Clues about the first stars from CEMP stars

Arthur Choplin, Georges Meynet, André Maeder

SF2A, 04/06/2015

What are CEMP stars?

- CEMP star = Carbon-Enhanced Metal-Poor star

  [Fe/H] < -1 }
  [C/Fe] > 1 } Beers & Christlieb 2005

  $$[X/Y] = \log_{10}(N_X/N_Y) - \log_{10}(N_{X\odot}/N_{Y\odot})$$

- Low [Fe/H] => close to early universe

- External source ?

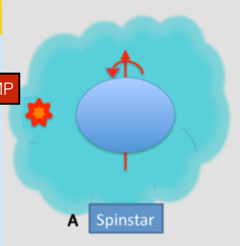
What are CEMP stars?

- CEMP star = Carbon-Enhanced Metal-Poor star

  [Fe/H] < -1 } Beers & Christlieb 2005
  [C/Fe] > 1

  $$[X/Y] = \log_{10}(N_X/N_Y) - \log_{10}(N_{X\odot}/N_{Y\odot})$$

- Low [Fe/H] => close to early universe
- External source ?



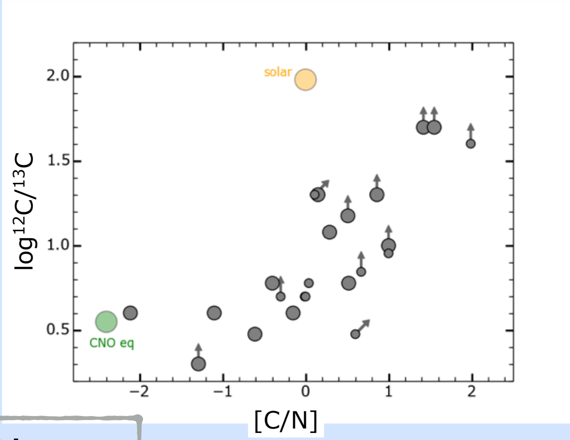
- Spinstar scenario

  Meynet et al. 2006,2010; Hirschi 2007; Maeder et al. 2015
- Spinstar ejecta = observed abundances?

  → wind (+SN)

What CEMP are made of?

- MS
- Bright giant
- Upper/lower limit

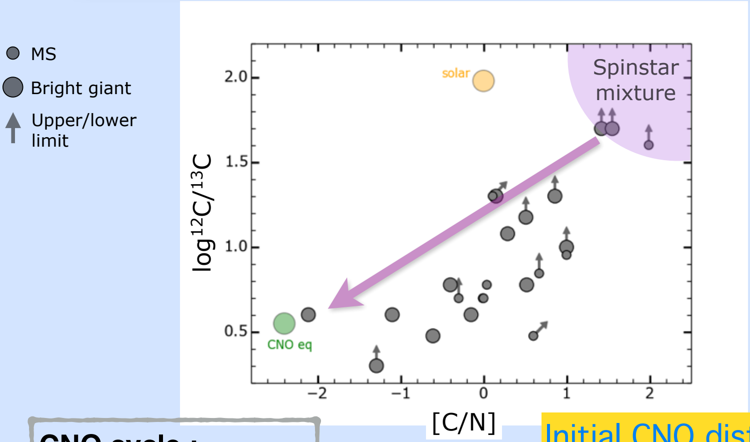


CNO cycle :

^{12}C, ^{16}O —> ^{14}N, ^{13}C

C+N+O = constant

What CEMP are made of?

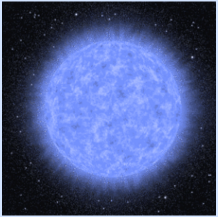


CNO cycle :
^{12}C, ^{16}O —> ^{14}N, ^{13}C
C+N+O = constant

Initial CNO distribution non solar in the spinstar

(Maeder et al. 2015)

A typical model of spinstar

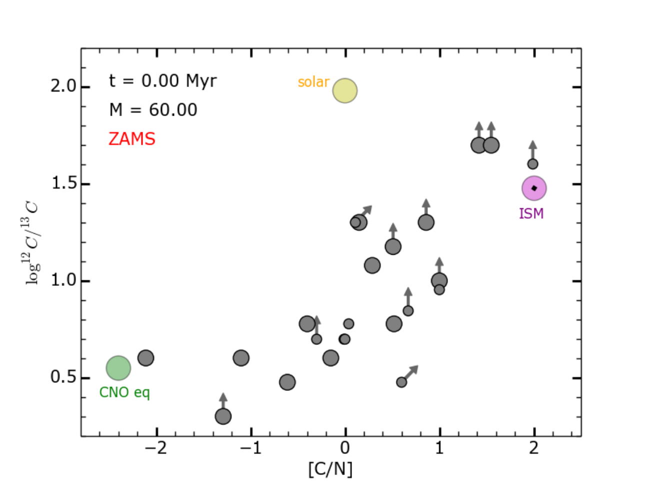


M = 60 $M_\odot$
Z = 10^{-5}
$\mathbf{v_{eq,ZAMS}}$ = 800 km/s (v/v_{crit} = 0.7)

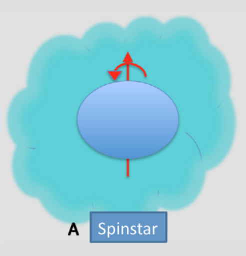
$\dot{\mathbf{M}}_{\mathbf{rad}}$: de Jager et al. (1988), Kudritzki & Puls (2000), Vink et al. (2001),…

Mixing : $\mathbf{D_h}$: Zahn (1992), Maeder (2003), Mathis & Zahn (2004)
$\mathbf{D_{shear}}$: Maeder (1997), Talon & Zahn (1997) (+Maeder 2014)

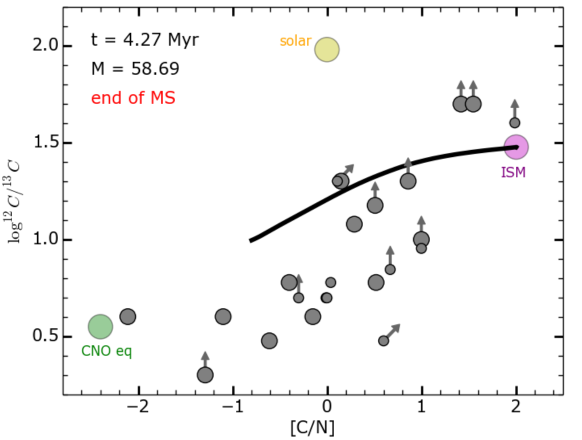
"Wind track" in log($^{12}C/^{13}C$) vs [C/N]



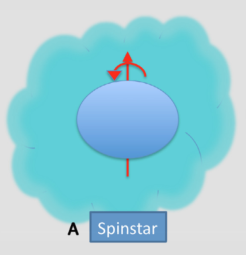
$M_{ini} = 60\ M_\odot$



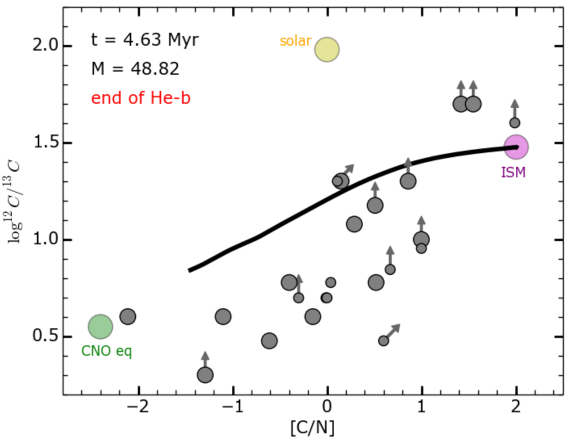
"Wind track" in log($^{12}C/^{13}C$) vs [C/N]



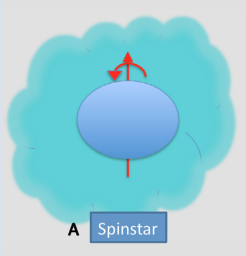
$M_{ini} = 60\ M_\odot$



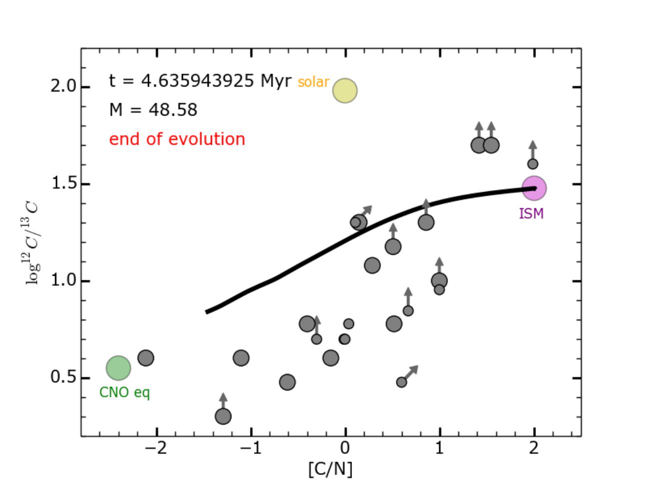
“Wind track” in log($^{12}C/^{13}C$) vs [C/N]



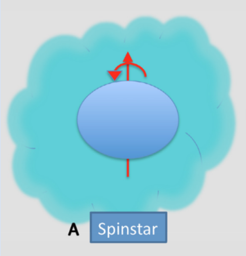
$M_{ini} = 60\ M_\odot$



"Wind track" in log($^{12}C/^{13}C$) vs [C/N]

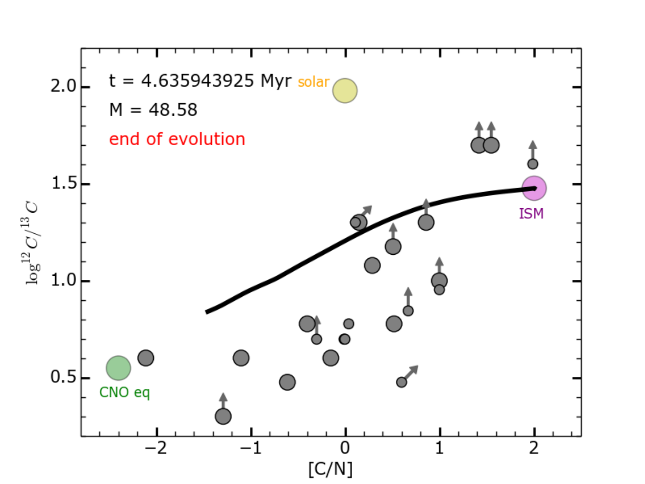


M_{ini} = 60 $M_\odot$

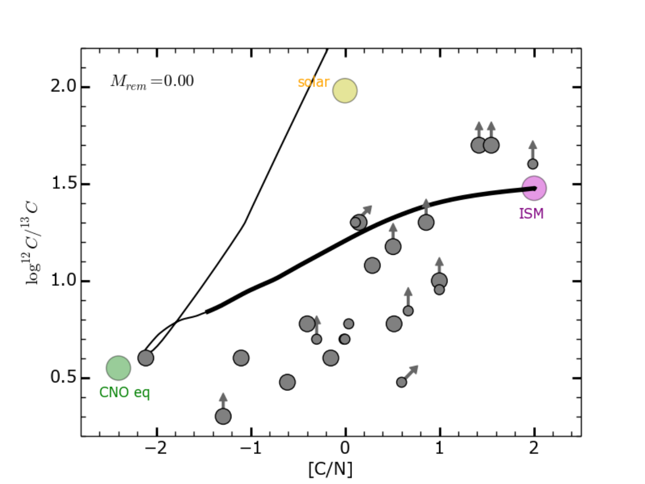


Most of the mass is lost when the surface is already enriched

Adding a supernova to the wind



Adding a supernova to the wind

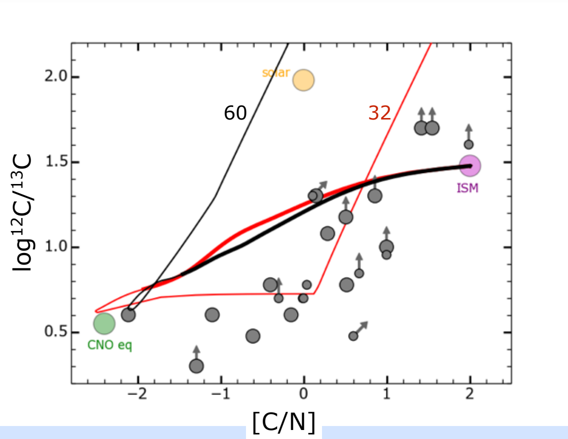


SN :

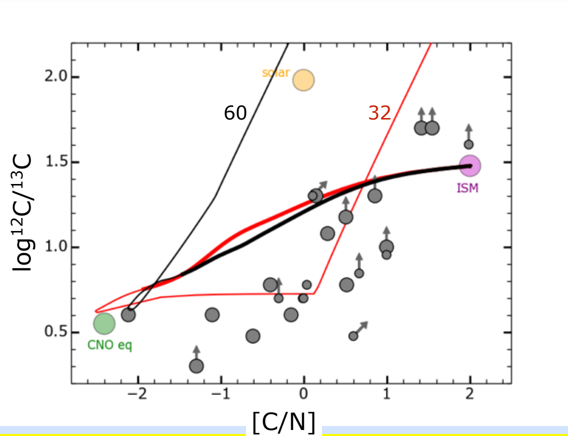
1) ^{14}N and ^{13}C
2) ^{12}C

$^{12}C/^{13}C$:
constraint on M_{rem}

Adding a supernova to the wind



Adding a supernova to the wind

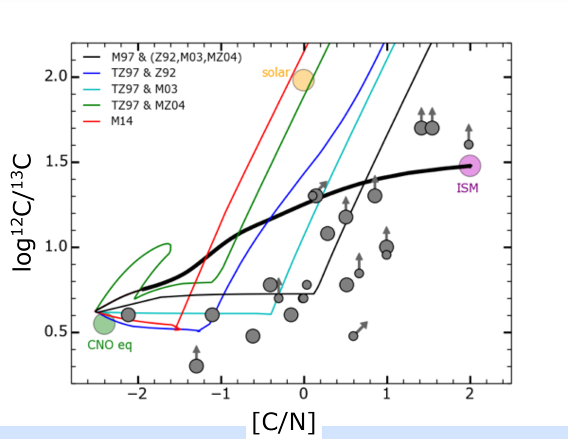


late connexion between H- and He-burning shells

=> ^{12}C ↗ in the H-burning shell

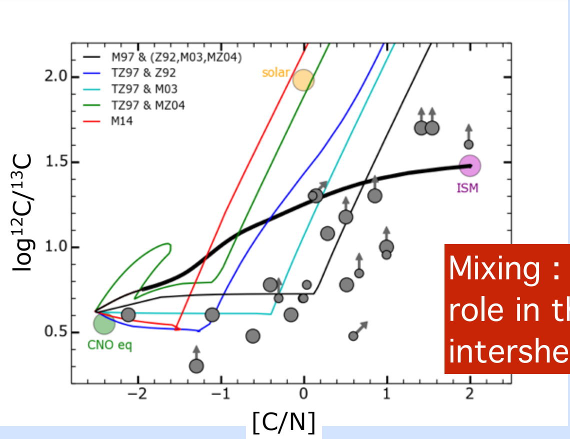
=> primary ^{13}C (quickly formed) and ^{14}N (formed slowly)

Various mixing prescriptions (after He-b)



other prescription for mixing
=> interaction between 2 shells occurs differently

Various mixing prescriptions (after He-b)



Mixing : important role in the intershell region

other prescription for mixing
=> interaction between 2 shells occurs differently

Summary & perspectives

- CEMP stars could be made of spinstar ejecta.

- Initial CNO mixture of the spinstar non solar(-scaled) ?

- Fast rotation => mass is lost after the surface enrichment in CNO products => material ''too much'' CNO processed.

- Late transfer between H- and He- burning shells seems to be needed to build some CEMP => importance of mixing, SN (or stronger winds in late stages ?)

  - Models at lower Z ? higher masses ?
  - More nuclear physics (Mg-Al, Ne-Na cycles)
  - Heavy elements (s-elements)