Rapid Black Hole Growth at the Dawn of the Universe: A Super-Eddington Quasar at z=6.6

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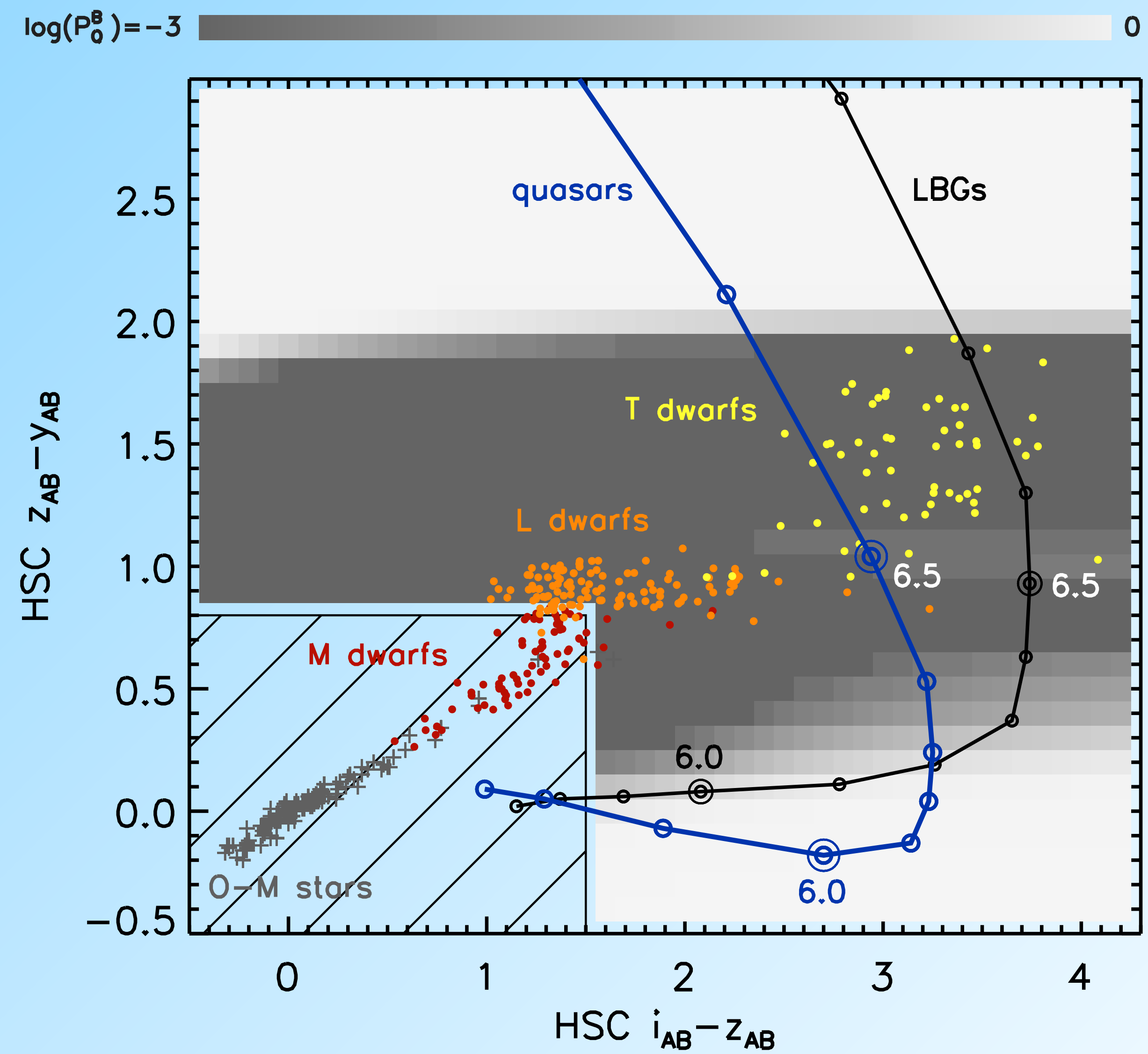
High Redshift QSOs

- High redshift quasars show Gunn-Peterson trough (Strong Lyα forest)
- Find candidates using broad band photometry
- Further confirmed by optical spectroscopy (z $\lessapprox$ 7)
- Most of them are discovered within this decade
  - z >= 6 (0.94 Gyr) QSOs ~142
  - z >= 6.5 (0.85 Gyr) QSOs ~ 40



Matsuoka+17

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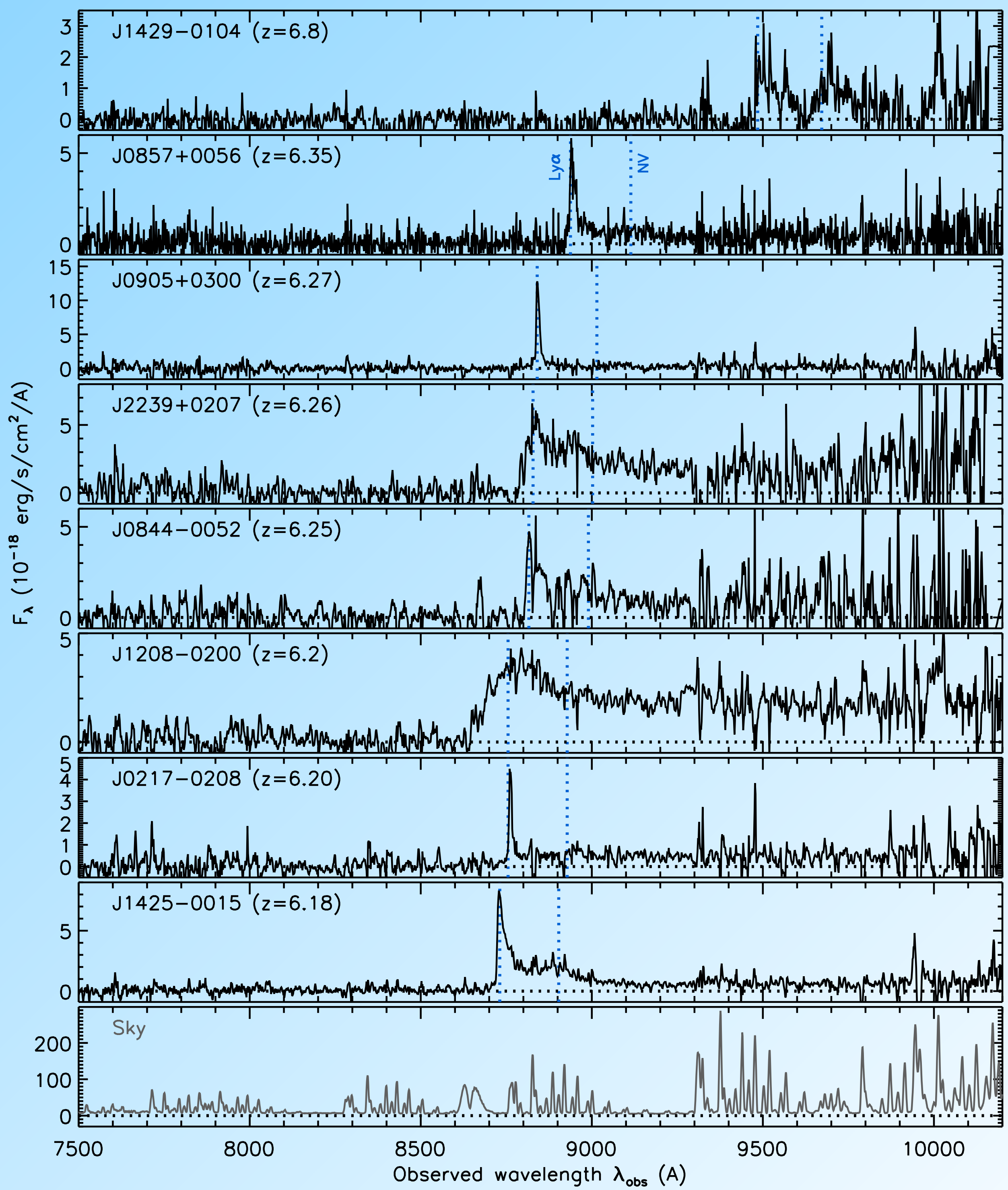

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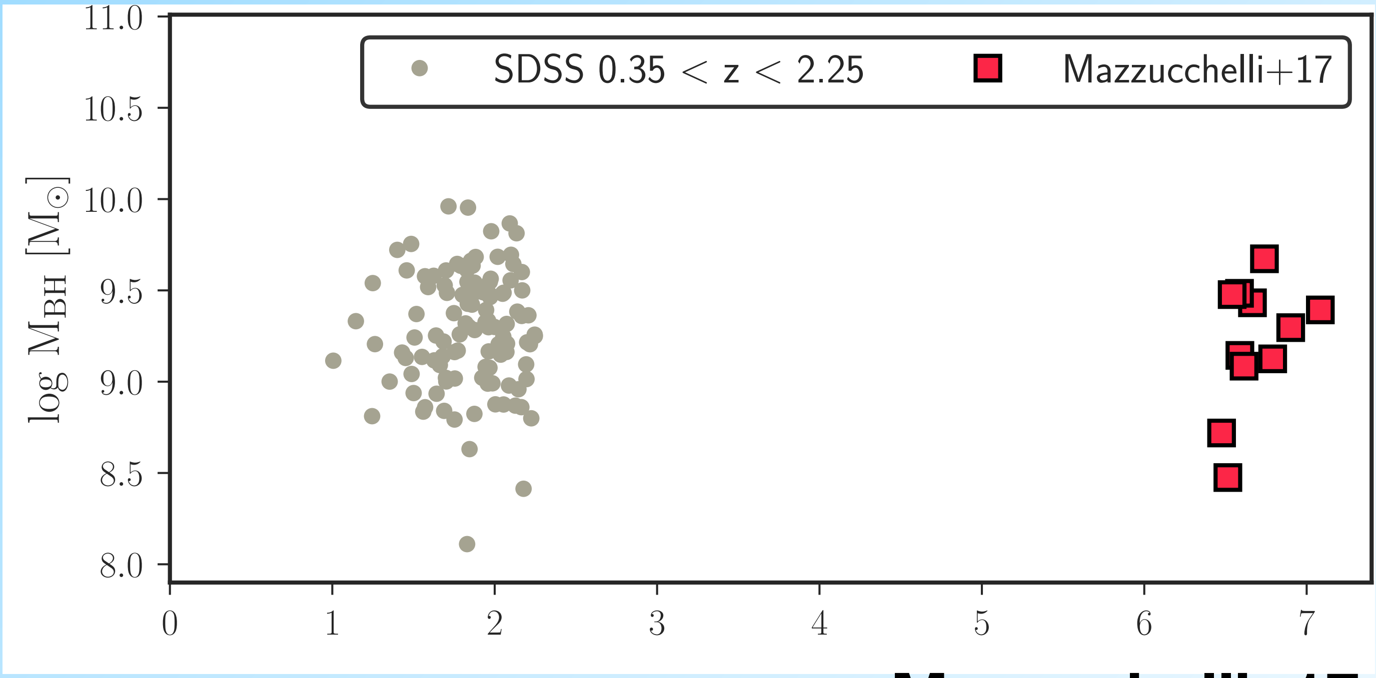
SMBH Growth at High Redshift

- QSO is powered by the accretion disk surrounding SMBH
- Constrain how fast SBMH can grow
- ~$10^9 M_\odot$ at ~ 0.9 Gyr



Redshift **Mazzuchelli+17**

SMBH Mass Estimation at High Redshift

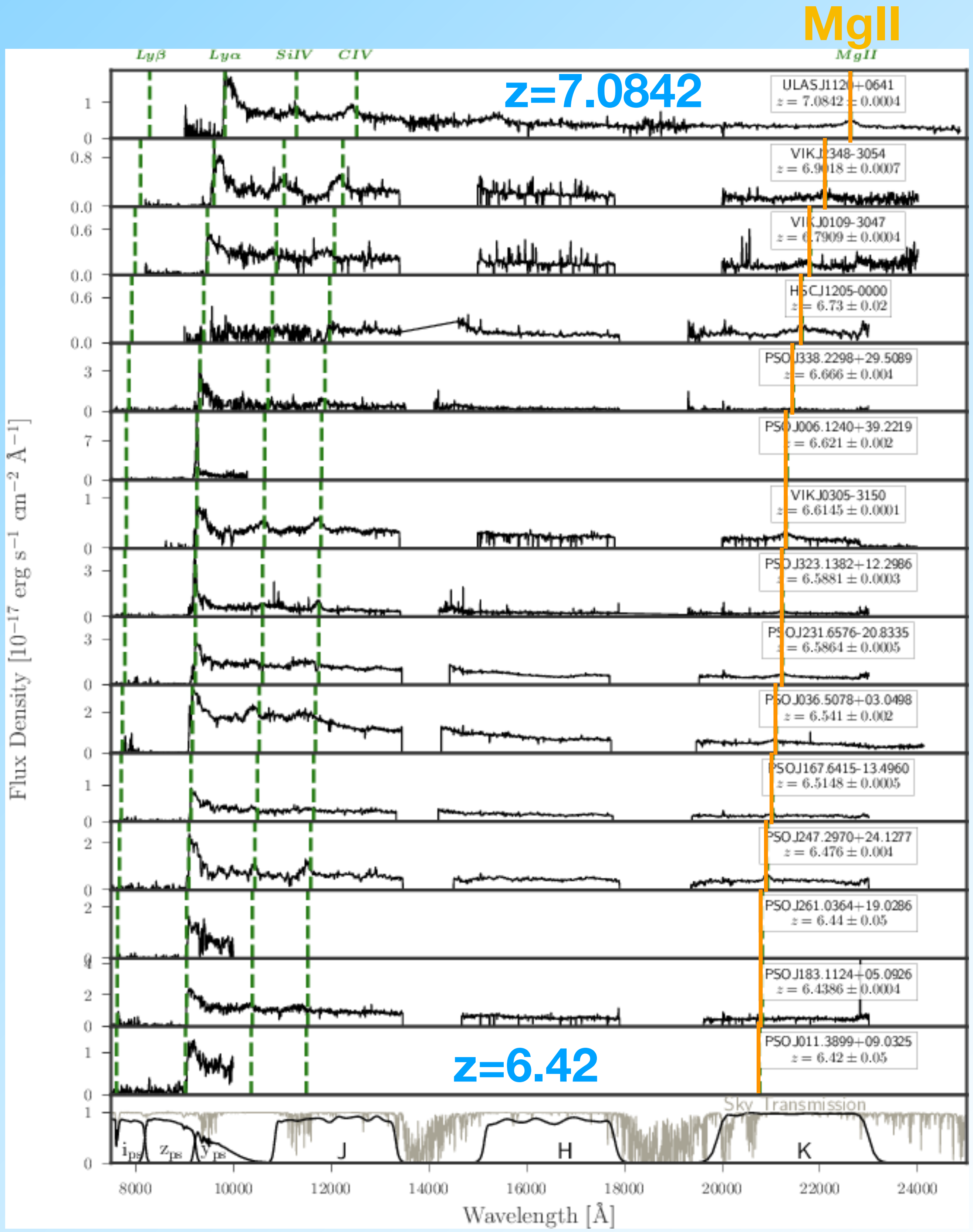
- Measuring the SMBH mass from gas in the broad line regions (BLRs):
  - Reverberation mapping for Hß: R_{BLR}-L relation
  - $M_{BH} \sim R_{BLR} \times (v_{BLR})^2/G$, $v_{BLR} \propto$ FWHM
  - Empirical scaling relation for MgII:

$$\log(M_{BH}/M_{\odot}) = 6.86 + 2 \times \log(\mathrm{FWHM}/(10^3 \mathrm{km/s})) + 0.5 \times \log(\lambda \times L_{\lambda,3000}/(10^{44} \mathrm{erg/s}))$$

(Vestergaard & Osmer 09)

SMBH Mass Estimation at High Redshift

- Near infrared (NIR) spectrum
- Hβ is usually redshifted outside of ground telescopes NIR detection range
- Adopt the empirical scaling relation of MgII line instead
- ~20 z > 6.5 quasars have NIR spectrum so far



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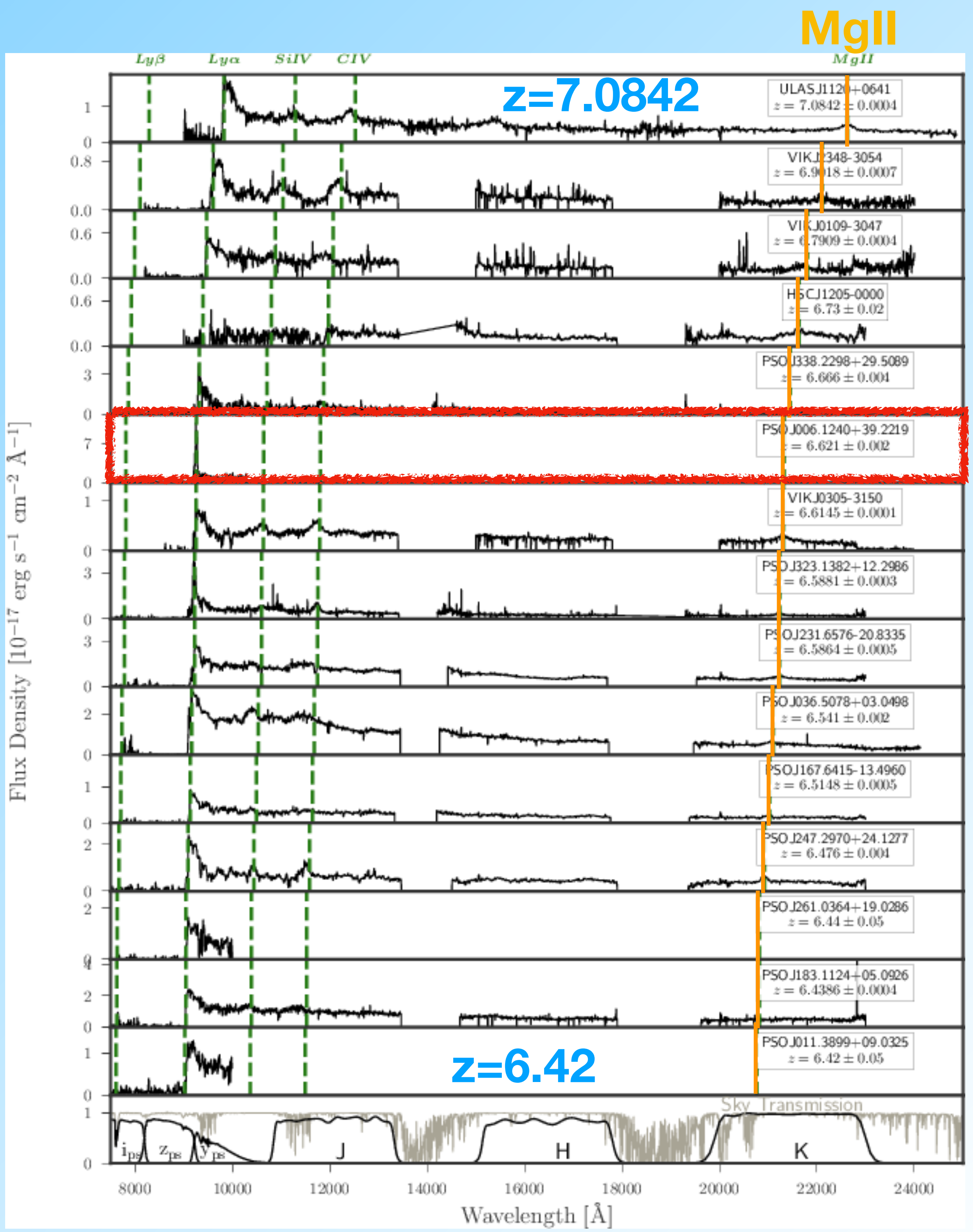

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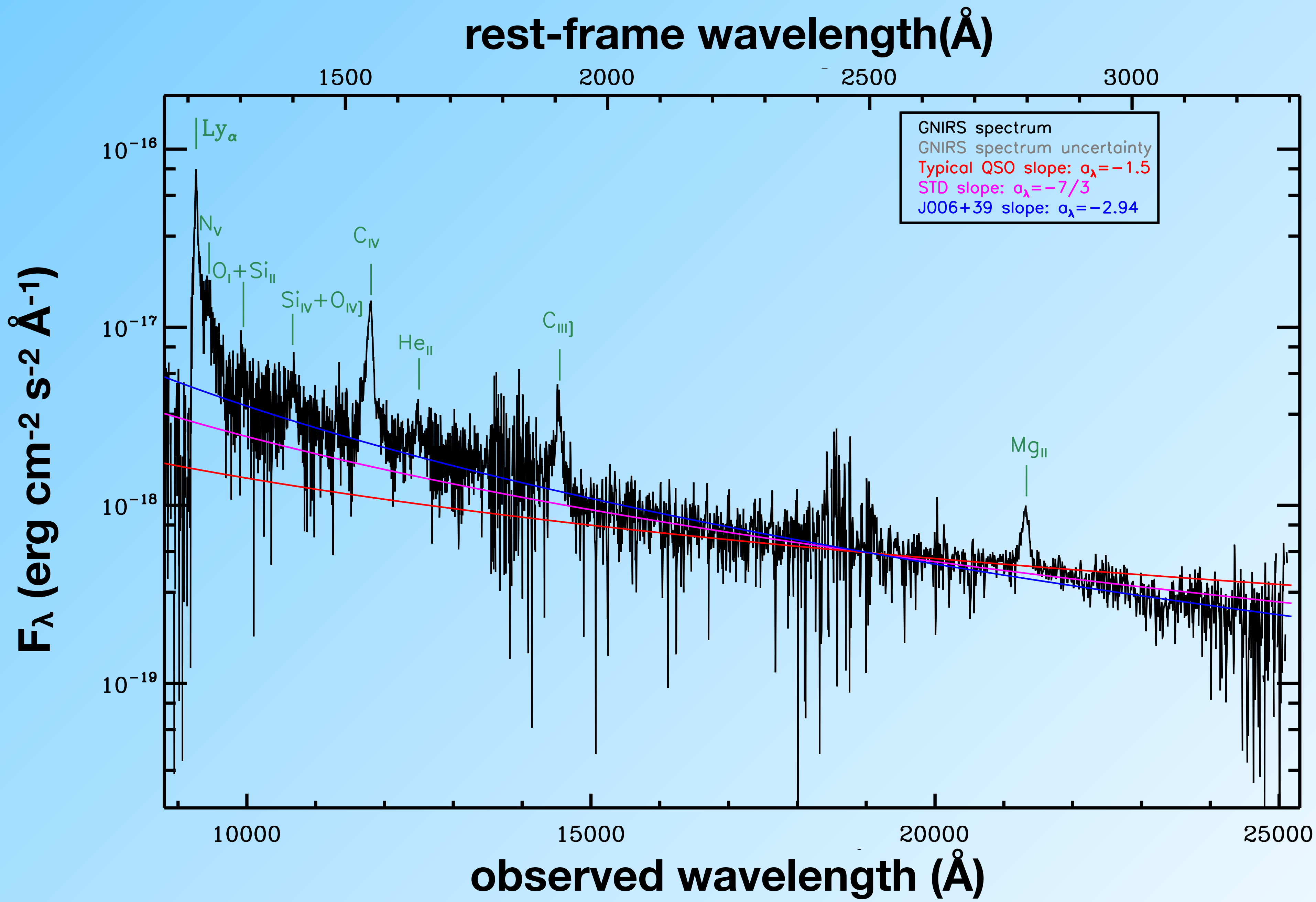
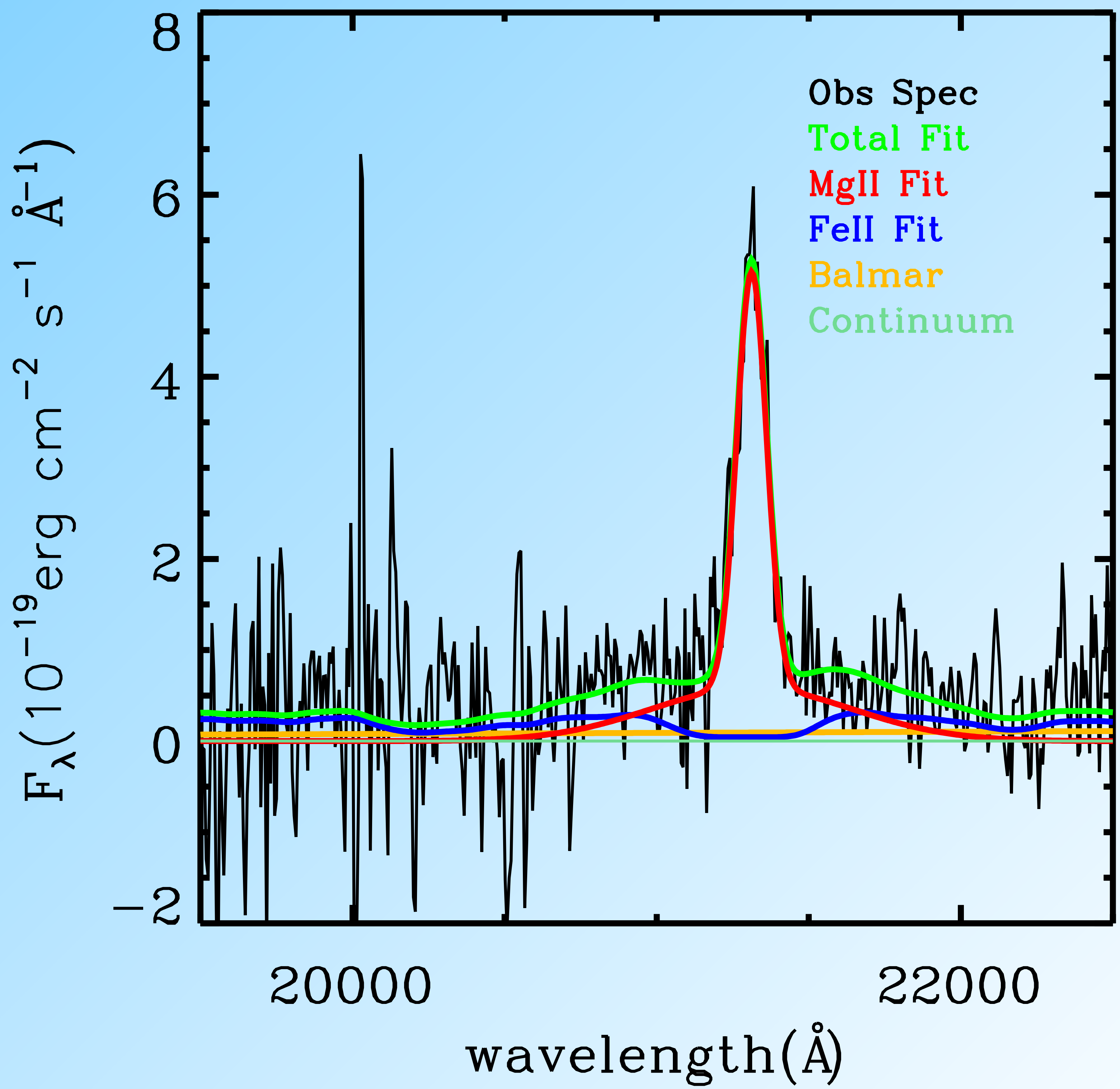
GNIRS spectrum of PSO J006+39

- PSO J006+39, z=6.621, discovered by Subaru-FOCAS (Tang+17)
- Gemini Near Infra-Red Spectrograph (GNIRS): 4hrs



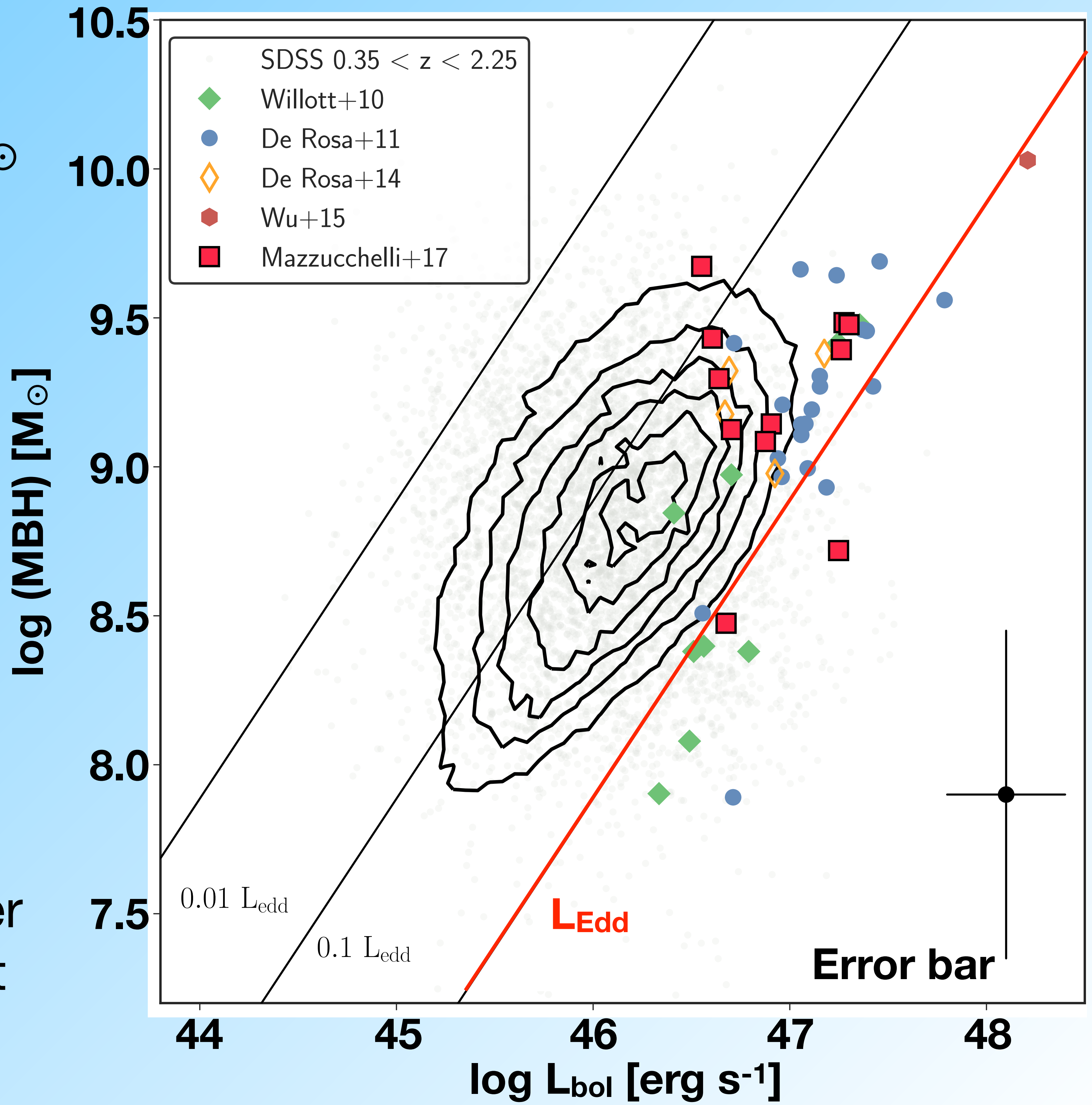
Fitting Around MgII Line

- Mass estimation → MgII FWHM and continuum luminosity



SMBH Mass

- The SMBH mass of this quasar is $1.37^{+3.51}_{-0.99} \times 10^8 M_\odot$
- Relative small compare to other high-z QSOs
- Super-Eddington luminosity
- Note: L_{bol} derived from scaling relation (Shen+08) here
- Note: Mass could be lighter by adopting Du+18's result



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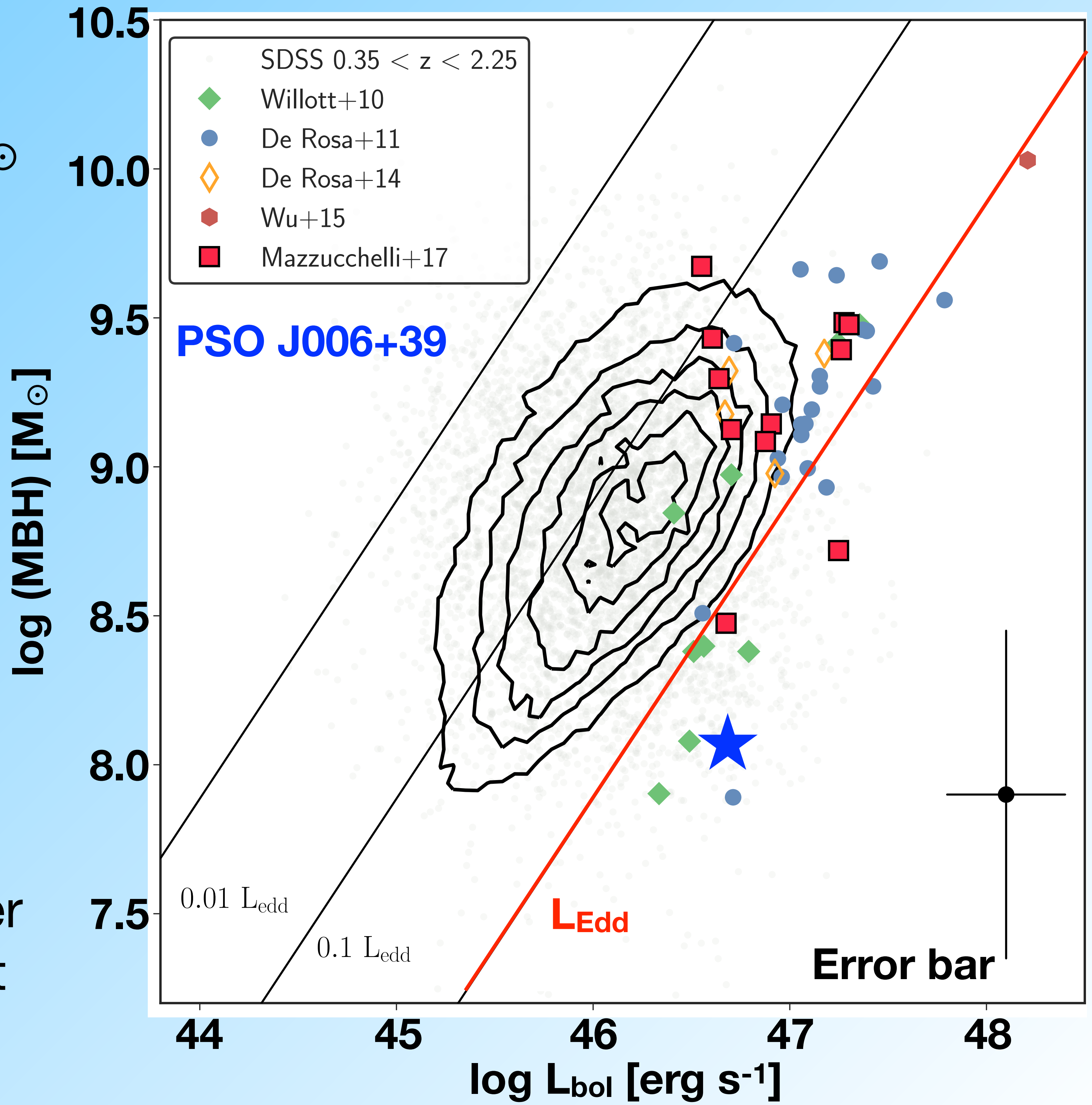

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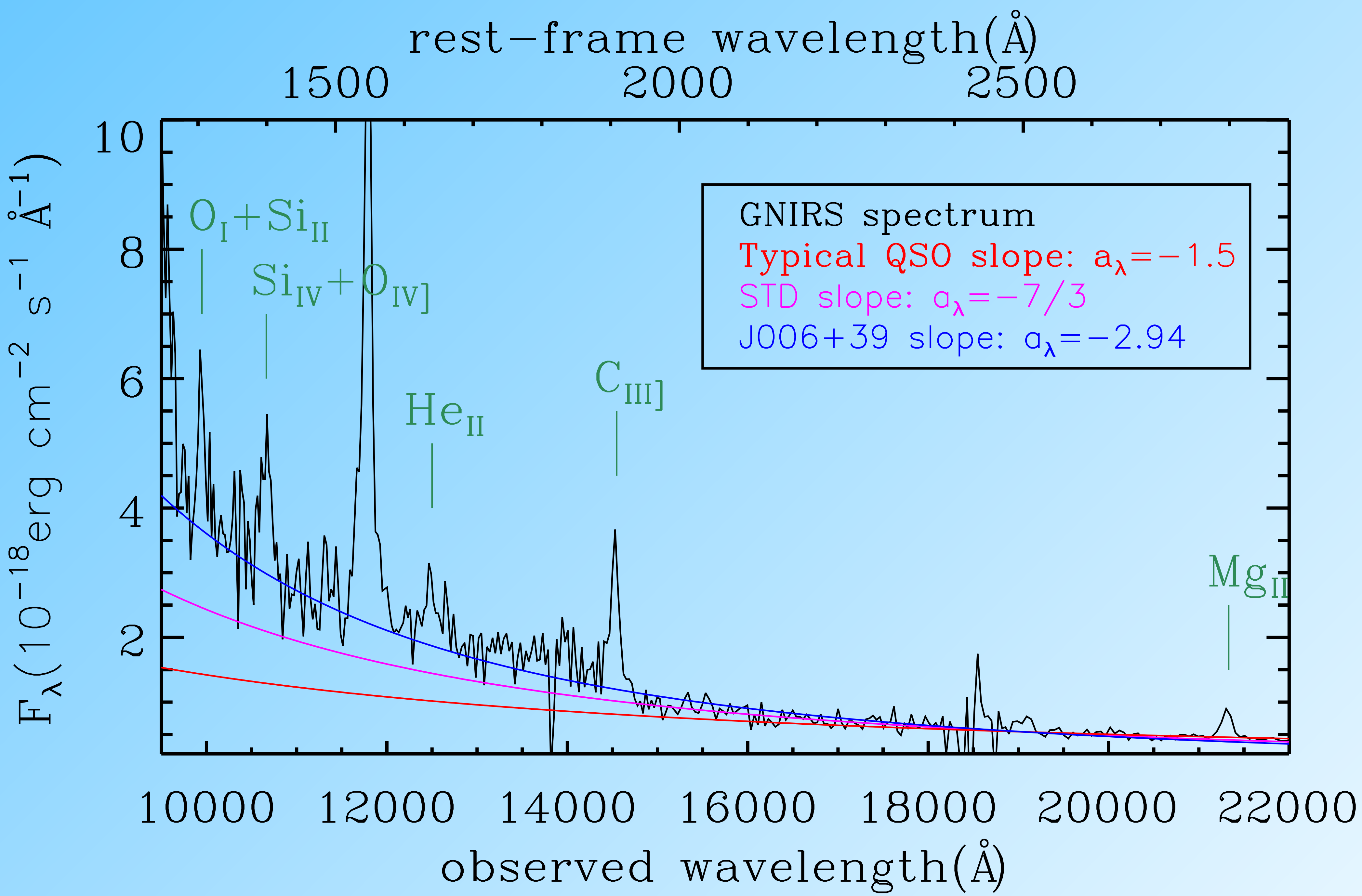
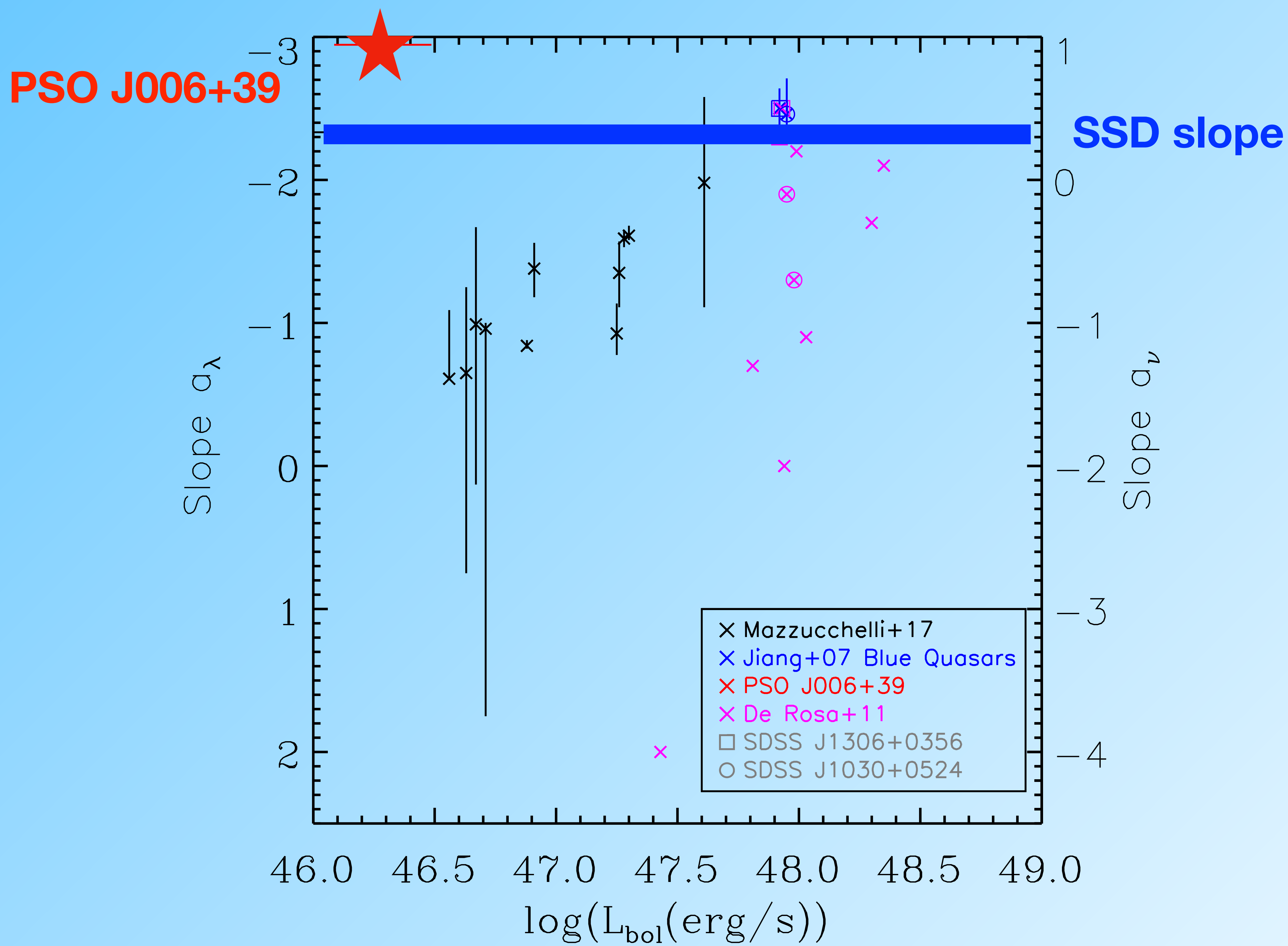
Continuum Slope



- Typical observed slope: α_λ=-1.5
- Standard thin accretion disk model: α_λ=-2.33

Continuum Slope



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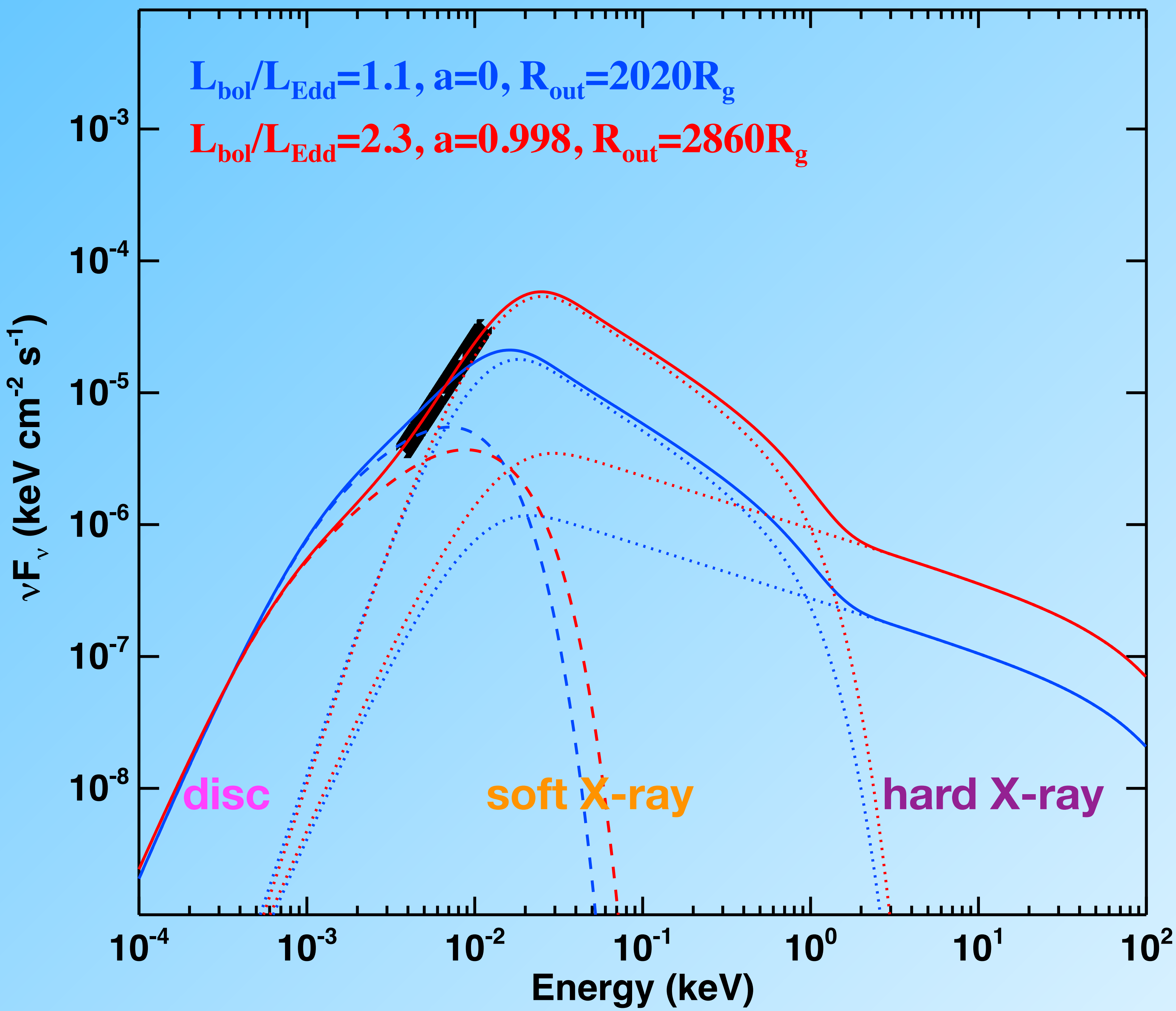
Spectral Energy Distribution Fitting

- energetically self-consistent model based on the standard disc (optxagnf)



- soft X-ray corona
- Artificial blue
- assume that the seed photons for the Comptonisation are blackbody rather than the disc blackbody which is expected for a slab Comptonisation layer above a range of radii in the disc (Kubota & Done 18)

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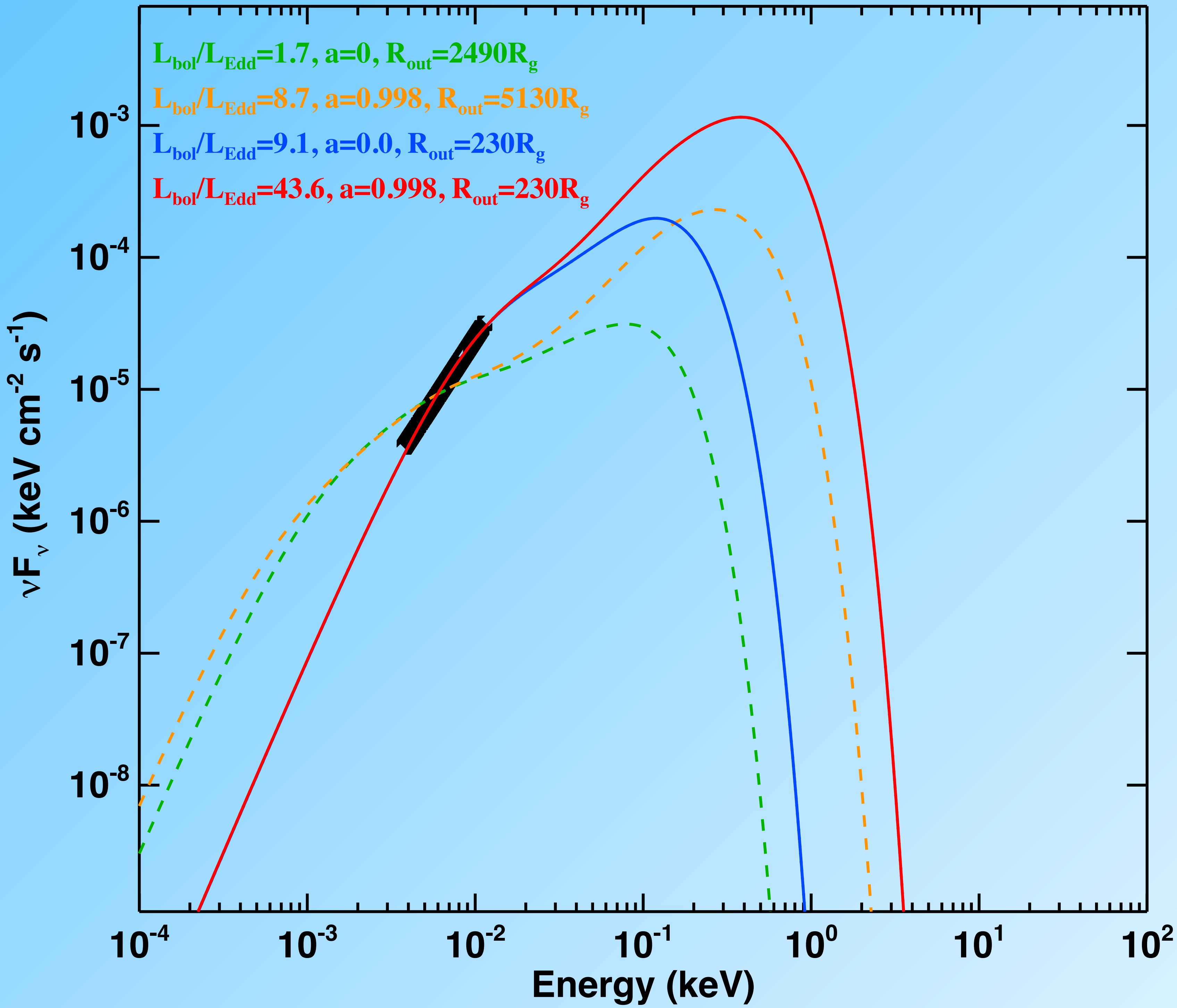
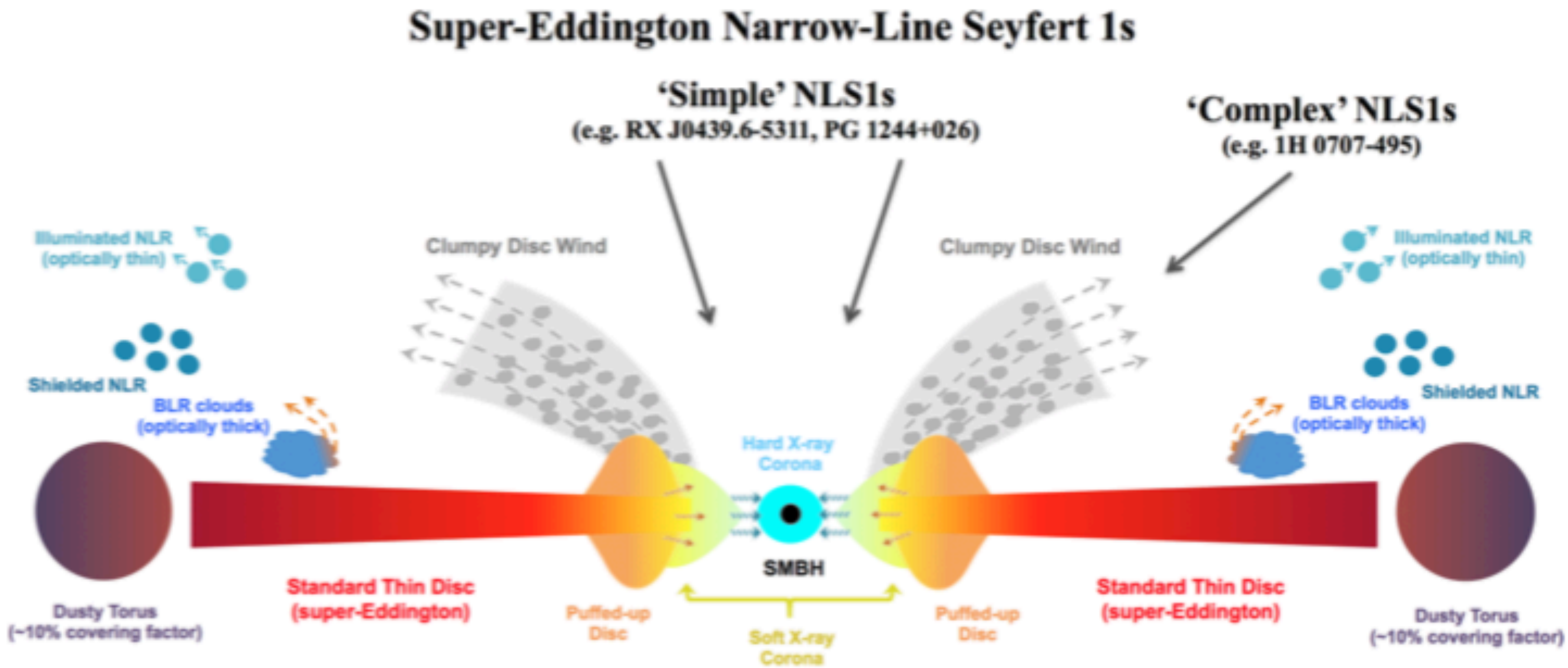


- Self-gravitational radius can not produce a good fit
- Find the outer radius that fit this slope and luminosity
- Explanations:
  - Puffed up small radius caused by super-Eddington flow
  - Smaller solid angle in our line of sight

What may Cause Bluer Continuum ?

- The schematic diagram of the accretion disk

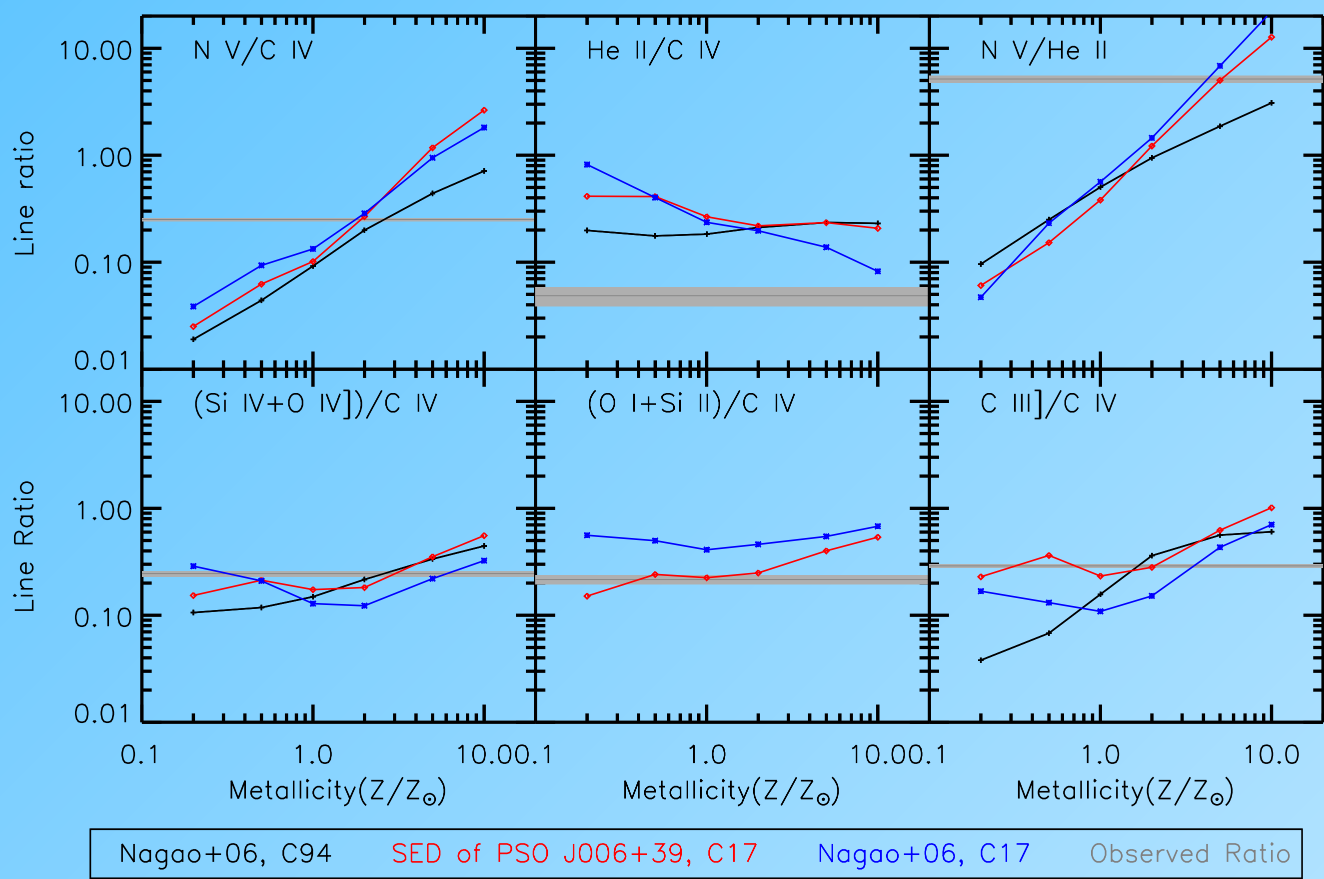


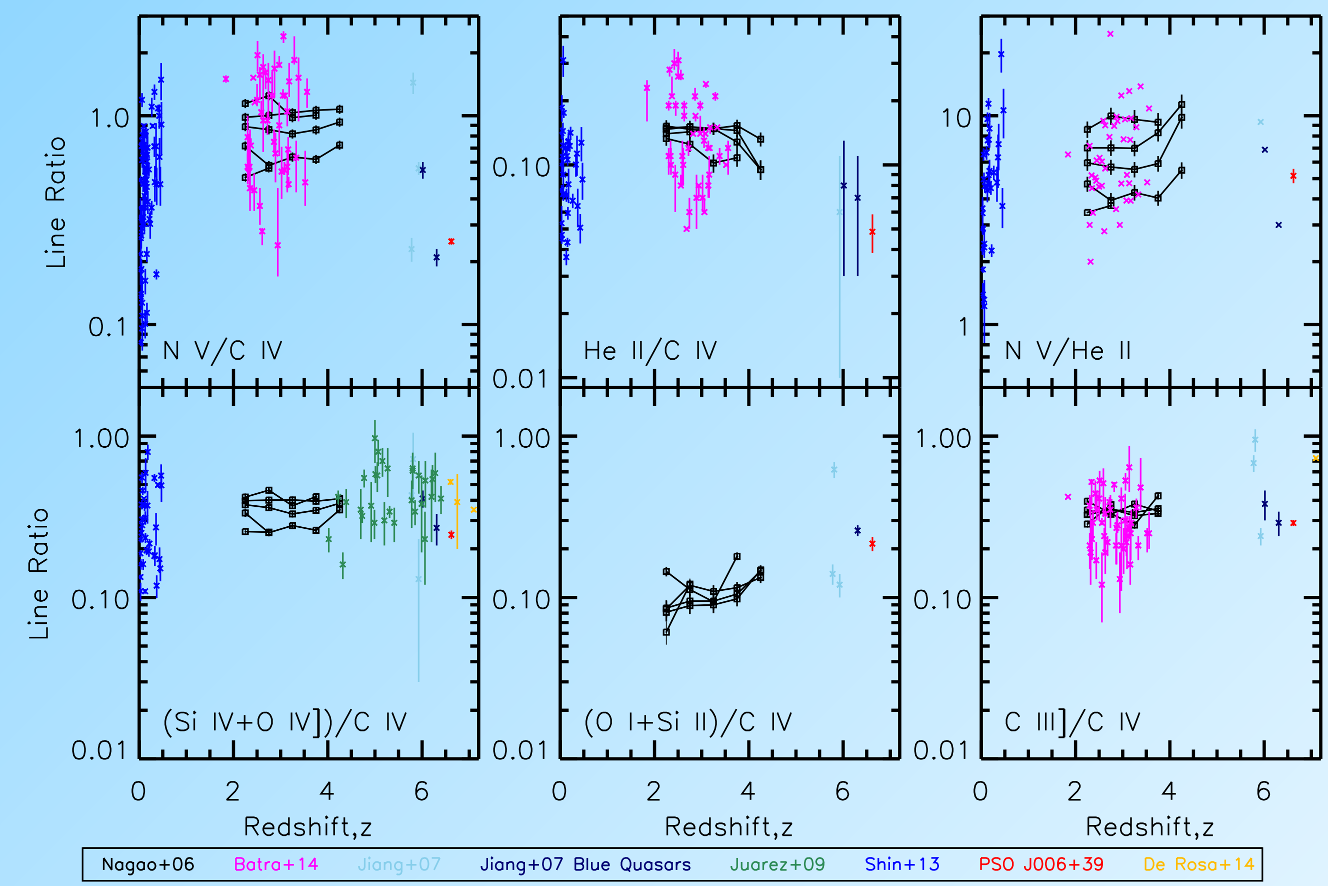
Jin+17

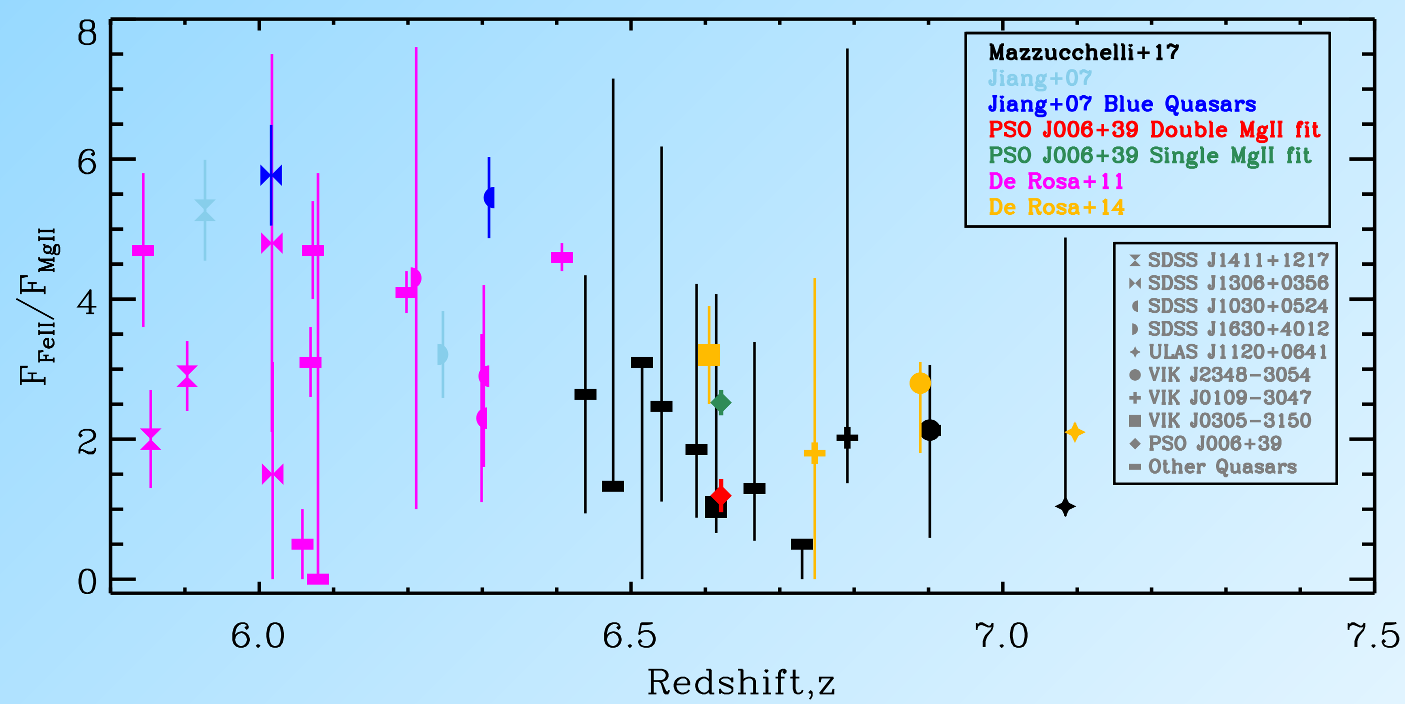
What does this Imply ?

- Super-Eddington accretion
  - Similar low redshift, low mass AGNs do not show such blue spectra
  - PSO J006+39 is an extreme case, it is more likely to have high black hole spin
- Contribution to the reionization epoch
  - Such source is usually not considered
- Provide a chance to study the black hole spin evolution in SMBH growth
- Possible jet (radio loud) if it has a high black hole spin

Metallicity







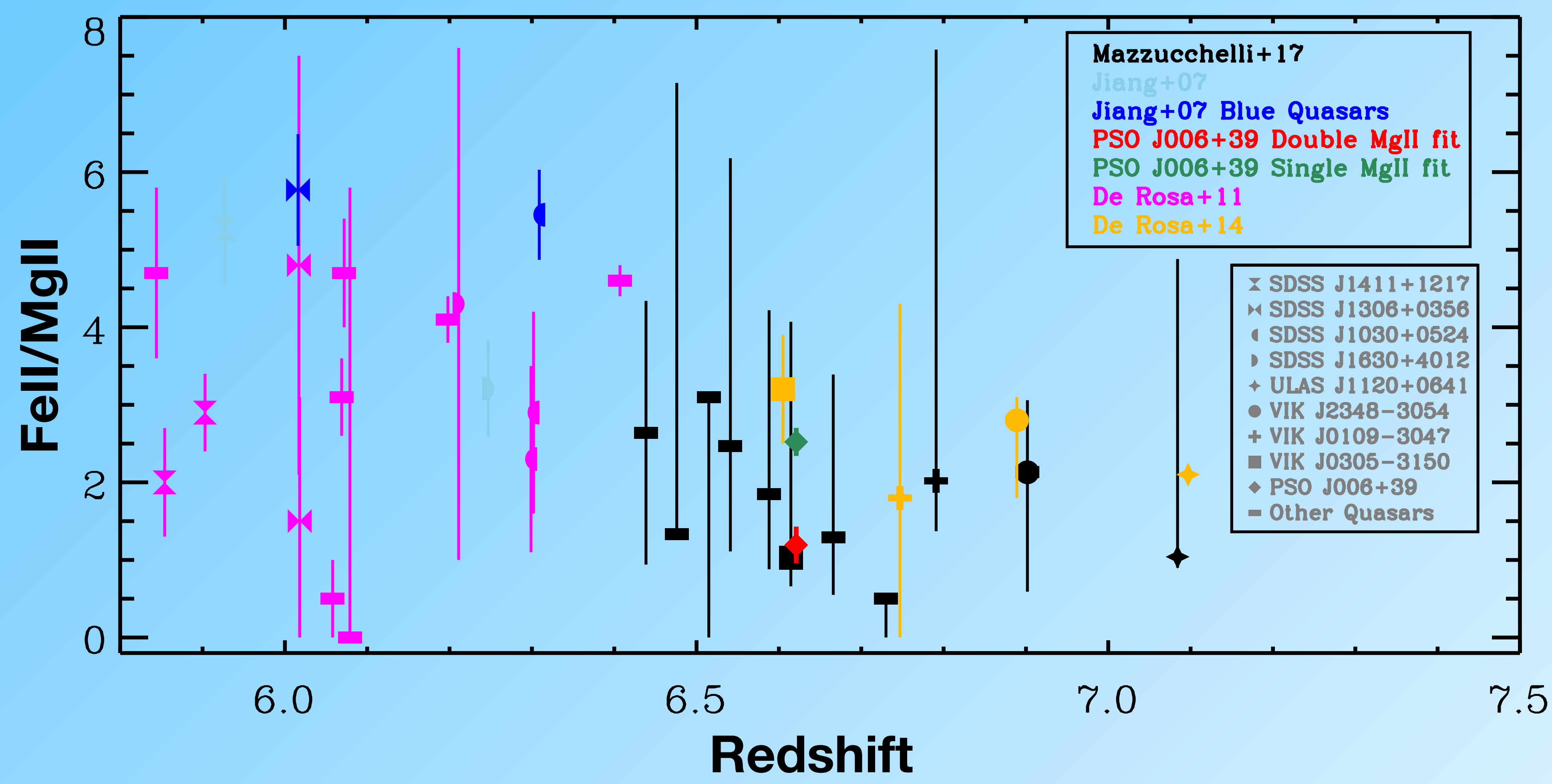
Conclusions from the NIR Spectrum of PSO J006+39

- Relatively small mass with super Eddington ratio
- Blue slope compare to other QSOs with theoretical explanation
- First high redshift quasar that show strong evidence of super-Eddington accretion process

Poster Ad: Quasar Variability from ATLAS Survey

- Quasar light curves from Asteroid Terrestrial-impact Last Alert System (ATLAS)
- Cross-correlate light curves for two optical broad band filters
- Estimate the size of the accretion disk
- See my poster or chat with me!

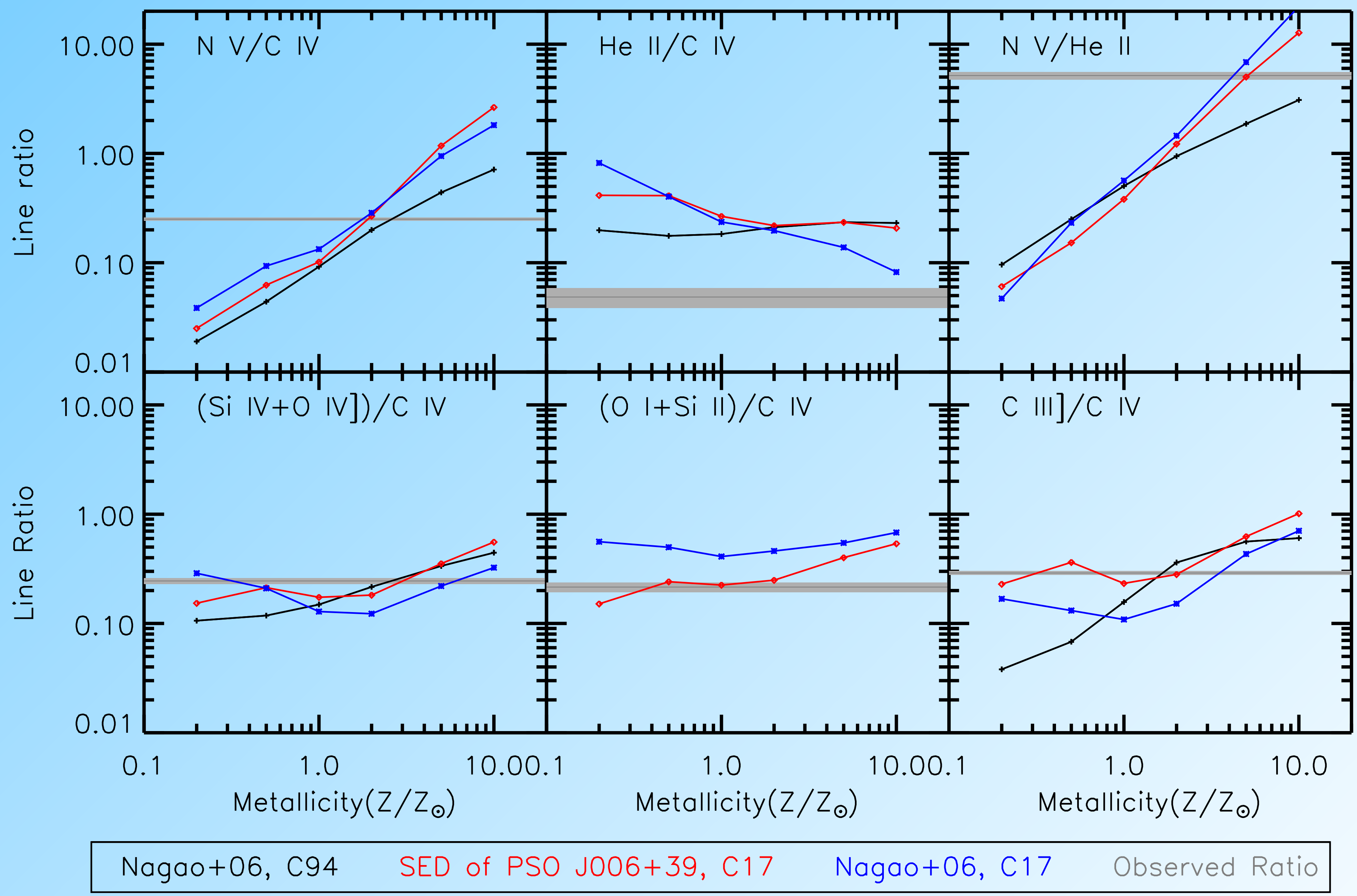
FeII/MgII Metallicity



- Fitted result from observation
- FeII/MgII=1.19±0.23 for double MgII fit
- Conventional method for other high-z QSOs
- Can not derive metallicity Z

Metallicity Z/Z⊙

- Cloudy simulations for broad line regions using best estimated (blue) SED for PSO J006+39
- Derive relationships between line ratios with metallicities Z from Cloudy results
- Compare with observed line ratios
- No consistent metallicities between different line ratios
- Super-solar metallicity



Metallicity Z/Z⊙

- Whether this quasar show lower metallicity comparing to other quasars? Uncertain.