The Effect of the $^{14}\text{N}(p, \gamma)^{15}\text{O}$ Reaction on the Blue Loops in Intermediate-Mass Stars

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What’s a blue loop?

Blue loop
Shell H burning
+ core He burning

Core H burning
Shell H burning

HR diagrams of stellar models with solar-like metallicity
Why does the blue loop occur?

Crossing of stars to the blue side of the HR diagram (high effective temperatures) of stellar masses 5 to 15$M_\odot$

- CNO cycle
- $^{14}\text{N}(p,\gamma)^{15}\text{O}$
- BIG effect, particularly with very recent rates (2012)
$^{14}\text{N}(p,\gamma)^{15}\text{O}$ reaction rate

Compare between two $^{14}\text{N}(p,\gamma)^{15}\text{O}$ rates (N14 rates):

- **NACRE rate:**
  Angulo et al. 1999.
  Over-estimated, only used here as a reference for an efficient rate.

- **C-rate:**
  → motivated by the evaluation of Adelberger et al. 2011
How do the rates compare?

C-rate/NACRE
HR diagrams of stellar models with the C-rate

Changing 1 rate => Big effect

1. Why low masses are most affected
2. How to restore the loops

Shallow H-discontinuity

\[ T = 2 \times 10^7 \text{ K} \]

\[ \log T \]

\[ X_H \]

\[ \log(e_{\text{H-shell}} / \text{erg/g.s.}) \]

\[ \log(T/K) \]

H-burning shell

\[ 6M_\odot \]

\[ M_r / M_\odot \]

X\(_H\) is up-scaled for clarity.
Convective Structure: Dark regions convective, white region is radiative

- Core H-burning
- 0.08\(M_\odot\)
- FDUP
- NACRE
- NEW
What about the more massive stars??
High temperature

$X_H$

$T = 2 \times 10^7 K$

$\log T$

$c$
How to restore the loops in the $5M_\odot$, $6M_\odot$ and $7M_\odot$?

Overshooting: extra mixing below the boundary of the convective envelope

CLOSER to the shell source
Comparing with observations
With overshooting
Work in progress:
Effect of core overshooting and modifications of the MLT

Predicted model properties adopted from Criscienzo et al. (2012). Blue circles denote the blue edge of the instability strip and red triangles denote its red edge.
Conclusions

• The blue loop is a delicate phenomena that cannot be attributed to single cause-effect scenario, as many parameters are at play contributing to its appearance and extension.

• The N14 rate has very interesting evolutionary implications that need to be carefully addressed.

• The effect of the N14 rate on loops has been studied for the whole mass range, which is a first.

• The new compilation of the N14 rate causes a severe reduction in the blue loops of the stellar masses 5M\(_{\odot}\), 6M\(_{\odot}\) and 7M\(_{\odot}\) which is very undesirable observationally.

• Moderate overshooting is called for in order to restore the loops in the models that would otherwise lack them.