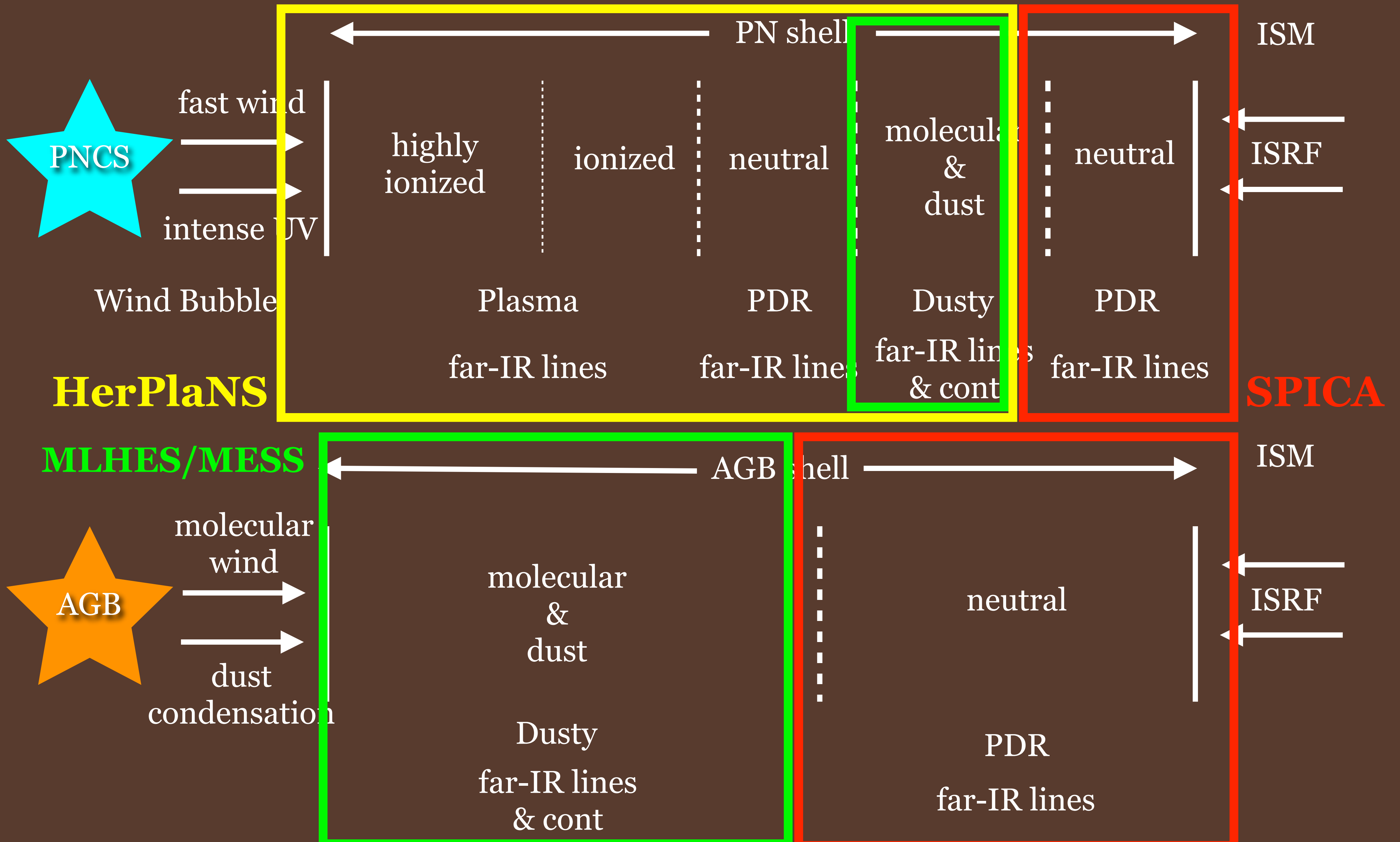
→ “Cold” Herschel = SPICA needed

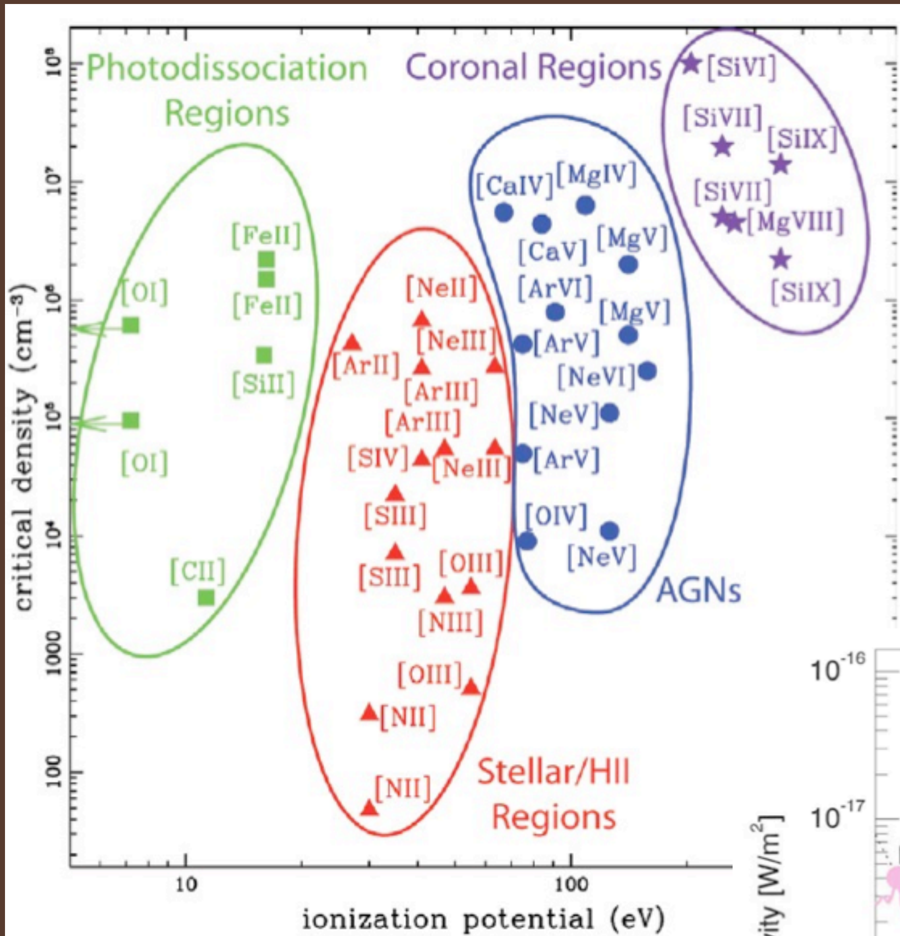
# Herschel HerPlaNS

- Herschel OT1 Planetary Nebula Survey (PI: Ueta)
  - 11 high-excitation PNs (coordinated with Chandra Survey)
  - PACS/SPIRE broad-band thermal dust mapping
  - PACS Line/Range Spectral Mapping
  - SPIRE FTS Mapping

Simultaneous probe of both the dust and gas components in the hi-ex regions of the shell

# Evolved Star Shells as Gas-Dust Systems






Far-IR line/continuum diagnostics of ionized, neutral, dust, and photo-dissociation regions

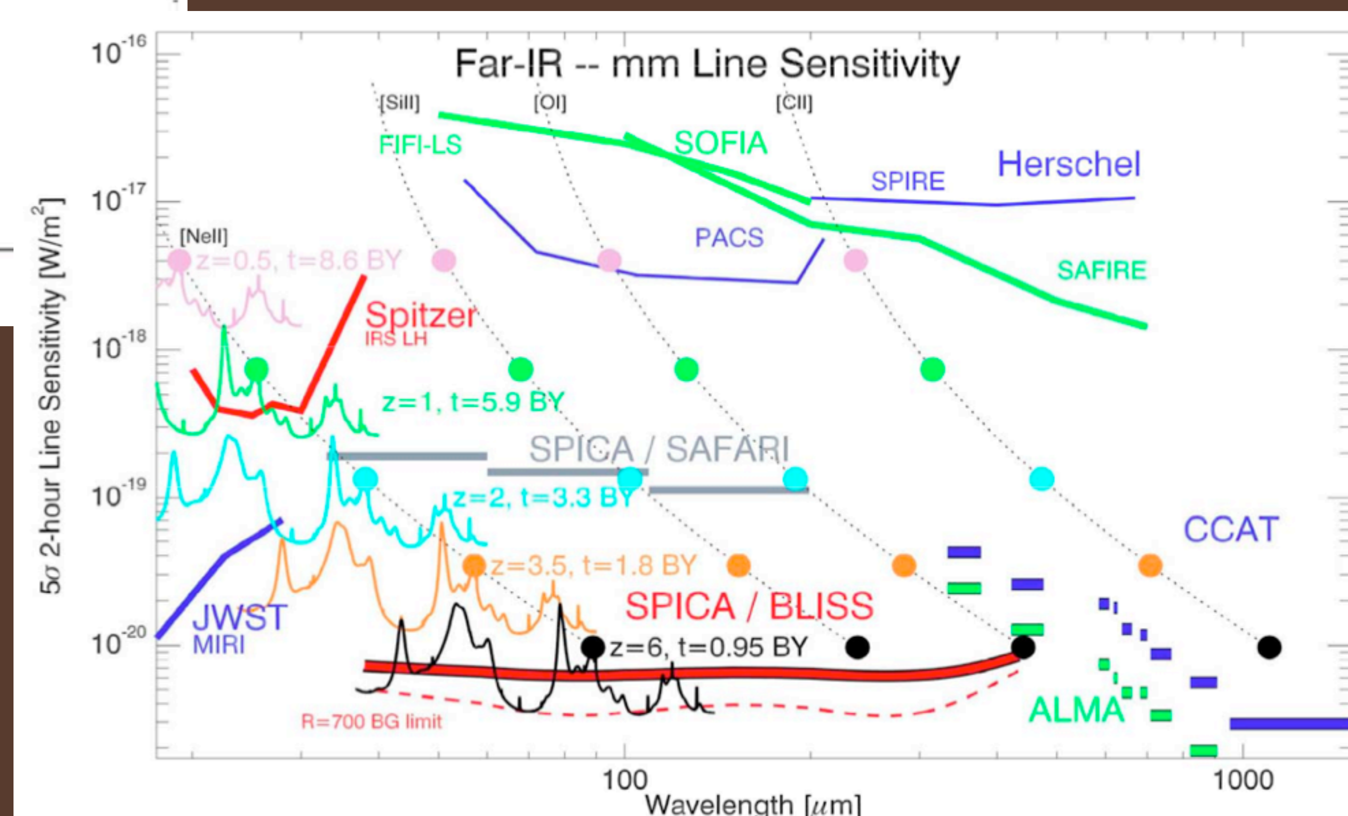
→ Min. spectral coverage of 50 to 200 μm of SAFARI and BLISS

Probing of the Shell-ISM interface regions

→ Background-limited sensitivity of BLISS

Probing of the faint shell near the bright central star

→ Mid-IR coronagraphic capabilities of SCI ($10^{-6}$ contrast is enough)



# Summary

- Needs for evolved star science
  - Simultaneous gas/dust probe in the “entire” shell
- SPICA capabilities relevant to evolved star science
  - Far-IR spectral mapping of gas (fine structure lines and molecular lines) and dust (continuum) at near background-limited sensitivity

    ➡ SAFARI+BLISS
    (required surface brightness sensitivities will be determined soon from HerPlaNS observations)
  - Detecting faint shell around the bright central star

    ➡ SCI (MLHES suggests $10^{-6}$ contrast is good enough)