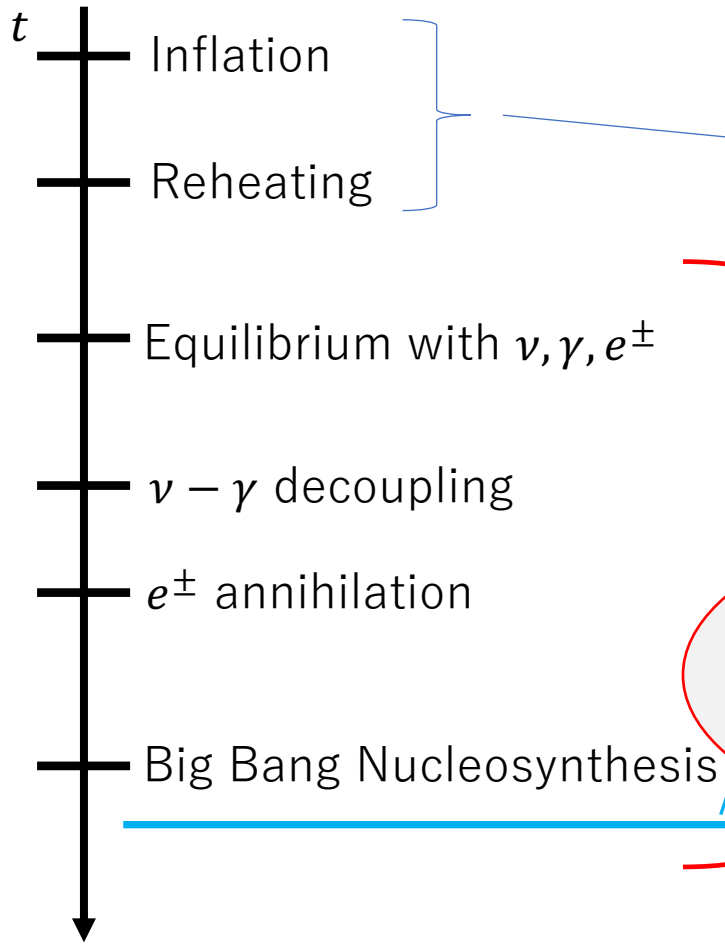
Determination of Primordial He Abundance and Neutrino Effective Number

Akinori Matsumoto　(University of Tokyo M1)

Scenario to Big Bang Nucleosynthesis (BBN)

Cosmic History



He mass fraction $\boldsymbol{Y_P}$ depends on

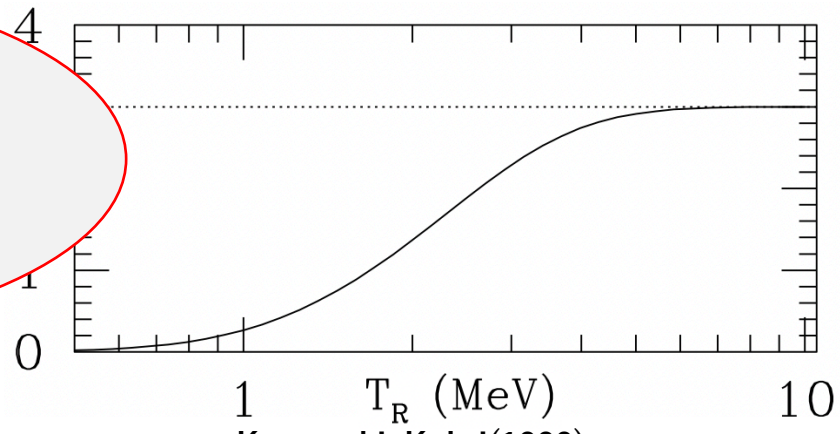
neutrino effective number

$$N_{\mathrm{eff}} \equiv \frac{8}{7}\left(\frac{11}{4}\right)^{\frac{4}{3}}\frac{\rho_\nu}{\rho_\gamma} = 3.046$$

Standard Model

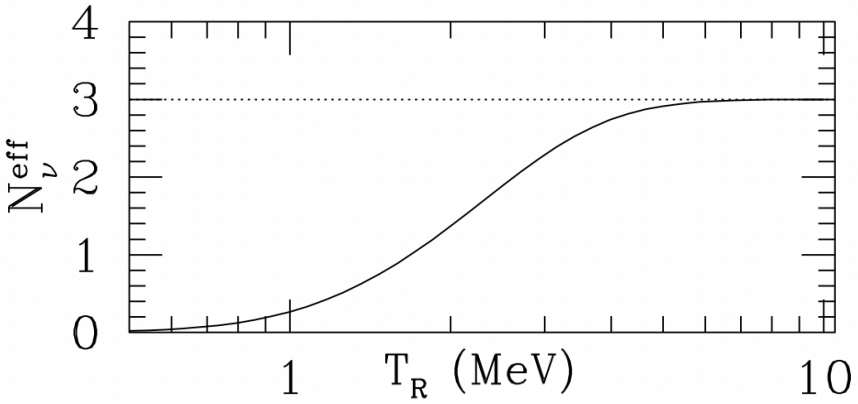
Goal of this study

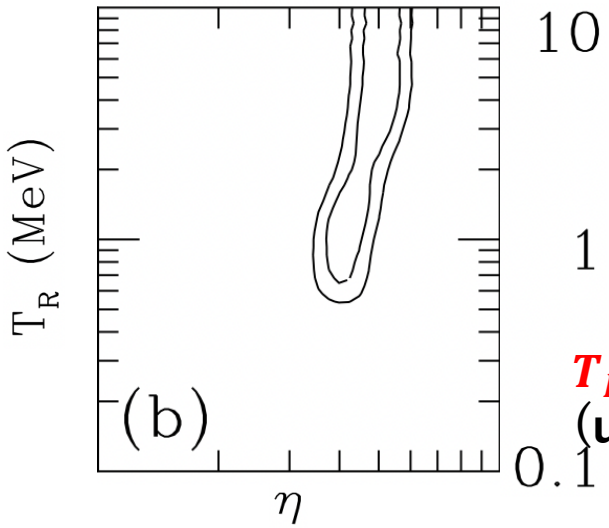
-To set constrain on Y_P, N_{eff} from **observation**



Kawasaki, Kohri(1999)

Importance of determination of Y_P





Kawasaki, Kohri(1999)

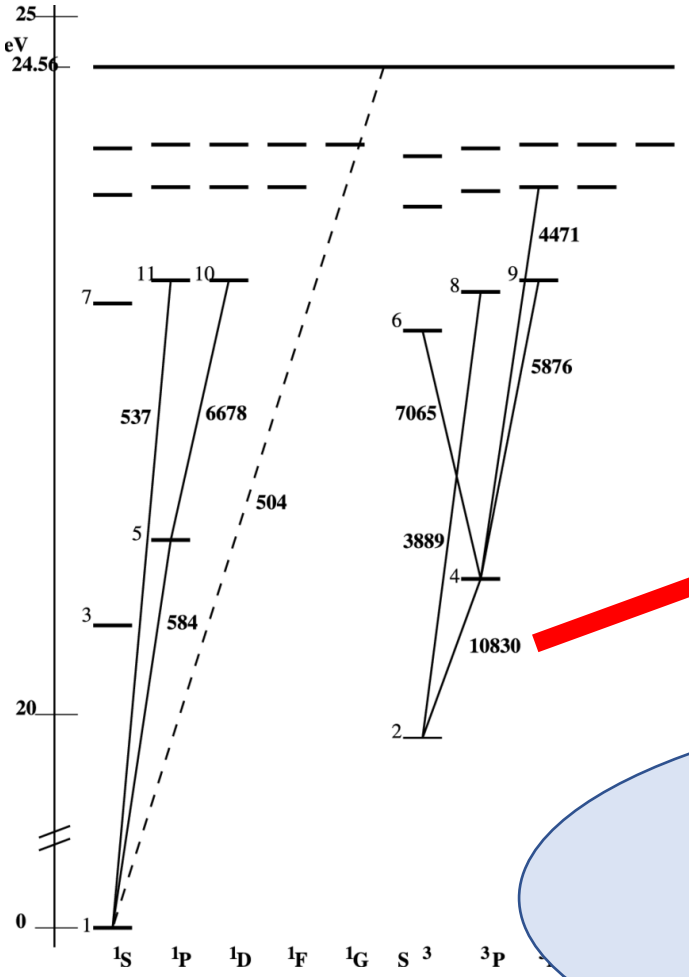
Uncertainty of the Y_P determination comes from

1. Systematic errors when deriving He/H of galaxies
2. Statistical errors due to sample size

(Hsyu et al. (2020) derived $Y_P = 0.2436^{+0.0040}_{-0.0039}$, $N_{\rm eff} = 2.85^{+0.28}_{-0.25}$)

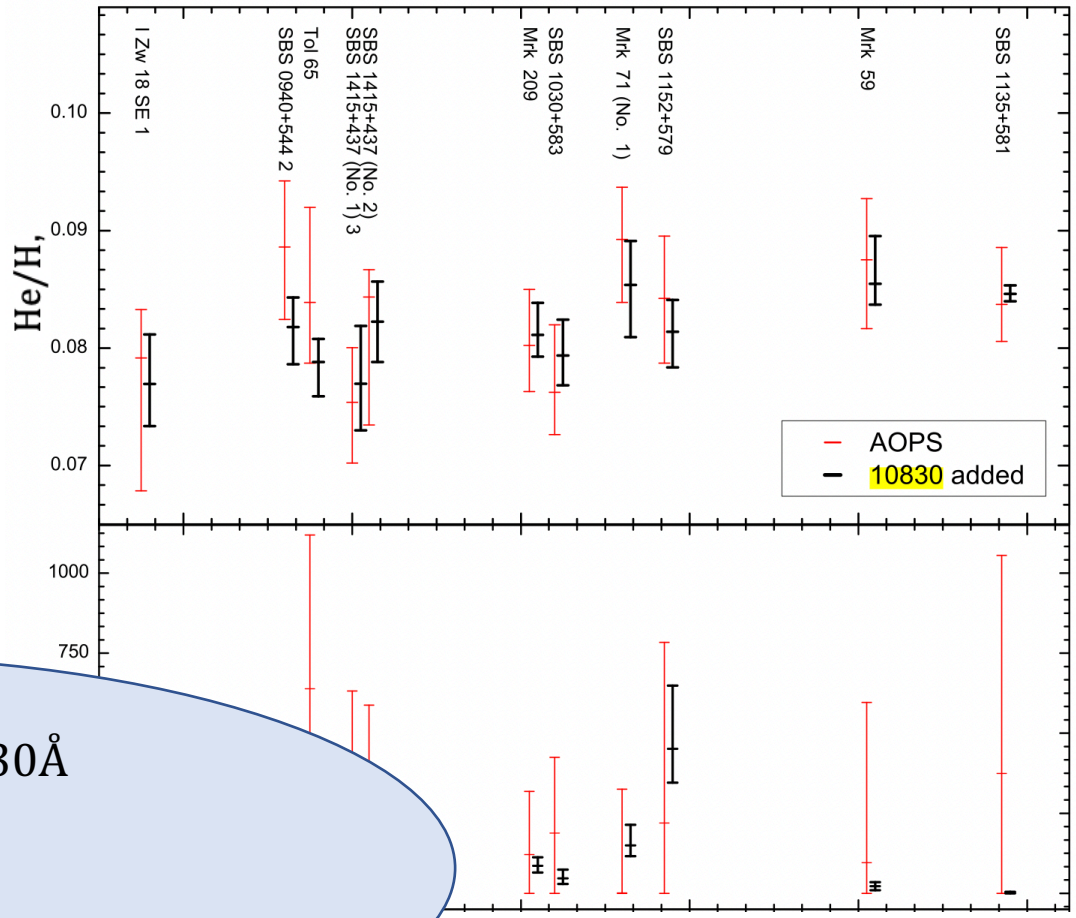
$T_R \gtrsim 1$ MeV…
(using Izotov et al (1999))

1. Importance of HeIλ10830Å



Helium energy levels

Labrosse,Gouttebroze+04



Addition of HeIλ10830Å

Well-constrained He/H, T_e , n_e

Aver+15

2. New Observations – EMPRESS 3D –

Previous Work's galaxies (Hsyu + 20)

Mostly galaxies with $0.1 - 0.4Z_{\odot}$ (48 galaxies)
&
only **6 EMPGs** (defined as $Z < 0.1Z_{\odot}$)

We have started a survey (EMPRESS 3D) !

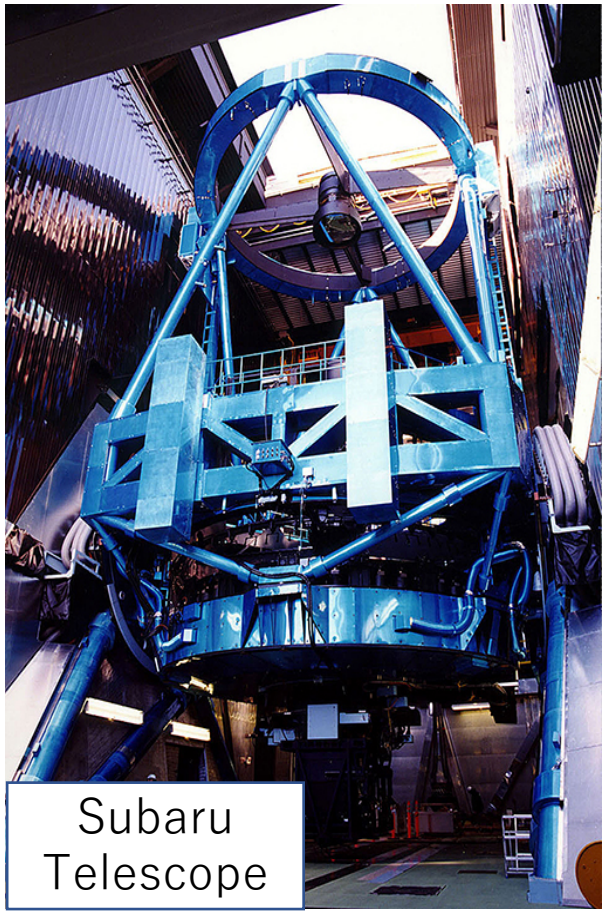
-With Subaru Telescope

-2021-2023

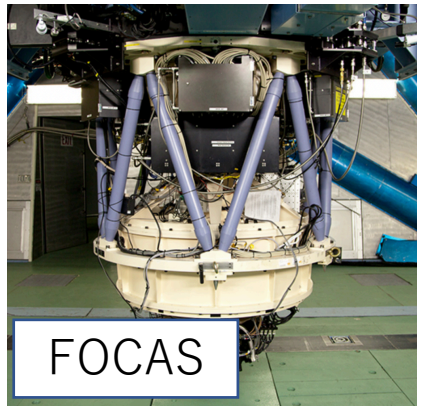
-10 nights with optical (FOCAS, MagE)
& near-infrared(NIR) spec (IRCS+SWIMS)

-30 EMPGs will be added to the sample

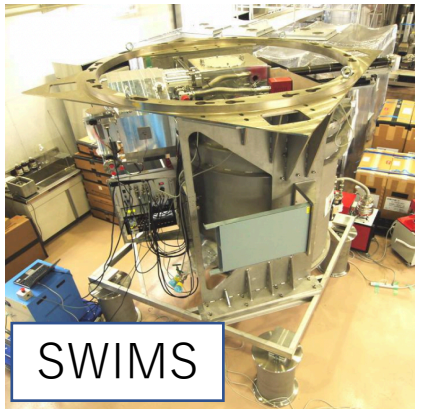
-We already observed 6 EMPGs



(https://subarutelescope.org/jp/about/)



(https://subarutelescope.org/jp/about/instrument/)



(http://www.ioa.s.u-tokyo.ac.jp/TAO/swims/)

Data and Measurements

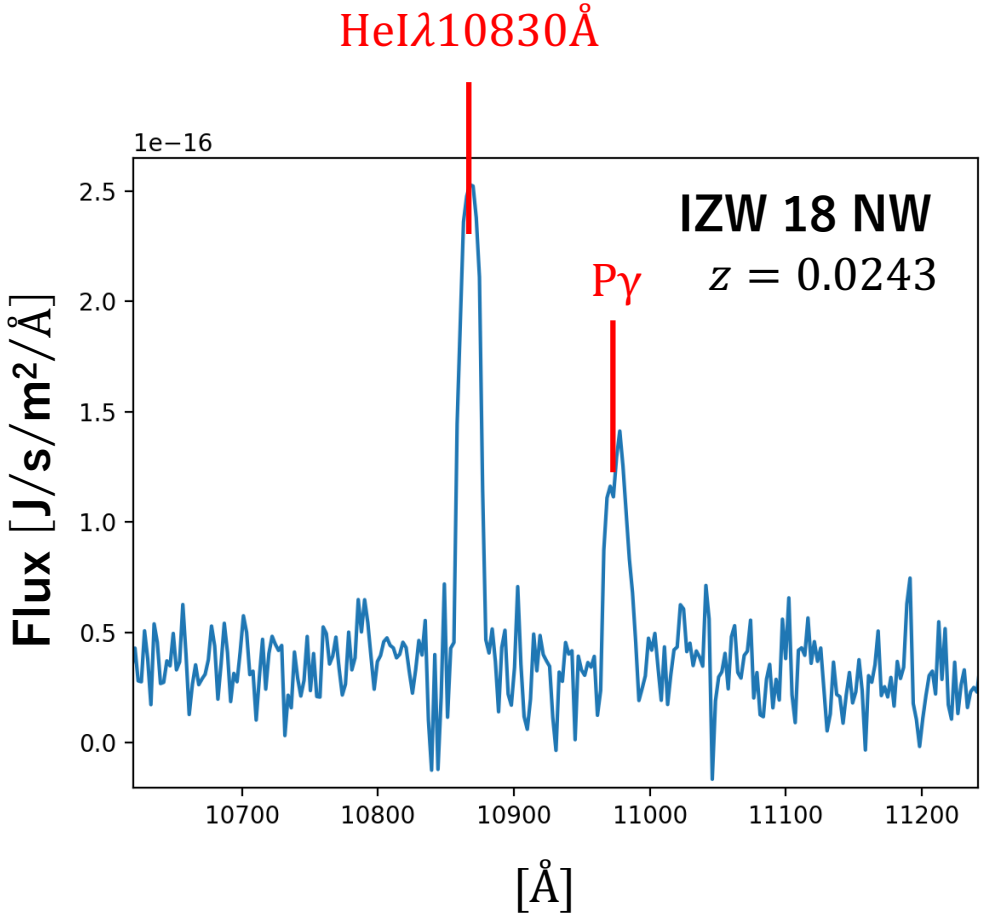
We aim to add galaxies with **HeI10830** in **low-metal** region

	$(O/H)\times10^5$	$F(HeI10830)/F(P\gamma)$
J1253-0312	12.303 ± 0.851	7.15 ± 0.01
J1418+2102	4.365 ± 0.249	5.33 ± 0.21
J1016+3754	4.365 ± 0.101	1.43 ± 0.59

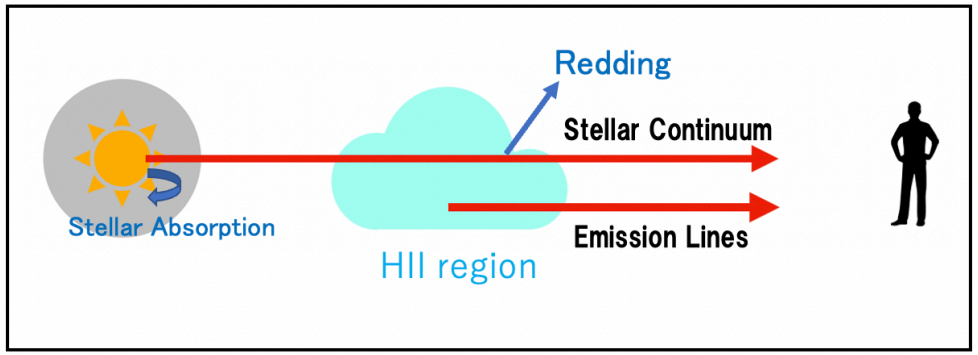
SUBARU IRCS Observation

	$(O/H)\times10^5$	$F(HeI10830)/F(P\gamma)$
IZW 18 NW	1.34 ± 0.15	2.19 ± 0.27
J1201+0211	3.126 ± 0.230	7.23 ± 0.65
J1119+5130	3.199 ± 0.399	2.44 ± 0.53

SUBARU SWIMS Observation



He/H determination



H8, Hδ, Hγ, Hβ, Hα, Pγ, HeI3889, HeI4026,

HeI4472, HeI5016, HeI5876, HeI6678, HeI7065, **HeI10830**

Input

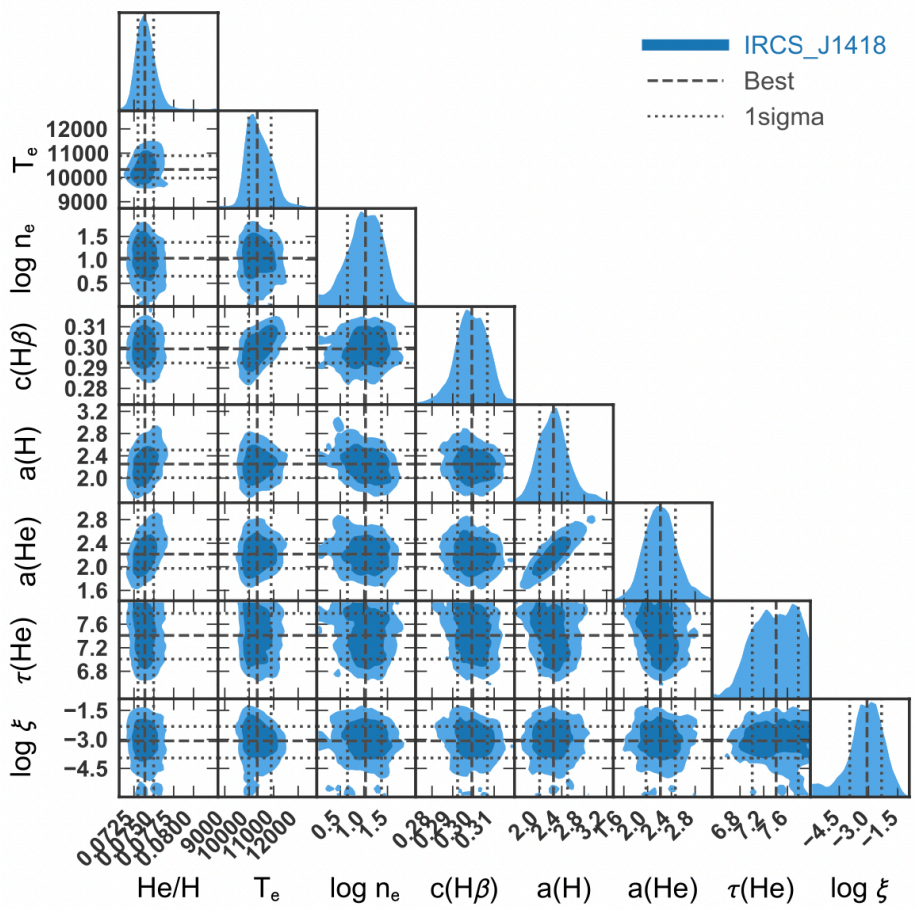
Output

by MCMC

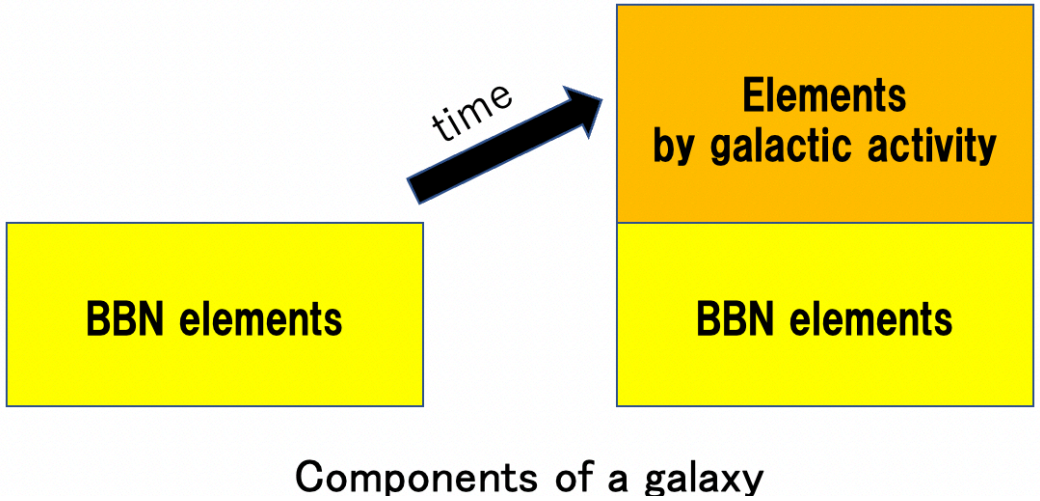
He/H, T_e [K], n_e [cm^{-3}], $c(H\beta)$ a_H [Å] , a_{He} [Å] , τ_{He} , ξ

J1418+4322: $\mathrm{He/H} = 0.0749^{+0.00130}_{-0.00135}$

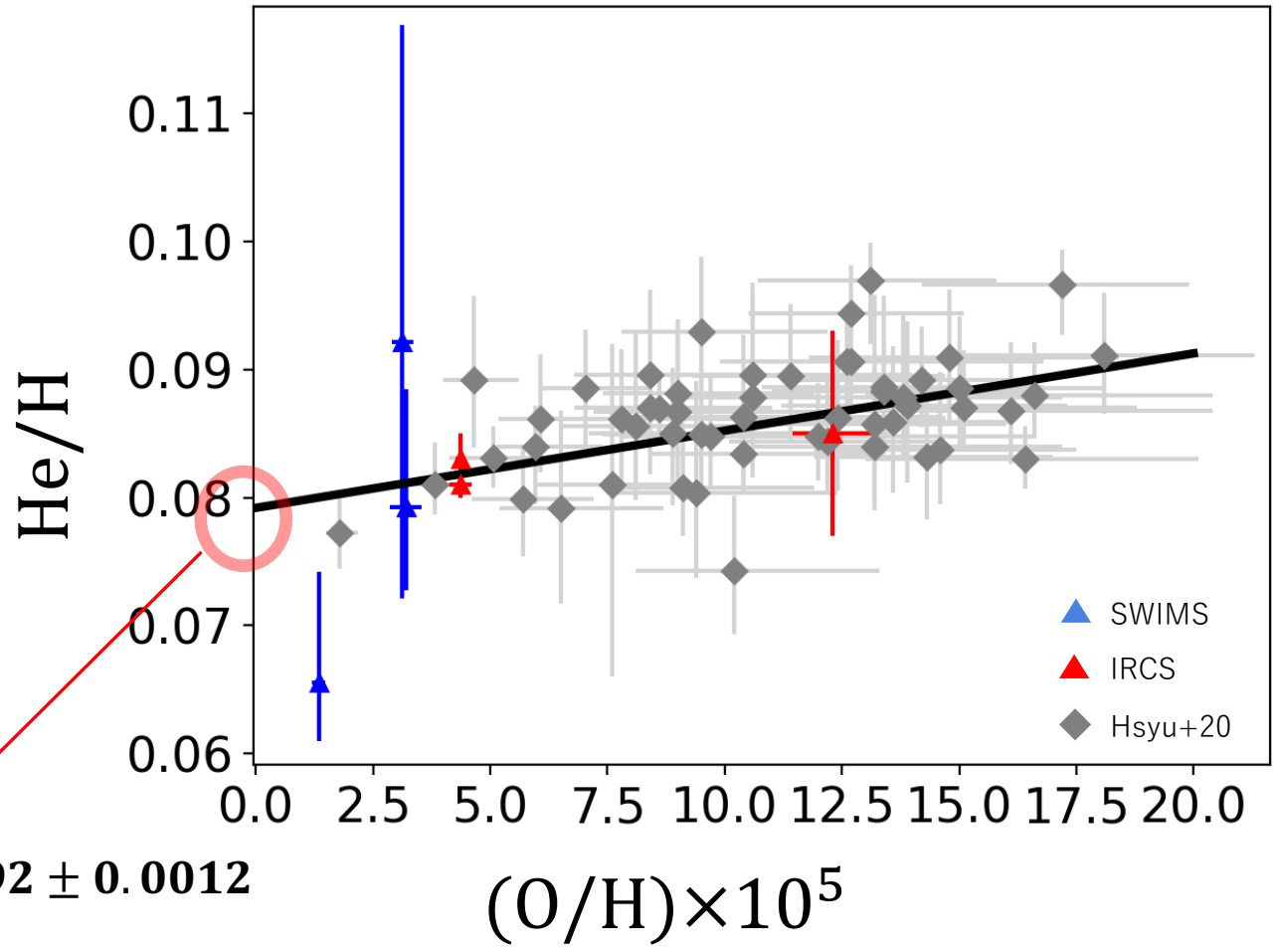
J1418+2102



Yp determination



Components of a galaxy

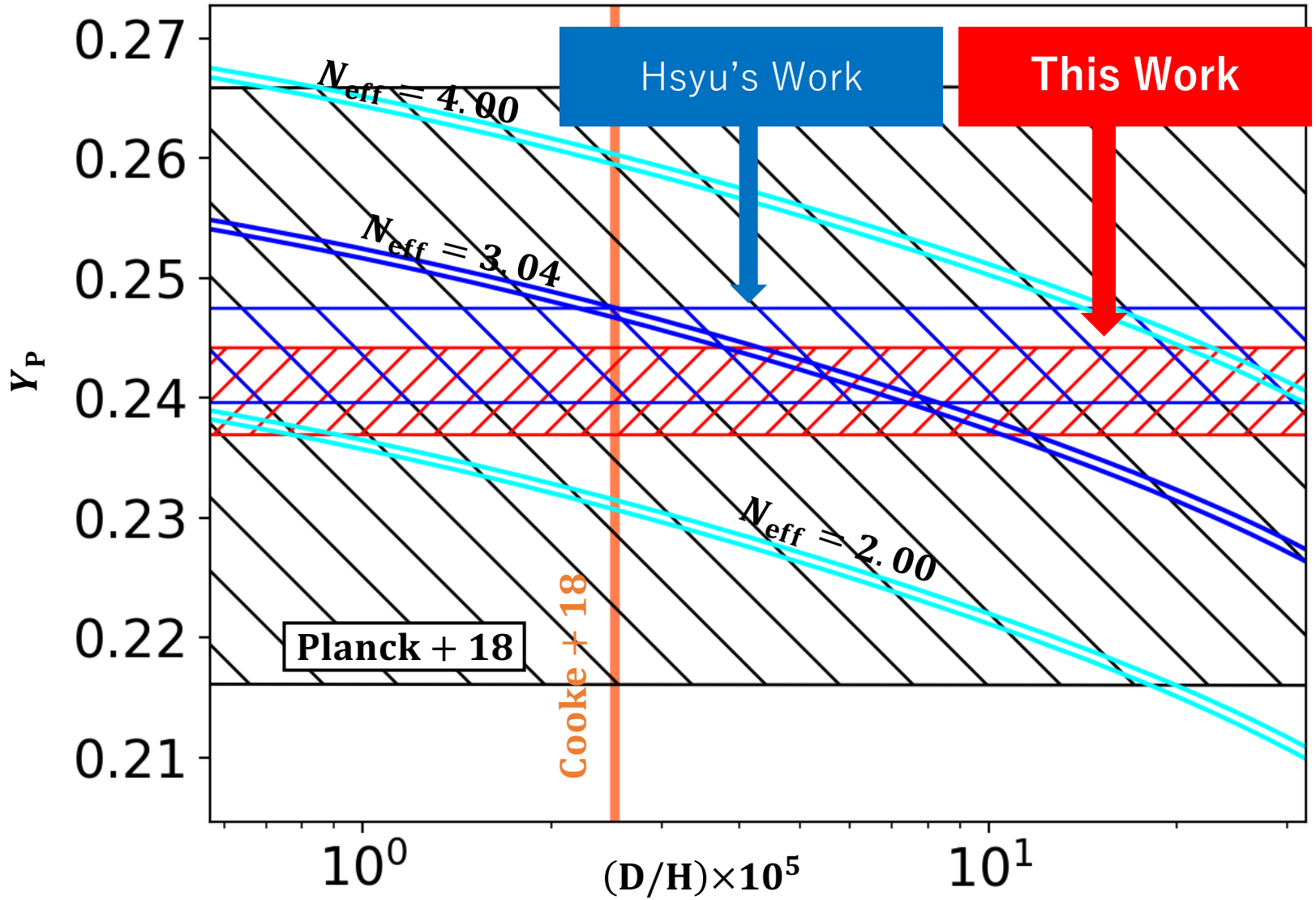


$$y_P = 0.0792 \pm 0.0012$$

$$Y_P = \frac{4y_P}{1+4y_P}$$

$$Y_P = 0.2406 \pm 0.0036$$

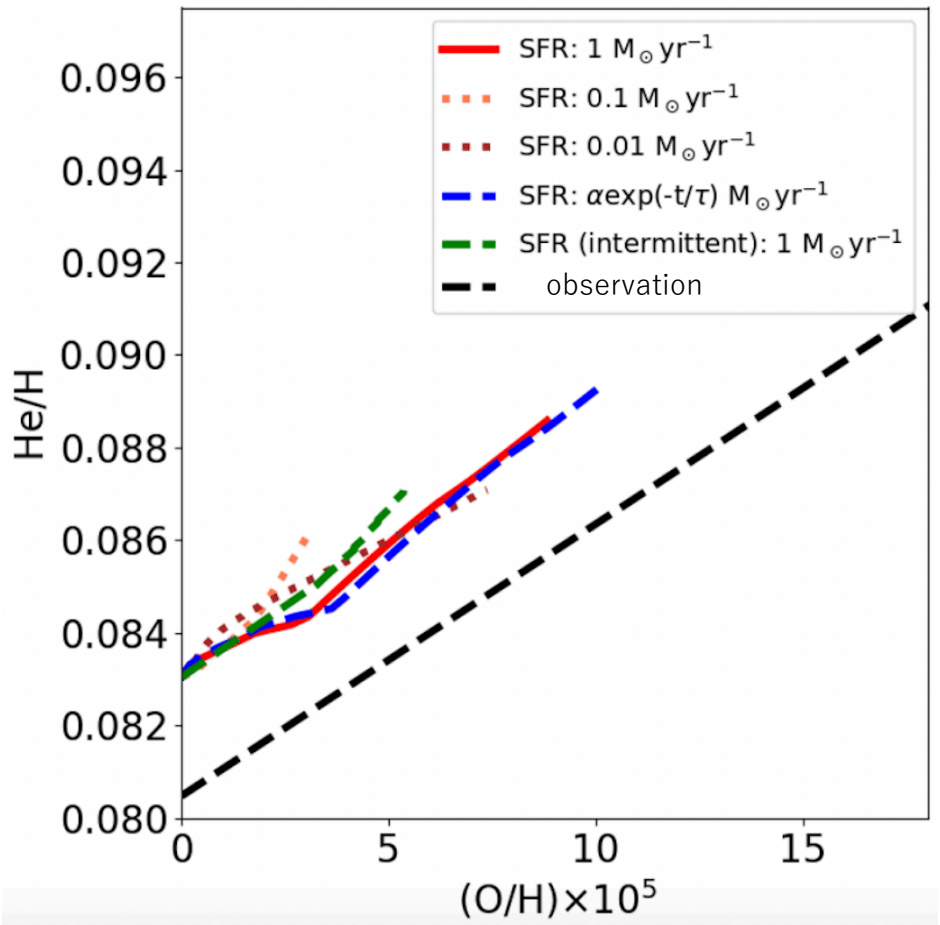
Neff constrains（68% CL）



$\sim 1.5\sigma$ agreement

Future Improvement

- Increasing the number of EMPGs
  - -30 EMPGs will be added by 2023
  - -Subaru Prime Focus Spectrograph will add thousands of galaxies $(\mathrm{O/H}\times 10^5 \lesssim 20)$
- Determine theoretical He/H-O/H relation
  - -we are simulating this using a software for chemical evolution of a galaxy



Fukushima, Nagamine+ '21

Star forming history may affects on He/H – O/H relation

Summary

- We aim to set constrain on Y_{P}, N_{eff}

  - We added 6 galaxies to the sample of previous work.
  - We obtained a result consisting with previous work.
  - We need to increase the sample size and determine theoretical relation between He/H-O/H.