A twist in the stellar evolutionary tale...

What's up with the third dredge-up???

Starring:

J005252

A "SMC" Production

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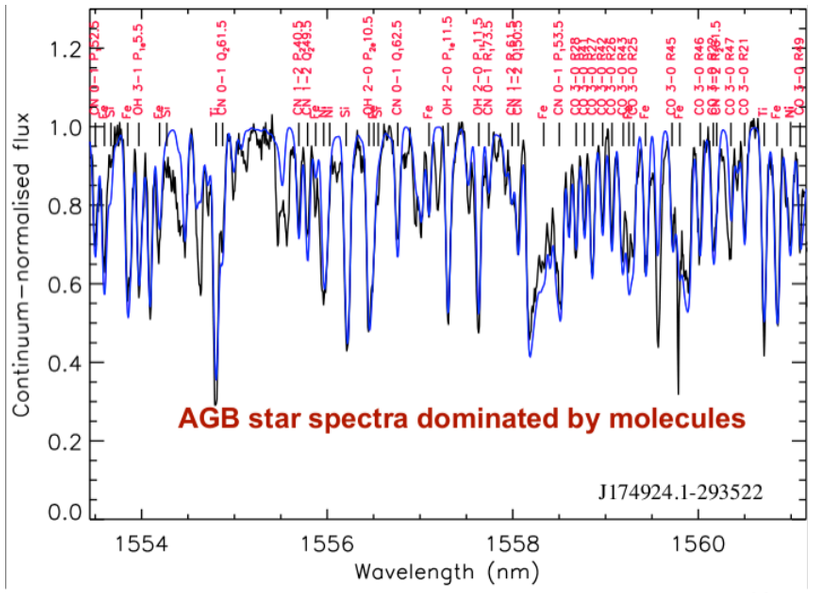
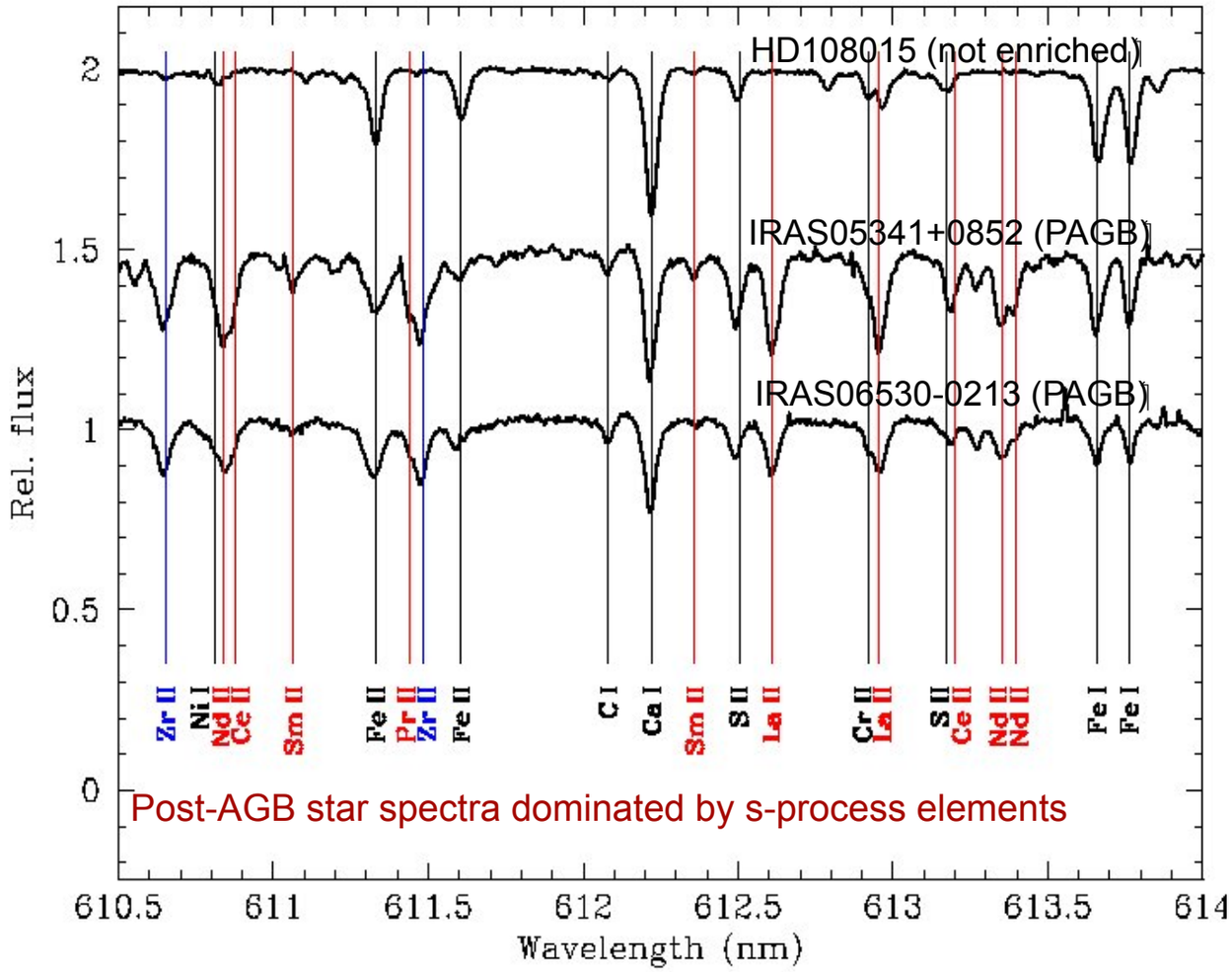
Premier @ the XIth Pacific Rim Conference, Hong Kong. Dec 2015

Why post-AGB stars to trace nucleosynthesis???

Observational constraints from:
AGB stars…
BUT
AGB star spectra dominated by molecules



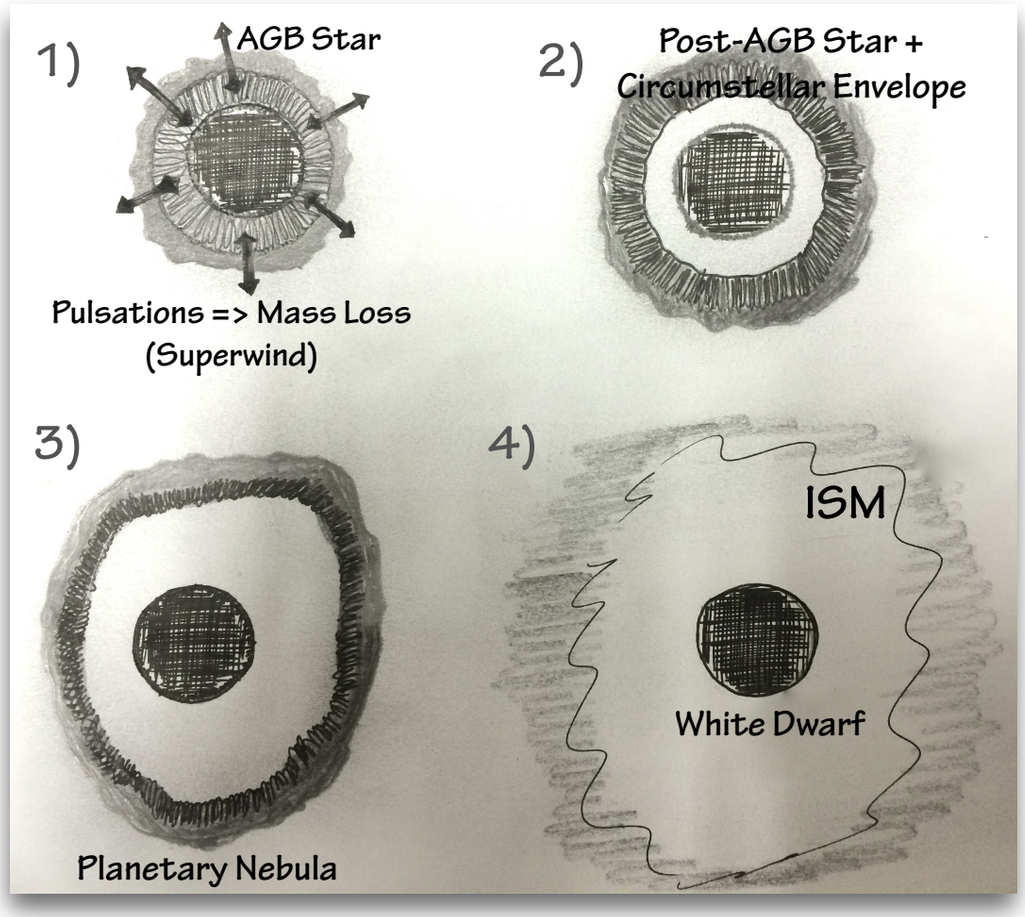
Uttenthaler et al., 2011



Reyniers et al., 2003, 2004, 2007 etc.

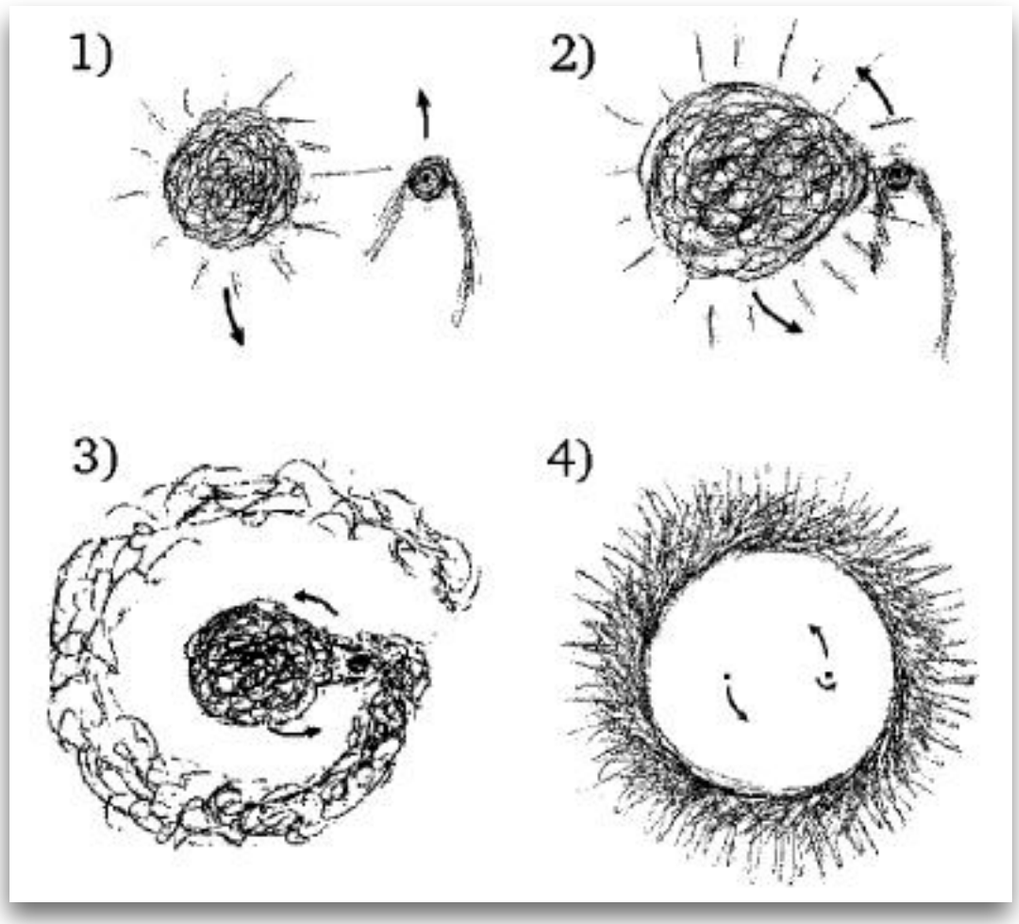
SINGLE/BINARY EVOLUTIONARY SCENARIOS

Single-star evolutionary scenario



Super-wind mass loss resulting in a ‘post-AGB’ star with a dusty circumstellar shell

Binary evolutionary scenario

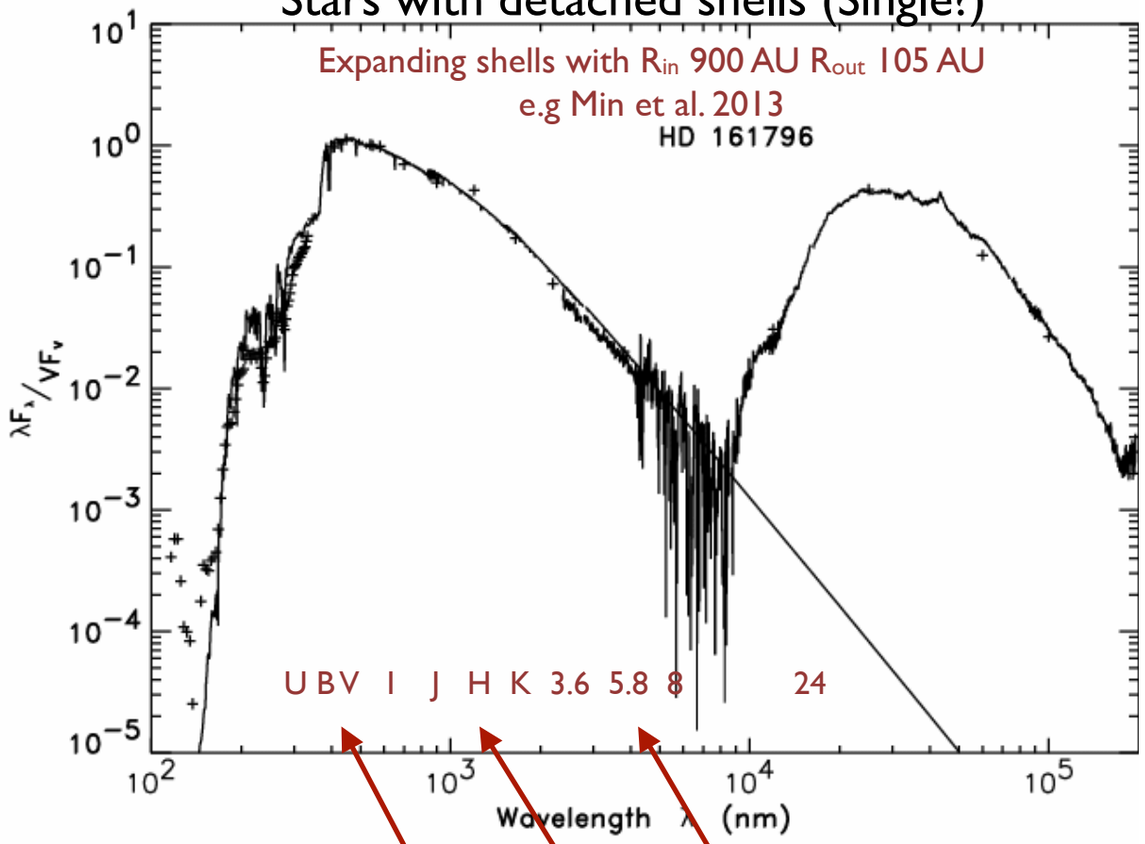


Common envelope evolution resulting in a circumbinary disc around the ‘post-AGB’ star

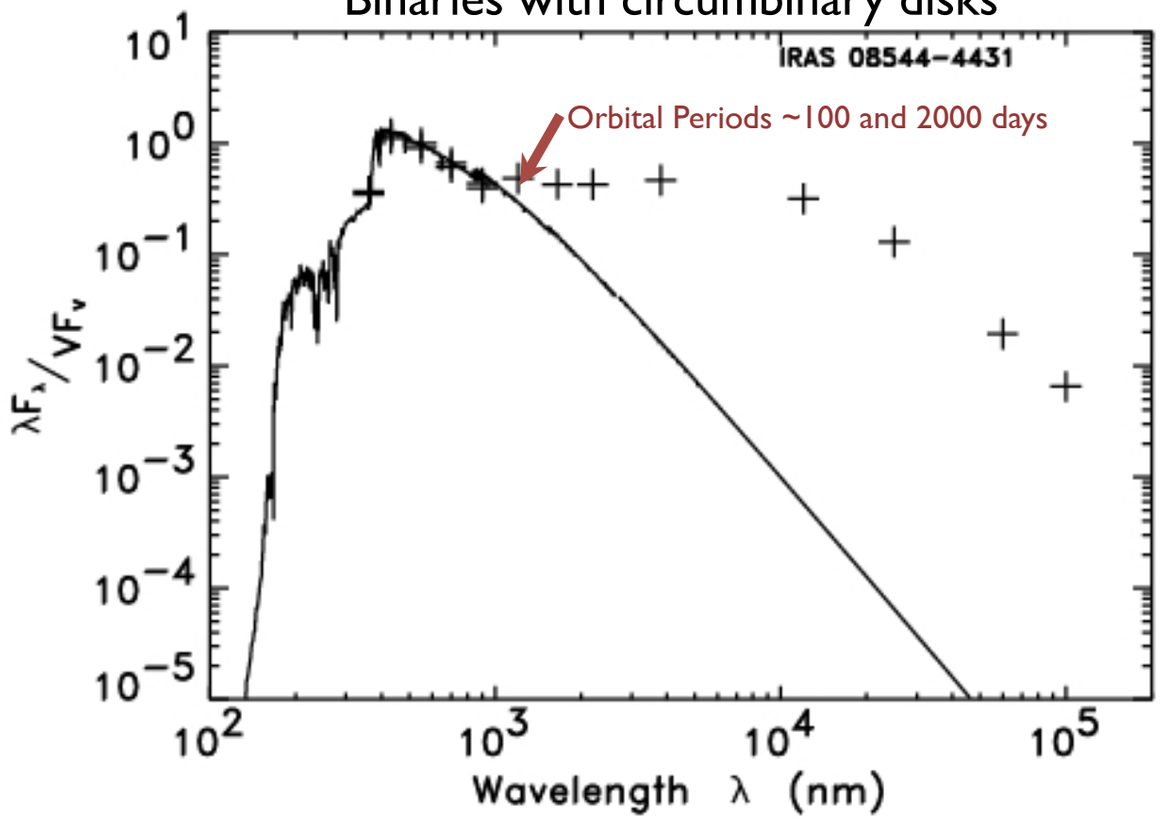
GALACTIC POST-AGB OBJECTS

(mid-IRAS - kwok 1993; Toruń Catalog - Szczerba et al. 2007)

Stars with detached shells (Single?)



Binaries with circumbinary disks



Studies by: Van Winckel 2003, 2007, 2009; De Ruyter et al. 2006; Gielen et al. 2009

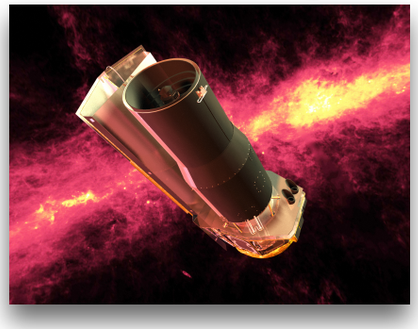
Optical + 2MASS + Spitzer bands allow us to distinguish between the two types - not always...

Mid-IR dust emission is characteristic of Post-AGB stars!

LIMITATION: LACK OF DISTANCES!!!

Optically visible (single and binary) Post-AGB stars in the **SMC* & LMC****

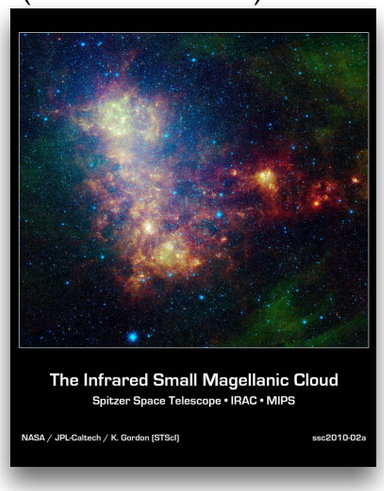
**Kamath et al. 2014 MNRAS*
***Kamath et al. 2015 MNRAS*



Mid-IR Spitzer Space Telescope Surveys

Candidates with Mid-IR excess selected from the Mid-IR SST survey

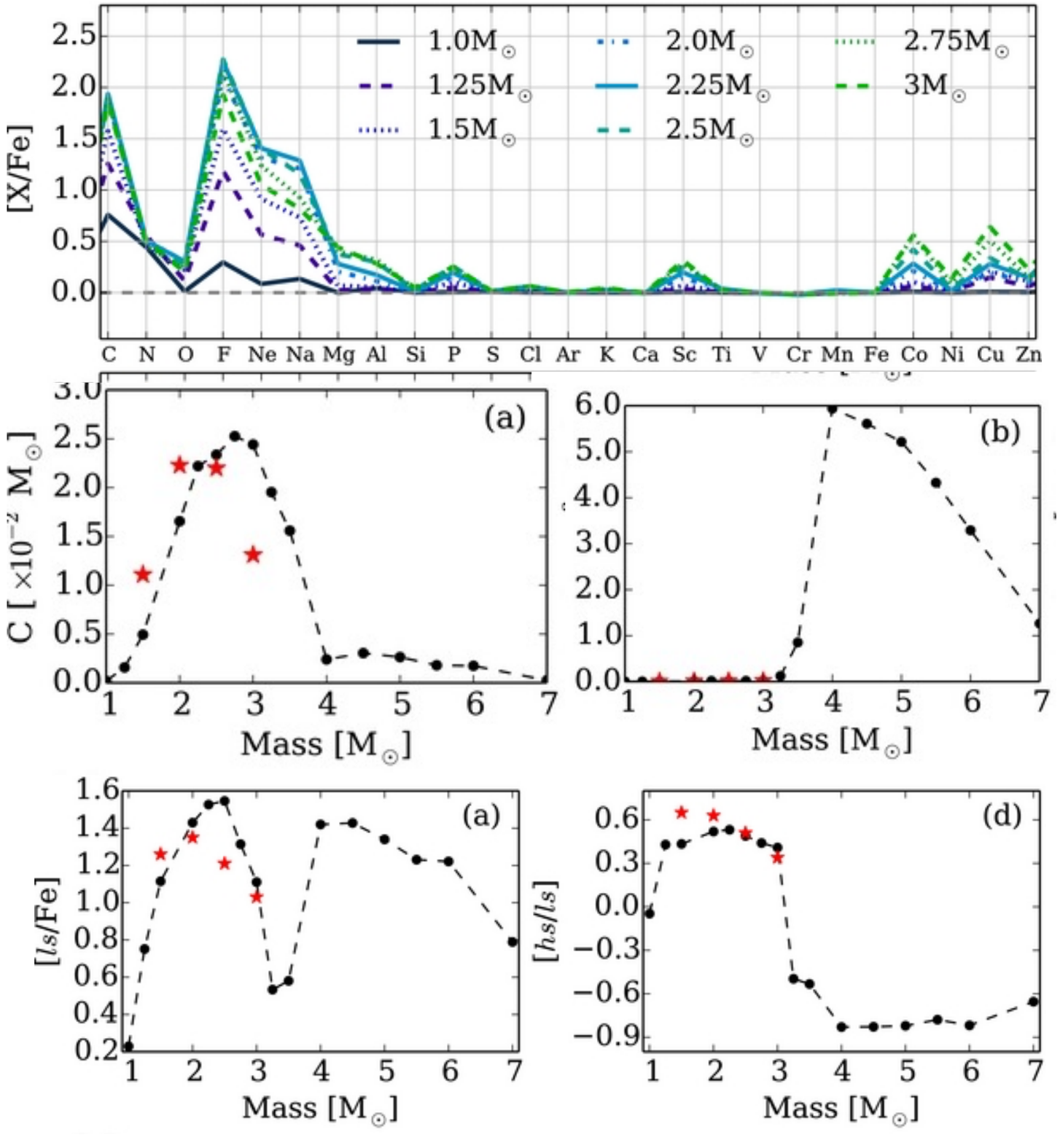
SMC: **S^{3}MC** (Bolatto et al. 2007) & **SAGE-SMC** (Gordon et al. 2010)



LMC: **SAGE** (Meixner et al. 2006) & (Blum et al. 2006)

✓ Candidate Selection
✓ Spectroscopic Examination
✓ SED Analysis
✓ Variability Analysis
✓ Spectroscopically verified Catalogues of Post-AGB, “Post-RGBs* and other interesting objects

Predicted nucleosynthesis in SINGLE stars…



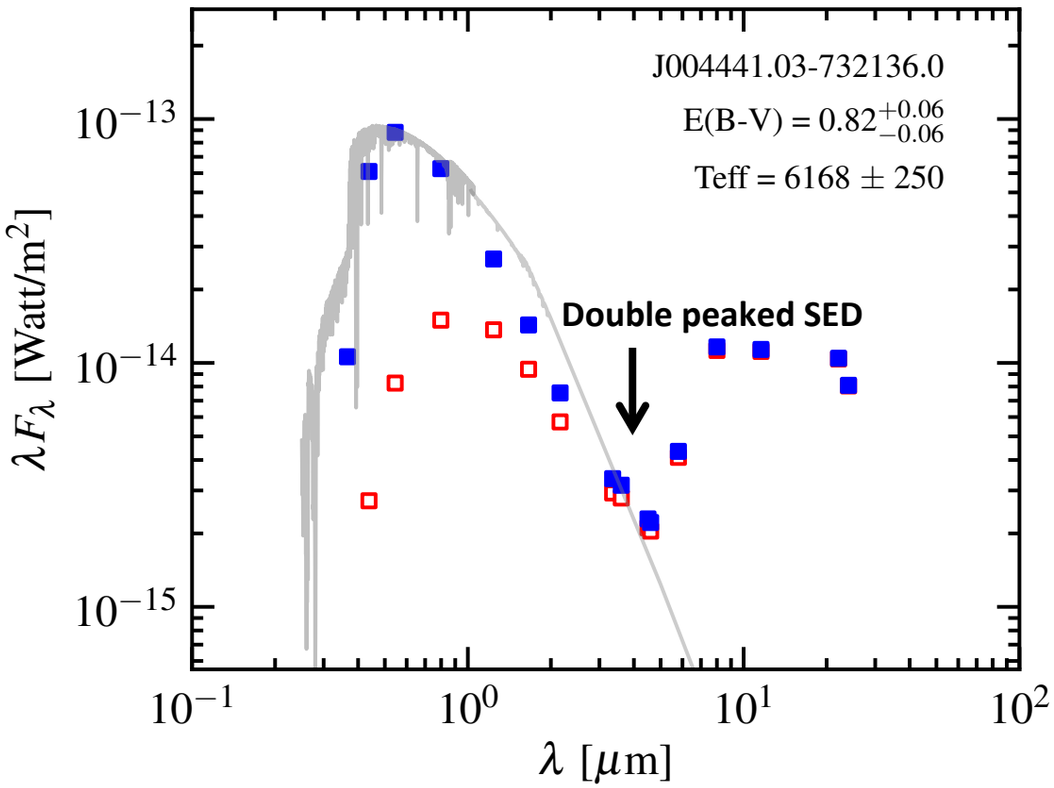
Dredge-up of Carbon and s-process elements

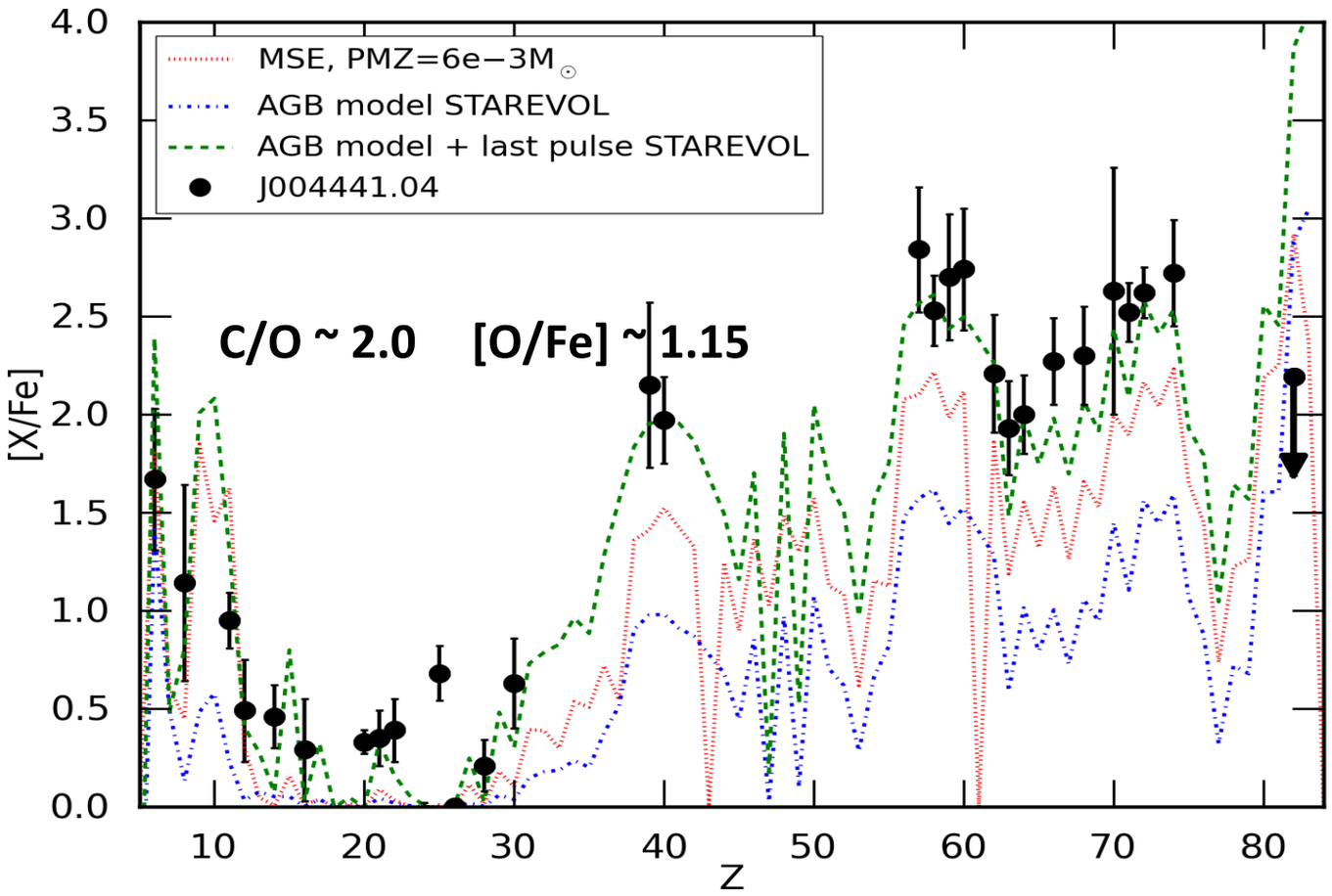
Fishlock, Karakas et al., 2014

Chemical Diversity in post-AGB stars…

Observed nucleosynthesis in SINGLE stars

C-enhancement and *s*-process nucleosynthesis…





- Shell-type SEDs
- C, N and O follow expected AGB nucleosynthesis yields
- s-process enhancement
- Conforms to single star evolution

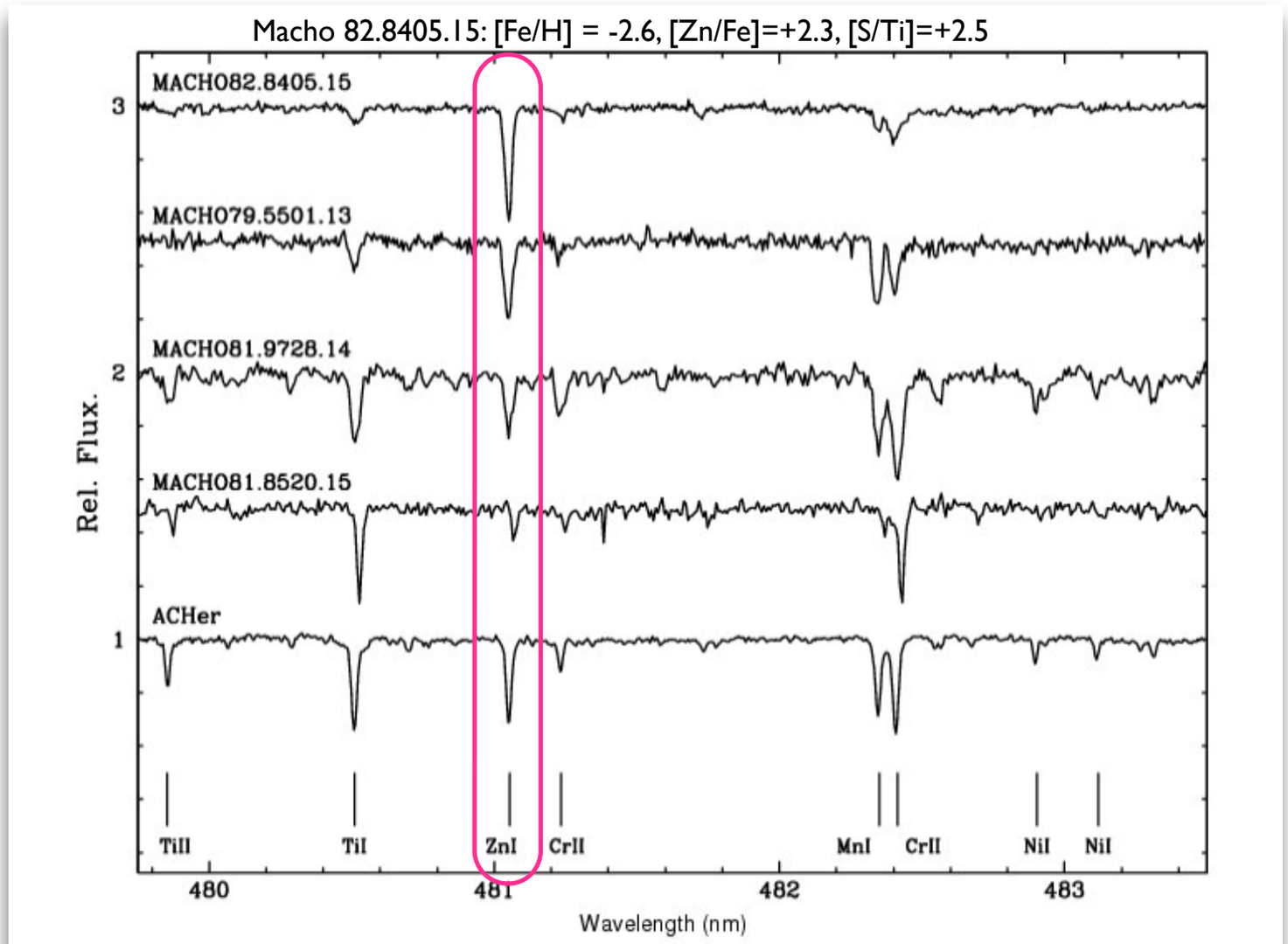
Trend observed in Galactic/SMC/LMC binary stars

De Smedt et al., 2012; Kamath et al., 2014

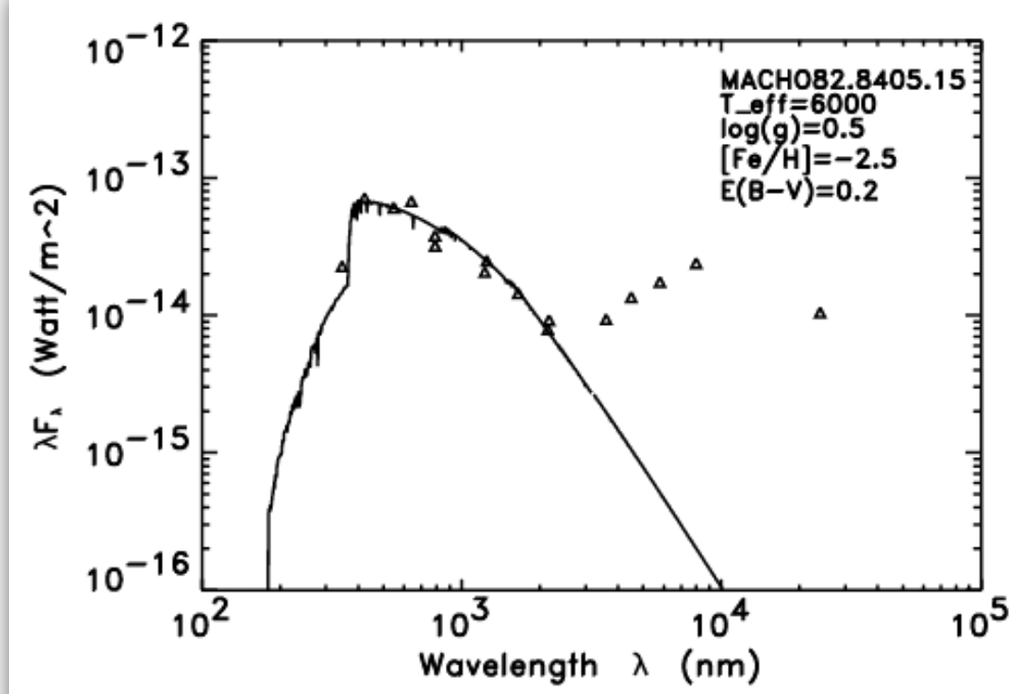
Chemical Diversity in post-AGB stars…
Observed nucleosynthesis in BINARY stars

Photospheric Depletion: Feedback from disc => Loss of nucleosynthetic history

IR spectra are very rich and strongly crystalline !

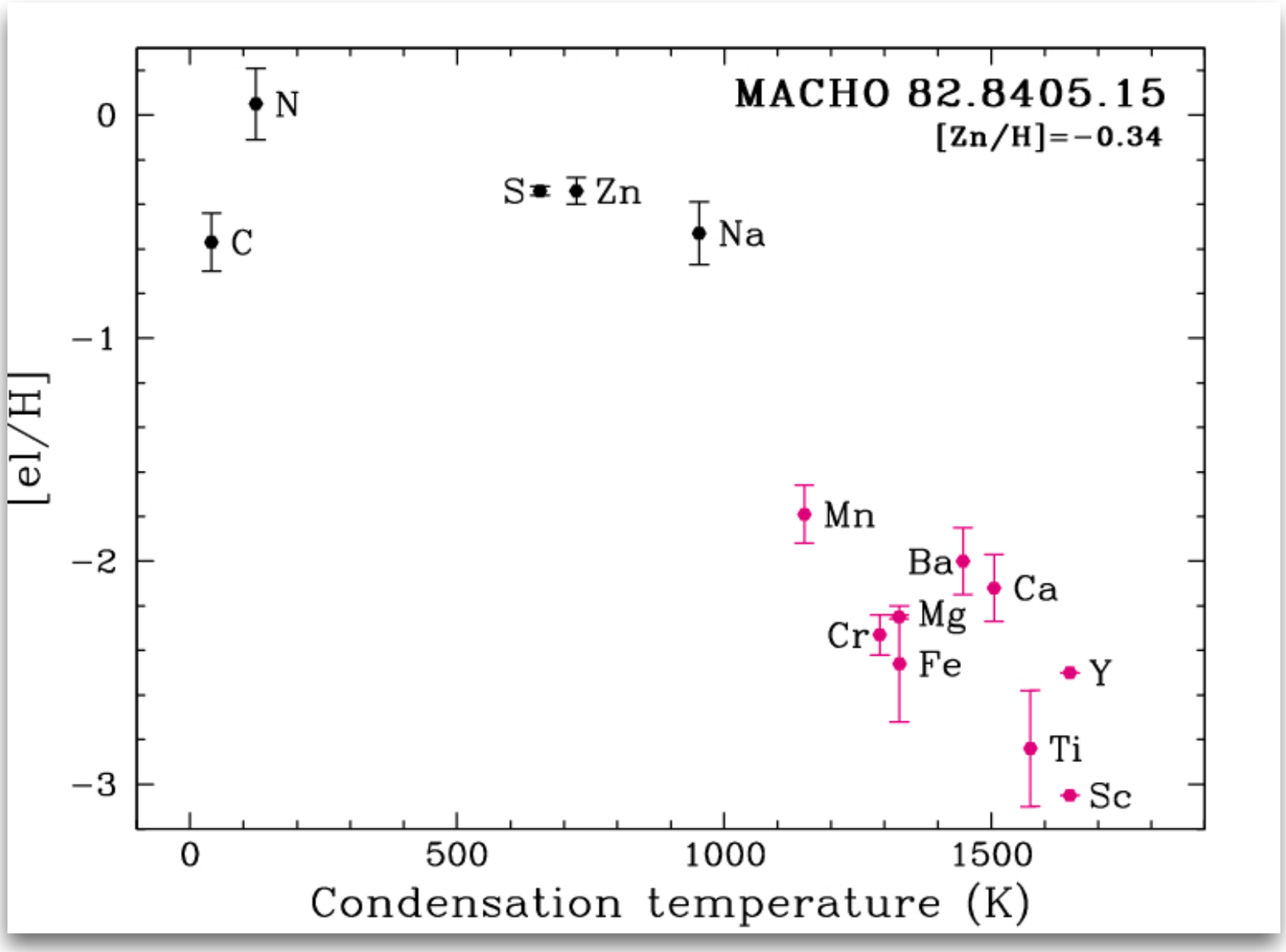


(Reyniers et al., 2007; Gielen et al., 2009, 2011)



- Disc-type SEDs
- Depletion patterns
- Conforms to **binary** evolution

Chemical Diversity in post-AGB stars…
Observed nucleosynthesis in BINARY stars



- [C/Fe]>0
- Depletion of refractory elements
- Volatile elements scale with Fe

Depletion scales with condensation temperature!
Depletion is very characteristic of binary stars!

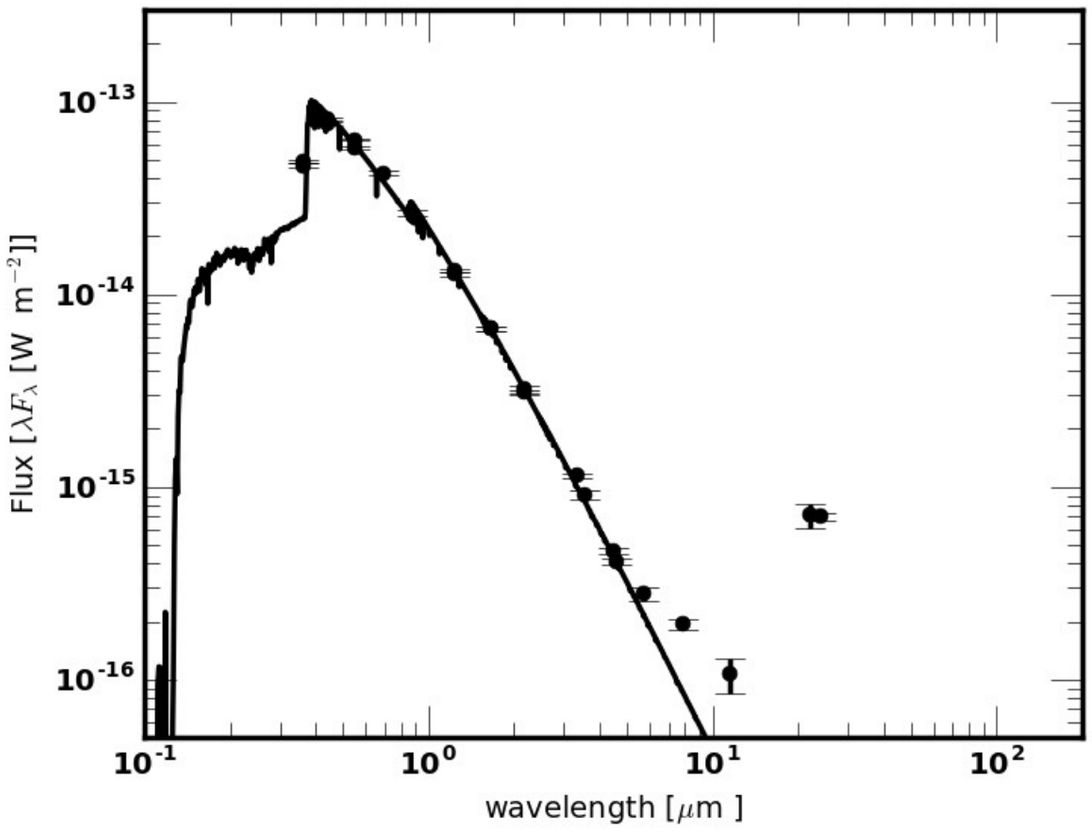
(Reyniers et al., 2007; Gielen et al., 2009, 2011)

… and then,
there was J005252…

Large scale spectroscopic surveys of optically visible post-AGB stars in the SMC and LMC
Kamath et al., 2014 and Kamath et al., 2015

J005252 - A Peculiar Star In The SMC

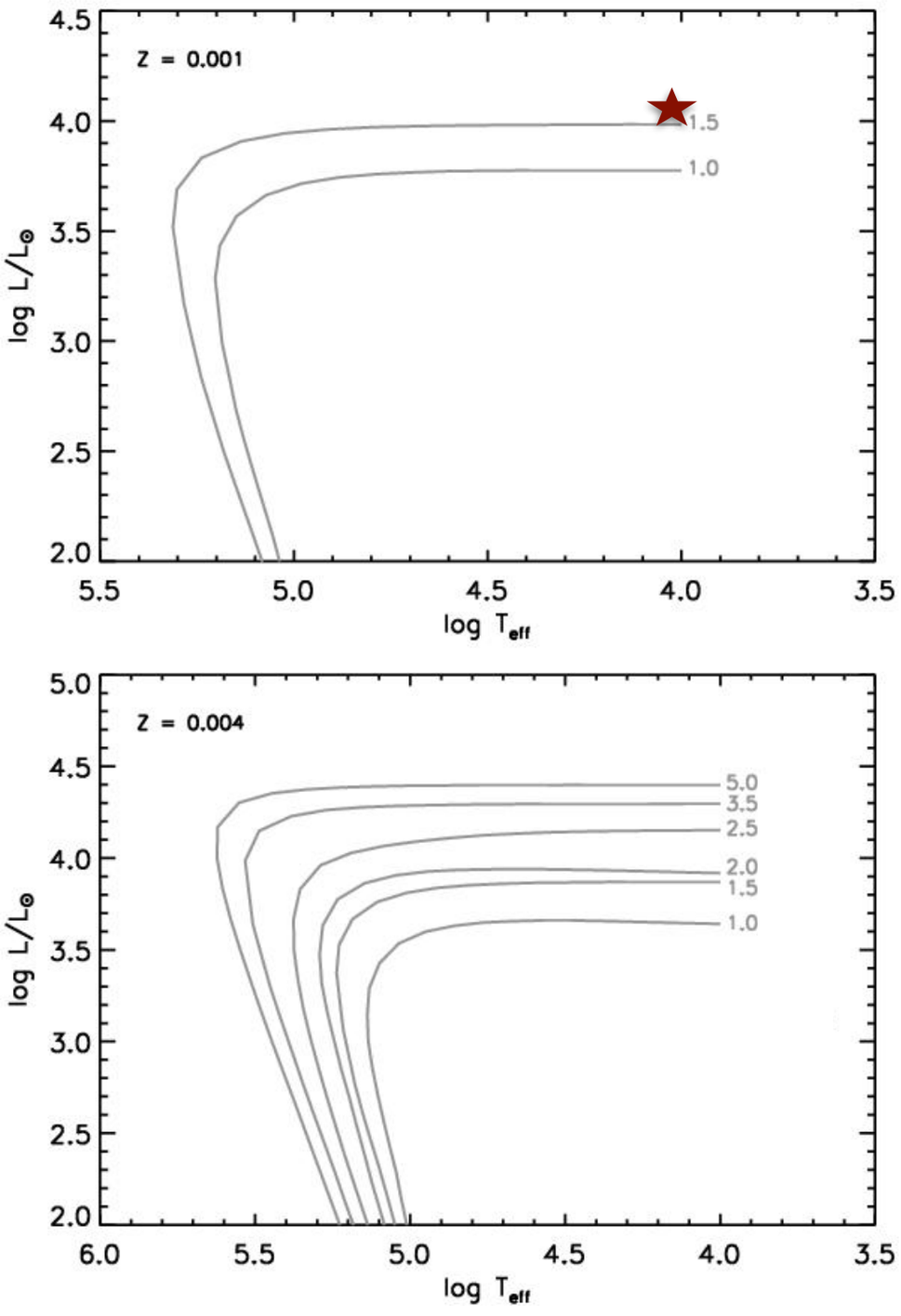
- L = 9000 Lsun
- Teff = 8500K
- Logg = 1.5
- [Fe/H] = -1.2
- E(*B*-*V*) = 0.55



- *Has a shell-type SED => single star !?!*

Deriving Initial Mass

The Luminosity-Core Mass Relation



Known luminosities to the LMC/SMC sources make them very valuable!

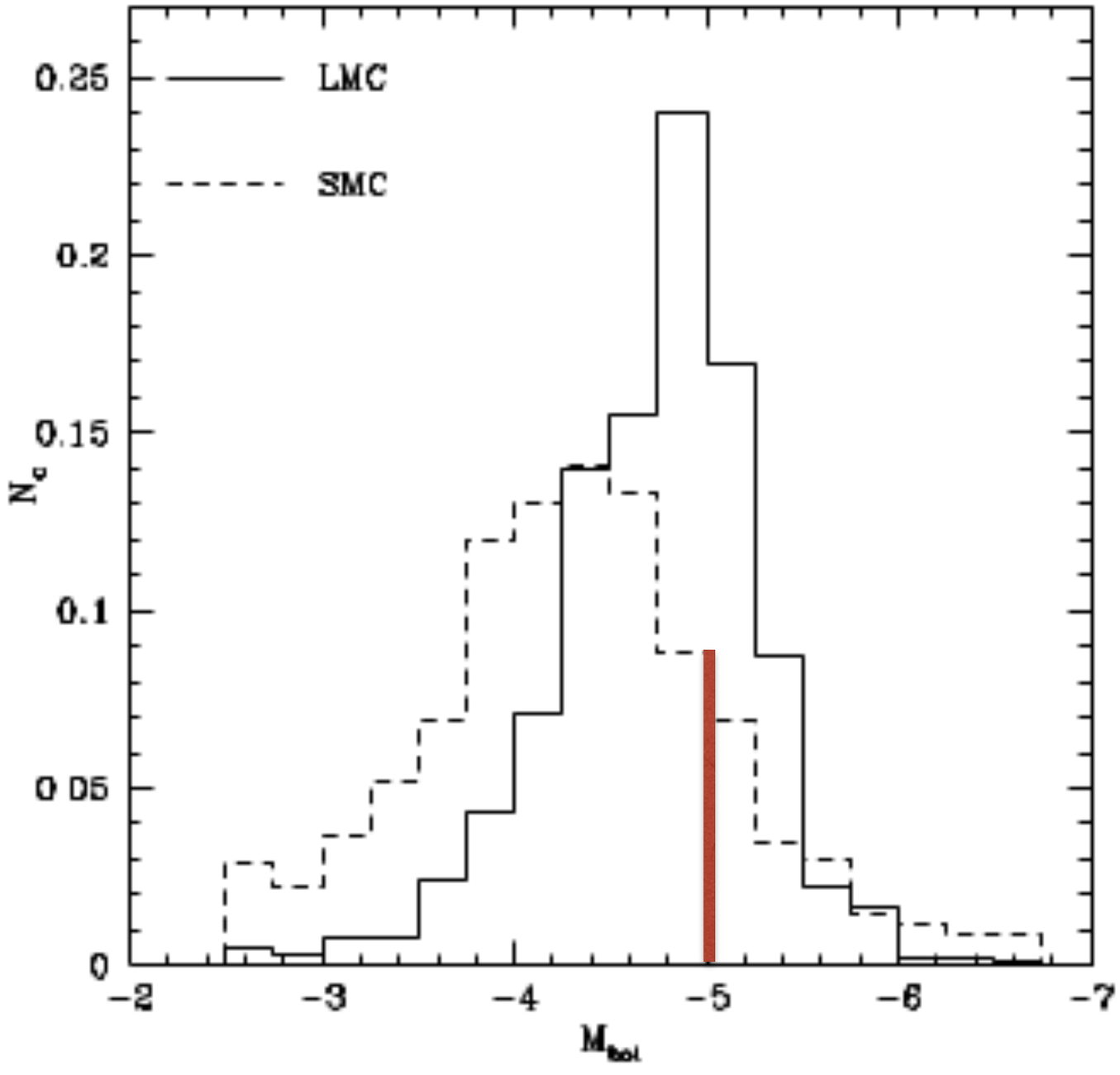
J005252

- L ~ 9000 $L_{\odot}$,
- Teff ~ 8500K
- Z = 0.001
- **$M_{initial}$ ~1.5 to 2 M_{sun}**

(Wood And Zarro 1981)

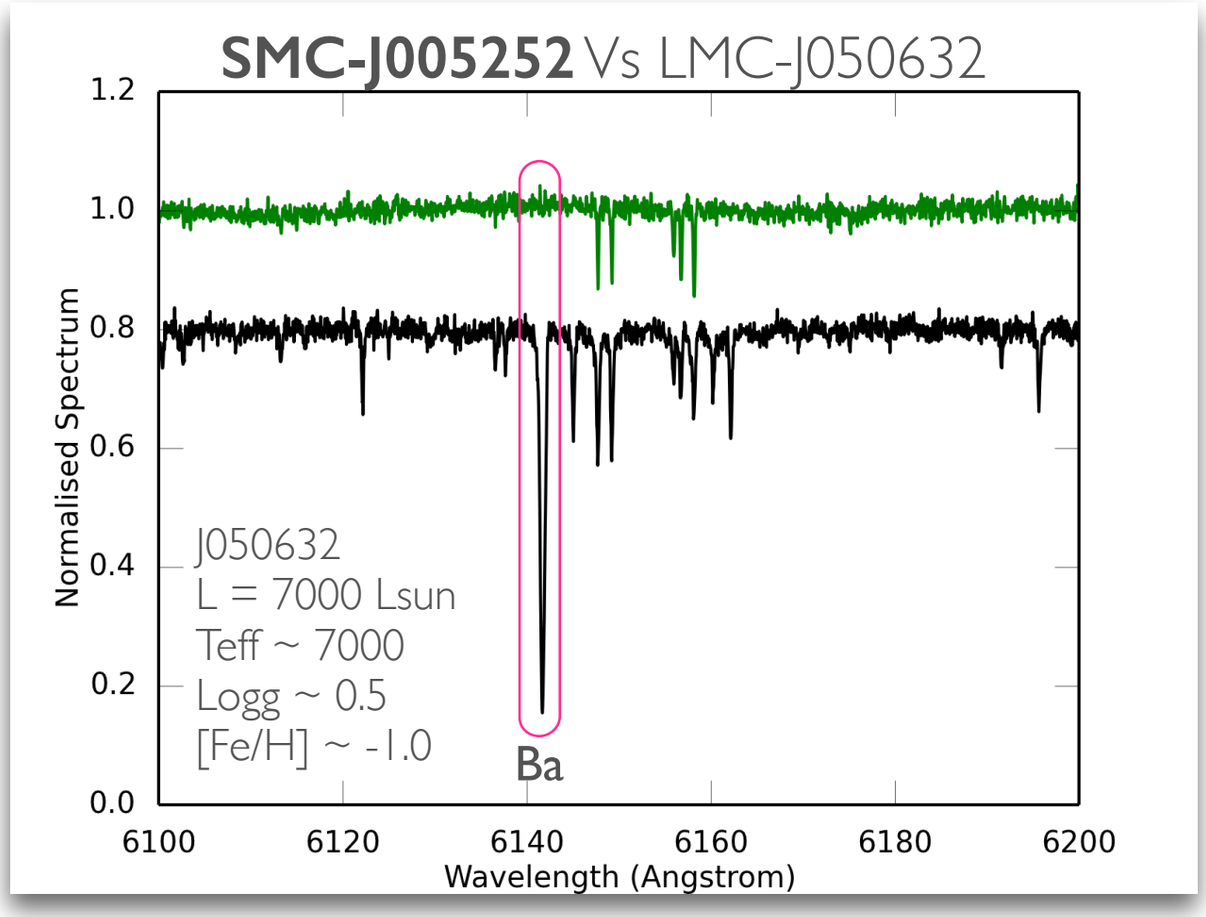
Based on the Carbon Star Luminosity Function of the SMC…

J005252 is likely to be a C-star at it's luminosity!

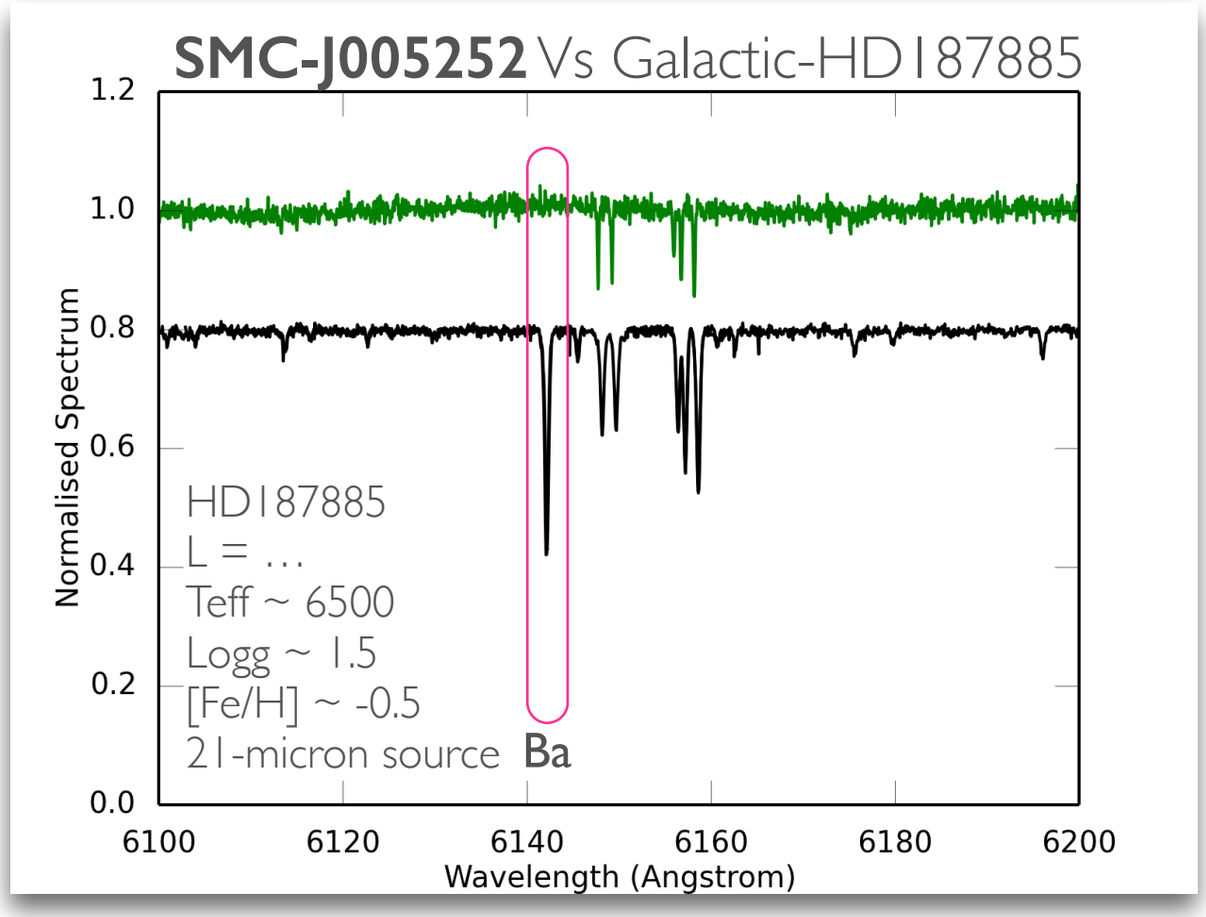


Costa & Frogel (1996); Groenewegen (1997); marigo et al., (1999)

BUT…**Not** a *s*-process enriched star!!!

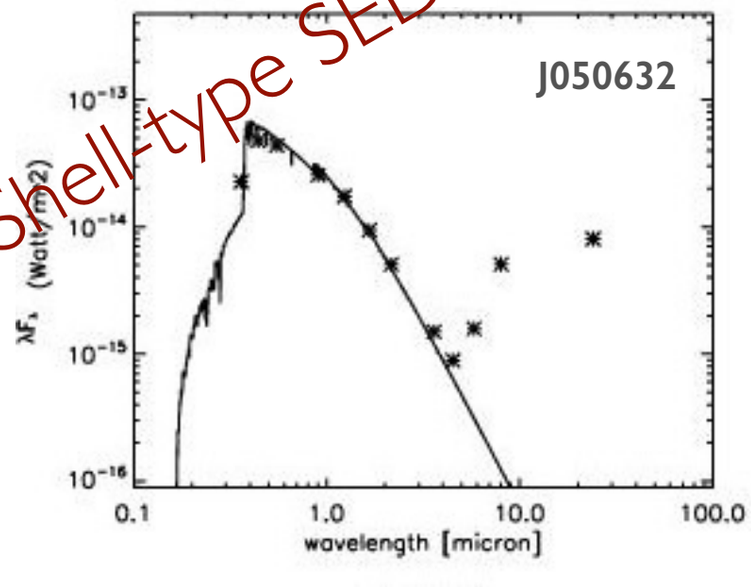


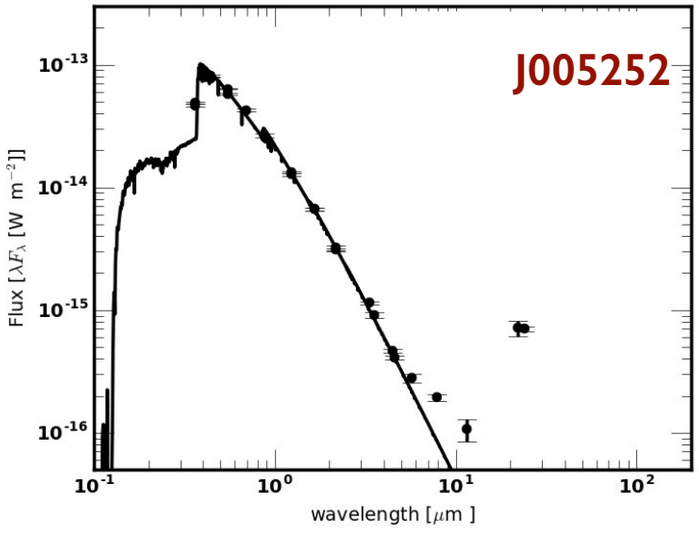
Kamath et al., in prep; van Aarle et al., 2013

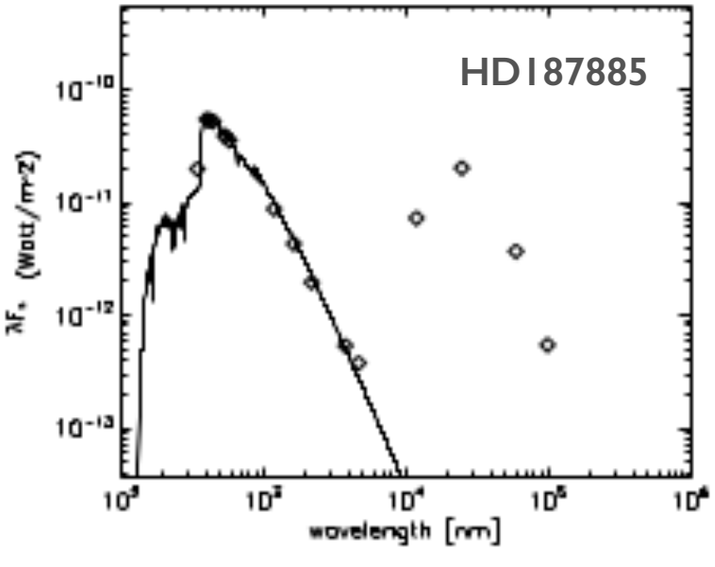


Kamath et al., in prep; Van Winckel et al., 1996

Shell-type SEDs

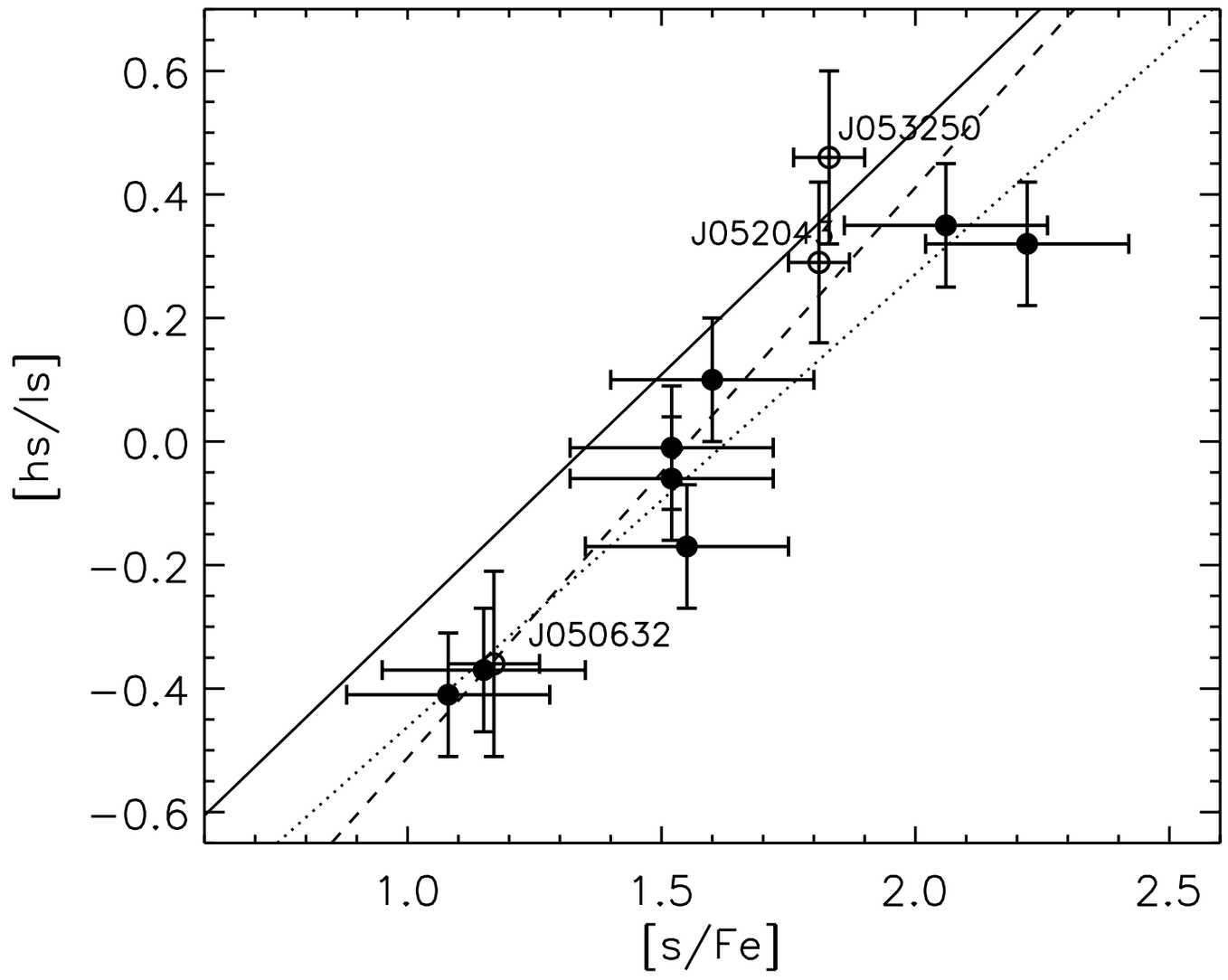






Does not follow the tradition relation between [hs/ls] and [s/Fe]…

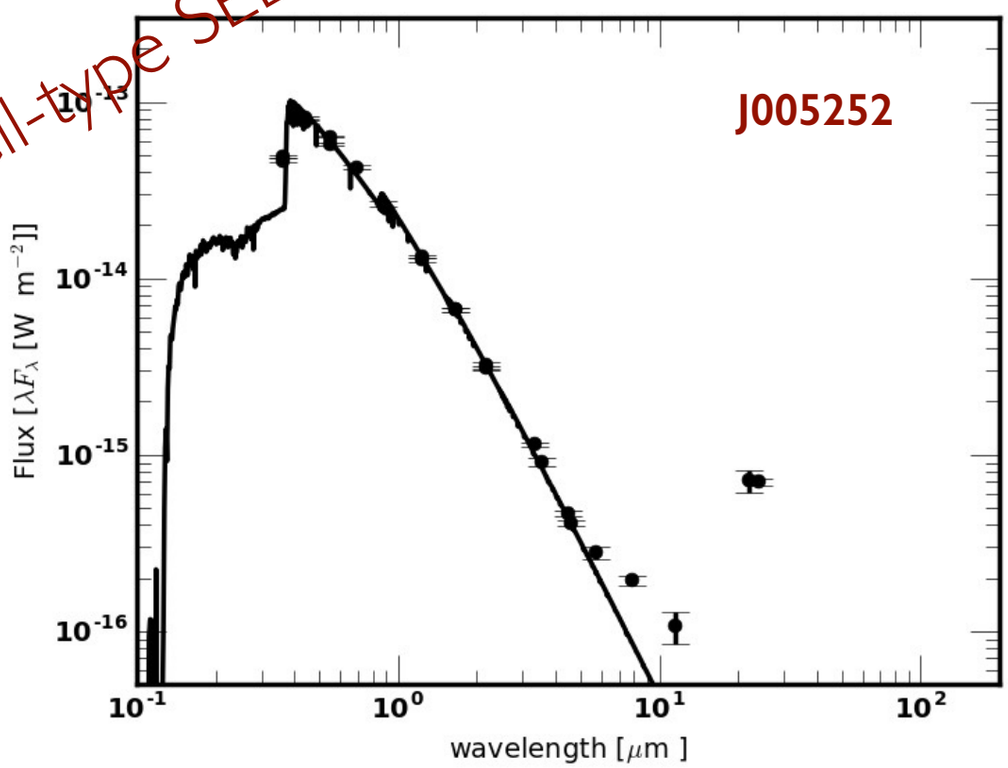
(followed by all studied single s-process enhanced post-AGB stars)



Van Aarle et al., 2013; De Smedt et al.2012; Kamath et al. in prep

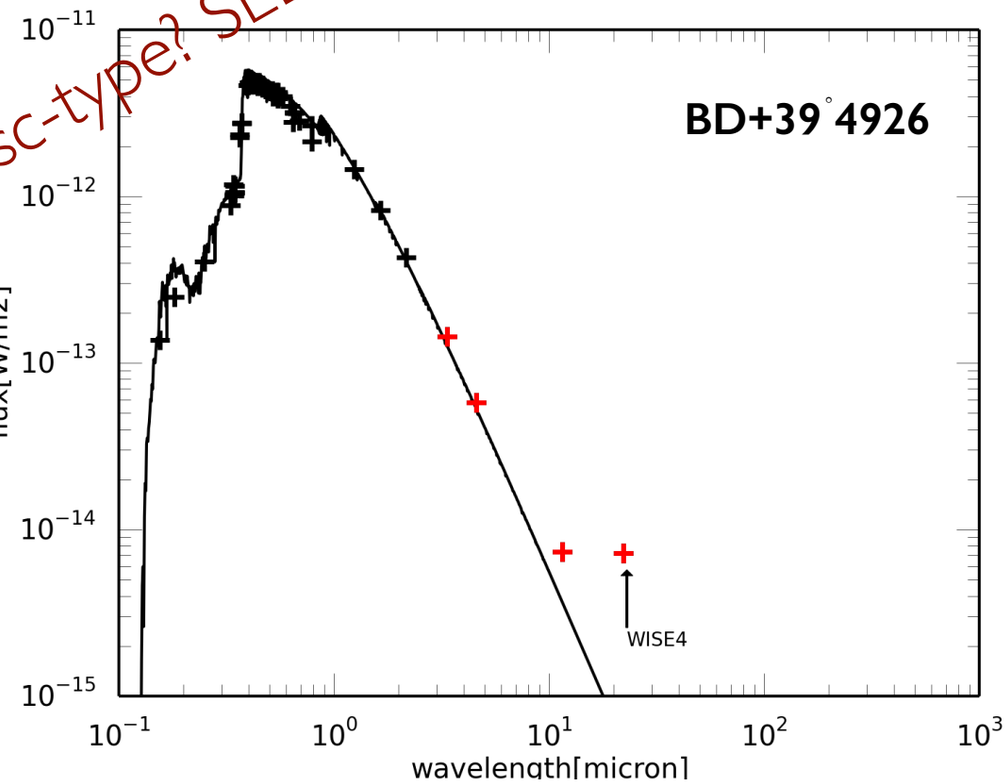
Is it a depleted object in a binary system?

Shell-type SED



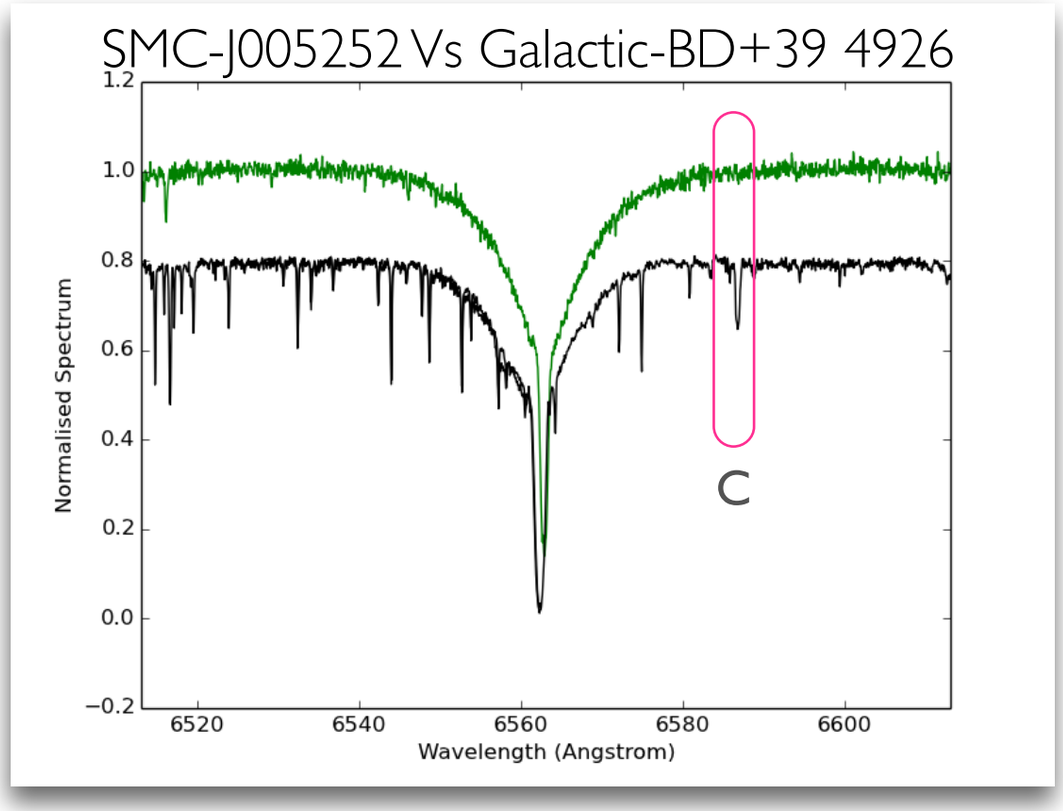
J005252
L = 9000 Lsun
Teff ~ 8500 K
Logg ~1.5
[Fe/H] ~ -1.2

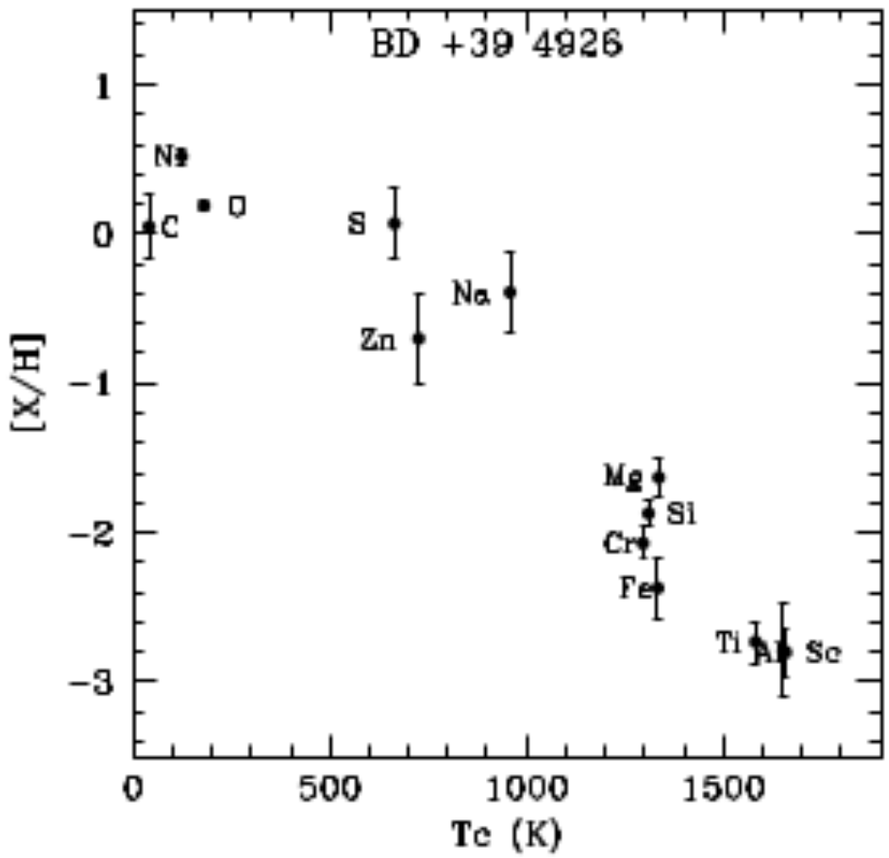
Disc-type? SED

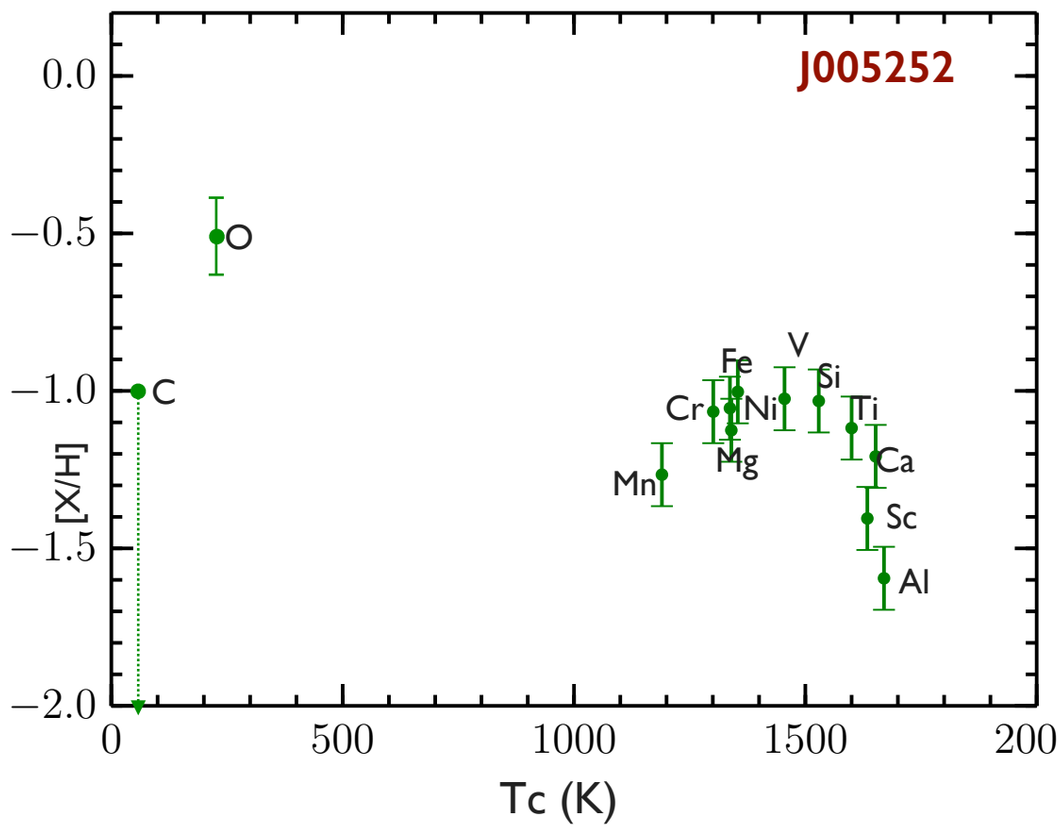


BD+39°4926
L = …*unknown*
Teff ~ 7500 K
Log g ~ 1.0
[Fe/H] ~ -2.9
P = 874 days

NOT a depleted object!!!







Hrivnak, B et al., 2008; Rao, S. S., et al., 2011; Kamath et al., in prep

Observed chemistry is **NOT** due to:

s-process

Depletion

This object did *NOT* undergo the Third-Dredge Up!?!

How can we get a low-metallicity (Z~0.001) and low-mass (M~1.5 to 2 Msun) AGB star to evolve without third-Dredge Up???

Suggestion 1: Is HOT BOTTOM BURNING doing it's thing? 💀
Problem: J005252 is a low mass star!

Suggestion 2: Are we looking at born-again post-AGB stars, or post-AGB stars with a late flash? 😎
Problem: These stars retain their s-process enrichment and they have high oxygen abundances. This is not observed in J005252

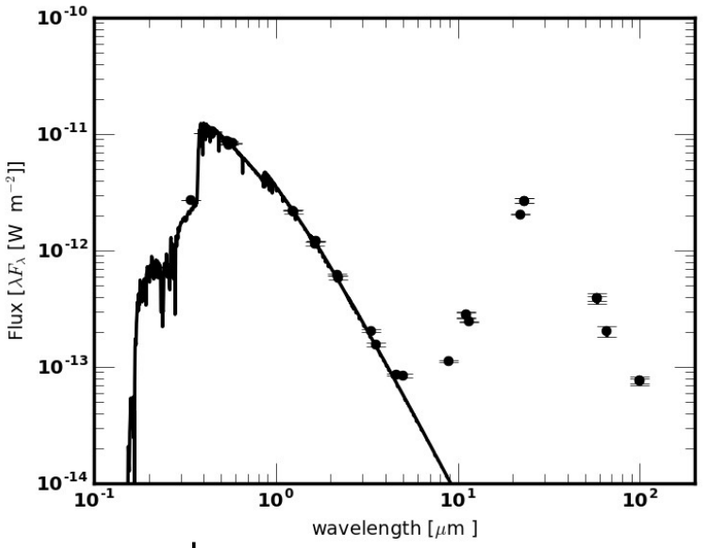
Suggestion 3: Is it Merger? 👽
Problem: Possibly, but how can we tell???

Suggestion 4: Different mass-loss history - so an AGB life without dredge-up 😱

Problem: … **John please help!!!**

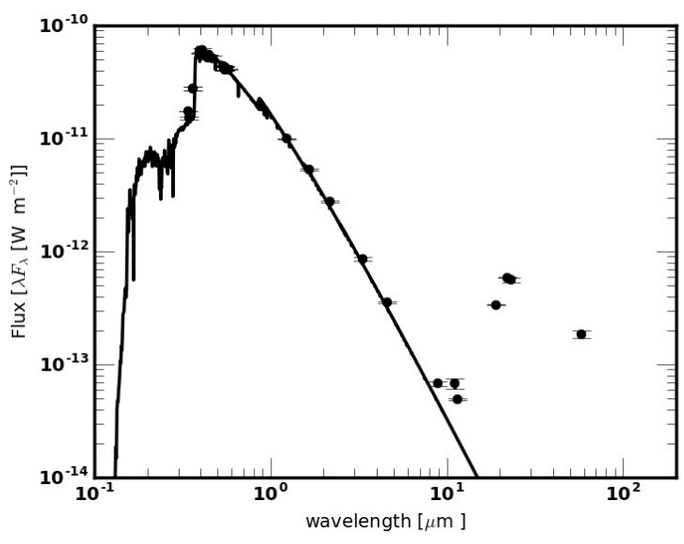
Other stars that are neither *s*-process enhanced NOR depleted
Galactic Objects: SAO 239853 and HD133656

SAO 239853



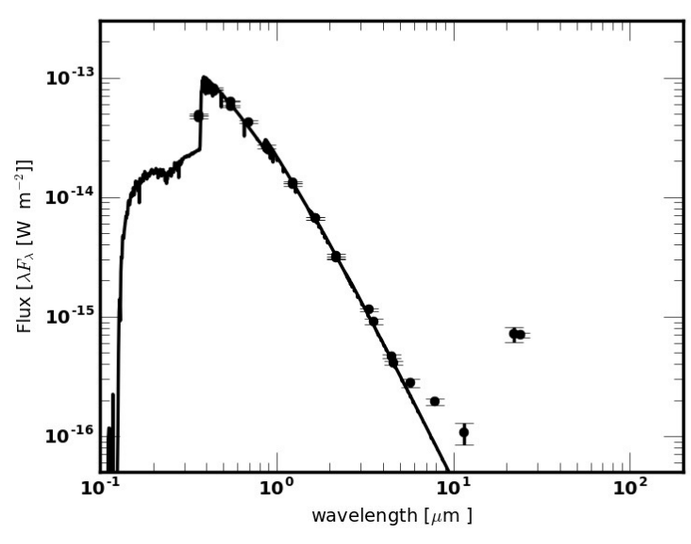
L = …
Teff ~ 7000K
Logg ~ 1.5
[Fe/H] ~ -1.0

HD 133656



L = …
Teff ~ 7500
Logg ~ 2.0
[Fe/H] ~ -1.0

J005252

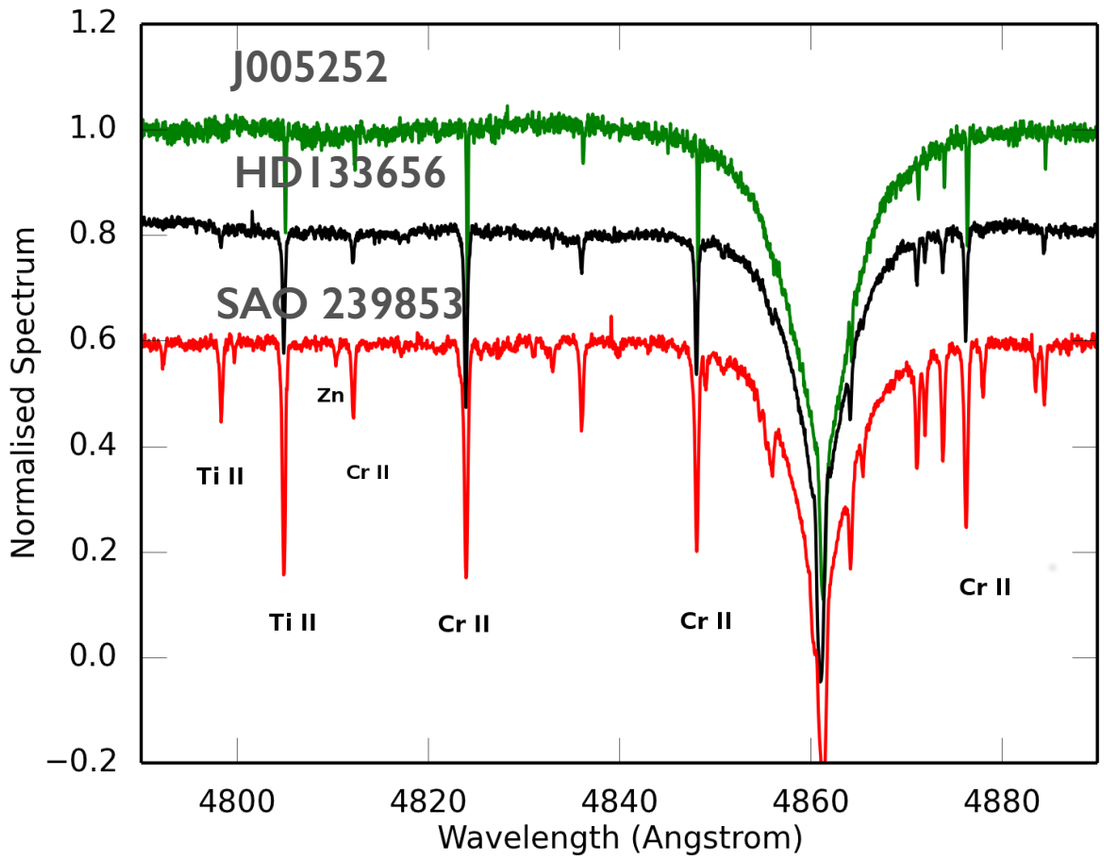


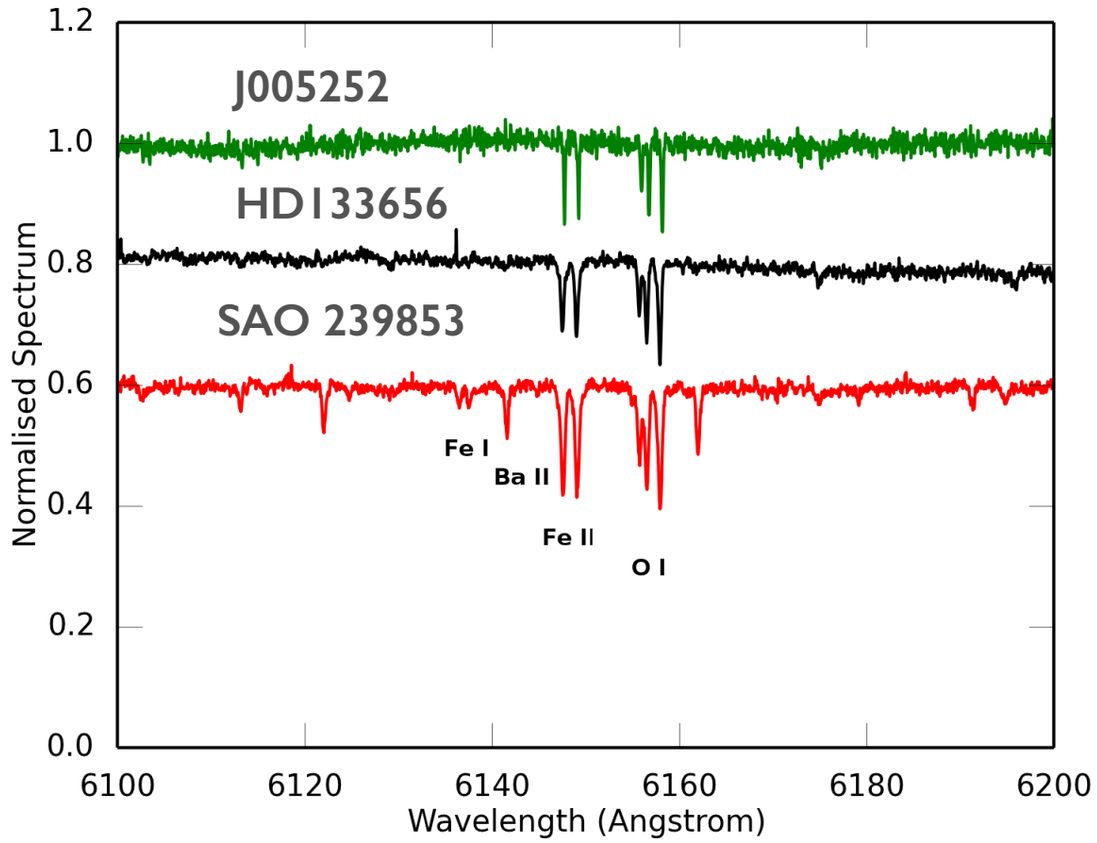
L = 7000 Lsun
Teff ~ 8500K
Logg ~ 1.5
[Fe/H] ~ -1.2

No Luminosity estimates to these objects!
Unlike for the SMC/LMC objects…

Van Winckel 1996; Kamath et al., in prep

Galactic analogues:
HD 133656 and SAO 239853 ALSO likely fail the third dredge-up!?!





Van Winckel 1996; Kamath et al., in prep

Conclusion

Post-AGB stars are essential tools to probe AGB nucleosynthesis of single and binary stars

- **Single** post-AGB stars are mostly ***s*-process enhanced**
- **Binary** post-AGB stars show a characteristic **depletion** pattern
- Post-AGB stars in the **LMC/SMC**, with **known luminosities**, are especially useful
- **J005252** - A SMC low mass, low metallicity post-star that fails TDU
  - Is this a product of a **merger**?
  - Is there some mechanism that **restricts TDU** during the AGB, a strange sort of **mass-loss** maybe?

Linking J005252 to probable progeny…

Carbon-poor halo Planetary Nebula

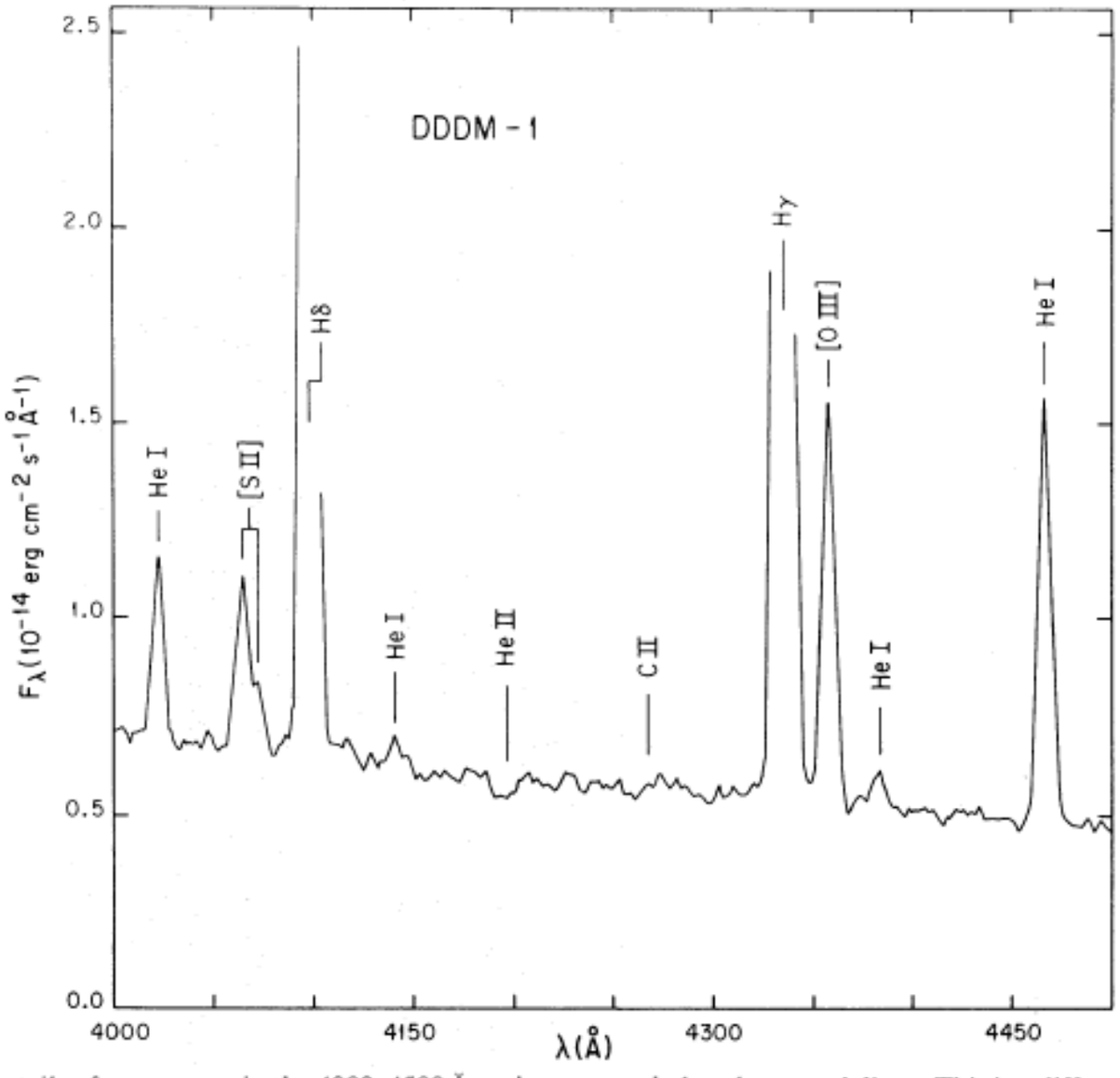


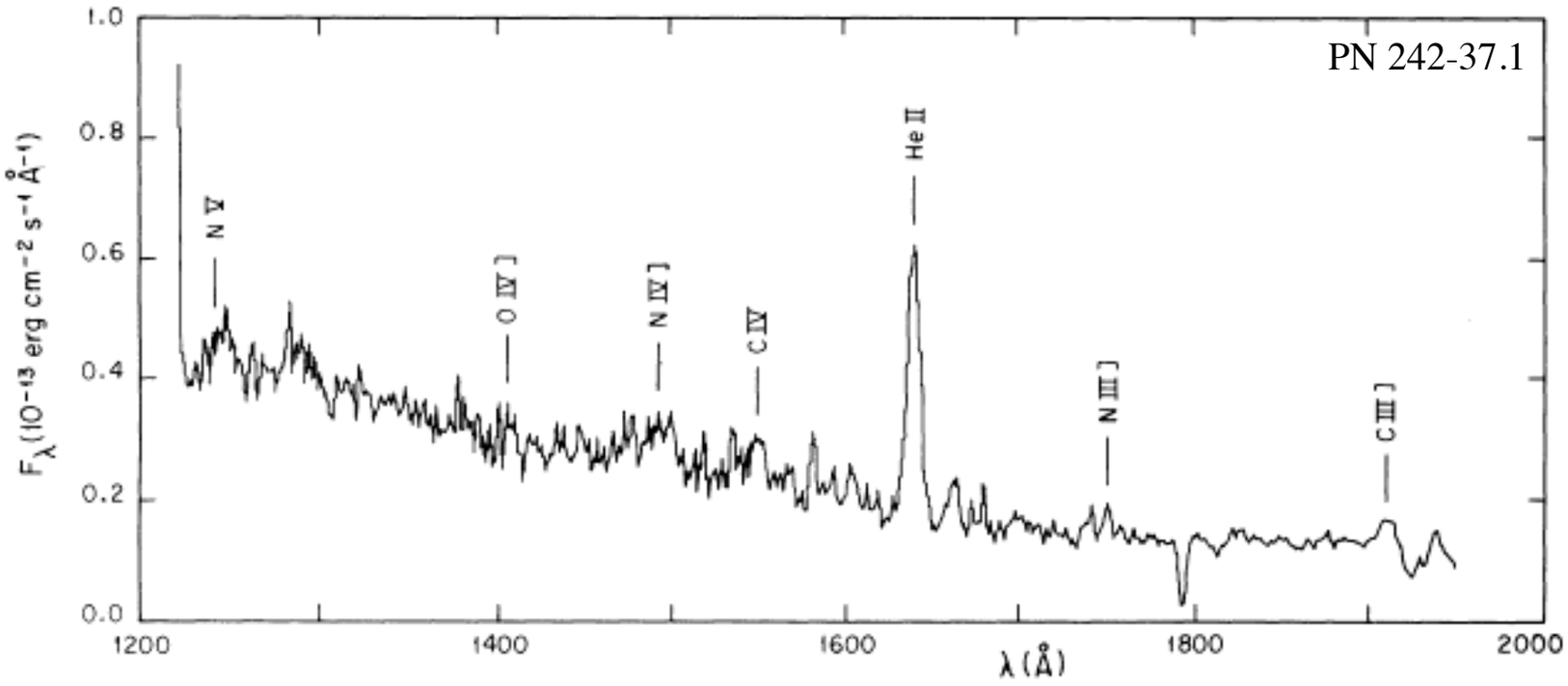
Figure 3. Details of a spectrum in the 4000–4500 Å region, expanded to show weak lines. This is a different spectrum to that shown in Fig. 1. The position of the undetected C II 4267Å line is shown.

C/O<0.1
[Fe/H] = -0.85
[O/Fe] = +0.5

Clegg, R. E. S., Pelmbert, M., & Torres-Pelmbert, S. 1978, MNRAS

Linking J005252 to probable progeny…

High excitation Carbon-poor Planetary Nebula

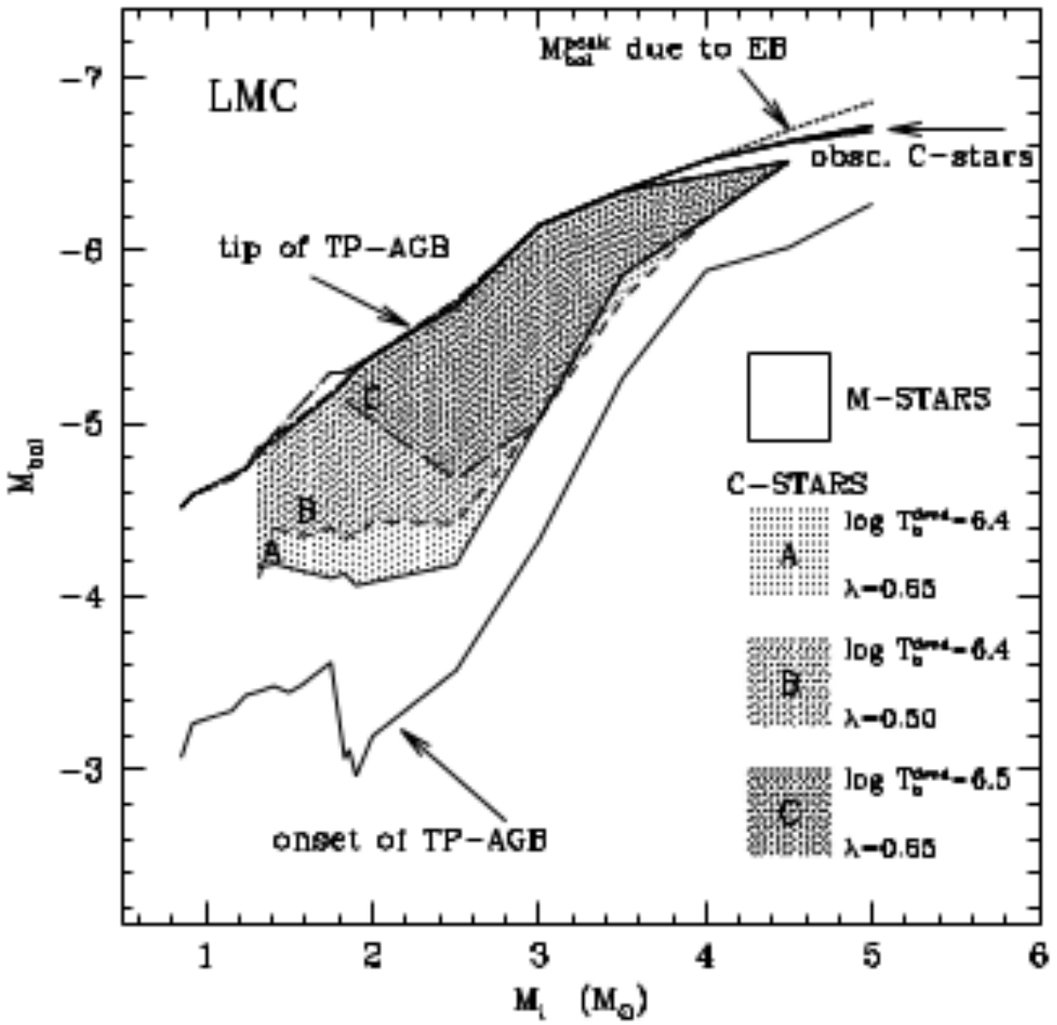


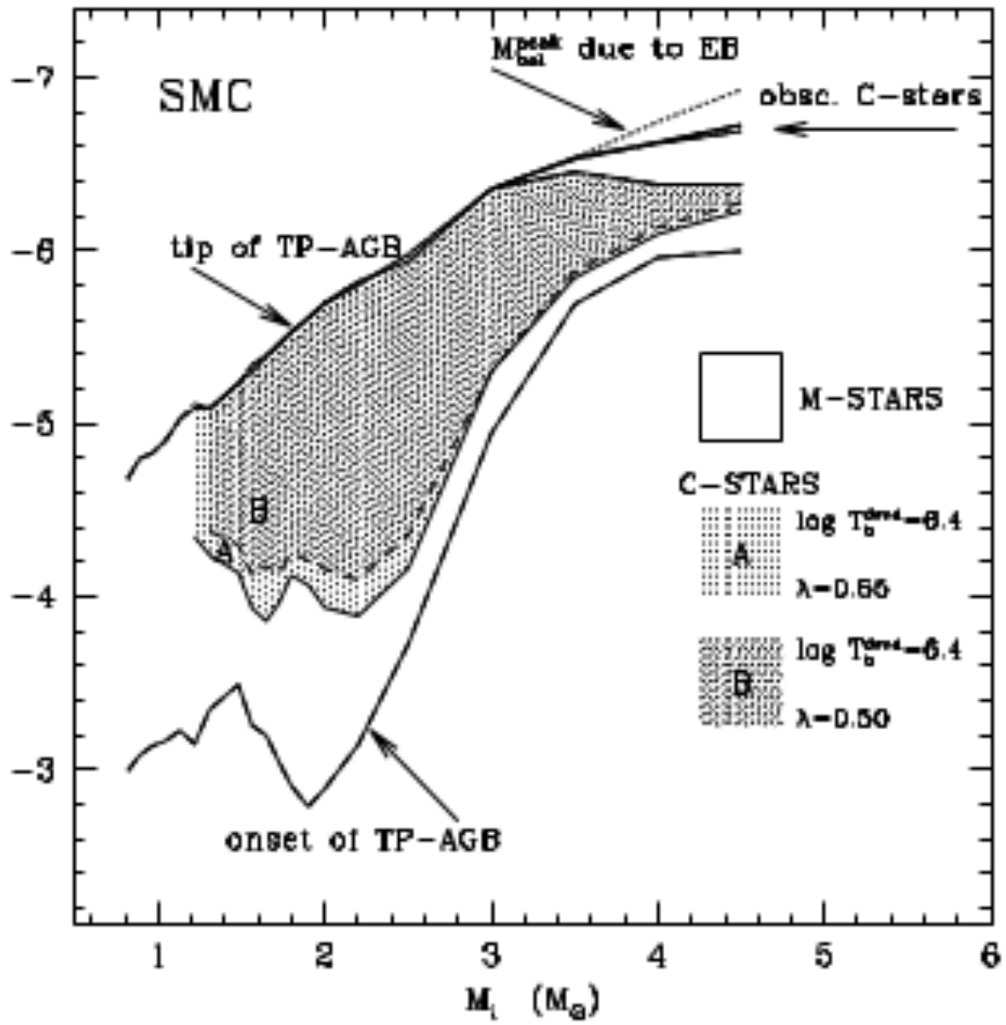
C/O<0.16

Fig. 3. IUE spectrum of PN 242-37.1. The carbon lines are noticeably faint relative to the He II λ1640 line. The continuum can be fitted to a black body distribution of temperature 90 000 ± 10 000 K (for this fit we did not subtract the nebular contribution)

Pena, M., Torres-Peimbert, S., Ruiz, M. T., & Maza, J. 1990, A&A

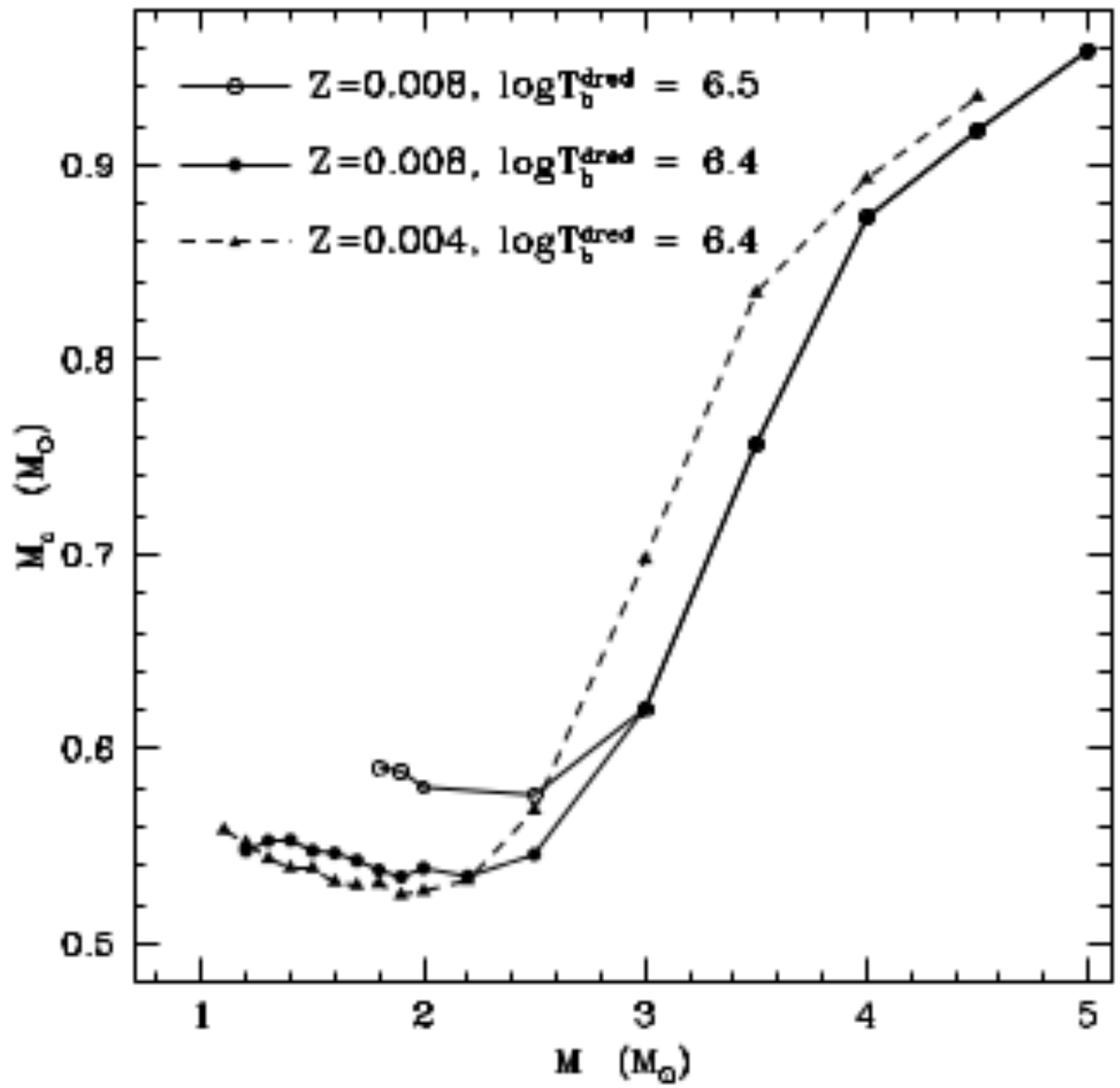
The likelihood of J005252 having TDU is high!





Marigo et al., 1999

The likelihood of J005252 having TDU is high!



Marigo et al., 1999