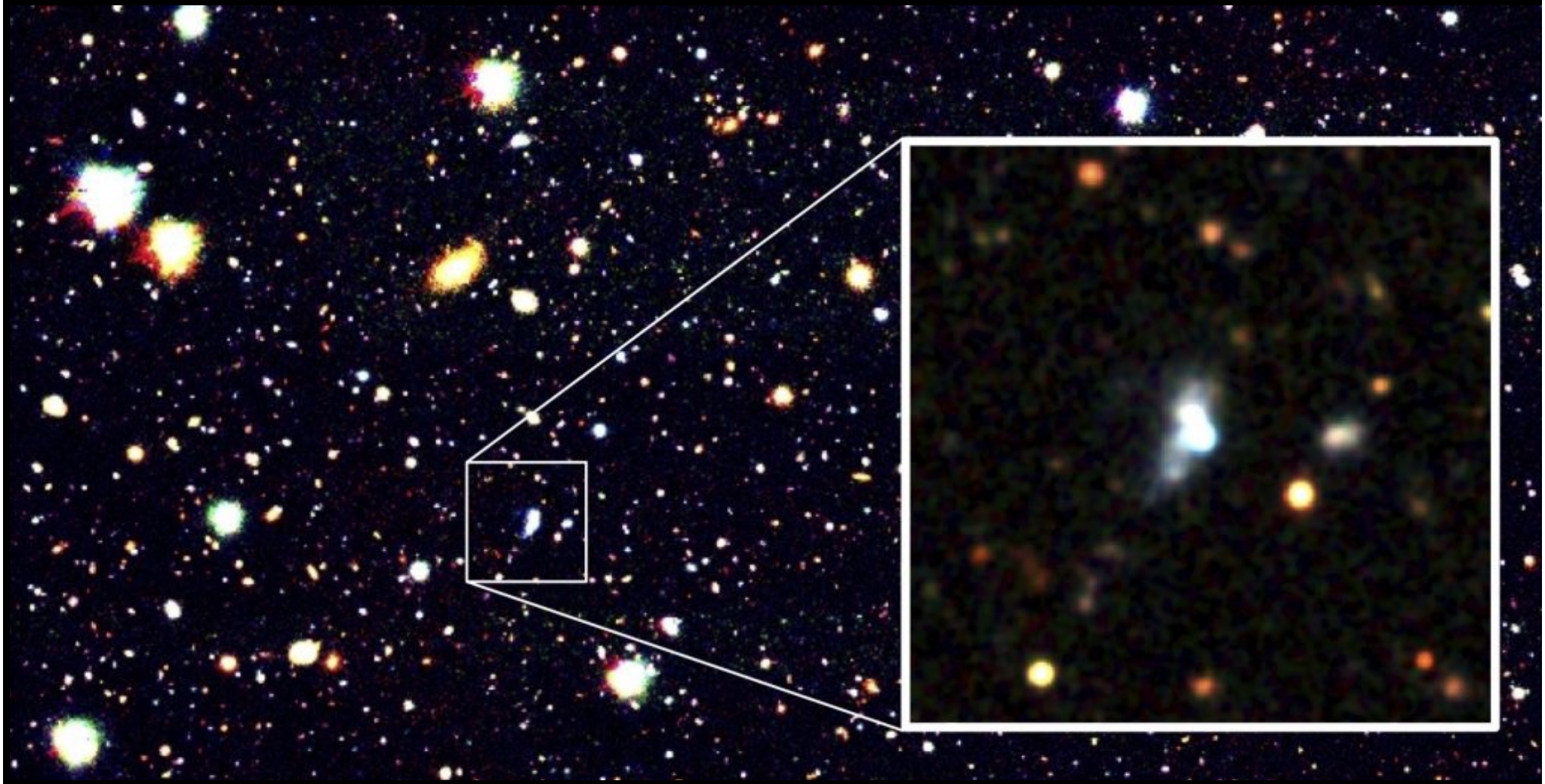
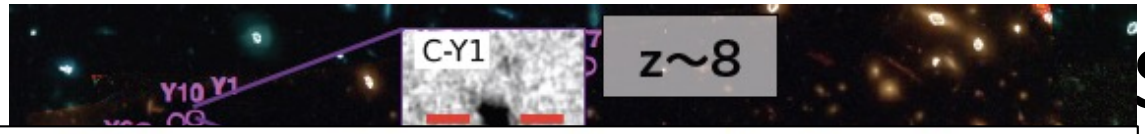
Extremely Metal-Poor Representatives Explored by the Subaru Survey for 3D (EMPRESS 3D)



Masami Ouchi (NAOJ/ICRR)

On Behalf of EMPRESS-3D Collaboration



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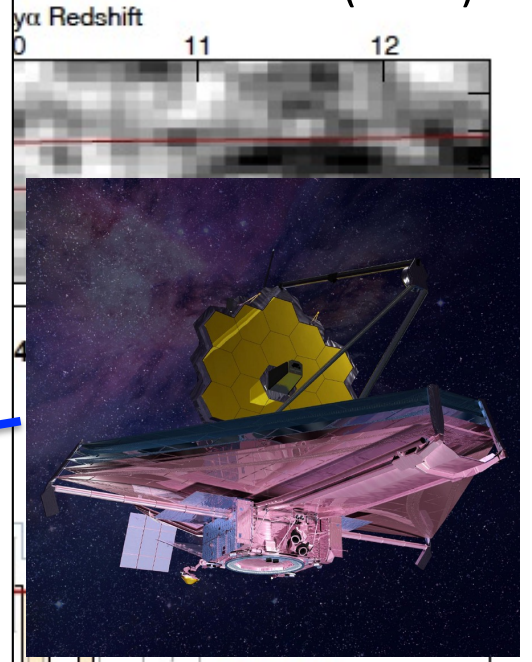
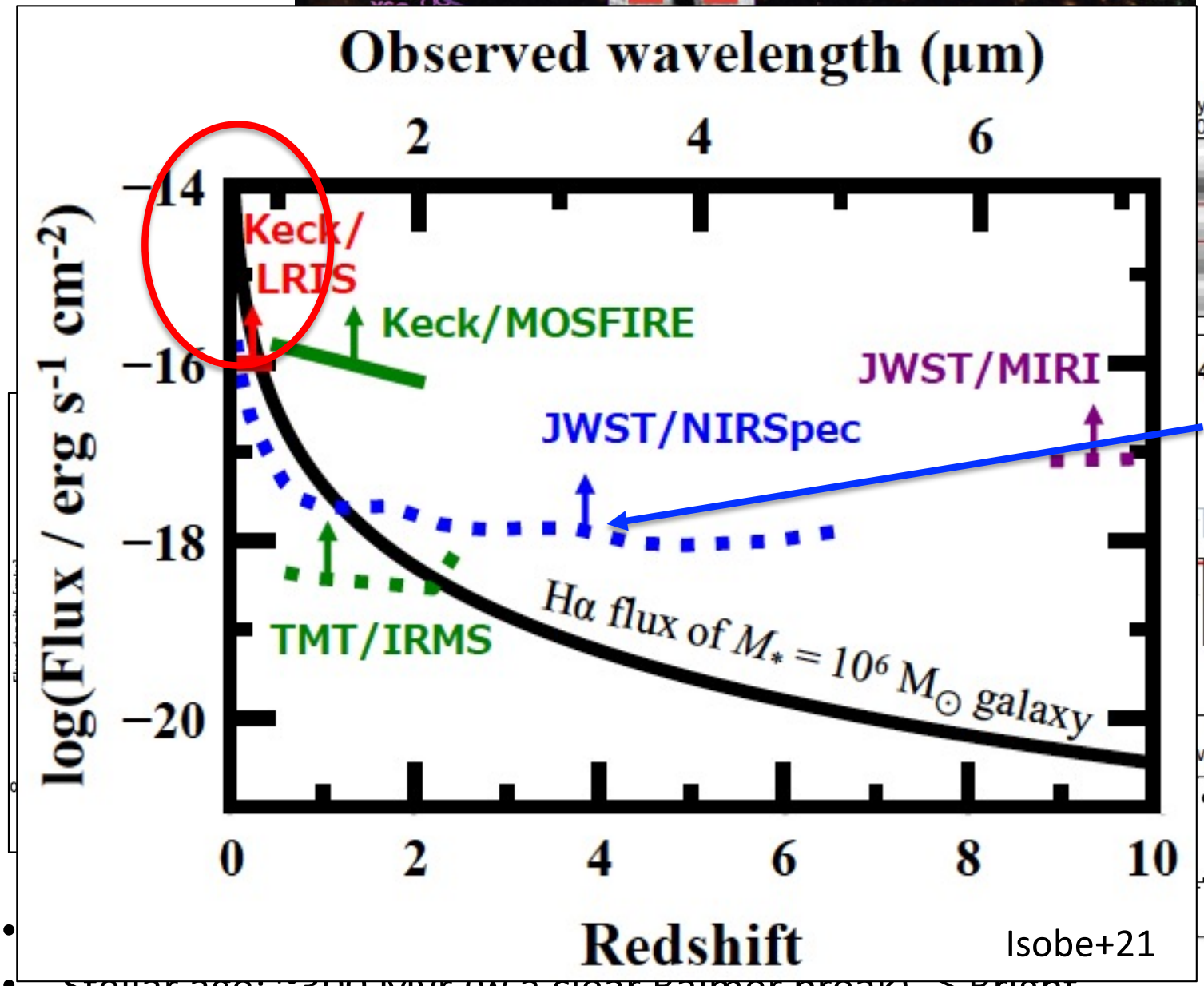
Oesch et al. (2016)





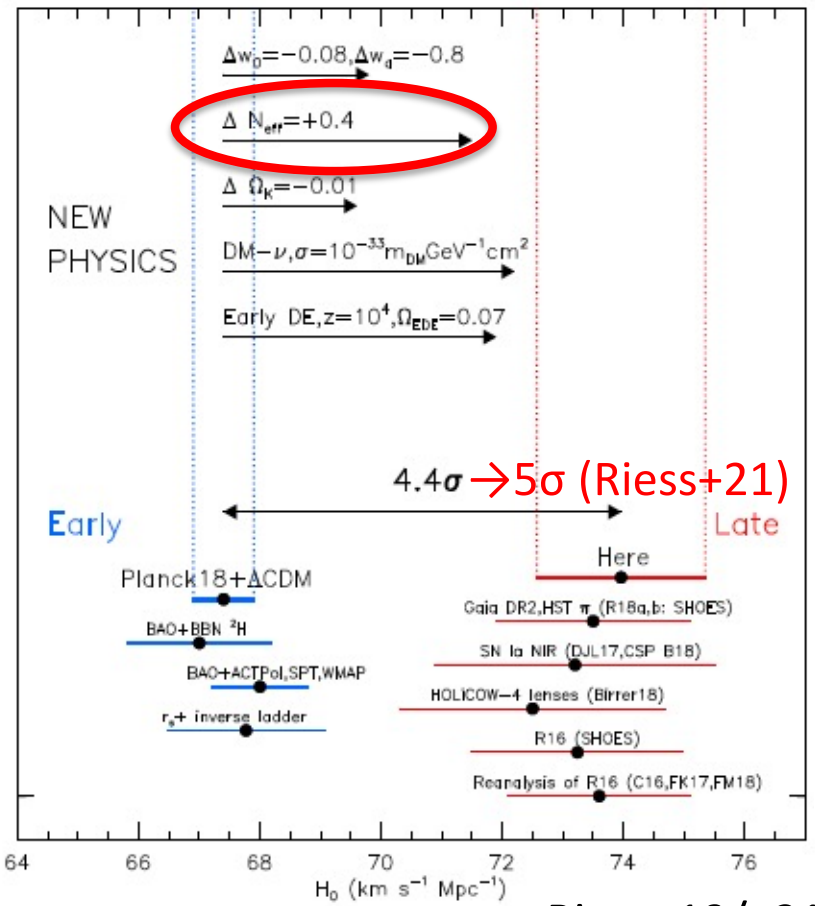
Isobe+21

Jiang+21

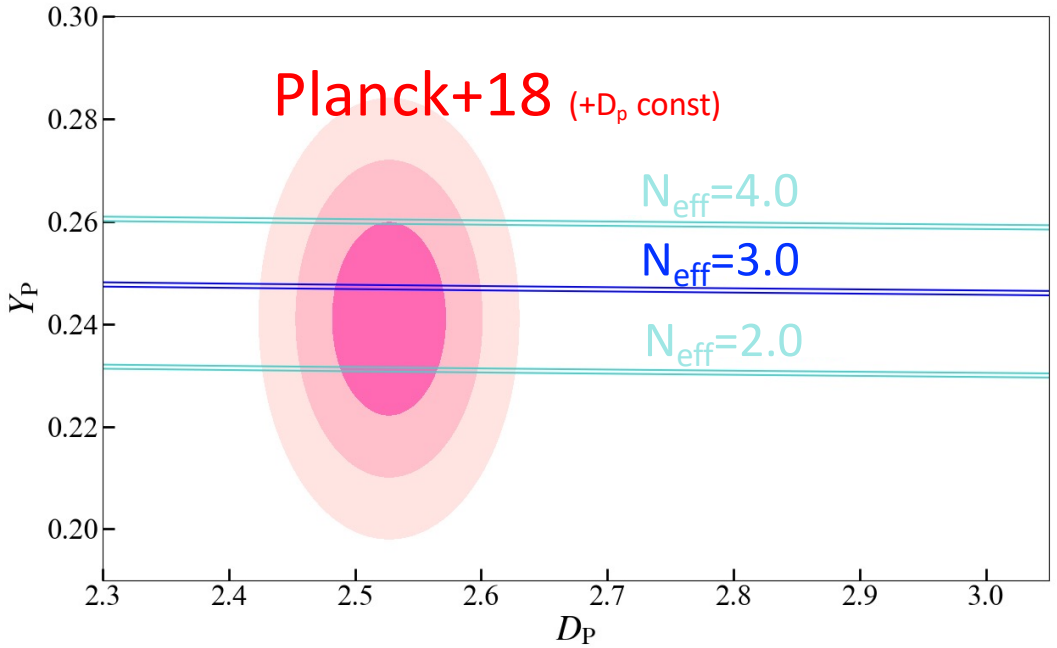
- Stellar age: ~300 Myr (w a clear Balmer break) -> Bright

Gravitational lensing survey (HFF)→ $M^* \gtrsim 10^7 M_\odot$ at z~10 w no spec (Kikuchihara+20)

Hubble Tension Puzzle and Primordial He Abundance



Riess+19/+21



Matsumoto+

- Puzzling Hubble Tension
  - H_0=67.4±0.5 (CMB; Planck+18) vs. 73.0±1.0 (Cephid/SNeIa) in km/s/Mpc
  - Scenario: effective number of neutrino, N_{eff}, higher than standard cosmology N_{eff}=3.046 (by ΔN_{eff} ~0.4)?
  - N_{eff} has not been determined in laboratory. It is sensitive to primordial He (D) abundance, Y_p and D_p.
- Present constraint w primordial He: Y_p (Planck+18) & D_p (QSO abs sys) → ΔNeff ~ 1

EMPRESS 3D Project

- Members: 43 astronomers

- Combination of
  1) High-z & low-z galaxy astronomers
  2) Theorists
  3) Instrumental astronomers

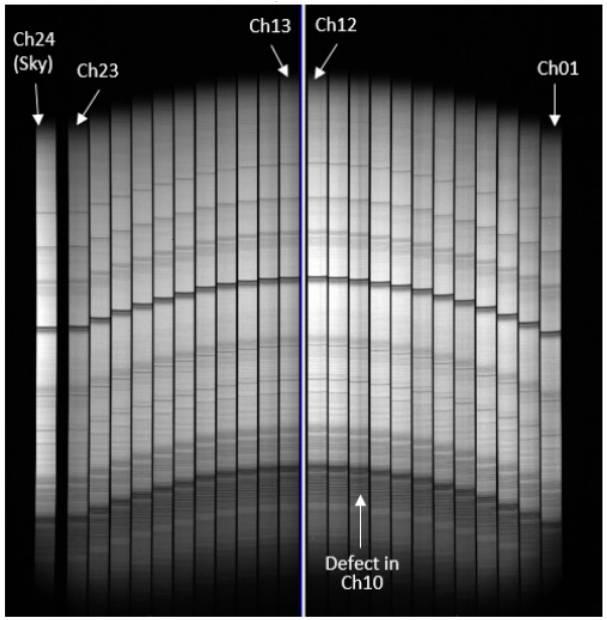
- Ouchi (NAOJ/Tokyo), Nakajima (NAOJ), Isobe (Tokyo), Xu (Tokyo), Kusakabe (Geneva), Ozaki (NAOJ), Hattori (NAOJ), Rauch (Carnegie), Murai (Tokyo), Kawasaki (Tokyo), Suzuki (NAOJ), Motohara (NAOJ), Hirai (Tohoku), Aoyama (Chiba), Komiyama (Subaru), Koyama (Subaru), Kojima (Tokyo), Inoue (Waseda), Nagao (Ehime), Hayashi (NIT), Onodera (Subaru), Moriya (NAOJ), Kashiwagi (Tokyo), Hashimoto (Tsukuba), Ono (Tokyo), Harikane (Tokyo), Fujimoto (Copenhagen), Mawatari (Subaru), Umemura (Tsukuba), Takeuchi (Nagoya), Saito (NHAO), Lee (NOIRLab), Hayashi (NAOJ), Kikuchihara (Tokyo), Shibuya (KIT), Sugahara (Waseda), Yabe (IPMU), Zhang (Tokyo), Matsumoto (Tokyo), Umeda (Tokyo), Nagamine (Osaka), Fukushima (Osaka), Konishi (Tokyo), Koyama (Tokyo), Takahashi (Tokyo)

EMPRESS 3D Project

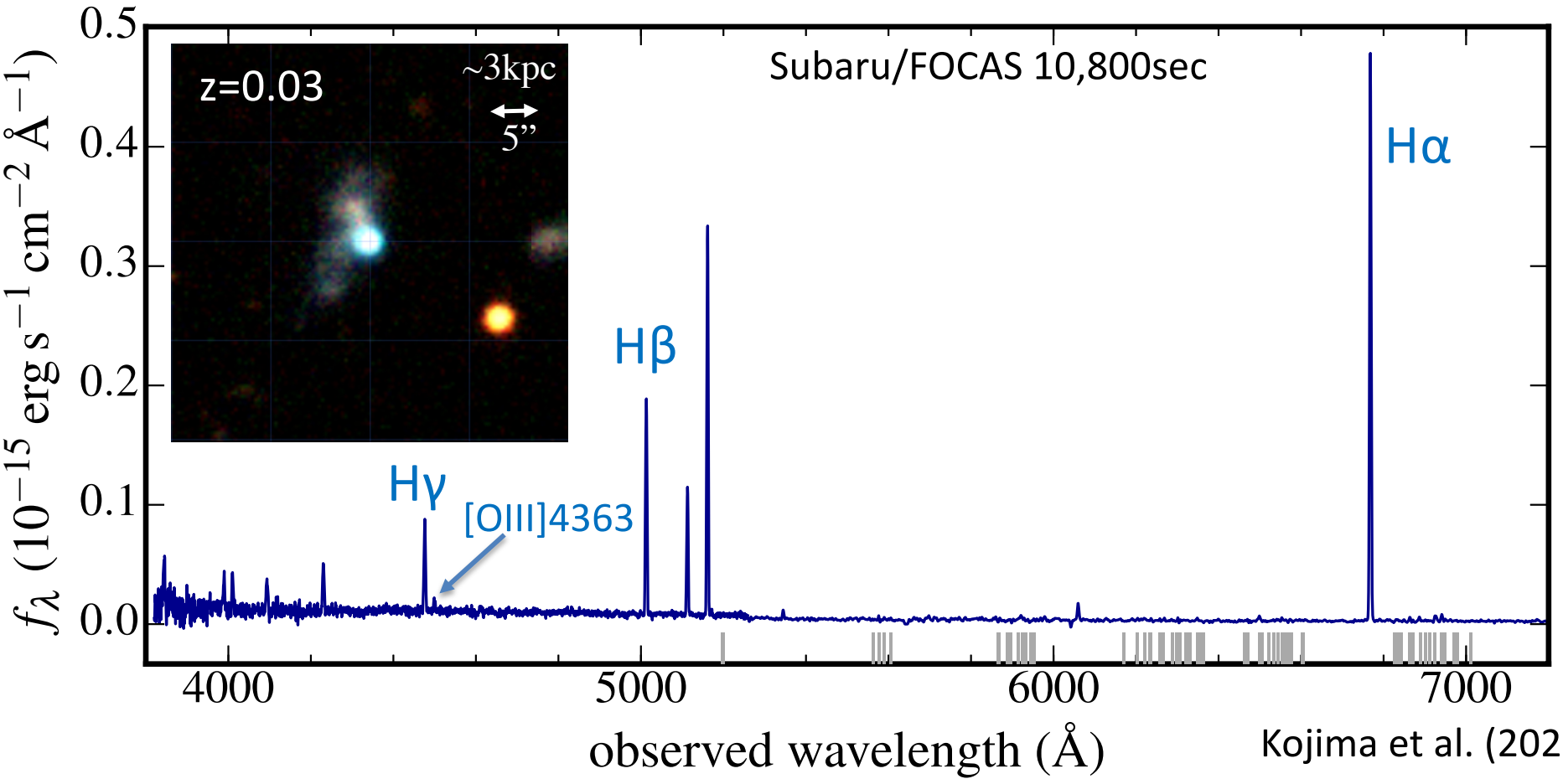
- 3D spec (FOCAS/IFU)
  - Dynamics & metallicity for GF
- NIR spec (IRCS+SWIMS)
  - Primordial He abundance for N_{eff}
- 30 low-mass extremely metal poor galaxies (EMPGs) at z=0.01-0.03

  by 10 night obs. since last April

- ~1/4 of the obs. completed (1 night was weathered out)



Example
--- Subaru HSC J1631+4426 ---



Kojima et al. (2020)

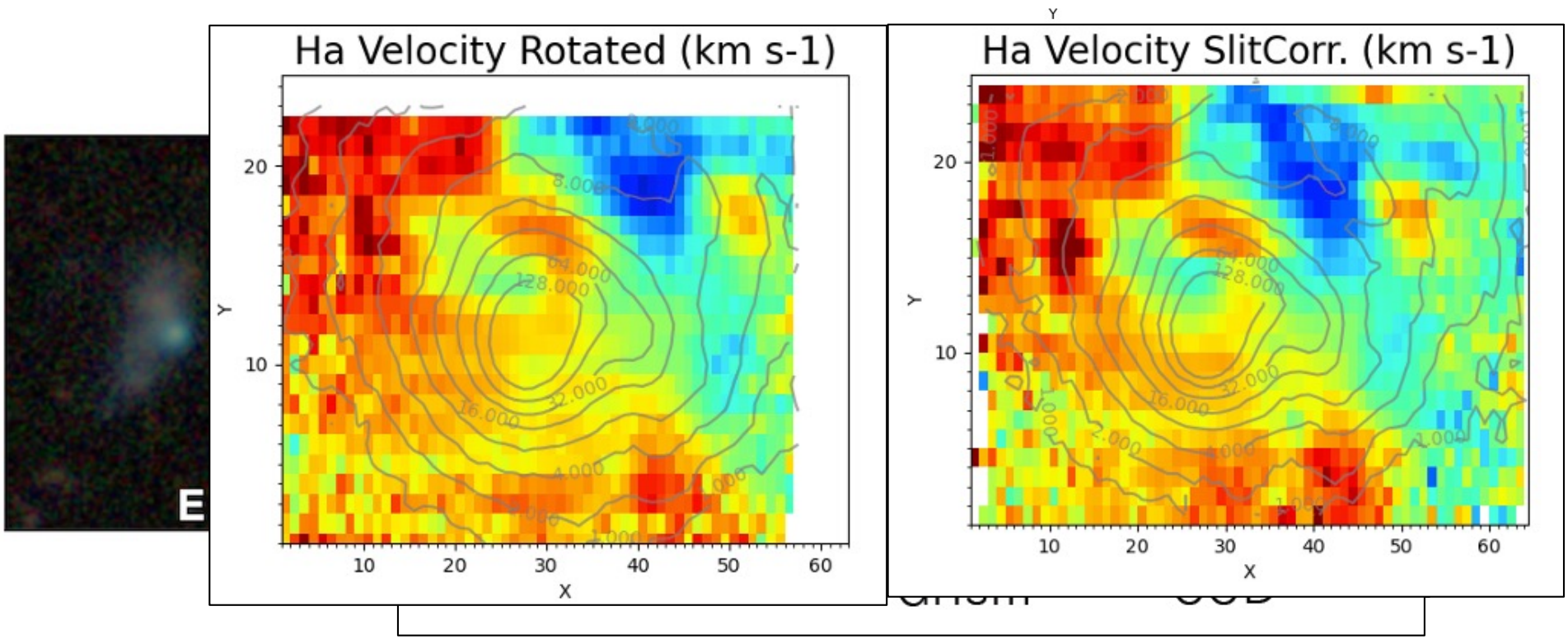
Most metal poor galaxy, so far identified.

0.016 Zo (M*=8x10^{5}Mo)

FOCAS IFU Data
Finding the Slit Width Effects

PA=90deg

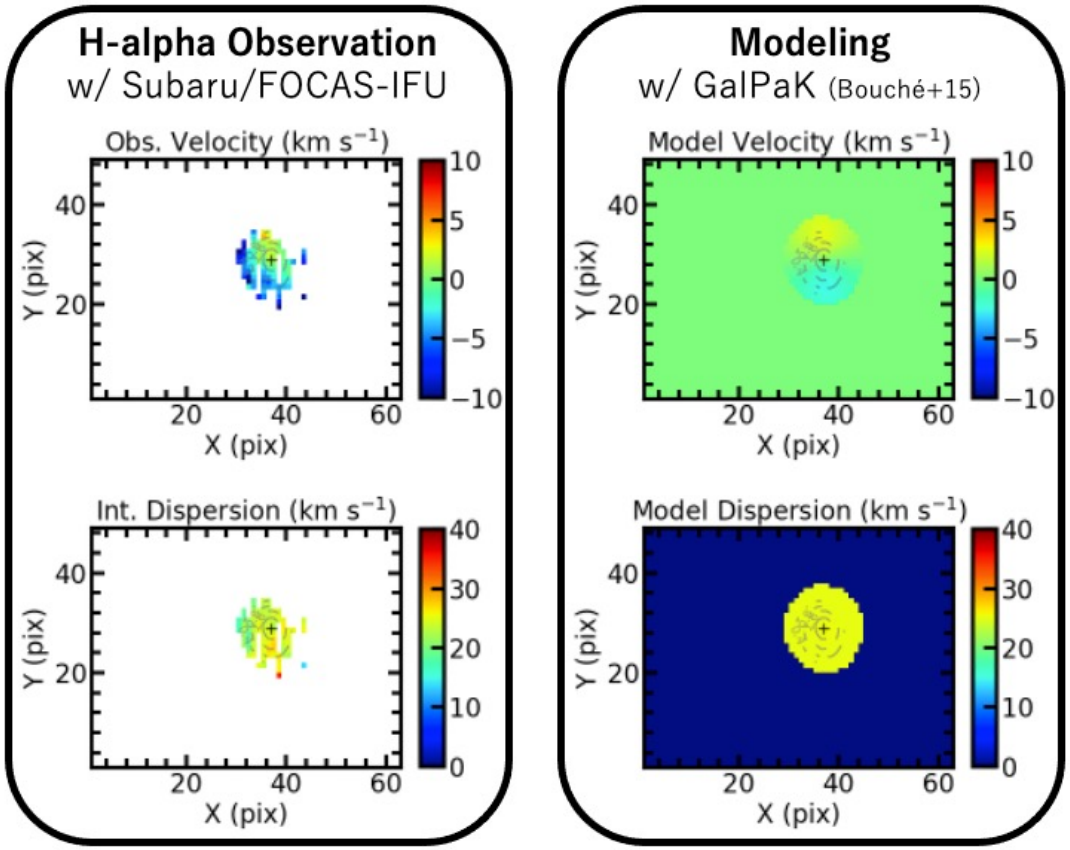
PA=0deg



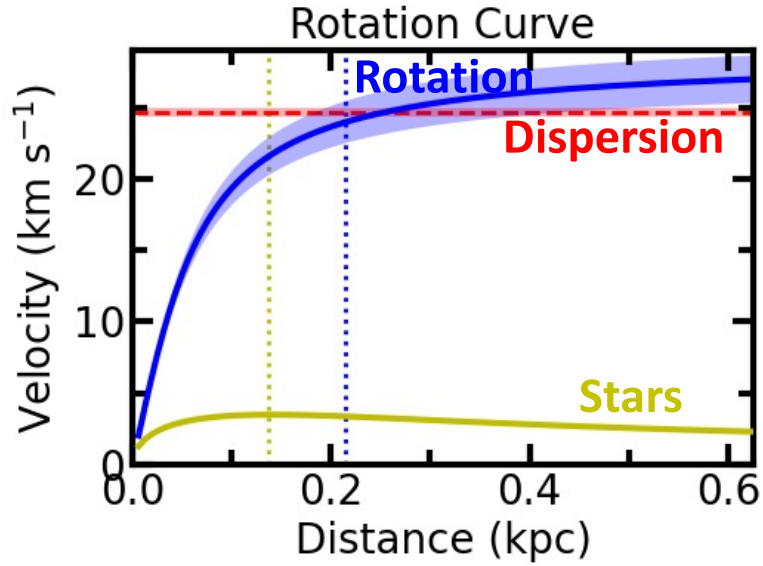
- Inconsistent velocity gradients w different position angles (PAs).
- What makes this inconsistency? → Slit width effect
  - No problems in the previous studies w MUSE etc. Our targets -> small velocity
- Correcting with moment 1 map (Ha flux map)
  -> Systematics only <~3-5km/s

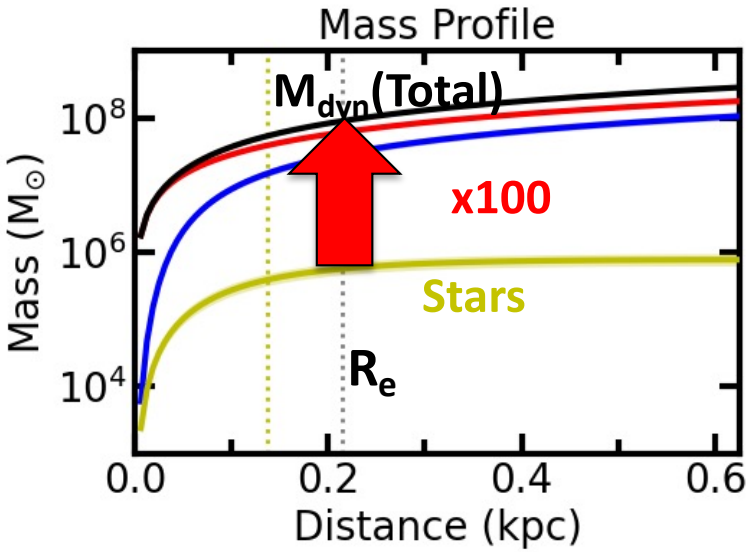
Dynamics (Preliminary)

J1631+4426



Isobe et al. in prep.

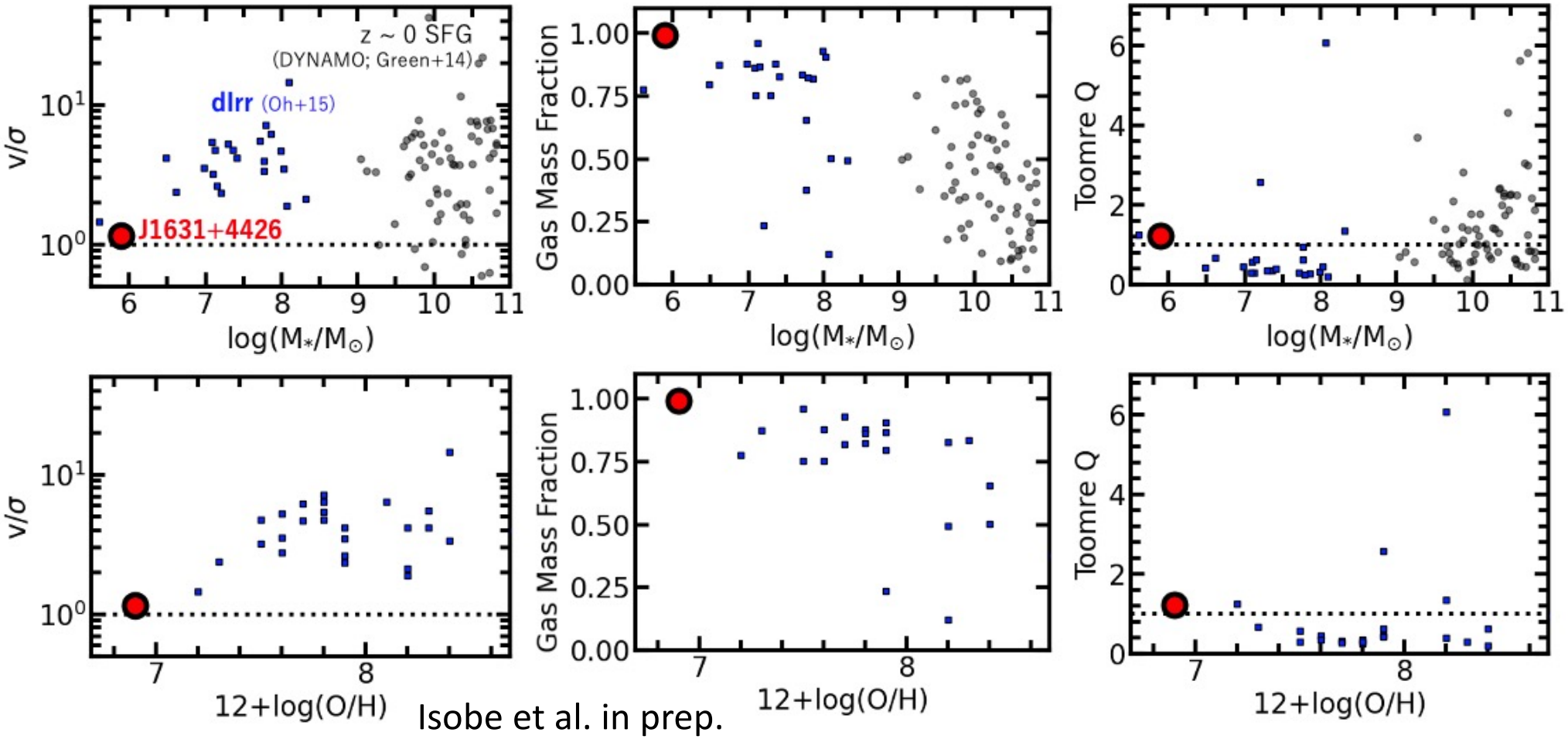




- Rot velocity vs. dispersion
  - $v_{rot}/\sigma = 1.16$ (comparable)
- $M_{dyn}(\mathrm{total}) \gtrsim 100\ M(\mathrm{Star})$→very gas rich f_{gas} =99.7% !!

Next step→testing dark matter halo or not at large dist.

Dynamics (Preliminary)

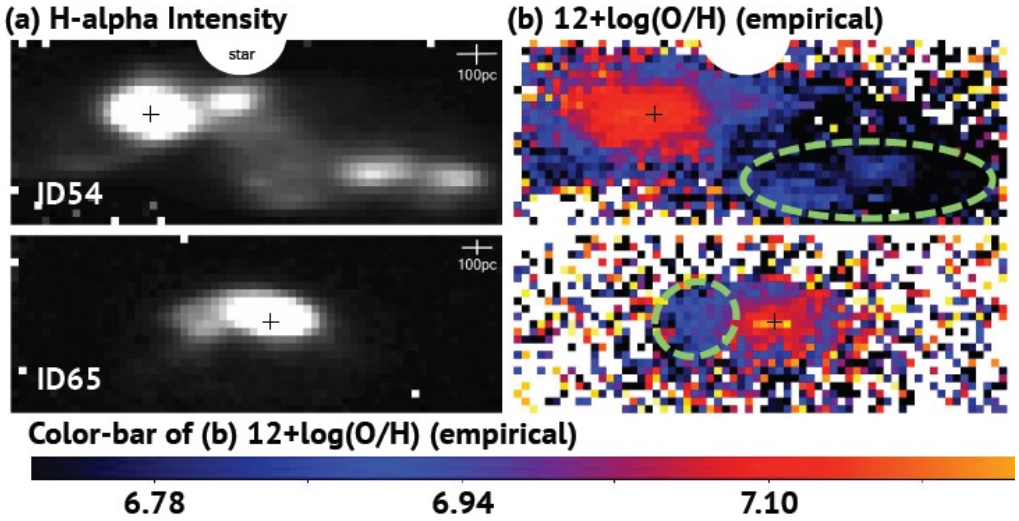


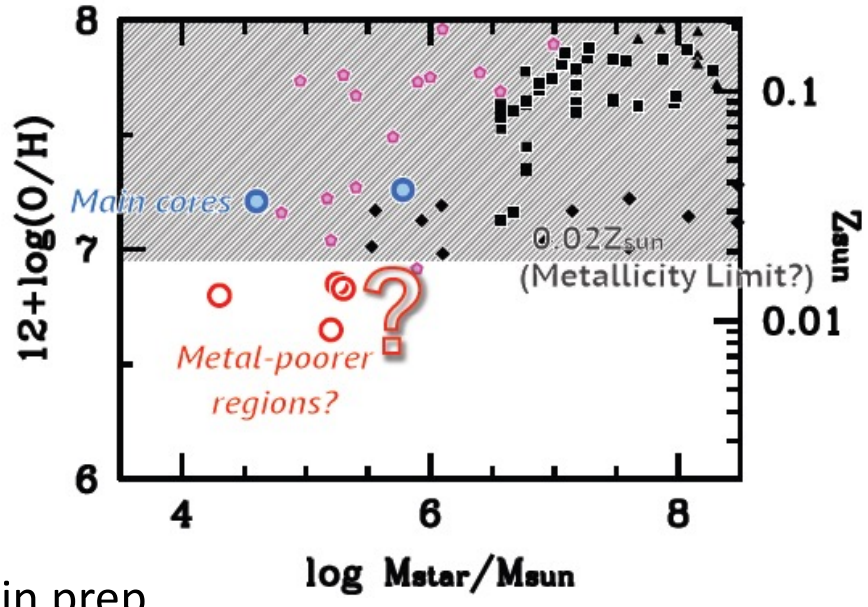
Isobe et al. in prep.

- v_{rot}/σ lower than typical dIrr
- Gas mass fraction: Higher than any galaxies
- $Q=1.2\pm0.1 \rightarrow$ Quasi-stable disk

Now increasing the number of the EMPGs, to 30 EMPGs

Metal Poorest Clump Candidates

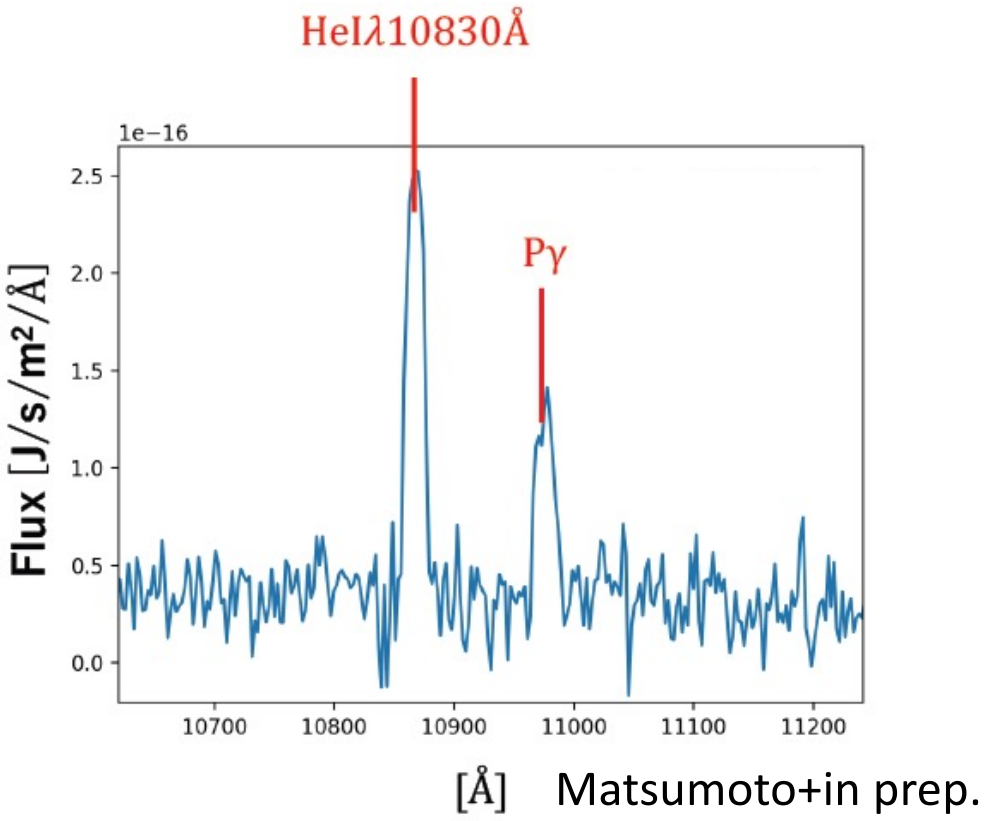


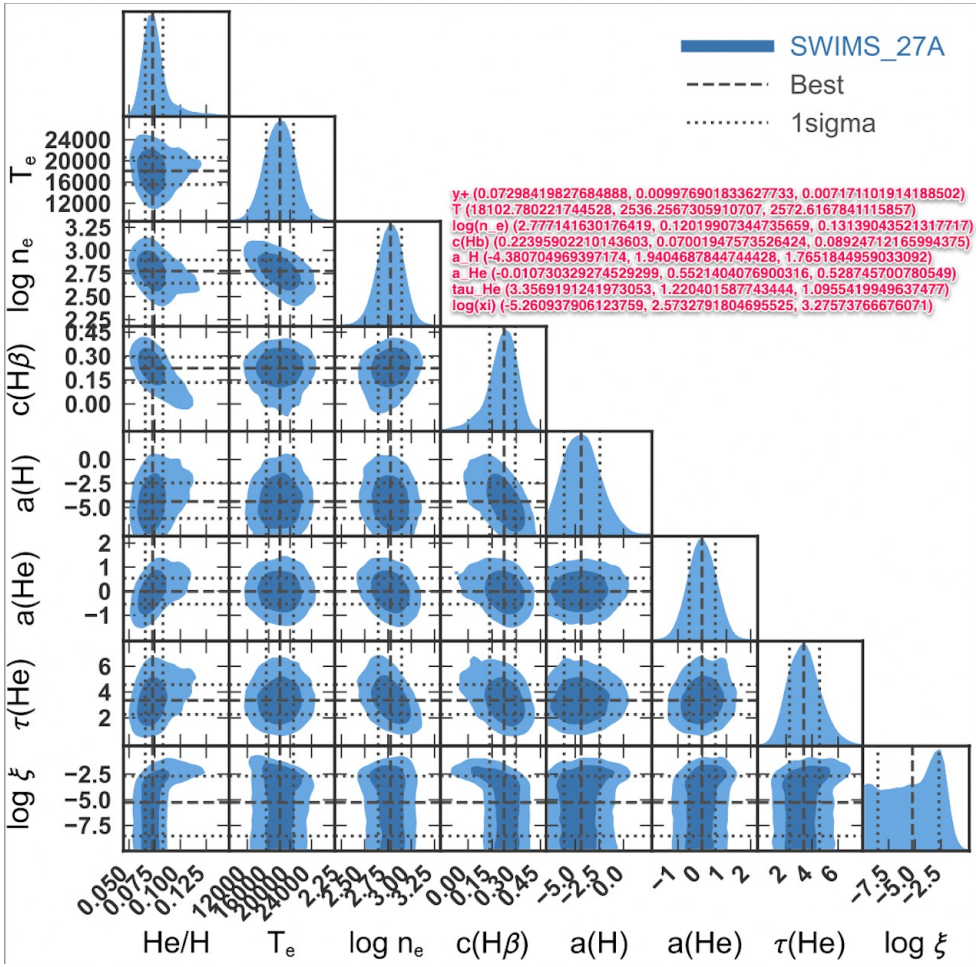


Nakajima et al. in prep.

- Substructures of EMPG revealed by IFU 3D spec.
- In EMPG ID54 and 65
  - Strong Ha, while missing [OIII]: Strong line metal estimates
  - 1-2 gas clumps with metallicities of ≲0.01 Zo (empirical)
  - Lowest Z galaxy SF regions-> Followup spec for Z determinatio

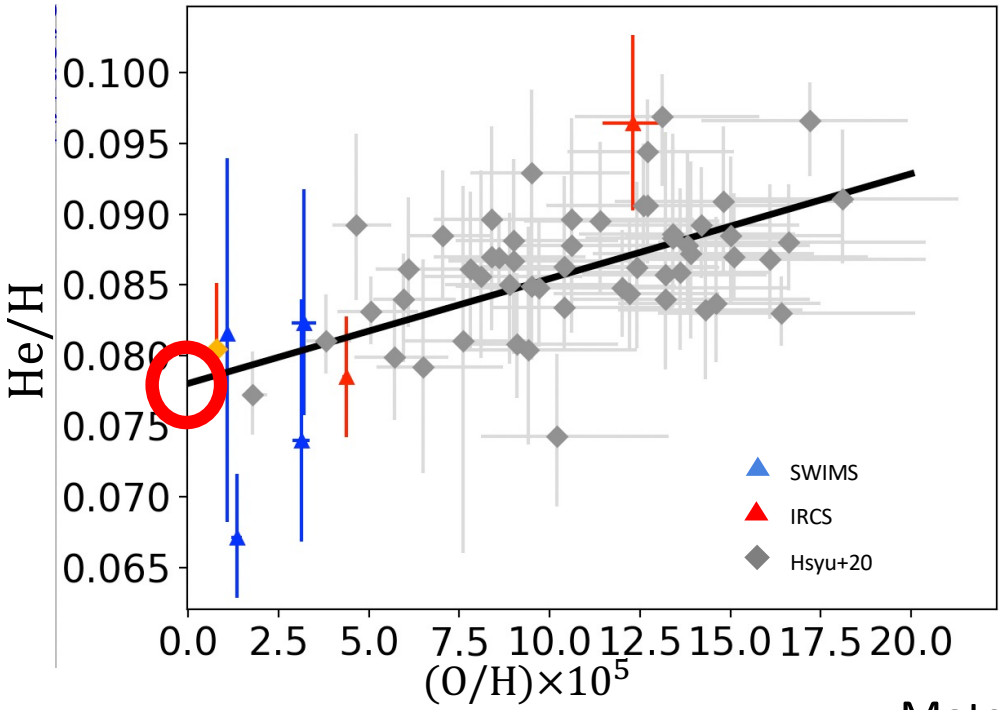
He Abundance: Analyses

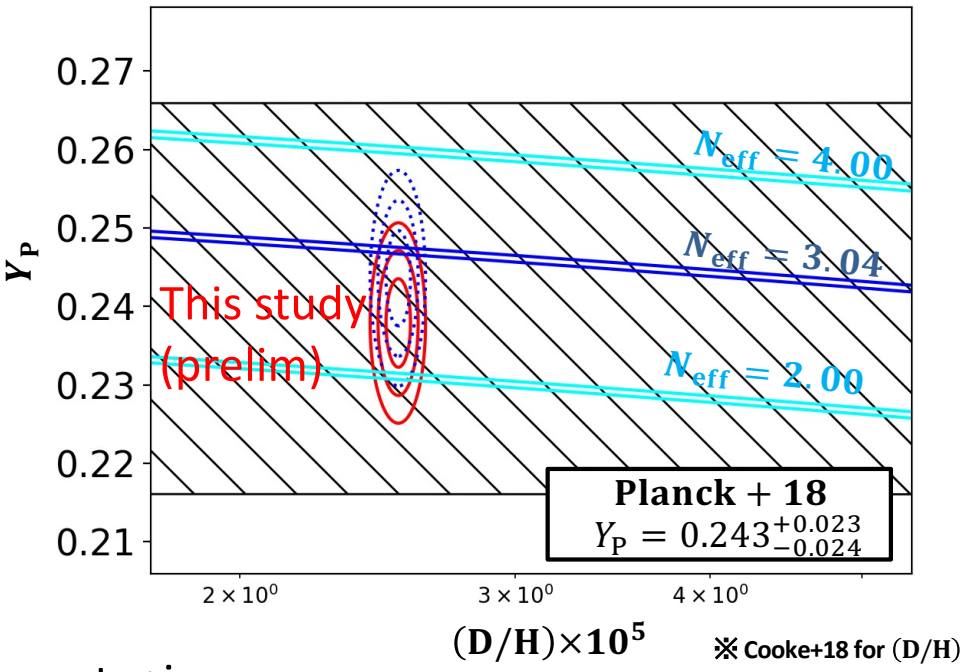




- NIR spec. w IRCS+SWIMS
  - Doubling the number of EMPGs (7+6 EMPGs in total)
- MCMC fitting w 14 hydrogen and He lines
  - 8 nebular param incl. He abundance

Y_p Determination





Matsumoto+in prep.

- He/H is determined -> Y_p = 0.2379+/-0.0037
- Consistent with Planck+18 (+ prev. Y_p), but significantly better than the one of Planck+18
- Relatively small Y_p

Tension with Standard Model?

Summary

- 3D spec (FOCAS/IFU) and NIR spec (IRCS/SWIMS)
  for 30 low-mass EMPGs at z=0.01-0.03 (10 nights)
  - Dynamics & metallicity dist. of EMPGs (Galaxy formation)
  - Primordial He abundance (Cosmology+Particle phys)

- Progress since last April
  - ~1/4 of the obs. completed (1 night was weathered out)
  - Slit-width effect problem of IFU is found and resolved.

- Preliminary results
  - J1631+4426: Extremely gas rich (f_{gas}>99%). Quasi-stable disk.
  - First 7 EMPGs w the existing data → Y_p = 0.2379+/-0.0037.
    - Preliminary results ning Hubble tension?

- Results with better statistics are coming soon!!