

The *s*-process in Rotating AGB Stars

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Abstract. We discuss the occurrence of the *s*-process during the radiative interpulse phase of rotating AGB stars. Due to differential rotation, protons are mixed into ^{12}C -rich layers after thermal pulses, in the course of the so called third dredge up episode. We follow the time evolution of key isotope abundances in the relevant layers with a post-processing code which includes time dependant mixing and nucleosynthesis. In rotating AGB models, the mixing persists during the entire interpulse phase due to the steep gradient of angular velocity at the envelope-core interface. As the layers containing protons and ^{12}C , which are formed this way, become hotter, a ^{13}C -pocket is formed in a natural way. However, in this situation also ^{14}N is formed and spread over the entire ^{13}C -pocket. We include the neutron consuming $^{14}\text{N}(n,p)$ reaction in our network and determine to what extent it reduces the production of trans-iron elements. We propose that rotation may be responsible for the spread of efficiencies of the ^{13}C neutron source as required by observations.

Current models of the *s*-process in Asymptotic Giant Branch (AGB) stars consider some kind of partial mixing of the H-rich convective envelope and the ^{12}C -rich intershell/core region, e.g. due to convective overshoot (Herwig, 2000), at the end of the third dredge up phase after advanced thermal pulses (e.g. Gallino et al., 1998). Neutrons are subsequently released by the $^{13}\text{C}(\alpha, n)$ -reaction under radiative conditions during the interpulse phase between thermal pulses and no further mixing processes have been considered in this layer.

Models of rotating AGB stars display large gradients in angular velocity at the core-envelope interface where they are able to produce a ^{13}C - and ^{14}N -pocket next to each other. In this case weak but persistent mixing of elements and angular momentum continues throughout the interpulse period (Langer et al., 1999). We have computed post-processing nucleosynthesis models of one thermal pulse cycle from a rotating $3 M_{\odot}$ ($Z=0.02$) AGB star (Langer et al., 1999) [CASE 1] using a new fully implicit code which treats mixing and all relevant nuclear reactions simultaneously. For comparison, we follow the nucleosynthesis without

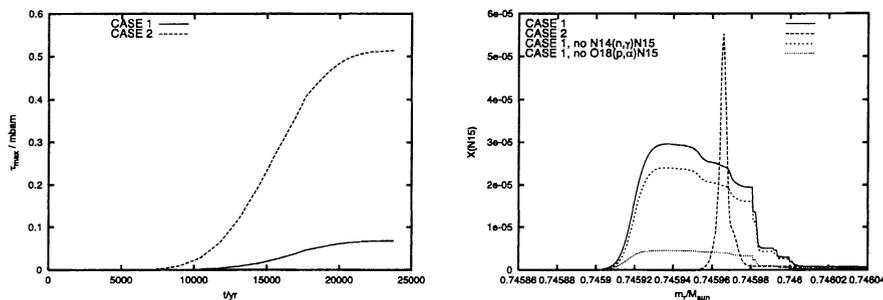


Figure 1. Maximum neutron exposure during the interpulse phase (left panel) and final ^{15}N -abundance (right panel) for the two cases described in the text.

mixing during the interpulse phase, i.e. we only process the ^{13}C -pocket which has formed due to rotationally induced mixing immediately after the third dredge up [CASE 2]. Such a model is conceptually equivalent to models without rotational mixing as discussed, e.g., in Lugaro & Herwig (2001).

We find that the maximum neutron density achieved for CASE 1 is about one order of magnitude smaller than in CASE 2, and accordingly the peak neutron exposure is significantly smaller (Fig. 1, left). The production of trans-iron elements is smaller by a factor of five as most neutrons are captured by ^{14}N . The neutron exposure integrated over the entire s-process layer is about 1.5 times larger, since the ^{13}C -pocket is significantly broadened by rotation and the neutrons are partially recycled by $^{14}\text{N}(n,p)^{14}\text{C}$. Some ^{15}N is produced, mainly by $^{14}\text{C}(\alpha,\gamma)^{18}\text{O}(p,\alpha)^{15}\text{N}$ (Fig. 1, right). This ^{15}N will be transformed in ^{19}F in the subsequent thermal pulse phase.

Both diffusive overshoot and rotation create ^{13}C at the beginning of the interpulse phase. However, differential rotation persistently mixes the ^{13}C and ^{14}N -rich layers during the entire interpulse phase. Our results indicate that, by combining these two phenomena, it may be possible to provide a range of trans-iron element productions as required according to parameterized s-process models and spectroscopic stellar observations (Busso et al., 2001).

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