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Population III Very-Massive Stars—Their Evolution and Explosion

Takuya Ohkubo[1], H. Umeda[1], K. Maeda[2], K. Nomoto[1], S. Tsuruta[3], and M.J. Rees[4]

[1]Department of Astronomy, University of Tokyo, 7-3-1 Hongo Bunkyo-ku, Tokyo, Japan
email: ohkubo, umeda, nomoto@astron.s.u-tokyo.ac.jp

[2]Department of Earth Science and Astronomy, University of Tokyo, 3-8-1 Komaba, Meguro-ku, Tokyo, Japan
email: maeda@esa.c.u-tokyo.ac.jp

[3]Department of Physics, Montana State University, Bozeman, MT 59717-3840, USA
email: uphst@gemini.msu.montana.edu

[4]Institute of Astronomy, Cambridge University, Madingley Road, Cambrigde CB3 0HA, UK
email: mjr@ast.cam.ac.uk

Abstract. We calculate evolution, explosion, and nucleosynthesis of $1000M_{\odot}$ stars. Even such massive stars may explode at the end of their lives if they rotate. We use a 2 dimensional hydrodynamical code to take aspherisity by the effect of rotation into account. Our results show that (1) abundance pattern of ejected matter by explosion is consistent with observational data of intracluster medium gas, and M82 hot gas, (2) such massive stars can supply more efficient UV photons to re-ionize HI, HeI, and HeII than ordinary massive stars (less than 100 solar-masses), and (3) final black hole mass is 500 solar-mass, which is consistent of the mass scale of intermediate-mass black hole (IHBH) found in M82.

Keywords. Nuclear reactions, nucleosynthesis, abundances – stars: evolution

1. Introduction

It has been noticed that population III stars may have been very-massive. There may have existed over 300 solar-mass stars. Research of such massive stars is important in relation to (1) chemical enrichment in early phase galaxy, (2) supply of UV photons contributing to re-ionization of the universe, and (3) the origin of intermediate-mass black hole (IMBH), which has been identified as 700 solar-mass or more in M82 recently. Motivated by these points, We calculate evolution, explosion, and nucleosynthesis of 1000 solar-mass stars. In section 2, we describe methods and models. Results for these three themes are shown in section 3.

2. Methods

We carry out the calculation of evolution in spherical models (Umeda, Nomoto, & Nakamura (1999)). In hydrodynamical simulation, we use 2-dimentional hydrodynamical code based on bipolar jet model (Maeda & Nomoto (2003)).

We compare the results of nucleosynthesis with the abundance patterns of extremely metal-poor (EMP) stars in the Galactic halo, hot gas in M82, intracluster matter (ICM), and intergalactic medium (IGM).

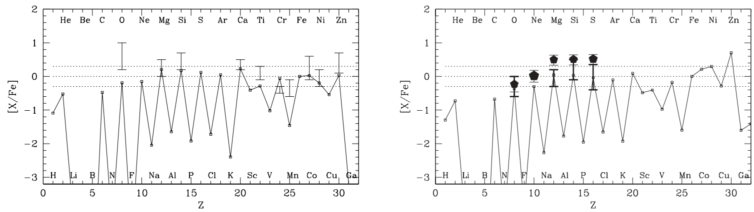

Figure 1. Abundance pattern of our $1000M_{\odot}$ star model and observational data. (left panel) EMP stars (Cayrel *et al.* (2004)). (right panel) ICM (bars, Baugartner, *et al.* (2005)), and hot gas in M82 (pentagons, Origlia *et al.* (2004)).

3. Results

Our findings are summarized as follows: (1) Our results of nucleosynthesis have similar patterns of [α/Fe] to the abundance pattern of the hot gas in M82 and ICM (figure 1). Resulting small [O/Fe], [Ne/Fe] and large [Mg/Fe], [Si/Fe], [S/Fe] are consistent with the observational data of M82 and ICM.

For iron-peak elements, the main feature of the yields of very-massive stars is that [Mn/Fe] is small while [Zn/Fe] is large. This is consistent with the observed ratios in the EMP stars. The oversolar ratios of [Mg/Fe] and [Si/Fe] are also consistent. We need more data of [O/Fe] in EMP stars to see whether very-massive stars contributed to the early Galactic chemical evolution.

[C/Fe] of our results are $-0.78 \sim -0.65$, consistent with IGM abundance ratio, -0.2 (Songaila (2001)), rather than the yields by PISNe ($-2.0 \sim -1.7$ (Umeda & Nomoto (2002), Heger & Woosley (2002)).

(2) Effective temperature (Log$T_{\rm eff}$(K)) of pop III $1000M_{\odot}$ star model is 5.05, higher than that of pop III $15 - 90M_{\odot}$ stars (Tumlinson & Shull(2000)). Our $1000M_{\odot}$ star supplies 1.6×10^{48} for HI, 1.1×10^{48} for HeI, 3.8×10^{47} for HeII ionizing photons per second per solar mass. It can supply ionizing photons more than 10 times than corresponding value with a Salpeter IMF obtained by Bromm, Kudritzki, & Loeb (2001).

(3) Final black hole mass is $500M_{\odot}$, which is consistent with the mass scale of IHBH found in M82 ($700M_{\odot}$). Core-collapse type very-massive stars ($> 300M_{\odot}$) can be the origin of IMBH.

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