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# Explosive Nucleosynthesis in Massive Pop III Stars and Abundances in Metal-Poor Stars and M87

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**Abstract.** In order to understand the elemental abundance pattern observed in galaxies and clusters of galaxies of various metallicity, we investigate stability, evolution and explosion of massive population III stars. We find the upper limit mass of the pulsationally stable Pop III ZAMS stars is $\sim 130M_\odot$, and the mass loss rate of unstable stars may be low. The nucleosynthesis results are compared with abundances of metal-poor halo stars and intragalactic medium around M87. We suggest that stars with enhanced [(Zn, V, Co, Ca, Si)/Fe] may be significantly contaminated by hypernova products rather than normal supernovae. It is also noticed that hypernovae can be important sources for high Si/O and S/O ratio observed in M87.

## 1. Introduction

Pop III stars, the first generation stars, are important since they make the first metal enrichment of the universe. There are several suggestions that IMF of Pop III stars is different from that of Pop I stars and the number of massive stars might be larger in the early universe. If this is the case, the abundance pattern of the early galaxy should show some signatures of the yields of these stars. We examine the stability of massive Pop III stars, their supernova explosions, and nucleosynthesis and compare the results with the observed abundance patterns.

## 2. Stability of Pop III stars

Here we analyze a linear non-adiabatic stability for $80M_\odot$ – $500M_\odot$ to constrain the upper limit mass of the Zero Age Main Sequence (ZAMS) star. Because the CNO elements are absent during the early stage of their evolution, the CNO cycle does not operate and the star contracts until the temperature rises sufficiently high for the $3\alpha$ reaction to produce $^{12}$C.

The critical masses of ZAMS are found to be $128M_\odot$ for Pop III and $94M_\odot$ for Pop I. This difference in the upper limit mass would come from very compact structure of Pop III stars. Stars which are more massive than the critial mass will undergo mass loss. But the mass loss rate is not so high, because the $e$-folding time scale for Pop III stars is much shorter.

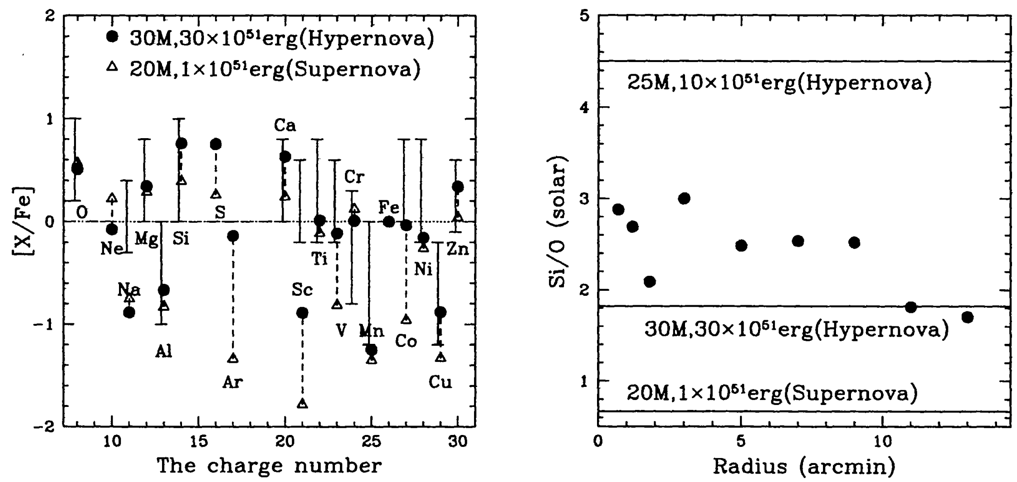


Figure 1. Left panel: The abundance patterns of the SNe ejecta for $20M_\odot, 1 \times 10^{51}$erg and $30M_\odot, 30 \times 10^{51}$erg. The bars show the abundance range of halo stars with [Fe/H] $\leq -3$. Right panel: Abundance ratio Si/O (solar) profile observed with XMM-Newton. The three lines show the ratios in the ejecta from Pop III hypernovae and supernovae.

## 3. Nucleosynthesis in Massive Pop III Stars and Metal-Poor Stars

We calculate various Pop III star models for the mass range of $13M_\odot$ - $30M_\odot$ and the explosion energy of $1 \times 10^{51}$ erg (supernova) - $50 \times 10^{51}$ erg (hypernova); detailed yields are shown in Umeda and Nomoto (2001). We compare the resulting abundance patterns with that of halo stars ([Fe/H] $\leq -3$) in Figure 1. Here, the bars indicate the range of diversity of individual supernova yields, because most of the very metal-poor stars would be made from individual supernovae. Figure 1 (left) shows that large [(Zn, V, Co, Ca, Si)/Fe] would be significantly contaminated by hypernova products rather than normal supernovae.

## 4. Abundance Pattern in M87

X-ray emission in the cD galaxy M87 comes from the hot gas via galactic winds driven by initial starburst, which may be mostly contributed by Pop III SNe. Hence we compare our results with M87 abundance (Böhringer et al. 2001). Figure 1 (right) shows that the Si/O ratio in M87 is enhanced. Such Si enrichment might be contributed by Type Ia supernovae (Böhringer et al. 2001), but we suggest that hypernovae can also make a significant contribution in enhancing Si/O in M87.

## References

Böhringer, H. et al. 2001, A&A, 365, L181B

Umeda, H. & Nomoto, K. 2001, ApJ, submitted (astro-ph/0103241)