# Progress Report

# 2024/05/09

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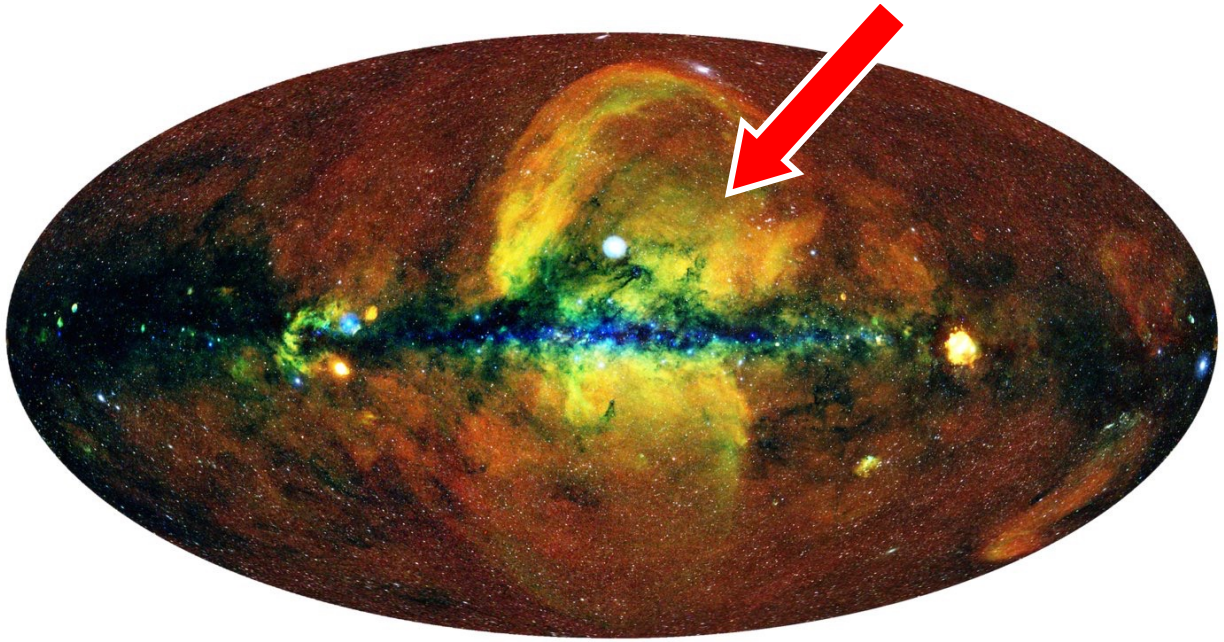
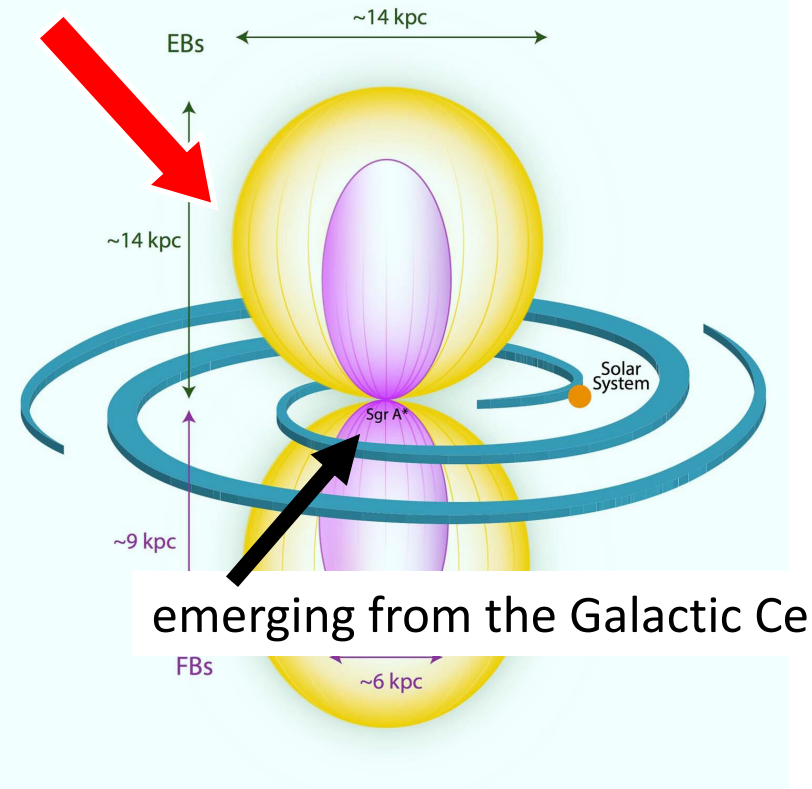
# What is eROSITA/Fermi bubble?

In  Our galaxy: Milky Way galaxy, X-ray bubble observed.
They are called **eROSITA/Fermi bubble**.



The SRG/eROSITA all-sky map as a false colour image (red for energies 0.3-0.6 keV, green for 0.6-1.0 keV, blue for 1.0-2.3 keV). The original image, with a resolution of about 12”, was smoothed in order to generate the above picture. © MPE/IKI




emerging from the Galactic Center (GC)

# What am I researching now?

provide an opportunity to understand the effects of feedback on galaxy evolution

cosmological simulation+zoom-in galaxy simulation

How much does AGN feedback contribute to the bubble?

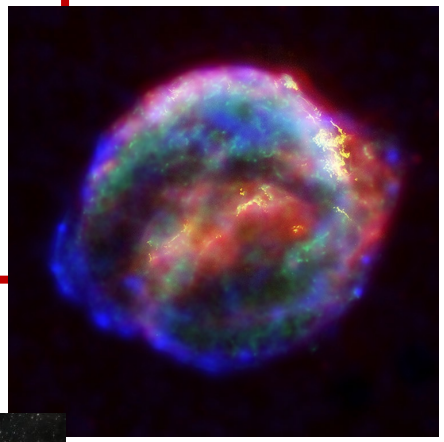
**AGN feedback**, from the result of TNG50 simulation analysis (Pillepich+2021)

## AGN or Steller feedback??

The physical origin of the Galactic bubbles is still under debate

On the basis of their feedback mechanisms, these models can be broadly divided into two categories;

- the nuclear star-forming activity similar to starburst galaxies
- the past AGN activity of the GC supermassive black hole



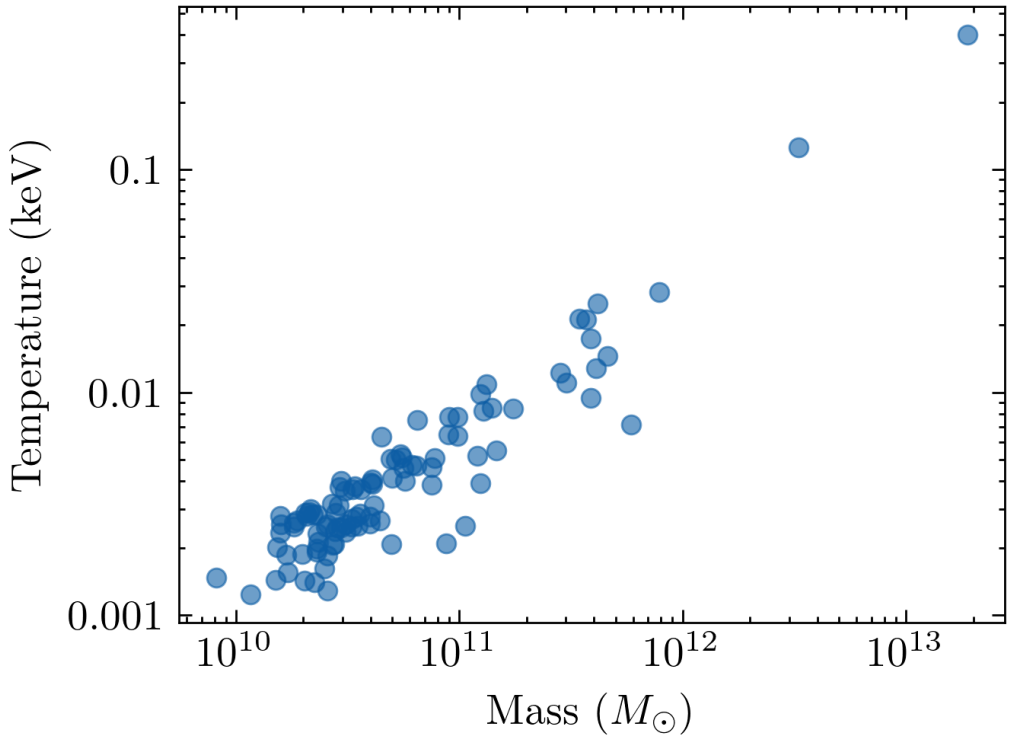
Is that assessment valid?

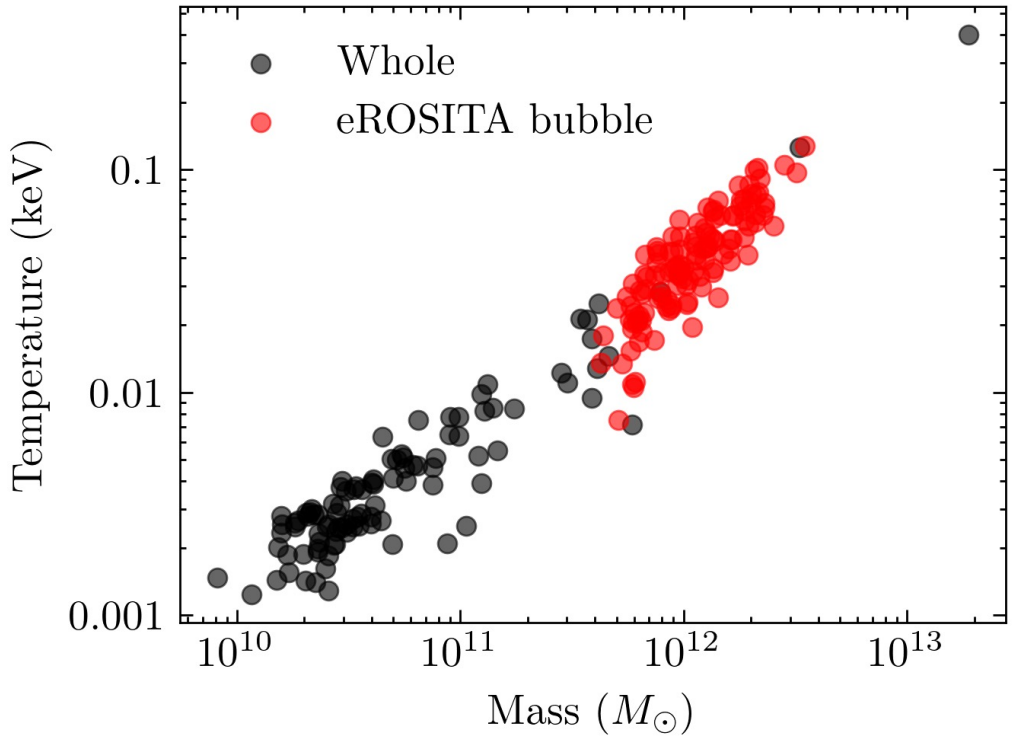
**Steller feedback**, from the result of Suzaku analysis (Gupta+2023)

But a lot of error and douts

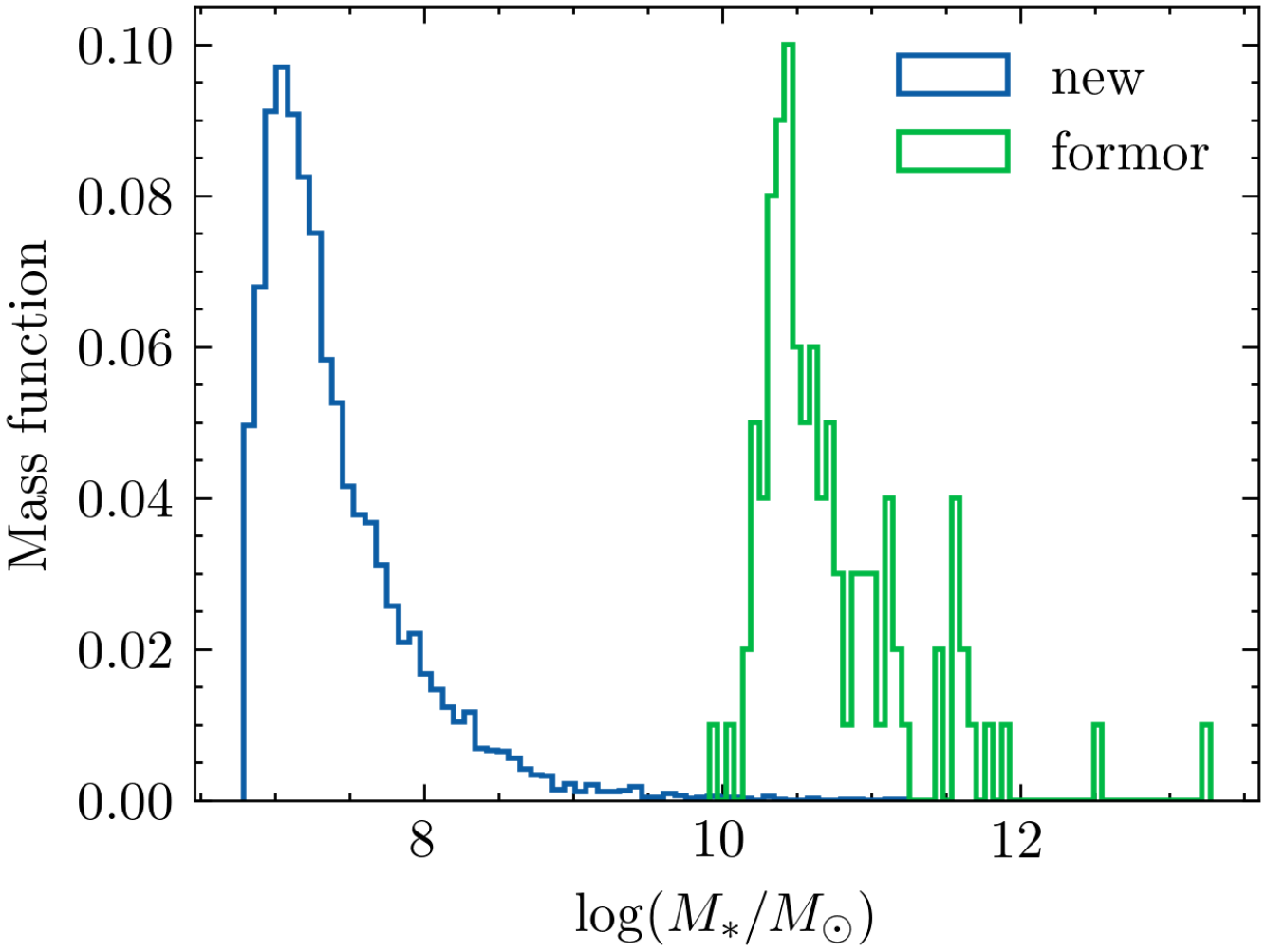
# Plotted Temperature vs Mass

both use pure average



# Plotted Mass function




1000 randomly selected?
(DMO galaxy included)

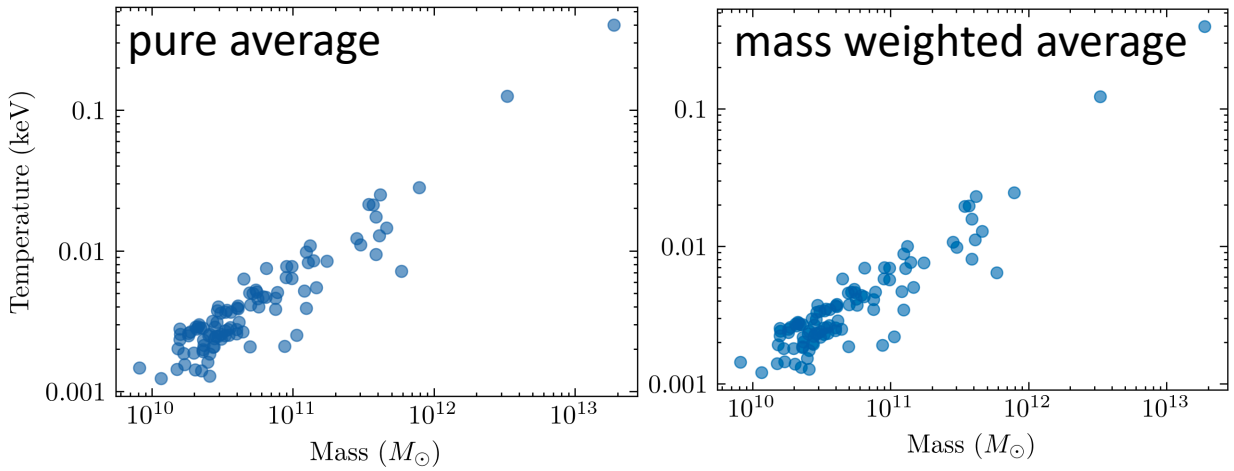
100 randomly selected?
(DMO galaxy excluded)

Maybe they weren't selected at RANDOM correctly?

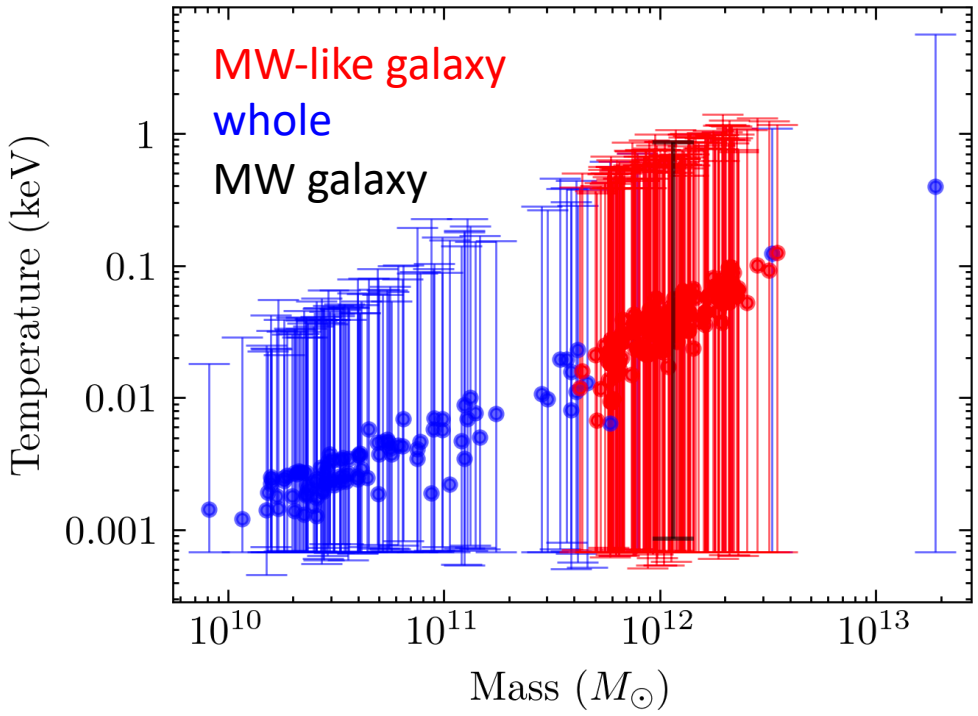
| Subhalo with gas | DMO galaxy | Percentage of galaxies containing gas [%] |
|---|---|---|
| 13 | 987 | 1.3 |
| 11 | 989 | 1.1 |
| 16 | 984 | 1.6 |
| 9 | 991 | 0.9 |
| 18 | 982 | 1.8 |
| 13 | 987 | 1.3 |
| 16 | 984 | 1.6 |
| 14 | 986 | 1.4 |
| 11 | 989 | 1.1 |
| 10 | 990 | 1.0 |

/1000 subhalos

# Temperature compared to Milky way galaxy




No differences



Max temp gas

mass weighted temp average

Min temp gas

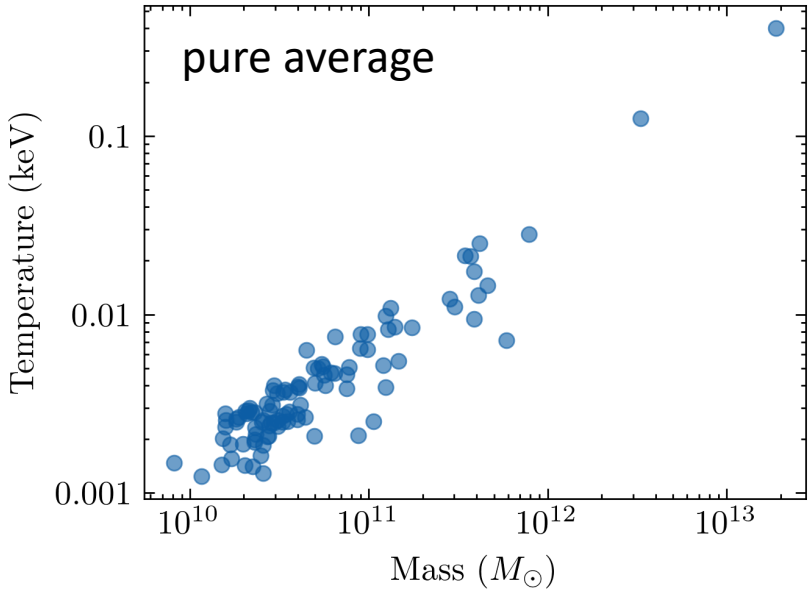
**Milky way galaxy:**

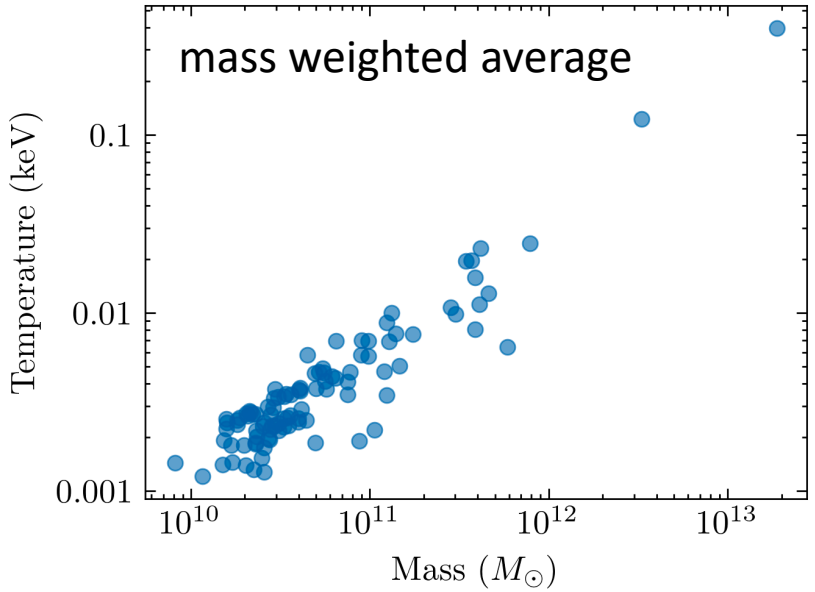
- Max temp gas: 1e+7 K = 0.861 kev (Sanskriti+2019)
- Min temp gas: 1e+4 K = 0.000861 kev (intentional)
- temp average: None
- Mass: 1e+12 solar mass (WenTing+2019)

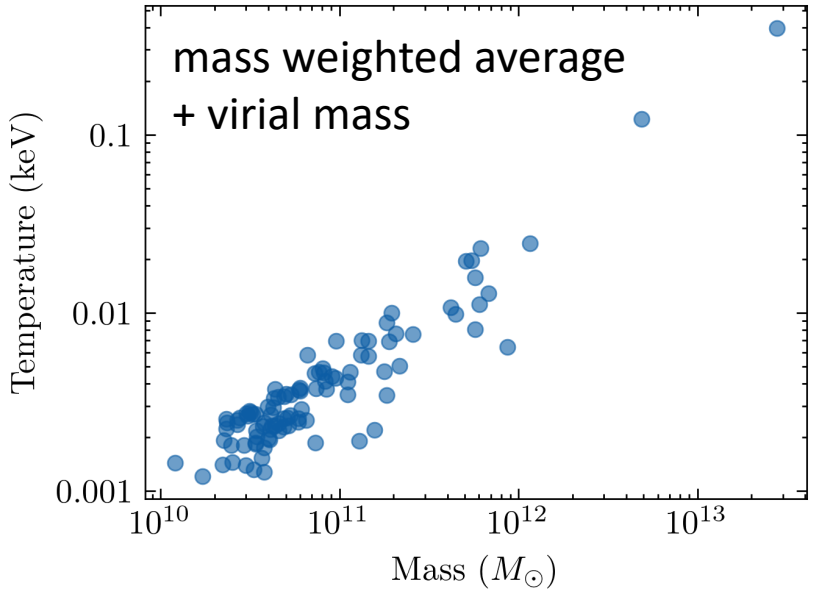
⚠ Milky way galaxy was estimated by virial masses, but my data are not with virial masses but masses that can be defined as Subhalo. ~~**There could be a big difference.**~~

**The next slide showed no difference.

# no difference between Virial Mass and Subhalo Mass

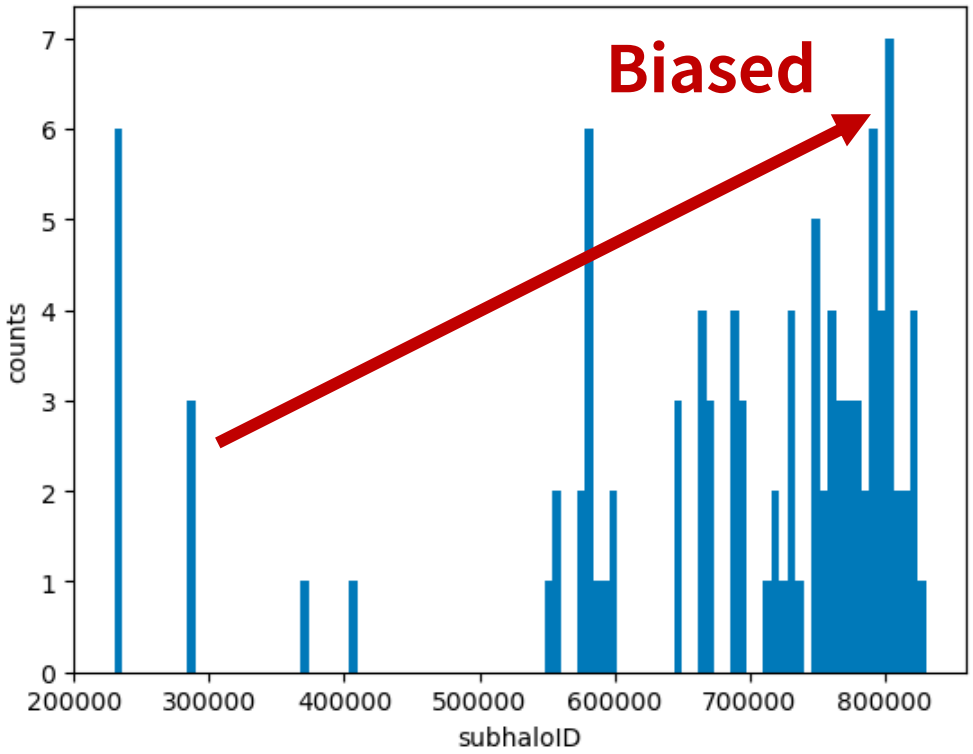


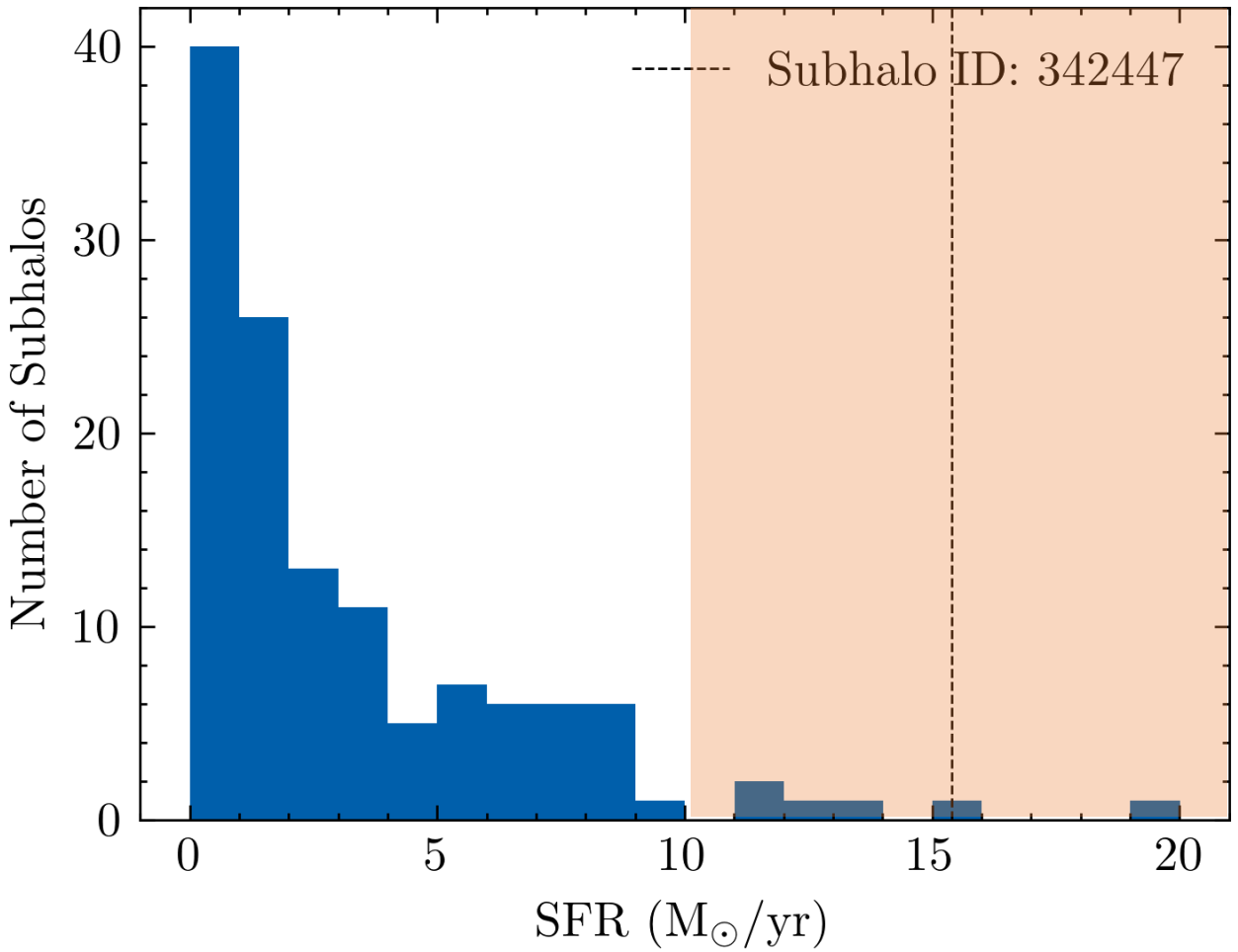
# Appendix

# Are randomly selected subhalo IDs really RANDOM?

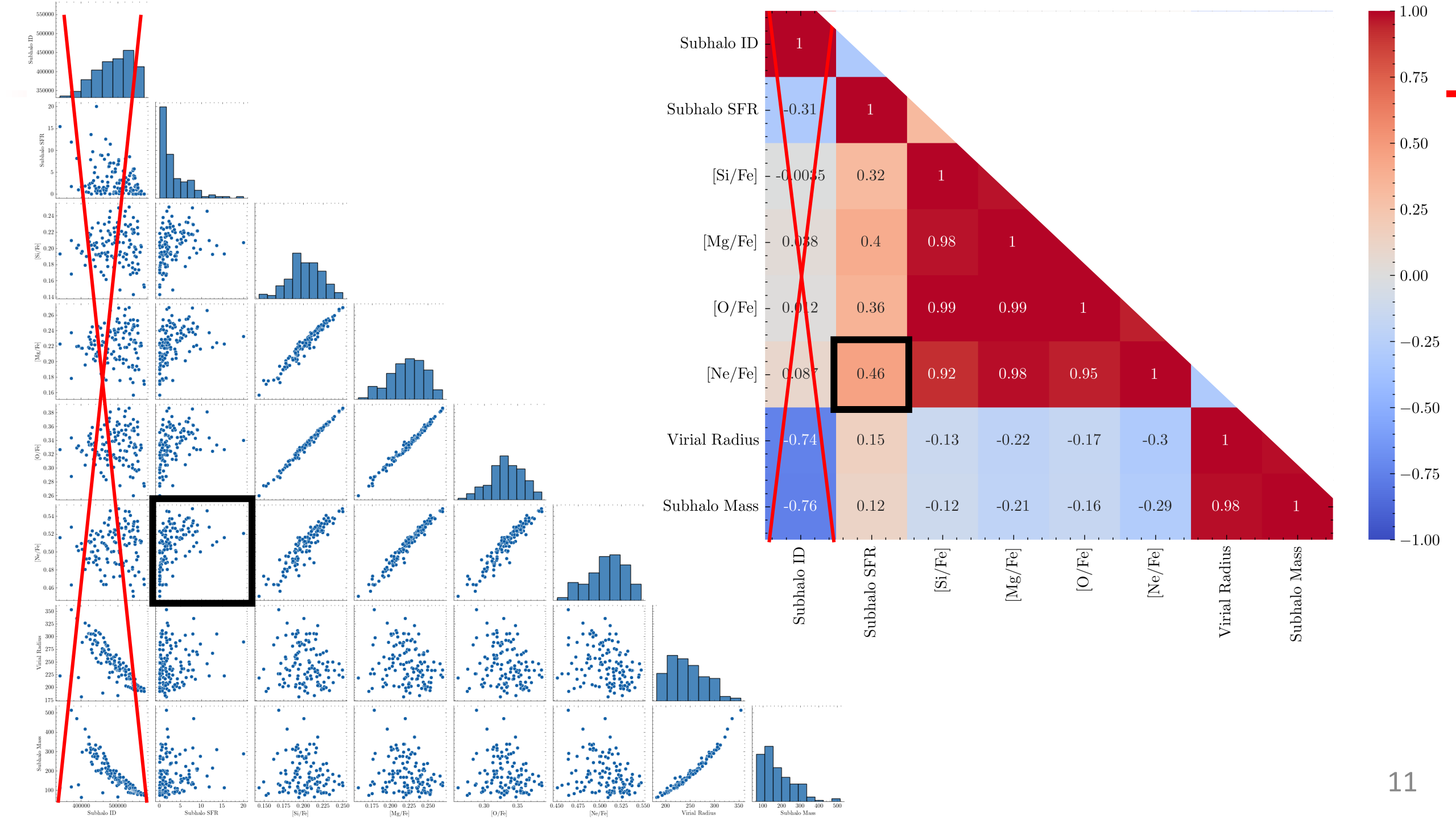



It is best to select Subhalo IDs with uniform random numbers,

but this is not possible because **some subhalo consist only of DM**



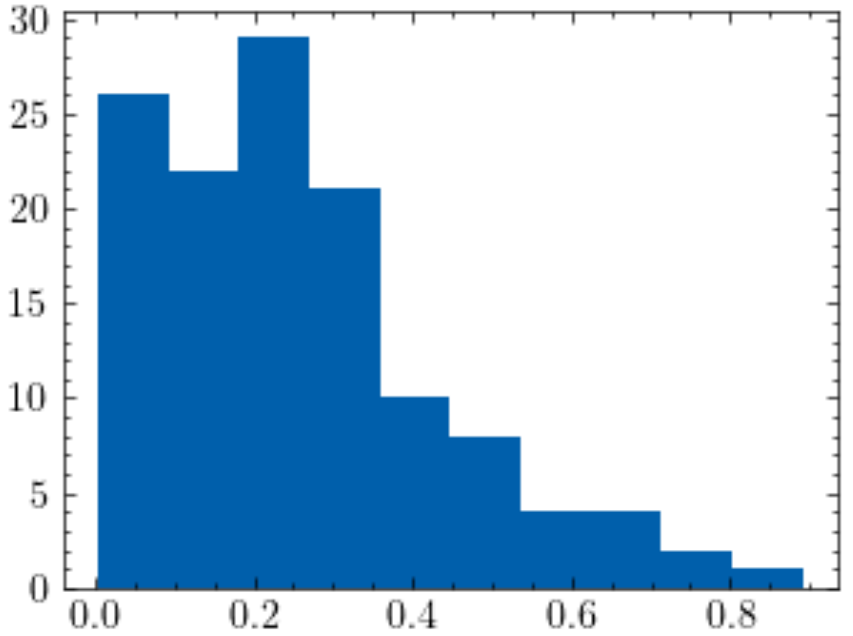

(Star Burst period) SFR ~ 10–100 Solar Mass/yr


Subhalo ID
Subhalo SFR
[Si/Fe]
[Mg/Fe]
[O/Fe]
[Ne/Fe]
Virial Radius
Subhalo Mass
1
-0.31 1
-0.0035 0.32 1
0.038 0.4 0.98 1
0.012 0.36 0.99 0.99 1
0.087 0.46 0.92 0.98 0.95 1
-0.74 0.15 -0.13 -0.22 -0.17 -0.3 1
-0.76 0.12 -0.12 -0.21 -0.16 -0.29 0.98 1
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00

- [X/Fe] について

単純平均 $\sum_{i=1}^{n} x_i$ ⟹ 加重平均 $\frac{\sum_{i=1}^{n} m_i x_i}{\sum_{i=1}^{n} m_i}$

[Si/Fe]について任意のsubhaloについて
変更による誤差は~0.8 %以下のため単純平均で十分




(単純平均 – 加重平均)/加重平均 * 100

α 元素

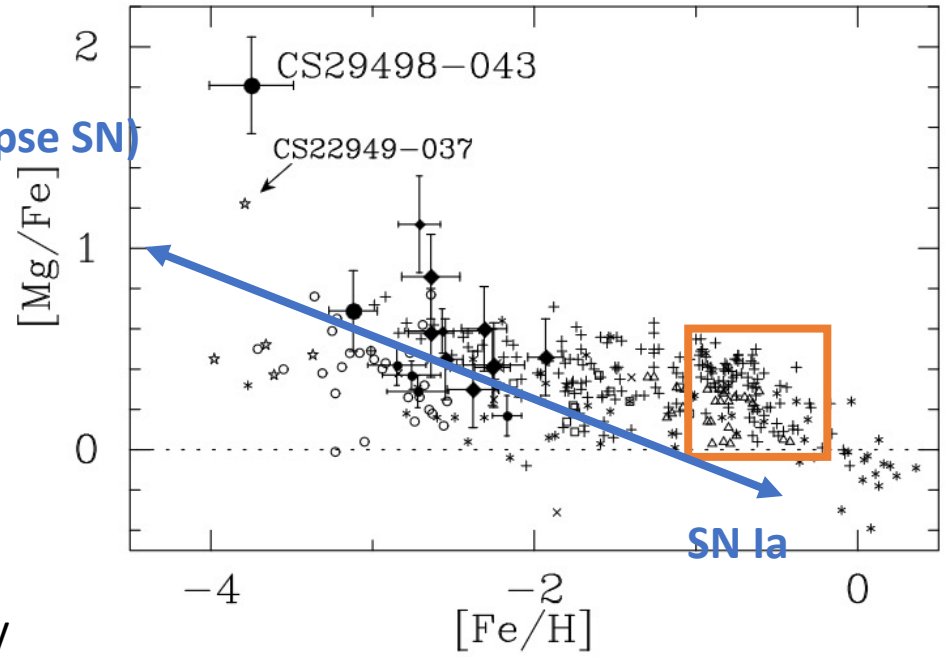
図 3.15 (81 ページ) に太陽近傍にある星に対する Mg と Fe の組成比 [Mg/Fe] と [Fe/H] の関係を示す．Mg は II 型超新星から，Fe は Ia 型超新星から主に放出されるので，縦軸の [Mg/Fe] は両超新星爆発の割合に依存した組成比になる．この図から以下の 3 点が示唆される．

(1) 金属量が [Fe/H] $< -1$ と太陽の値の 10 分の 1 未満の星では [Mg/Fe] $> 0$ となり，このような星を作るガスは，質量が大で寿命の短い星の終焉である II 型超新星爆発によって重元素が供給されていることを示す．

(2) [Fe/H] $< -2.5$ のようにもっと金属量が少ない星では，[Mg/Fe] の比が一定の分散を持って分布している．これは，超新星の爆発エネルギーや質量などの特性を反映したばらつきになっているが，星の形成と超新星のサイクルがさらに繰り返されて金属量が増えてくるとばらつきはなくなっていく．

(3) [Fe/H] が $-1$ より多い星では [Mg/Fe] が 0 に近づいていて，Ia 型超新星が爆発するほど十分に時間が経って Fe が多く供給されていることを示唆している．

SN II
(Core-collapse SN)




eROSITA bubble like galaxy

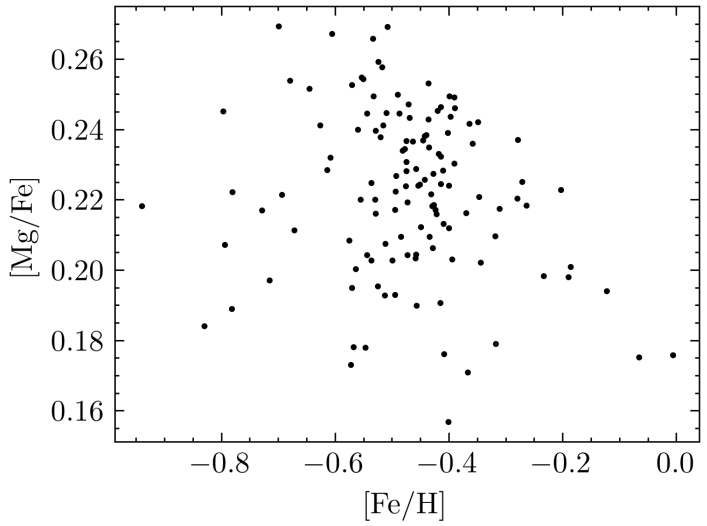
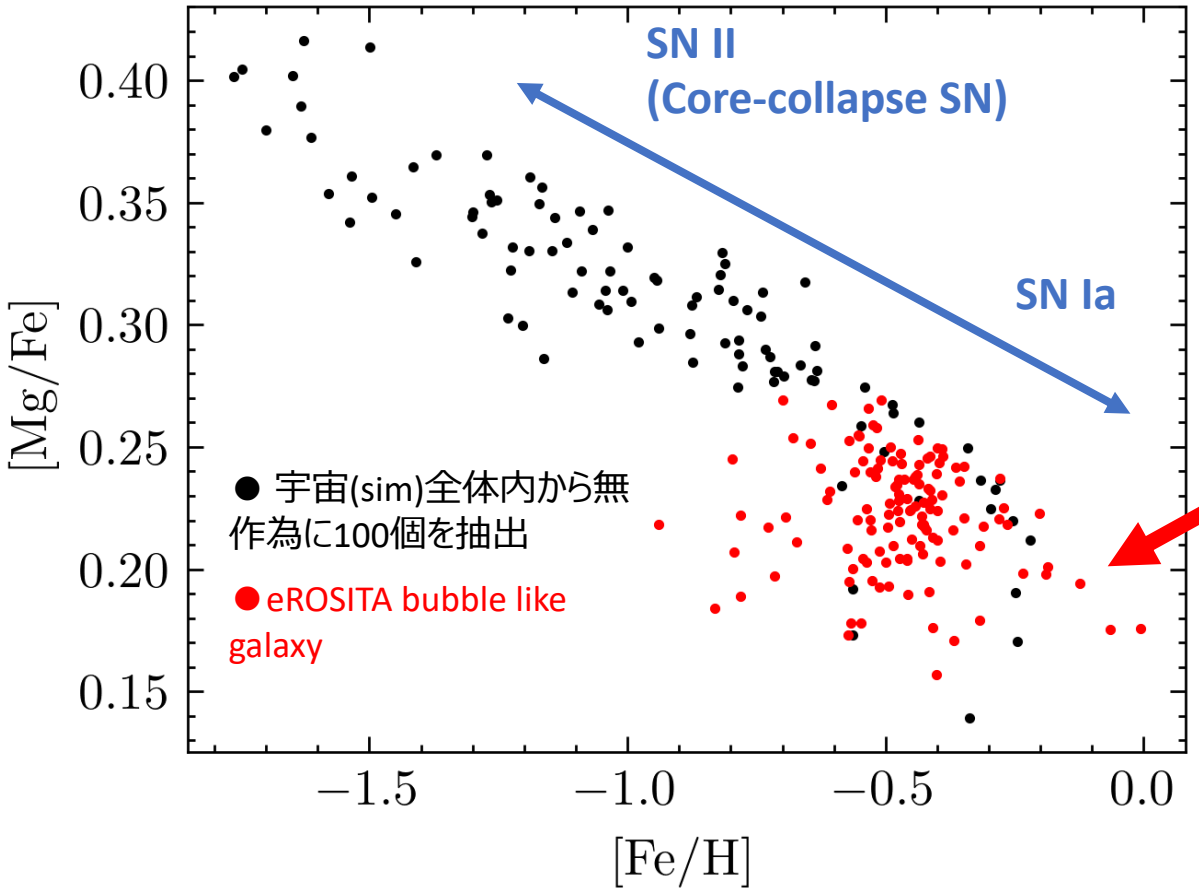
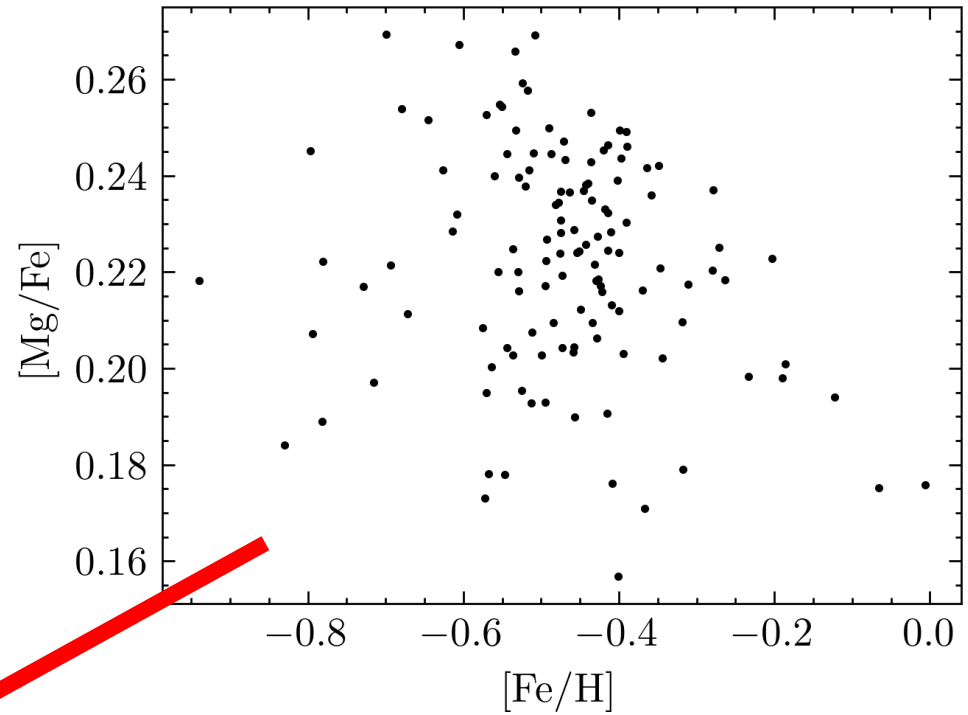



**Fig. 8.** [Mg/Fe] as a function of [Fe/H]. The *filled diamonds* indicate the values for the objects with excesses of *s*-process elements, and the *filled circles* indicate those for objects with normal *s*-process abundances. The larger symbols show the results by the present work, and the smaller ones show those by our previous studies (Aoki et al. 2002a,b). The others are adopted from Norris et al. (2001) and references therein.

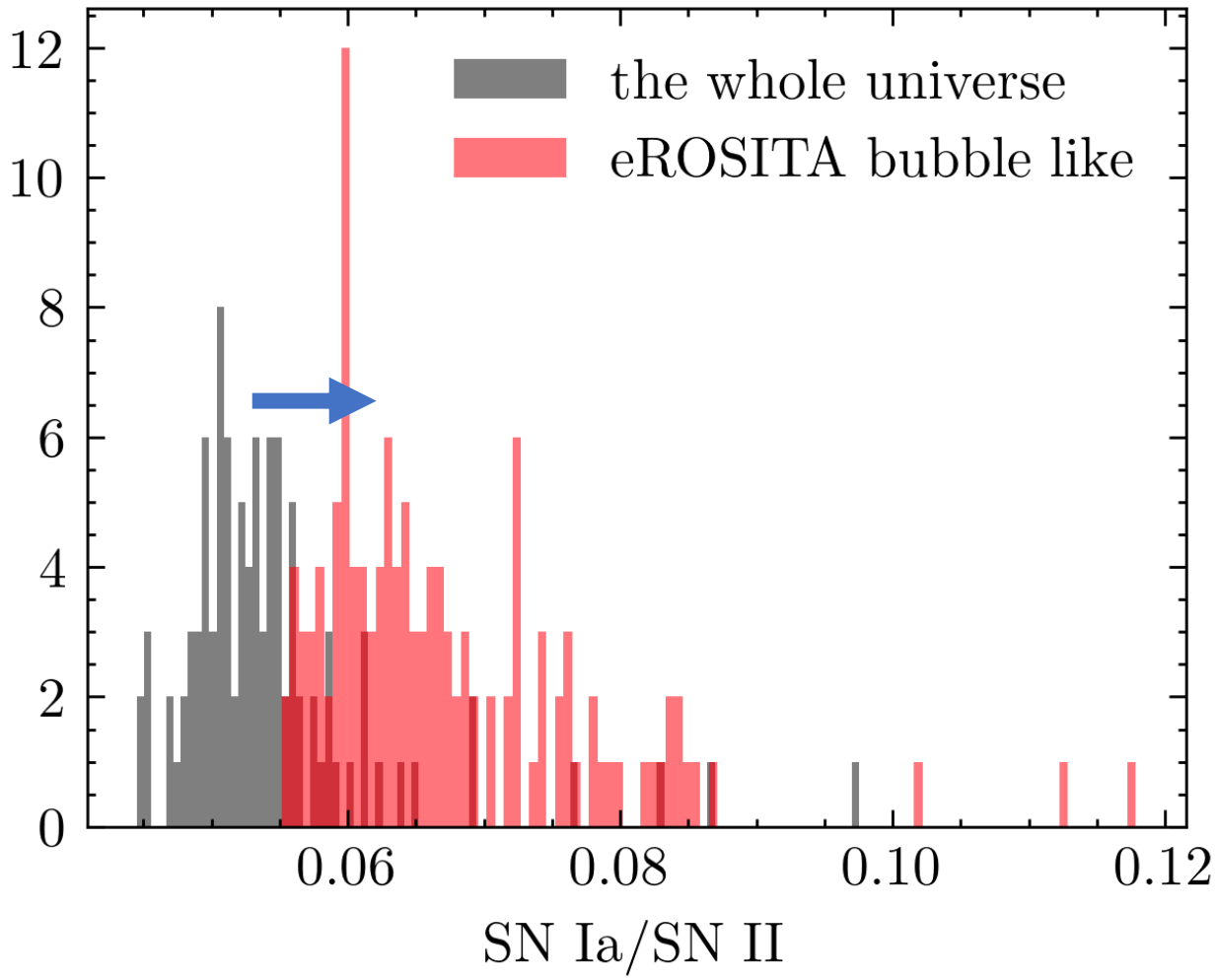
Wako Aoki, John E. Norris, Sean G. Ryan, Timothy C. Beers, Hiroyasu Ando, Subaru/HDS Study of the Extremely Metal-Poor Star CS 29498-043: Abundance Analysis Details and Comparison with Other Carbon-Rich Objects , *Publications of the Astronomical Society of Japan*, Volume 54, Issue 6, 25 December 2002, Pages 933–949, https://doi.org/10.1093/pasj/54.6.933




eROSITA bubble like galaxの拡大図

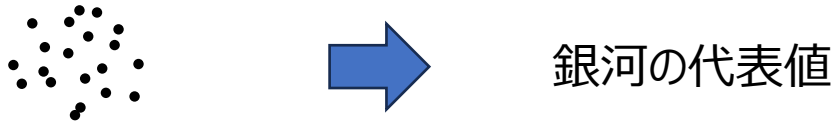



eROSITA bubble/Fermi bubble的な銀河はSN Iaの供給が多い




（シミュレーションなので）

- ガス一個一個の粒子ごとに
  SN Ia由来/SN II由来の割合が記録されている



銀河の代表値

銀河のSN Ia/SN IIを計算
（平均を取る）

銀河のSN Ia/SN II の値の分布をプロット

宇宙全体の銀河の分布よりも少し右に分布があることから

eROSITA bubble like galaxyのほうがSN Ia的といえる

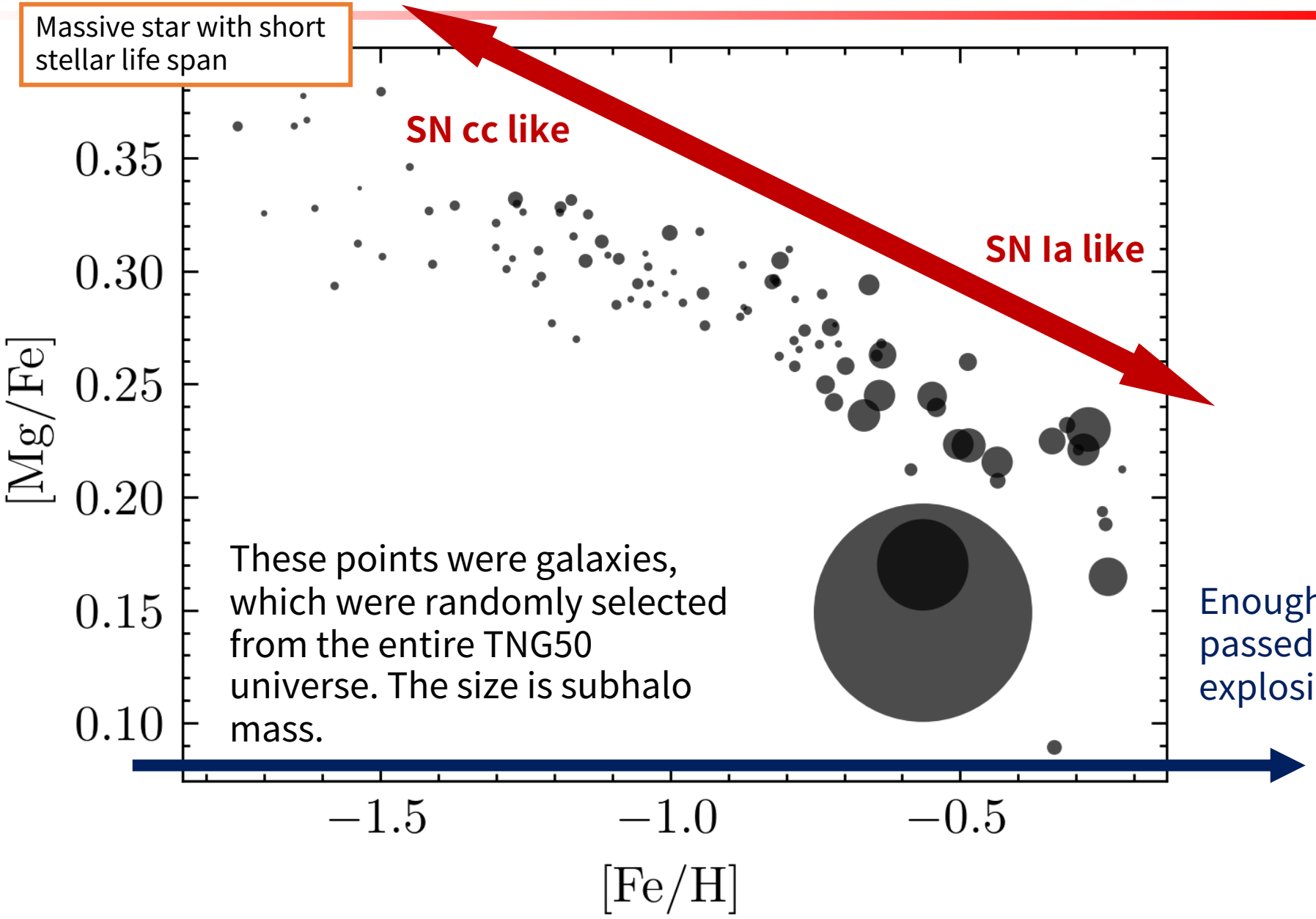
- Full ver
  - 418,000/5,688,111 = 7.34%
- Light ver
  - 20,000
  - Percentage of galaxies made up of only DM: 99.67 %

- 短期間に起こるSNCC のスターバースト期を過ぎて、長期的に起こるIa 型でできたメタル

- 下のような画像を作成中。
- （今まで動いていたコードなのに…）エラーが出て苦戦。

# Plotted [Mg/Fe] vs [Fe/H] + Mass

Massive star with short stellar life span



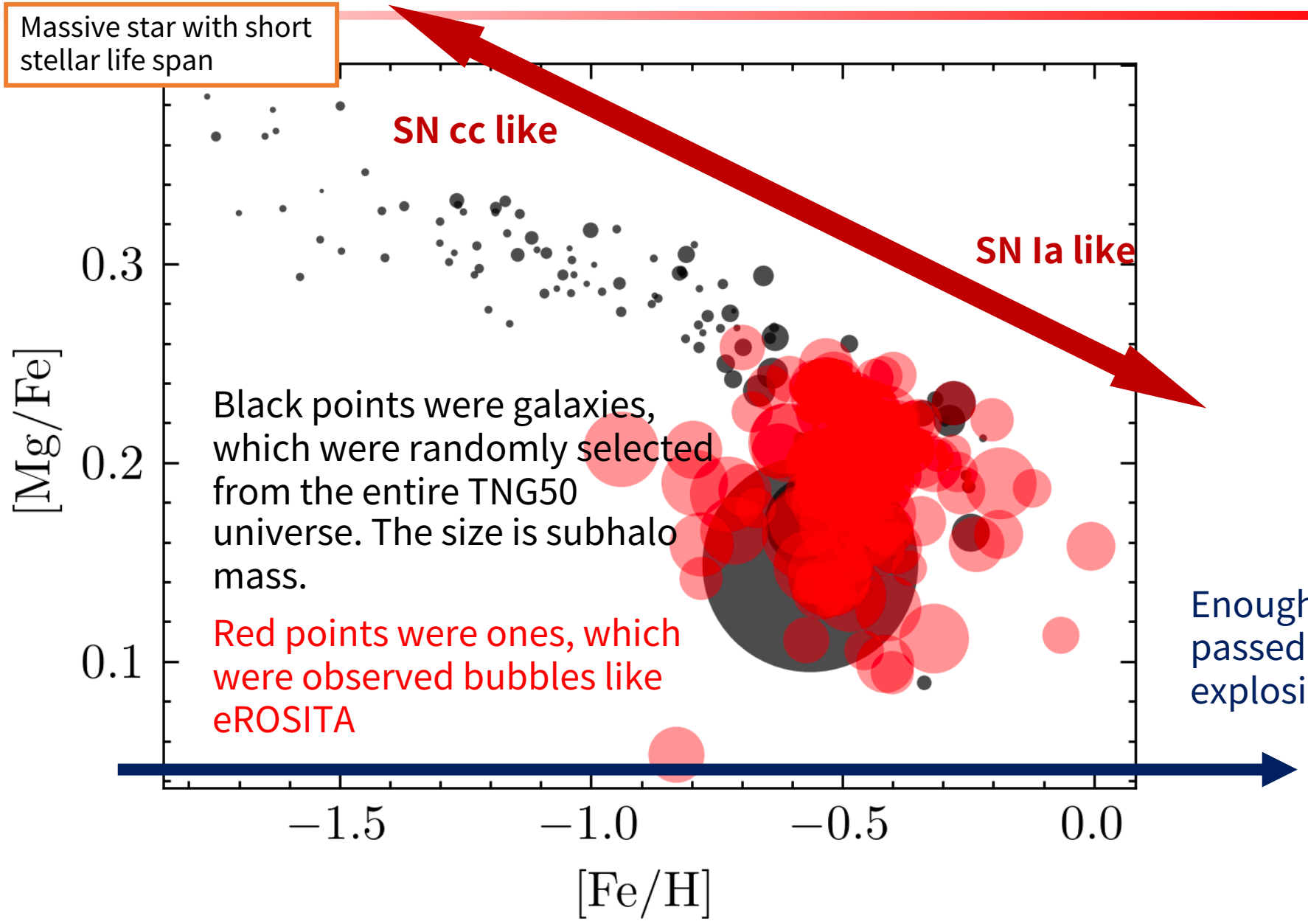

These points were galaxies, which were randomly selected from the entire TNG50 universe. The size is subhalo mass.

Enough time has passed for SNIa explosion to occur

**As expected !!**

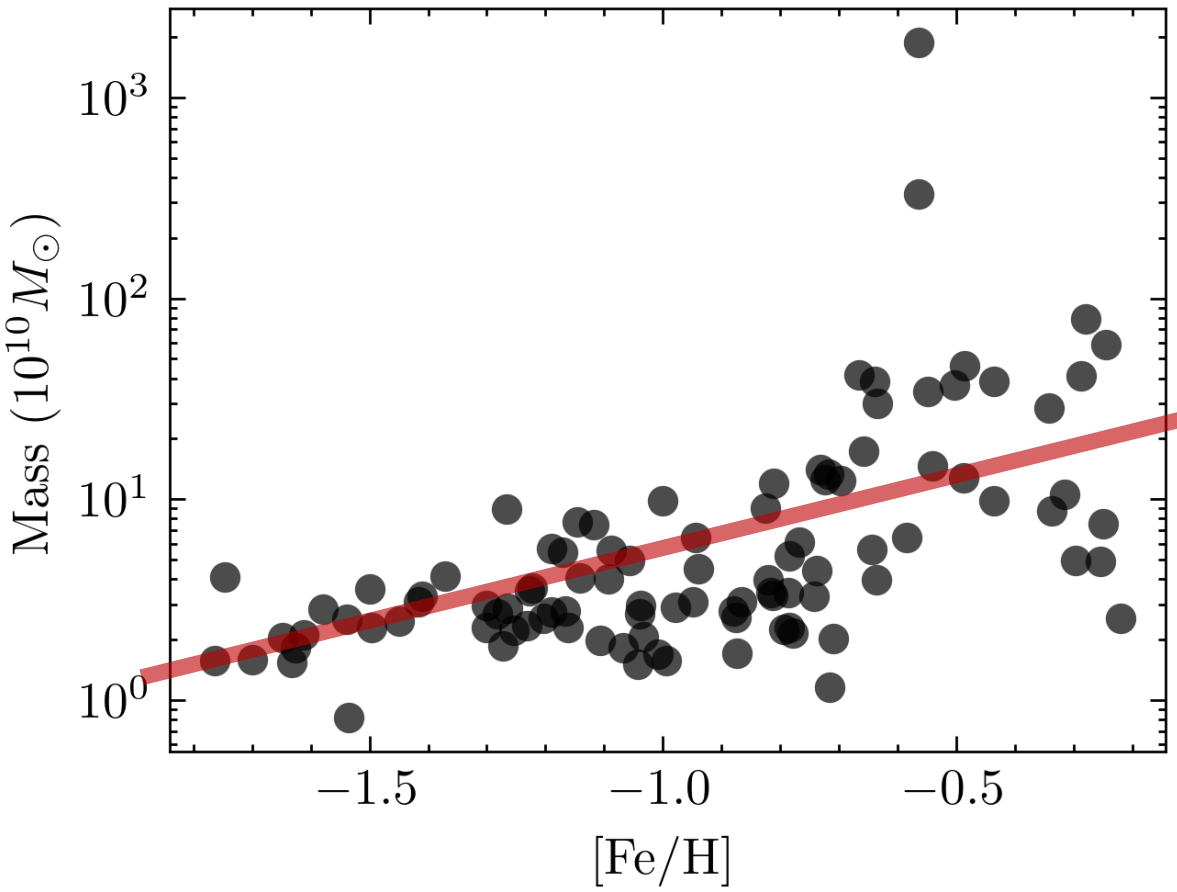
# Plotted [Mg/Fe] vs [Fe/H] + Mass + eROSITA bubble-like galaxies

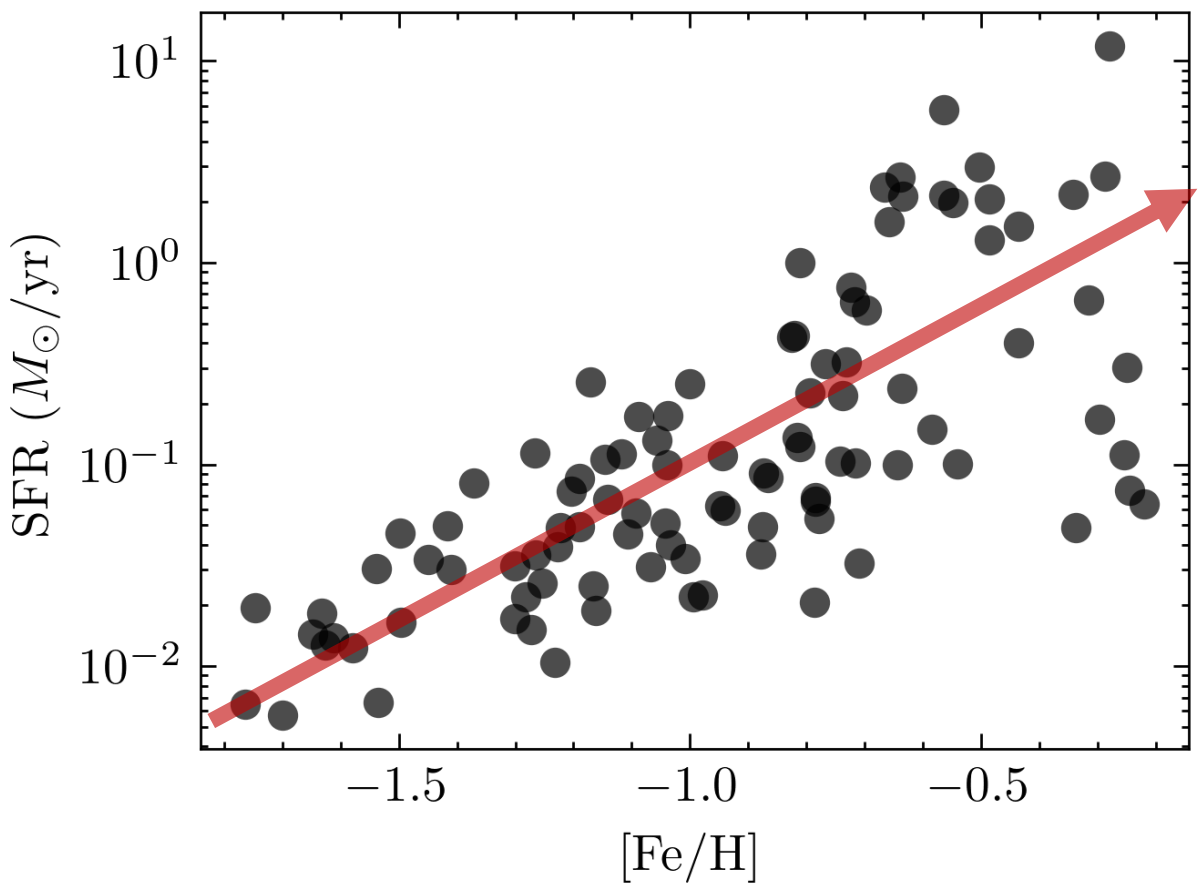
Massive star with short stellar life span



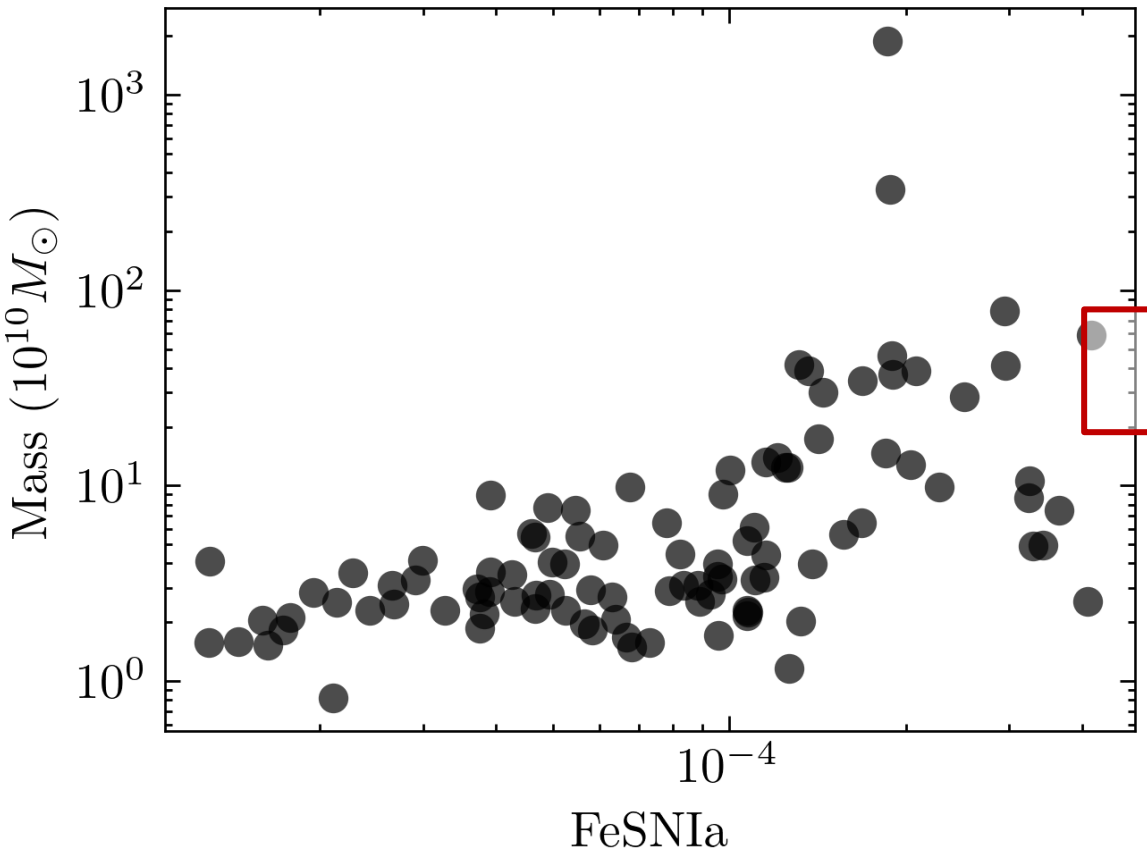

**As expected !!**

# Plotted Mass vs [Fe/H]  and SFR vs [Fe/H]

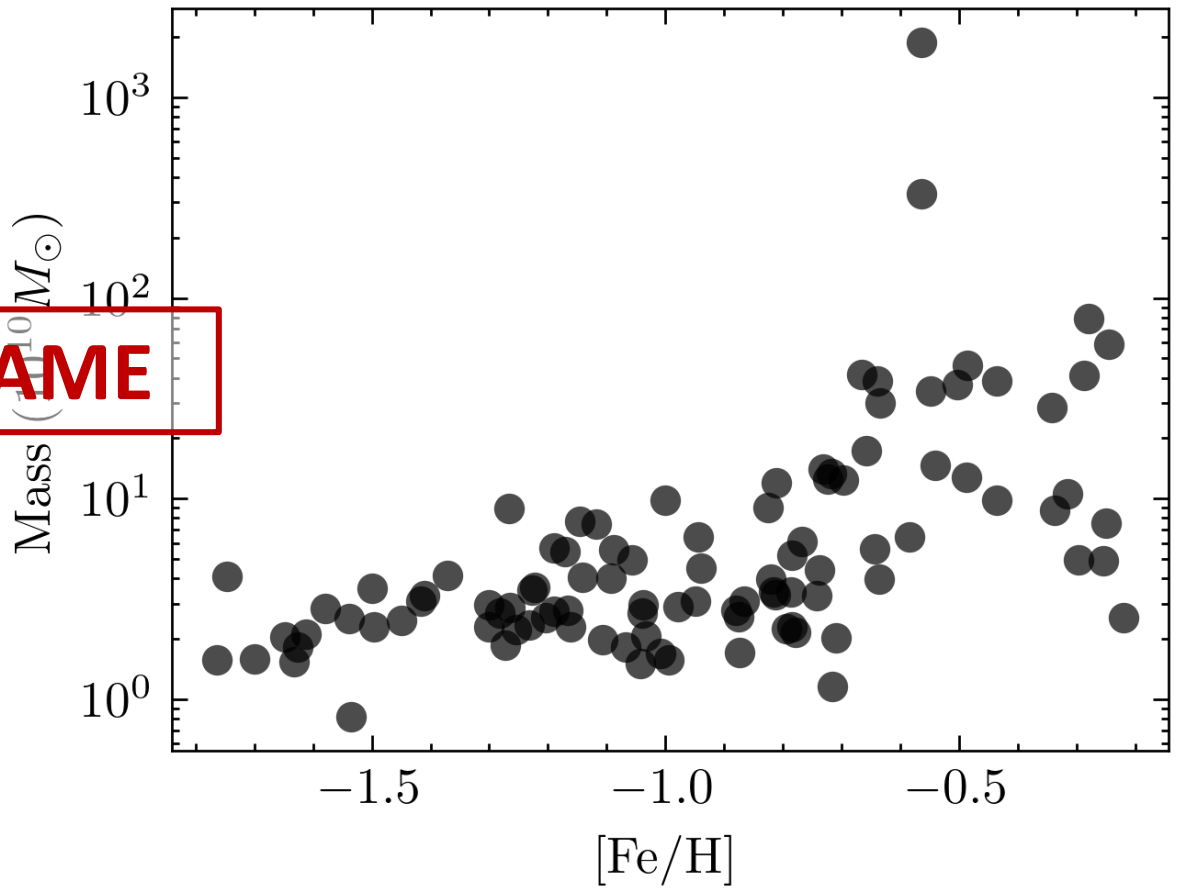


# Plotted Mass vs FeSNIa (tagged in TNG50)

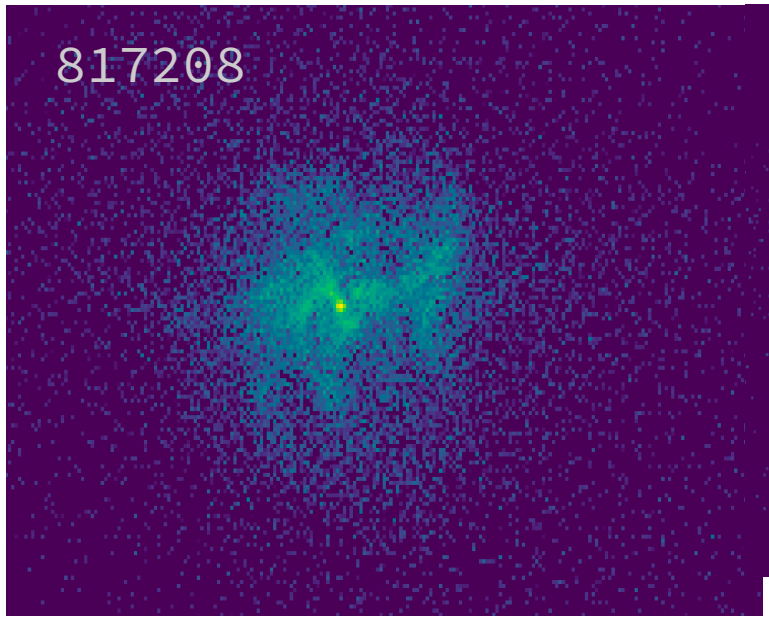


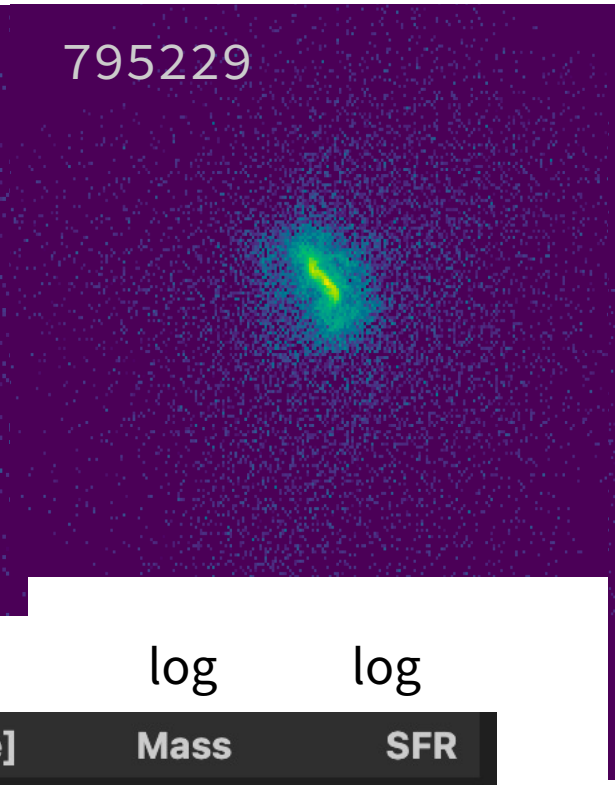

SAME

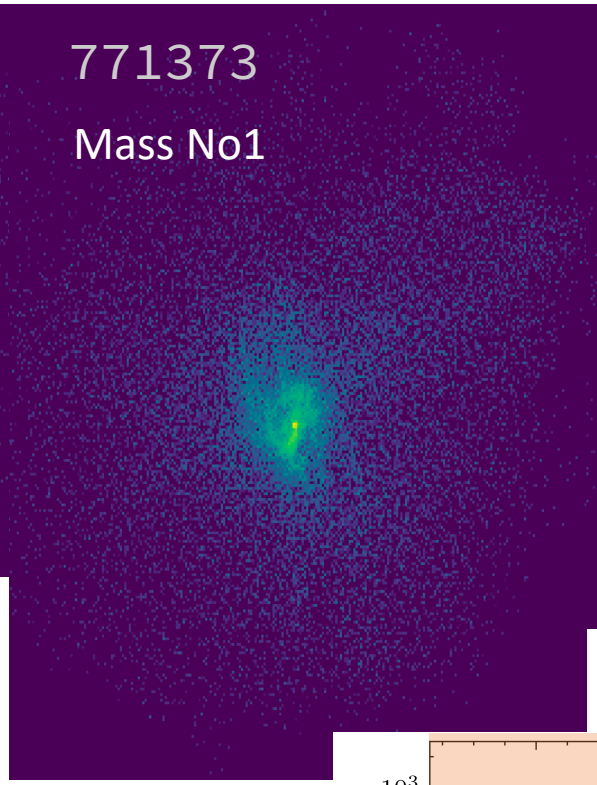


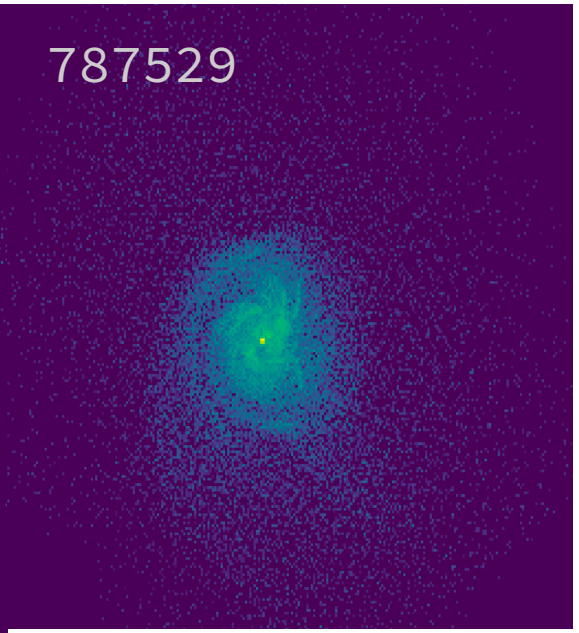

* The total iron ejected by Type Ia supernovae alone
* the Fe entry of GFM_Metals roughly equals the sum of FeSNIa+FeSNII, modulo the small amount of iron consumed (i.e. negative contribution) by AGB winds.

# Some galaxies with [Fe/H] < - 1.0



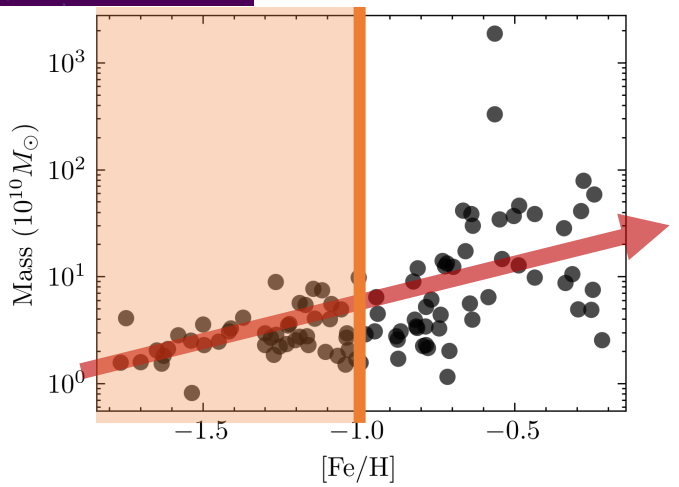



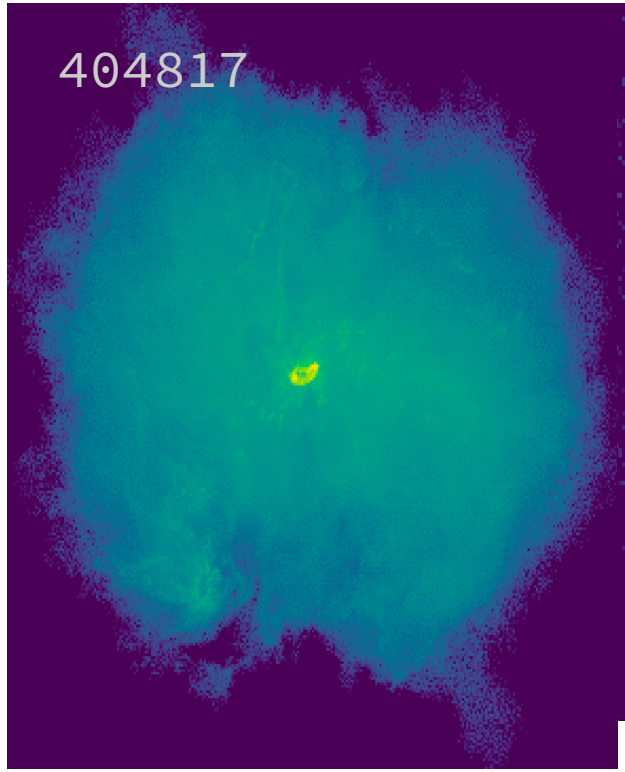



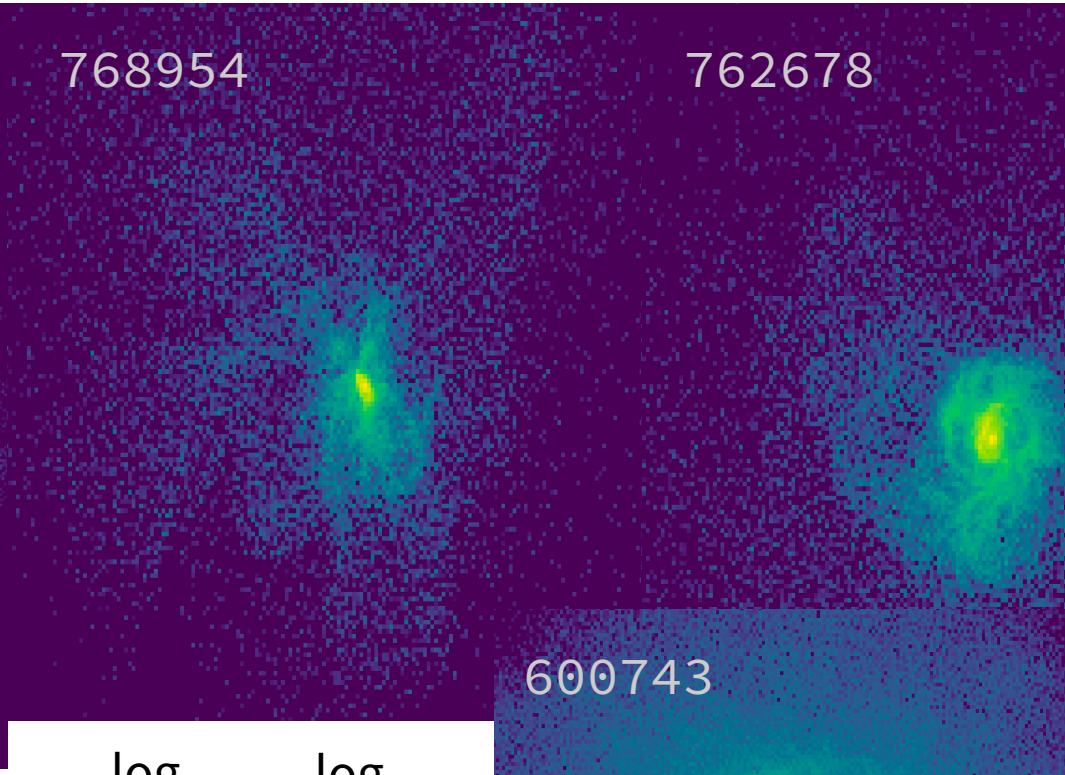

| | SubhaloID | [Fe/H] | [Mg/Fe] | log Mass | log SFR |
|---|---|---|---|---|---|
| 3 | 795229 | -1.282314 | 0.300878 | 0.429701 | -1.656480 |
| 6 | 771373 | -1.264508 | 0.329644 | 0.459207 | -1.446920 |
| 85 | 787529 | -1.039745 | 0.285222 | 0.430999 | -1.001398 |
| 92 | 817208 | -1.008696 | 0.289948 | 0.226286 | -1.468858 |

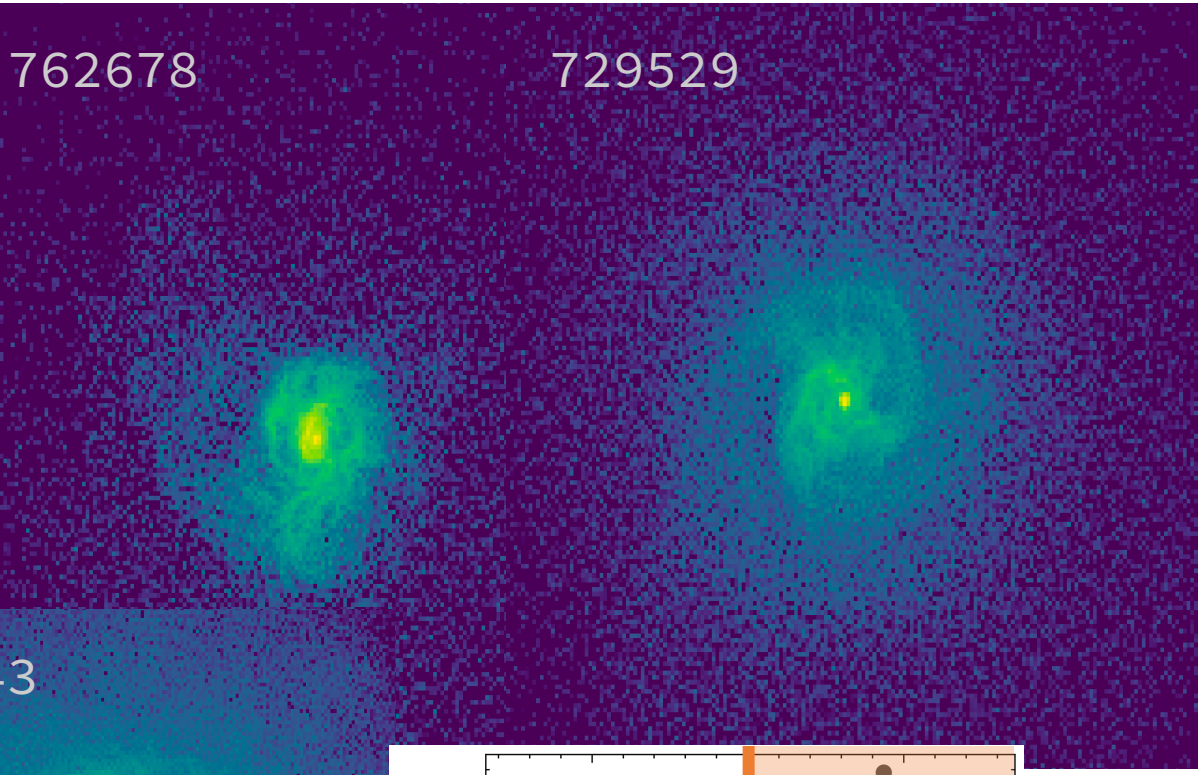
Extracted randomly



# Some galaxies with [Fe/H] > - 1.0

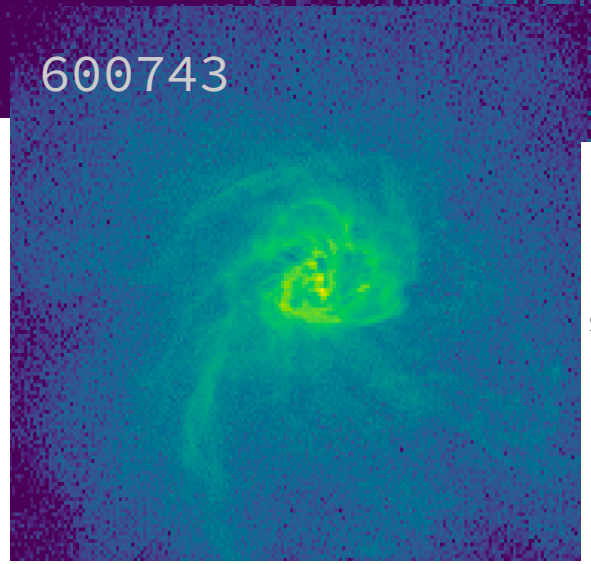


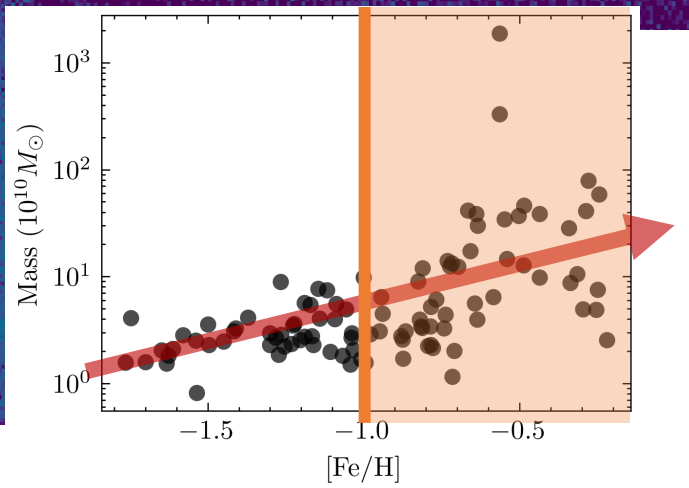







| | SubhaloID | [Fe/H] | [Mg/Fe] | log Mass | log SFR |
|---|---|---|---|---|---|
| 18 | 404817 | -0.564489 | 0.170050 | 2.517745 | 0.335421 |
| 37 | 768954 | -0.811988 | 0.262300 | 0.520503 | -0.911701 |
| 39 | 762678 | -0.635943 | 0.267951 | 0.600650 | -0.622877 |
| 66 | 729529 | -0.768146 | 0.273723 | 0.787911 | -0.499261 |
| 95 | 600743 | -0.633861 | 0.262945 | 1.478117 | 0.328172 |

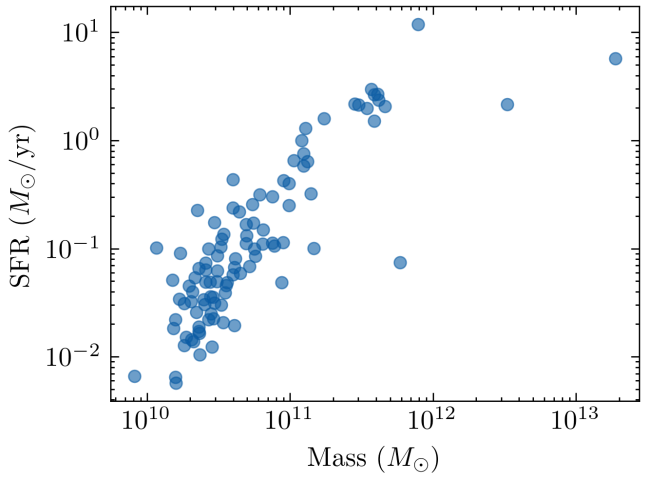
Extracted randomly



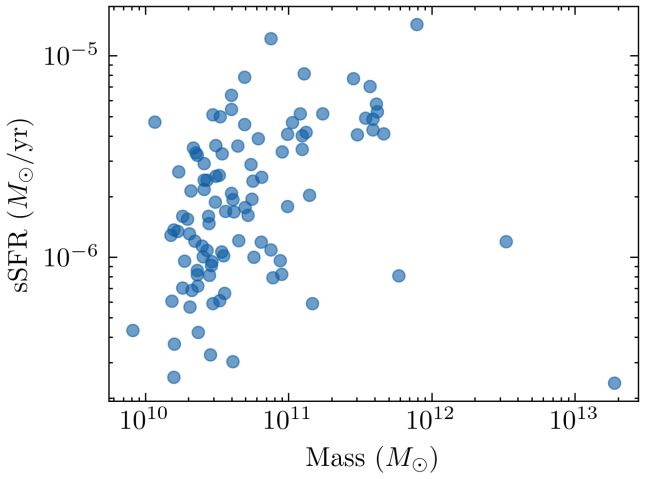
# Various parameters vs Mass

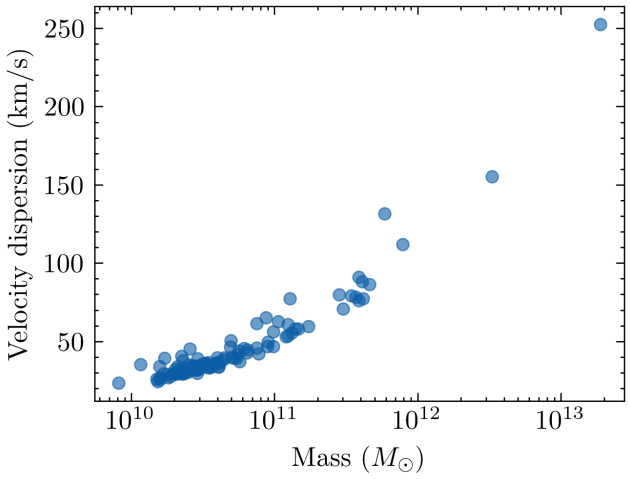
- SFR
- sSFR
- Velocity dispersion

Corrcoef = 0.834

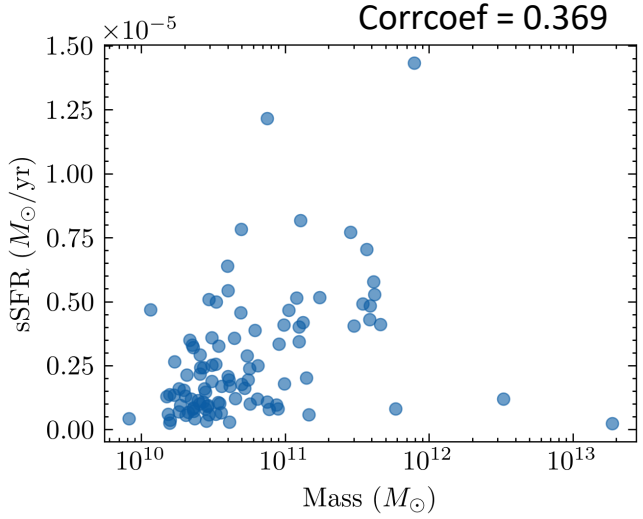



Corrcoef = 0.276

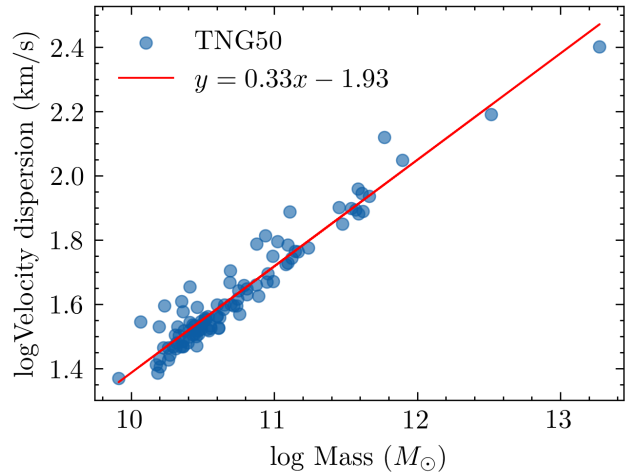



Corrcoef = 0.369




Corrcoef = 0.963




* sSFR denotes SFR per unit galaxy stellar mass, calculated here **per gas cell**.

# Does SFR increase as Mass increases?

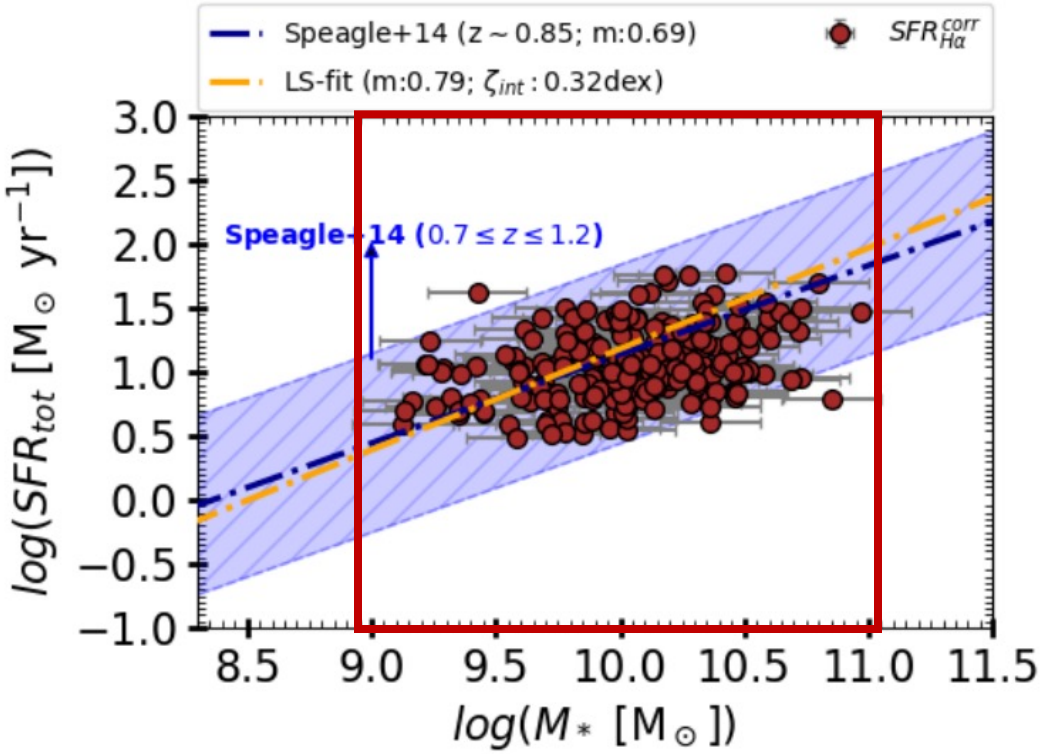



**Fig. B.1.** Star formation rate (SFR) vs. total stellar mass ($M_*$), tracing the MS of galaxies, where $SFR_{tot}$ = $SFR_{H\alpha}$ corrected for dust reddening. The brown filled circles represent the data used in this work. The dashed-dotted orange line shows the least-squares fit to our data, and the blue line shows the Speagle et al. (2014) MS relation at $z \sim 0.85$. The shaded blue region represents the MS limit between redshift $0.7 \leq z \leq 1.2$, which includes 0.3 dex uncertainty at each redshift.

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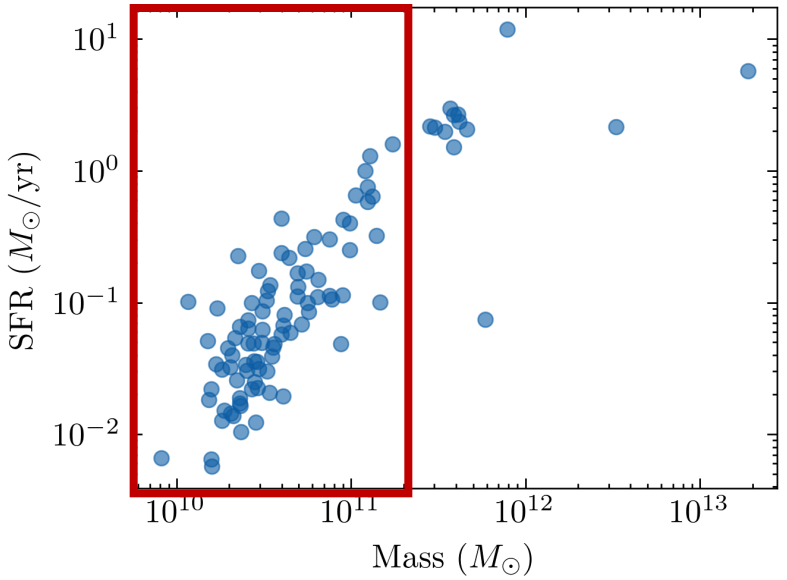
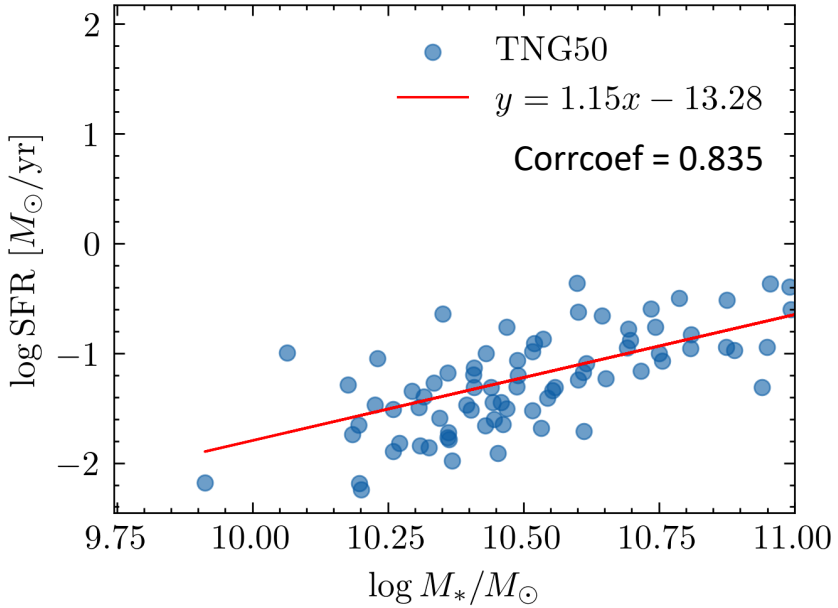
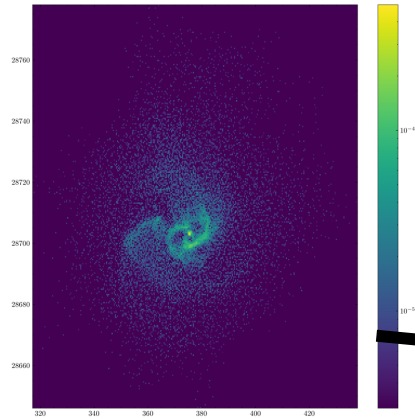
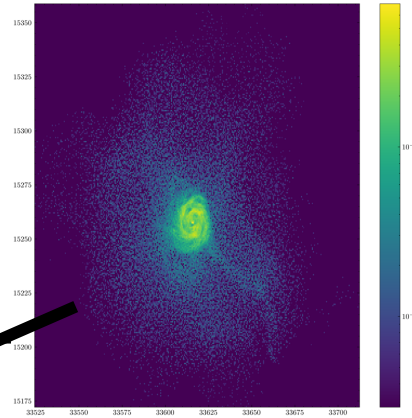
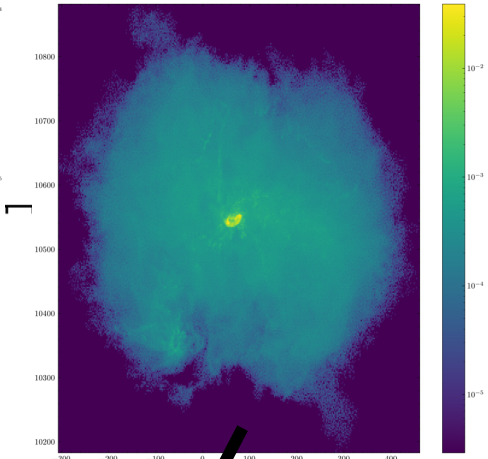


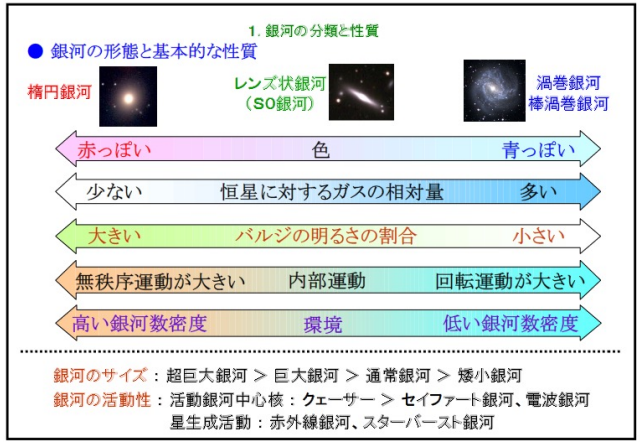



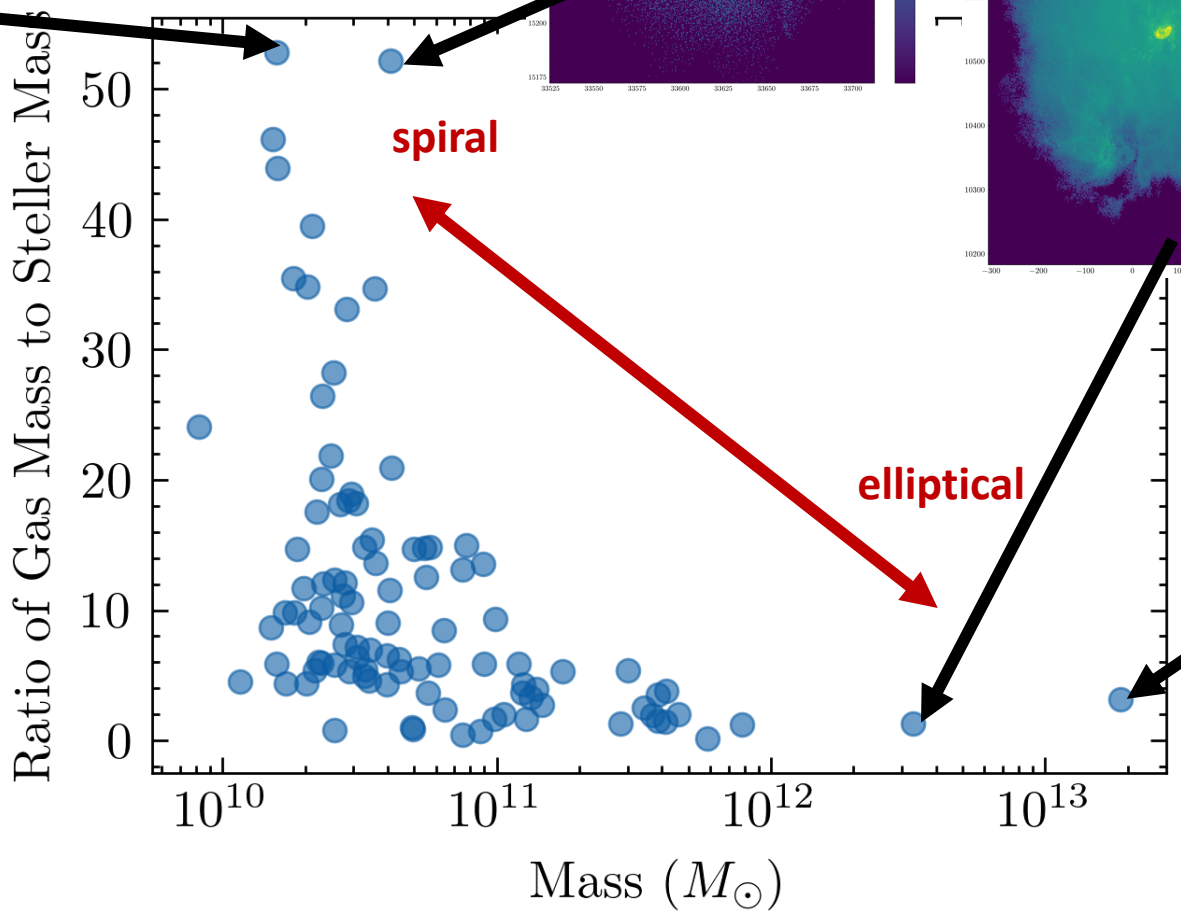
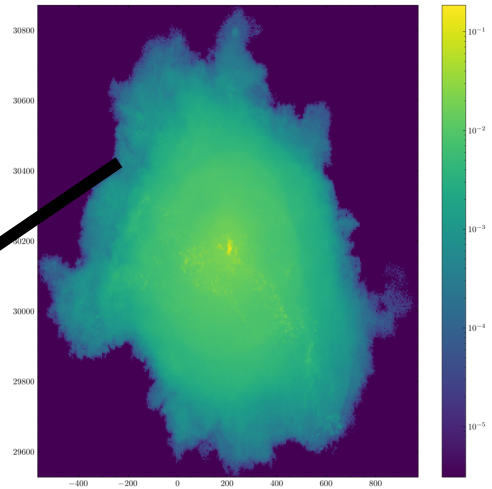
# Distinguish between elliptical and spiral










Supported by Nishiura-san's (東京学芸大) lecture slide; http://astro.u-gakugei.ac.jp/~nishiura/MEMO/2016-aegairon-nishiura-01x2.pdf

$$\frac{\sum \text{gas mass}}{\sum \text{Steller mass}}$$