

Gravitational Collapse and Neutrino Emission of Population III Massive Stars

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Abstract. We compute the collapse of Population III massive stars (the first stars in the universe) with 300 - 13500 M_{\odot} . In this study, we solve the general relativistic hydrodynamics and the neutrino transfer equations simultaneously and we also solve the evolution of space time of the spherically symmetric model. As a result, it is shown that the neutrino transfer plays a crucial role in the dynamics of gravitational collapse and the emitted neutrino spectrum does not become harder for more massive stars. We also evaluate the flux of relic neutrino background from Pop III massive stars and discuss the possibility to III massive stars and discuss the possibility to study the Pop III star formation history.

1. Introduction

Population III (Pop III) stars are the first stars formed in the universe. Recent theoretical studies suggest that Pop III stars may have a large population of very massive objects from hundreds to thousands solar mass and lose little of their mass during the quasi-static evolutions because of zero-metallicity. If an initial stellar mass is larger than $\sim 100M_{\odot}$, the star becomes unstable against gravitational collapse due to the pair-instability. As a result, if an initial stellar mass is smaller than $\sim 260M_{\odot}$, the collapse is bounced and makes pair-instability supernova explosion (so-called pair-instability supernova). On the other hand, more massive stars can not halt the collapse and form a black holes directory emitting a large amount of neutrinos. Here, we investivate these black hole forming models. For more detailed discussion, please refer our another article [1] and see also the previous studies [2][3].

2. Models and Methods

Collapses caused by the pair-instability occur in the helium burning stage and start the oxygen burning. Consequently, stars with over $\sim 260M_{\odot}$ form the iron cores which are unstable to collapse due to the photodisintegration. These iron cores are isentropic and the entropy per baryon is determined by the initial core mass [4]. Our makes the iron cores which is the equilibrium configurations as initial models solving Oppenheimer-Volkoff equation. In our computations, the general relativistic hydrodynamics and the neutrino Boltzmann equations are solved simultaneously [5][6]. Our models are spherically symmetric and have 127 radial mesh

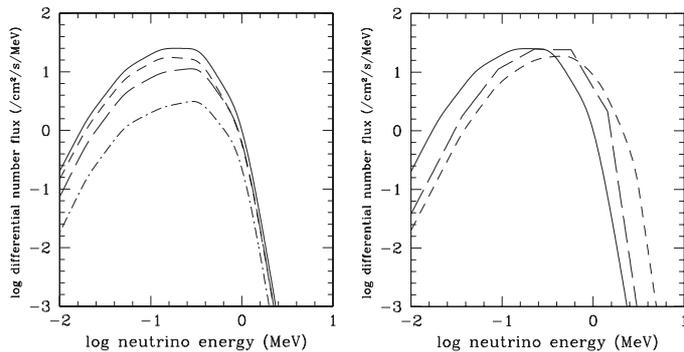


Figure 1. Relic $\bar{\nu}_e$ number fluxes from Pop III massive stars for various values of β and different star formation histories. The left panel shows the result of model A and the short dashed line, solid line, long dashed line and dot-dashed line correspond to $\beta = 1.1, 1.35, 2$ and 3 , respectively. The right panel shows the result for $\beta = 1.35$ and the solid line, long dashed line, and short dashed line represent models A, B and C, respectively.

points. For the neutrino distribution, the energy space and the angular space are discretized to 12 and 4 mesh points respectively. And we compute 4 species of neutrino ($\nu_e, \bar{\nu}_e, \nu_\mu, \bar{\nu}_\mu$).

3. Collapse of Pop III stars

At first, we find that the neutrino cooling crucially affect the dynamics of the collapse when we compare the results with and without neutrino transport. As regards the initial mass dependence, the total neutrino energy emitted from Pop III massive star becomes larger as the initial mass is more massive, but the average energy of neutrinos does not become so large. This is because at first, the effects of neutrino cooling become stronger and the temperature is not so high, as the stellar mass is more massive. The second reason is the thick outer core preventing high energy neutrinos from escaping for more massive models.

4. Relic neutrino

We estimate the flux of the relic neutrino from Pop III massive stars which are computed above. Here we use 4 assumptions. (1) Λ CDM cosmology model. (2) Pop III star formation efficiency is 10%. (3) Initial mass function (IMF) is the top heavy type such as, $\frac{dn}{dm} \propto m^{-\beta-1}$, where $m > 100M_\odot$ and $1 < \beta < 3$ from [7]. (4) As for the star formation history, we employ the following 3 models. (A) The reionization age suggested WMAP observation. (B) The theoretical investigation by [8]. (C) Proportional to the GRB rate [9]. For our result, it is difficult for the currently operating detectors to detect this flux. However, if ever observed, because the peak energy is mainly determined by the Pop III star formation model and not sensitive to the IMF (see Figure 1.), the spectrum will enable us to estimate the formation history of Pop III stars.

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