Chemical evolution calculation using population synthesis accounting for Type Ia supernova

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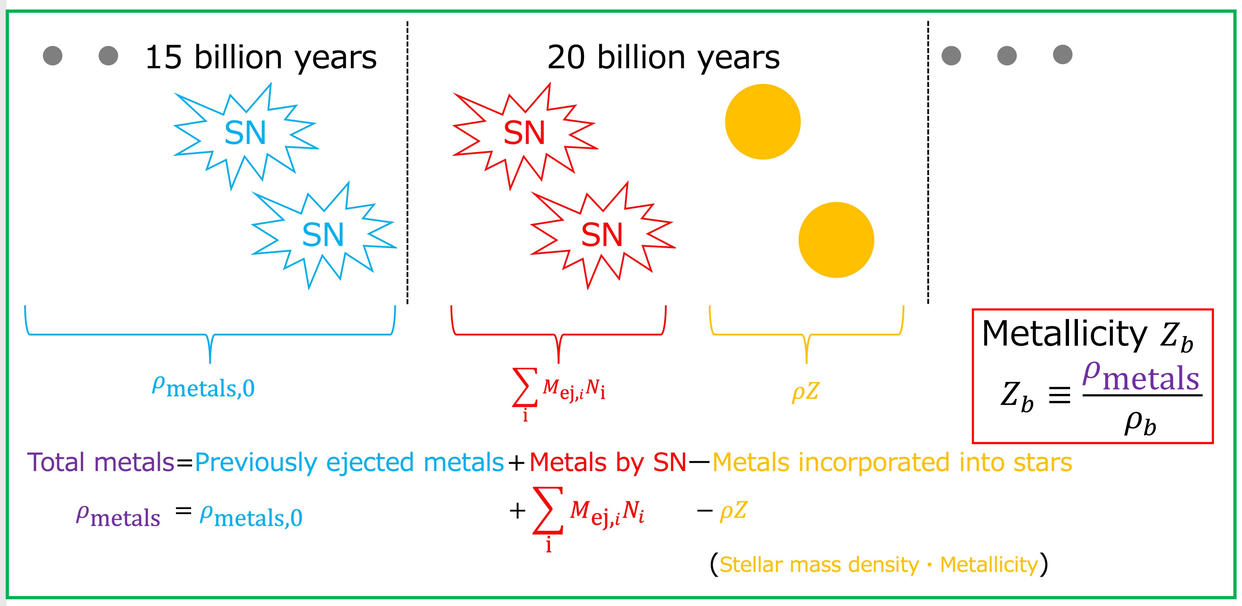
Background

◎Chemical evolution

・ The process of metal production and accumulation, include C,O,and Fe,through cycles of stellar birth and supernova.

◎Research Objective

・Calculating the time evolution of the mean metallicity Z_b in the universe as a method to understand cosmic history.



◎Type Ia supernova

・Supernova triggered by the interaction of low mass stars.
・A long time before the supernova(0.1~10 billion years).
⇨ **Delay Time**

$$t_{\mathrm{delay}} = t_{\mathrm{SN}} - t_0 (t_{\mathrm{delay}} = 0 \text{ for CCSNe})$$

Method

◎Calculation code $M_{\mathrm{rem}}, t_{\mathrm{delay}}$

・An improved version of the population synthesis code SSE & BSE (Hurley et al.(2000), (2002)[1][2]). ex)$M(t), M_{\mathrm{C}}(t)$

➢ Features

・It is based on fitting formulae obtained from detailed computational codes, so star populations can be derived quickly.
・The calculation accuracy is low because fitting formulas are used.

The model adopted this time

◎The number of stars

$$\Delta N(M\sim M+\Delta M, p\sim p+\Delta p, q\sim q+\Delta q, e\sim e+\Delta e) = \int_t^{t+0.5\,\text{billion years}} \dot{\rho}(t)\left(MF(M)\psi_{\mathrm{IMF}}(M)P(p)Q(q)E(e)\right)\Delta M\Delta p\Delta q\Delta e dt$$

➢ Star Formation Rate Density(SFRD) $\dot{\rho}(t)$

・Madau et al.,(2014)

➢ Multiplicity frequency $MF(M)$

・The ratio of single stars to binary stars is 1:1 & 0:1

➢ Initial mass function(IMF) $\psi_{\mathrm{IMF}}(M)$

・Chabrier IMF

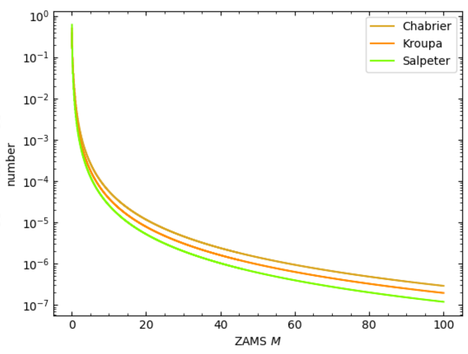
$$\psi_{\mathrm{IMF}}(M) \propto \begin{cases} e^{-(\log M - \log m_c)^2/2\sigma^2}/M (M < 1M_\odot) \\ M^{-2.3} (M \geq 1M_\odot) \end{cases}$$

・Kroupa IMF

$$\psi_{\mathrm{IMF}}(M) \propto \begin{cases} M^{-0.3} (0.01M_\odot \leq M < 0.08M_\odot) \\ M^{-1.8} (0.08M_\odot \leq M < 0.50M_\odot) \\ M^{-2.7} (0.50M_\odot \leq M < 1.00M_\odot) \\ M^{-2.3} (1.00M_\odot \leq M) \end{cases}$$

・Salpeter IMF

$$\psi_{\mathrm{IMF}}(M) \propto M^{-2.35}$$



➢ Period,Mass ratio, and Eccentricity $P(p), Q(q), E(e)$

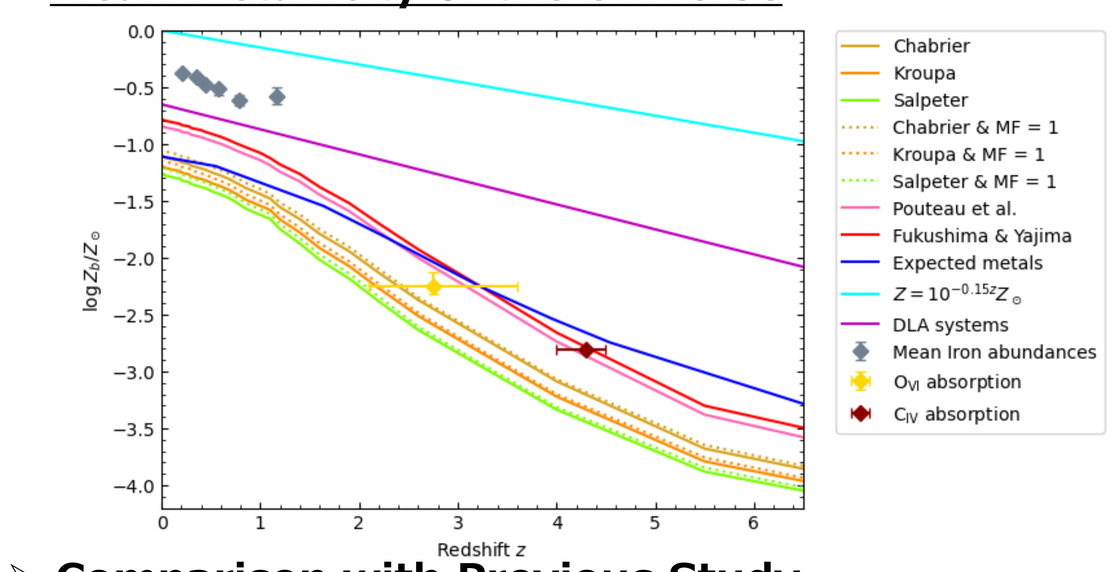
・Period P $3\sim3\times10^5$ days,$\Delta \log P = 0.025$(log flat)
・Mass ratio q $0.0125\sim1, \Delta q = 0.0125$(flat)
・Eccentricity $e = 0.0, 0.5, 0.6, 0.7, 0.8, 0.9, 0.95$(flat)

➢ Metallicity evolution $Z(z)$

・$Z(z) = 10^{-0.15z} Z_\odot$(Langer et al.,(2006)[3])

Results and Discussion

◎Mean Metallicity of the Universe



➢ Comparison with Previous Study

・Similar results in the local universe($z \approx 0$).
・Previous study shows **a gradual increase**,whereas my study shows **a steep increase**.

■ Methodology of Previous Study

$$\rho_{\mathrm{metals}} = y\rho_\star$$
$$\rho_\star = (1-R)\int \dot{\rho}(t)dt$$

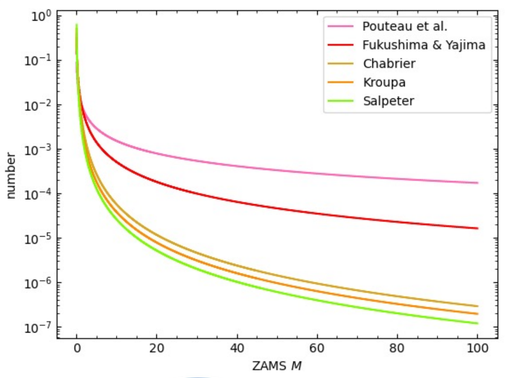
Previous study:**Neglecting** Delay Time
My study:**Accounting for** Delay Time

➢ Comparison with Observations

・Calculated values are **systematically lower than observations**.

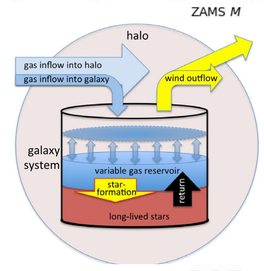
■ Yüksel SFRD
・A distribution of more active SFRD
⇨**Increase in Metallicity Z_b**

■ Top-heavy IMF
・Pouteau IMF
$\psi_{\mathrm{IMF}} \propto M^{-0.95}$
・Fukushima & Yajima
$\psi_{\mathrm{IMF}} \propto M^{-1.5}$



➢Better Modeling

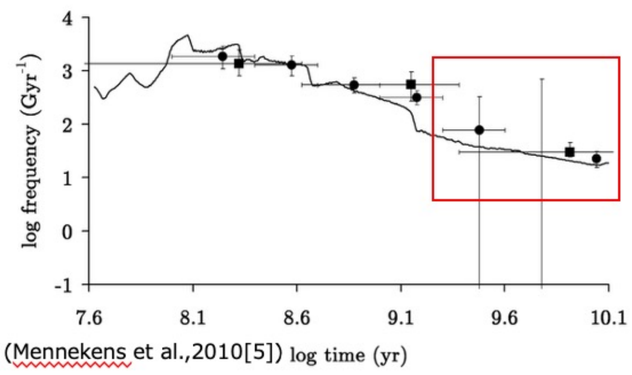
・gas inflow and outflow
・Improvement of calculation code.
ex)Mass Transfer in binary system.



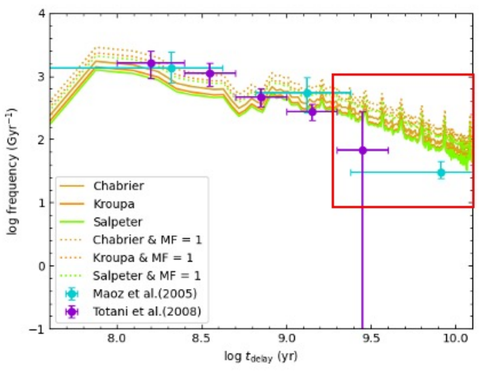
gas-regulated model (Lilly et al.,(2013)[4])

◎Delay Time Distribution

Brussels code



BSE code



■ Code characteristic
・ Overestimate the number of stellar mergers.
⇨Possibility of deviations from actual stellar evolutionary paths.

Conclusion and Future plan

◎Conclusion

・Consistent with previous theoretical results,but shows discrepancy with observations.

◎Future plan

・Modeling gas inflow and outflow process.
・Refinement of distribution and introduction of time evolution.
・Better modeling consistent with the latest observations.

[References]
[1] Hurley, J. R., et al.,MNRAS, 315, 543-569, 2000.
[2] Hurley J.R.,Tout C.A.,Pols O.R., MNRAS, 2002, vol.329, pp.897-928
[3] Langer et al., American Astronomical Society, 638, L63-L66, 2006.
[4] Lilly et al., American Astronomical Society,772,119,2013
[5] N. Mennekens, D. Vanbeveren, J. P. De Greve, and E. De Donder. Astronomy and Astrophysics, Vol. 515, p. A89, June 2010.