

The Mass-Metallicity Relation of High- z Type-2 AGNs



An artist's impression of the quasar 3C 279. Credit: ESO/M. Kornmesser

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Introduction

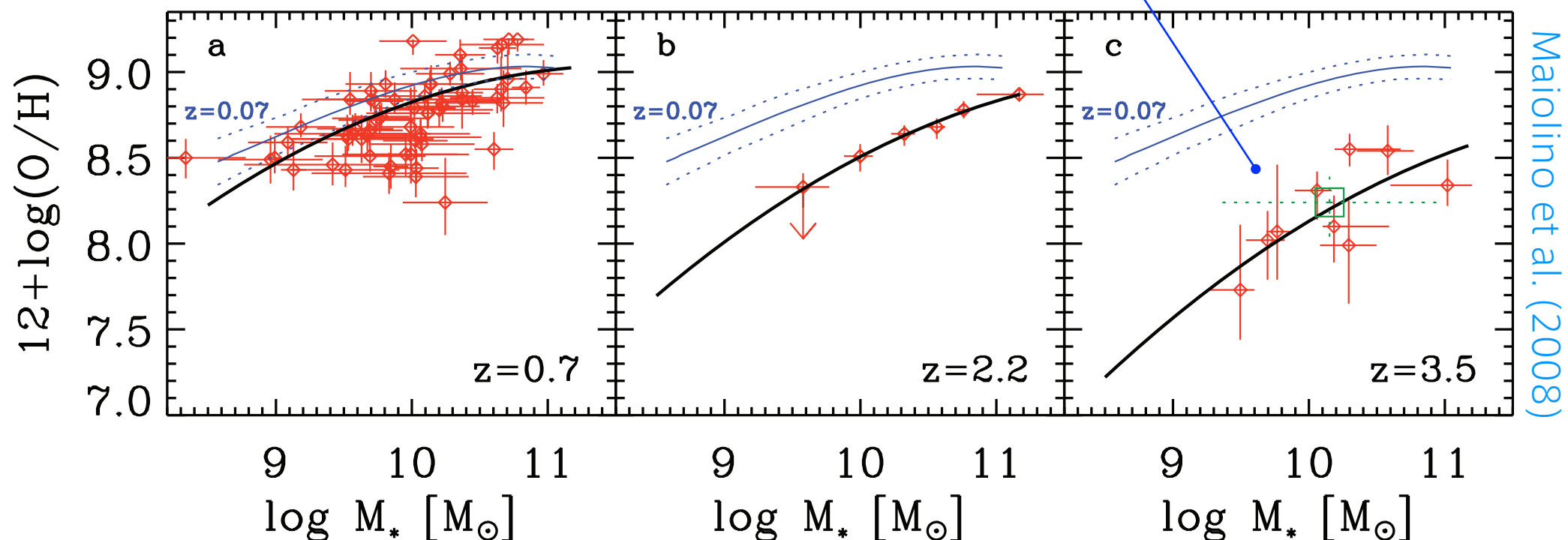
■ Metals in the universe

Chemical properties are one of the most important clues to understand the galaxy formation and evolution, since **metals** are produced through their past star formation.

■ Metallicities of star-forming galaxies

Gas metallicities of star-forming (SF) galaxies have been studied by adopting **optical emission-line diagnostics** (e.g., [Pagel et al. 1979](#); [Nagao et al. 2006](#)). However, such diagnostics are difficult in the early universe, because those emission lines are often very faint and redshifted into infrared (IR) range.

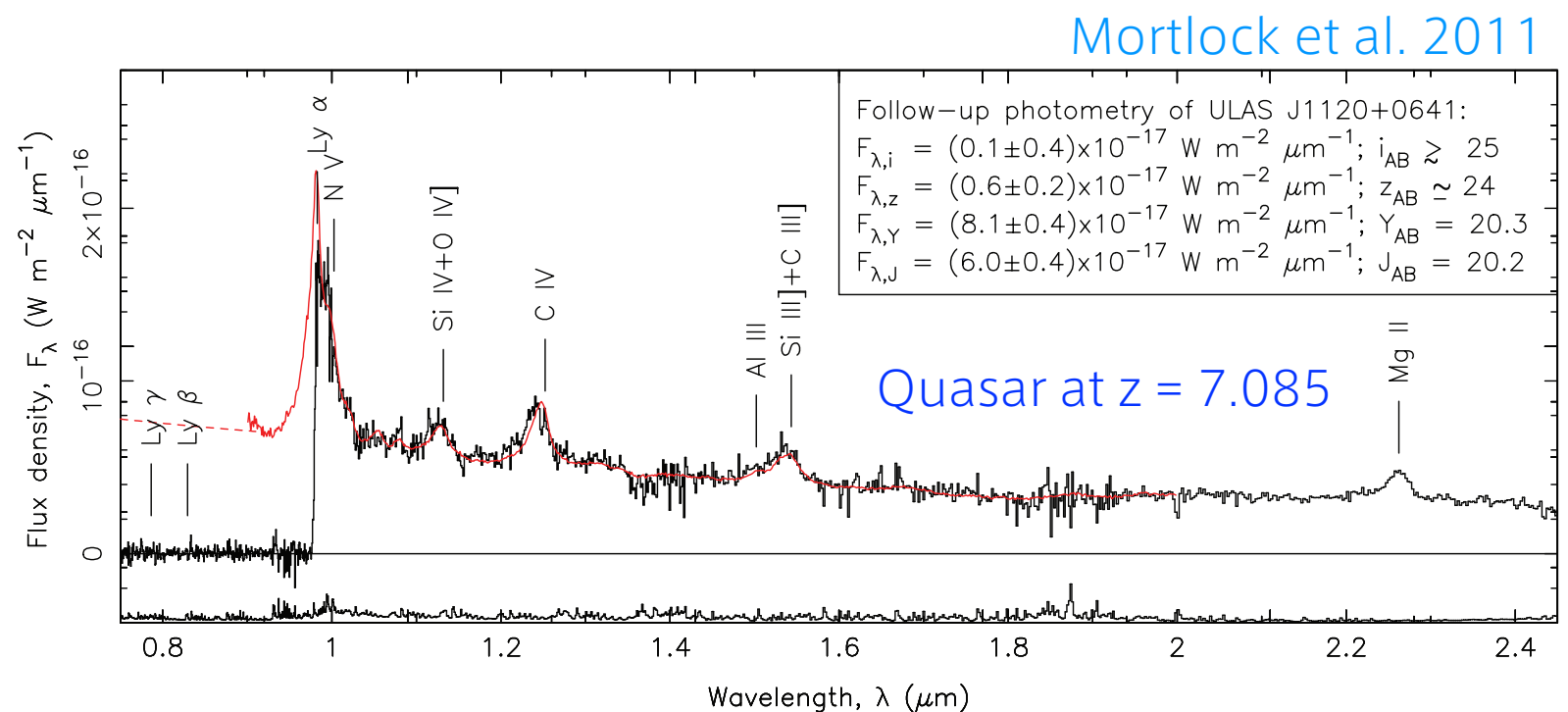
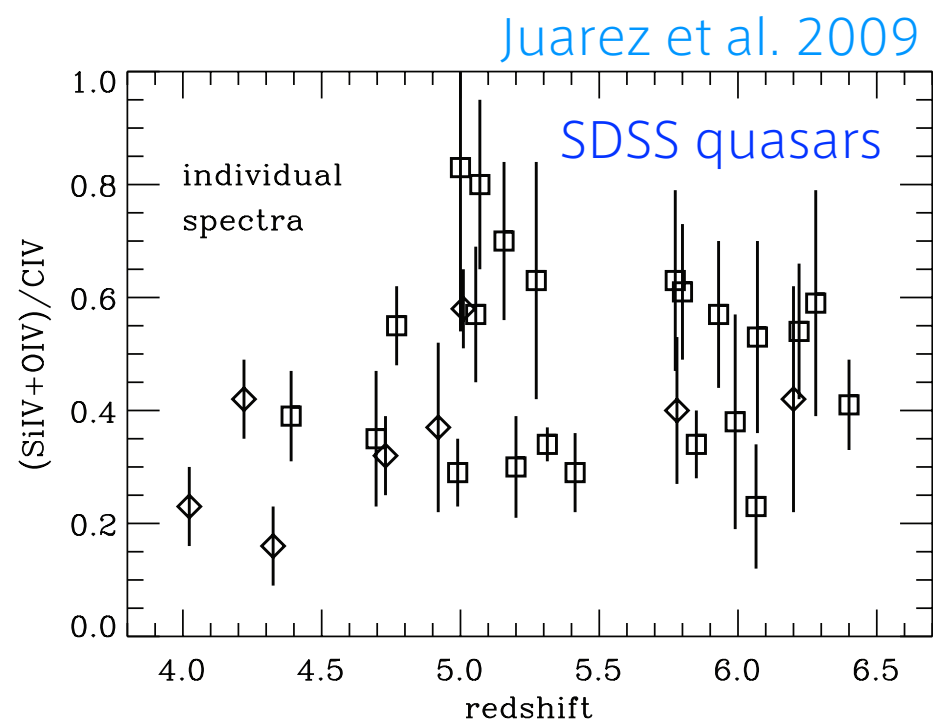
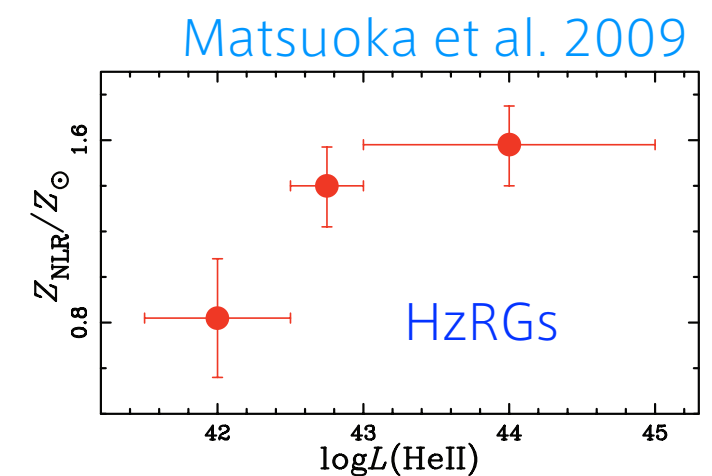
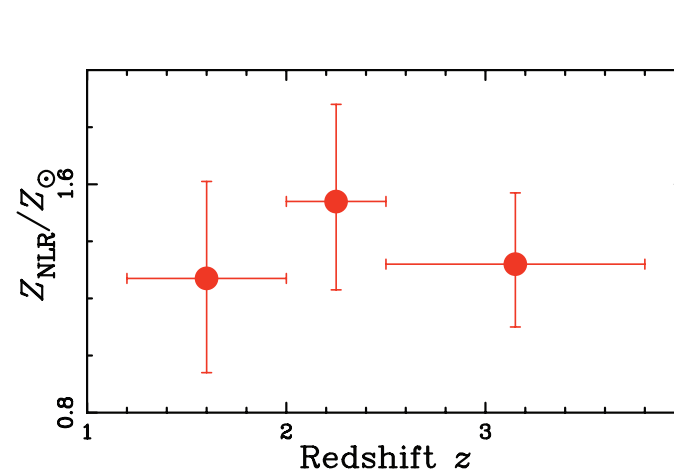
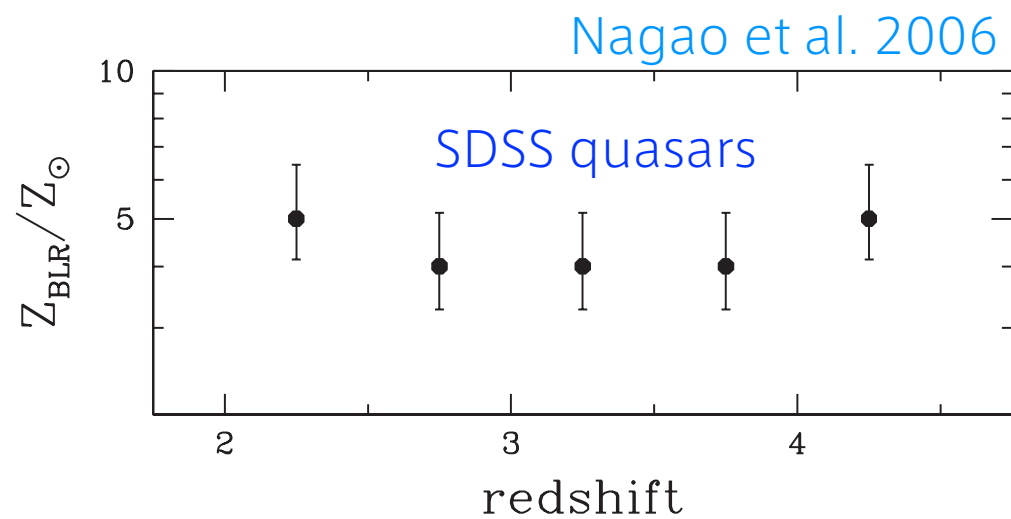
Very deep IR observations are needed!



Metallicities at High Redshift

AGN gas metallicities

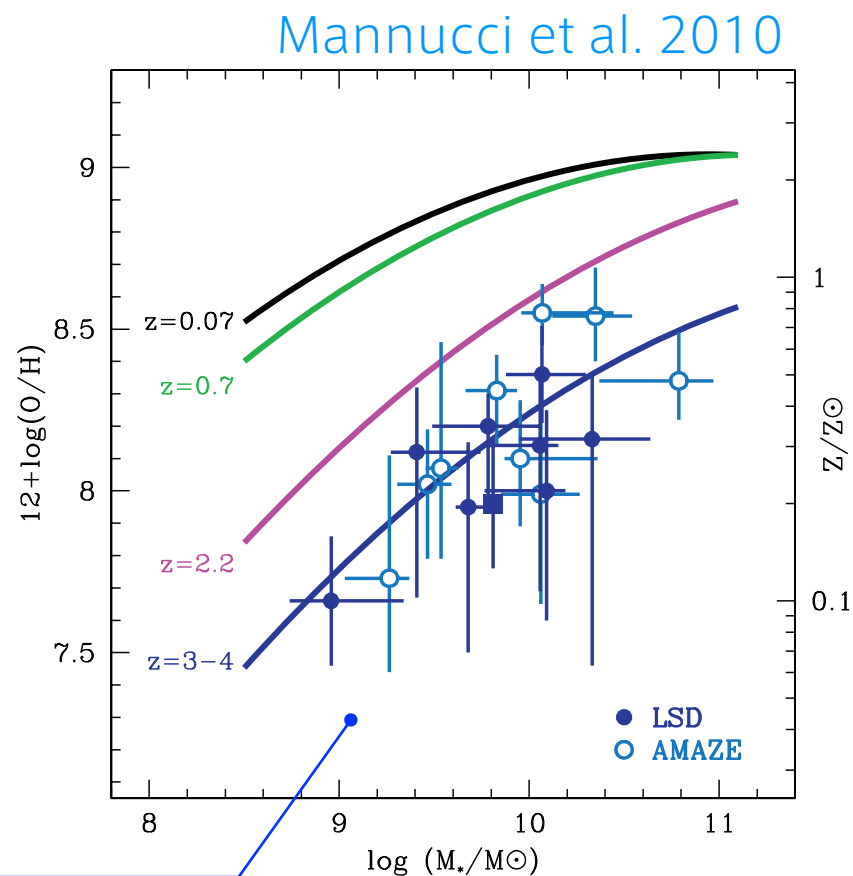
An alternative way to measure high- z metallicities is by focusing on the active galactic nucleus (AGN). Its **huge luminosity** and **various ultraviolet emission lines** allow us to investigate metallicities in the early universe.



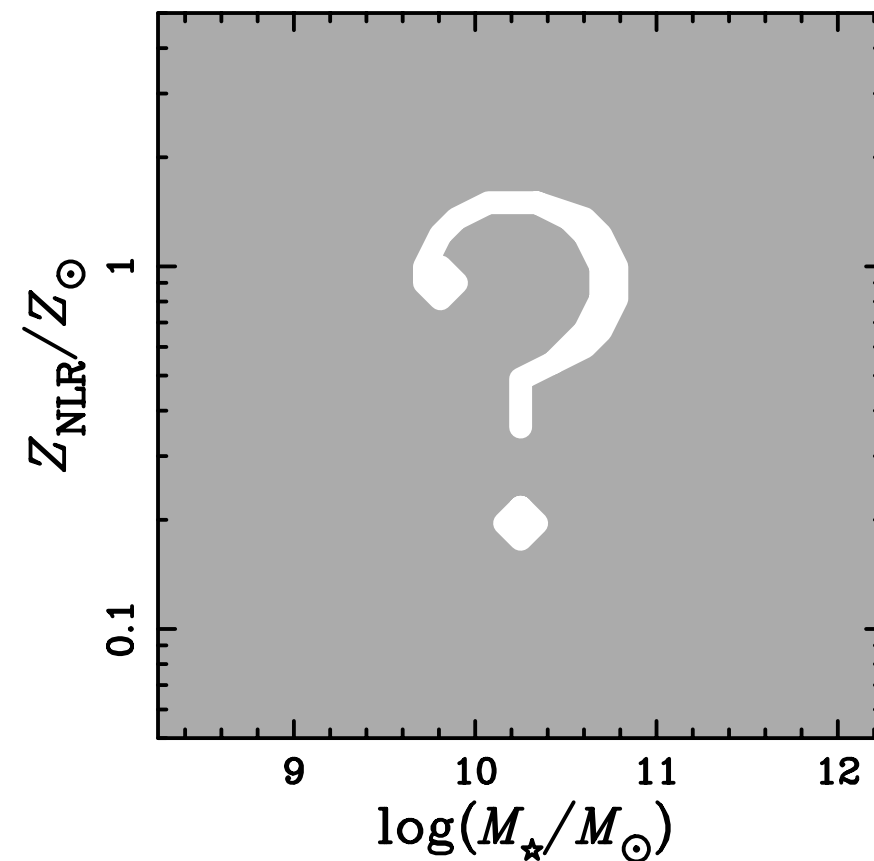
Concern

■ Metallicities of AGNs and galaxies

We usually assume that AGN metallicity would trace chemical properties of their host galaxies. But, this is not clear. In this study, **we focus on narrow-line regions (NLRs) of type-2 AGNs and investigate their metallicities as a function of stellar masses.**



The M-Z relation
of SF galaxies

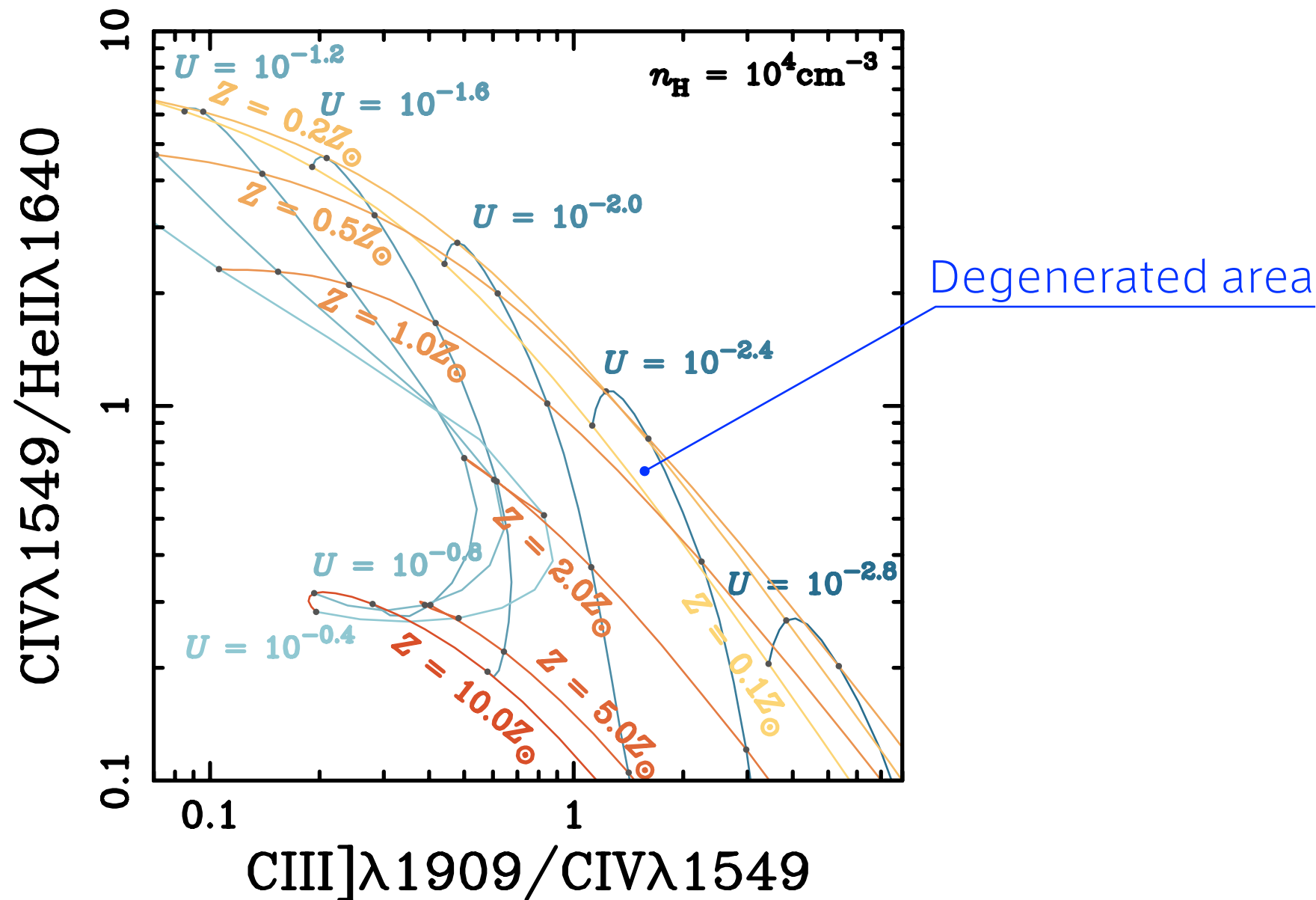


And, we compare them with the M-Z relation of SF galaxies to examine **how NLR metallicities trace those of host galaxies.**

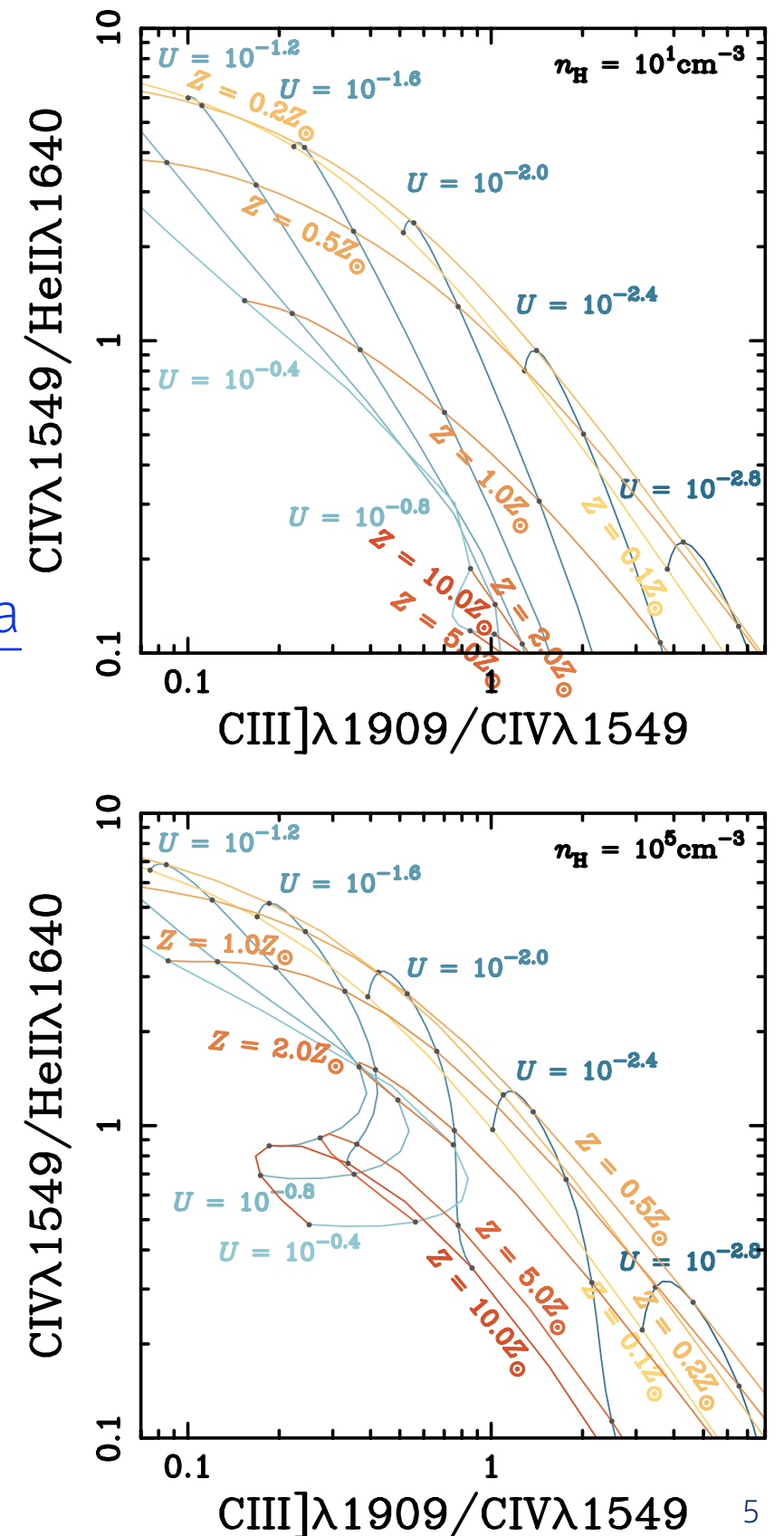
Photoionization Models

Cloudy (C17.00)

To infer the NLR metallicity, we carried out model calculations by using the photoionization code Cloudy (Ferland et al. 1998).



By comparing observed emission line flux ratios with model predictions, we estimate NLR metallicities.



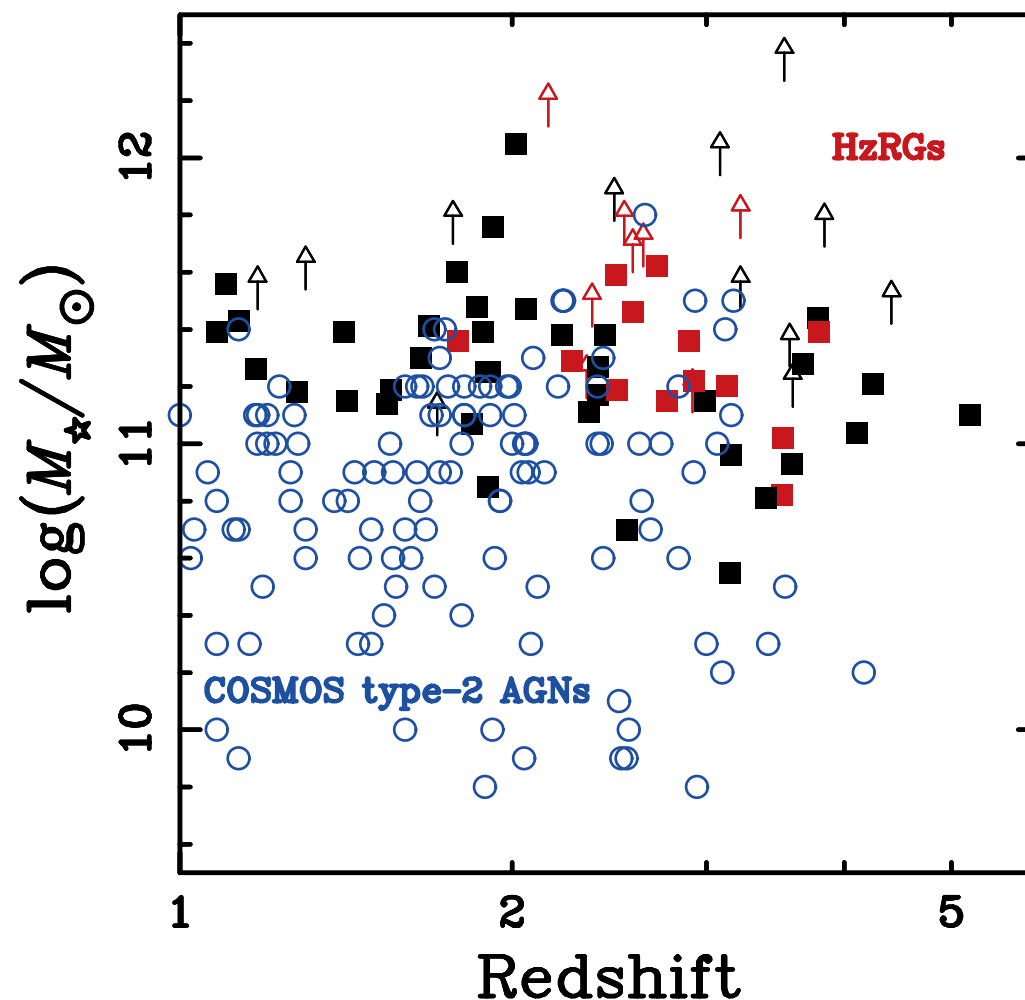
Sample

■ High-z radio galaxies

Previous studies about NLR metallicities have been done by using type-2 AGNs, especially high-z radio galaxies (HzRGs) which can be found easily with radio at high redshift. However, they are massive ellipticals...

■ COSMOS X-ray selected type-2 AGNs

In order to increase low-mass sample, we also focus on X-ray selected type-2 AGNs in the COSMOS field ([Mainieri et al. 2011](#)) in addition to HzRGs.



Observations

■ Optical spectroscopic observations

We observed 9 X-ray selected type-2 AGNs using the Faint Object Camera and Spectrograph (FOCAS) installed at the Cassegrain focus of Subaru Telescope.

Date: 24 – 25 Dec. 2012 (S13B-019: 2 nights),
29 Dec. – 01 Jan. 2014 (S14B-003: 4 half nights)

MOS mode: slit width of 0.8"

R300 grism & SY47 filter : 4900 – 9100Å ($R \sim 500$)

Redshift: $2.2 < z < 3.6$

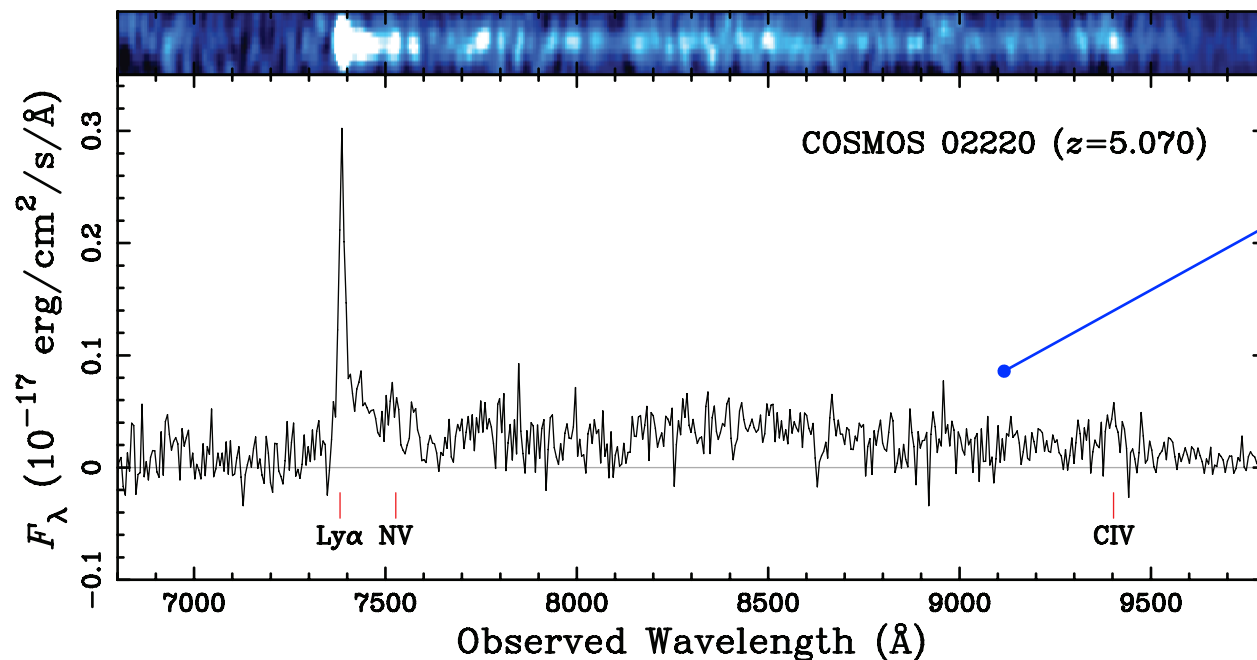
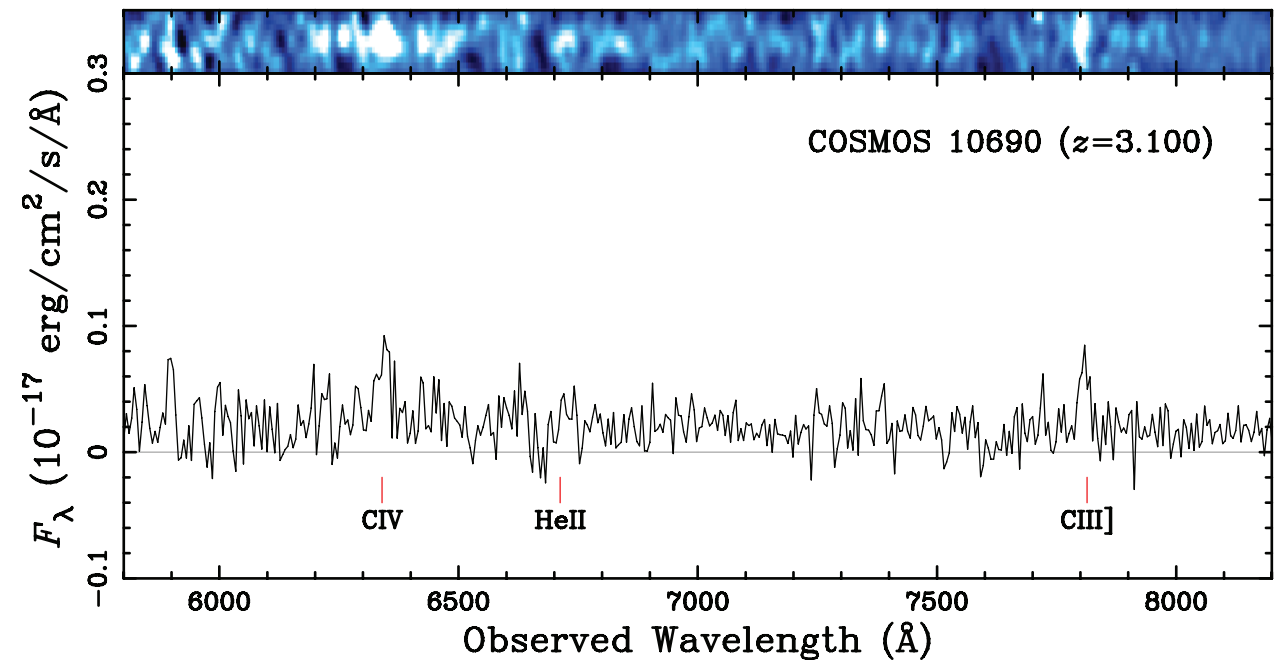
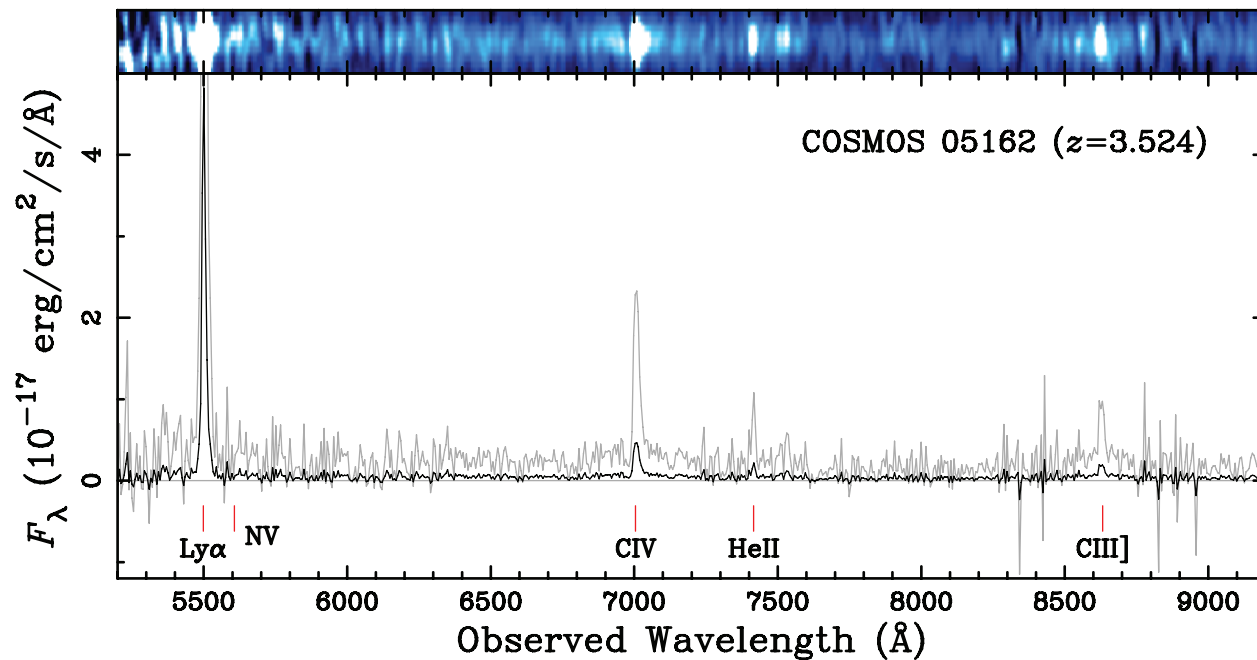
Typical exposure time: ~ 6600 s (1.8 hrs)



Observational Results

■ Optical spectra

We could obtain rest-frame UV spectra for three type-2 AGNs. Unfortunately, the remains cannot be identified as high- z type-2 AGNs (low- z objects, broad-line AGNs, etc.)...



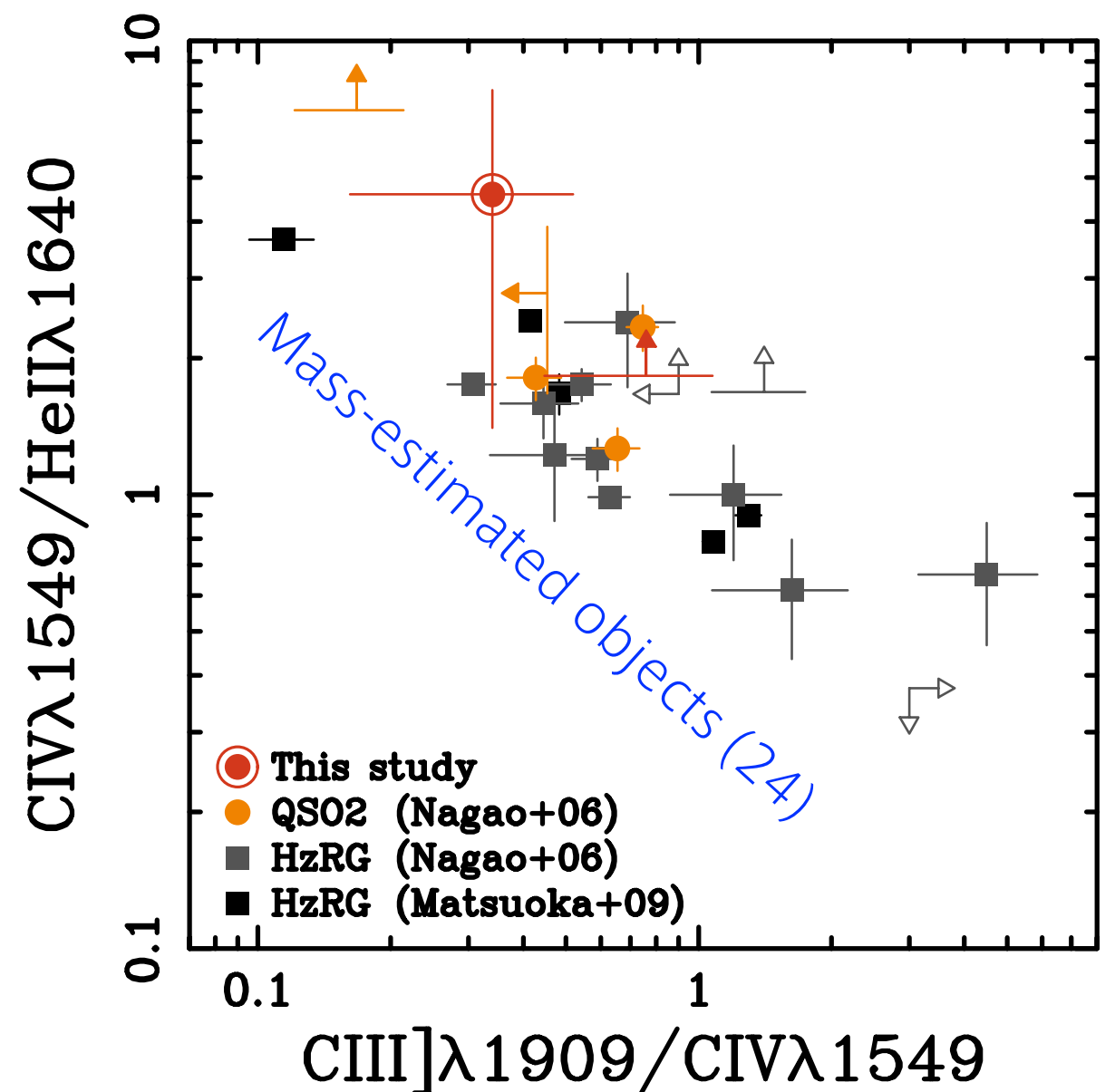
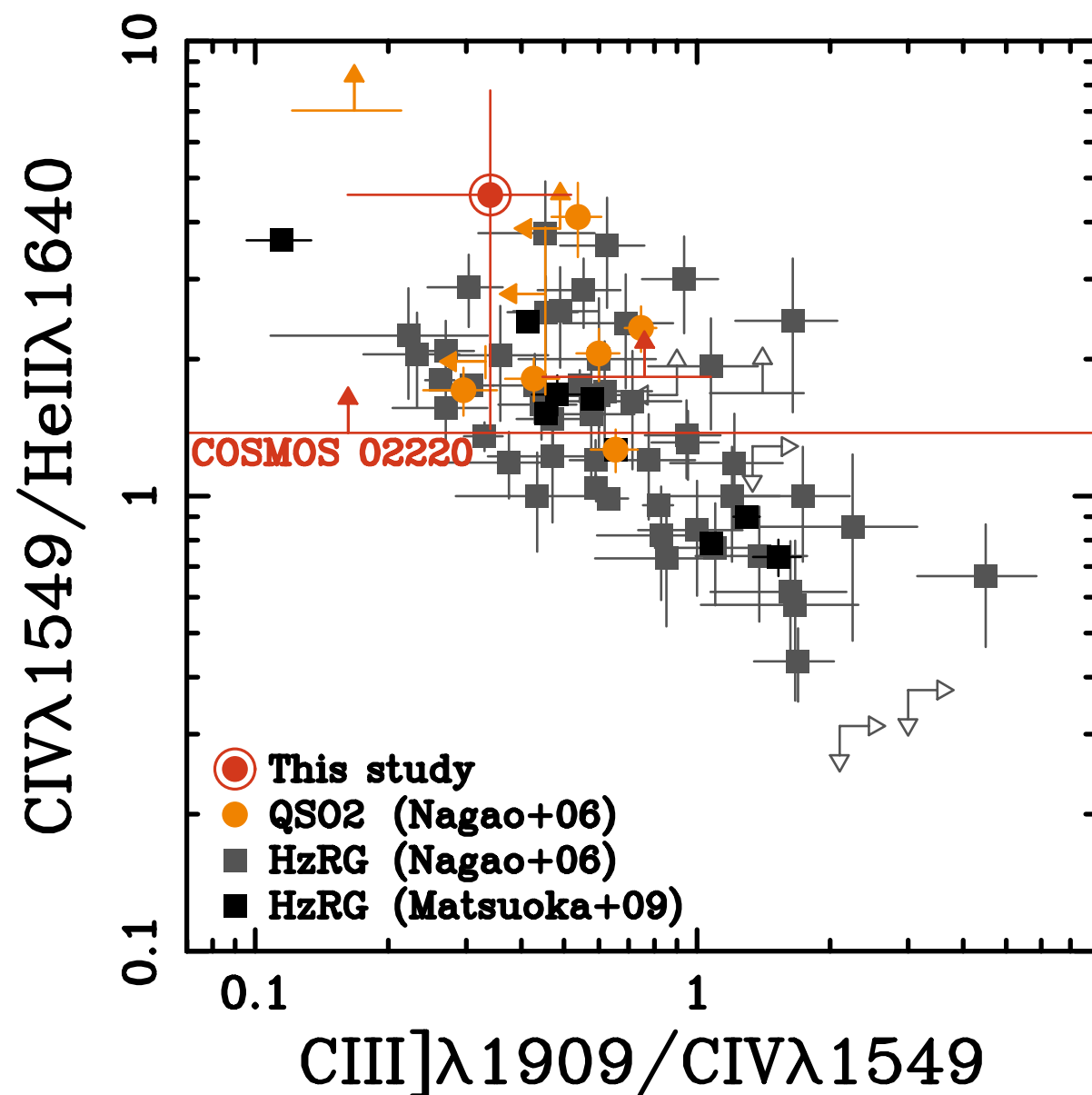
A second-priority object w/o stellar mass...

Additionally, we collect high- z X-ray selected type-2 QSOs from literatures, which optical spectra are available (e.g., [Nagao et al. 2006](#)).

Observational Results

■ Emission-line flux ratios

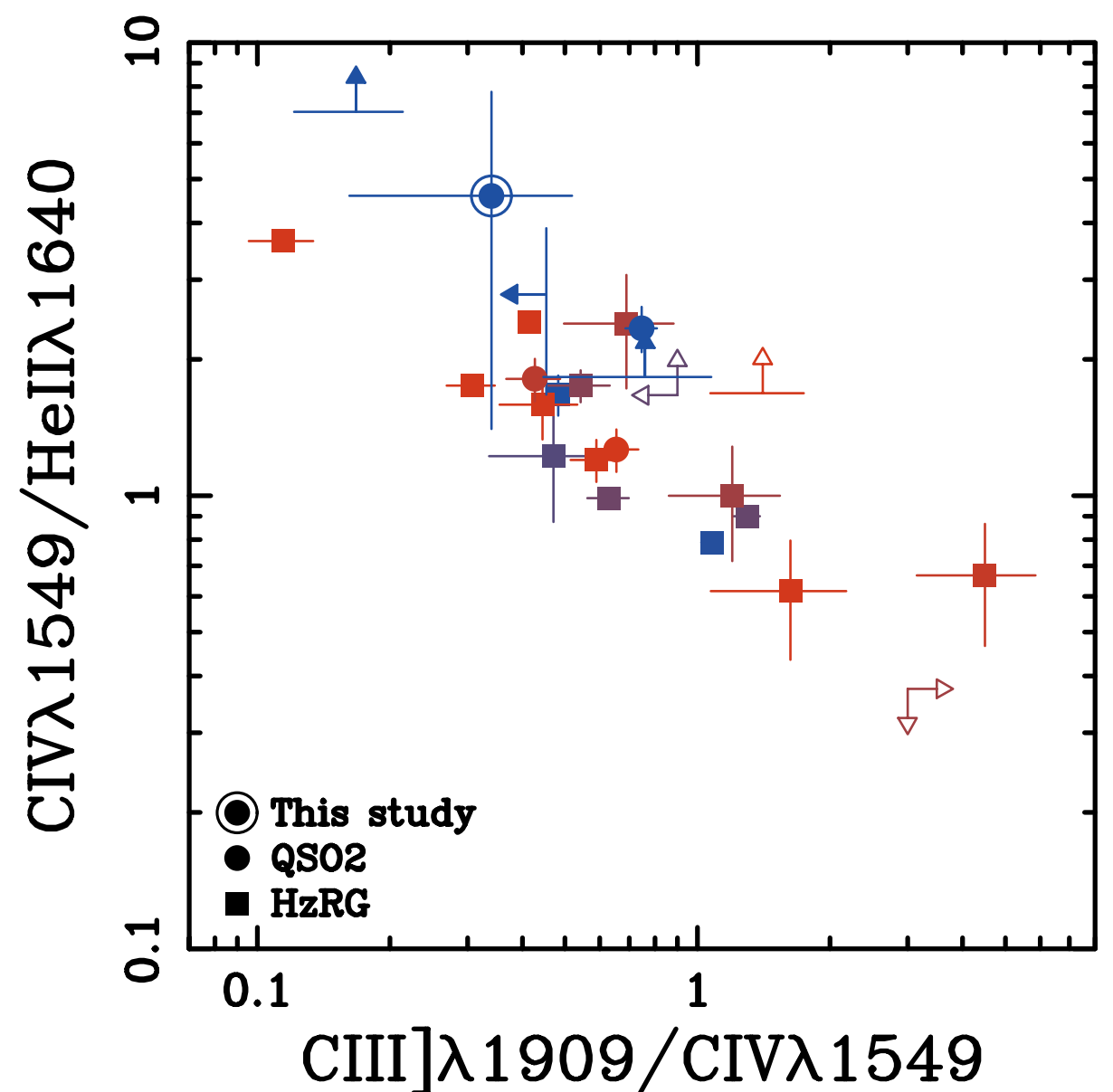
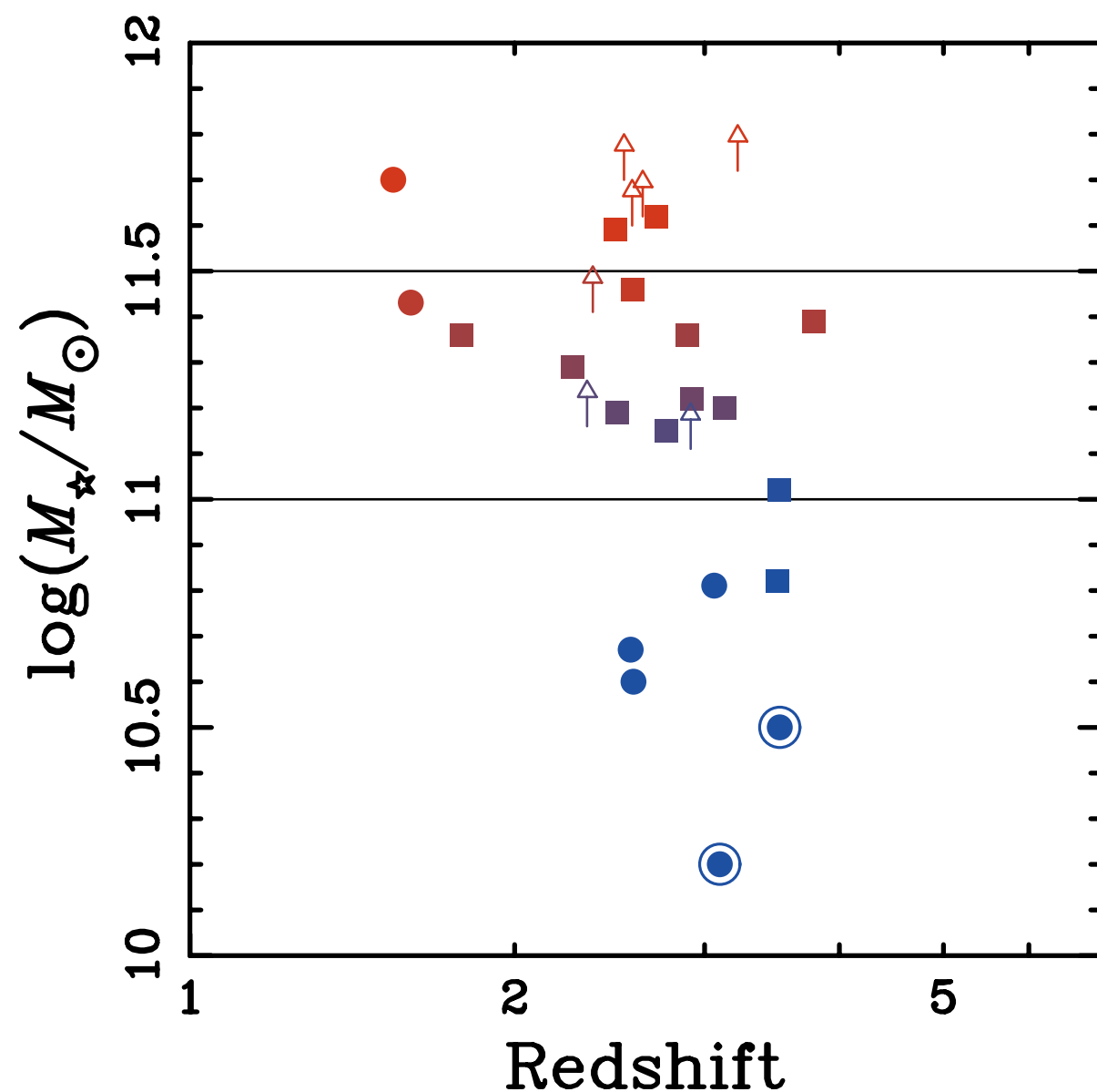
We measure the emission-line fluxes of CIV, HeII, and CIII], and plot on the diagnostic diagram of CIV/HeII vs. CIII]/CIV. We collect stellar masses of HzRGs and X-ray selected type-2 AGNs (24 objects in total).



Stellar Masses

■ Stellar masses of type-2 AGNs

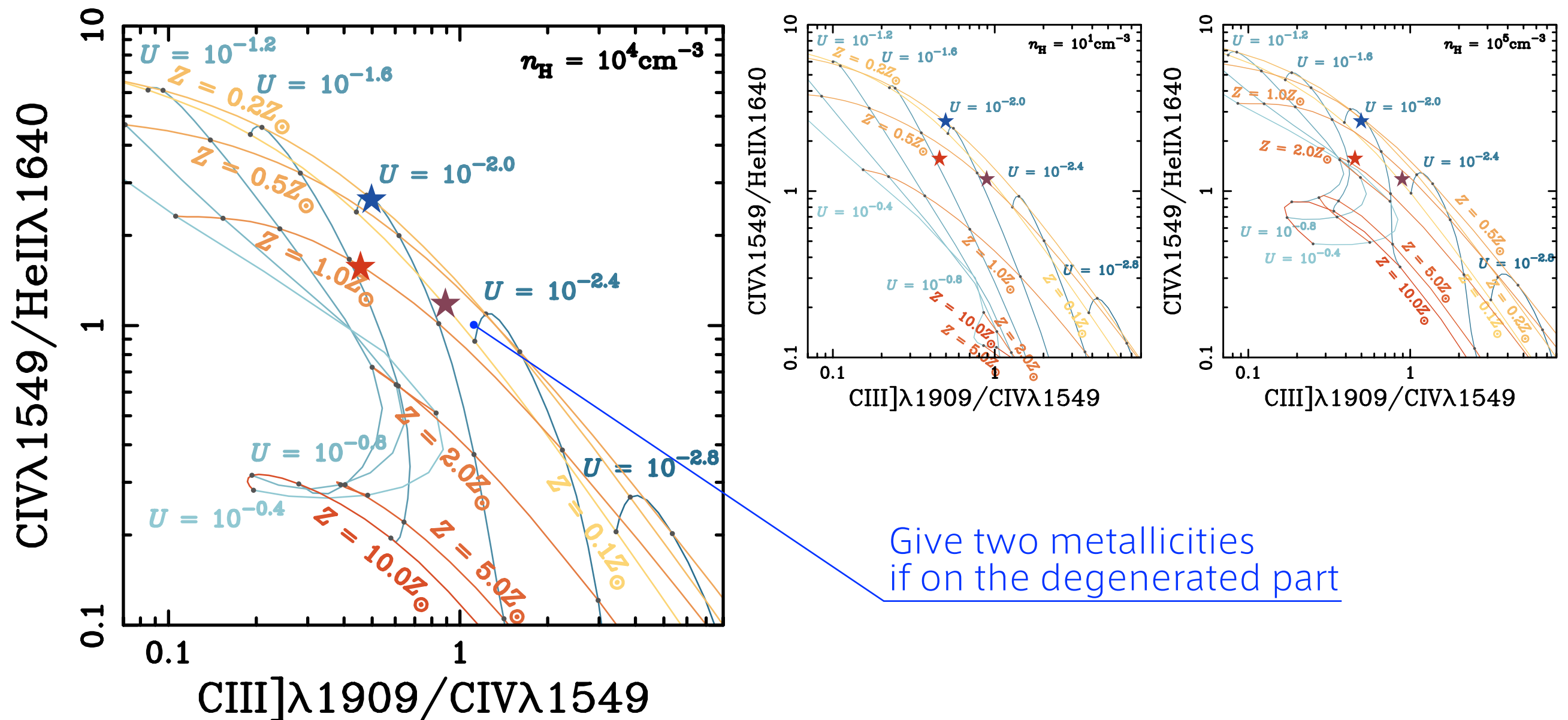
Almost all masses are estimated by SED fit ([Seymour et al. 2007](#); [De Breuck et al. 2010](#); [Mainieri et al. 2010](#)), although mass-to-light ratio in K band are adopted for a few objects ([Xue et al. 2010](#)). Thanks to X-ray selected type-2 AGNs, we can obtain a wide mass range sample.



NLR Metallicity Estimates

■ NLR metallicities for each mass

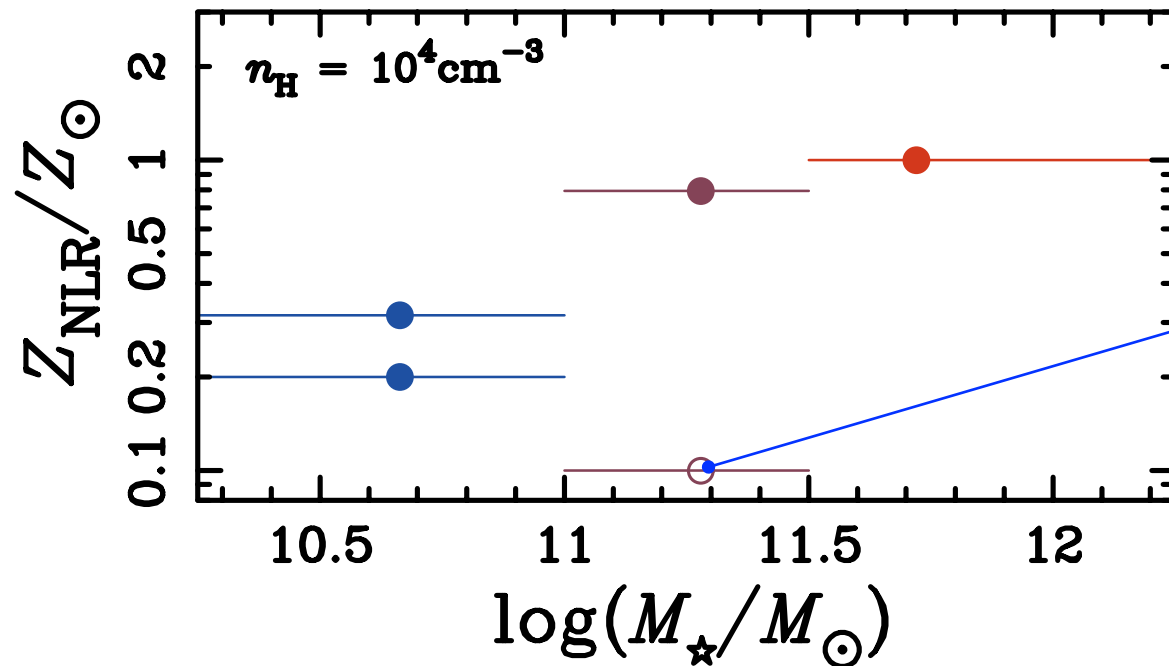
By comparing the mean observed flux ratios with model predictions, we estimate NLR metallicities for each stellar mass (★: low, ★: middle, ★: high).



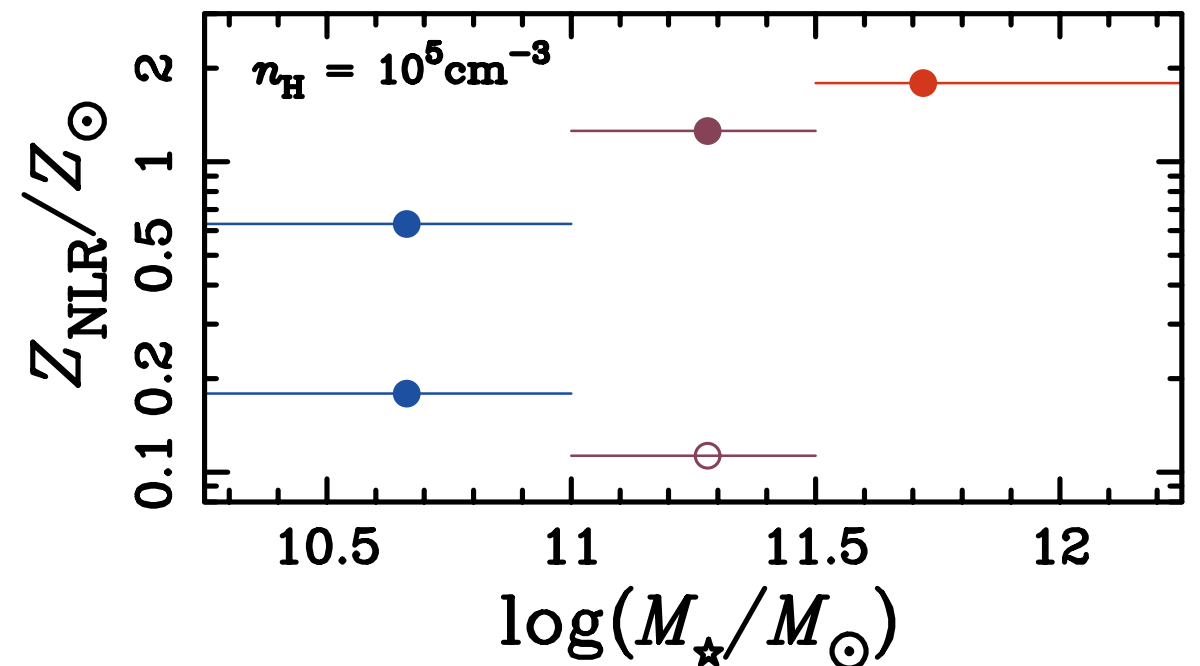
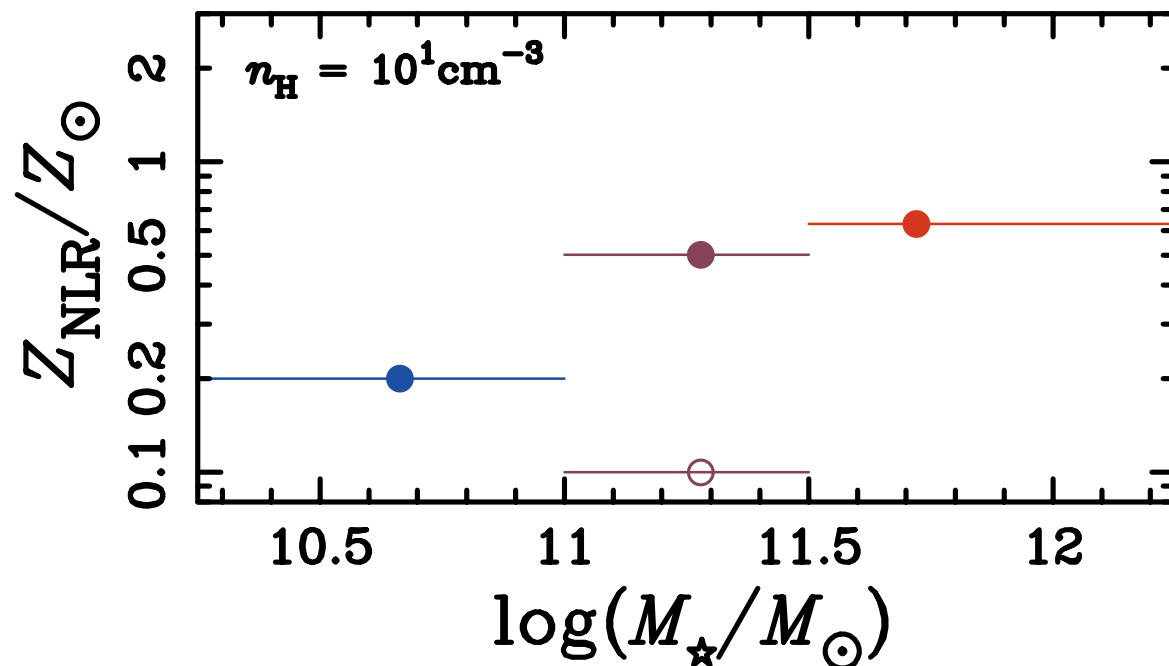
Mass-Metallicity Relation

■ Mass-metallicity relation of type-2 AGNs

We found that there are significant correlations between stellar masses and NLR metallicities of type-2 AGNs at $z \sim 3$.



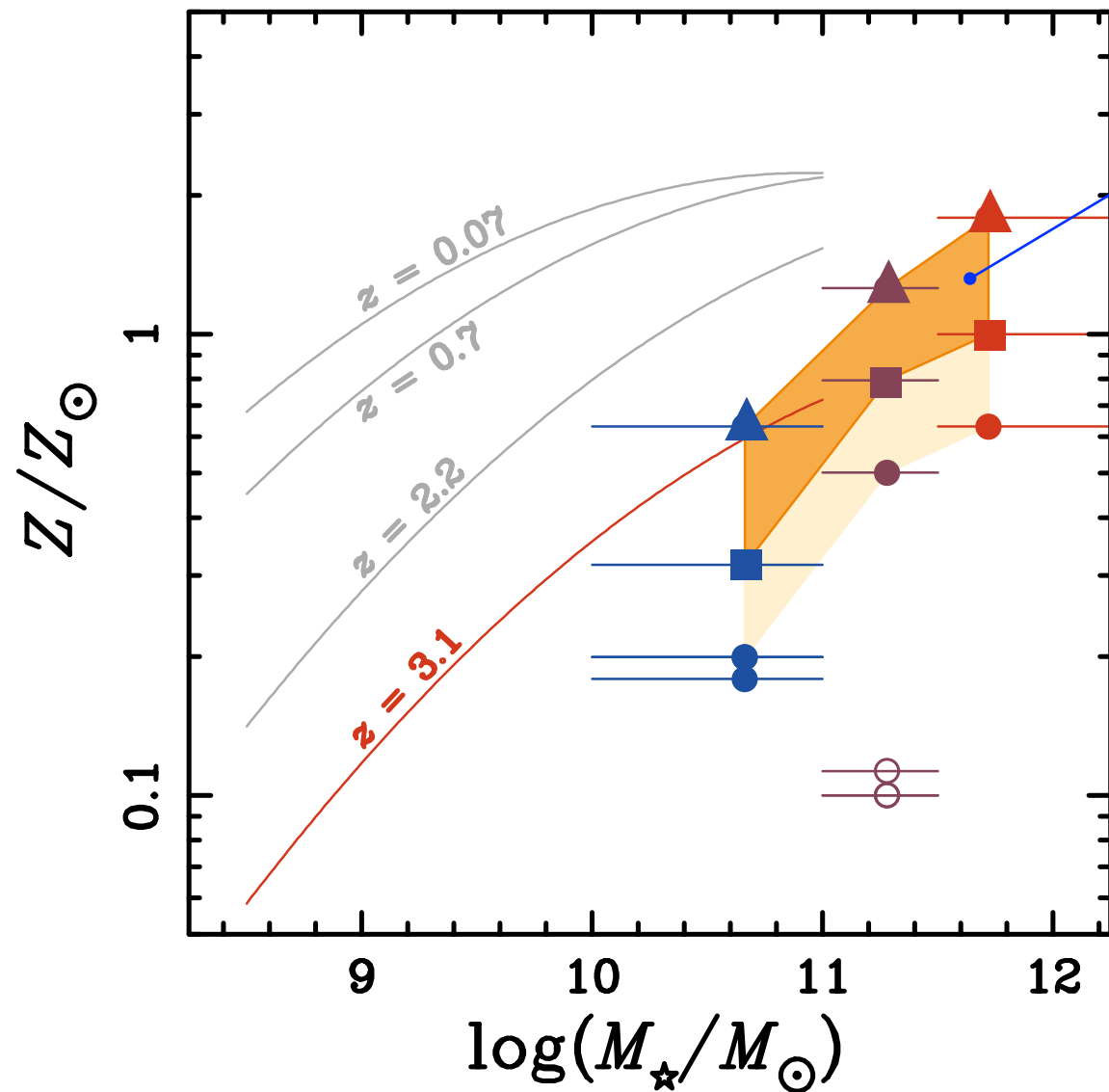
It is difficult to believe Z_{NLR} in the mid-M bin is lower than those of low-M bin.



Mass-Metallicity Relation

■ Comparison between AGNs and SF galaxies

We compare the M-Z relation of type-2 AGNs ($z \sim 3$) with those of SF galaxies (Mannucci et al. 2010).



High- n_{H} models would be more reliable at high redshift

Check posters: P6-05 Yusuke Nitta
P6-12 Koki Terao

Our results seem to be consistent with the extrapolated M-Z relation of SF galaxies, indicating the NLR metallicity would be a reliable indicator of host metallicity.

Summary

■ The mass-metallicity relation of high- z type-2 AGNs

Chemical properties are one of the most crucial properties in understanding the galaxy formation and evolution.

At high redshift, AGN is a powerful tool to investigate metallicities. However, it is not clear whether AGN metallicities really trace those of host.

In this study, we estimate NLR metallicities of type-2 AGNs (HzRGs and X-ray selected type-2 AGNs) at $z \sim 3$ in the mass range of $10 < \log M_{\text{stel.}}/M_{\text{Sun}} < 12$ and compare the M-Z relation with that of SF galaxies.

We found that there is a significant correlation between NLR metallicities and stellar masses of host galaxies. This is the first result that AGN gas metallicities are correlated directly with their host properties.

We compare the M-Z relation of type-2 AGNs with that of SF galaxies and confirm NLR metallicities seem to be a reliable indicator of host metallicities (Matsuoka et al. in prep.).

It is important to investigate the fundamental M-Z relation (M-Z-SFR relation) of type-2 AGNs as a next step. We will show you results by expanding sample size that is sufficient to discuss an effect of SFR.