- **Lithium rich K-type giant stars as a new source of organic compounds in the Galaxy**

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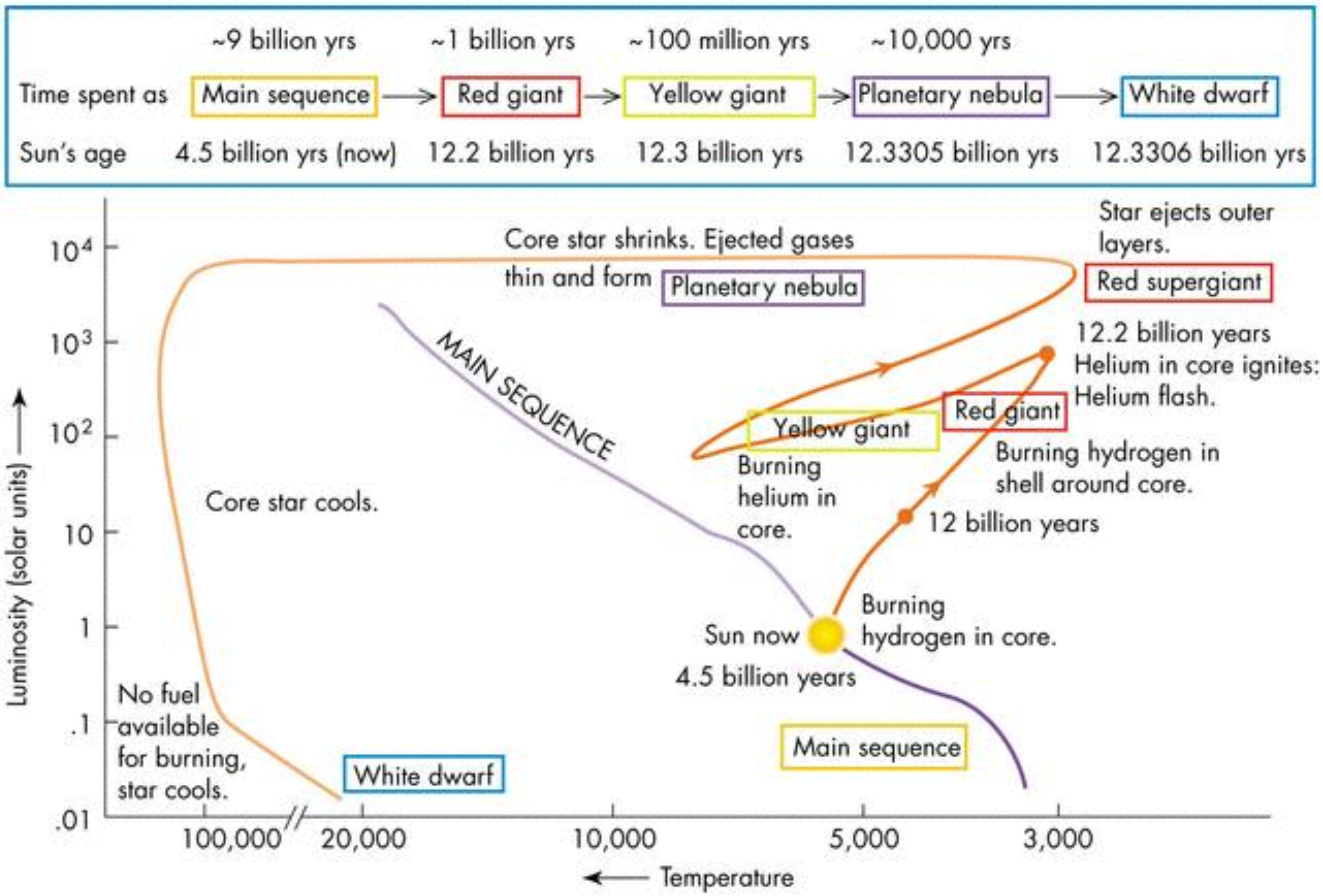
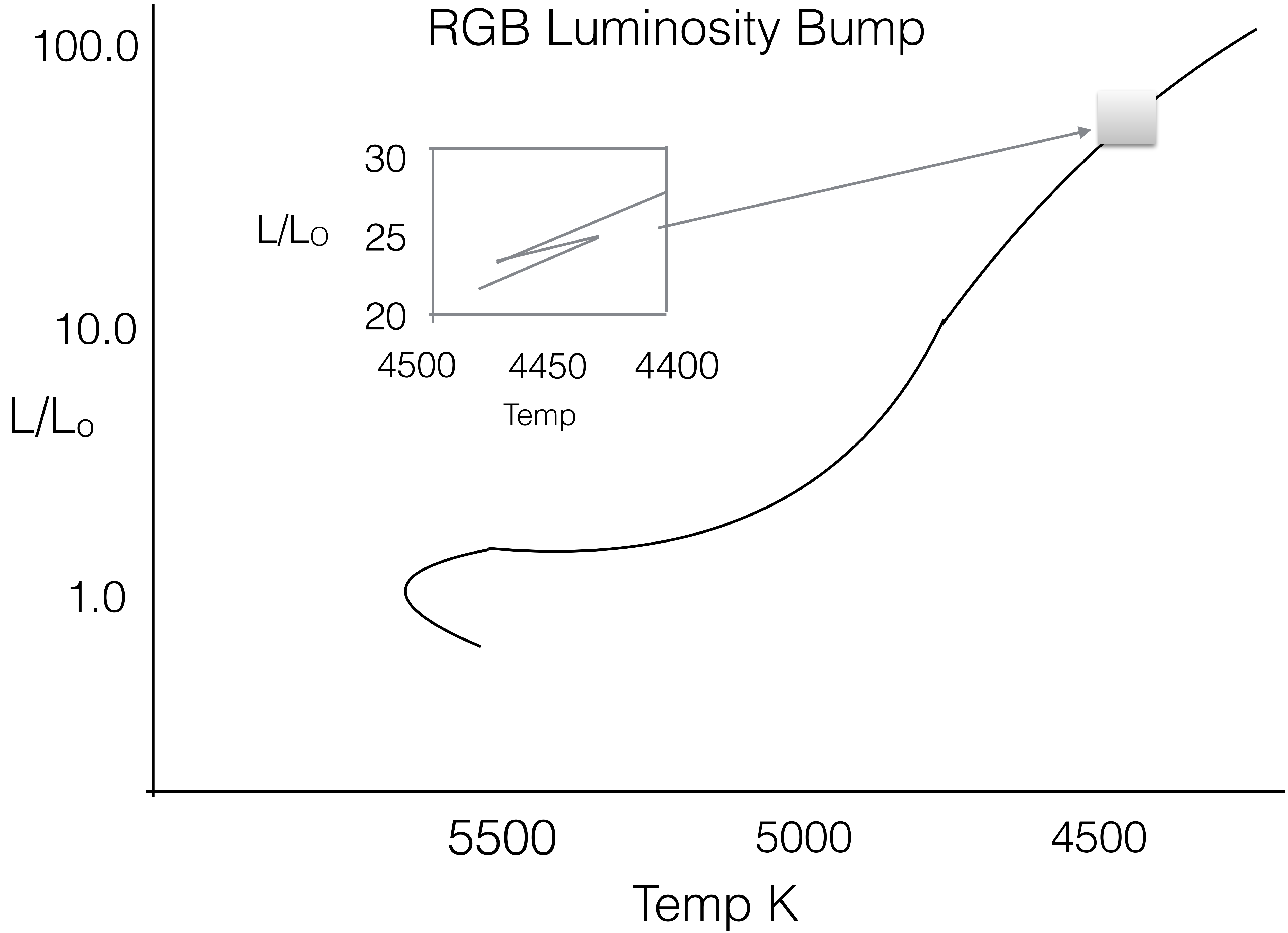
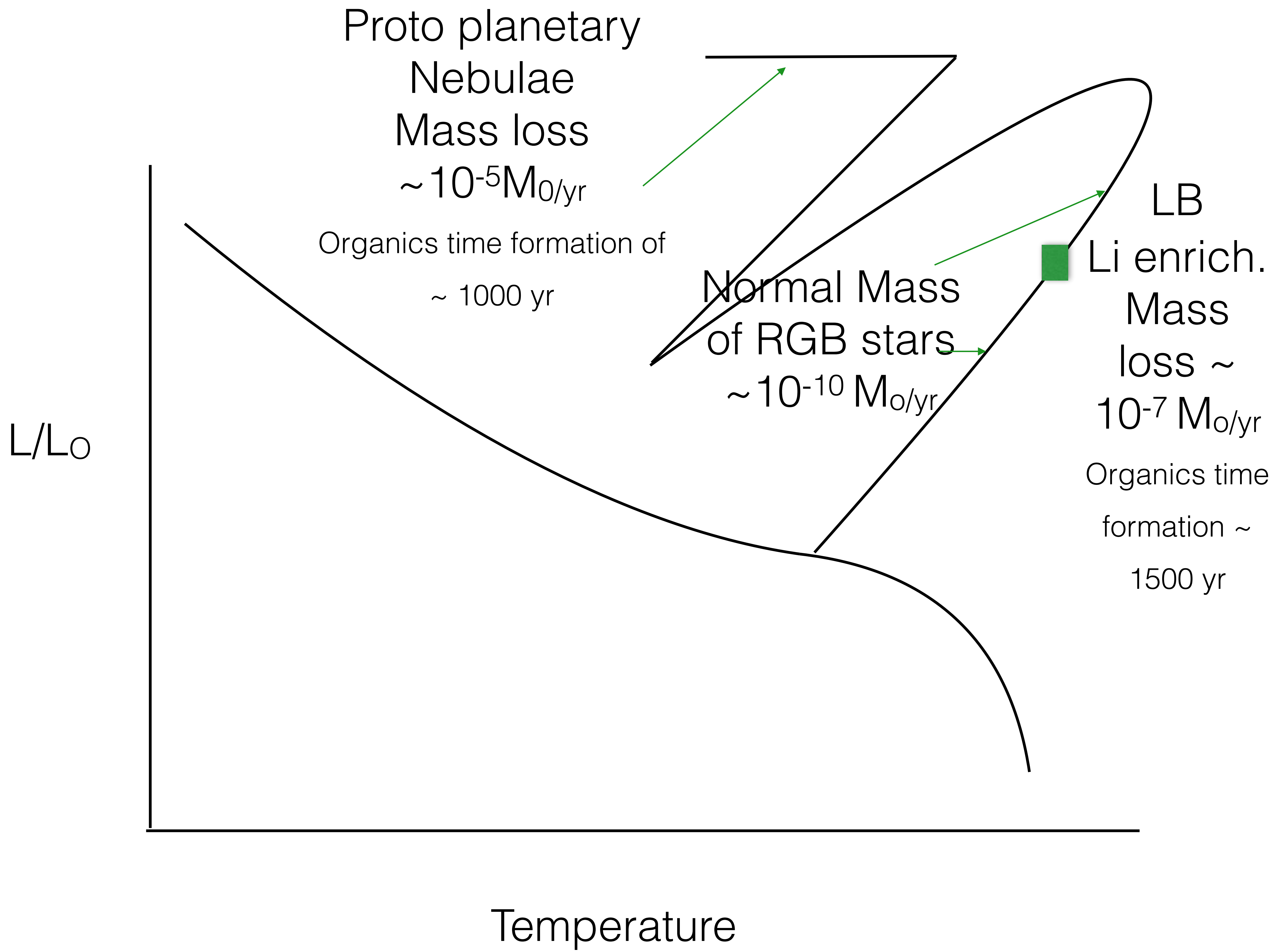
- Observatorio Nacional – MCTI- Rio de Janeiro

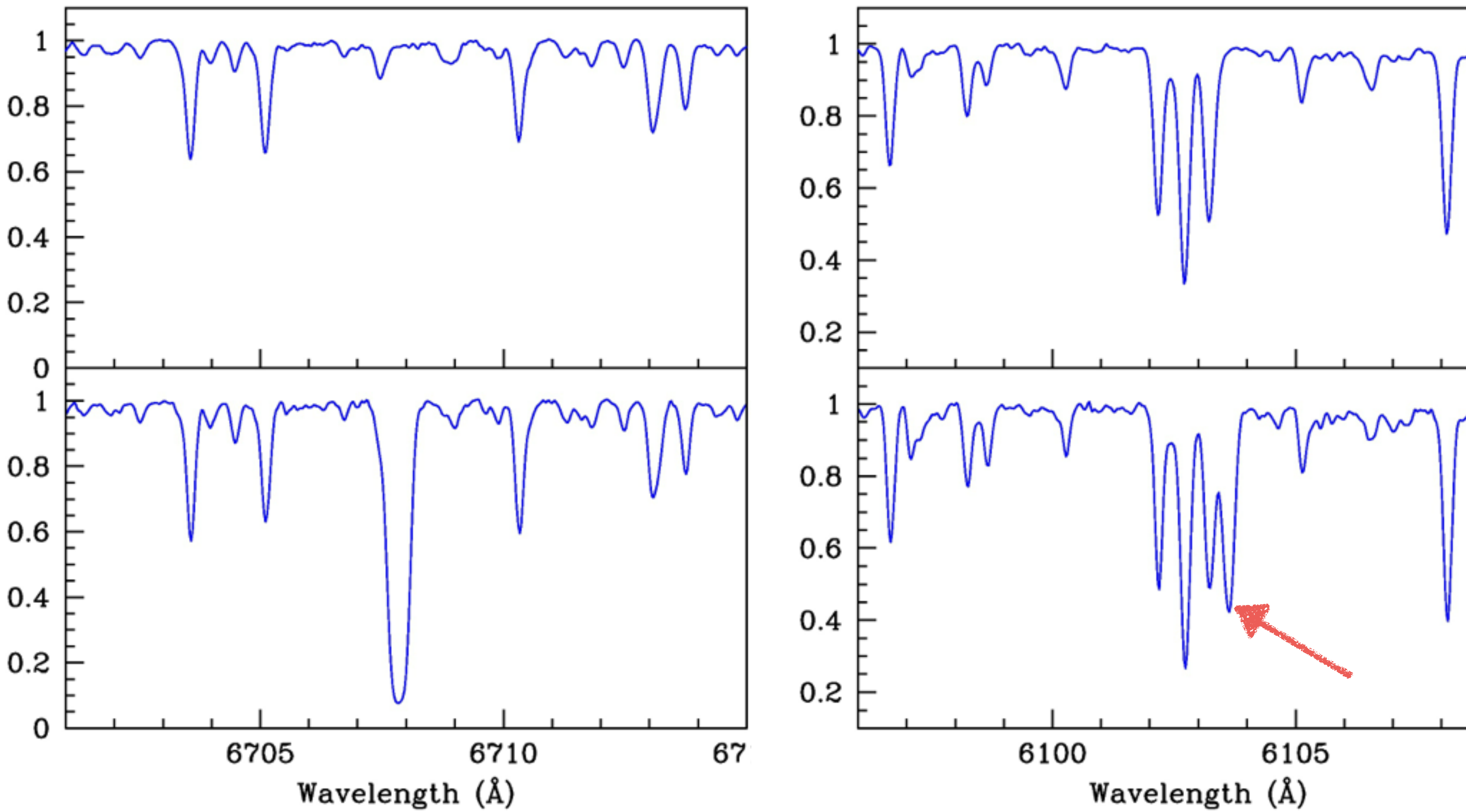
- de la Reza et al. 2015, ApJ, 806, 86


~9 billion yrs
~1 billion yrs
~100 million yrs
~10,000 yrs
Time spent as
Main sequence
Red giant
Yellow giant
Planetary nebula
White dwarf
Sun's age
4.5 billion yrs (now)
12.2 billion yrs
12.3 billion yrs
12.3305 billion yrs
12.3306 billion yrs
Star ejects outer layers.
Core star shrinks. Ejected gases thin and form
Planetary nebula
Red supergiant
12.2 billion years
Helium in core ignites: Helium flash.
MAIN SEQUENCE
Yellow giant
Red giant
Burning hydrogen in shell around core.
Burning helium in core.
Core star cools.
12 billion years
Burning hydrogen in core.
Sun now
4.5 billion years
No fuel available for burning, star cools.
White dwarf
Main sequence
Luminosity (solar units)
10^4
10^3
10^2
10
1
.1
.01
100,000
20,000
10,000
5,000
3,000
Temperature

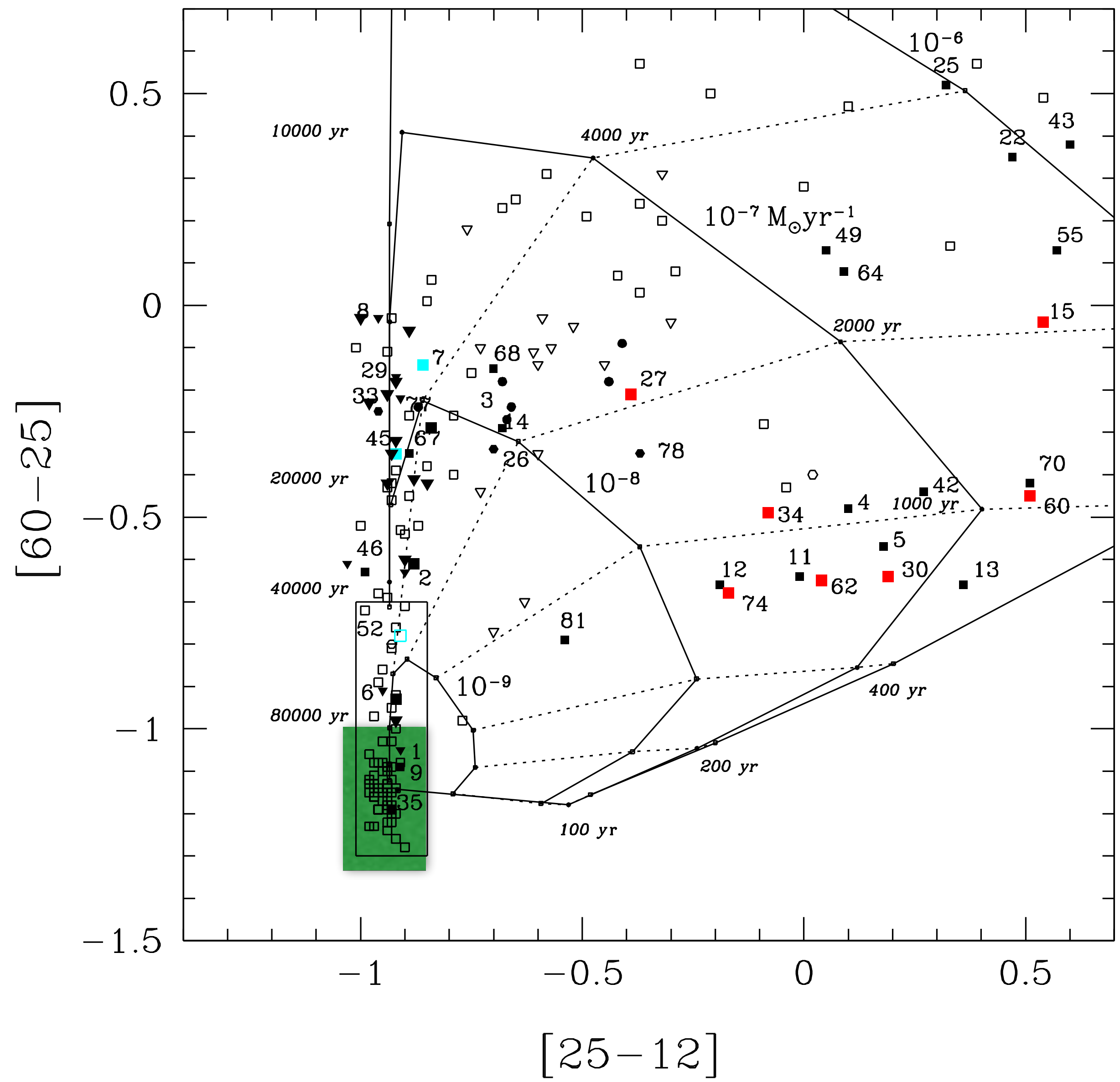

RGB Luminosity Bump
100.0
10.0
1.0
L/Lo
5500
5000
4500
Temp K
30
25
20
L/Lo
4500
4450
4400
Temp



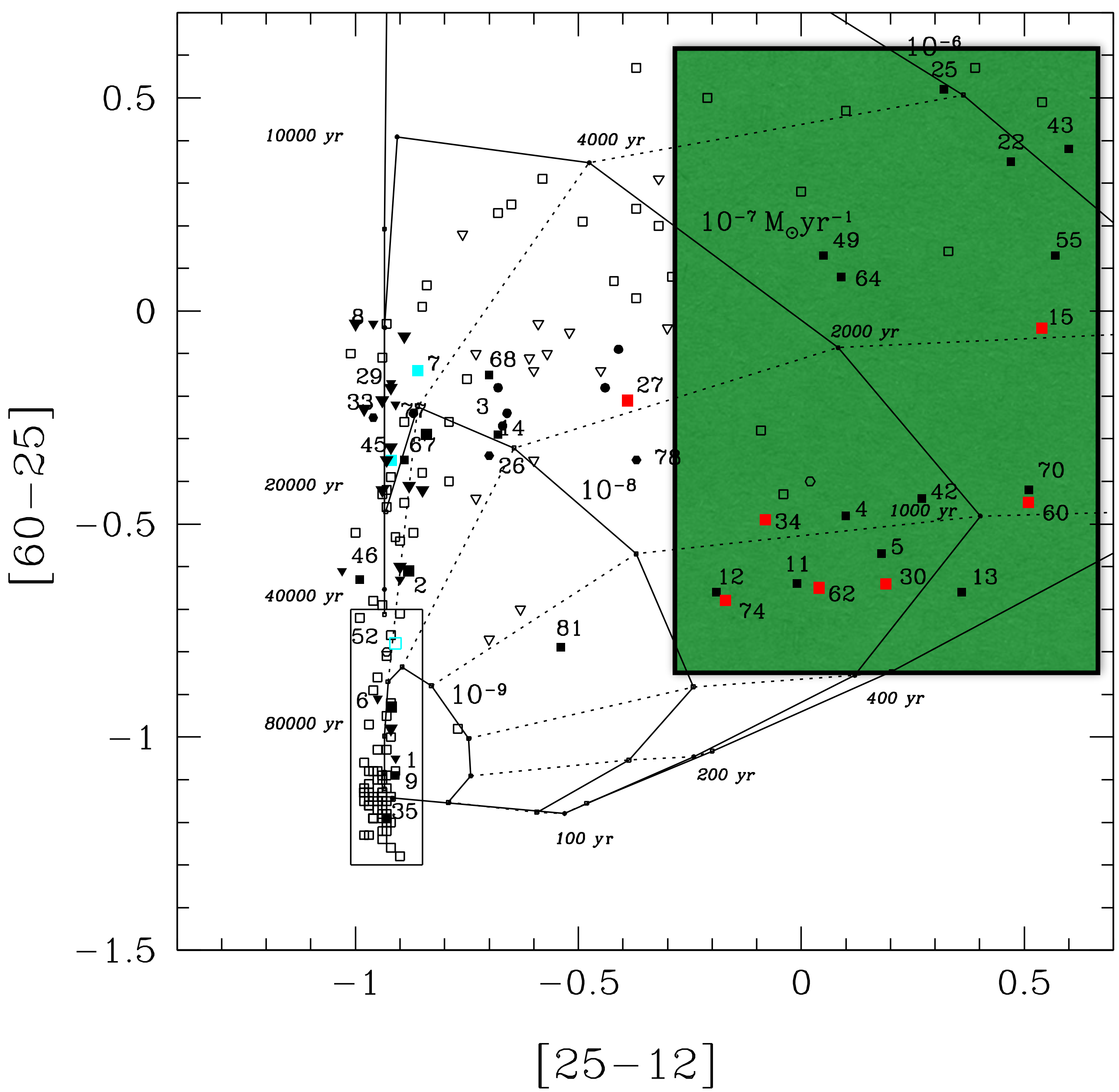
Proto planetary
Nebulae
Mass loss
~10-5M0/yr
Organics time formation of
~ 1000 yr
Normal Mass
of RGB stars
~10-10 Mo/yr
LB
Li enrich.
Mass
loss ~
10-7 Mo/yr
Organics time
formation ~
1500 yr
L/LO
Temperature

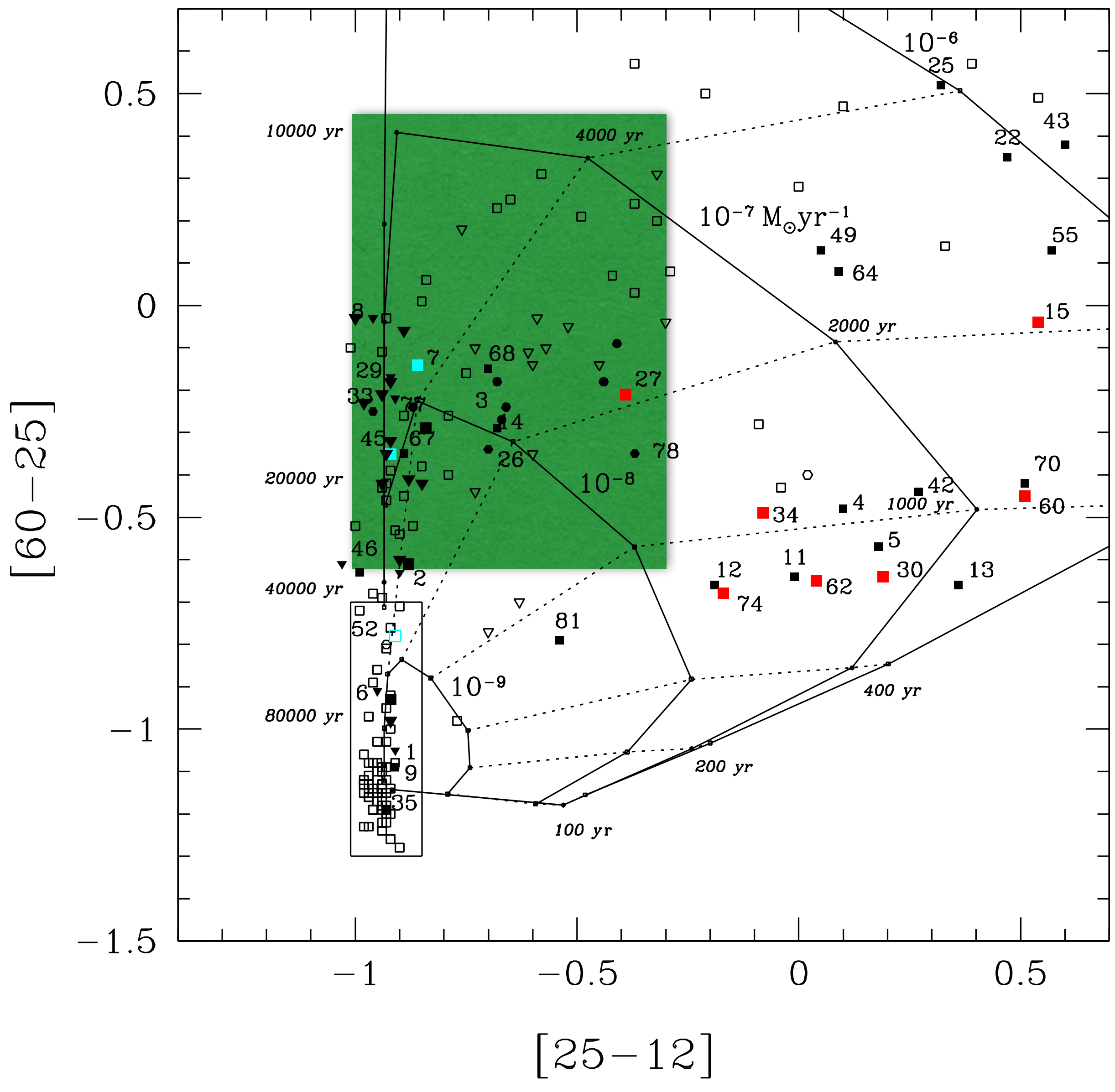


1
0.8
0.6
0.4
0.2
0
6705
6710
67
Wavelength (Å)
6100
6105
Wavelength (Å)

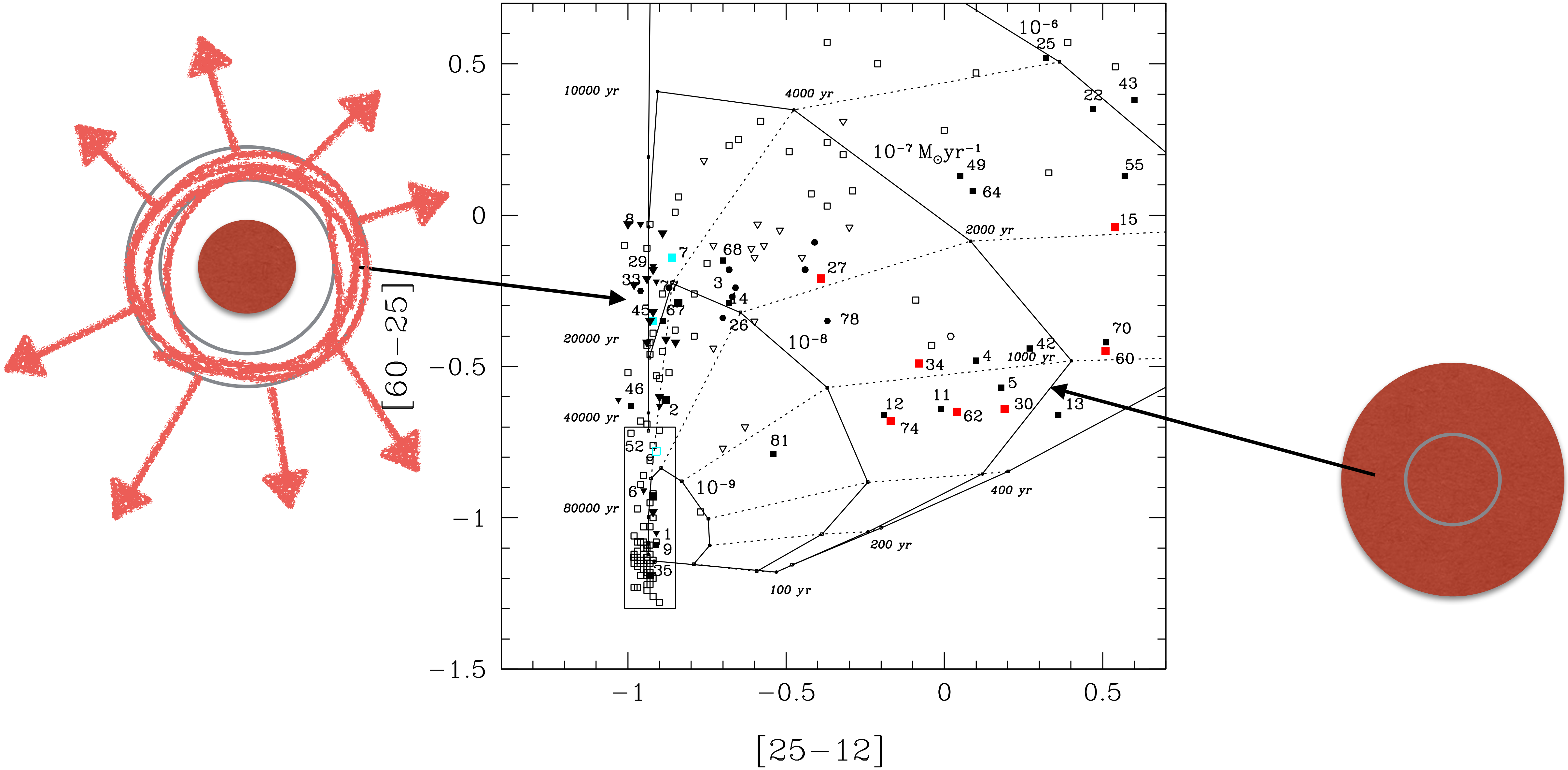


[60−25]
[25−12]
10000 yr
4000 yr
2000 yr
1000 yr
400 yr
200 yr
100 yr
20000 yr
40000 yr
80000 yr
10−6
10−7 M⊙yr−1
10−8
10−9
0.5
0
−0.5
−1
−1.5

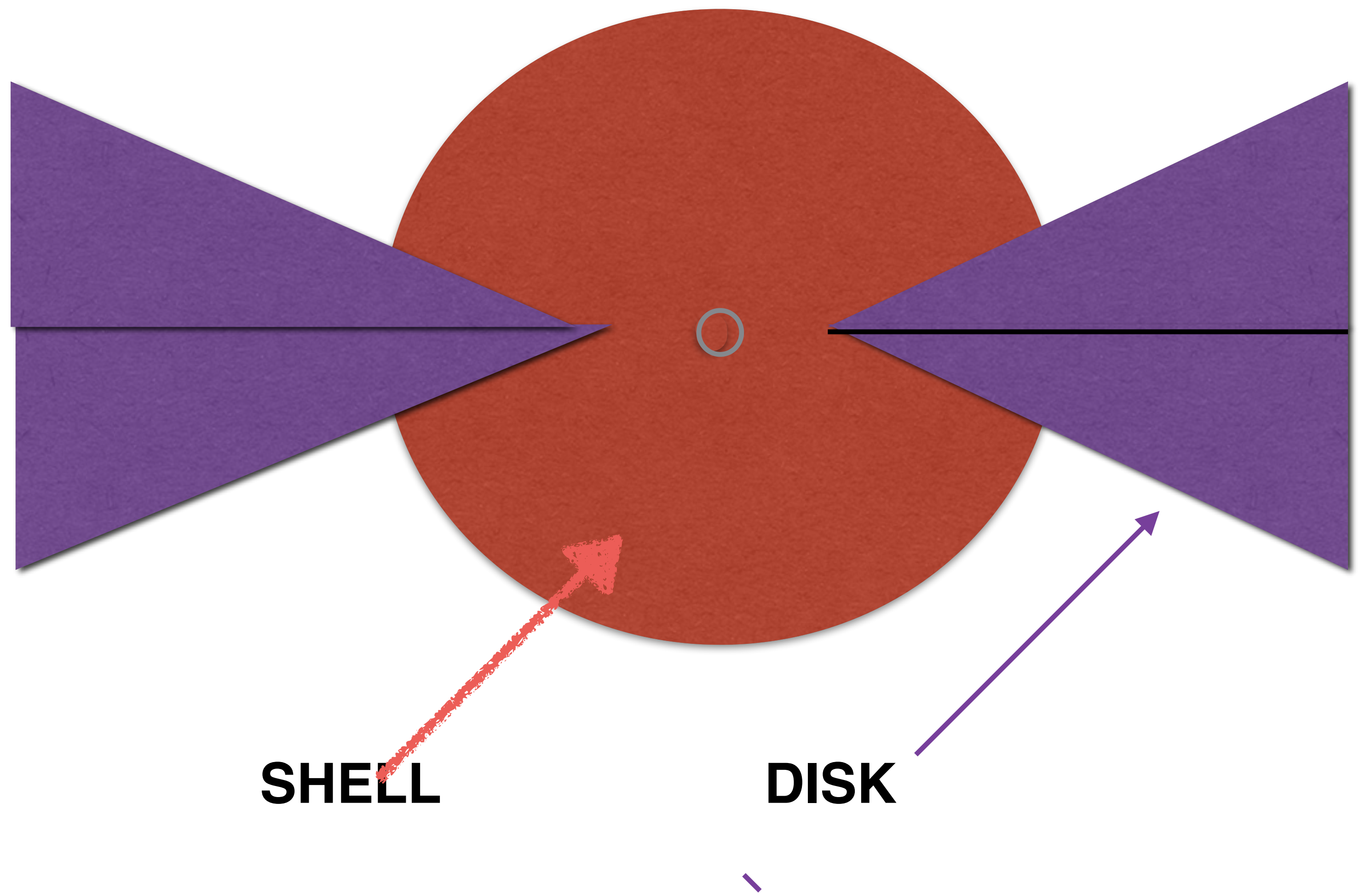

[60−25]
[25−12]
0.5
0
−0.5
−1
−1.5
−1
−0.5
0
0.5
10000 yr
20000 yr
40000 yr
80000 yr
4000 yr
2000 yr
1000 yr
400 yr
200 yr
100 yr
10⁻⁶
10⁻⁷ M⊙yr⁻¹
10⁻⁸
10⁻⁹



10⁻⁶
10⁻⁷ M⊙yr⁻¹
10⁻⁸
10⁻⁹
10000 yr
4000 yr
2000 yr
20000 yr
1000 yr
40000 yr
80000 yr
400 yr
200 yr
100 yr
[60−25]
[25−12]



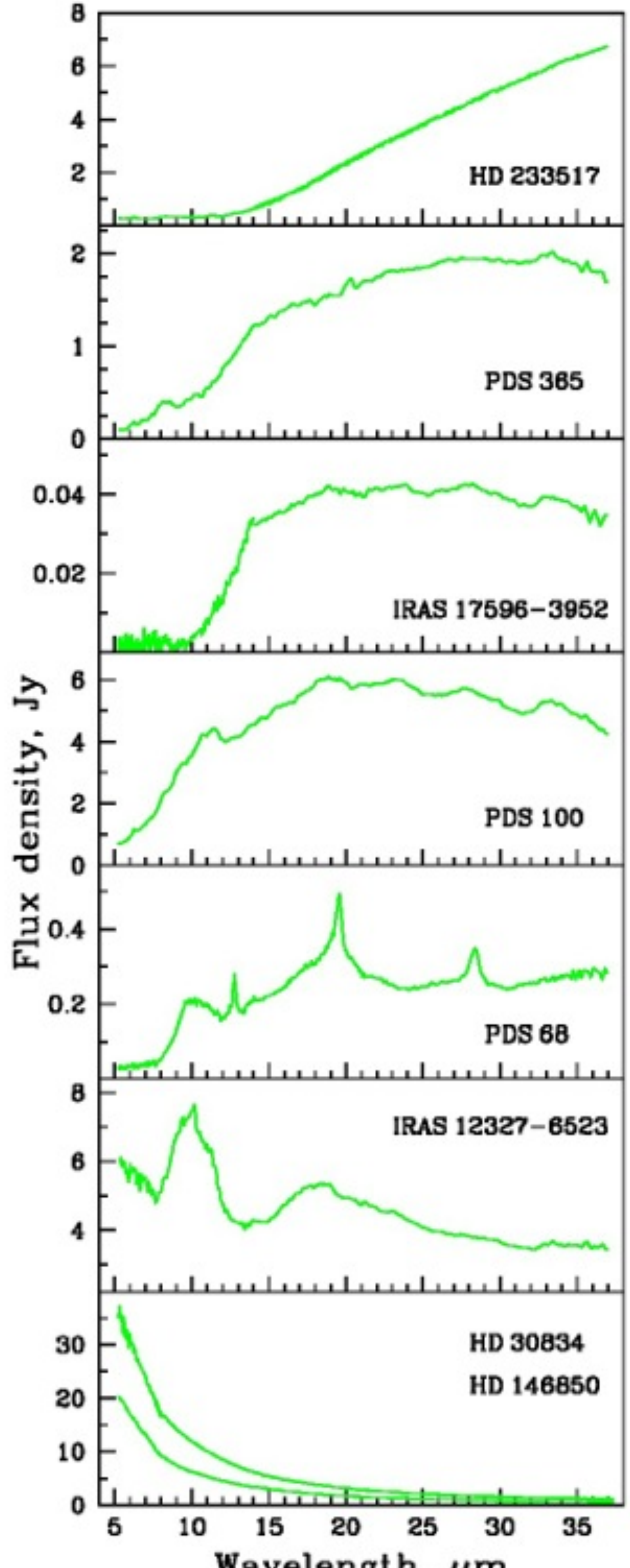
0.5
0
−0.5
−1
−1.5
−1
−0.5
0
0.5
[60−25]
[25−12]
10000 yr
20000 yr
40000 yr
80000 yr
4000 yr
2000 yr
1000 yr
400 yr
200 yr
100 yr
10⁻⁶
10⁻⁷ M⊙yr⁻¹
10⁻⁸
10⁻⁹



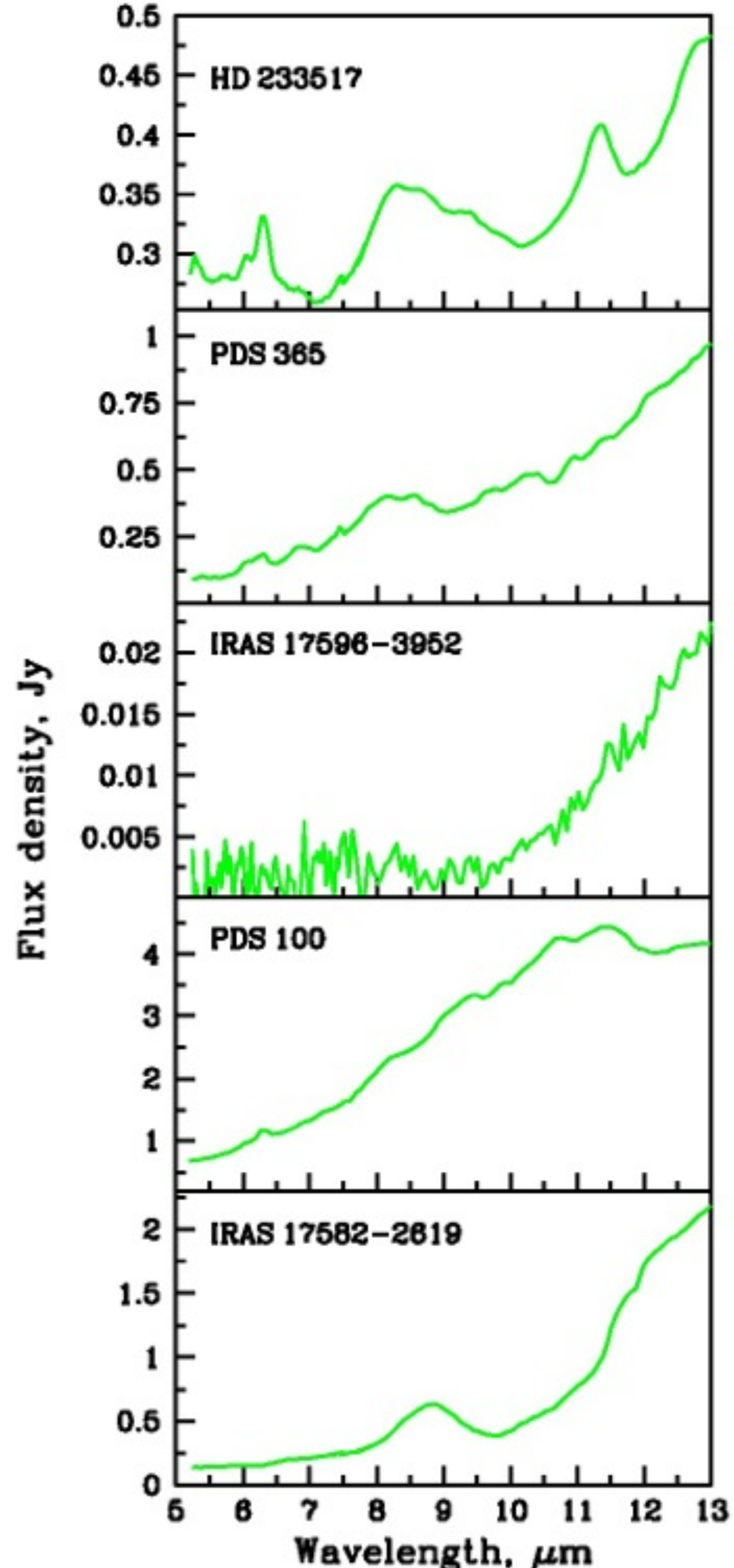
Ex. an Early K-Giant and a disk of a A5 dwarf

Disk remaining when the present giant star was in the MS

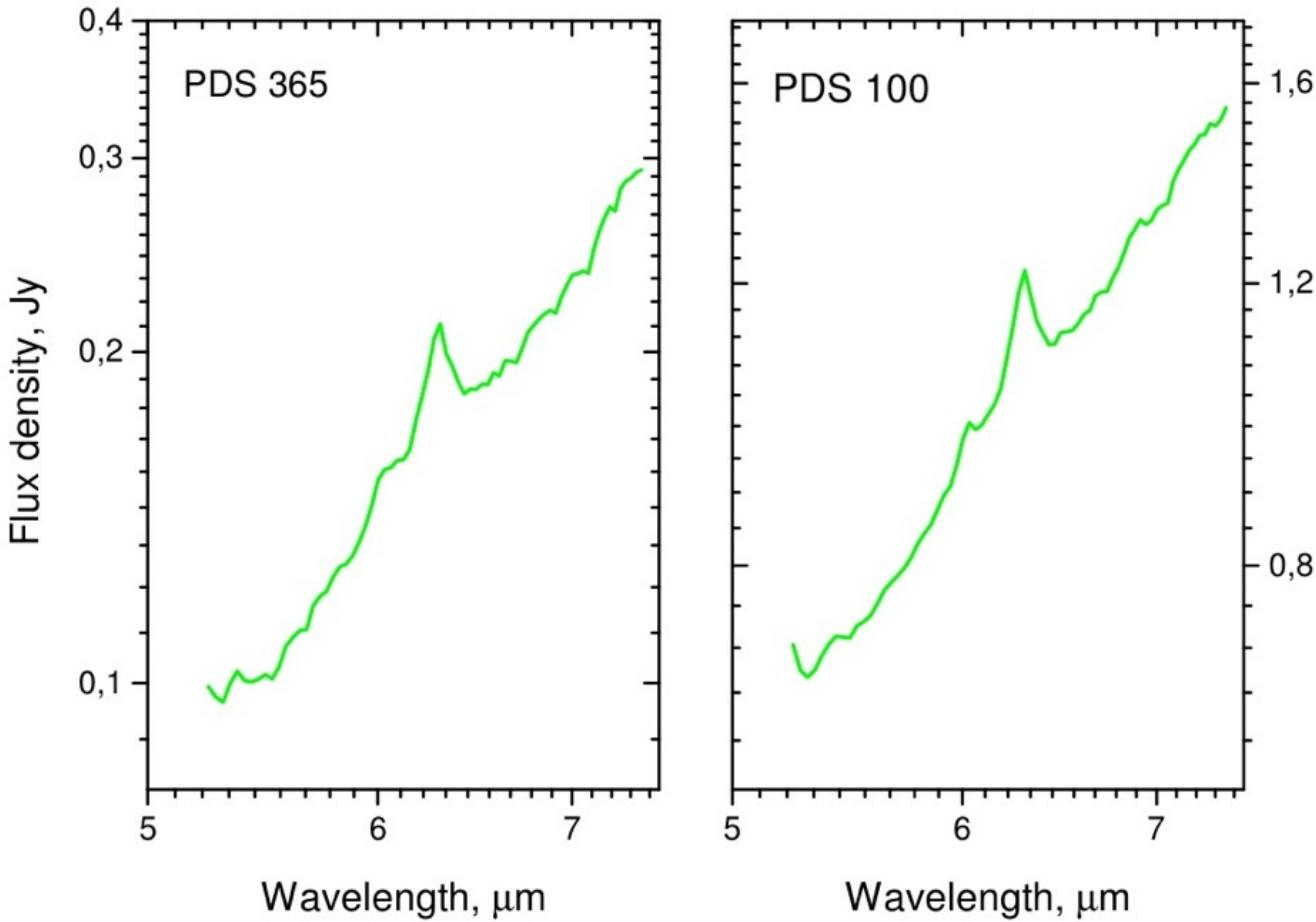
STELLAR WIND DRAG ACTING ON A DISK



Flux density, Jy
HD 233517
PDS 365
IRAS 17596-3952
PDS 100
PDS 68
IRAS 12327-6523
HD 30834
HD 146850
5
10
15
20
25
30
35



Flux density, Jy
HD 233517
PDS 365
IRAS 17596-3952
PDS 100
IRAS 17582-2619
Wavelength, μm
5
6
7
8
9
10
11
12
13


PDS 365
PDS 100
Flux density, Jy
0,4
0,3
0,2
0,1
1,6
1,2
0,8
5
6
7
5
6
7
Wavelength, µm
Wavelength, µm

MODEL OF THE DISK DRAGGING BY THE SHELL

$$R_b^C = (3dM_s/dt/16\pi)\,(V_w)^{-1}(D)^{-5/2}\,(\varrho_b)^{-1}\,(G)^{1/2}\,(M_s)^{1/2)}\,\Delta t$$

Any body with a radius larger than R_b^C will not suffer the drag and will survive at the corresponding distances D. For typical values of lithium rich K-giants at the LP we have:

$dM_s/dt = 10^{-7}\,M_\odot\,yr^{-1}$, $V_W = 2\,km\,s^{-1}$, $M_s \sim 1.0\text{-}1.5 M_\odot$, $\varrho_a = 2.1 g\,cm^{-3}$,

$\Delta t = 1500$ yr and for D = 10, 50, 100, 500AU the respective mean values of R_b^C are approximately 2.2 cm, 0.04 cm, $7 \cdot 10^{-3}$ cm and $1.3 \cdot 10^{-4}$ cm representing small particles.

Larger perturbations can in fact achieved in the inner disk regions.

ORGANIC FEATURES IN THE MID-INFRARED SPECTRA

- There is a family of Unidentified Infrared Emission features **(UIE)** at
- 3.3, 6.2, 7.7, 8.6 and 11.3 μm
- discovered almost 40 yrs ago corresponding to different stretching modes of C-H, C-C of **aromatics** components.
- Others have been found at other frequencies 3.4,15.8, 16.4, ….18.9 μm
- There are also broad bands of broad emission plateaus at:
- 6 - 9, 10 -15 μm known as the 8, 12 plateaus due to a superposition of modes of a mixture of **aliphatics** attached to **aromatics** rings. Also at 15 - 20 μm of **aromatic** rings.
- The whole problem (and a debated subject in the literature) consist to know which are the carriers of the **UIE**.
- Several have been proposed as:
- 1) **PAHs** (Polycyclic Aromatic Hydrocarbons) molecules
- 2) Small carbonaceous molecules
- 3) Hydrogenated amorphous carbon nano particles
- 4) **MAONs** (mixed aromatics/aliphatic organic nano particles)

Table 1: Stars properties and spectral emission features.

Star	Number in Fig. 1	Evolution Phase	$T_{\rm eff}$, K	$\log\varepsilon$(Li)	$\log L/L_\odot$	Emission features (μm)
HD 233517	15	RGB	4475	3.95	2.00[18]	6.26[9] A, 8.2 ALP?, 11.3[9] A, 12.7 ALP?
PDS 365	30	RGB	4540[26]	2.40[26]	1.85[18]	6.26 A, 8 - 9 ALP, 20.0 F/E?, 34.0 F/E?
IRAS 17596-3952	62	RGB	4600	2.30	1.70[18,19]	8.3[20] Si?, 20.0 F/E?, 34.0 F/E?
PDS 100	74	RGB	4500	2.40	1.65[18,21]	6.26 A, 11.4 A, 19.0 F/E?, 23.5 F/E?, 28.0 F/E?, 33.0 UIE
PDS 68	34	RGB	4300	3.9 - 4.2	1.60[18,19]	10.0[22] CE, 12.7 ALP, 19.5[22] CE, 28.2[22] CE
IRAS 17582-2619[(a)]	60	EAGB?	-	~1.40	-	8.7 ALP
IRAS 12327-6523[(b)]	27	EAGB	4200	1.4 – 1.6	2.91[19]	10.0 AM, 18.5 AM

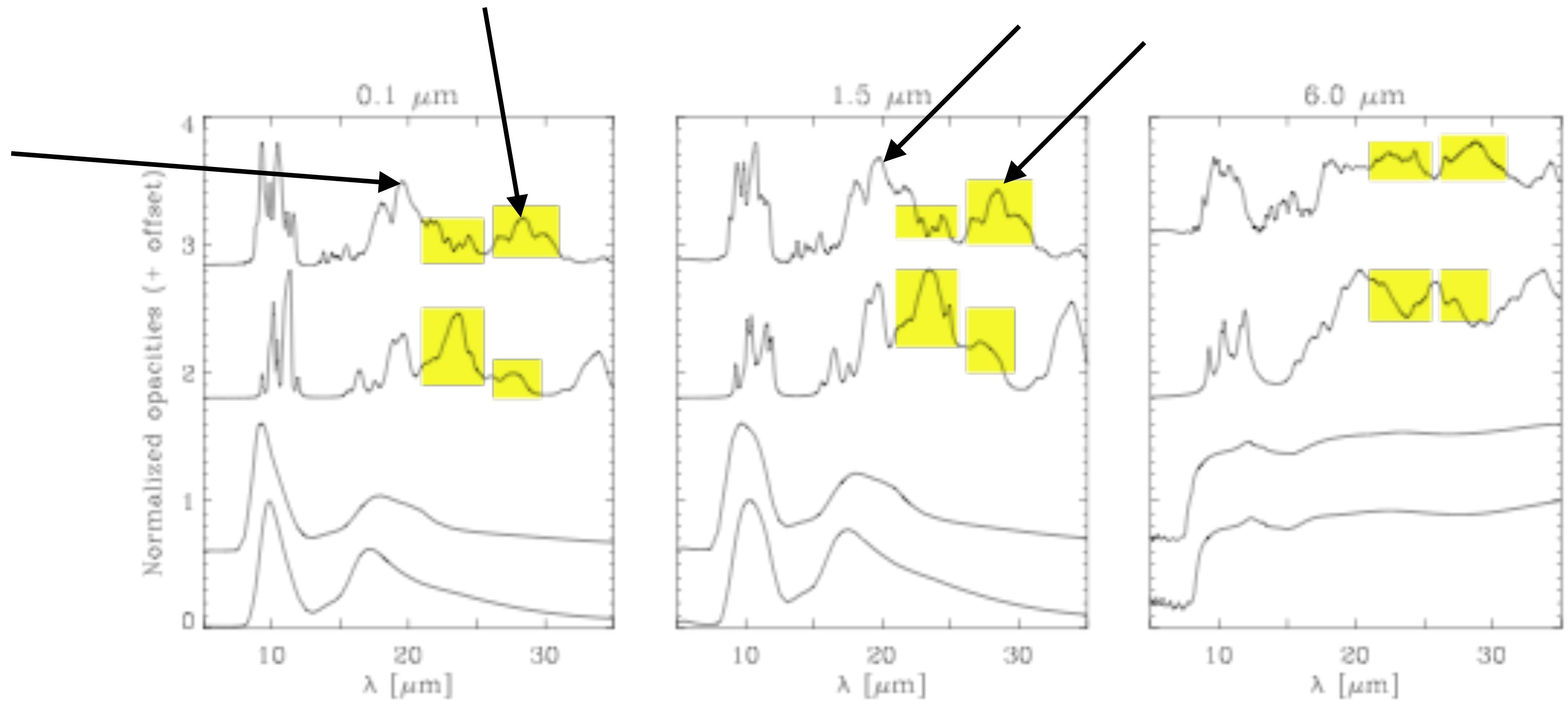
Abbreviations: A - aromatic, ALP - aliphatic plateau, F - fosterite, E - enstatite, Si - silica, CE - crystalline enstatite, AM - amorphous inorganic compound, UIE - Unidentified Infrared Emission.

[(a)] Star IRAS 17582-2619 could be an early-AGB[23] star with a mass loss of $10^{-7}\,M_\odot\,{\rm yr}^{-1}$ following Fig. 1.

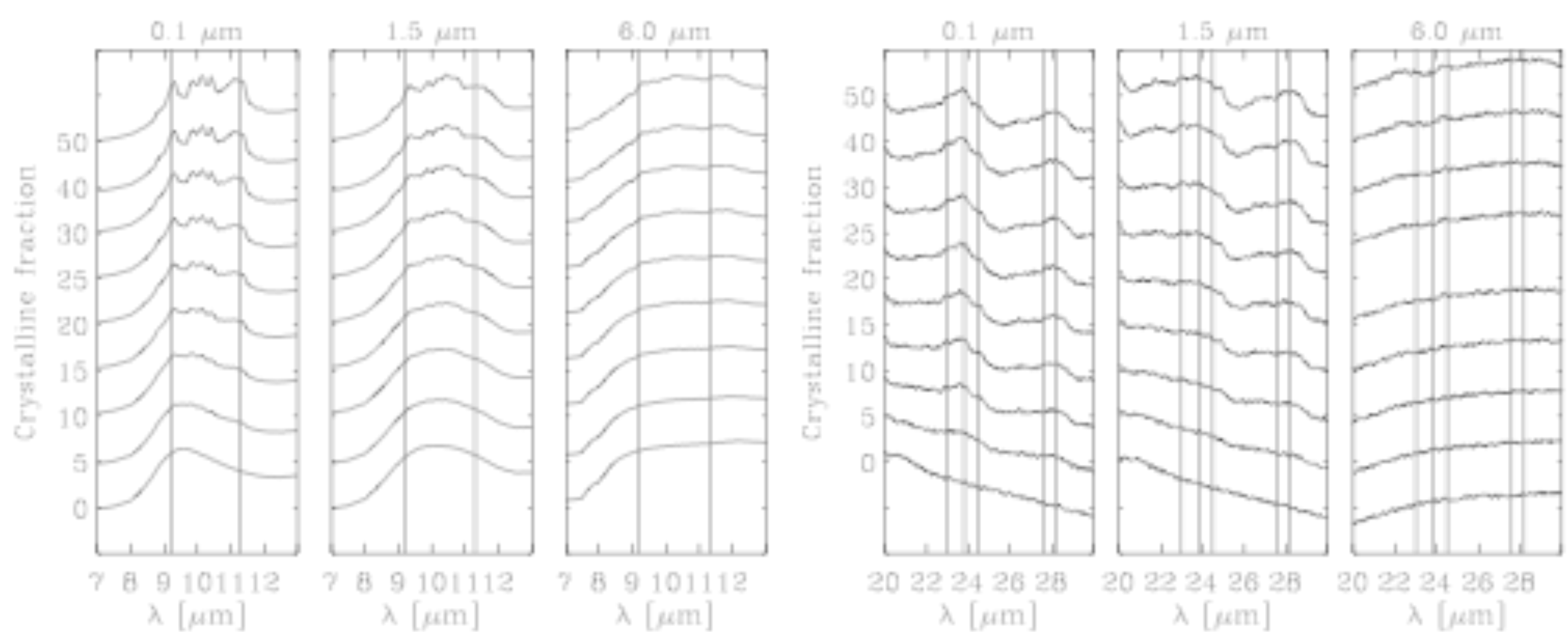
[(b)] Star IRAS 12327-6523 contains two strong emissions at 10.0 and 18.5 μm of possible amorphous inorganic material formed in the stellar wind[28]. Because this early-AGB star has a low mass-loss rate around $5\cdot10^{-8}\,M_\odot\,{\rm yr}^{-1}$ following Fig. 1, it is expected that crystallization is inefficient due to the lower dust formation temperatures expected for these low mass-loss rates[28]. Can emissions at 17.4 and 18.9 μm due to fullerenes contribute to the emission at 18.5 μm?

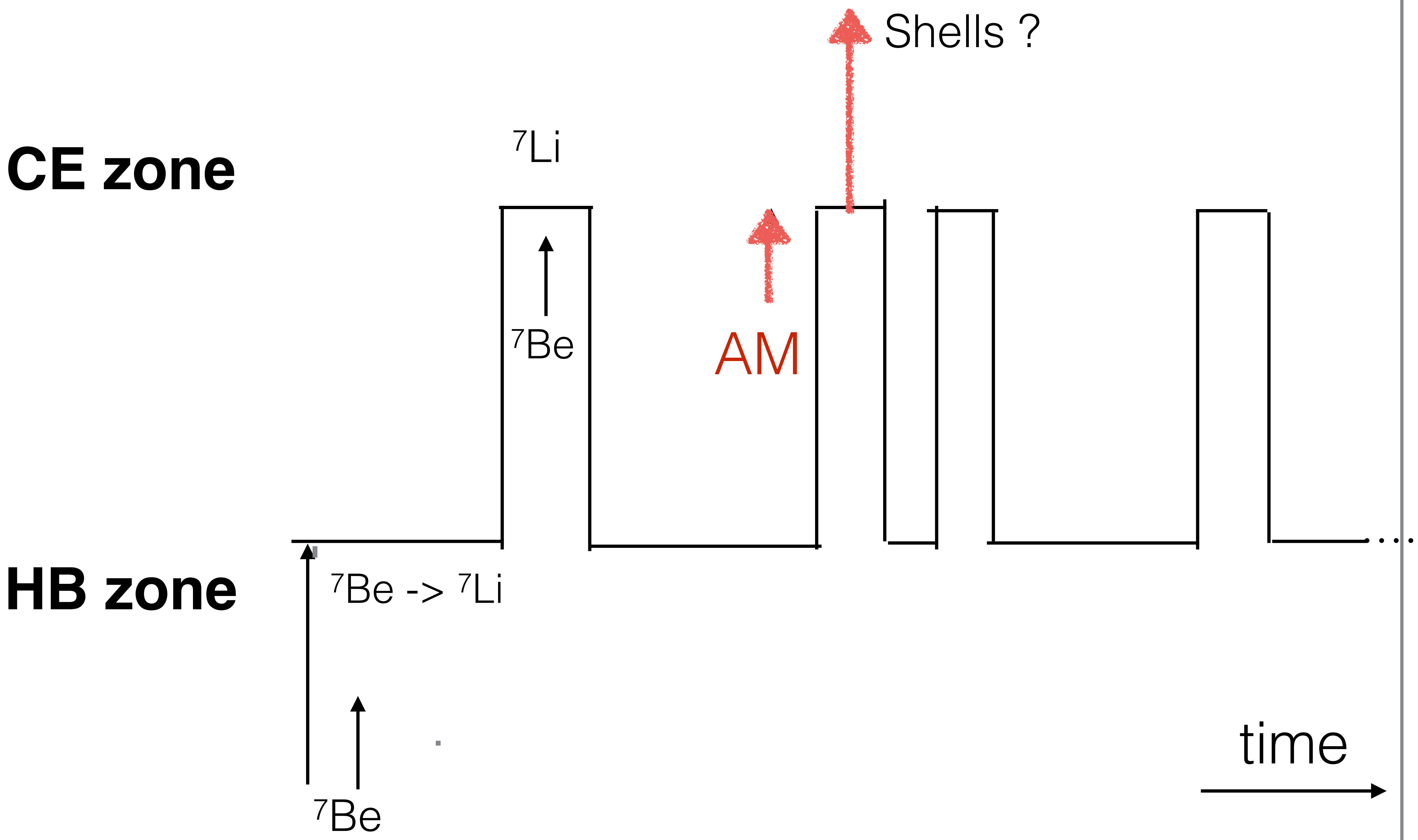
- **CONCLUSIONS**
- **- A new Galactic source of complex organic hydrocarbons compounds is detected.**
- **- This new source appears in ordinary first ascending red K-giant stars (RGB) placed at the Luminosity Bump when an important shell is emerging accompanied by a strong surface Li enrichment.**
- **This phenomena has a very short time life of ~ 1500 yr in which the stellar mass losses are in mean 1000 times larger than the normal mass losses of K-giants.**
- **These attached shells appear in the Mid-IR spectra as spectacular continuum in emission. Superposed to these emission continuum are emission features, normally known as UIE in form of lines and bands.**
- **Some UIE lines and bands correspond to aromatic and aliphatic organic complexes which the simultaneous presence of both organics is compatible with the presence of a low UV radiation field which is the case of these stars.**
- **Other UIE lines correspond to inorganic complexes where are attributed to rests of cm sizes due to the partial destruction by the stellar shell of the debris disk remaining when the star was in the MS. Crystallised and amorphous particles are detected.**
- **We have no found new sources of C to form the hydrocarbons in these oxygenated K-type stars. It is then considered that these organics can be formed with the normal C abundance of these stars.**
- **The main problem remain to know which are the carriers of the organic UIE. Maybe, because of the particulate nature of the stellar shells of these stars, solid 3D particles as the MAONSs could be carriers ?**

Olfsson et al. 2009

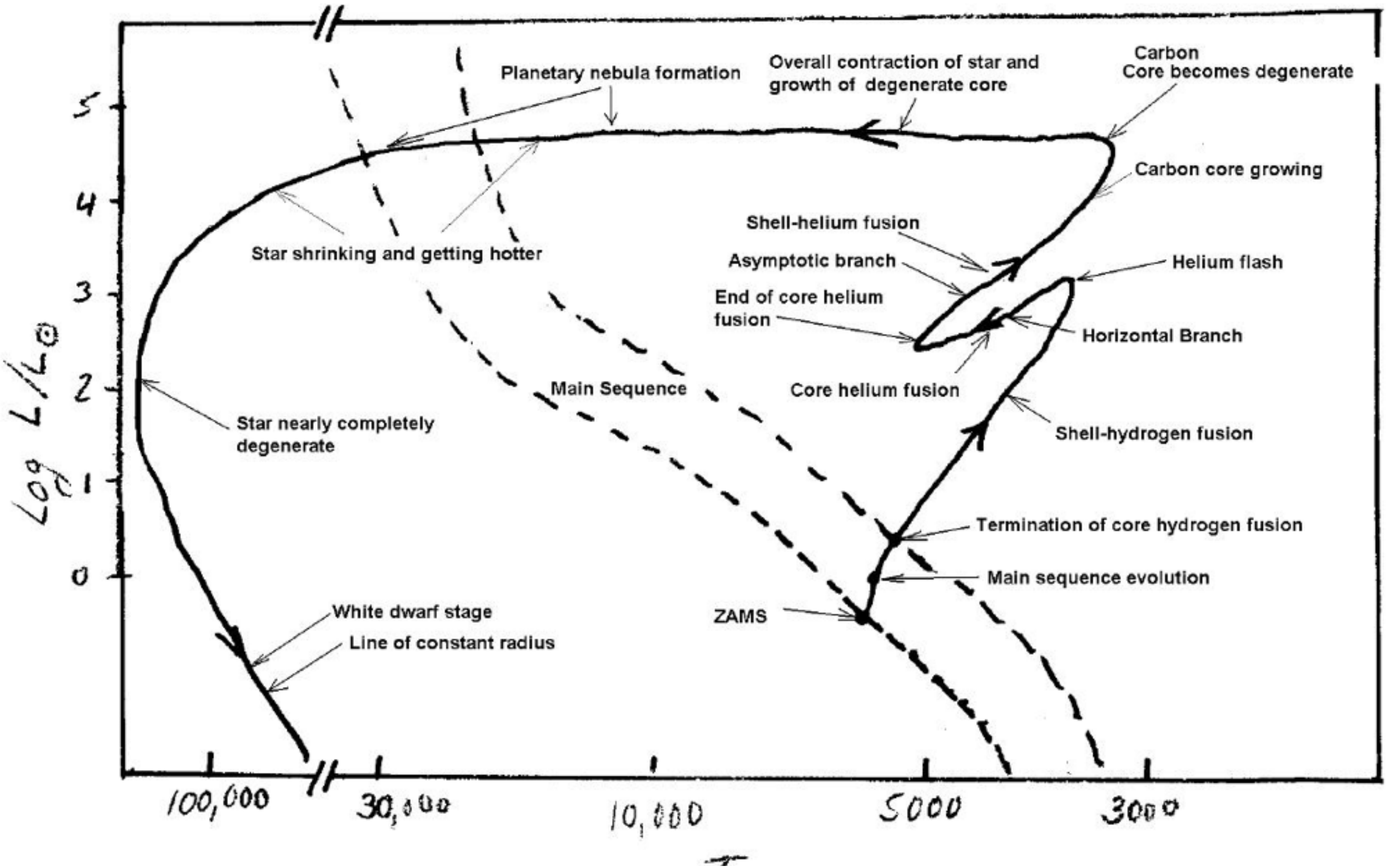


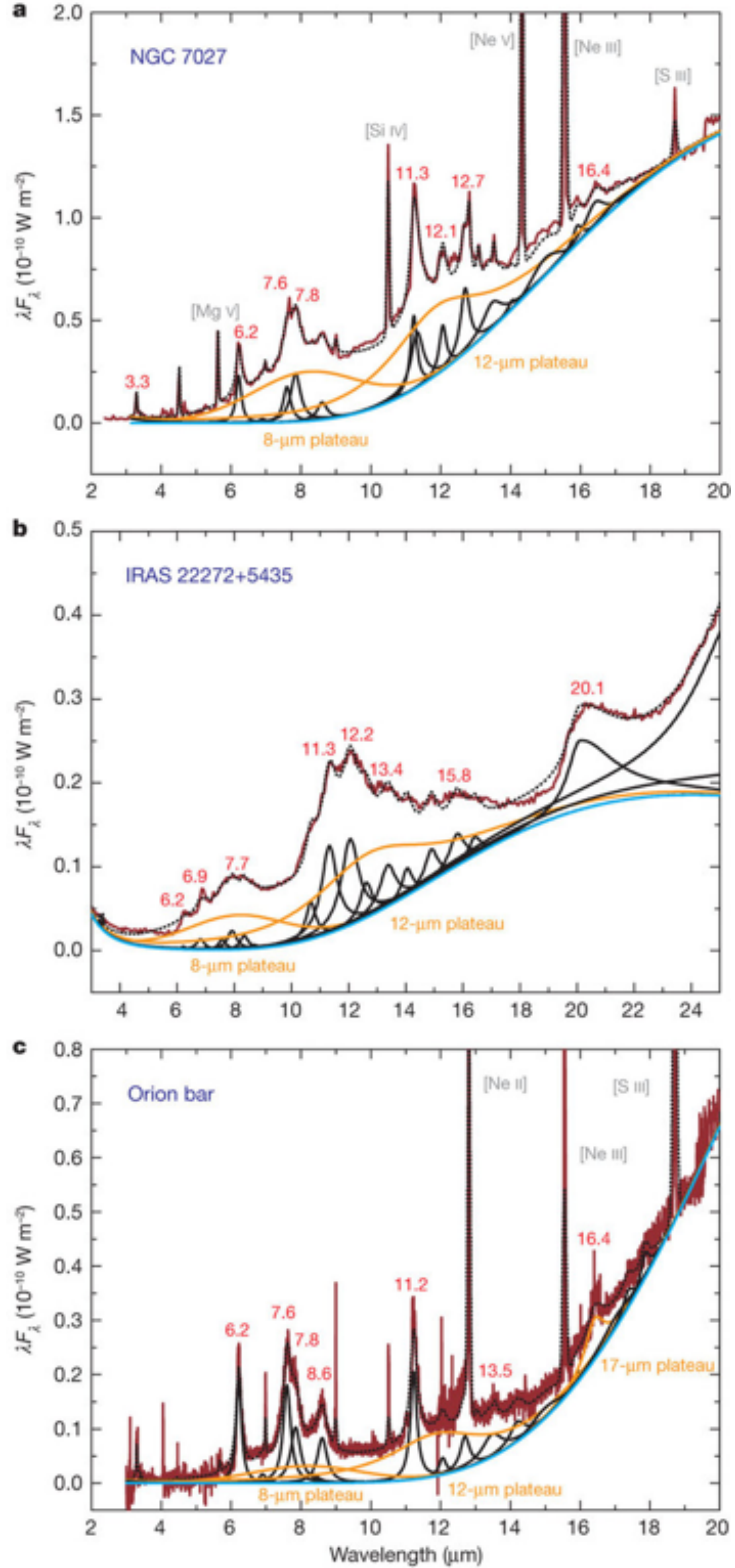
Example mass opacities (in arbitrary units) used to model the IRS observations. From bottom to top: amorphous olivine, amorphous pyroxene, crystalline forsterite and crystalline enstatite. The left panel shows opacities for a grain size a = 0.1 µm, a = 1.5 µm for the middle panel and a = 6.0 µm for the right panel. Some of the features discussed in Secs. 3.1.1 and 3.1.3 can be recognized. Yellow boxes are places of both C23 and C28 crystalline complexes.

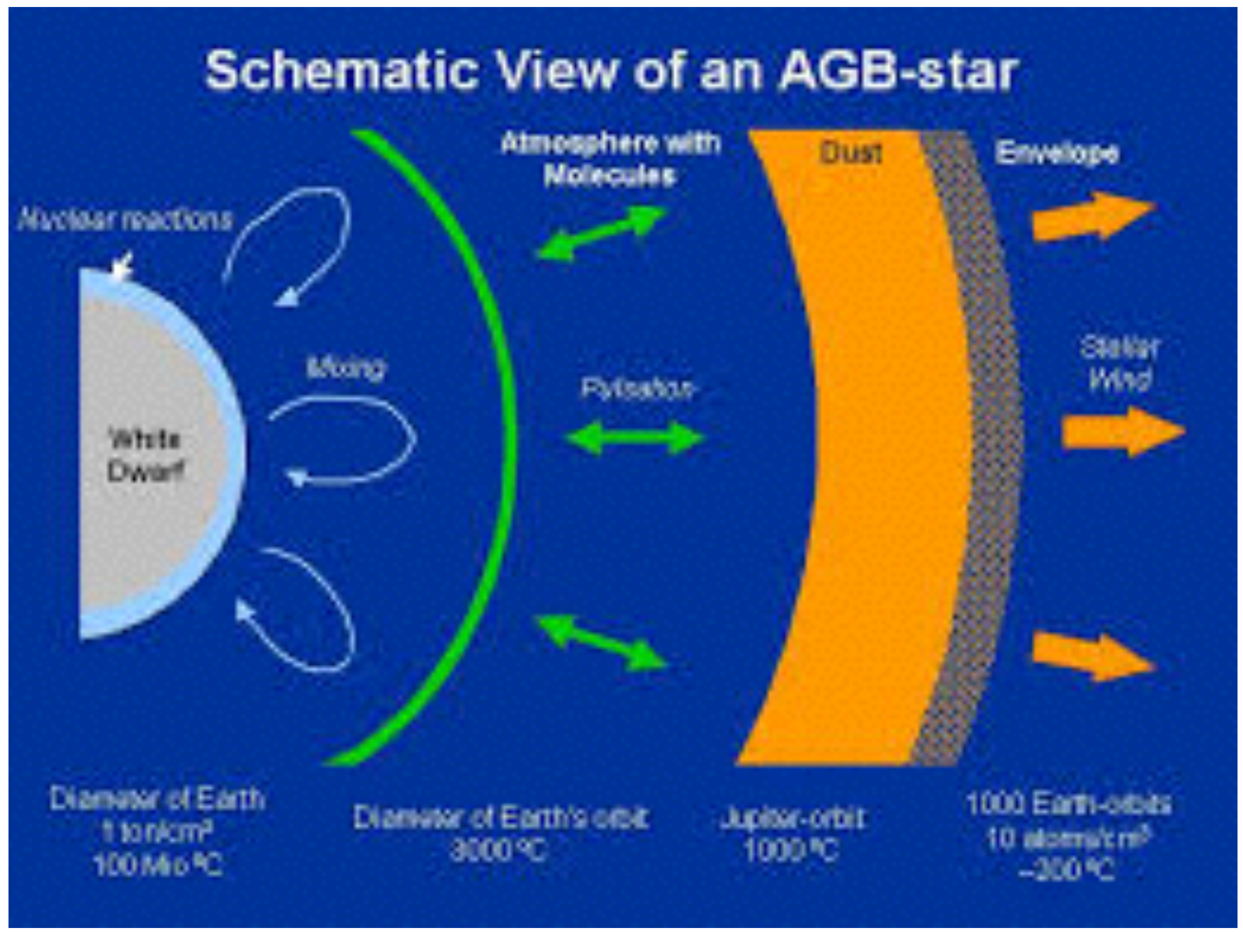




Mixing the ^{7}Li and the stellar core angular momentum transport puzzles


Planetary nebula formation
Overall contraction of star and growth of degenerate core
Carbon Core becomes degenerate
Carbon core growing
Shell-helium fusion
Asymptotic branch
Helium flash
End of core helium fusion
Horizontal Branch
Core helium fusion
Star shrinking and getting hotter
Main Sequence
Star nearly completely degenerate
Shell-hydrogen fusion
Termination of core hydrogen fusion
Main sequence evolution
ZAMS
White dwarf stage
Line of constant radius
Log L/L⊙
5
4
3
2
1
0
100,000
30,000
10,000
5000
3000


a
NGC 7027
[Ne V]
[Ne III]
[S III]
[Si IV]
[Mg V]
3.3
6.2
7.6
7.8
11.3
12.1
12.7
16.4
8-μm plateau
12-μm plateau
λF_λ (10^-10 W m^-2)
b
IRAS 22272+5435
6.2
6.9
7.7
11.3
12.2
13.4
15.8
20.1
8-μm plateau
12-μm plateau
λF_λ (10^-10 W m^-2)
c
Orion bar
[Ne II]
[Ne III]
[S III]
6.2
7.6
7.8
8.6
11.2
13.5
16.4
8-μm plateau
12-μm plateau
17-μm plateau
λF_λ (10^-10 W m^-2)
Wavelength (μm)



Schematic View of an AGB-star
Nuclear reactions
Mixing
White Dwarf
Atmosphere with Molecules
Pulsation
Dust
Envelope
Stellar Wind
Diameter of Earth
1 ton/cm³
100 Mio °C
Diameter of Earth's orbit
3000 °C
Jupiter-orbit
1000 °C
1000 Earth-orbits
10 atoms/cm³
-200 °C