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The Chemical Evolution of Heavy Elements in Globular Clusters

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Abstract. We present preliminary results from a chemical evolution model that tracks the composition of heavy elements beyond iron in a globular cluster. The heavy elements can be used as tracers of the nucleosynthetic events that defined the formation and evolution of star clusters in the early Universe. In particular, the chemical evolution model focuses on the hypothesis that rapidly-rotating massive stars produced the heavy elements via the slow neutron-capture process and seeded the proto-cluster while the stars we see today were still forming.

We compare our model with heavy element abundances in M4 and M5, and M22. Our results are strongly dependent on the highly uncertain rate of the $^{17}O(\alpha,\gamma)^{21}Ne$ reaction, which determines the strength of ^{16}O as a neutron poison. We find that the [Pb/Ba] ratio is too low to match the empirical value, which might suggest that a contribution from AGB stars is required.

Keywords. globular clusters: general, stars: rotation

1. Globular Clusters

We aim to understand the origin of heavy elements in globular clusters by constructing chemical evolution models with yields fromrotating massive stars and AGB stars.

1.1. *s-Process Enrichment and Distributions*

M4 and M5 have similar mean metallicities of [Fe/H] = -1.2, but M4 is enriched in s-process elements over M5 (Yong *et al.* 2008). M22 hosts two populations with distinct Fe and s-process abundances: an s-rich group with [Fe/H] = -1.68 and an s-poor group with [Fe/H] = -1.82 (Marino *et al.* 2009). Subtracting the s-poor from the s-rich abundances results in two empirically derived s-process distributions (Figure 6 of Roederer *et al.* 2011). An explanation for the s-process distribution likely involves contributions from rotating massive stars and intermediate-mass AGB stars.

1.2. *Rotating Massive Stars*

Rotation induced mixing between the H and He-burning zones leads to an almost primary production of ^{22}Ne, the main neutron source for the weak s-process (see e.g., Hirschi 2007). Thus, rotation at low metallicity greatly enhances s-process production (Frischknecht *et al.* 2012). Star formation might stochastically produce differences in rotation rates between clusters and populations that affect s-process production.

2. Chemical Evolution Models and Results

Using a new one-zone chemical evolution code (Evel ChemEvol), we combined the SNII Fe yields from Limongi & Chieffi 2012 with s-process yields for a grid of massive stars between 15 $M_\odot$ and 40 $M_\odot$ at $Z=10^{-5}$ from Hirschi *et al.* (2013, in prep). We

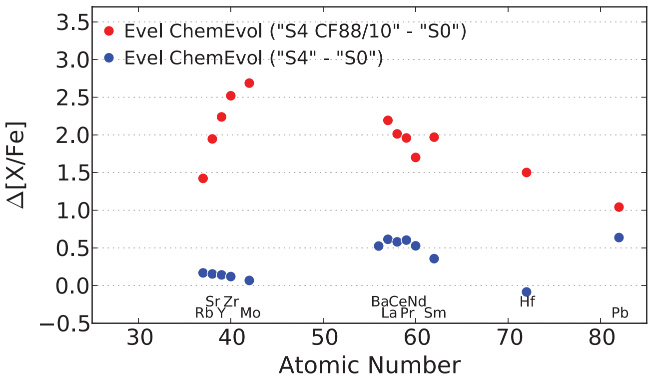

Figure 1. Preliminary: The abundance differences between our chemical evolution models with and without rotation. Labels are explained in the text.

independently tested rotating massive star yields (S4 case), rotating massive star yields multiplied by a set of factors to approximate the rate of $^{17}O(\alpha,\gamma)^{21}Ne$ being ten times lower (S4 CF88/10 case; similar to Cescutti *et al.* 2013) and non-rotating massive star yields (S0 case). All models were run until [Fe/H] of -1.2 and their abundances have been subtracted and plotted in Figure 1.

In agreement with the results of Cescutti *et al.* 2013 for halo stars, the CF88 normal rate leads to an insufficient s-process production. The [Pb/Ba] ratio is too low, possibly due to the absence of AGB stars. Future models with different rotation rates and including AGB yields will help us to further understand the origin of heavy elements in GCs.

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