Single Stellar Population Production of Nitrogen

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Production Timescales Relative to Fe

Using $y_\text{N}^\text{CC} = 5 \times 10^{-4}$, the AGB star yields of N from the FRUITY database (Cristallo et al., 2011), and supernova yields of Fe as in Johnson & Weinberg (2020) and Weinberg et al. (2017) (i.e. $y_\text{Fe}^\text{CC} = 0.0012$ and $y_\text{Fe}^\text{Ia} = 0.0017$), **what is the net production of N and Fe as a function of stellar population age and metallicity?**

Figure 1 shows the net production of N and Fe as a function of stellar population age and metallicity. Since Fe has metallicity-independent yields under these assumptions, it's plotted with only one curve, whereas N has different production timescales at different metallicities. In general, the CCSN yields of N under these assumptions make up a substantially larger fraction of the N production than the CCSN yields of Fe does for its production. This means that the characteristic timescales for N production are significantly shorter than for Fe.

The AGB yields of N are also significantly weighted toward high masses such that even at solar metallicity, $\gtrsim$90% of the N production is complete by the time the population is $\tau =$ 1 Gyr old. Although the fractional yields are higher for more massive AGB stars, this does not mean that the total N produced in low-mass AGB stars is lower than that produced by high mass AGB stars due to the steep nature of the initial mass function. In a window of progenitor mass $[m, m + dm]$ at a metallicity Z, the total mass of N produced is given by:

$$dm_\text{N} = y(m|Z)m\frac{dN}{dm} = y(m|Z)\xi m^{1-\alpha} \tag{1}$$

where α is the power-law index of the IMF. If the production at two masses m_1 and m_2 are comparable, then the scaling of the yield y with progenitor mass can be derived:

$$dm_\text{N}|_{m=m_1} = dm_\text{N}|_{m=m_2} \tag{2a}$$

$$\implies y(m_1|Z)\xi m_1^{1-\alpha} = y(m_2|Z)\xi m_2^{1-\alpha} \tag{2b}$$

$$\implies \frac{y(m_1|Z)}{y(m_2|Z)} = \left(\frac{m_1}{m_2}\right)^{\alpha-1} \tag{2c}$$

This demonstrates that if the IMF-integrated mass production of any element in AGB stars is to be mass-independent, then the yield must scale with 1 less than the power-law index of the IMF at masses of $M \gtrsim 1\ M_\odot$. If the IMF has a slope of $\alpha = 2.3$ at these masses, then the yield must scale with m^β where $\beta \geq 1.3$. Any higher, and the IMF-integrated net production is more biased toward high mass stars, and conversely toward low mass stars for lower values of β. Based on these investigations of the Cristallo et al. (2011) yields (see `../yields/yields.pdf`), it appears that $\beta \approx 1$ for nitrogen, indicating the IMF-integrated production is actually dominated by low-mass stars.

How can the production be dominated by high-mass stars if the IMF-integrated yields are dominated by low-mass stars? This appears to be due to the long lifetimes of low mass stars. It's one thing for low mass stars to contribute significantly to a given yield, but only those with lifetimes on the order of a hubble time or shorter are going to enrich the ISM.

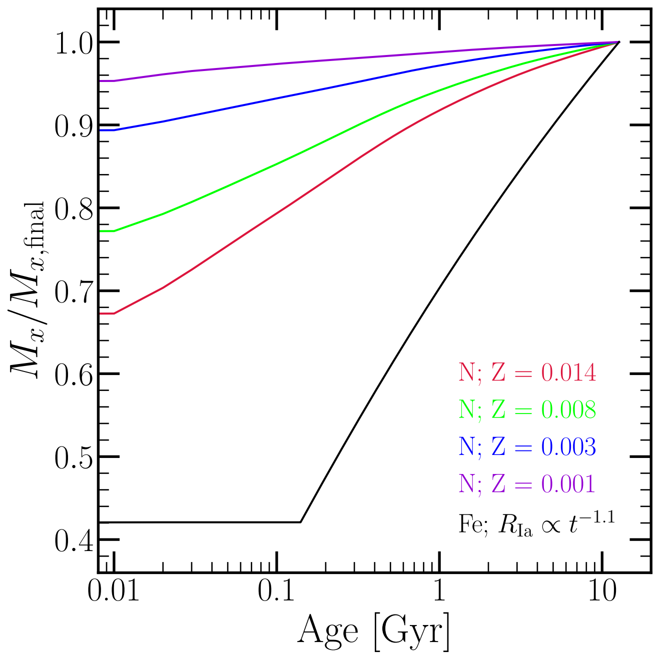

Figure 1: Net mass of N (colored lines) and Fe (black) as a function of stellar population age and metallicity (color-coded according to legend for N), in units of the mass produced at $\tau = 12.2$ Gyr.

Bibliography

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