Remnant mass distribution using Hurley's Single Star Evolution code

K. Igarashi, H. Suzuki (Tokyo University of Science ・ Graduate School of Science and Technology ・ Department of Physics)

Overview

We want to know the relation between supernova relic neutrino and the galactic chemical evolution with stellar population synthesis (SPS) model. To learn how to use SPS model, we calculated remnants mass for three metallicities using a Hurley's single star evolution code. Then, we combined the results with three initial mass functions to make remnant mass distributions and show them in this poster.

Single Star Evolution code(SSE)(Hurley et al.(2000))

- Stellar luminosity, radius and core mass are given as a function of age, M and Z from zero-age main sequence to remnant stage.
- There are analytic formulae that approximate the evolution of stars for a wide range of mass M and metallicity Z.

- **Stellar type**

In stellar model they assign each evolution phase an integer type, k.

$$\begin{aligned} 0 &= \text{MS star } M \lesssim 0.7 \\ 1 &= \text{MS star } M \gtrsim 0.7 \\ &\vdots \\ 13 &= \text{Neutron Star (NS)} \\ 14 &= \text{Black Hole (BH)} \end{aligned}$$

- **Procedure**

Luminosity L, radius R, age t and lifetime at the start and end point of each stellar type (except for remnant) are determined by M_{ZAMS} and metallicities. Then, L and Ron evolution phases are calculated using a fractional timescale τ and them. If a star has the core, core mass M_{c} are given by M_{ZAMS} and metallicities, and we can determine L by $M_{\mathrm{c}} - L$ relation. (The starting values for L and R are the ZAMS points fitted by Tout et al.(1996).)

ex1) CHeB(Core Helium Burning) phase for high mass stars

$$t_{\mathrm{He}} = t_{\mathrm{BGB}} \frac{b_{41}M^{b_{42}} + b_{43}M^5}{b_{44} + M^5}, \qquad \tau = \frac{t - t_{\mathrm{HeI}}}{t_{\mathrm{He}}} \qquad 0 < \tau < 1$$

$$L_{\mathrm{HeI}} = \frac{b_{11} + b_{12}M^{3.8}}{b_{13} + M^2}, L_{\mathrm{BAGB}} = \frac{b_{31} + b_{32}M^{b_{33}+1.8}}{b_{34} + M^{b_{33}}}$$

$$L = L_{\mathrm{HeI}} \left(\frac{L_{\mathrm{BAGB}}}{L_{\mathrm{HeI}}}\right)^{\lambda}$$

ex2) $M_{\mathrm{c}} - L$ relation on GB(Giant Branch)

$$L = \min\left(BM_{\mathrm{c}}^{q}, DM_{\mathrm{c}}^{p}\right) \qquad (B, D, p, q \text{ are parameter})$$

$$M_{\mathrm{c,GB}} = M_{c,\mathrm{BGB}} + \left(M_{\mathrm{c,HeI}} - M_{\mathrm{c,BGB}}\right)\tau$$

$$\tau = \frac{t - t_{\mathrm{MS}}}{t_{\mathrm{HeI}} - t_{\mathrm{BGB}}}$$

Method

1. We calculate NS and BH masses for $8 \leq M \leq 100M_{\odot}$ at three metallicities ($Z = 0.0001, 0.02, 0.03$).

2. Then, we make mass distributions combining the NS and BH masses with IMF (Initial Mass Function)

$$\varphi(M) \propto M^{-\alpha}$$

for three values ($\alpha = 1.3, 1.5, 2.35$).

There are some mass distributions on the right space.

Results

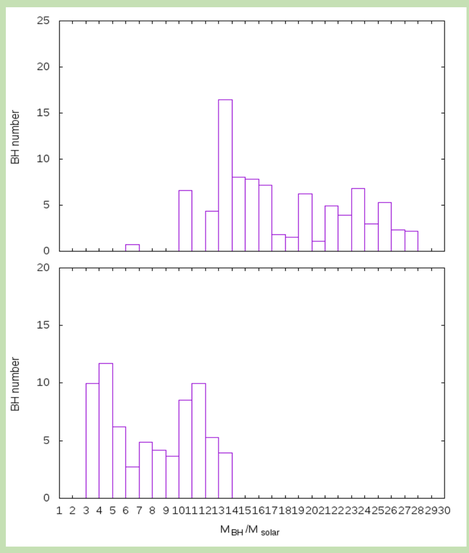

Figure 1. Mass distribution of BH at Z=0.0001(upper figure) and 0.03(lower figure) for $\alpha = 2.35$.
BH mass is lager at Z=0.0001 than Z=0.03.

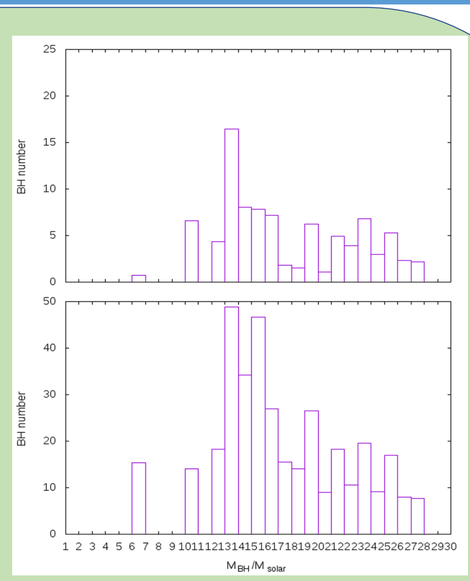

Figure 2. Mass distribution of BH at Z=0.0001 for $\alpha = 2.35$ (upper figure) and $\alpha = 1.3$(lower figure).
BH number become large in all mass range when $\alpha = 1.3$.

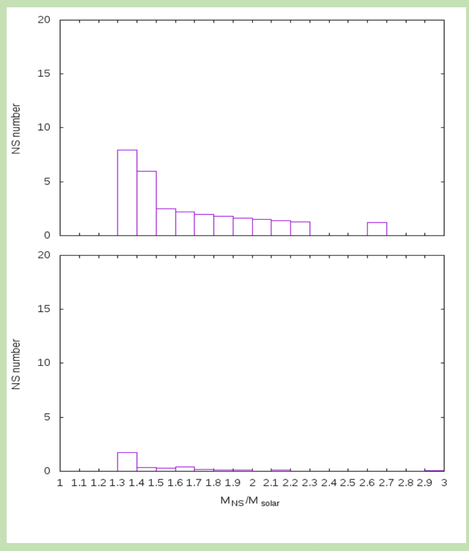

Figure 3. Mass distribution of NS at Z = 0.03(upper figure) and 0.0001(lower figure) for $\alpha = 2.35$.
NS number become large in all mass range when Z= 0.03.

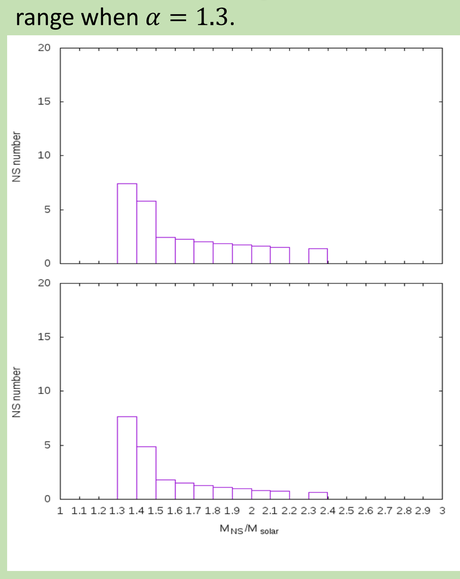

Figure 4. Mass distribution of NS at Z=0.02 for $\alpha = 1.3$ (upper figure) and $\alpha = 2.35$(lower figure).
NS numbers decrease as NS mass increase.

Future work

- We will make mass distributions for binary evolution using binary star evolution code.
- We consider the condition for the relation between CO-core and remnants like Figure 5.

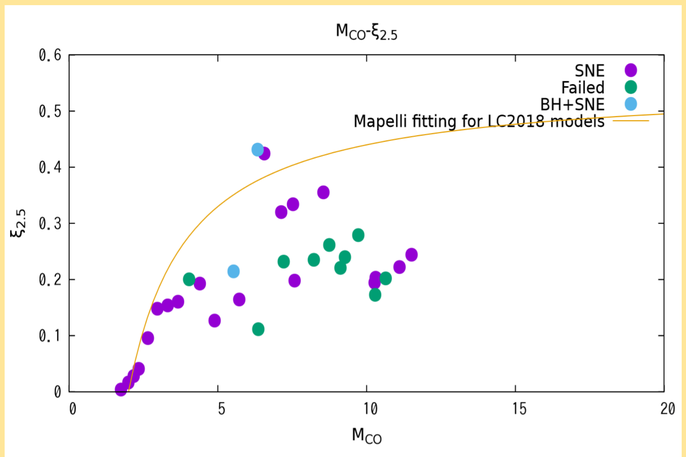

Figure 5. $M_{\mathrm{CO}} - \xi_{2.5}$ relation for stellar models by Woosley, Herger and Weaver (2002) (non-roatating, solar metallicity) and Mapelli's fitting for stellar models by Limongi and Chieffi(2018). Colors represent the explodability estimated with Mueller's (2016) scheme.

References

[1] Jarrod R. Hurley, Onno R. Pols and Christopher A. Tout doi:10.1046/j.1365-8711.2000.03426