Osservatorio Astronomico di Roma

Gas and dust pollution from AGB stars.

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The chemical species at the base of life (C, O, N, Fe..) derive from nucleosinthesis in the stars..

Why we care about AGB stars when we study stellar pollution?

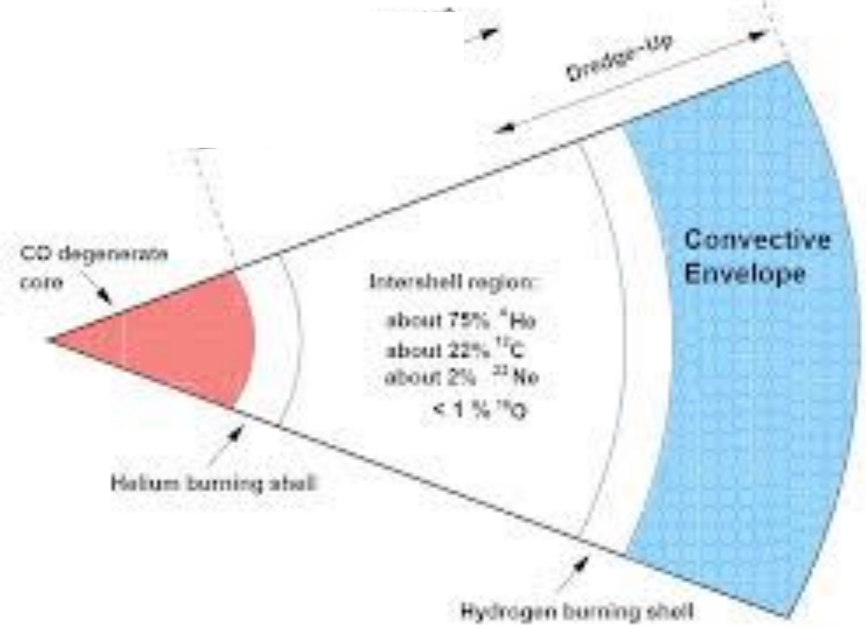
- Significant mass loss occurs (up 10**(-4)Mo/yr)
- low velocity wind (~ 10 km/s)
- AGB is an evolutionary phase crossed by about 90% of stars

Though short-lived, the AGB phase is of paramount importance for a number of astrophysical topics:

IN THE MILKY WAY :
1)light elements abundance,
2)provide the gas required to form second generation stars in globular clusters (Ventura+01)
.....

IN THE EXTRAGACTIC CONTEXT:
1)Can dominate bolometric flux
2)crucial to interpret the infrared fluxes of the galaxies (Jones+17)
3)prove essential for the understanding of the dust content observed in high-redshift Universe (Qang+13, Valiante+11, Pipino+11)

The pollution of AGB stars is determined by the relative importance of:



● Third Dredge Up (TDU)

after each thermal pulse the base of the convective envelope deepens down to the C-rich zone processed by 3-alpha nucleosynthesis

- Increase the carbon surface fraction (and N and O)

-> C/O> 1 = CARBON STARS!!

● Hot Bottom Burning (HBB)

proton capture nucleosynthesis base of the convective envelope when Tbce>30-40MK

-O-rich envelope altered by proton capture nucleosynthesis

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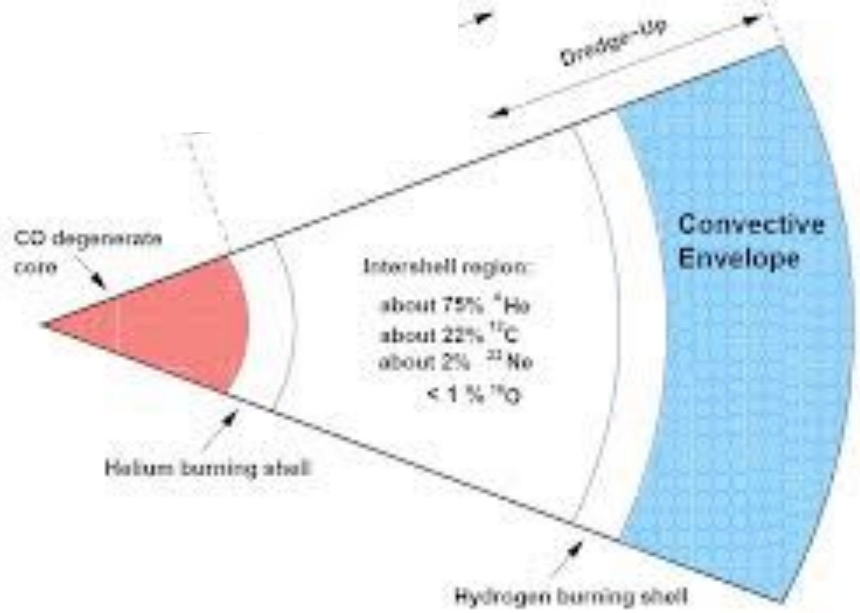

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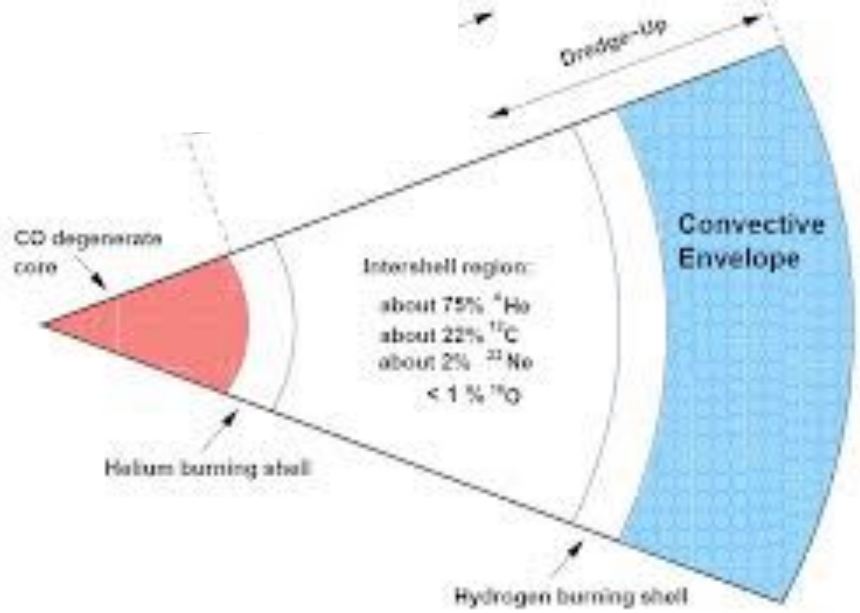

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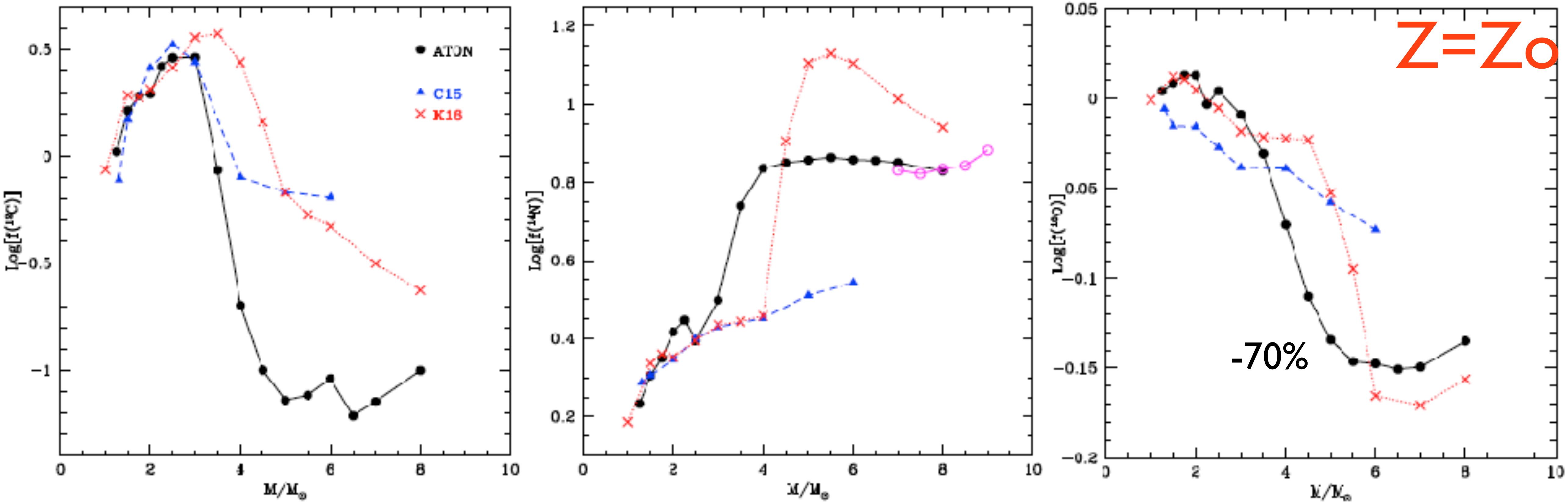
The robustness of the present generation of AGB models; dependence by convection and mass loss treatment

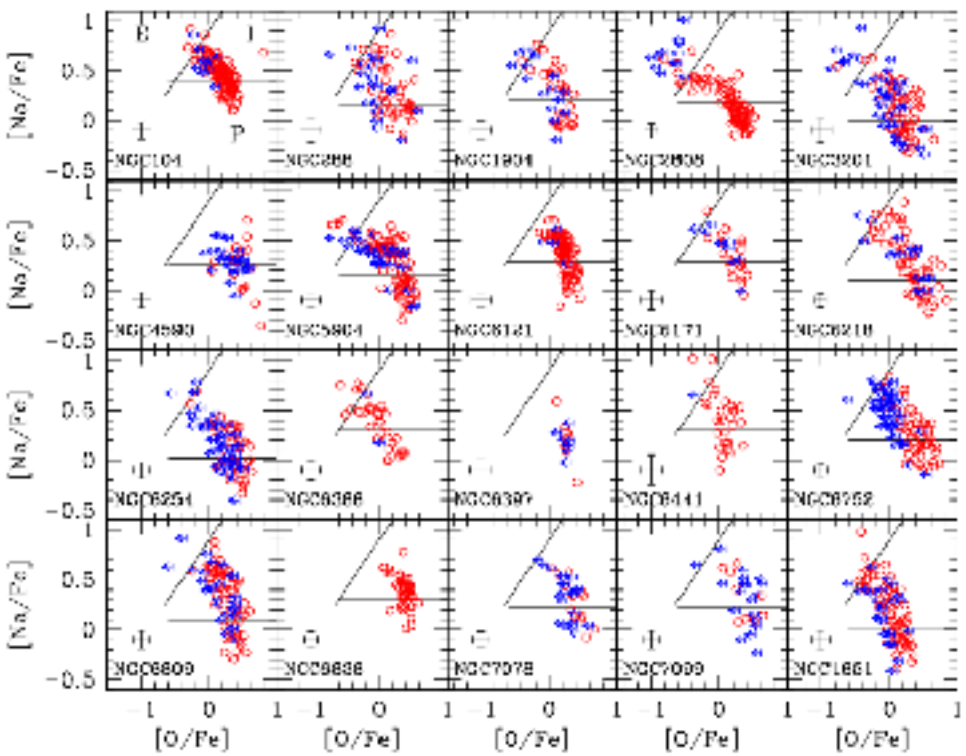


ATON- Di Criscienzo et al 2016
C15 - Cristallo et al. 2015
K16 - Karakas & Lugaro 2016

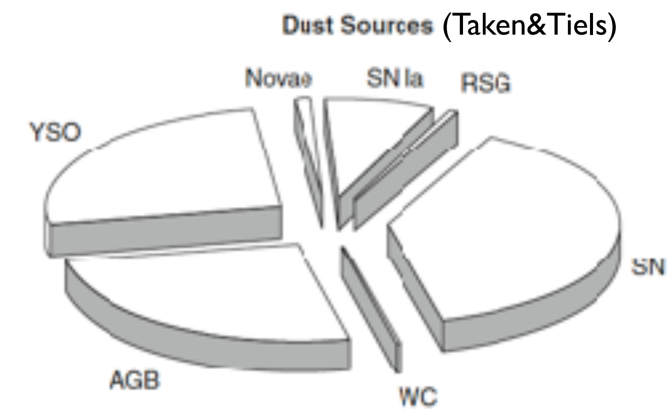
f(X)= the ratio between the average mass fraction of a given element X in the ejecta and its initial quantity

Large uncertainties but large importance of AGB models in the interpretation of the observations. Examples:

*Multiple stellar populations in Galactic Globular Clusters
(Renzini+2015, Piotto+2015..)

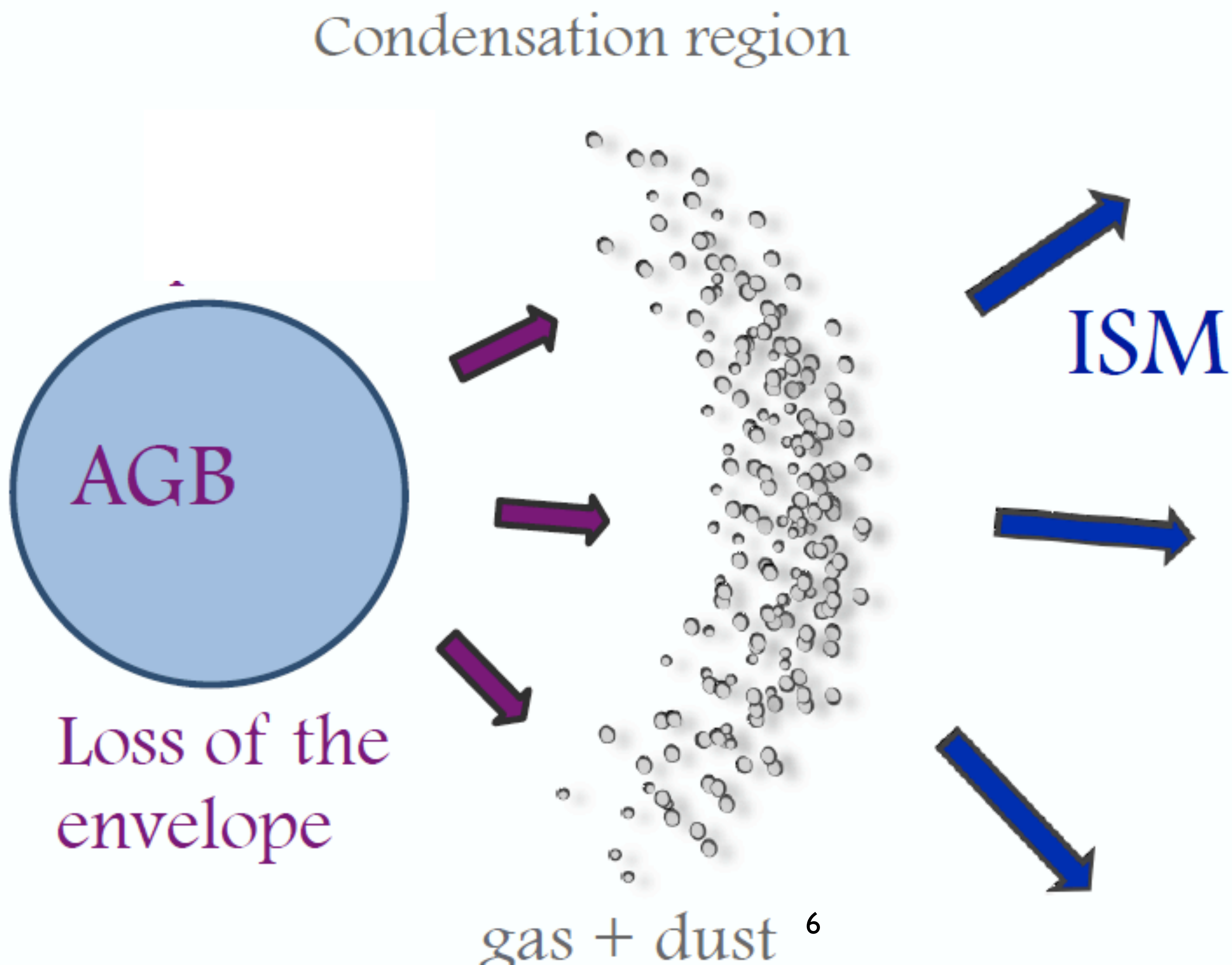


Dust production from AGB stars

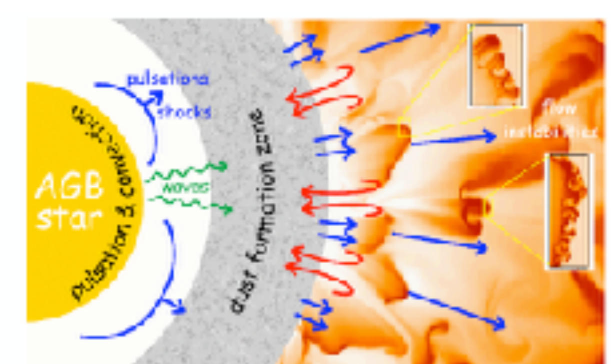


-Low gravity -> high mass loss rate -> dense winds

-Large external regions and low temperature -> NO sublimation



pulsation



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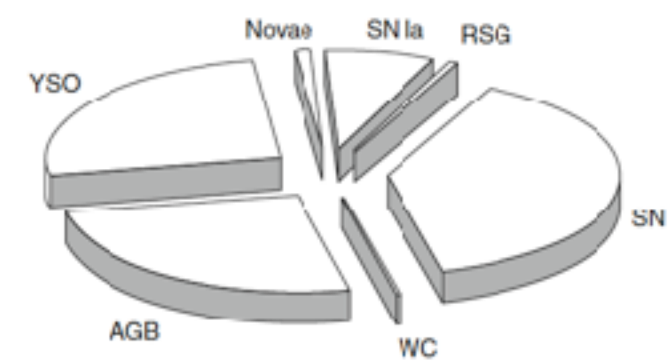

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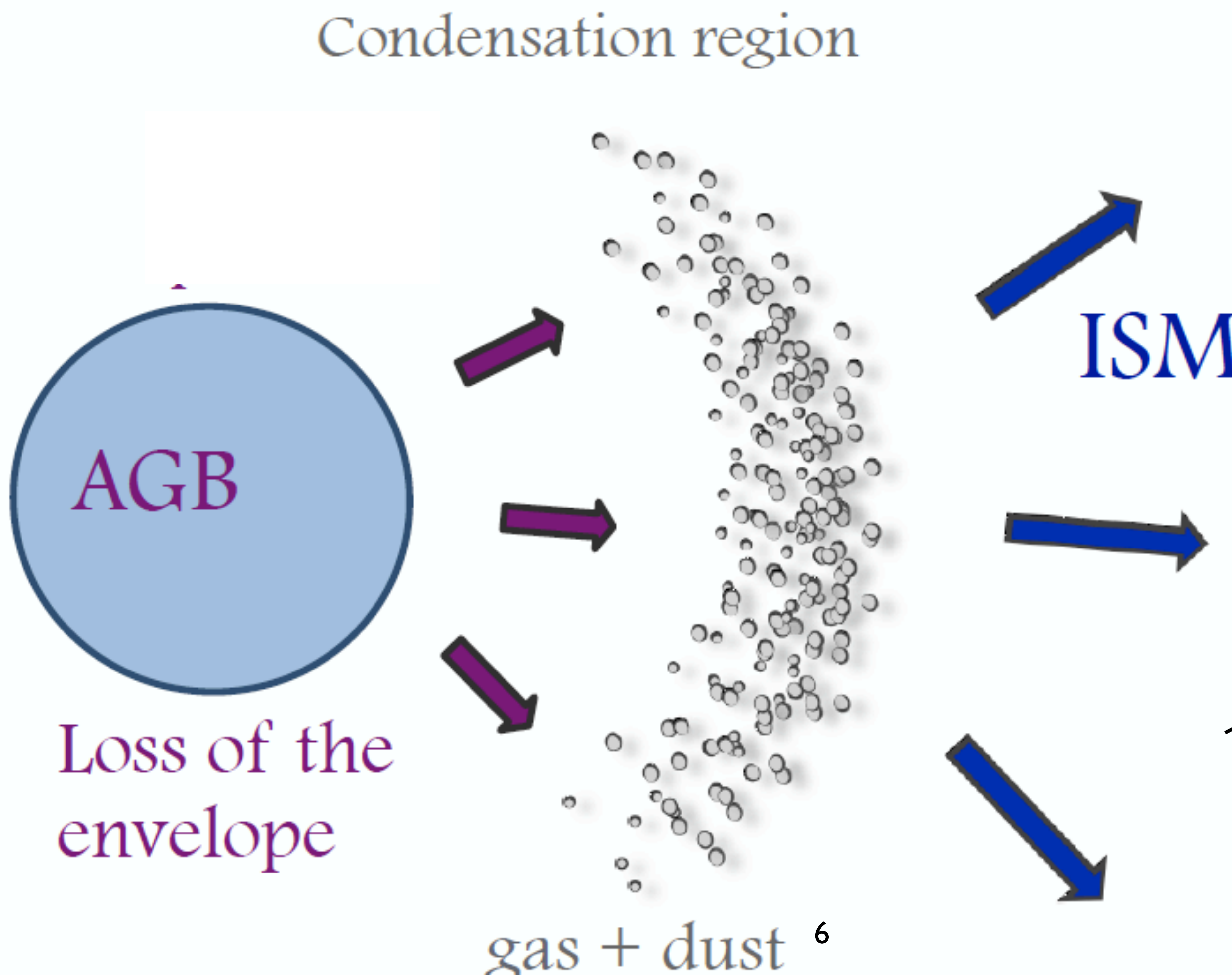

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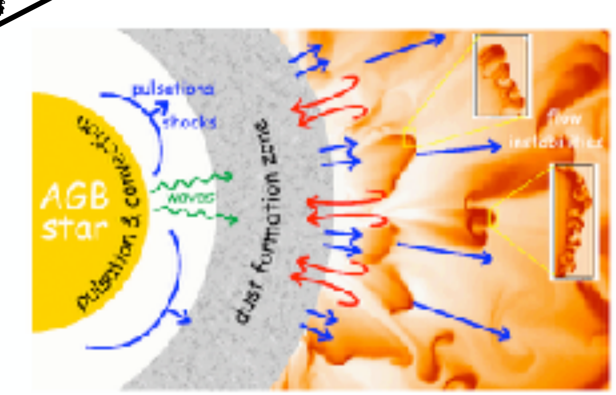
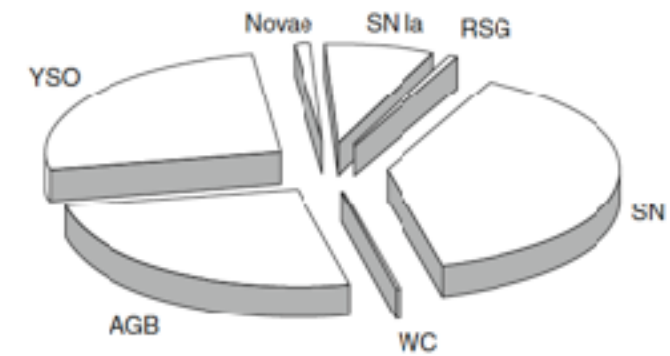


Dust production from AGB stars

Dust Sources (Taken&Tiels)



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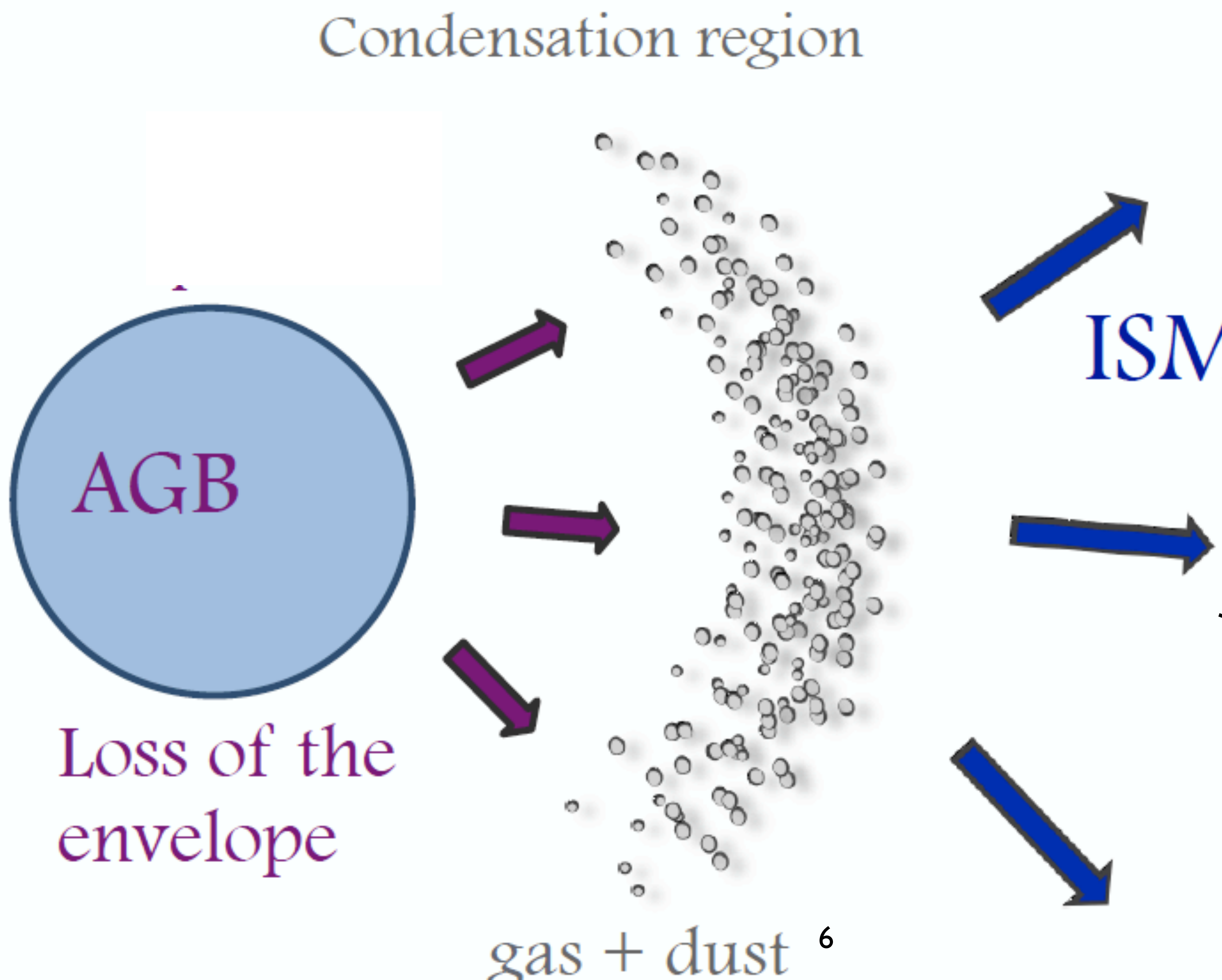

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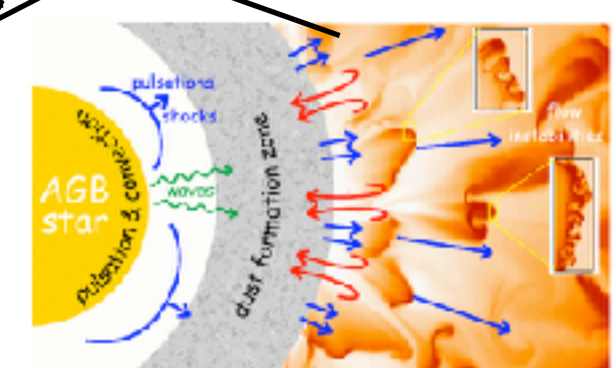


Simple scheme of wind and dust production

(Ferrarotti & Gail, 2002, 2003, 2006)

The schematization adopted is based on the assumption that the wind expand isotropically from the stellar surface,and is accelerated under the push of radiation pressure acting on newly formed dust grains.

The velocity of the wind particels is given by the momentum equation

$$\mathrm{v}\frac{\partial \mathrm{v}}{\partial r} = \frac{\partial P}{\partial r} + \frac{GM_*}{r^2}(1-\Gamma)$$

$$\Gamma = \frac{L_*}{4\pi c GM} k$$

Extinction coefficient: knowledge of the dust present in the wind needed

$$k = \sum k_i f_i$$

Density and temperature stratification of the wind required

$$T^4 = \frac{1}{2}T_{\mathrm{eff}}^4\left(1-\sqrt{1-\frac{R_*^2}{r^2}}+\frac{3}{4}\tau\right)$$

$$\frac{\partial \tau}{\partial r} = -\frac{k\rho}{r^2}$$

Mass conservation

$$\rho = \frac{\dot{M}}{4\pi r^2 \mathrm{v}}$$

This approch is actually the **only way** to allow “in human time”the description of dust formation in the winds of AGB
of different mass, with different chemical composition and extended on the whole evolutionary phase

I. Chemistry of the dust

The dominant component of dust formed will depend on the relative abundance of carbon or oxygen:

C/O
(CO molecule)

C stars (C/O>1)

- solid carbon (C)
- silicon carbide (SiC)
- solid iron(Fe)

M stars(C/O<1)

- Silicate
- Aluminia dust (Al2O3)
- quartz (SiO2)
- solid iron

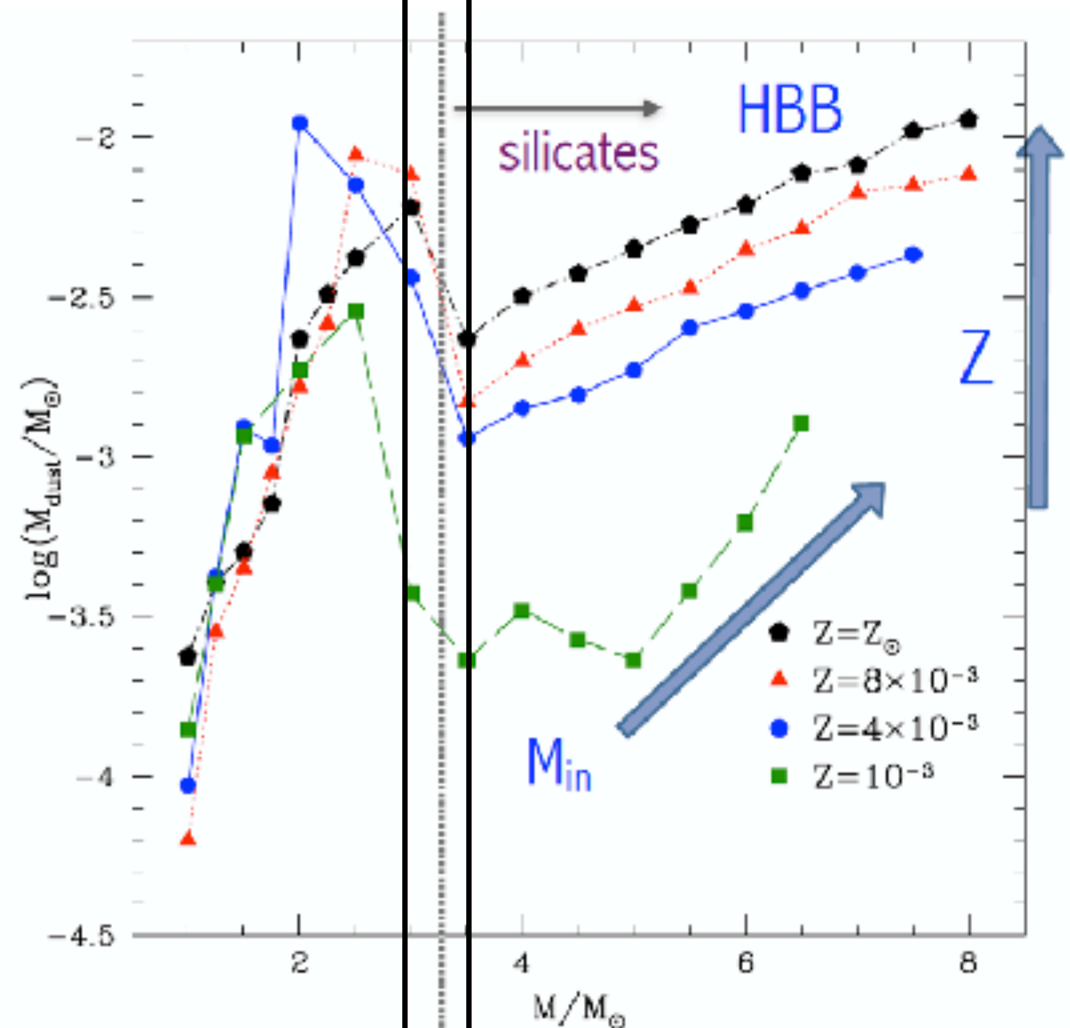
The same dichotomy with mass present in the chemistry of the envelope is present in the chemistry of the dust.

Grain species	Formation reaction	Key element
Olivine	$2x\mathrm{Mg} + 2(1-x)\mathrm{Fe} + \mathrm{SiO} + 3\mathrm{H_2O} \rightarrow \mathrm{Mg}_{2x}\mathrm{Fe}_{2(1-x)}\mathrm{SiO_4} + 3\mathrm{H_2}$	Si
Pyroxene	$x\mathrm{Mg} + (1-x)\mathrm{Fe} + \mathrm{SiO} + 2\mathrm{H_2O} \rightarrow \mathrm{Mg}_x\mathrm{Fe}_{(1-x)}\mathrm{SiO_3} + 2\mathrm{H_2}$	Si
Quartz	$\mathrm{SiO} + \mathrm{H_2O} \rightarrow \mathrm{SiO_2}(s) + \mathrm{H_2}$	Si
Silicon carbide	$2\mathrm{Si} + \mathrm{C_2H_2} \rightarrow 2\,\mathrm{SiC} + \mathrm{H_2}$	Si
Carbon	$\mathrm{C} \rightarrow \mathrm{C}(s)$	C
Iron	$\mathrm{Fe} \rightarrow \mathrm{Fe}(s)$	Fe

II. Quantity of dust and trend with mass and metallicity

C stars

carbon dust



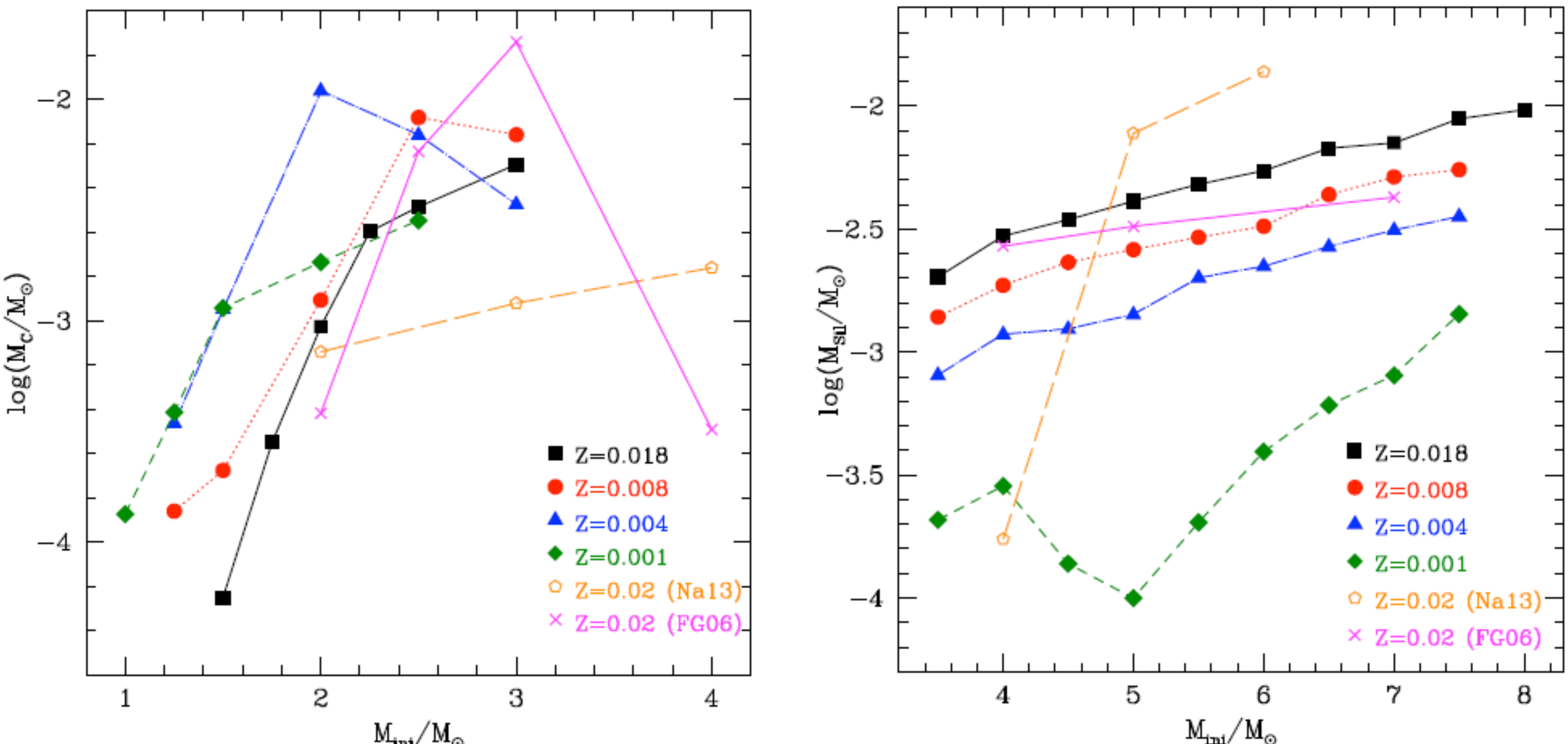
O stars

Silicate dust

Dell'Agli + 2017; Ventura + 2014, 2012 a, b; Di Criscienzo + 2013

AGB stars with Z=4*10**-3 can only contribute to carbon dust enrichment of the ISM (Di Criscienzo+13)

III.Comparison with other AGB dust yields.



Dell'Agli+2017

FG06-Ferrarotti & Gail, 2006

Na13- Nanni+2013

Dust formation model + updated stellar AGB tracks are useful to:

Interpreting infrared observations of evolved stellar populations in:

a) Magellanic Clouds (SAGE,Dell'Agli+14,15, Ventura+15,16, Nanni+16)

b) Local group galaxies (DUSTING SURVEY , Boyer+2015, Dell'Agli, Di Criscienzo+2016)

c) and beyond--->JWST-ERS on NGC300 (PI Iacco Van Loon) and... (see Jones+2017)

@ to put contraints on star formation hystories of galaxies.

@ to understand the origin of the dust content of the galaxies (f Ginolfi +2017 on ArXIV)

@ to Understand the origin of the dust content of Early universe and the ballance with SN (Valiante et al. 2009,2011, 2014)

Summary

@AGBs are important in various astrophysical contexts, especially in the chemical enrichment of the Universe.

@To understand the role of AGBs as a polluters it is necessary to know how the surface chemistry is influenced by TDU and HBB step after step

@The different efficiency of these two phenomena is attributable to the treatment of convection and mass loss is at the basis of differences in the yields.

@SInce It is to be ruled out that in short, it will be possible to improve the description of these phoenomena , from my point of view it is necessary to continue to work hard on the comparison with observations in the context of multiple populations in GCs , Planetary nebula and galactic AGB stars.

@I focused on the role of stars as dust polluters

@I have described the mechanism of formation of dust in the wind of AGB and a simple toy model which is able to study the chemistry and the quantity of dust and the dependence by mass and metallicy. Large uncertainties in the dust content derive from the AGB modelling (and not to much from the description of dynamic wind)

@At the end I showed you how useful can be these predictions in the interpretation of infrared surveys, for dust content and setting constraints on the star formation history of the galaxies.

Thank You

We owe our existence to stars, because they make the atoms o f which we are formed. So if you are romantic you can say we are literally starstuff. I f you 're less romantic you can say we 're the nuclear waste from the fuel that makes stars shine. "

Sir M.Rees, Astronomer Royal