Predicting the Spectrum of Diffuse SN Neutrino Background and Understanding the Chemical Evolution of the Universe Using Population Synthesis

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Abstract

In order to compare with observations, we need to calculate the energy spectrum of the **DSNB**. In preparation, I calculated the time evolution of the total energy of DSNB and the total mass of the ejected heavy elements. We estimated the two quantities using the results of population synthesis that takes into account **IMF**, **multiplicity frequency**, **binary period**, **mass ratio**, and **eccentricity distribution**, as well as SFR and the time evolution of the metallicity. We find that the dependence on the IMF is larger than the other distributions. We plan to estimate the energy spectrum of DSNB using our code and the average energy of neutrinos emitted from SNe.

1.Introduction

◎ **D**iffuse **S**upernova **N**eutrino **B**ackground ,**DSNB**

DSNB is neutrinos emitted by supernova explosions, which have been repeated since the birth of the universe and accumulated throughout the universe.

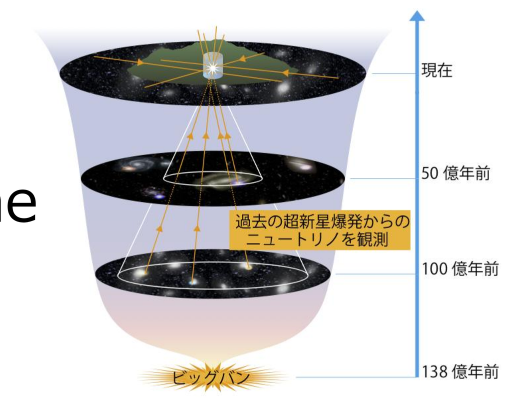
$$\frac{dF_\nu(E_\nu,t_0)}{dE_\nu} = c\int_0^{t_0}\int_{M_{\min}}^{M_{\max}}\int_0^{Z_{\max}} \frac{d^2R(t,M,Z)}{dMdZ}dMdZ\frac{dN_\nu(E'_\nu,M,Z)}{dE'_\nu}\frac{dE'_\nu}{dE_\nu}dt$$

$$E_\nu(z) = \int_z^{z_{\max}} R_{\rm cc}(z)\int_{M_{min}}^{M_{max}} E'_\nu(M,Z)\,N(M)\,dM\frac{dz}{(1+z)^2H(z)}$$

E_ν : observed energy
E'_ν : emitted energy

◎ **Objective**

- Develop code to calculate DSNB energy for future observations
- Investigate how much the DSNB affects the distribution of stars (Initial Mass Function, Multiplicity Frequency, etc…)



2.Method

➢ **Stellar Evolution Code**

SSE (Hurley et al. (2000))・BSE(Hurley et al. (2002)) with improvements based on Müller 1D supernova model (Müller et al. (2016)) ⟹

$$\begin{cases} \dfrac{E_\nu}{10^{53}\,{\rm erg}} = a\left(\dfrac{M_{\rm CO}}{M_\odot}\right)+b \\ M_{\rm ej} = M_{\rm CO}-M_{\rm NS} \end{cases}$$

➢ **Population synthesis**

$$N(M)dM = \int_p\int_q\int_e \psi_{\rm IMF}(M)\psi_{\rm MF}(M)\frac{d^3n}{dpdqde}dpdqde\ dM$$

➢ **Distributions**

- Initial Mass Function, IMF ($\psi_{\rm IMF}=\frac{dn}{dm}$)

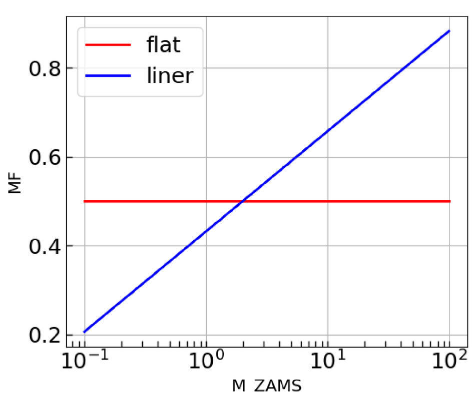
  Salpeter IMF $\frac{dn}{dm} \propto m^{-2.35}$

  Chabrier IMF $\frac{dn}{dm} \propto \begin{cases} \exp\left\{\frac{(\log m - \log m_c)^2}{2\sigma^2}\right\}/m & (m<M_\odot) \\ m^{-2.3} & (m>M_\odot)\end{cases}$

- Multiplicity Frequency, MF ($\psi_{\rm MF}$)

  Flat (single:binary = 1:1)

  Liner (Fig.1 Duchêne,G., & Kraus,A. (2013))



- Eccentricity Distribution, ED ($\frac{dn}{de}$)

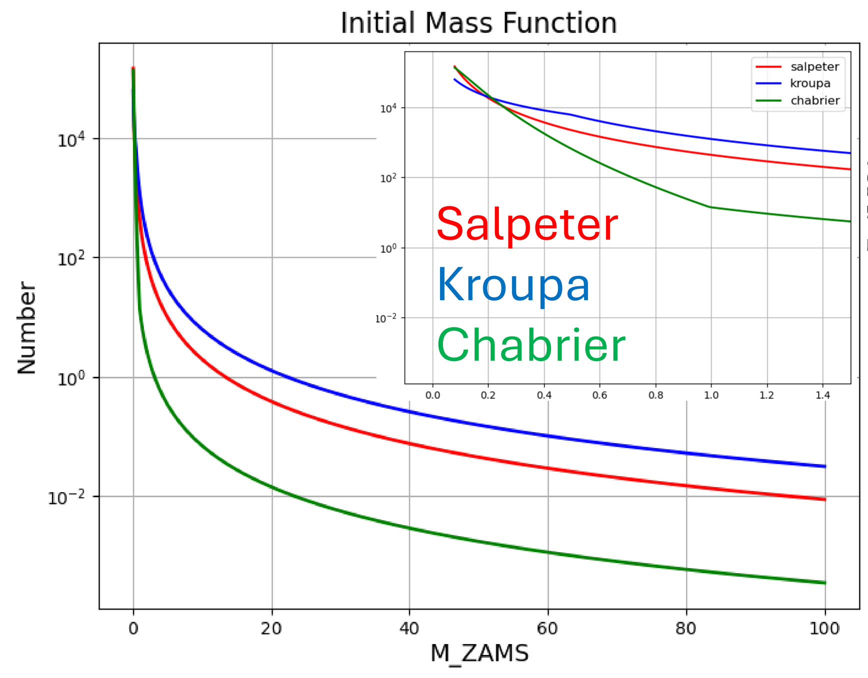
  Flat ($\frac{dn}{de}\propto e^0$) , thermal ($\frac{dn}{de}\propto e^1$)

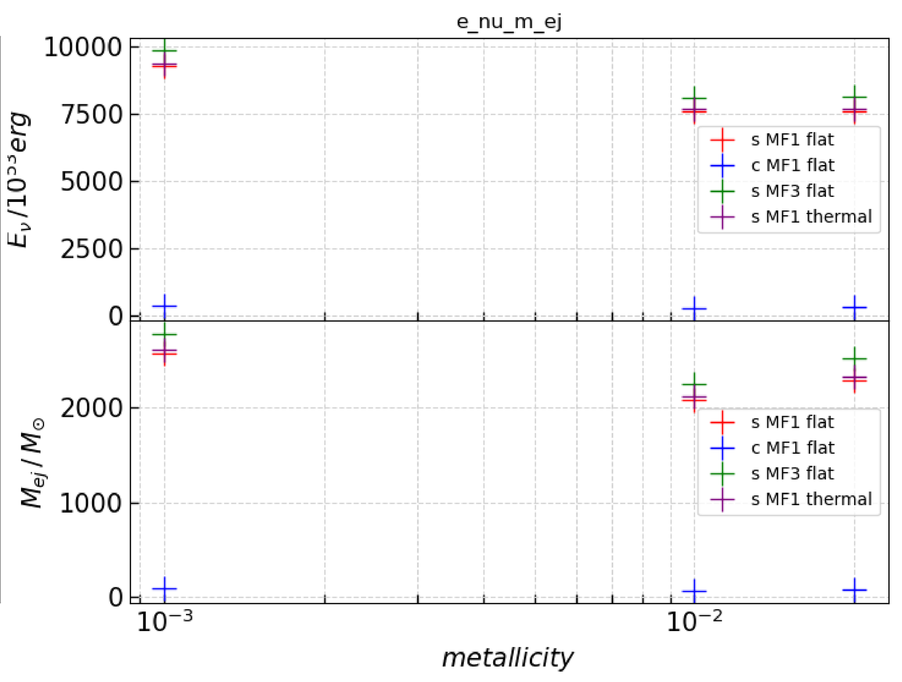
➢ **Star Formation Rate** ($\psi_{\rm SFR}\propto R_{\rm CC}$)

$$\psi_{\rm SFR}(z) = 0.015\frac{(1+z)^{2.7}}{(1+[(1+z)/2.9]^{5.6})}\ M_\odot{\rm yr}^{-1}{\rm Mpc}^{-3}$$

3.Result & Discussion

- **Result of population synthesis**





	IMF	MF	ED
Red	Salpeter	flat	flat
Blue	Chabrier	flat	flat
Green	Salpeter	liner	flat
Purple	Salpeter	flat	thermal

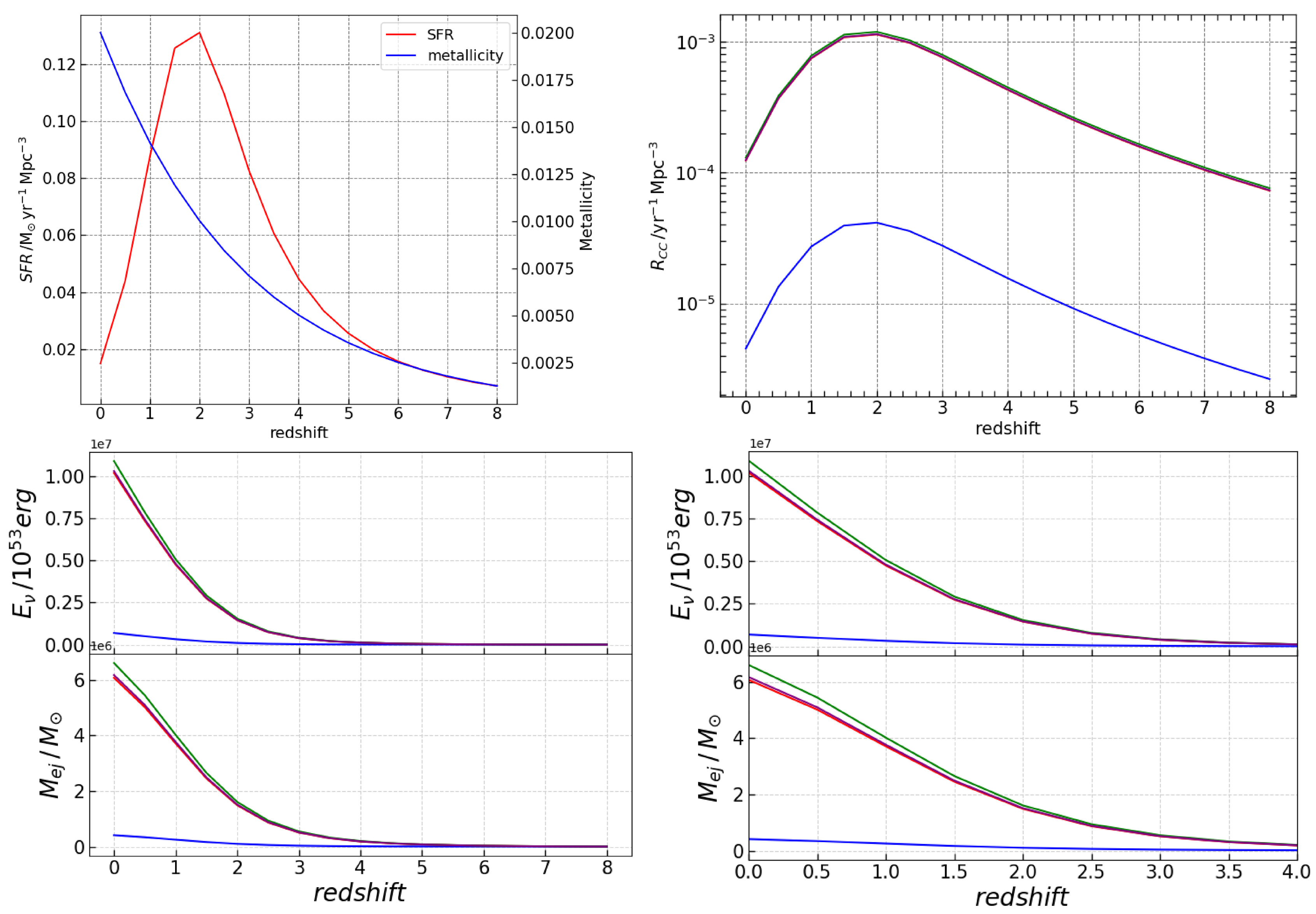
The number of light stars is greater than that of heavy stars.

If the metallicity is low (less mass loss), the lighter star will go supernova.

The neutrinos and ejecta emitted depend on the number of NS and BH.

- **Considering the time evolution**

Metallicity $Z(z) = Z_\odot\times10^{-\gamma z}$



- Impact of distribution on $E_\nu(z=0)$

  IMF : Salpeter -> Chabrier 96% down

  MF : flat -> liner 7% up

  ED : flat -> thermal 1% up

The IMF has the greatest impact because it directly affects the number of stars that are born.

Based on the results of $R_{\rm CC}$, Salpeter IMF is more suitable than Chabrier IMF in the current setup.

4.Conclusion and Future Plans

Conclusion

- Using population synthesis, I calculated the time evolution of the total energy of the DSNB and the total mass of the ejected heavy elements.
- The parameters that affect **the number of NSs and BHs** produced also have a significant impact on DSNB results.

Future Plans

- Using other distributions, for example SFR, I will calculate the total energy of the DSNB.
- To calculate **the energy spectrum**, information on the average energy of neutrinos emitted from SN will be introduced into the developed program.