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Lithium Synthesis in Late Stages of Stellar Evolution

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We have investigated the lithium production in asymptotic giant branch (AGB) stars of intermediate mass ranging from 4 to $8M_\odot$ for Pop. I metallicity and from 4 to $7M_\odot$ for Pop. II metallicity. An AGB star consists of a carbon-oxygen core, (unstable) helium burning shell, helium rich buffer layer, hydrogen burning shell, and a convective envelope. The Li production occurs in the deep convective envelope whose bottom temperature is high enough to activate nuclear reactions (hot bottom burning; HBB). The produced lithium is ejected into the interstellar medium by mass loss. One of the purpose of this investigation is to clarify whether the ejected Li contributes significantly to the Li enrichment of the Galaxy.

We have calculated evolutionary models from the zero-age main sequence stage to the AGB stage, in which lithium is produced by the beryllium transport mechanism, through a large number of thermal pulses. A model sequence is terminated at a phase after which significant production of lithium is no longer expected. The models of masses $M \gtrsim 6M_\odot$ for Pop. I and $M \gtrsim 5M_\odot$ for Pop. II as found to produce considerable Li having a strong HBB during the interpulse phase. They have surface lithium abundances higher than the present cosmic abundance of lithium. Comparing with observed Li-rich stars in the Magellanic clouds, we have found the predicted ranges of Li abundances and their luminosities are consistent with the observations.

We have also shown the variations of the surface abundance ratios of $^{12}C/^{16}O$, $^{12}C/^{13}C$, and $^{12}C/^{14}N$ during the thermally pulsing AGB phase. It turns out that these ratios have complicated behaviors coming from the interplay between HBB and third dredge-up. Super lithium rich stars with $C/O > 1$ are not obtained in our model sequences for both metallicities.

We have estimated the influence of uncertainties involved in the numerical modeling of a star, such as mixing length parameter α, mass loss rate, overshooting, mixing time scale, and ^3He abundance, on lithium production and ejected lithium mass. The most influential uncertainties in our exploration are α, overshooting, and slow mixing of convection. The former two uncertainties make the bottom of the convective envelope deep toward the hydrogen burning shell. The latter allows lithium to stay in the outer portion of the envelope for a long time and lithium at the surface is insensitive to influences of HBB and thermal pulses. We have found that the lower mass loss rate has minor influence for producing lithium, but an increase of the initial ^3He abundance leads to an enhancement of the ejected lithium mass without depending on the HBB.

Finally, we have evaluated the contribution of lithium production in AGB stars to the lithium enrichment of the Galaxy. We have calculated the overproduction factor for both metallicities using the results of the standard models. We have found that ratios of the total lithium mass ejected from the stellar surface to the mass of lithium initially present in the part of the star that is finally ejected are only ~ 0.07 and ~ 0.40 for metallicities $Z = 0.02$ and $Z = 0.002$, respectively. Therefore, we have concluded that according to our standard models, intermediate mass AGB stars are not a major contributor to the cosmic lithium abundance, in particular, for metal rich stars. However, we must point out that these conclusions would be modified by adopting non-standard assumptions (e.g. $\alpha > 1.5$ and overshooting).