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# On the Nucleosynthesis of Nitrogen: Insight from Chemical Evolution Models

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**ABSTRACT**
We investigate the astrophysical production of nitrogen (N) in the Milky Way. We have the best simulations.

**Key words:** Awesomeness

## 1 INTRODUCTION

- Nitrogen (N) is an element that traces slow neutron capture (s-process) nucleosynthesis. To first order it's produced only in core collapse supernovae (CCSNe) and asymptotic giant branch (AGB) stars (Johnson 2019).
- The observed [N/O]-[O/H] relation in the gas phase is more or less the same between different environments. We demonstrate this in Fig. 1 where we compile measurements from previous studies interested in various astrophysical systems.
- Qualitatively, the rise in N abundances with increasing [O/H] can be attributed to the metallicity-dependent nature of N yields from AGB stars (Vincenzo et al. 2016; see also discussion in § X).
- How well do chemical evolution models for the Milky Way with various "off-the-shelf" yield models perform at reproducing this trend?
- Nitrogen has considerable yields through *secondary* channels: the processing of already produced metals into nitrogen.

  – First and foremost is the CNO cycle, in which carbon (C), N, and oxygen (O) catalyze the fusion of four protons into helium-4. The reactions of the CNO cycle:

  $$^{12}\mathrm{C}(p,\gamma)^{13}\mathrm{N}(\beta^+,\nu_e)^{13}\mathrm{C}(p,\gamma)^{14}\mathrm{N}(p,\gamma)^{15}\mathrm{O}(\beta^+,\nu_e)^{15}\mathrm{N}(p,\alpha)^{12}\mathrm{C} \tag{1}$$

  Due to a small cross section for proton capture, the $^{14}\mathrm{N}(p,\gamma)^{15}\mathrm{O}$ reaction is particularly slow. As a result, to first order the effect of the CNO cycle is to process all of the available C and O into $^{14}$N.

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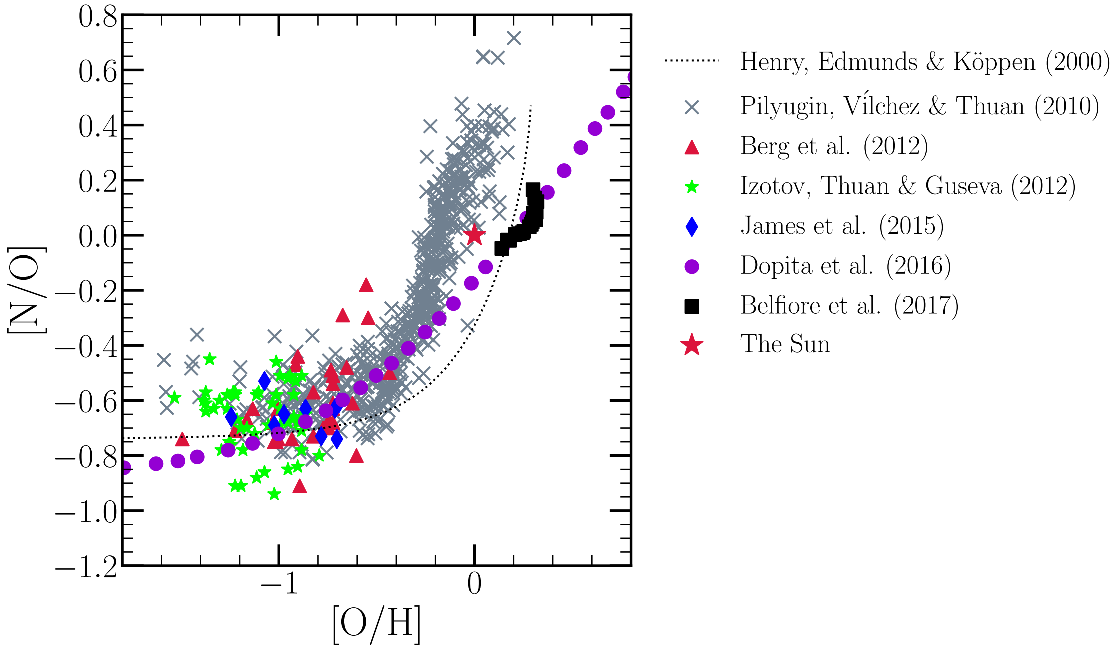


**Figure 1.** The [N/O]-[O/H] relation observed in HII regions in nearby NGC spiral galaxies (grey X's: Pilyugin, Vílchez & Thuan 2010), in HII regions in blue, diffuse star forming dwarf galaxies (red triangles: Berg et al. 2012; green stars: Izotov, Thuan & Guseva 2012; blue diamonds: James et al. 2015), in local stars and HII regions (purple circles: Dopita et al. 2016), and in the MaNGA IFU survey (black squares: Belfiore et al. 2017). The fit to [N/O] as a function of [O/H] in Galactic and extragalactic HII regions by Henry, Edmunds & Köppen (2000) is shown in a black dotted line. The Sun, at (0, 0) on this plot by definition, is marked by a red star. We omit the uncertainties for visual clarity.

## 2 METHODS

### 2.1 Nucleosynthetic Yields

#### *2.1.1 Asymptotic Giant Branch Stars*

- A significant portion of N's observed abundances can be attributed to yields from AGB stars (Johnson 2019).

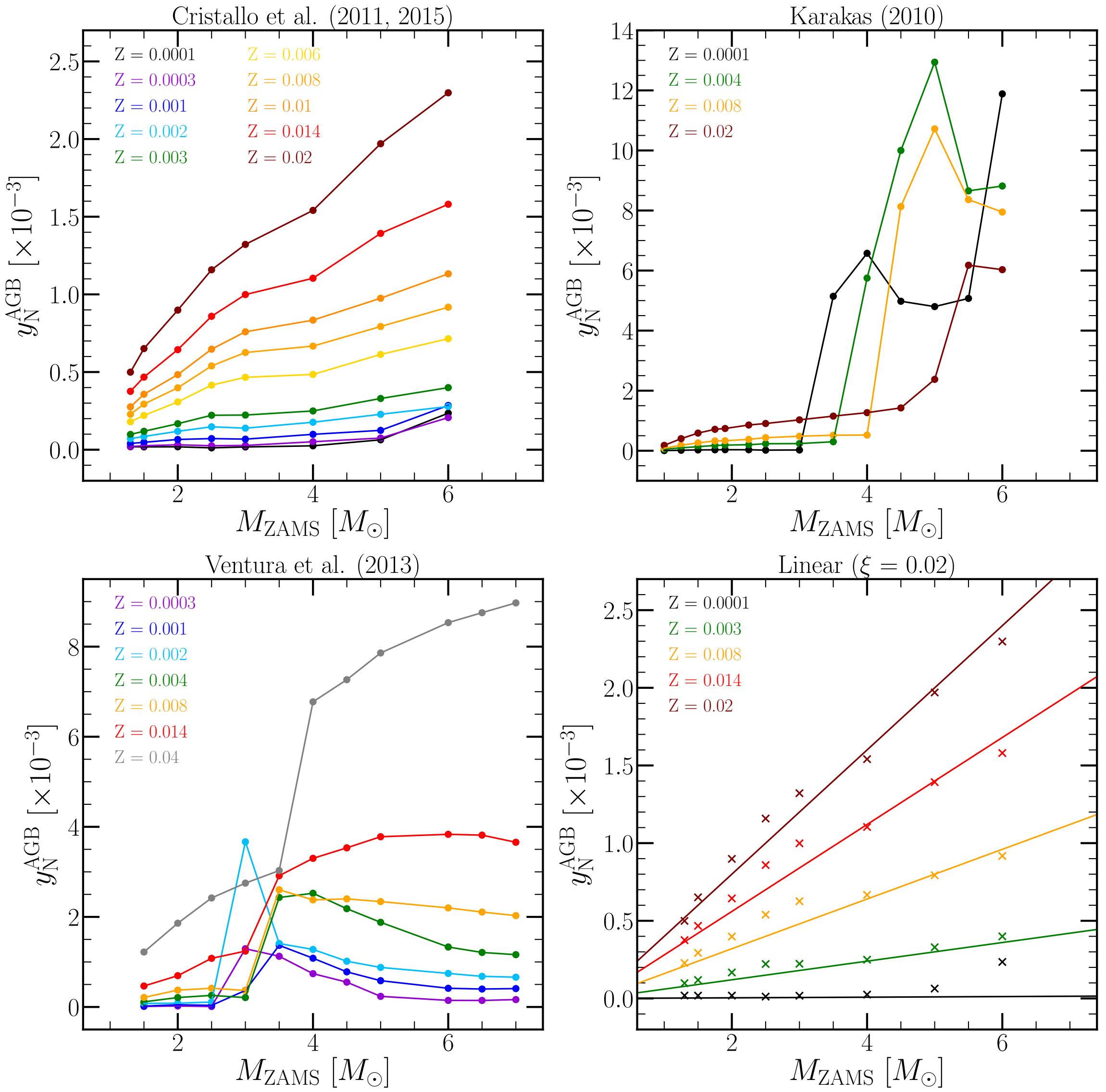


**Figure 2.** The fractional yields of N from AGB stars $y_N^{AGB}$ as a function of progenitor ZAMS mass and birth metallicity $Z$ as reported by Cristallo et al. (2011, 2015) (upper left), Karakas (2010) (upper right), and Ventura et al. (2013) (lower left). In the lower right panel, we show the yields predicted by our linear model (colored lines; see discussion in § X) in comparison to the Cristallo et al. (2011, 2015) predictions (colored X's).

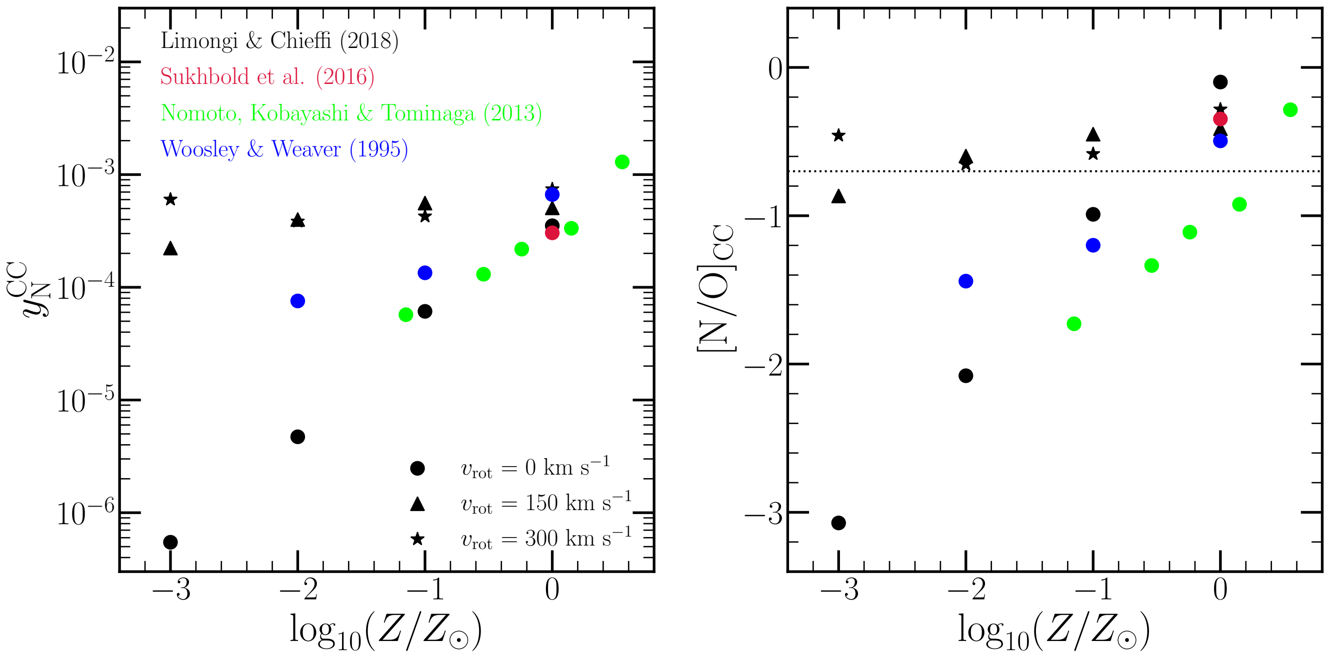


**Figure 3.** **Left**: IMF-averaged CCSN yields of N calculated using `VICE`'s `vice.yields.ccsne.fractional` function with the tables published by Woosley & Weaver (1995, blue), Nomoto, Kobayashi & Tominaga (2013, green), Sukhbold et al. (2016, red), and Limongi & Chieffi (2018, black). All studies report yields for non-rotating progenitors only with the exception of Limongi & Chieffi (2018), who also report yields for progenitor rotational velocities of 150 (triangles) and 300 km/s (stars). **Right**: The [N/O] ratio predicted by each of the explosion models in the left-hand panel, under the same colour-coding and marker scheme. We mark the position of [N/O] = −0.7 with a black dotted line, the value roughly suggested by the observations of low-metallicity systems highlighted in Fig. 1.

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