KOOLS-IFU followup observations of extremely strong emission line galaxies discovered with Subaru/HSC

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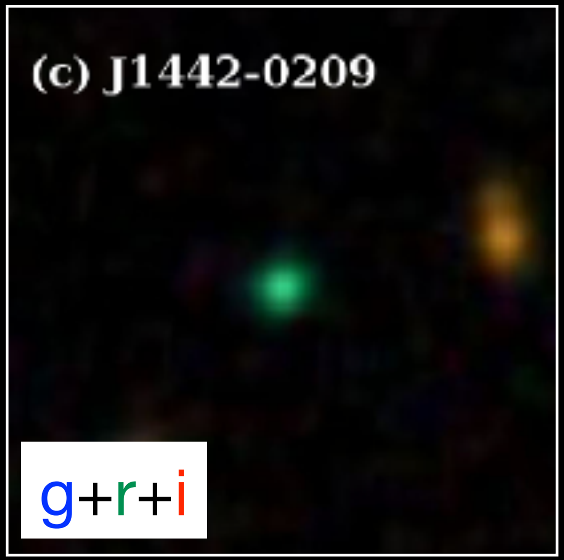
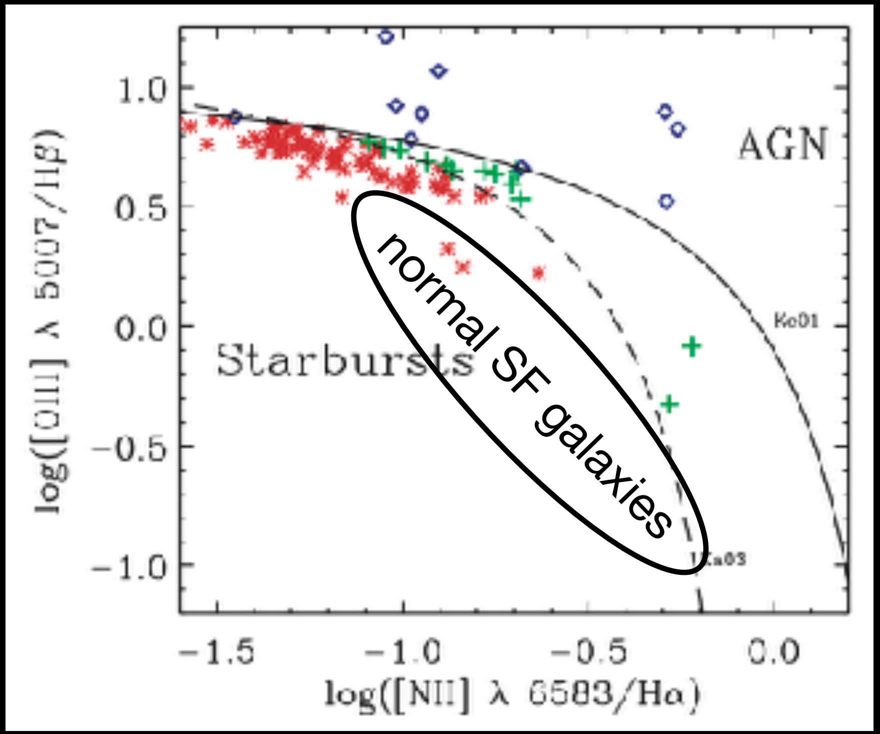
HSC Hyper Suprime-Cam Subaru Strategic Program

Background:

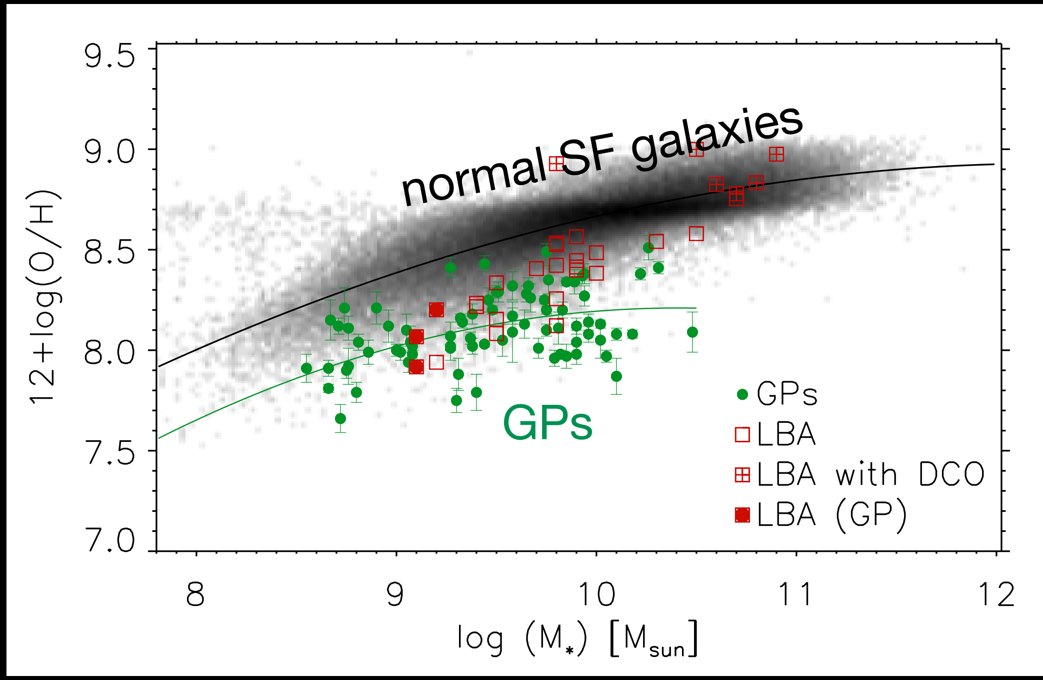
- Low-mass galaxies with strong emission lines
  - Important to understand the formation and evolution galaxies in the early phase
  - Difficult to examine in details at very high redshift
  - Examine similar galaxies at lower redshift
- Narrow/Intermediate band excess galaxies at z<1 (e.g., Kakazu+07, Ly+14, 16)
- Broad band excess galaxies in SDSS sample so-called "Green Pea (GP)" (Cardamone+09)
  - Low stellar mass and high star-formation rate (SFR)
  - High [OIII]/Hβ emission line ratio
  - Metal poor
- Deep and wide Subaru/Hyper Suprime Cam(HSC) data can provide us galaxy sample at higher redshift with lower stellar mass and stronger emission line compared to the SDSS GPs



Izotov+16

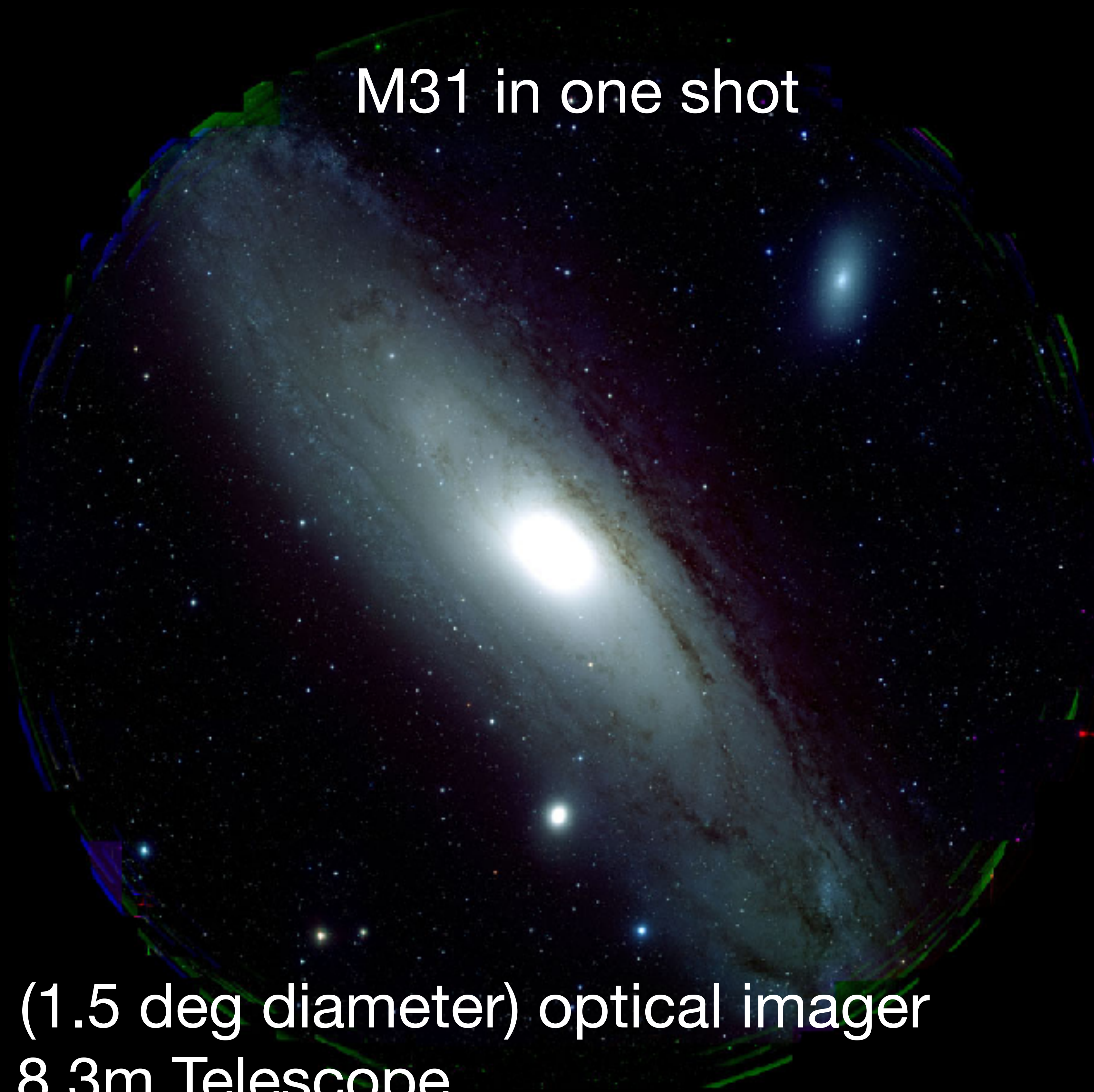


Cardamone+09



Amorin+10

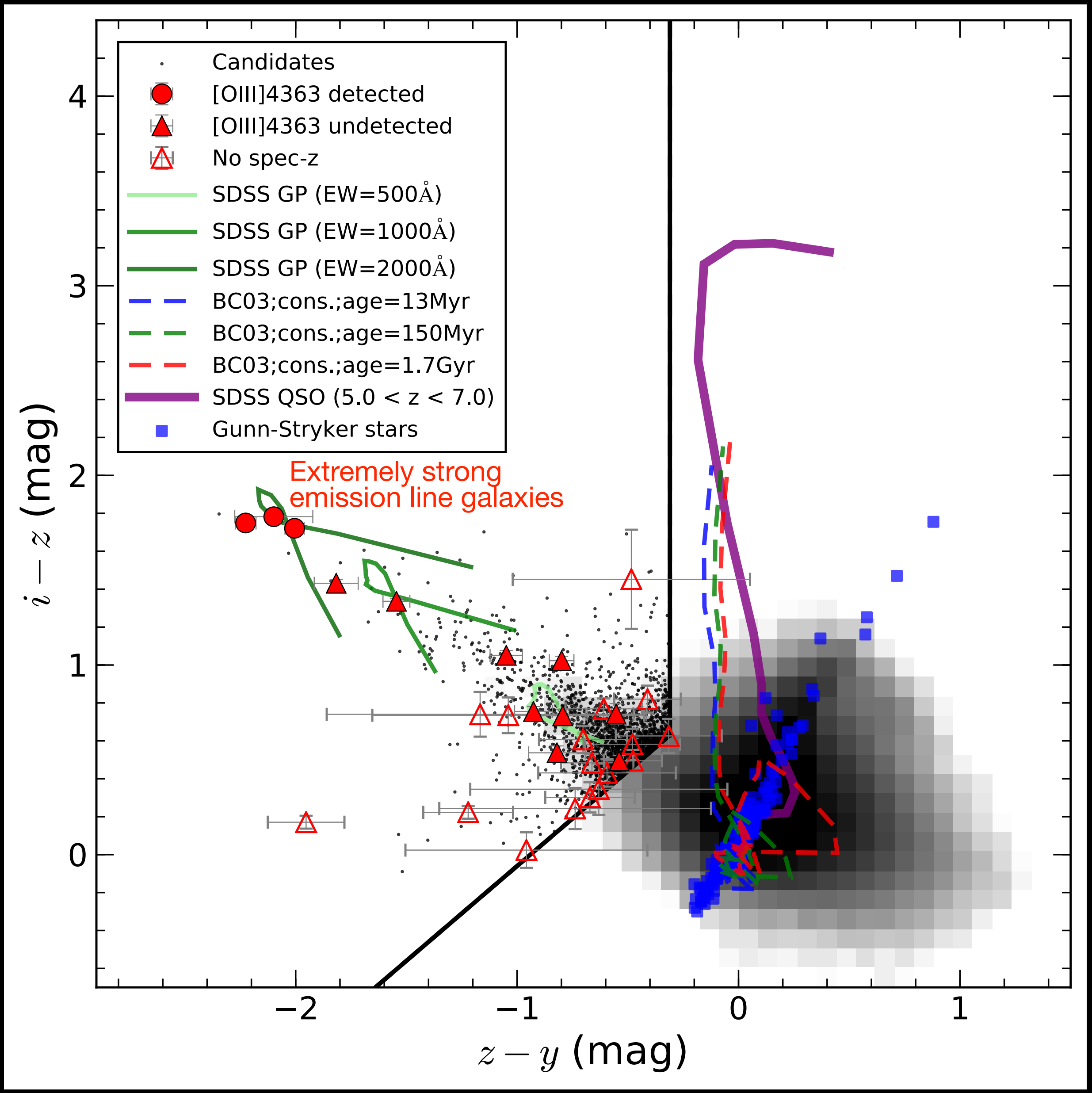
Subaru Hyper Suprime-Cam (HSC):

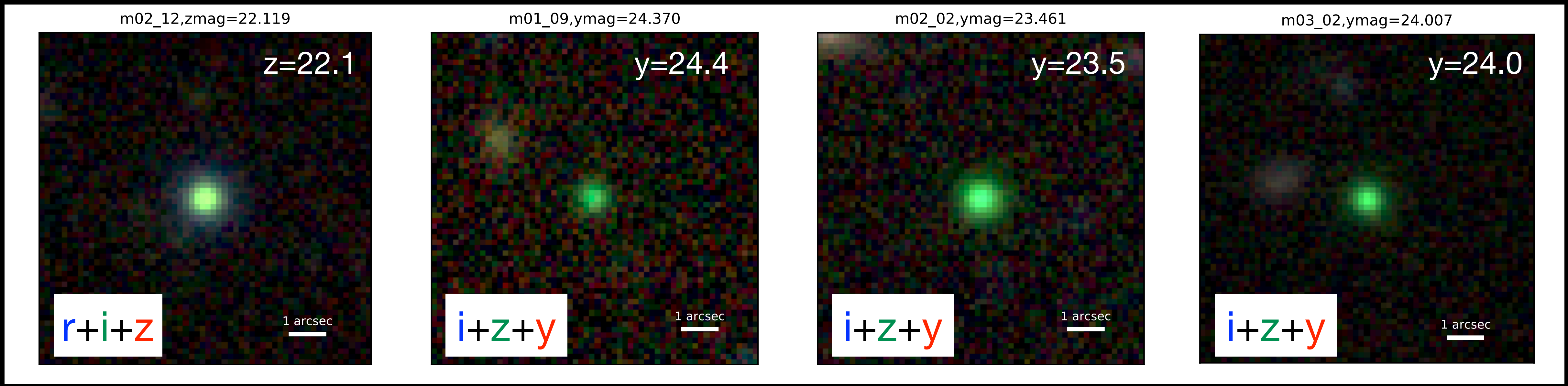


Wide field (1.5 deg diameter) optical imager
of Subaru 8.3m Telescope

Sample selection:

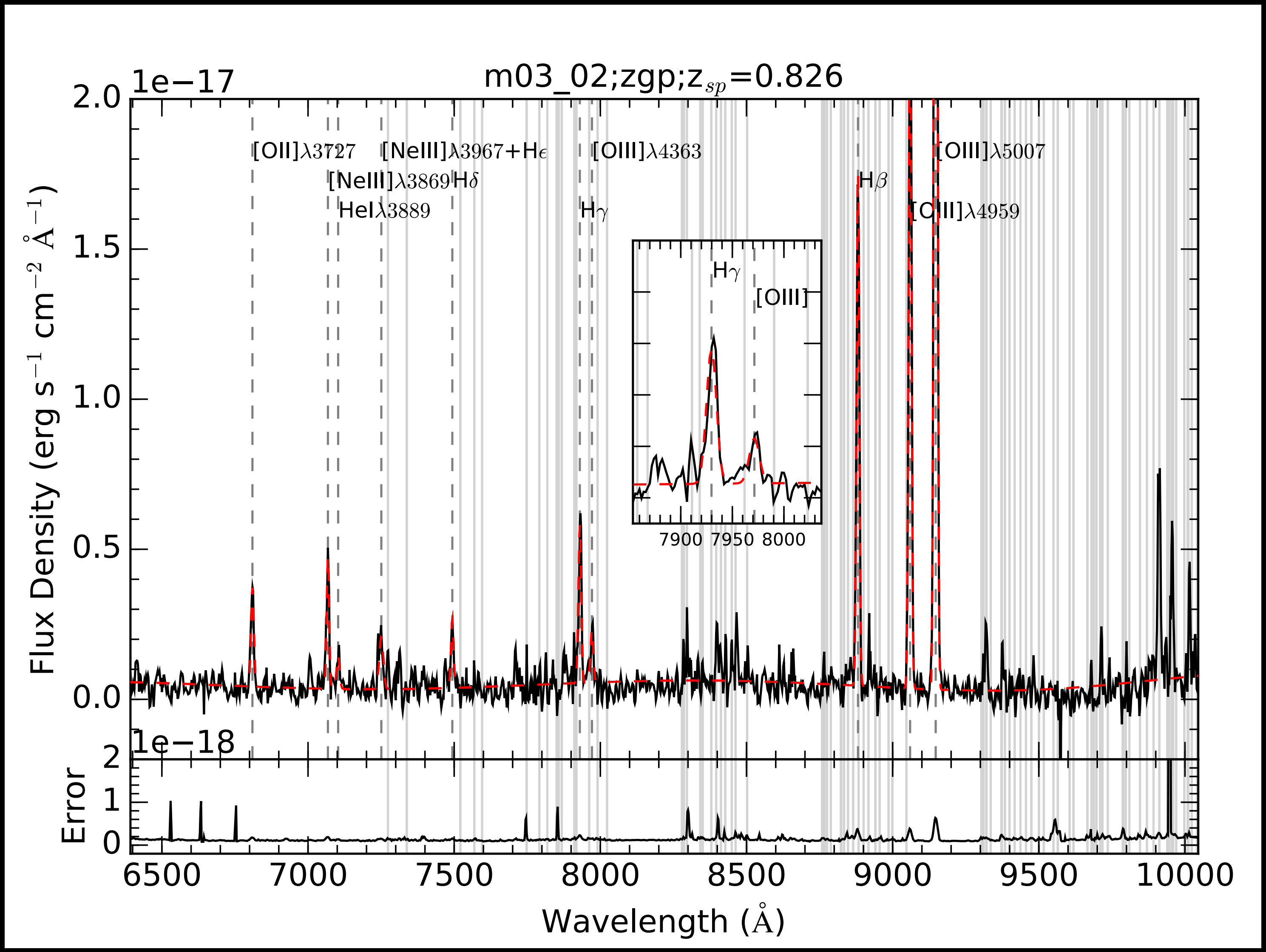
- HSC SSP data (planned)
  - HSC-Wide: ~1400 deg^2, r_{limit}~26 AB
  - HSC-Deep: ~27 deg^2, r_{limit}~27 AB
  - HSC-UltraDeep: ~3 deg^2, r_{limit}~28 AB
  - All 5 broad-band data will be available
- Internal data release (S16a) is used
  - HSC-Wide coverage: ~300 deg^2
- Broad band excess by strong emission lines
  - Similar techniques to SDSS GPs
  - Tentative selection criteria are used
  - i-band excess from r-i vs. i-z (iGPs)
  - z-band excess from i-z vs. z-y (zGPs)
  - z<26 AB (for iGPs) and y<26 AB (for zGPs)
- The rest-frame emission line equivalent width of EW^{rest} > a few x 100 Å
- Very compact (almost point sources)

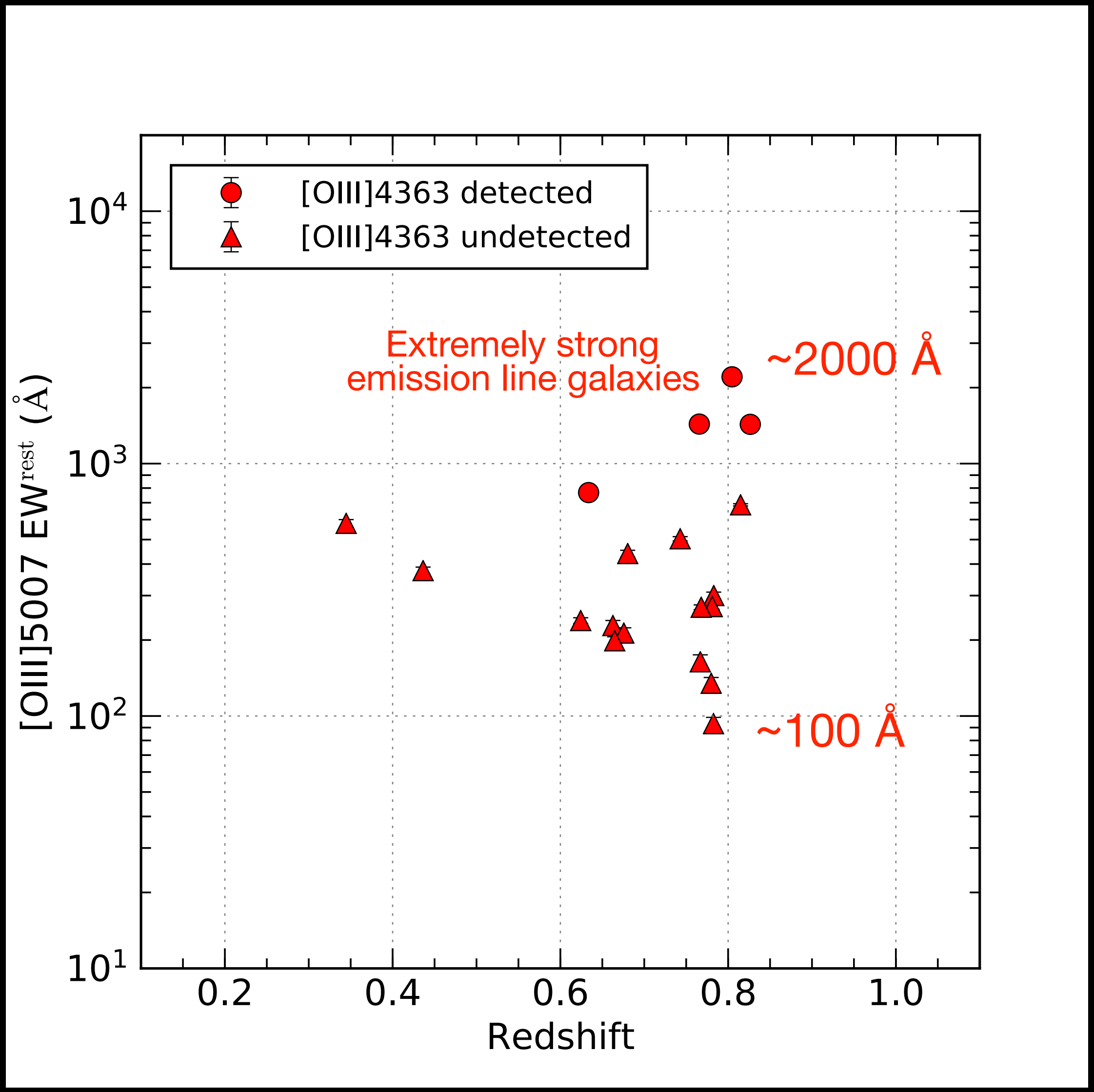




Spectroscopic observation:

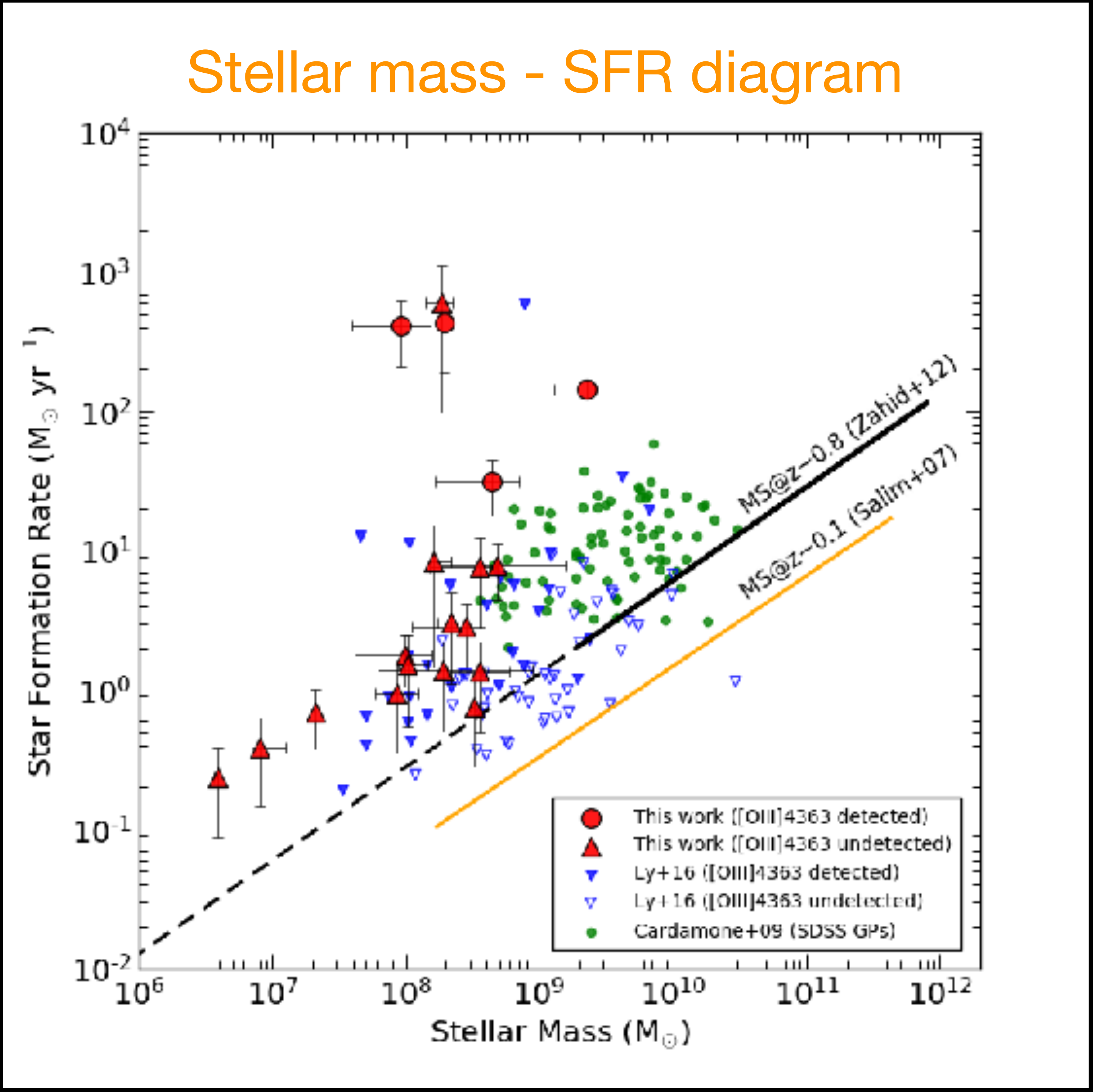
- Spectroscopic observation
  - Gemini/GMOS-S (in Gemini Fast Turnaround program)
  - R150_G5326 (R~700), λ=5000-10000Å, MOS mode
  - Total on-source exposure time of each object is 3600 sec.
  - 40 objects were observed in total
- Detected multiple emission lines from 19 objects at z=0.3-0.85
- A weak [OIII]λ4363 emission line is detected significantly from 4 objects
- [OIII]λ5007 EW^{rest} is 100 Å - 2000 Å (extremely strong emission line)





Stellar mass and star formation rate:

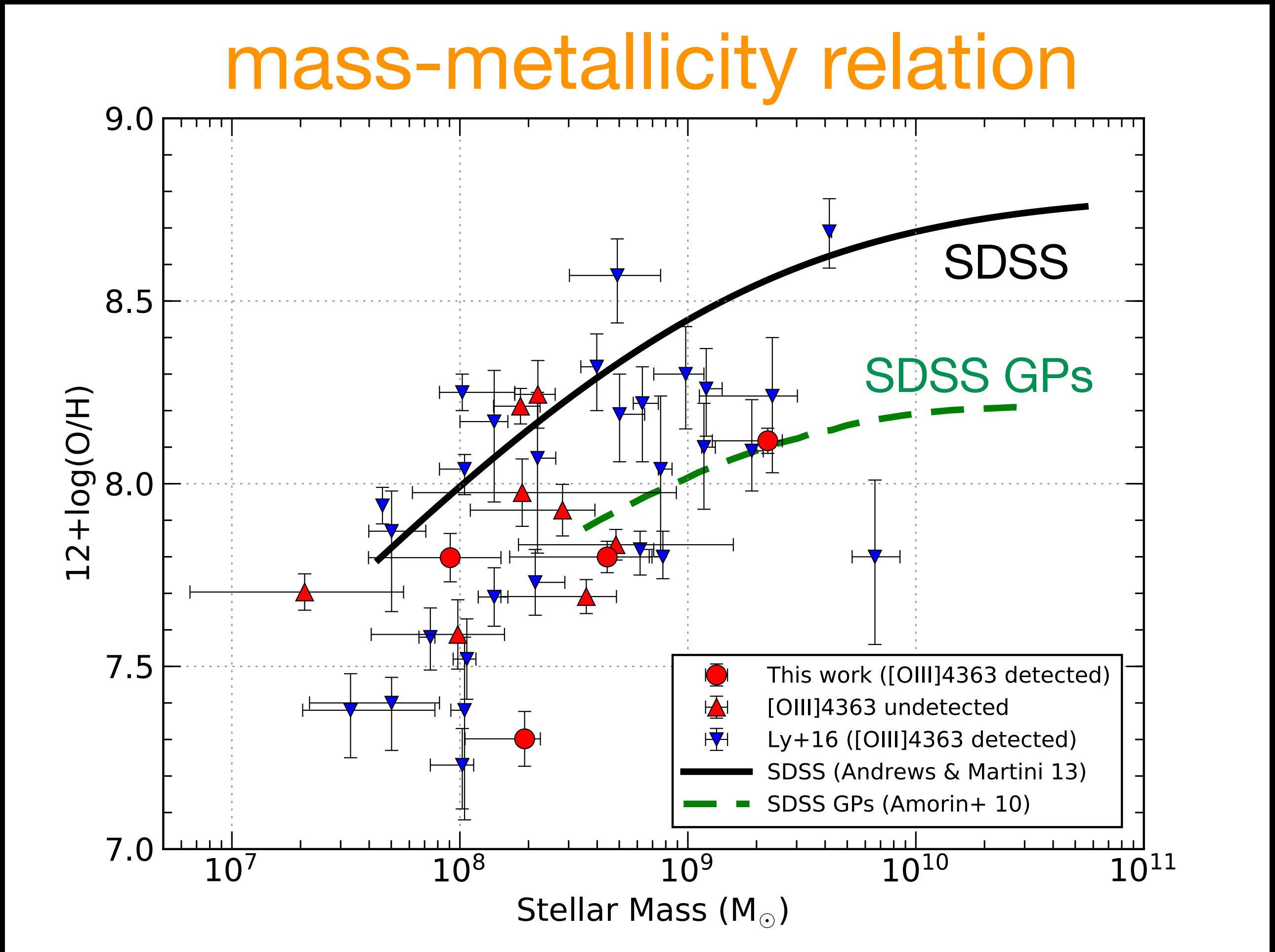
- Stellar mass is derived from SED fittings using broad-band photometry after subtracting the contribution from the emission lines
- Dust extinction is derived from Balmer decrements using Hβ, Hγ, Hδ if possible
- Star formation rate (SFR) is derived from the extinction corrected Hβ luminosity

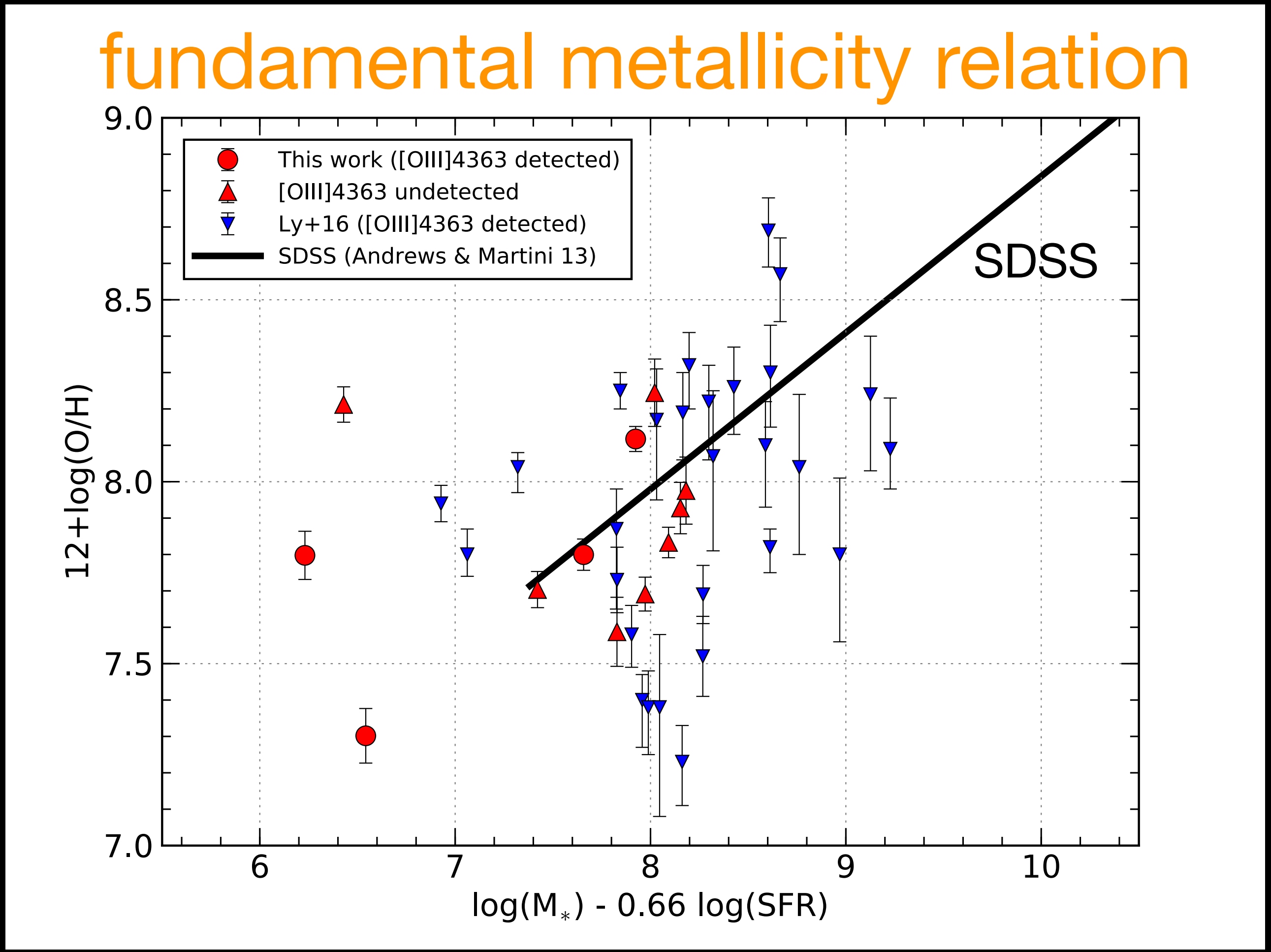


- Stellar mass vs. SFR diagram (so-called main sequence of galaxies)
- Our sample shows higher SFR by up to 1000x compared to normal star-forming galaxies at the similar redshift

Oxygen abundance:

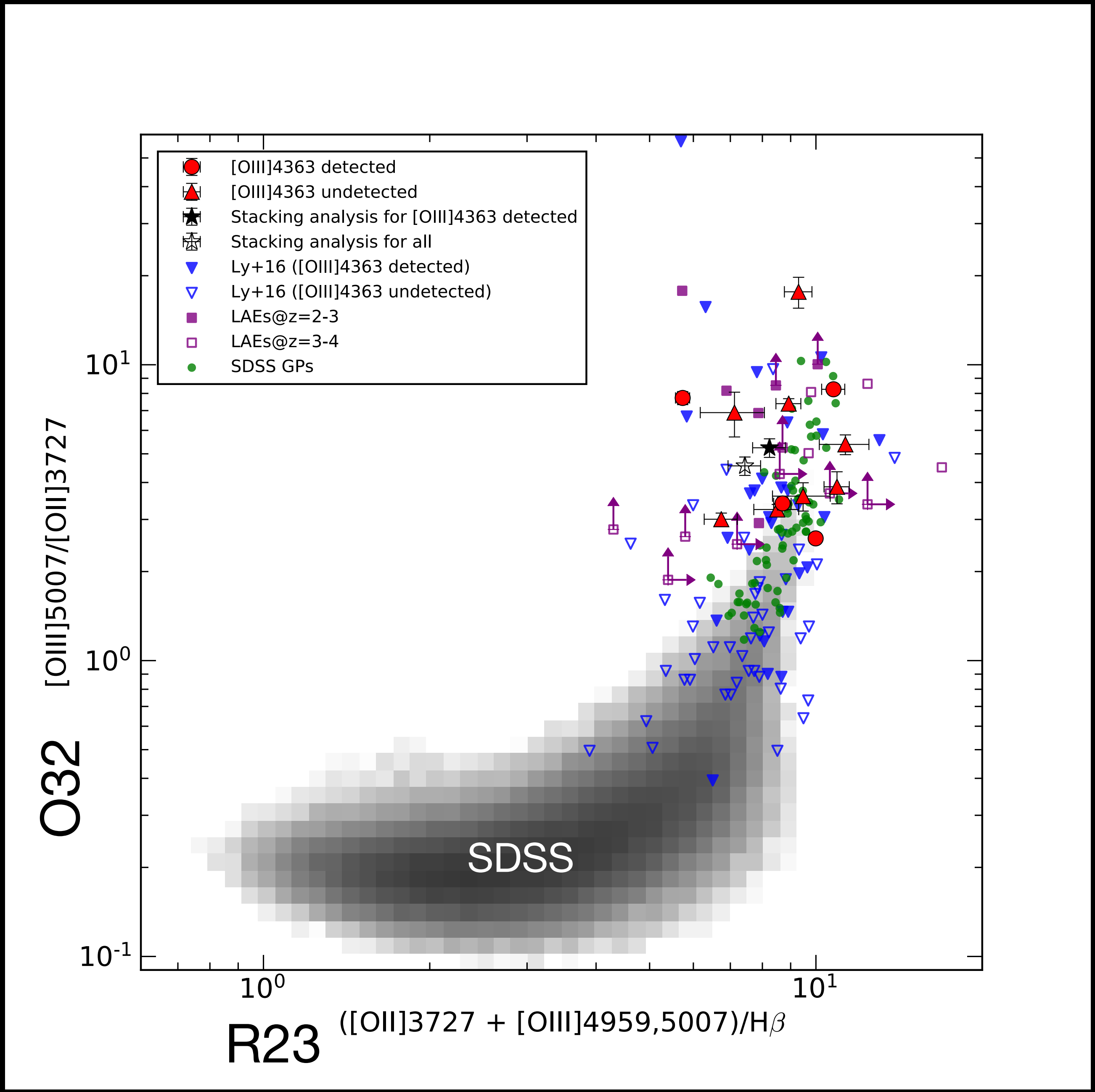
- The "direct" method for gas phase metallicity measurements if [OIII]λ4363 is detected
  - Electron temperature measured from [OIII]λ4363/[OIII]λ5007
  - We follow Izotov+06 for the "direct" method
- The "strong line" method if [OIII]λ4363 is not detected
  - KK04 (Kobulnicky&Kewley04; theoretical approach) is used (R23 indicator)
  - ~0.3-0.7 dex overestimated compared to the "direct" method --> correction
- The oxygen abundance of our sample: 7.3 (extremely metal poor) < 12+log(O/H) < 8.3
- The mass-metallicity relation (MZR) is the extension of the MZR of the SDSS GPs towards lower stellar mass
- The fundamental metallicity relation (FMR; SFR dependence of the MZR) is in rough agreement with the local (SDSS) FMR

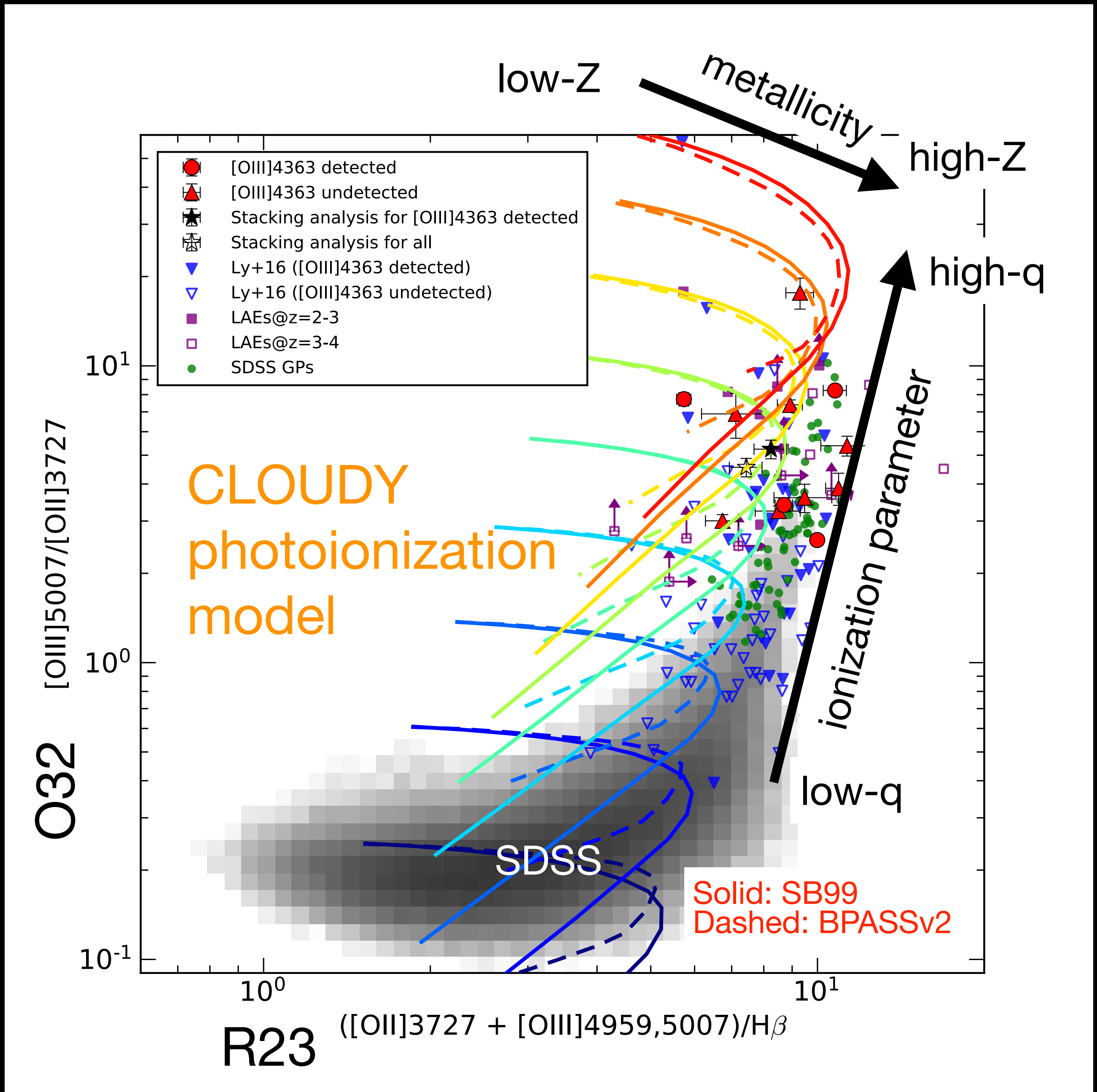




Ionization state:

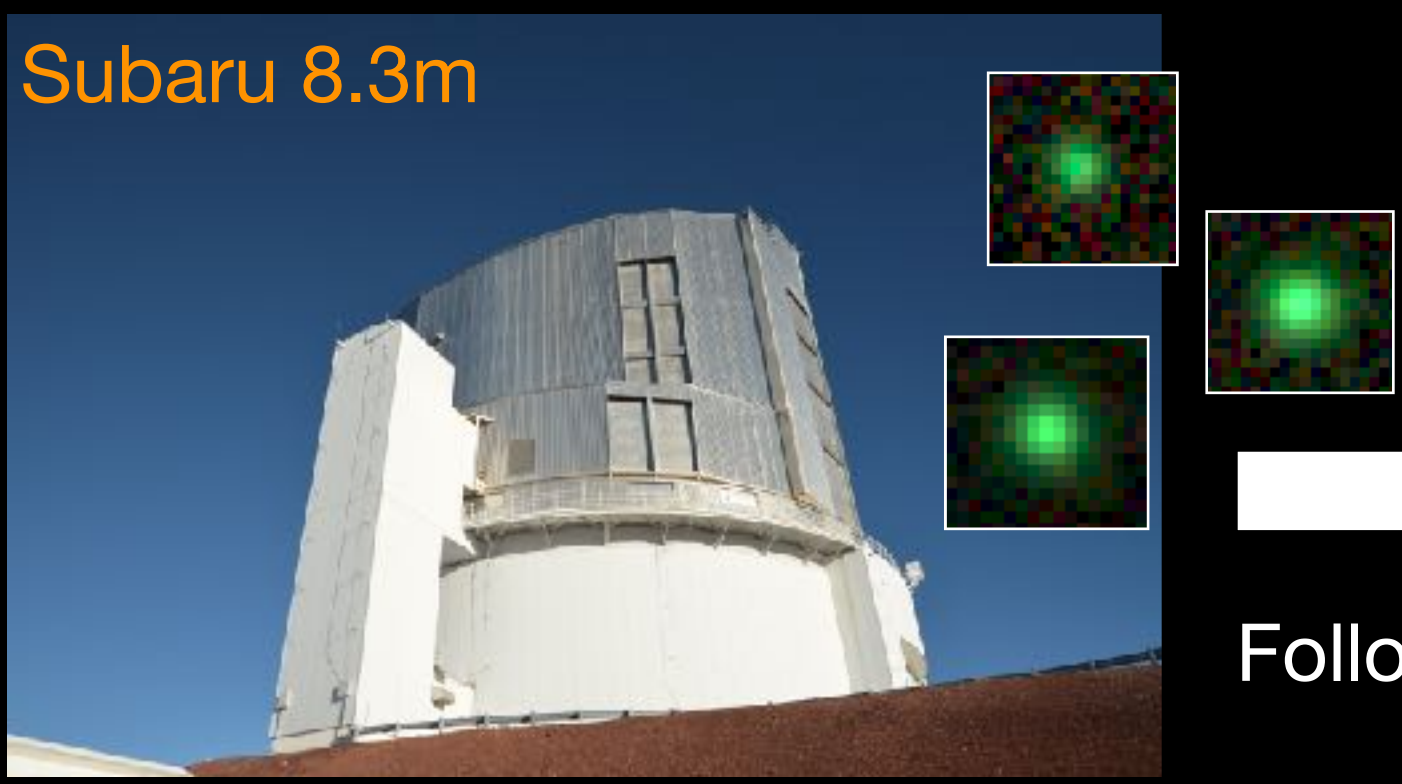
- Ionization diagnostics by using emission line ratios
  - R23 index (metallicity) vs. O32 index (ionization parameter)
  - Our sample is very high [OIII]λ5007/[OII]λ3727 ratio, which is comparable or higher than that of the SDSS GPs and other emission line galaxies at the similar redshift
  - The high [OIII]λ5007/[OII]λ3727 is originated from high ionization parameter
  - The high ionization parameter of our sample may be due to high SF activity?



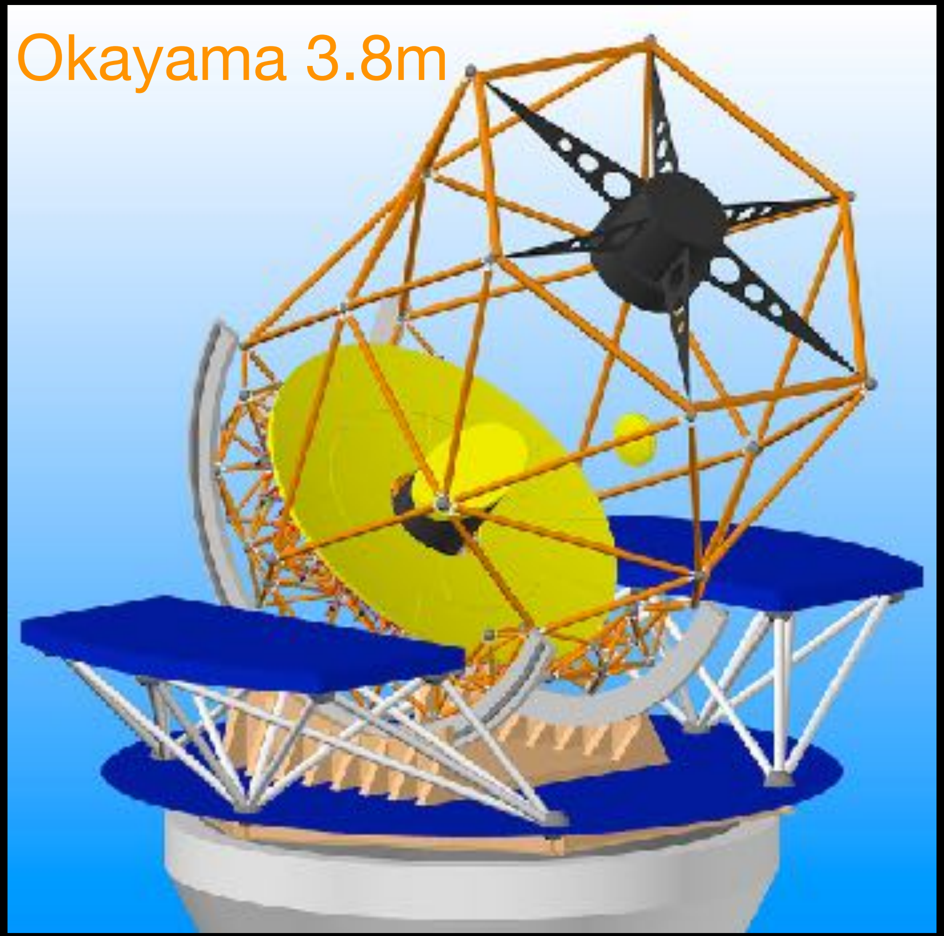


Follow up observations with 3.8m KOOLS-IFU:

- A normal way of follow-up observations may be:
  - Find out interesting objects by using small/middle-class telescopes
  - Observe them by using larger telescopes
- We take an opposite strategy to observe interesting objects (strong emission line galaxies) found with an 8m-class telescope (Subaru) and a wide FoV camera (HSC) by using a smaller telescope (3.8m telescope)
- Optical instruments of large telescope are very competitive
- The advantage of our sample is that they are very bright emission line galaxies
- Because they are "rare" objects with very low density (~1 deg^{-2} for extremely strong emission line galaxies) on the sky, we do not need MOS

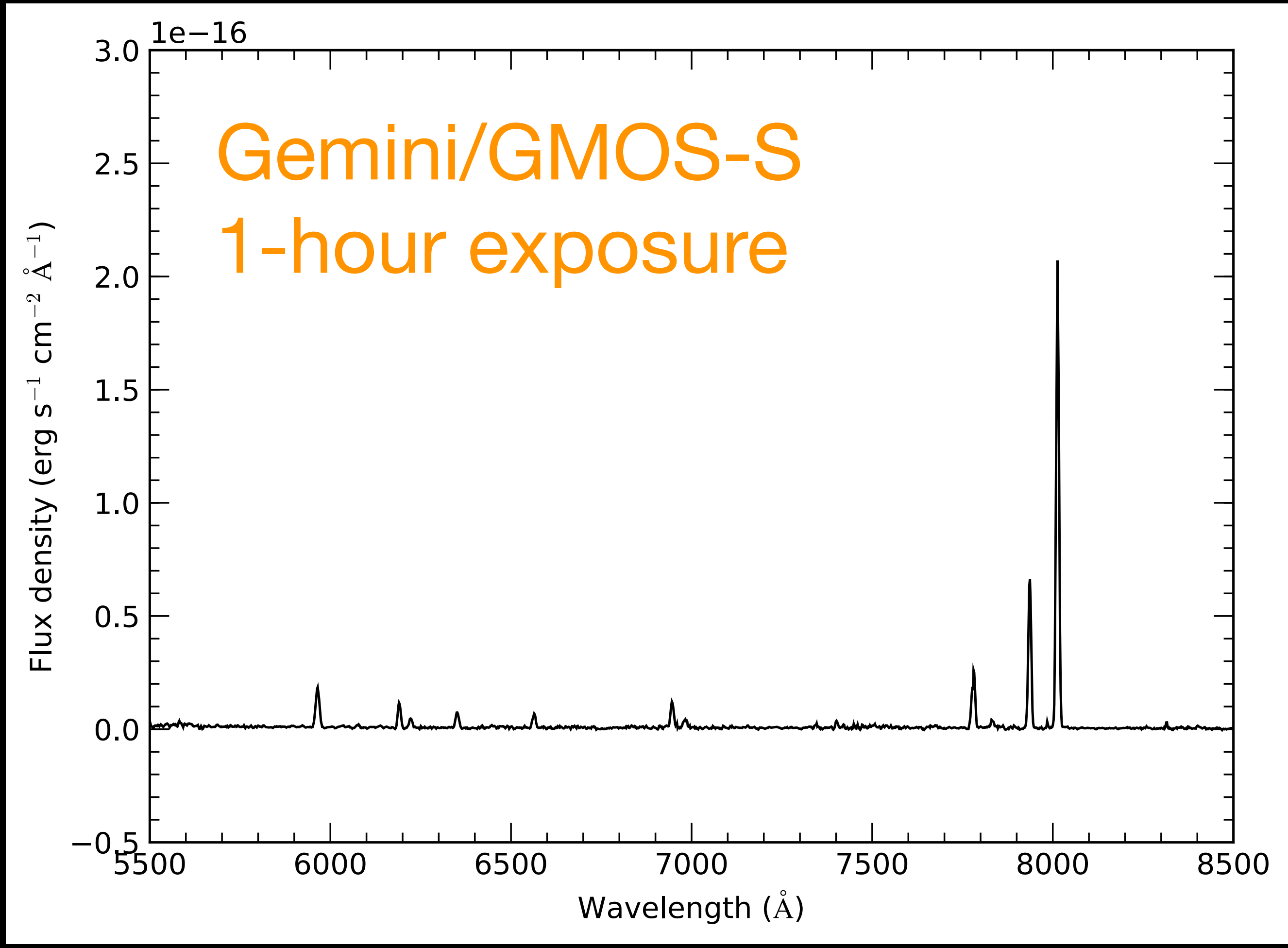


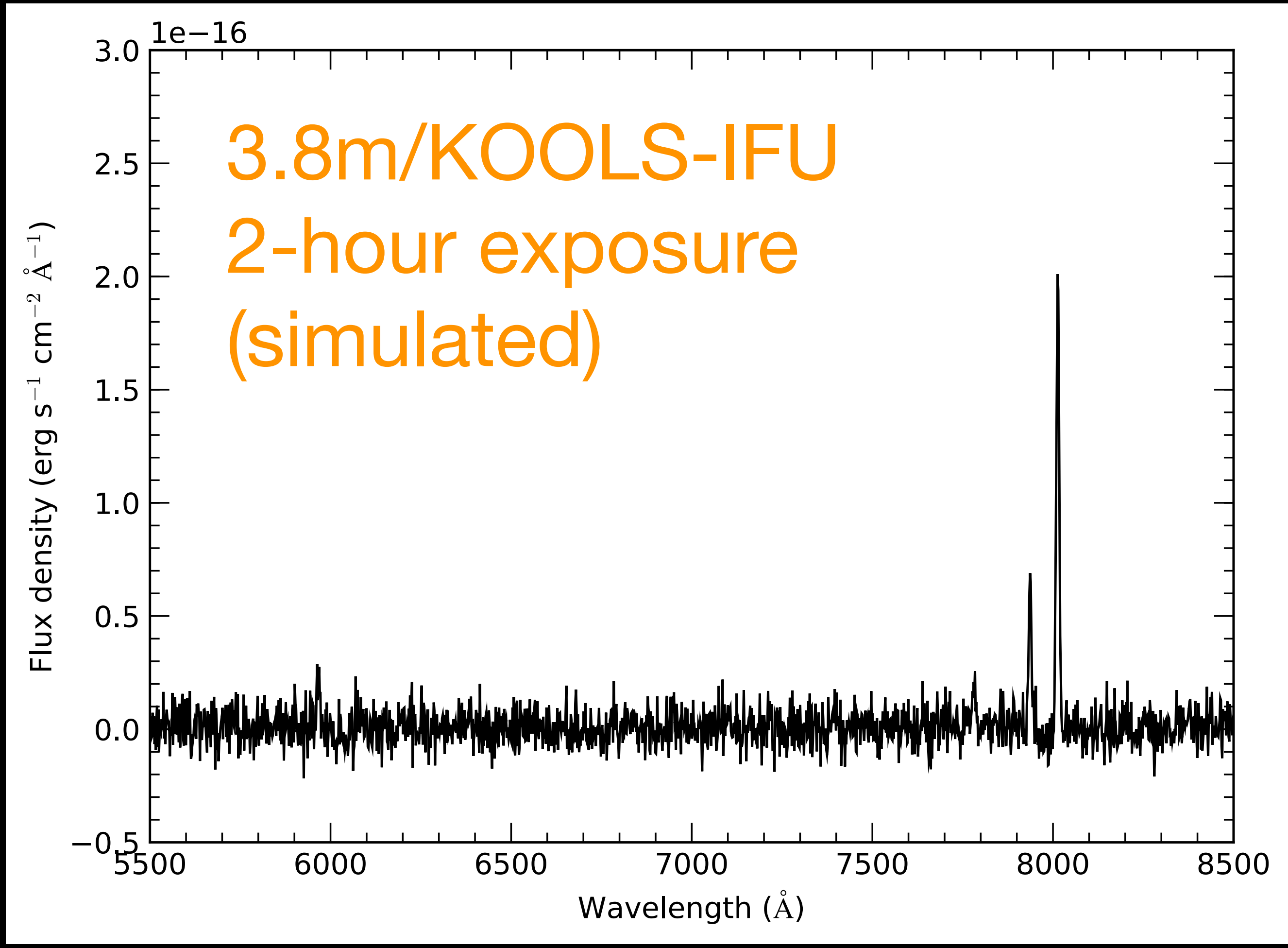
Follow-up



Follow up observations with 3.8m KOOLS-IFU:

- Specification of 3.8m/KOOLS-IFU
  - IFU unit with 127 fibers (but our targets are basically point sources)
  - Wavelength coverage: 4000 - 9000 Å
  - Resolution: R~400-1600
  - Sensitivity: $\sim3\times10^{-16}$ erg s^{-1} cm^{-2} (1 hour, S/N=5)
- Simulated spectrum of a bright zGP at z=0.6
- We will plan to use No.2 grism (λ=5000-9000Å, R~700)
- We will detect [OII]λ3727 (S/N~7), Hβ (S/N~6), [OIII]λ5007 (S/N~55) in 2-hour exposure
- In 10 nights, we will observe 30 objects in total (25% overheads are assumed), which expands our sample of extremely strong emission line galaxies by a factor of ~10





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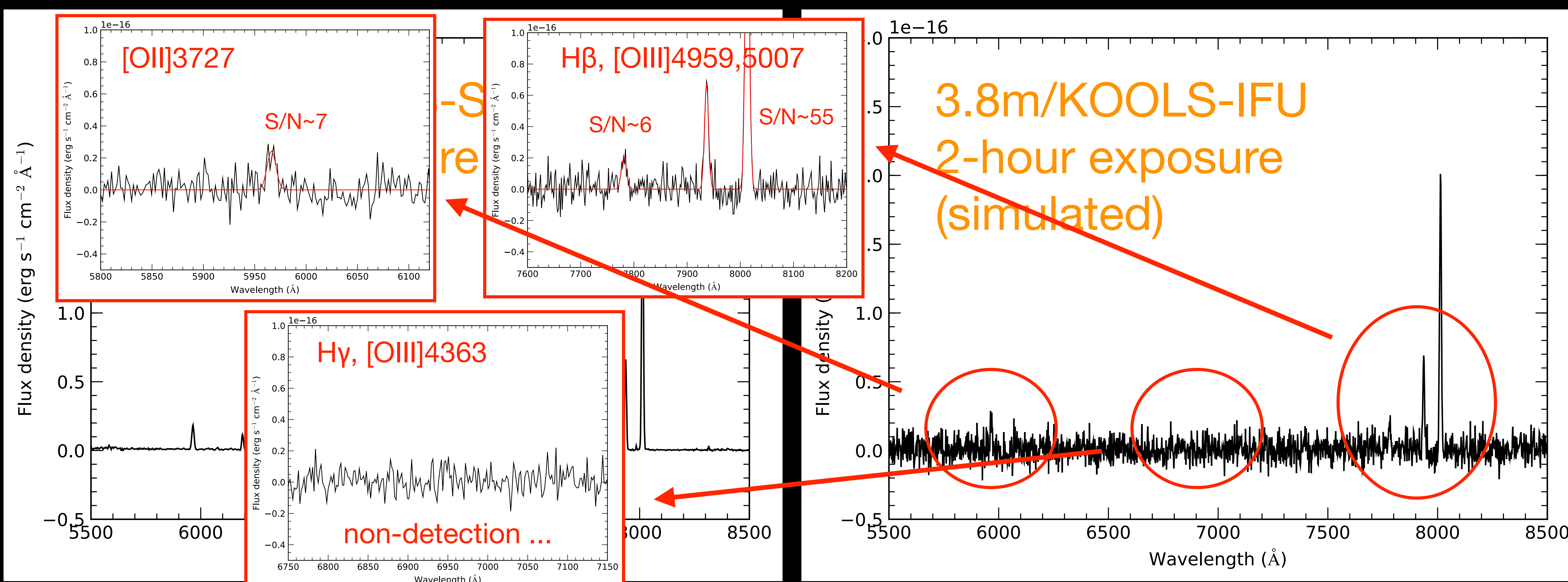

Summary:

- Extremely strong emission line galaxies discovered by using Subaru/HSC
- Follow up observation by using Gemini/GMOS-S to examine detailed properties
  - Very low-mass and high SFR
  - Metal poor comparable to local extremely metal poor galaxies
  - High [OIII]λ5007/Hβ and [OIII]λ5007/[OII]λ3727 indicating high ionization parameter
- Because they are very bright, these galaxies will be a good target for 3.8m/KOOLS-IFU
- We expect to detect some lines ([OII]λ3727, Hβ, [OIII]λ4959,5007) in 2-hour exposure
- We can expand our existing sample by a factor of ~10