From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution
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PopII 1/2 stars: very high ^{14}N and low ^{16}O yields

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Abstract. Nine $20\,M_{\odot}$ models were computed with metallicities ranging from solar, through $Z = 10^{-5}$ ([Fe/H]∼-3.1) down to $Z = 10^{-8}$ ([Fe/H]∼-6.1) and with initial rotational velocities between 0 and $600\,\mathrm{km\,s^{-1}}$ to study the impact of initial metallicity and rotational velocity (Hirschi (2005)). The very large amounts of ^{14}N observed (∼$0.03\,M_{\odot}$) are only produced at $Z = 10^{-8}$ (PopII 1/2). The strong dependence of the ^{14}N yields on rotation and other parameters like the initial mass and metallicity may explain the large scatter in the observations of ^{14}N abundance. The metallicity trends are best reproduced by the models with $\upsilon_{ini}/\upsilon_c \sim 0.75$, which is slightly above the mean observed value for OB solar metallicity stars. Indeed, in the model with $\upsilon_{ini} = 600\,\mathrm{km\,s^{-1}}$ at $Z = 10^{-8}$, the ^{16}O yield is reduced due to strong mixing. This allows in particular to reproduce the upturn for C/O and a slightly decreasing [C/Fe], which are observed below [Fe/H]∼ -3.

Keywords. Stars: evolution, stars: rotation

1. Introduction

Precise measurements of abundances of low metallicity stars have recently been obtained by Cayrel, *et al.* (2004), Spite *et al.* (2005) and Israelian *et al.* (2004). These provide new constraints for the stellar evolution models (see Chiappini, *et al.* (2005), François, *et al.* (2004) and Prantzos (2004)). The most striking constraint is the need for primary ^{14}N production in very low metallicity massive stars. Rotation helps producing large amounts of primary ^{14}N through mixing of newly synthesised carbon and oxygen during helium burning (see Meynet et al. *et al.* (2005) and contributions by these authors in this volume). Other constraints are an upturn of the C/O ratio with a [C/Fe] about constant or slightly decreasing (with increasing metallicity) at very low metallicities, which requires an increase (with increasing metallicity) of oxygen yields below [Fe/H]∼ -3. This seems hard to reproduce with rotating models where mixing usually increases the size of the helium burning core and therefore increases the oxygen yields.

2. Computer model & calculations

The computer model used here is the same as the one described in Hirschi *et al.* (2004). Convective stability is determined by the Schwarzschild criterion. Overshooting is only considered for H– and He–burning cores with an overshooting parameter, $\alpha_{\rm over}$, of 0.1 $\mathrm{H_P}$. Since the distribution of velocities at very low metallicities is not well know, two initial rotational velocities were explored at very low metallicities. The first one is the same as at solar metallicity, $300\,\mathrm{km\,s^{-1}}$. The ratio $\upsilon_{\rm ini}/\upsilon_c$ decreases at very low metallicities for the initial velocity of $300\,\mathrm{km\,s^{-1}}$ because stars are more compact at lower metallicities. However there are some indirect evidence (see Chiappini, *et al.* (2005) and Meynet et al. *et al.* (2005) for details) that stars rotate faster at low metallicities. Therefore, the second

$\upsilon_{\rm ini}$ is 500 km s^{-1} at Z=10^{-5} ([Fe/H]$\sim$-3.1) and 600 km s^{-1} at Z=10^{-8} ([Fe/H]$\sim$-6.1). These values are chosen such that the ratio of the initial velocity to the break–up velocity, $\upsilon_{\rm ini}/\upsilon_c$ (~ 0.75), is slightly larger than the mean observed value for OB solar metallicity stars (0.63). The evolution of the models was followed until core Si–burning. The yields of these models were calculated in the same way as in Hirschi *et al.* (2005).

3. Evolution of the structure

The bulk of ^{14}N is produced in the convective zone created by shell hydrogen burning. If this convective zone deepens enough to engulf carbon (and oxygen) rich layers, then significant amounts of primary ^{14}N can be produced ($\sim$0.03 $M_\odot$). This occurs in both the non–rotating model and the fast rotating model at $Z = 10^{-8}$ but for different reasons. In the non–rotating model, it occurs due to structure rearrangements at the end of carbon burning similar to the third dredge–up. In the model with $\upsilon_{\rm ini} = 600$ km s^{-1} it occurs during shell helium burning because of the strong mixing of carbon and oxygen into the hydrogen shell burning zone.

The most interesting model is the one with $\upsilon_{\rm ini} = 600$ km s^{-1} at $Z = 10^{-8}$. In the course of core helium burning, the increase in the strength of the shell H–burning (due to mixing of C and O) is so important that the star expands and the convective He–burning core becomes and remains smaller than at the start of core He–burning. The yield of ^{16}O is closely correlated with the size of the CO core. Therefore the yield of ^{16}O is reduced due to the strong mixing (see also Meynet et al. *et al.* (2005)).

4. Stellar yields

The observational constraints at very low Z are a very high primary ^{14}N production, a flat or slightly decreasing [C/Fe] (with increasing metallicity) and an upturn in [C/O] for [Fe/H] $\lesssim -3$ Chiappini, *et al.* (2005). This requires not only extremely high primary ^{14}N production and a similar or larger ^{12}C production at very low Z but also a reduced ^{16}O production in massive stars. All these criteria are best fulfilled in the models with values of the ratio of the initial velocity to the break–up velocity ($\upsilon_{\rm ini}/\upsilon_c \sim 0.75$) slightly larger than the mean observed value for OB solar metallicity stars (0.63). It thus favours faster rotation at very low metallicities. The very large amounts of ^{14}N observed ($\sim$0.03 $M_\odot$) are only produced at $Z = 10^{-8}$ (PopII 1/2). The strong dependence of the ^{14}N yields on rotation and other stellar parameters like the initial metallicity and mass (see Chieffi & Limongi (2004) for the mass dependence at $Z = 0$) may explain the large scatter in the observations of ^{14}N abundance.

References

Cayrel, R., Depagne, E., Spite, M., *et al.* 2004, *A&A* 416, 1117
Chiappini, C., Matteucci, F., & Ballero, S. K. 2005, astro-ph/0503492
Chieffi, A. & Limongi, M. 2004, *ApJ* 608, 405
François, P., Matteucci, F., Cayrel, R., *et al.* 2004, *A&A* 421, 613
Hirschi, R. 2005, in preparation
Hirschi, R., Meynet, G., & Maeder, A. 2004, *A&A* 425, 649
Hirschi, R., Maeder, A & Meynet, G. 2005, *A&A* 433, 1013
Israelian, G., Ecuvillon, A., Rebolo, R., *et al.* 2004, *A&A* 421, 649
Meynet, G., Ekström, S., & Maeder, A. 2005, submitted to *A&A*
Prantzos, N. 2004, astro-ph/0411392
Spite, M., Cayrel, R., Plez, B., *et al.* 2005, *A&A* 430, 655

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Marco Limongi presenting the nucleosynthesis of zero-metal stars.

Ken Nomoto, chaired by Christina Chiappini.

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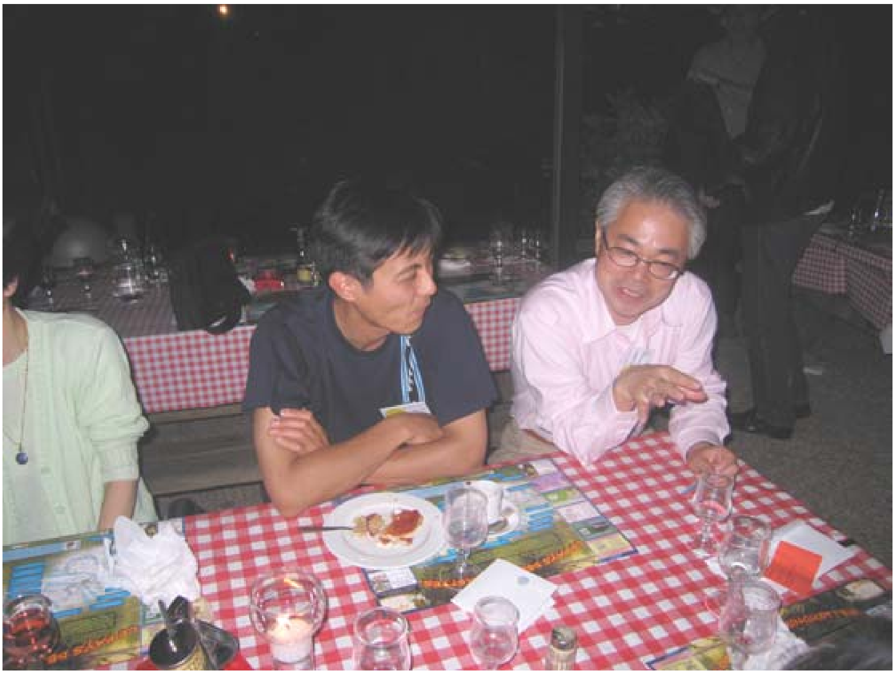
Paul Barklem, Corinne Charbonnel, Martin Asplund and Kim Venn at the conference dinner.



Wako Aoki and Nobuo Arimoto at the conference dinner.

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