Nucleosynthetic contributions of the massive stars to the bulk galactic inventories of the stable nuclides from C to Zn

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Introduction

The universe originated around 13.7 billion years ago [1]. The formation of the milky-way galaxy initiated probably within the initial one billion years [2,3]. The pristine bulk inventories of hydrogen, helium and lithium were established by the primordial nucleosynthesis prior to the initiation of the formation of the galaxies. The heavier elements from C to U were synthesized inside several generations of stars that formed over the galactic timescales. The galactic chemical evolution (GCE) models deal with understanding the origin and the evolution of the galaxy in context with the stable isotopic abundance evolution [2,3].

The GCE models incorporate the formulations related with the accretion and the evolution of the galaxy, the star formation rate, the stellar mass distribution function and the stellar nucleosynthetic yields of the various stars of different masses and metallicities [1-3]. The present work makes an assessment of the stellar nucleosynthetic yields of the massive stars [4-7] to the bulk galactic inventories of the stable nuclides from C to Zn. The assessment is made on the basis of the nucleosynthetic yields of supernova (SN II & SN I b/c) resulting from the massive (≥11 $M_\odot$) stars. The stellar yields of the massive stars obtained earlier [4] served as the only available yields for developing majority of the GCE models [2,3]. However, with the development of stellar models with refinements in the stellar evolution theories and the revised nuclear reaction cross-sections, the new stellar nucleosynthetic yields have become available [6,7]. In the present work, we have developed the GCE models with the refined stellar nucleosynthetic yields of the massive stars [5-7]. Further, we make comparisons of the GCE models based on the stellar nucleosynthetic yields obtained by different groups [4], [5-7] to understand the contributions of the massive stars to the bulk inventories of the stable nuclides from C to Zn. The preliminary results of this work will be reported in the meeting.

Galactic chemical evolution models

The traditional approach of developing the GCE model is to solve the integro-differential equations dealing with the stable isotopic abundance evolution of all elements from H to Zn during the galactic evolution [1,2]. These equations integrate the stellar nucleosynthetic yields of the various stars of different masses and metallicities during the galactic evolution by taking into account the accretional growth of the galaxy and its star formation history [1,2]. The stars include the AGB stars, nova and supernovae (SN II, SN Ia and SN I b/c) [1,2].

An alternative approach [3] has been developed recently to numerically simulate the entire evolution of the galaxy in a realistic manner by considering the formation and the evolution of successive generations of stars. The nucleosynthetic contributions of several generations of stars to the interstellar medium are incorporated to understand the stable isotopic abundance evolution [3]. Further, these models incorporate the recently revised solar elemental abundance distribution [8]. The elemental abundance of the sun that serves as a standard for the cosmic elemental abundance distribution has been recently revised [8]. The solar metallicity has been reduced to a value of ~0.014 from an earlier value of ~0.02 [8]. In the present work, we have developed GCE models to reproduce the revised bulk solar isotopic abundance at the time of its formation with three distinct choices of the nucleosynthetic yields of the massive stars.

Nucleosynthetic yields of massive stars

The massive stars in the mass range 11-100 $M_\odot$ are considered to be the main contributors of majority of the stable isotopes from C to Zn [3,9]. In the present work, we have developed three GCE models based on the stellar nucleosynthetic yields of the massive stars obtained earlier [4] and recently [5-7] by two distinct groups. The recent refined works [6,7] incorporate stellar mass-loss rates and stellar rotation that substantially influence the nucleosynthetic yields. Further, in comparison to the smaller mass range of 11-40 M⊙ [4], the recent works [6,7] cover the entire range of 11-100 M⊙ in terms of the stellar nucleosynthetic yields from the massive stars. This reduces the uncertainties associated with extrapolating the nucleosynthetic yields for the >40 M⊙ stars [4]. The GCE models were developed based on the gradual accretional growth of the galaxy on the timescales of ~7 billion years [2,3]. The standard prescriptions were adopted for formulating the star formation rate and the stellar initial mass function. The available stellar yields of the AGB stars and supernova Ia were used [2,3].

The normalized stable isotopic yields obtained from the three GCE models are presented in **Fig. 1**. It should be noted that due to the uncertainties associated with the physical processes associated with the galactic and stellar evolution, a variation by a factor of two over the anticipated normalized value is considered to be tolerable. It should be noted that the GCE models based on the three distinct set of stellar yields predict almost identical stable isotopic abundances for the elements lighter than S within a factor of two. Identical trend continues even in the case of elements from Ti to Ni. The GCE predictions are significantly different in the case of F, Cl, Ar, K, Cu, Zn and Ge, with the recent stellar nucleosynthetic models [5-7] inferring lesser yields compared to the earlier models [4]. The results obtained from the elemental abundance evolution over the galactic timescales will be presented in the meeting.

Acknowledgements: This work is supported by PLANEX (ISRO) research grant.

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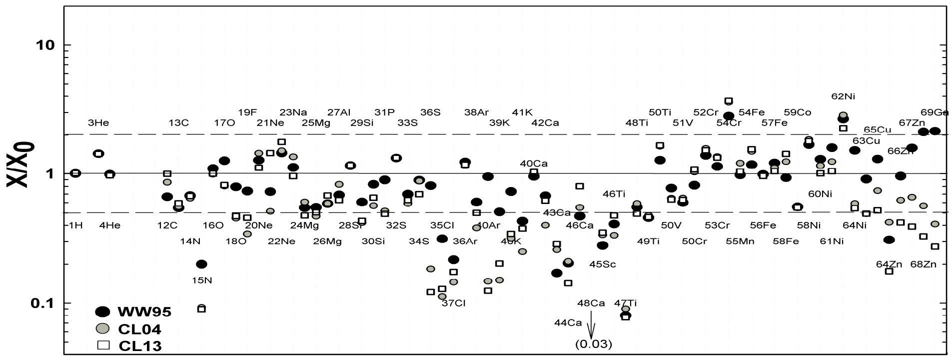

Fig. 1 The estimated GCE yields of the various stable nuclides at the time of the formation of the solar system around 4.56 billion years ago. The three GCE models were run with three distinct stellar nucleosynthetic yields of the massive stars, viz., WW95 [4], CL04 [5] and CL13 [6,7]. The isotopic yields obtained were normalized with respect to the revised bulk solar system isotopic abundances [8]. The solid line represents the best match, whereas, the two dashed lines represents a spread by a factor of two over the best match. This spread is considered to be tolerable given the numerous uncertainties associated with the processes involved in the galactic and stellar evolutions.