The Astrophysical Journal, 799:54 (13pp), 2015 January 20 doi:10.1088/0004-637X/799/1/54

TESTING THE ROLE OF SNe Ia FOR GALACTIC CHEMICAL EVOLUTION OF p-NUCLEI WITH TWO-DIMENSIONAL MODELS AND WITH s-PROCESS SEEDS AT DIFFERENT METALLICITIES

C. Travaglio[1], R. Gallino[2], T. Rauscher[3,4,5,8], F. K. Röpke[6], and W. Hillebrandt[7]
[1] INAF, Astrophysical Observatory Turin, Strada Osservatorio 20, I-10025 Pino Torinese (Turin), Italy B2FH Association, Turin, Italy; travaglio@oato.inaf.it, claudia.travaglio@b2fh.org
[2] Dipartimento di Fisica, Università di Torino, Via P. Giuria 1, I-10125 Turin, Italy
[3] Centre for Astrophysics Research, School of Physics, Astronomy and Mathematics, University of Hertfordshire, Hatfield AL10 9AB, UK
[4] Department of Physics, University of Basel, 4056 Basel, Switzerland
[5] UK Network for Bridging Disciplines of Galactic Chemical Evolution (BRIDGCE), UK
[6] Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany
[7] Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, D-85748 Garching bei München, Germany
Received 2014 August 28; accepted 2014 November 7; published 2015 January 15

ABSTRACT

The bulk of p isotopes is created in the "gamma processes" mainly by sequences of photodisintegrations and beta decays in explosive conditions in Type Ia supernovae (SNIa) or in core collapse supernovae (ccSN). The contribution of different stellar sources to the observed distribution of p-nuclei in the solar system is still under debate. We explore single degenerate Type Ia supernovae in the framework of two-dimensional SNIa delayed-detonation explosion models. Travaglio et al. discussed the sensitivity of p-nuclei production to different SNIa models, i.e., delayed detonations of different strength, deflagrations, and the dependence on selected s-process seed distributions. Here we present a detailed study of p-process nucleosynthesis occurring in SNIa with s-process seeds at different metallicities. Based on the delayed-detonation model DDT-a of TRV11, we analyze the dependence of p-nucleosynthesis on the s-seed distribution obtained from different strengths of the ^{13}C pocket. We also demonstrate that ^{208}Pb seed alone changes the p-nuclei production considerably. The heavy-s seeds ($140 \leqslant A < 208$) contribute with about 30%–40% to the total light-p nuclei production up to ^{132}Ba (with the exception of ^{94}Mo and ^{130}Ba, to which the heavy-s seeds contribute with about 15% only). Using a Galactic chemical evolution code from Travaglio et al., we study the contribution of SNIa to the solar stable p-nuclei. We find that explosions of Chandrasekhar-mass single degenerate systems produce a large amount of p-nuclei in our Galaxy, both in the range of light ($A \leqslant 120$) and heavy p-nuclei, at almost flat average production factors (within a factor of about three). We discussed in details p-isotopes such as ^{94}Mo with a behavior diverging from the average, which we attribute to uncertainties in the nuclear data or in SNIa modeling. Li et al. find that about 70% of all SNeIa are normal events. If these are explained in the framework of explosions of Chandrasekhar-mass white dwarfs resulting from the single-degenerate progenitor channel, we find that they are responsible for at least 50% of the p-nuclei abundances in the solar system.

Key words: atomic processes – Galaxy: abundances – Galaxy: evolution – nuclear reactions, nucleosynthesis, abundances – supernovae: general

1. INTRODUCTION

The origin of heavy nuclei was discussed by Cameron (1957), who called 35 species *excluded isotopes*. Indeed they are outside of both the s and r neutron capture paths, and they are typically 10–1000 times less abundant than the corresponding s and/or r isotopes in the solar system. The origin of p-nuclei was investigated starting with the pioneering work of Cameron (1957) and Burbidge et al. (1957), and later by Audouze & Truran (1975) and Arnould (1976). The first work analyzing the possibility of having efficient photodisintegrations in Chandrasekhar-mass SNIa explosions was published by Howard et al. (1991). The initial s-seed distribution they used was derived from helium flashes as calculated by Howard et al. (1986). In Figure 2 of that work, the authors claim that they can reproduce the abundance pattern of all p-nuclei, including light-p nuclei, within a factor of about three. However, they obtained an overproduction of ^{74}Se, ^{78}Kr, and ^{84}Sr. The p-process abundances of these three isotopes are very sensitive to the proton density, which the authors considered rather uncertain. They also obtained a rather low production of ^{94}Mo and ^{96}Ru with respect to the other light p-nuclei. A detailed discussion on these light p-nuclei will be given in Section 4 of the present paper. Later, Goriely et al. (2002, 2005), and Arnould & Goriely (2006) analyzed the p-process production in He-detonation models for sub-Chandrasekhar-mass WDs. These authors considered s-process solar abundances as seeds. They found Ca to Fe to be overabundant with respect to p-nuclei (with the exception of ^{78}Kr) by a factor of $\simeq$100. They concluded that a He detonation is not an efficient scenario for the production of the bulk solar system p-isotopes. Kusakabe et al. (2011) presented p-process nucleosynthesis calculations in a CO-deflagration model of SNIa, i.e., the W7 model of Nomoto et al. (1984). Similar to Howard et al. (1986), they assumed enhanced s-seed distributions using the classical s-process analysis, testing two different mean neutron exposures τ_o, a flat distribution for $\tau_o = 0.30$ mb^{-1}, and a decreasing s-process distribution corresponding to $\tau_o = 0.15$ mb^{-1}.

They noticed that for a flat s-seed enhanced distribution the production factors of light p-nuclei show a strong deficiency in the range ^{78}Se to ^{98}Ru. From this, they concluded that SNIa may have contributed to the enrichment of p-nuclei more effectively than ccSNe.

[8] http://www.astro.keele.ac.uk/bridgce