Chemical abundances of Local Extremely Metal-poor Galaxies (EMPGs) with Subaru Machine Learning Survey

Yuki Isobe (University of Tokyo)

M. Ouchi, K. Nakajima, T. Kojima,
& 32 people from HSC Project 251

subarutelescope.org

Introduction

Background

To understand early galaxy formation:

1. Observing high-z galaxies → Difficult
2. Studying **local analogs** of early galaxies
   (e.g., Green Pea galaxies, Blueberry galaxies)

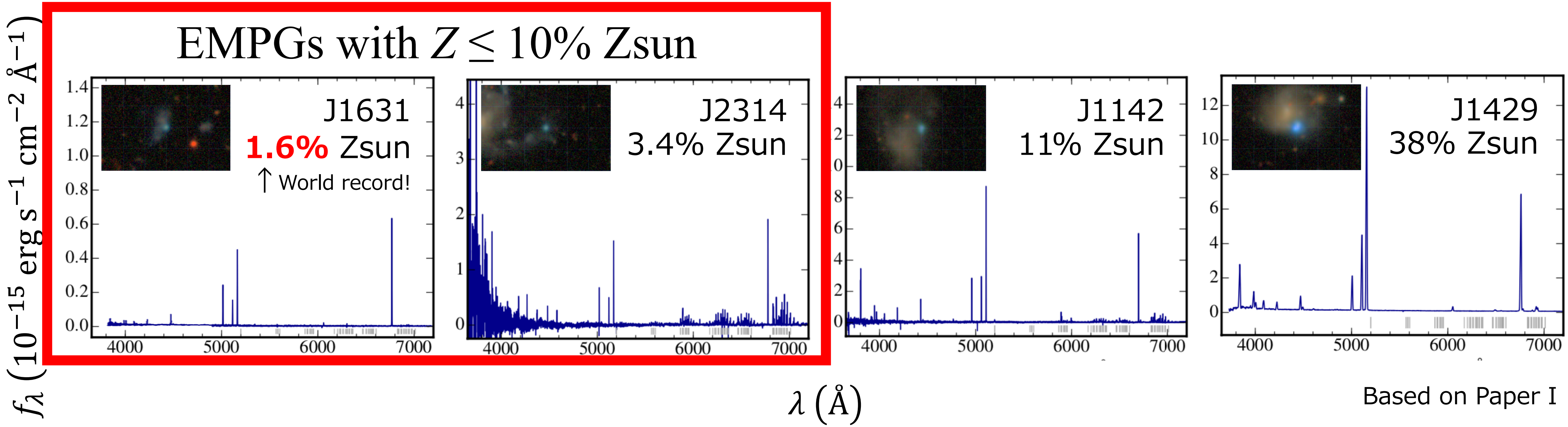
Extremely metal-poor galaxies (**EMPGs**):

$12 + \log(\mathrm{O/H}) \leq 7.69$ (i.e., $Z \leq 10\%$ Zsun)
Properties similar to high-z galaxies (e.g., young, low-M_*)
→ Expected to be local analogs of high-z galaxies

Introduction

Kojima+20a (Paper I)

- Use Subaru/**HSC** + **machine learning** → $z \sim 0.03$ EMPG
- Select 27 EMPG candidates from ~ 40 million sources
- Pilot spec. follow-up for 4 candidates → Find **2** EMPGs!



Based on Paper I

Introduction

Today's topic

- Reporting **additional follow-up** for 13 EMPG candidates

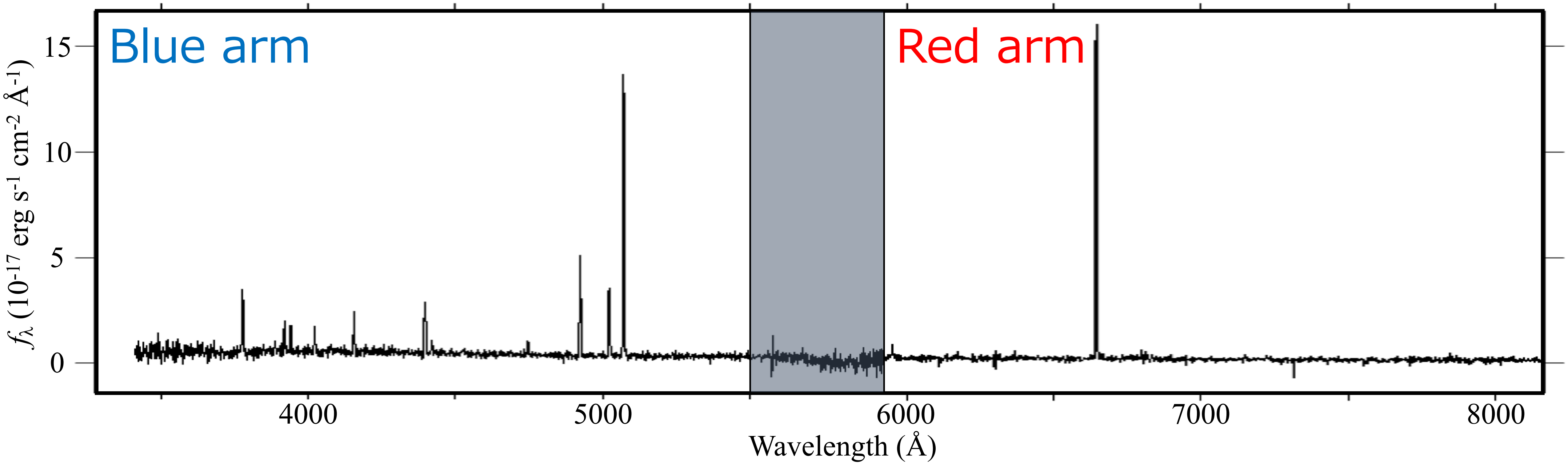
- Deriving metallicity, EW, SFR
  → Discussing the candidates are likely to be **local analogs**

- Showing chemical abundances
  → Discussing **process of metal enrichment**

Observation

Keck/LRIS

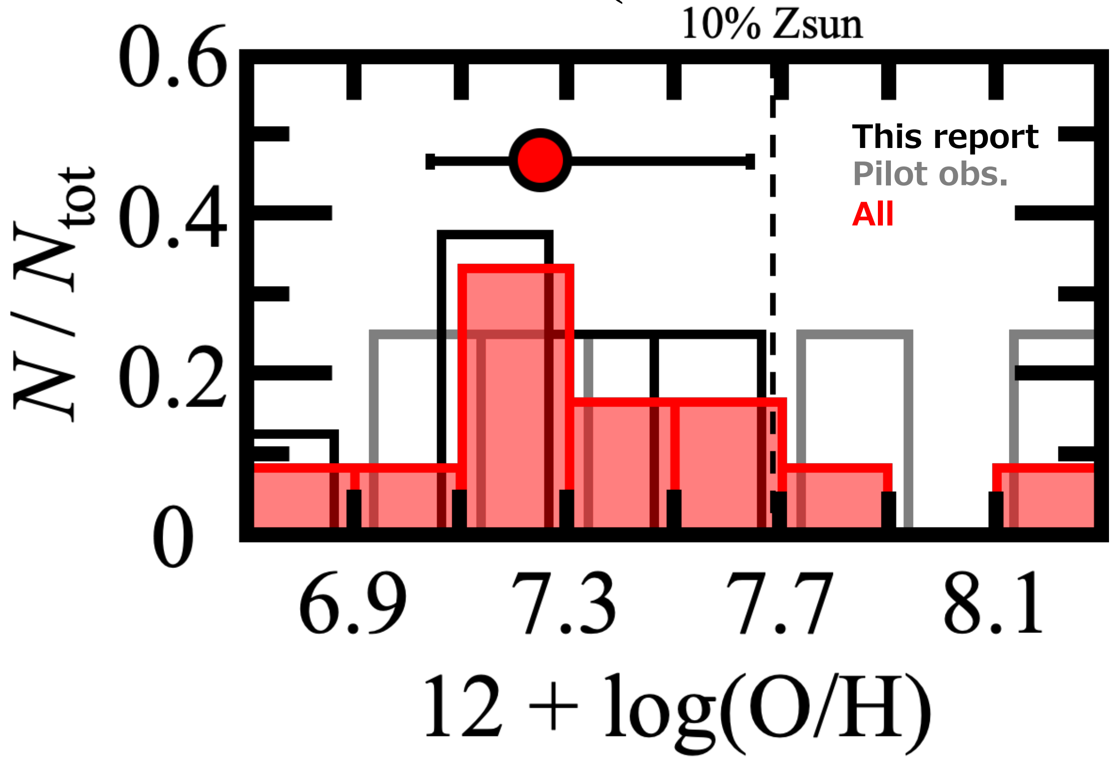
・High sensitivity & spatial resolution (~ 0.1 arcsec)
・3000-5500 (blue arm) & 6000-9000 Å (red arm)
・Integrate 20 min. for each object



Result

Confirmation & Metallicity

- 10/13 are emission-line galaxies at $z = 0.01\text{-}0.05$
- Analyses completed for 8/10
- **All** are EMPGs (i.e., ≤ 10% Zsun) with Z = **1.4**-8.3% Zsun!



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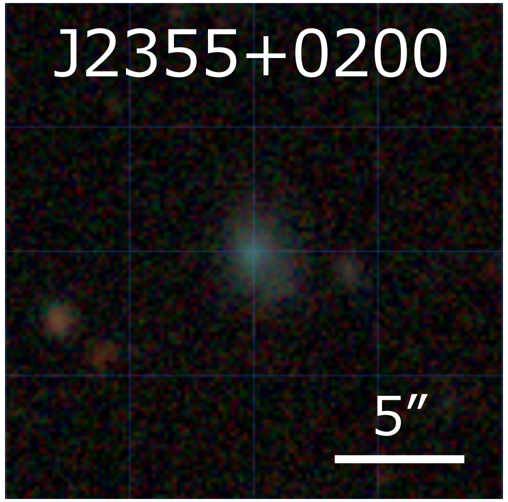
Breaking **world record**?

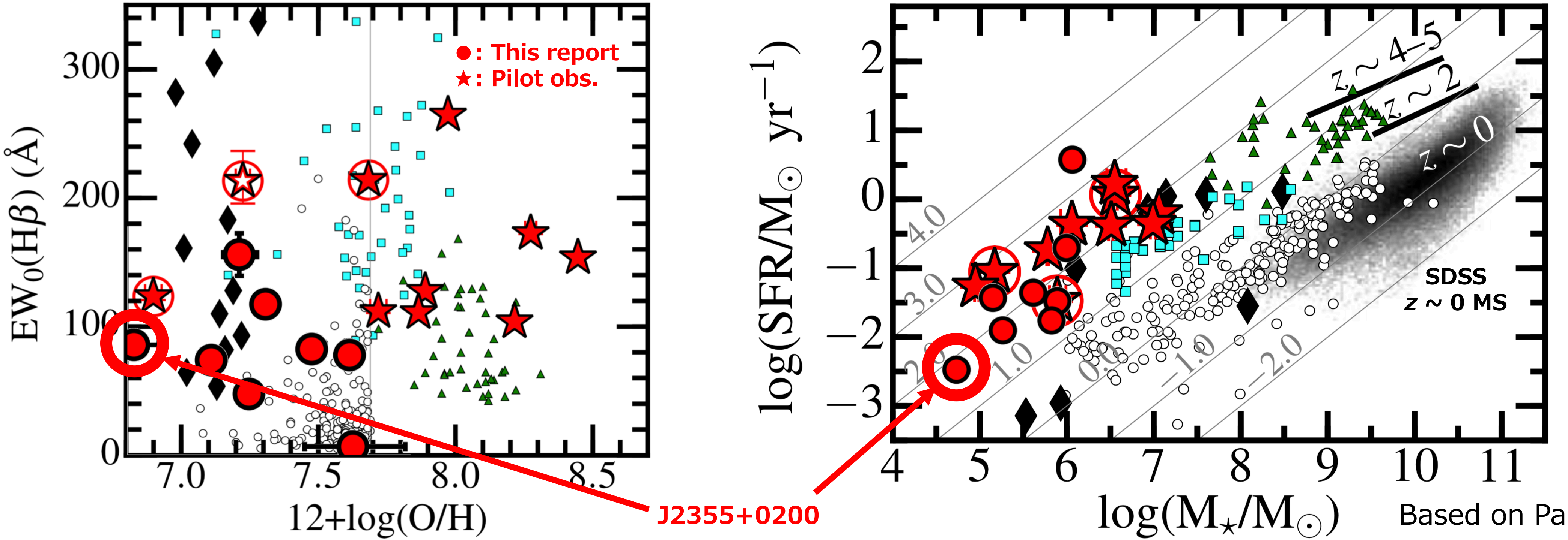


Based on Isobe+20
(Paper III)

Result

EW, M_*, SFR

- EW(Hβ): High ($\gtrsim$ 80 Å) → **Young** ($\lesssim$ 100 Myr)
- M_*: Very **low-mass** (10^{4-6} Msun; SED fitting based on Paper III)
- Star formation: **Higher** than $z \sim 0$ main sequence (MS)

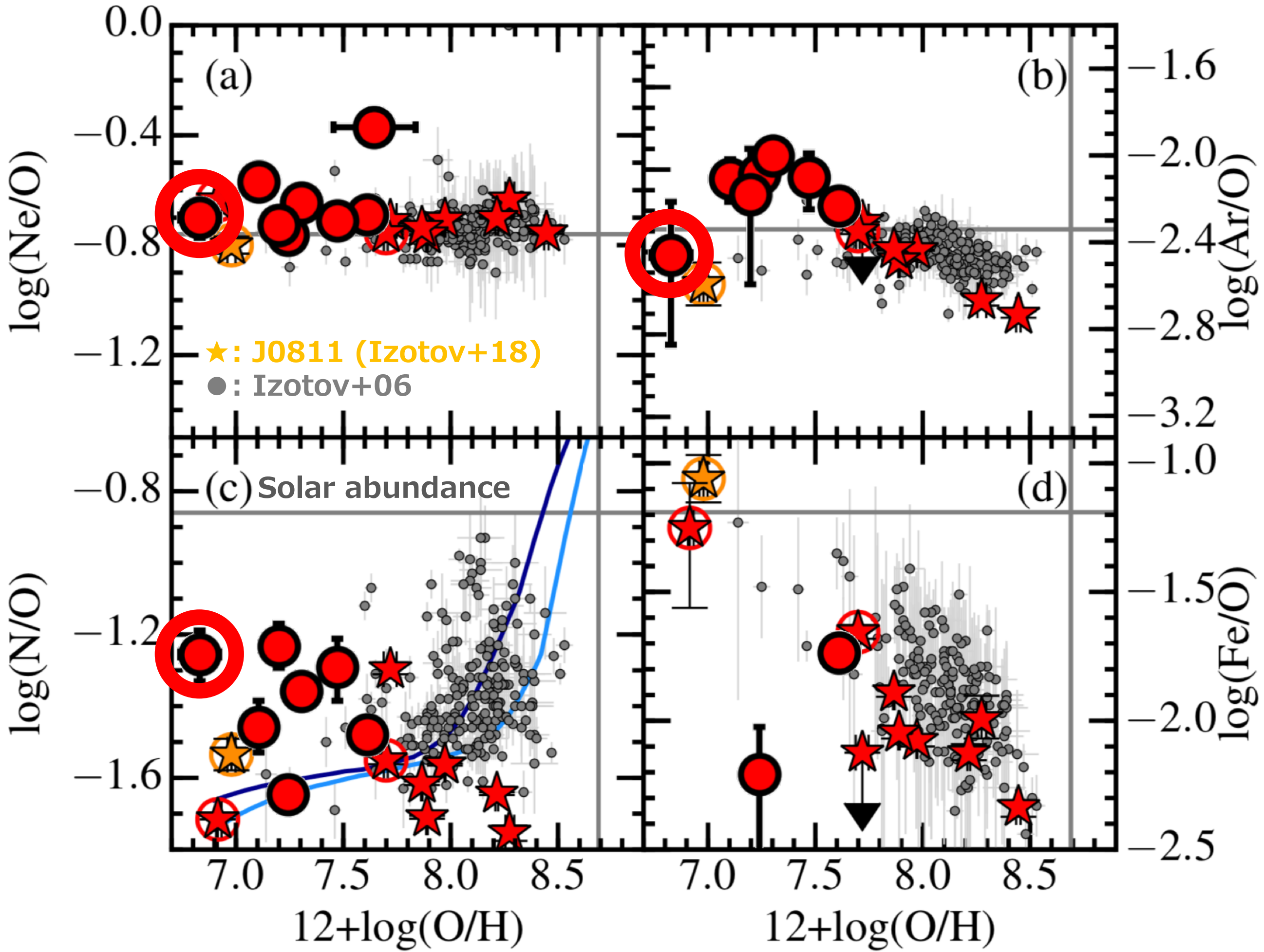


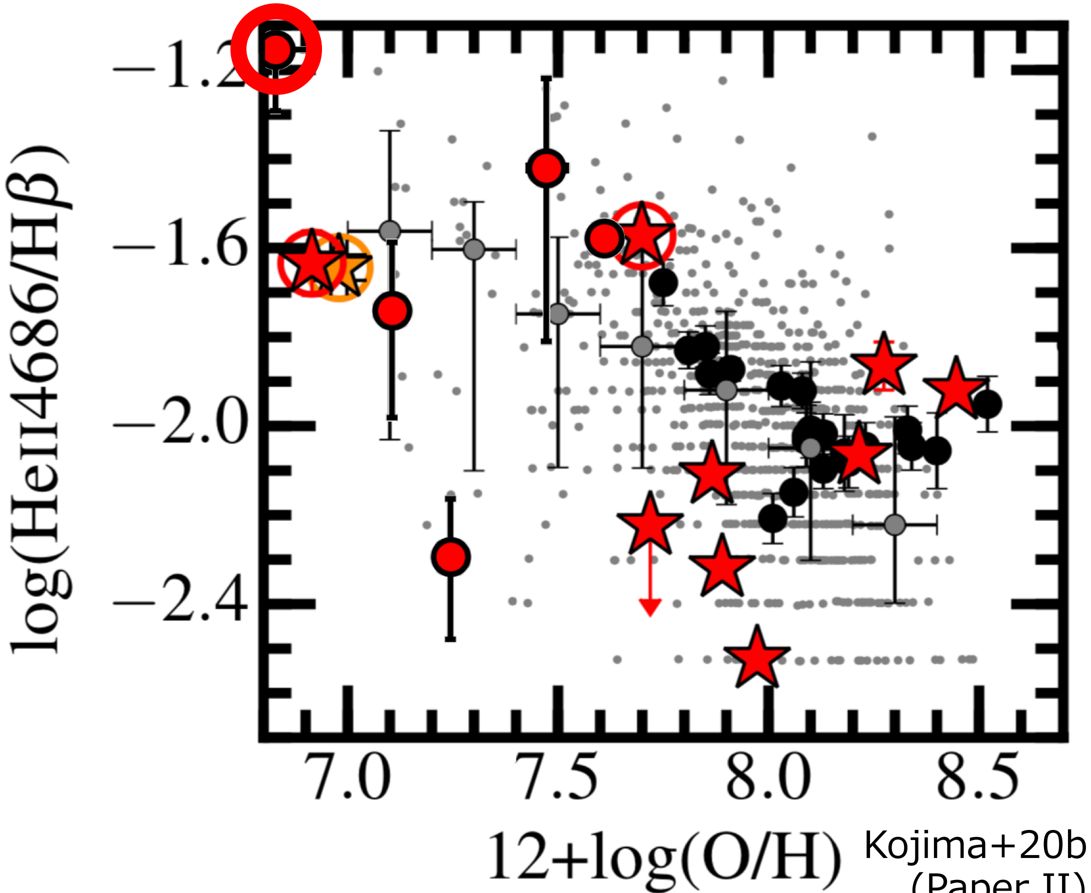
Based on Paper I

Result

Metal-to-oxygen, HeII4686/Hβ vs. *Z*

- **Confirming** the relations seen in pilot observations





Kojima+20b (Paper II)

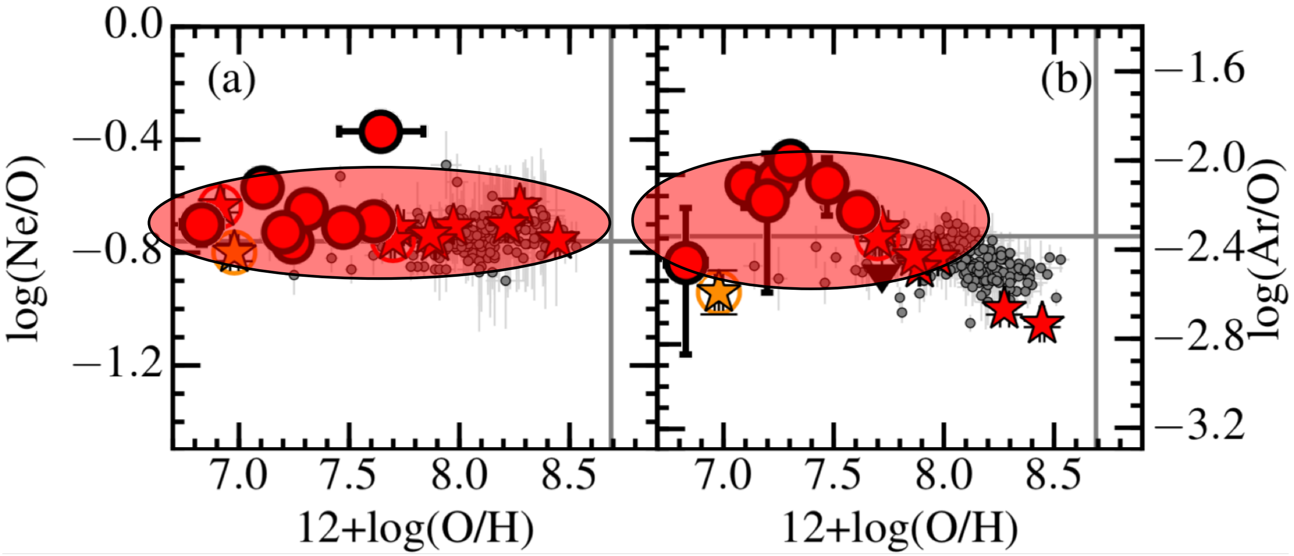
Discussion

Ne/O, Ar/O vs. *Z*

Roughly constant

~ solar abundance

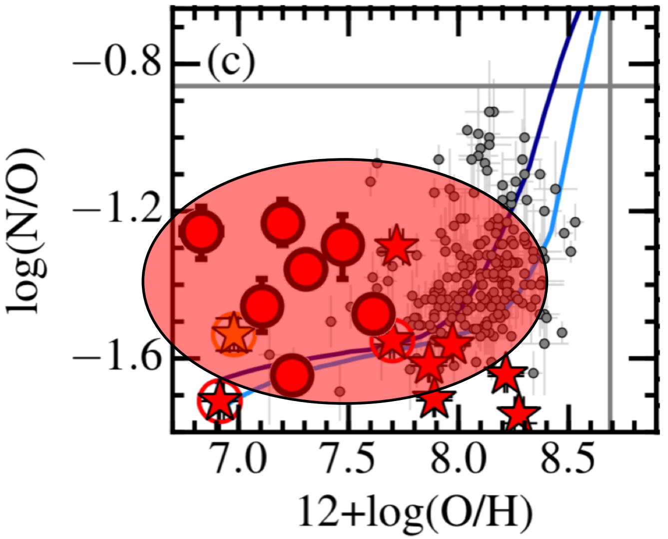
∵ O, Ne, Ar are α elements



N/O vs. *Z*

Roughly constant; log(N/O) ~ −1.4

∵ **AGB stars** (CNO cycle) are **yet born**



Discussion

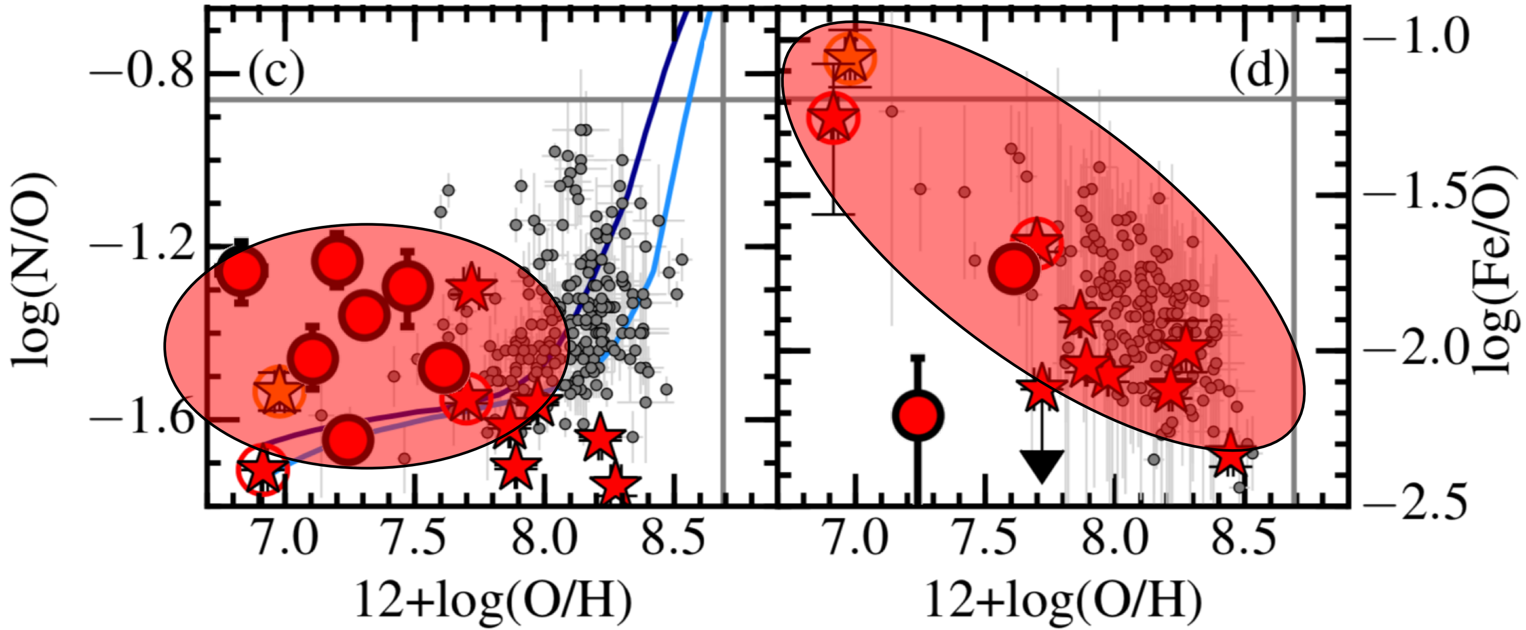
Fe/O vs. *Z*

・Anti-correlation

・High Fe/O while low N/O

→ Not likely inflow or type-Ia SNe (after ~ 1 Gyr)

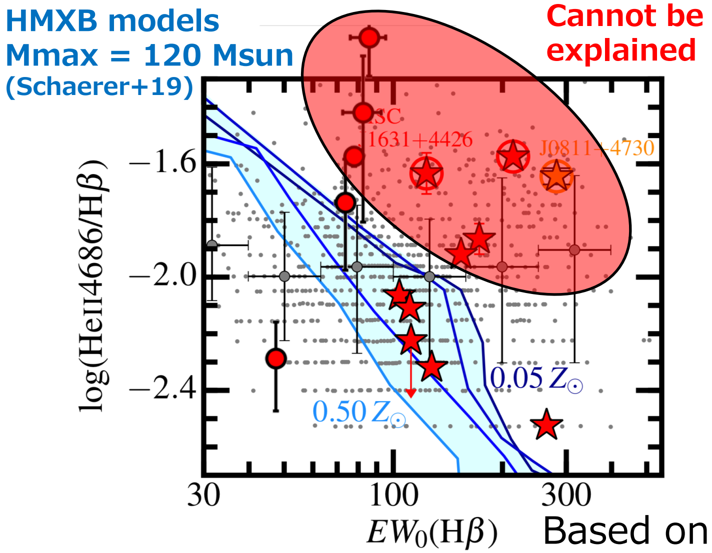
→ **Pair-instability SNe**? (progenitor mass ≳ **140 Msun**)



Discussion

HeII4686/Hβ vs. *Z*

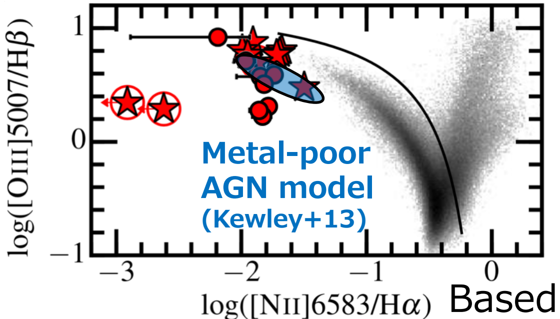
- Anti-correlation → Harder radiation in lower metallicity
- HeII4686 are sensitive to photons ≥ 54.4 eV (i.e., ≤ 228 Å)
  → Need hard radiation (e.g., X-ray sources)



Based on Paper II

Possibilities:

1. High mass X-ray binary (**HMXB**)
   Progenitor mass ≲ 120 Msun is not enough
   → Progenitor mass ≳ **300 Msun** (to be BHs)
2. Metal-poor AGN
   Cannot be excluded on BPT diagram



Based on Paper I

Discussion

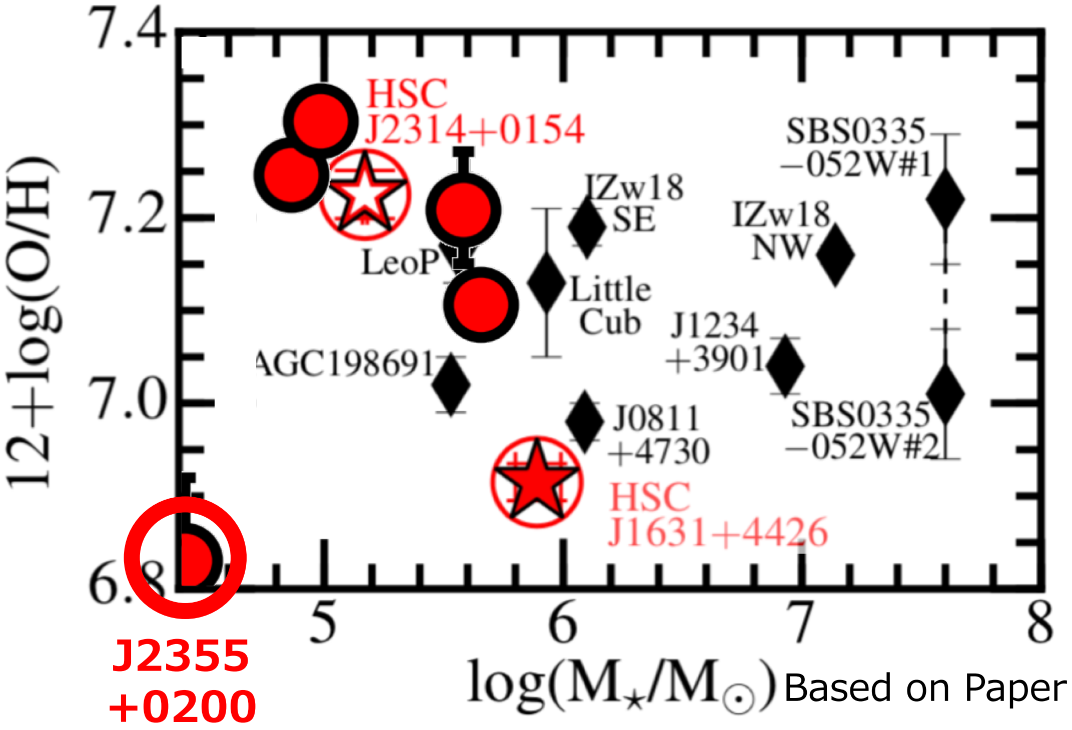
J2355+0200

- Extremely low Z (**1.4%** Zsun)
- Extremely low M_* (**$10^{4.7}$** Msun)
- High sSFR (~ **100** Gyr^{-1})

→ Analog of first galaxy (Wise+12)

- Extremely **strong** HeII4686

→ HMXB with progenitor mass ≳ 300 Msun (or metal-poor AGN)

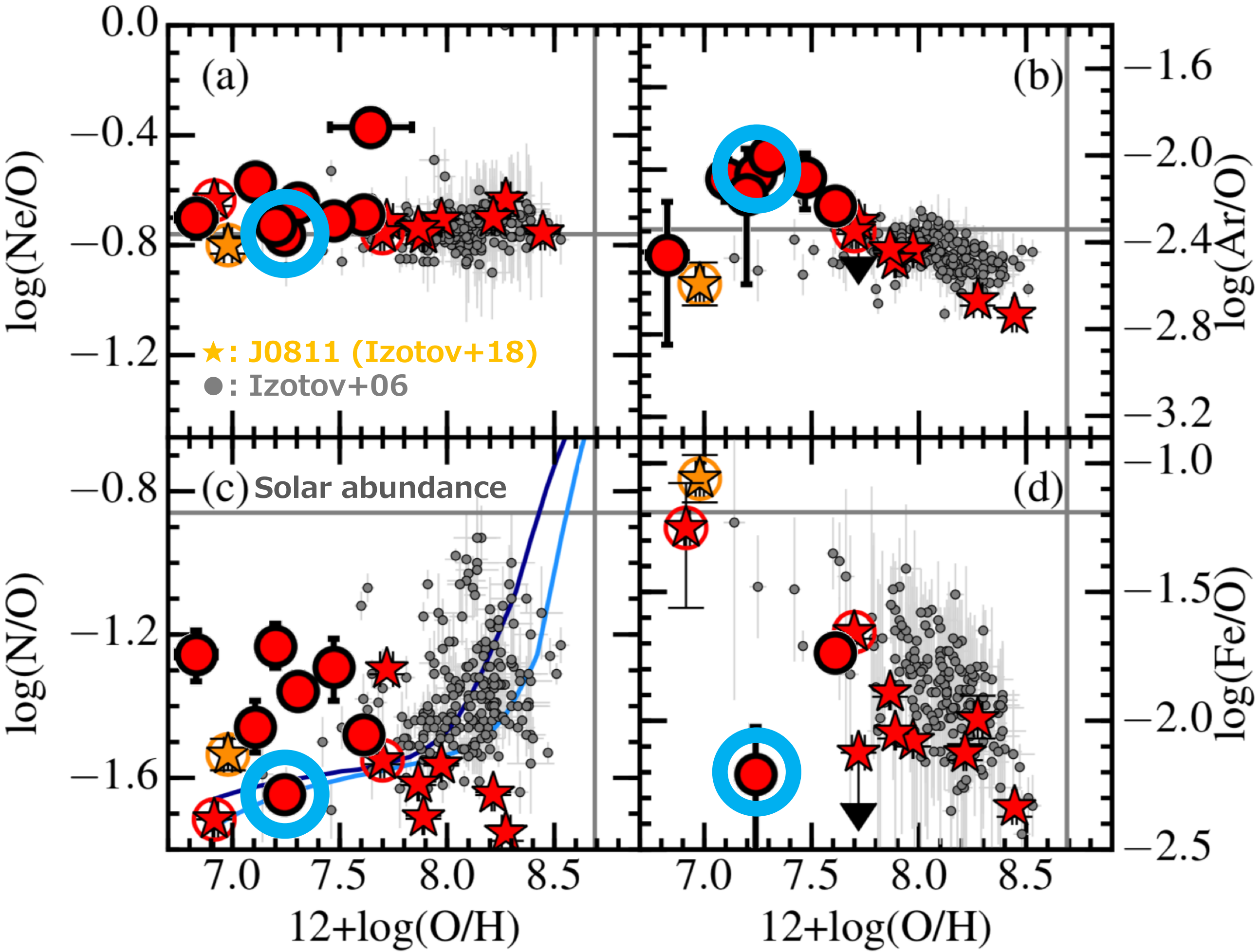


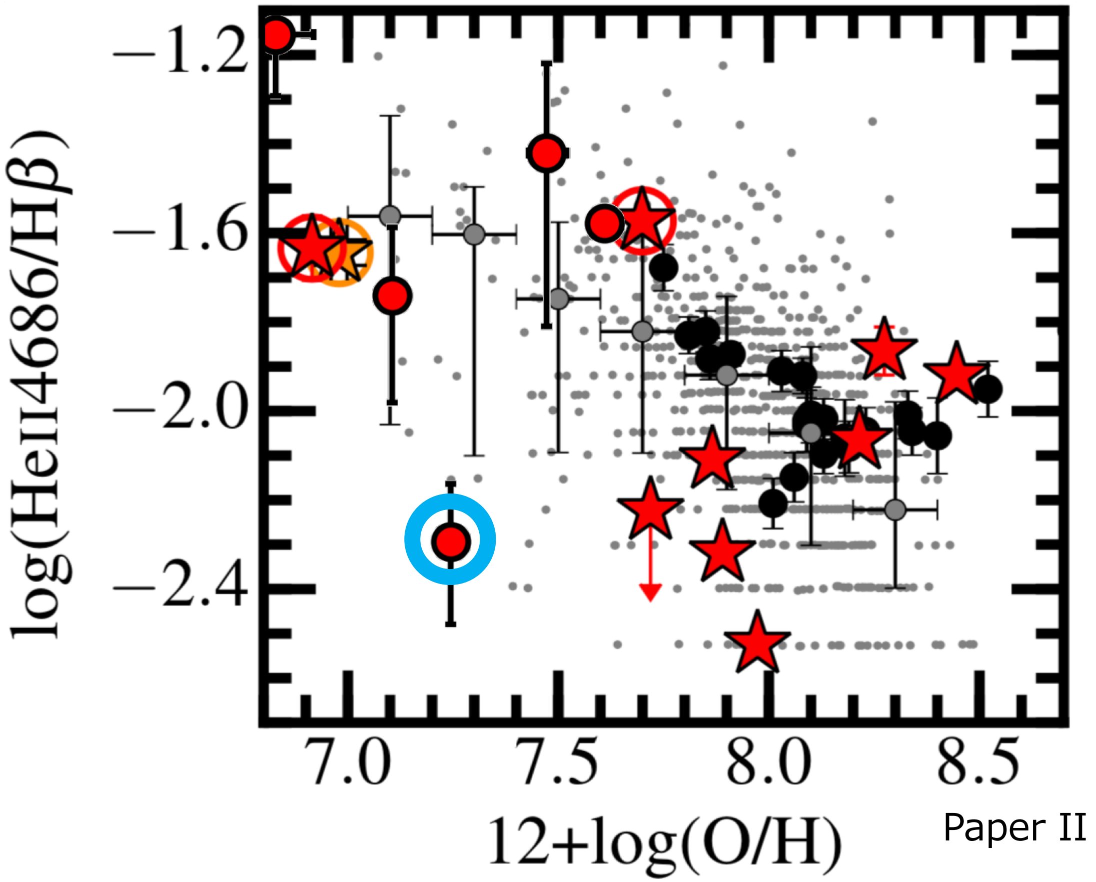
Based on Paper I

Discussion: Exception

Metal-to-oxygen, HeII4686/Hβ vs. *Z*

- Finding object with **low** Fe/O & **weak** HeII4686, **J0210-0124**

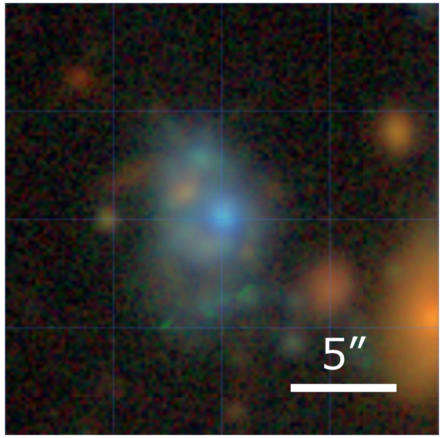


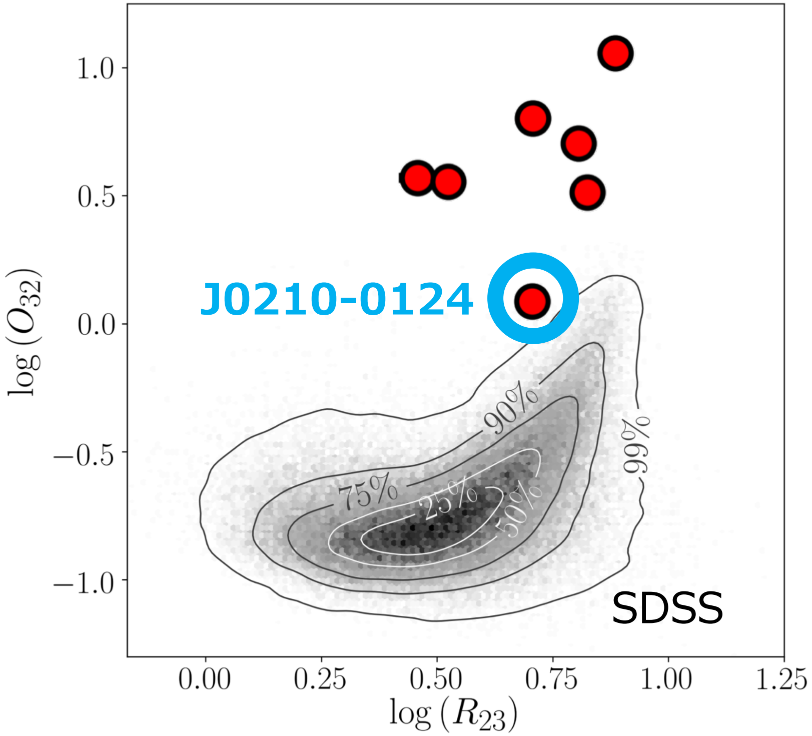


Discussion: Exception

J0210-0124

- **Low** log(Fe/O) ~ –2.2
- **Weak** HeII4686
- **Low** O32
  (= [OIII]4959,5007/[OII]3727)
  → Not so young?





Based on Hogarth+20

- Relatively low EW ~ 50 Å → Age ≳ 100 Myr
- Low log(N/O) ~ –1.6 → Age < 1 Gyr (Absence of AGB stars)
  → **Several hundred** Myr old?

Summary

Follow-up observation with LRIS

Finding 8 EMPGs, including **1.4%** Zsun object

Young, low-mass, high-SFR → Likely to be **local analogs**

High Fe/O & strong HeII4686
→ Suggesting super massive (> **300** Msun) stars

Identifying **exception** with low Fe/O & weak HeII4686

End

If you get interested in our EMPG survey, please read

Paper I: Selection method, pilot spectroscopy
Kojima+20a, arXiv: 1910.08559

Paper II: Chemical abundances, ionizing radiation
Kojima+20b, arXiv: 2006.03831

Paper III: Morphology, kinematics
Isobe+20, arXiv: 2004.11444