The ionising radiation of AGN: Ultraviolet quasar composite from WFC3

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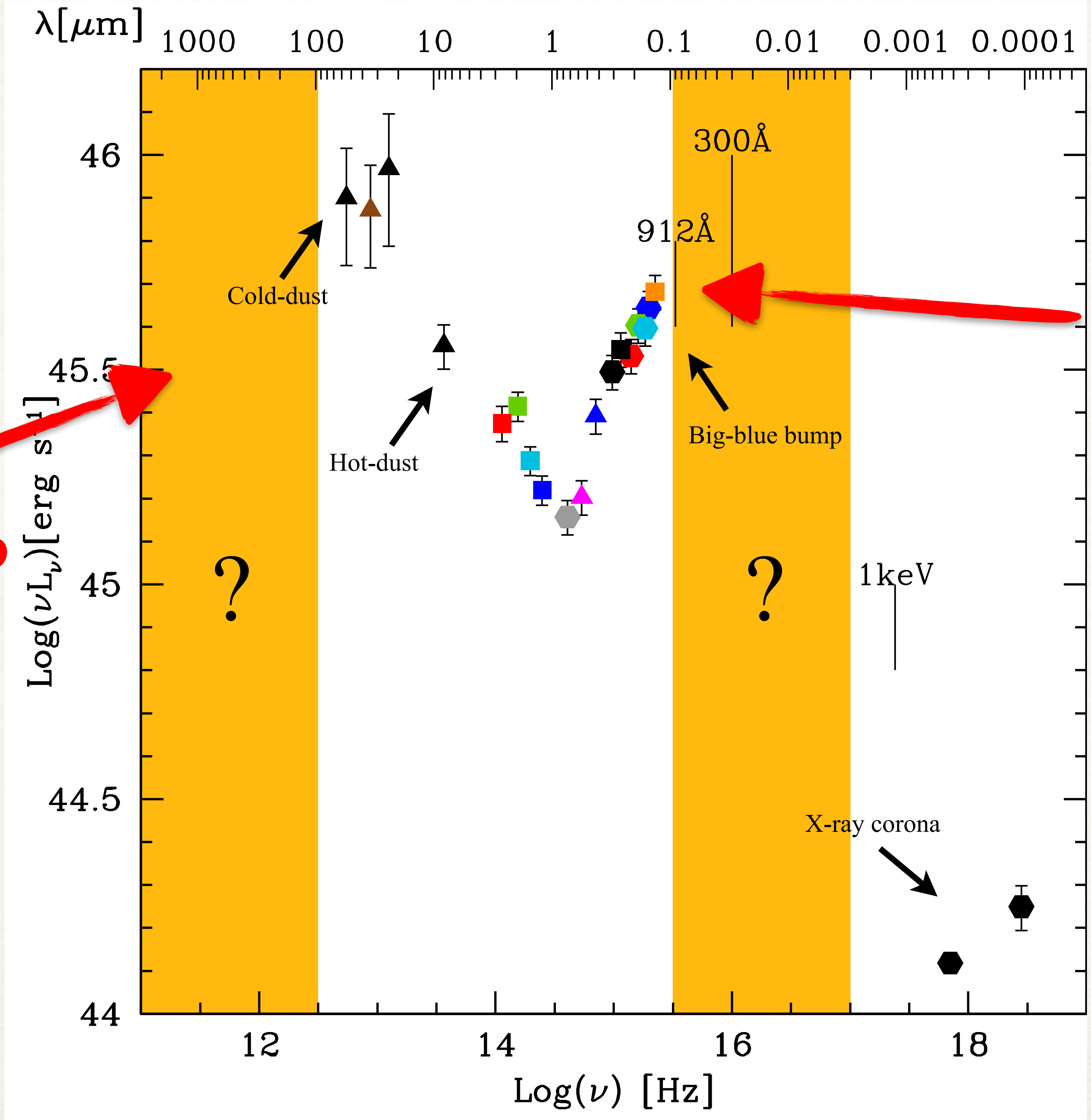
"Quenching & Quiescence"

Heidelberg, Germany. July 14-18, 2014

Broad band quasar SEDs

Lusso+10



ALMA WILL FILL THE FIR GAP! PROBLEM SOLVED

Absorption by neutral hydrogen along the l.o.s. makes detection at these λ challenging

but see also Edelson&Malkan+86, Ward+87, Kriss+88, Sanders+89, Elvis+94, Richards+06, Krawczyk+13, Shang+11, Elvis+12

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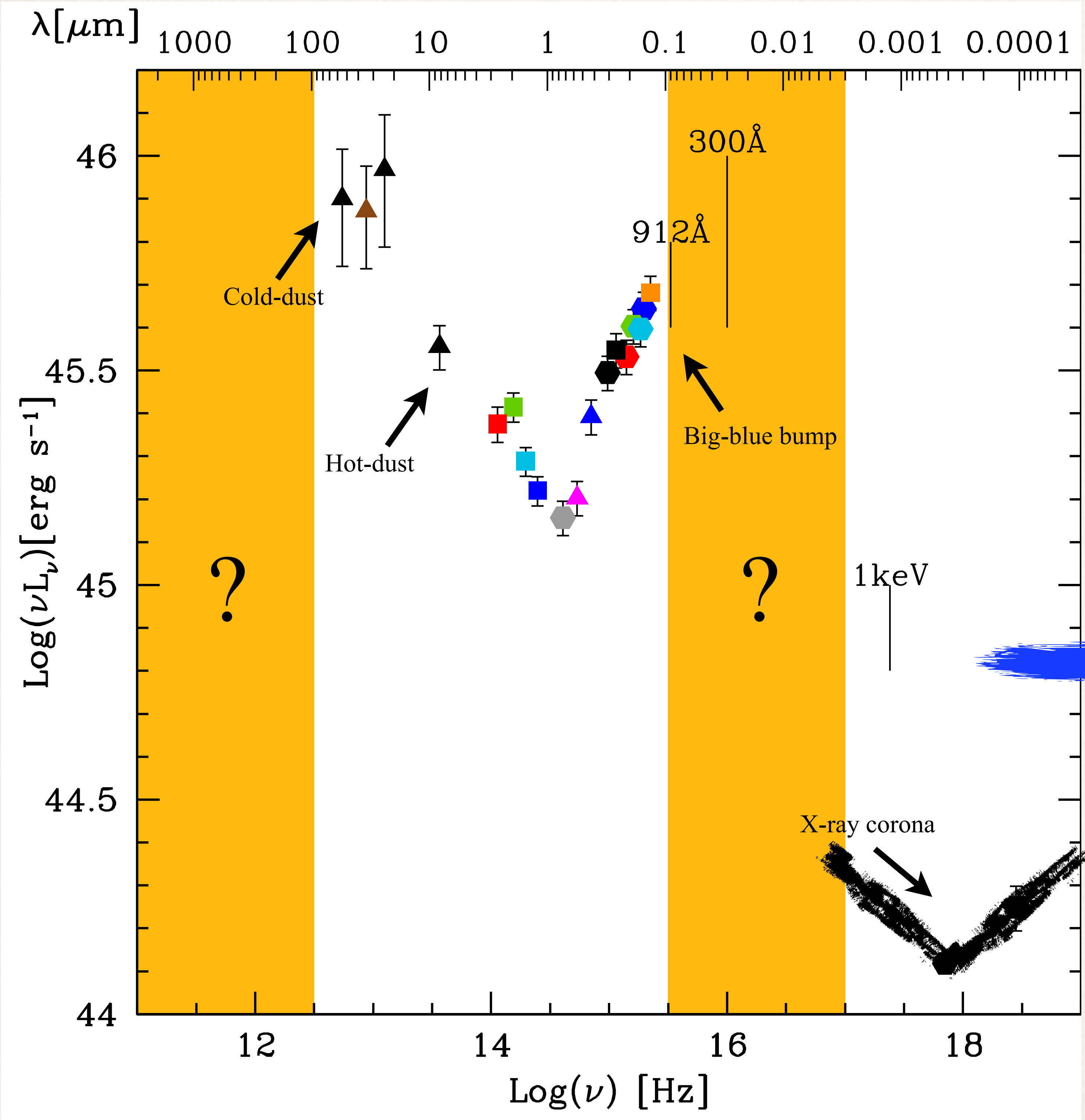
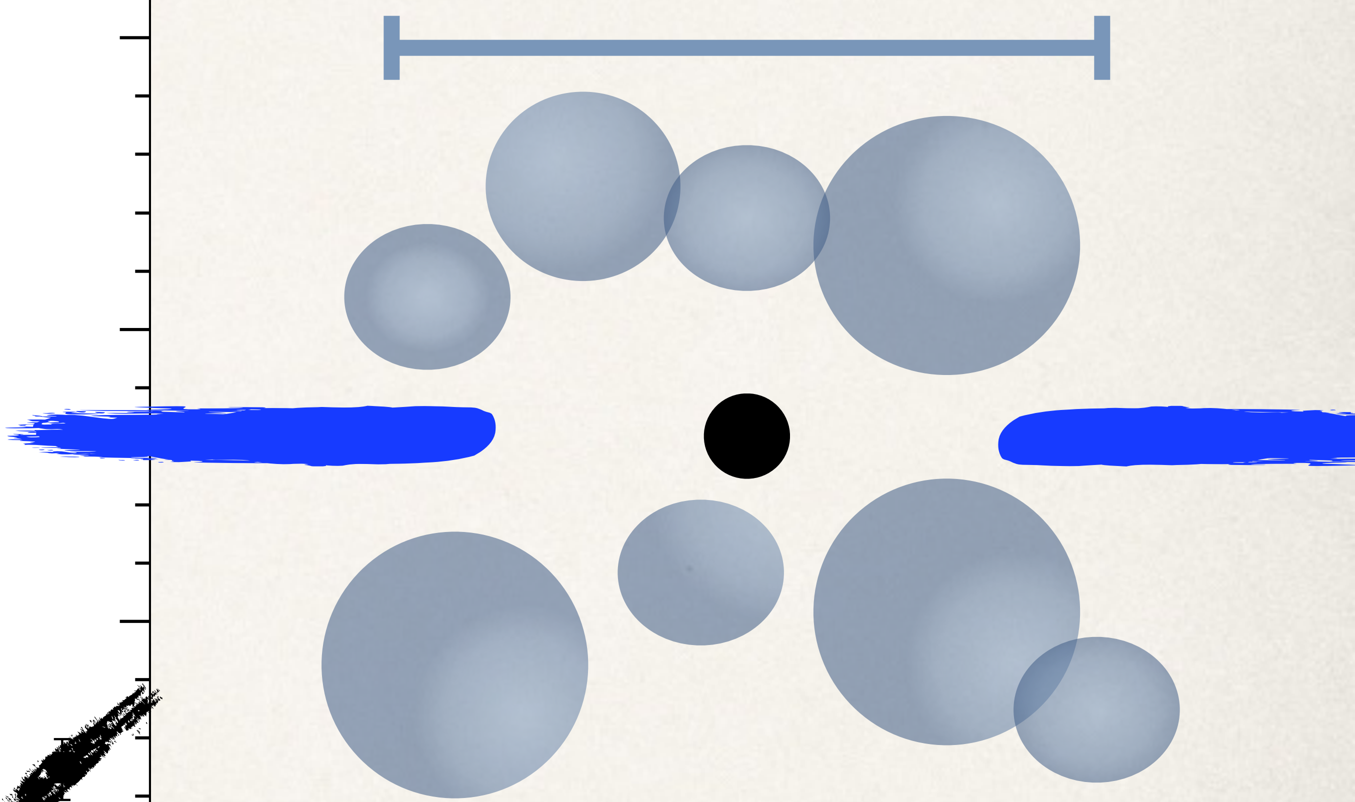


X-ray "corona"

0.0001 pc (~10 R_S)



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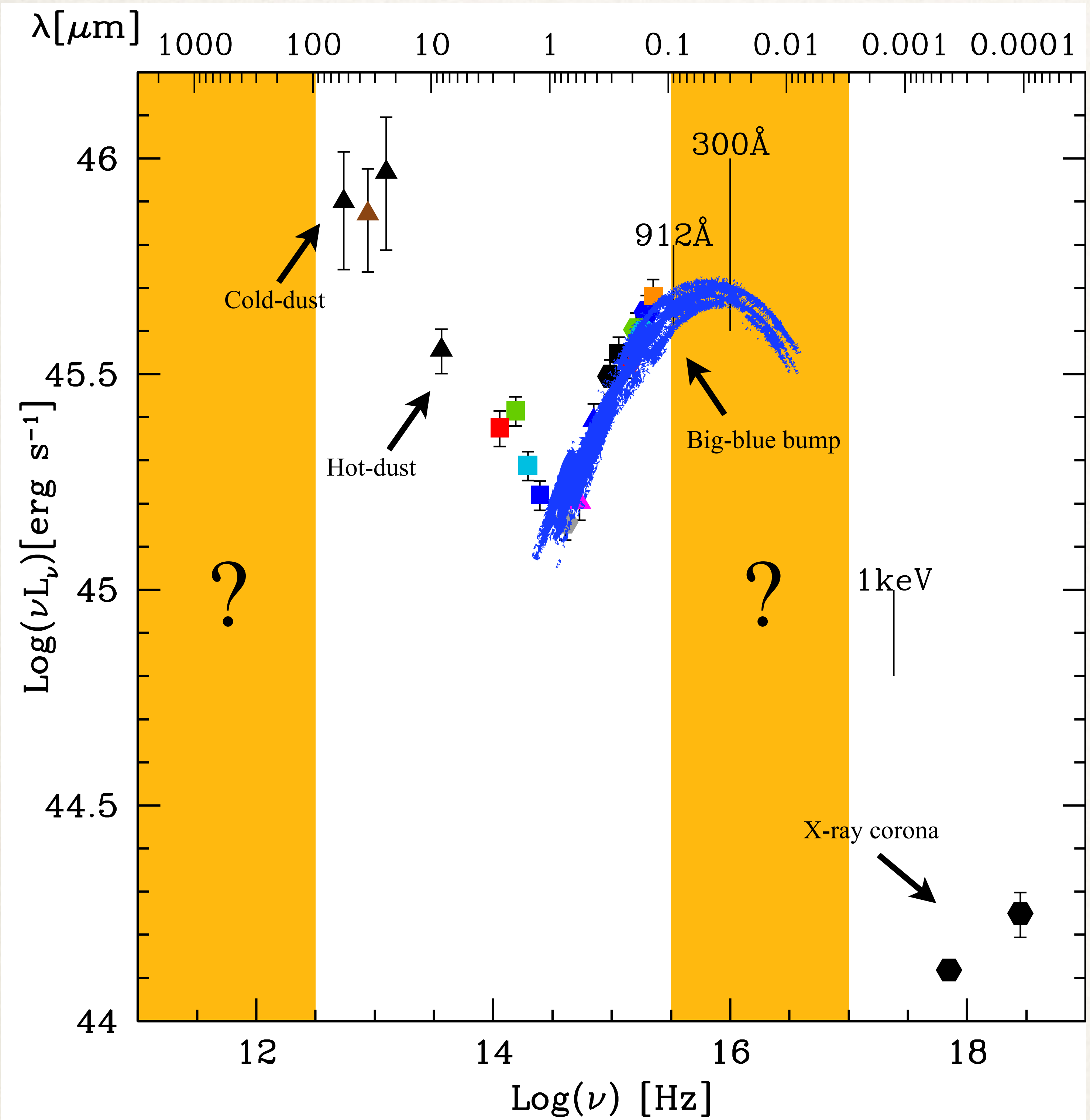
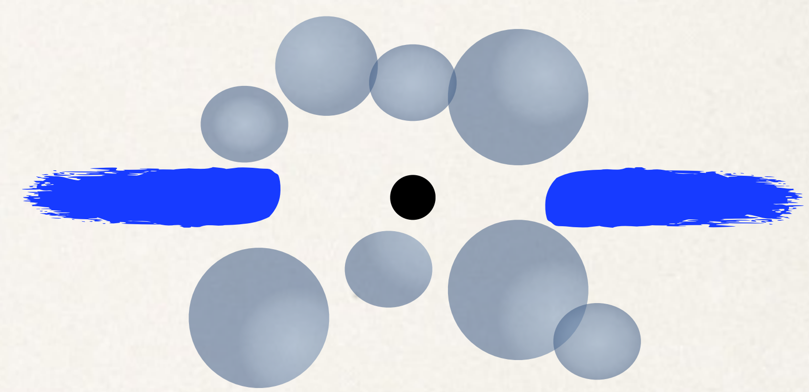


UV continuum
"Big Blue Bump"

0.0001-0.001 pc (10-100 R_S)



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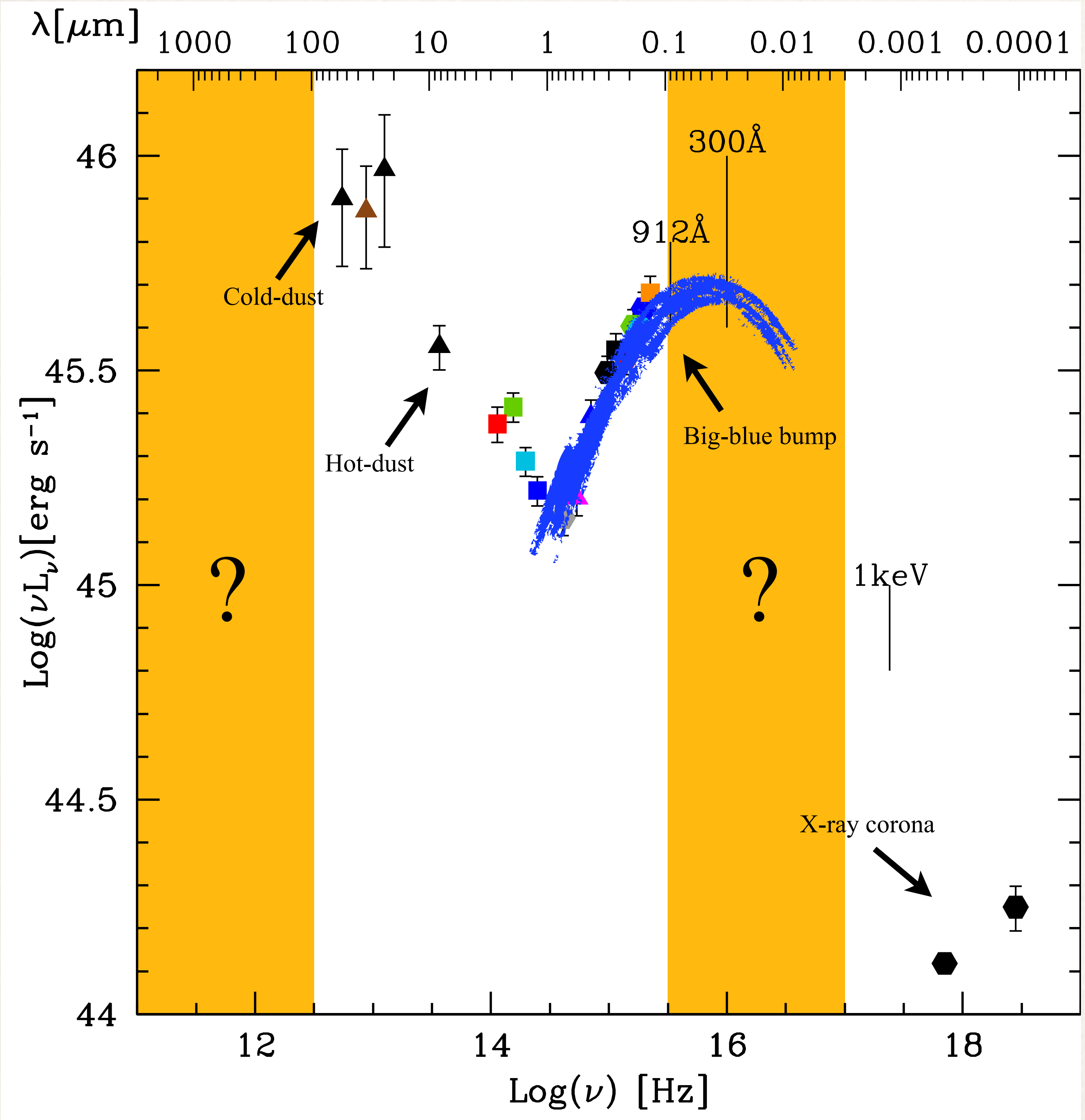
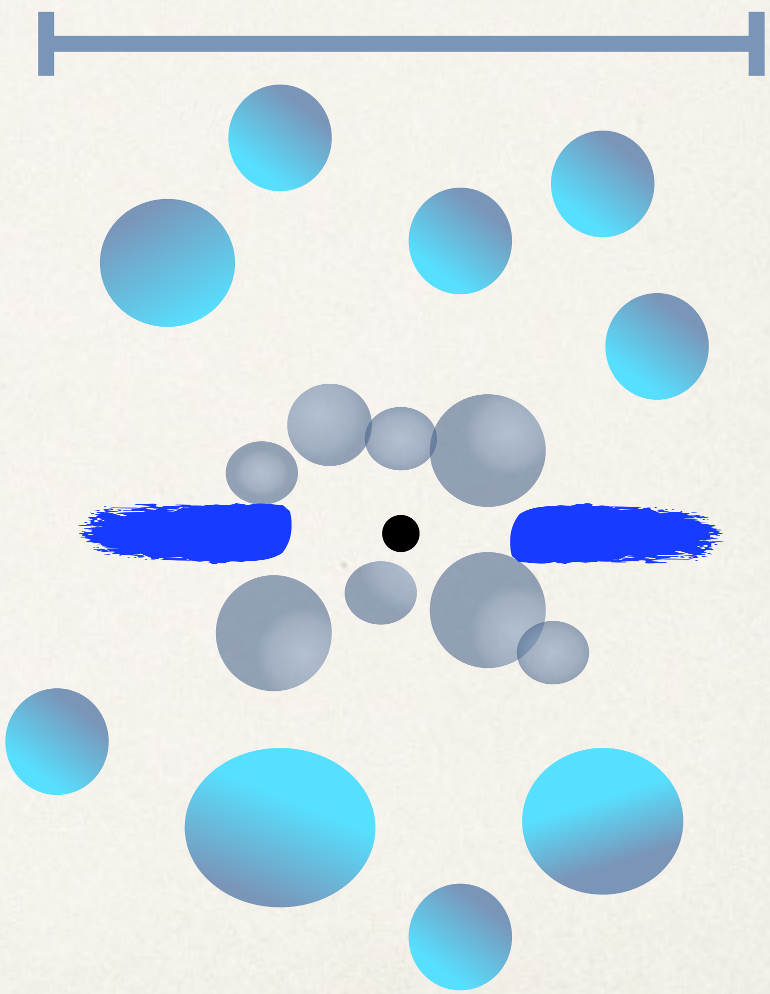


High ionization broad em lines
CIV, HeII, OVI, Coronal lines?

<1 pc (1000-10^5 R_S)



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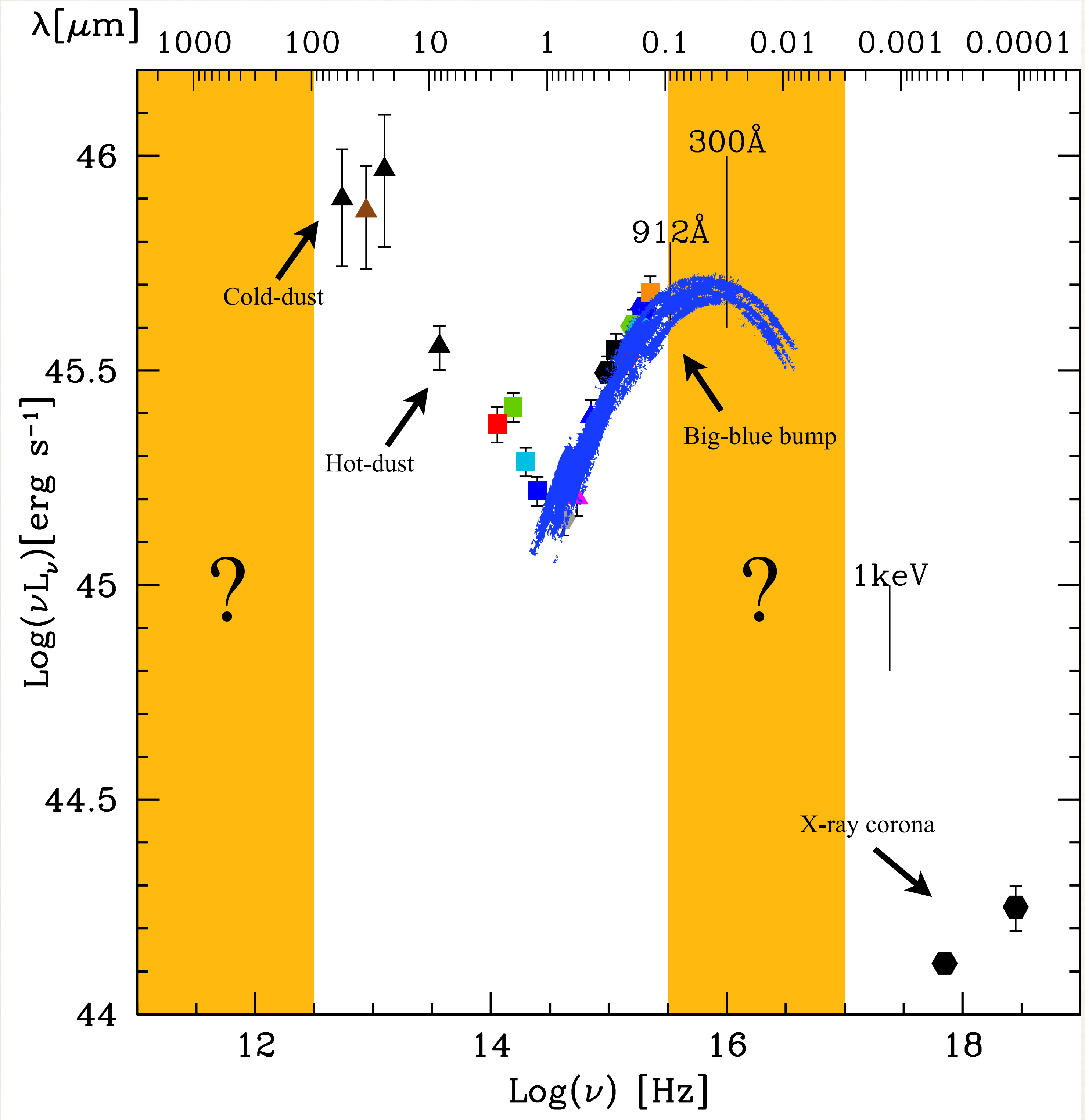
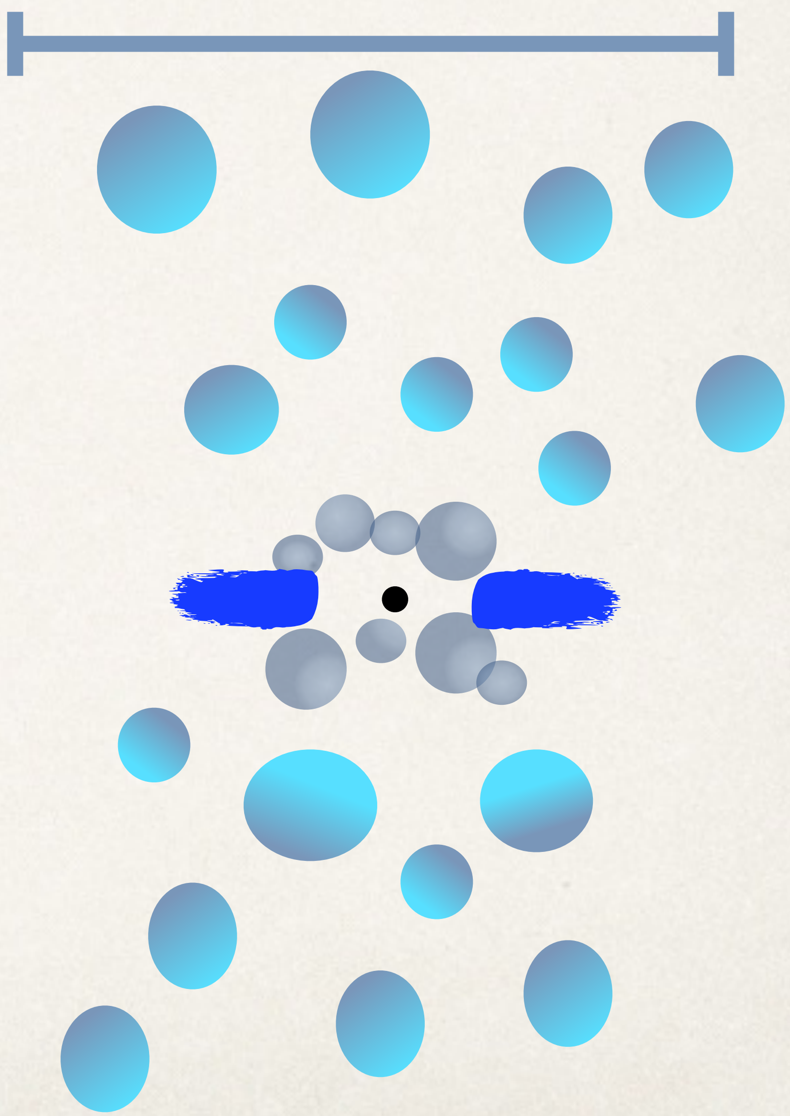


Low ionization broad em lines

MgII, Balmer, Paschen series

(crossing 2000 K = 1μm dip)

<1 pc (1000-10^5 R_S)



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Broad band quasar SEDs

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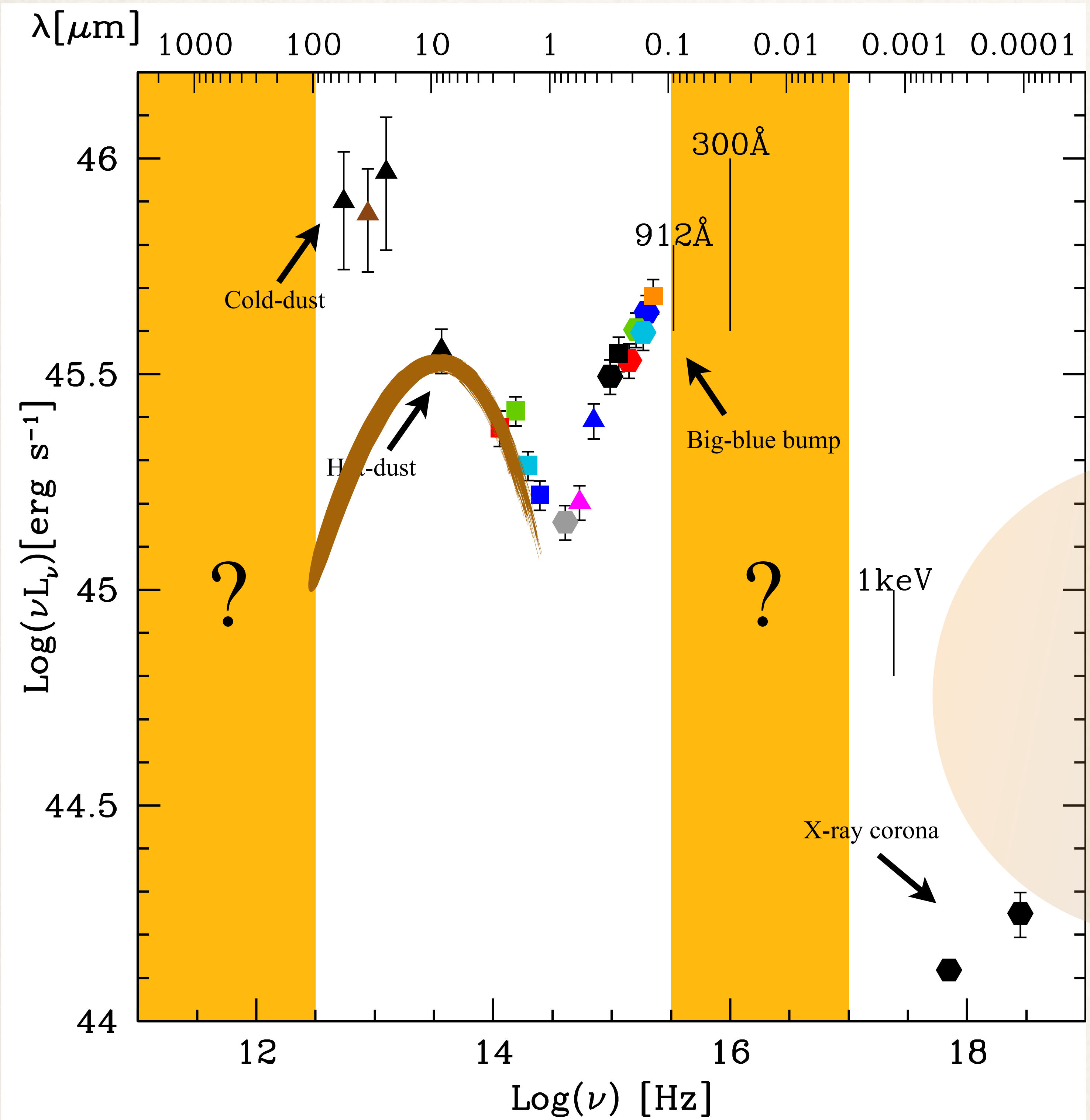
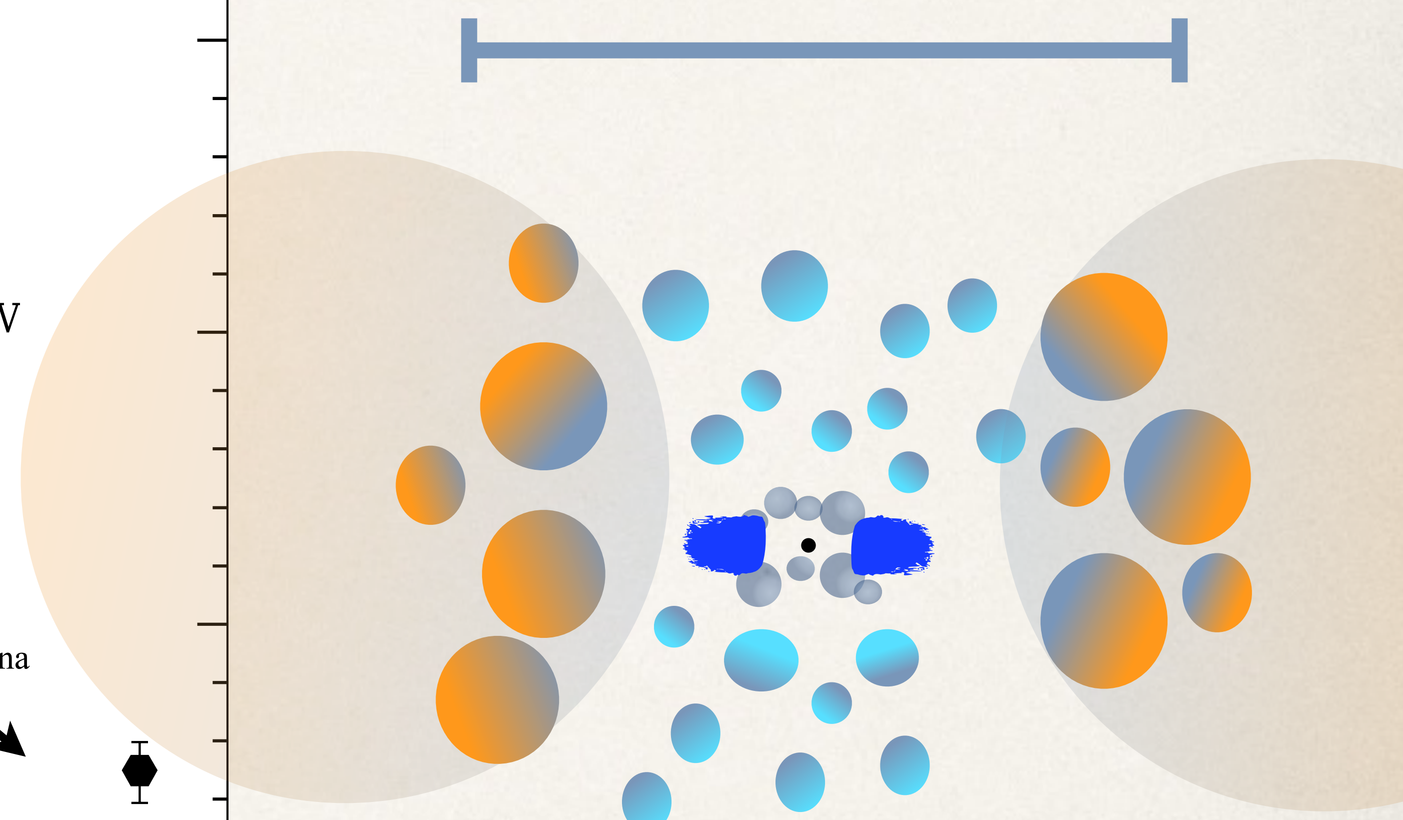


near-IR and mid-IR continuum

Dusty "torus"

Hα, [OIII]

>1 pc (up to few tens of parsec)



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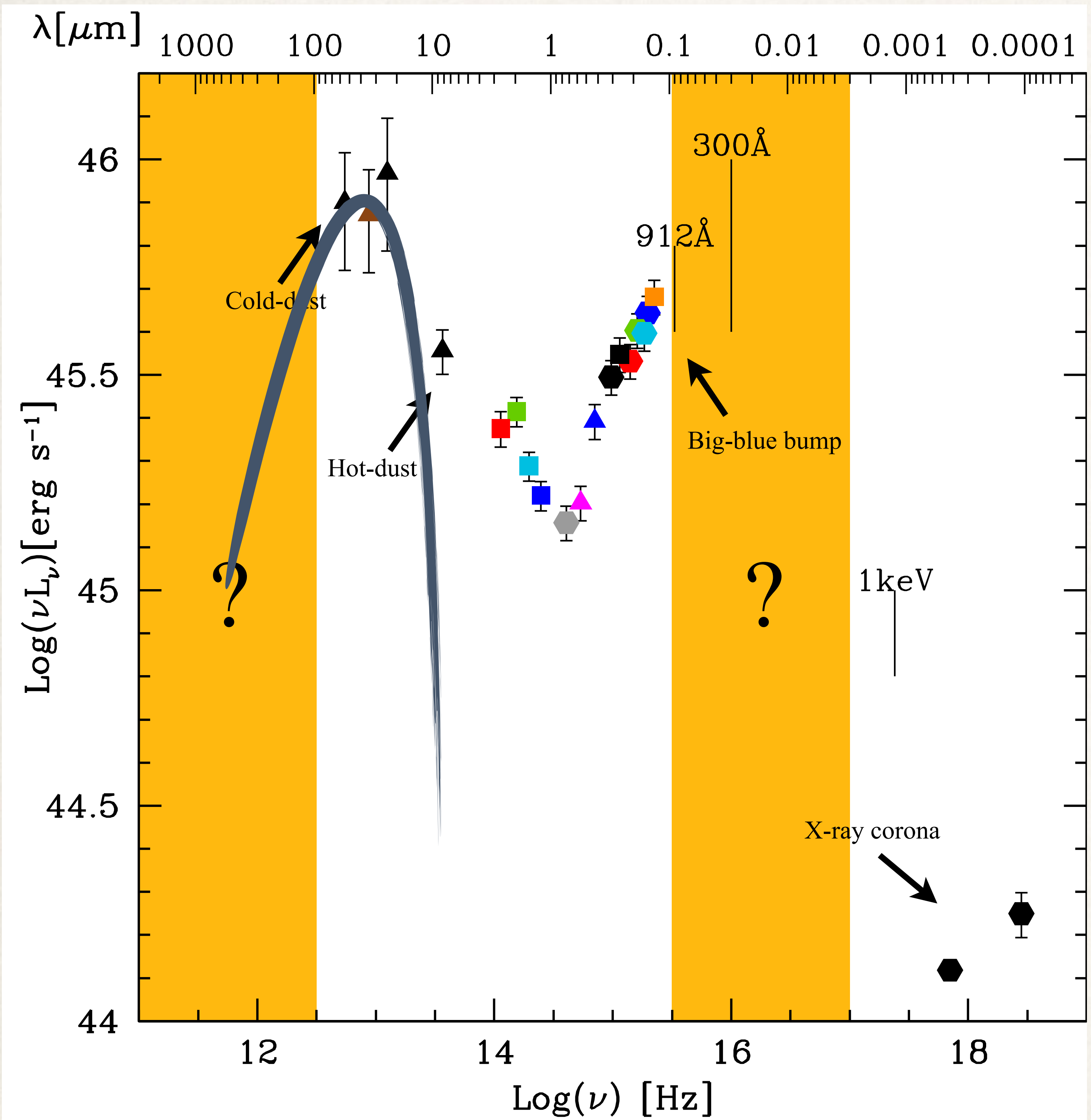

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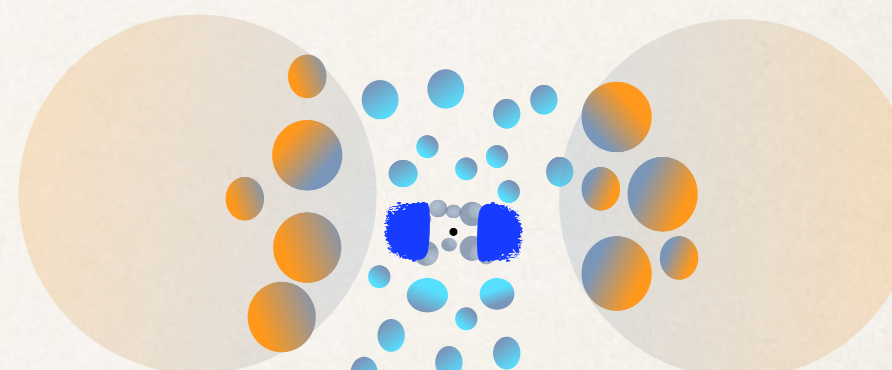
far-IR continuum

Molecular dust (~20 K)

CO, H_2

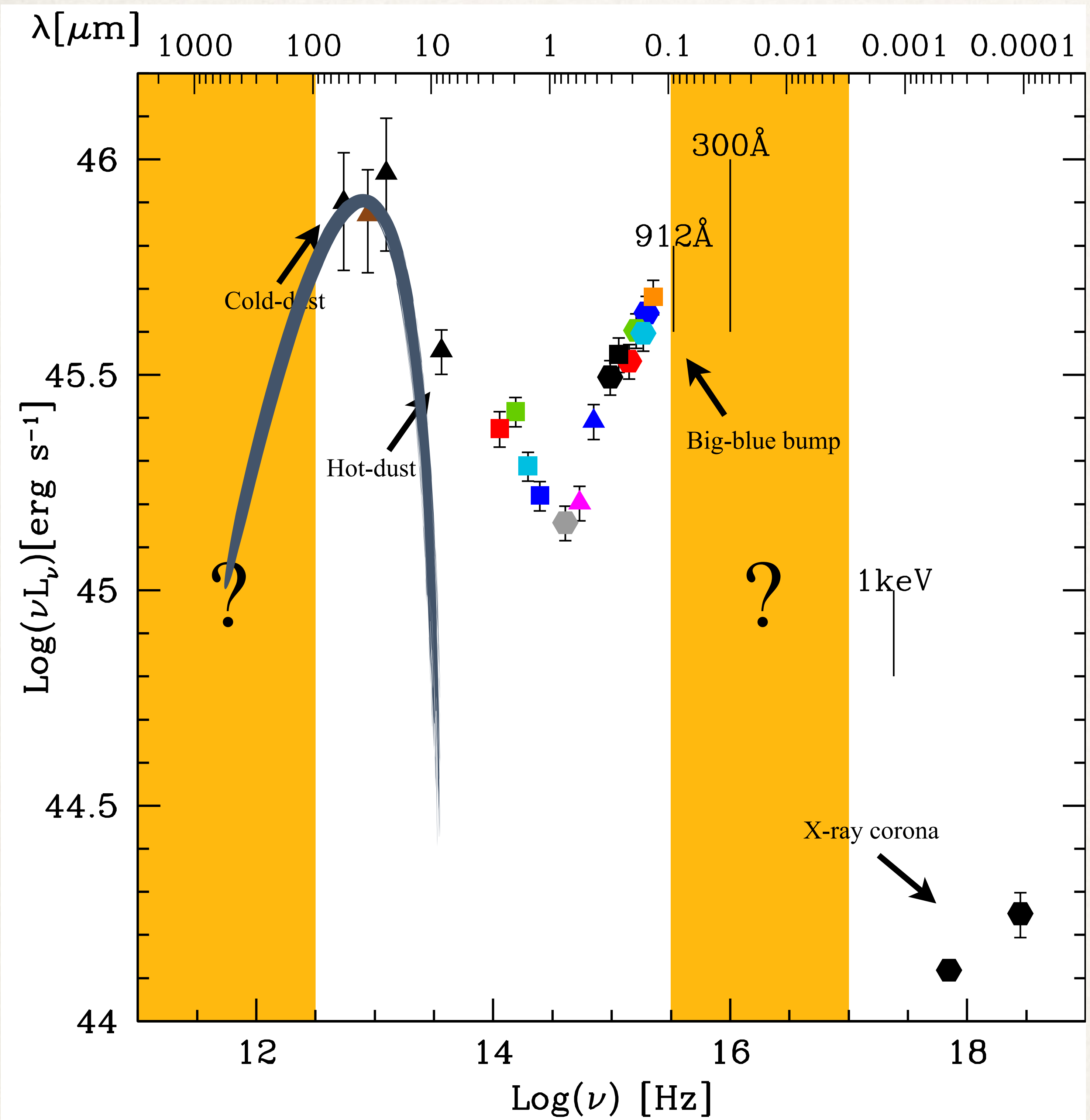
~100 pc



transition region: from nucleus to galaxy

Broad band quasar SEDs

Lusso+10



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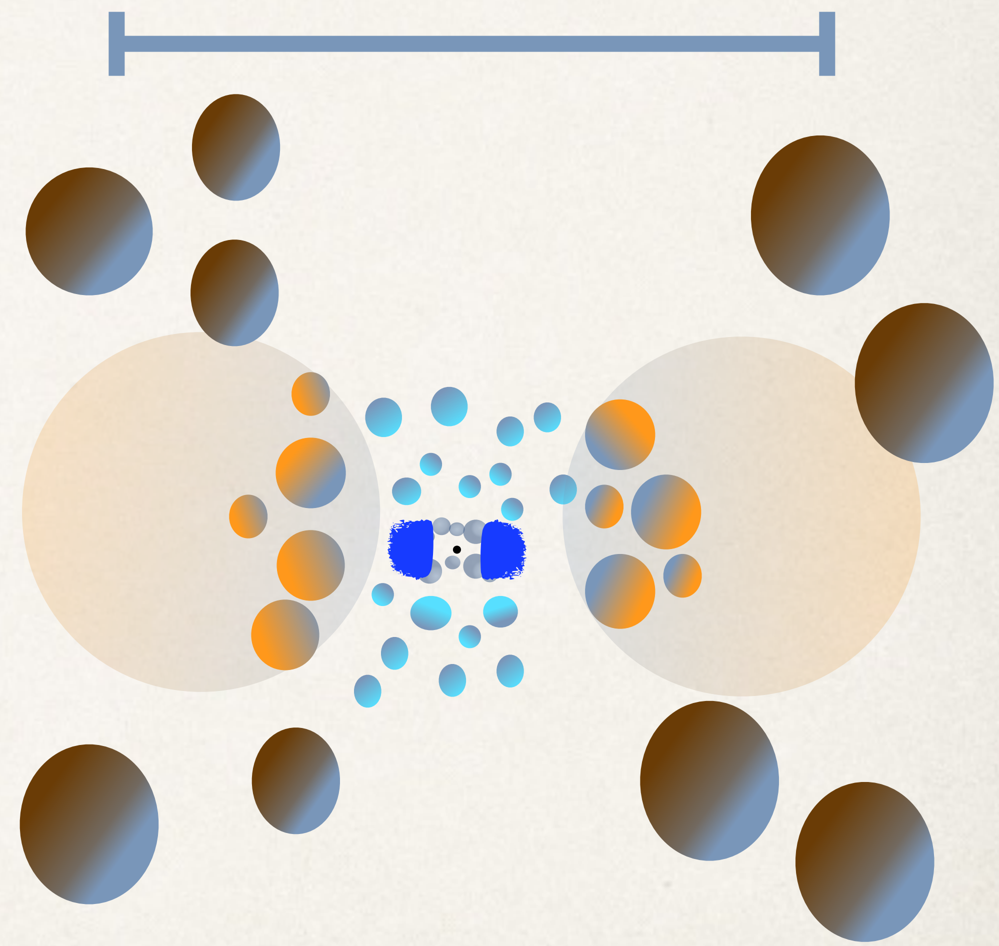

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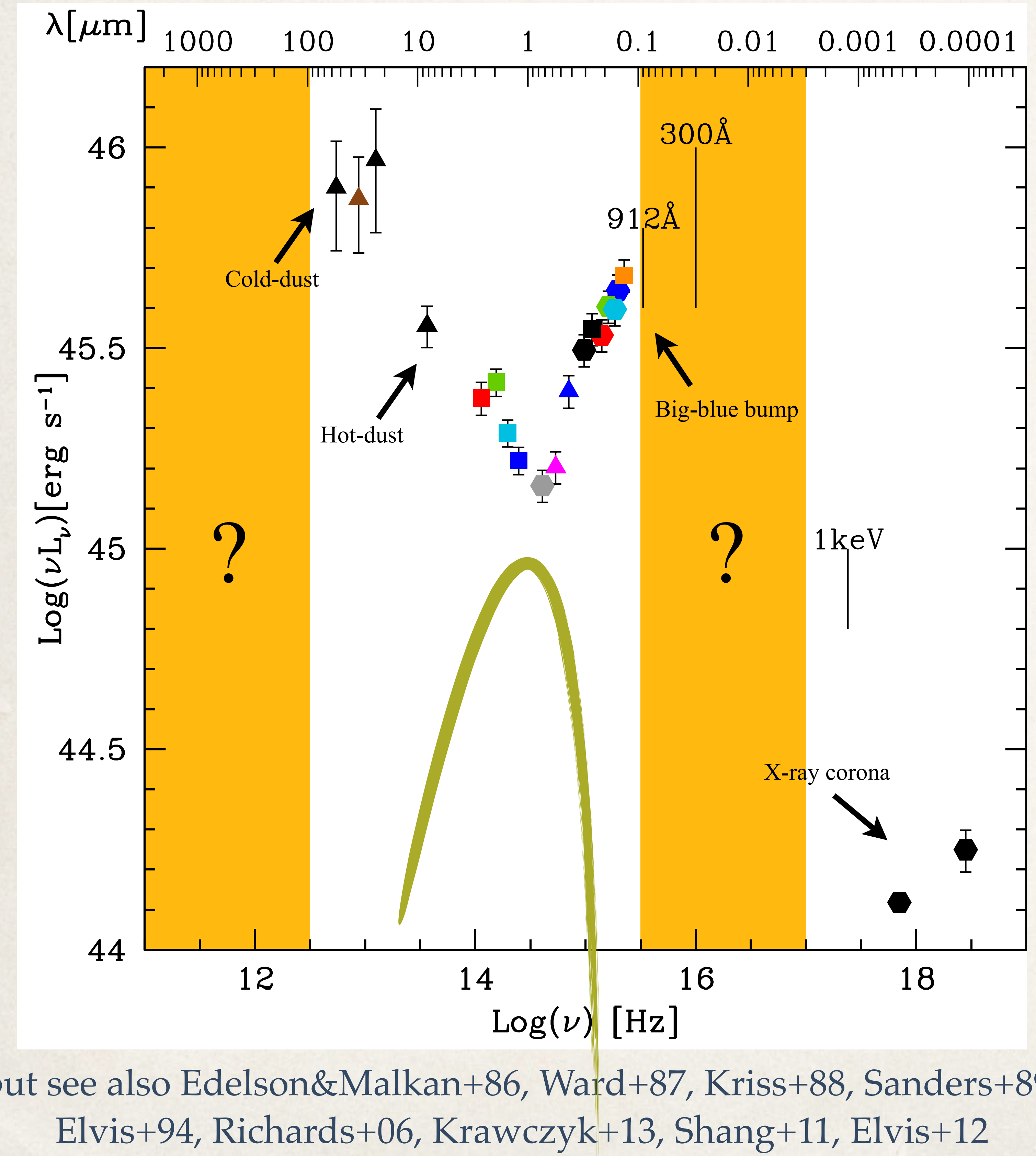
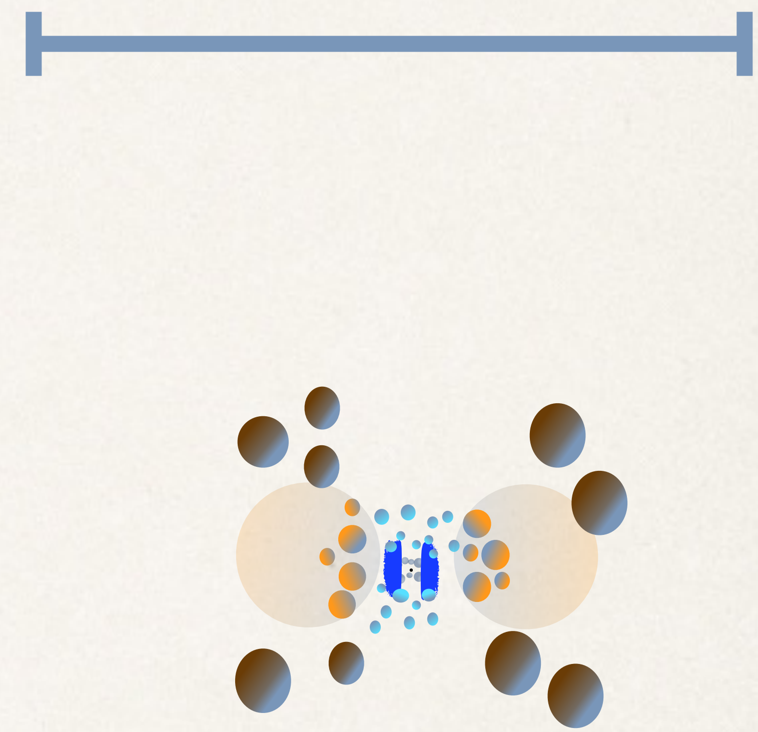


Bulge

Bicones extended NELR

OIII, coronal lines

~1 kpc



Galaxy

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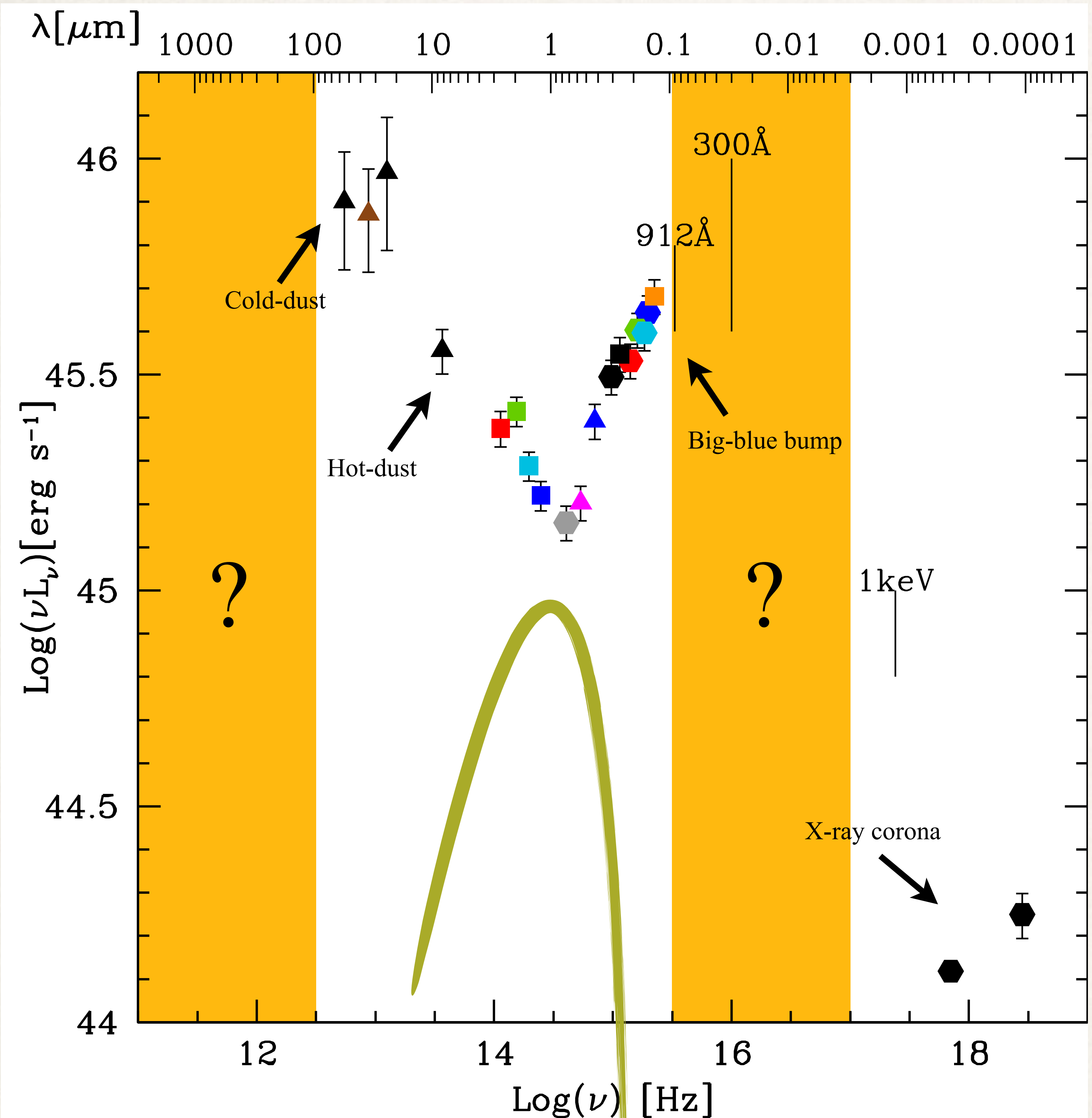

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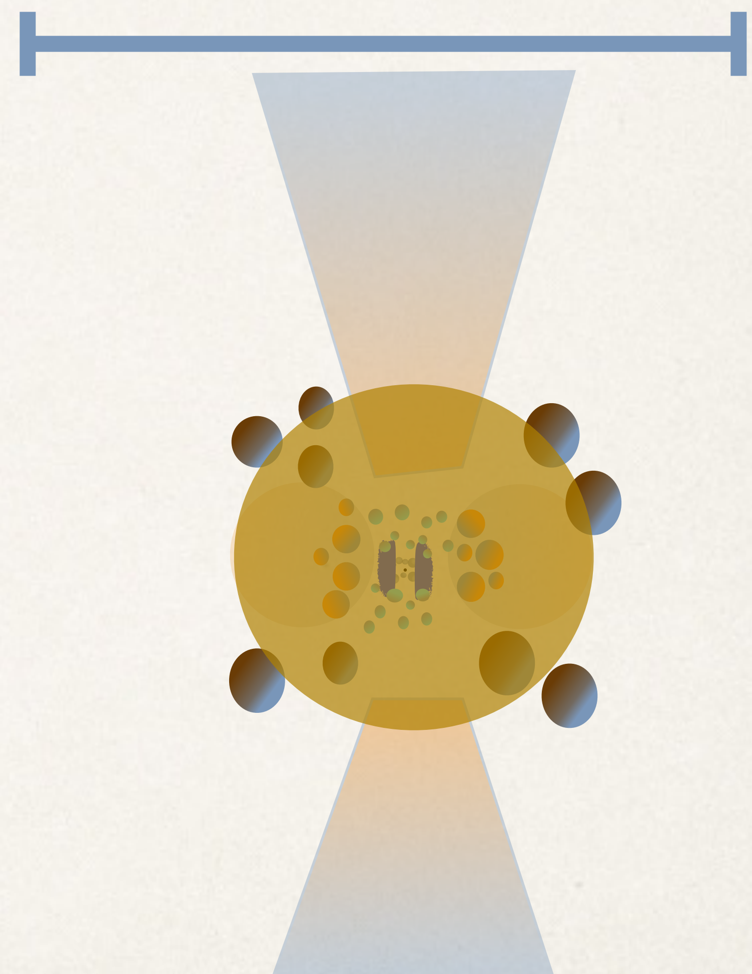

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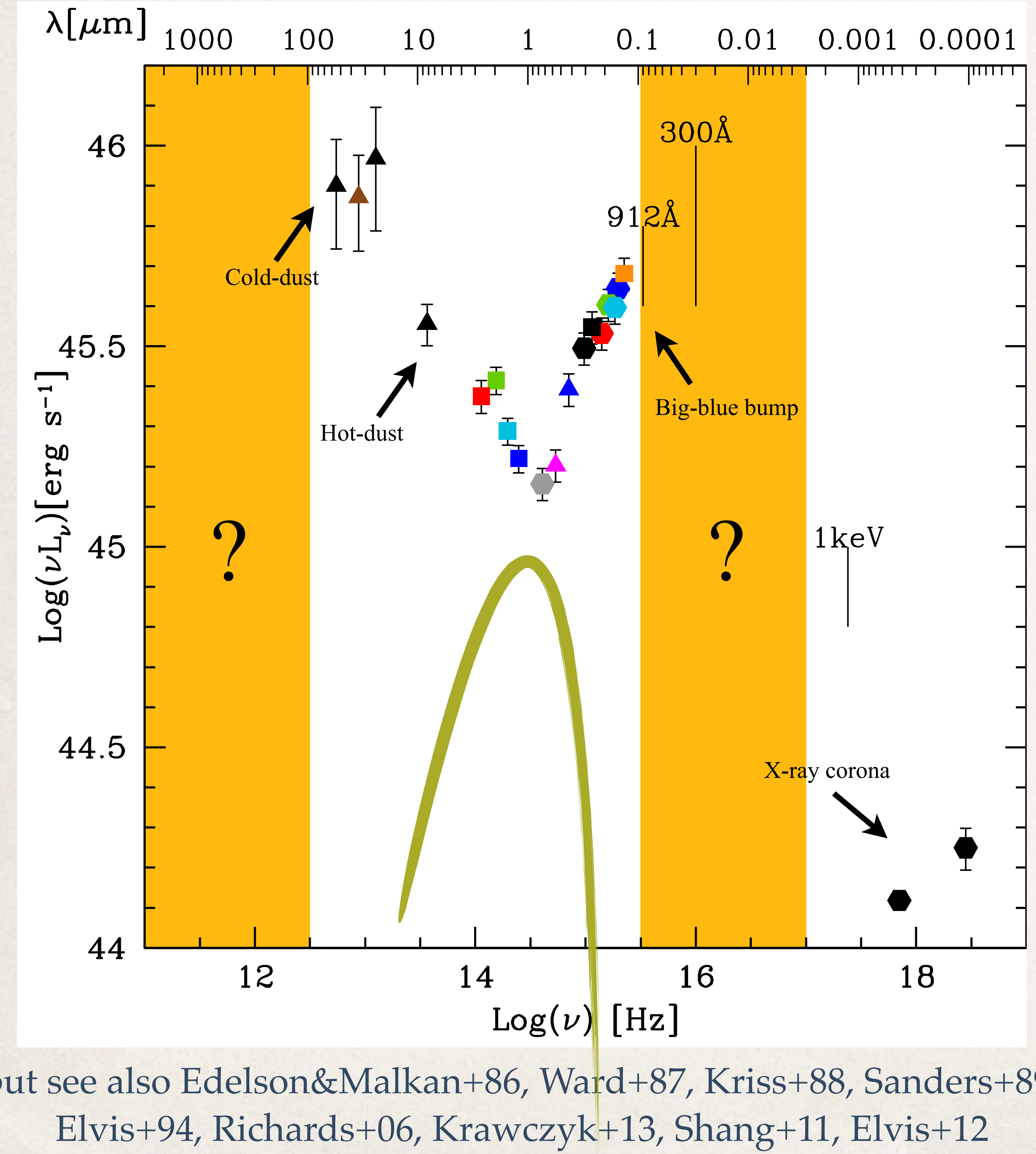
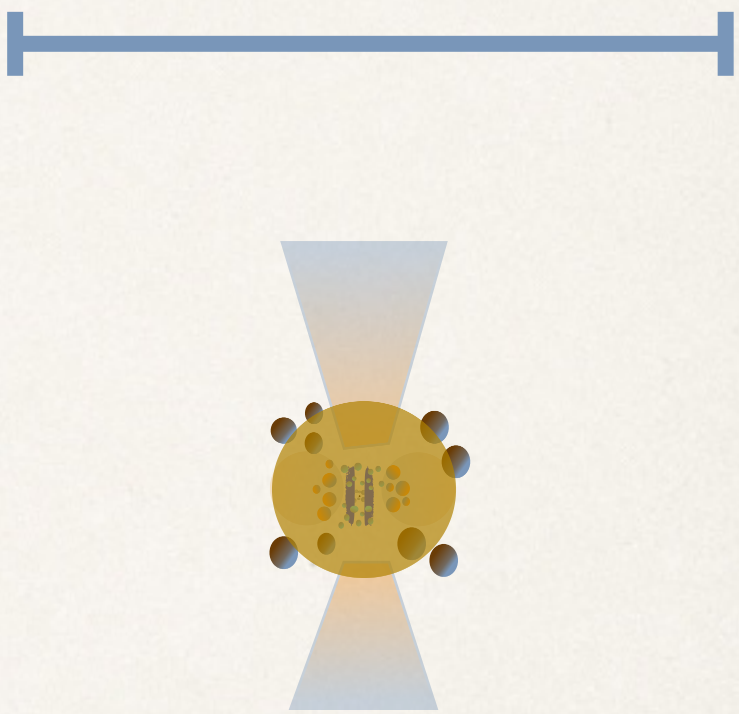


Disk

>10 kpc



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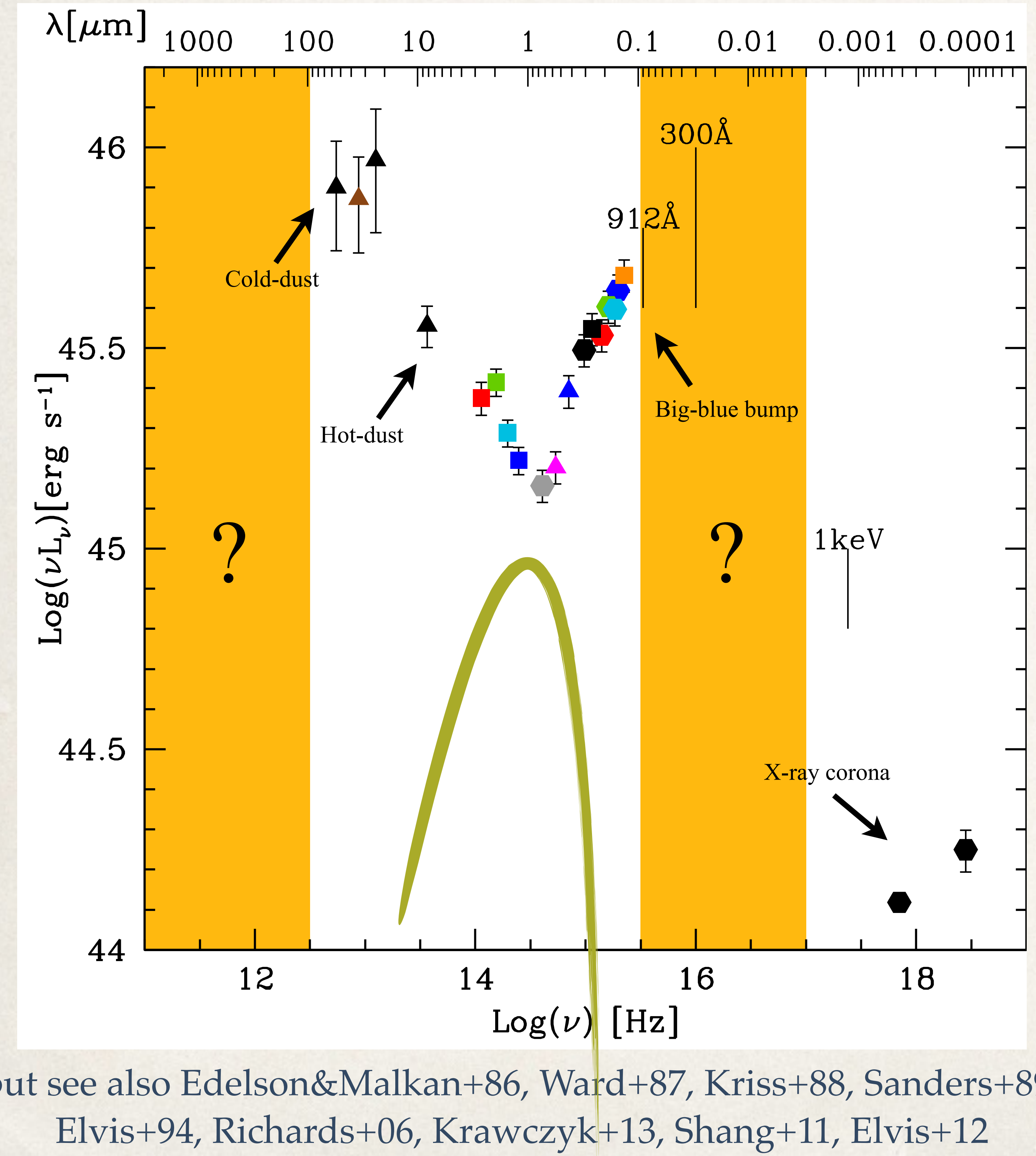

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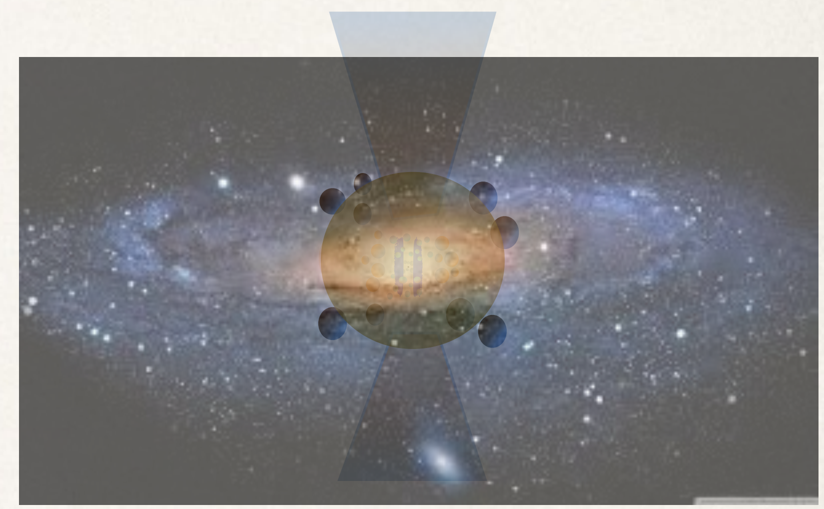

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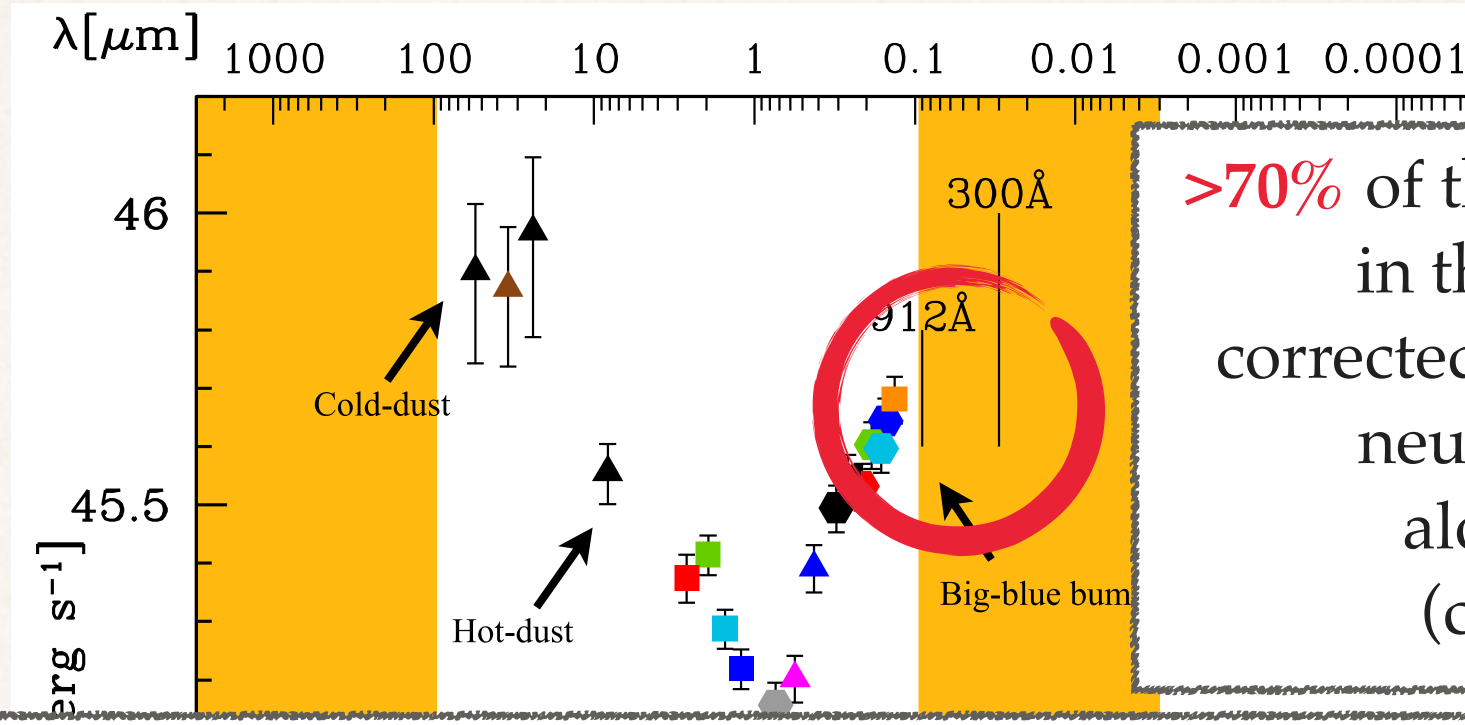


>70% of the AGN emission is in the **optical-UV** corrected for absorption by neutral hydrogen along the l.o.s. (challenging)

- According to the classical **Soltan argument**
  $L_{QSO} = \varepsilon\, dM/dt\, c^2$
  build up of SMBH is a fundamental ingredient in every galaxy/BH co-evolution studies
- **Radiative or quasar-mode feedback**: strongly depends on L_{QSO} and on the (shape) quasar SED (zero-order assumption: one unique SED at every quasar luminosity and redshift)

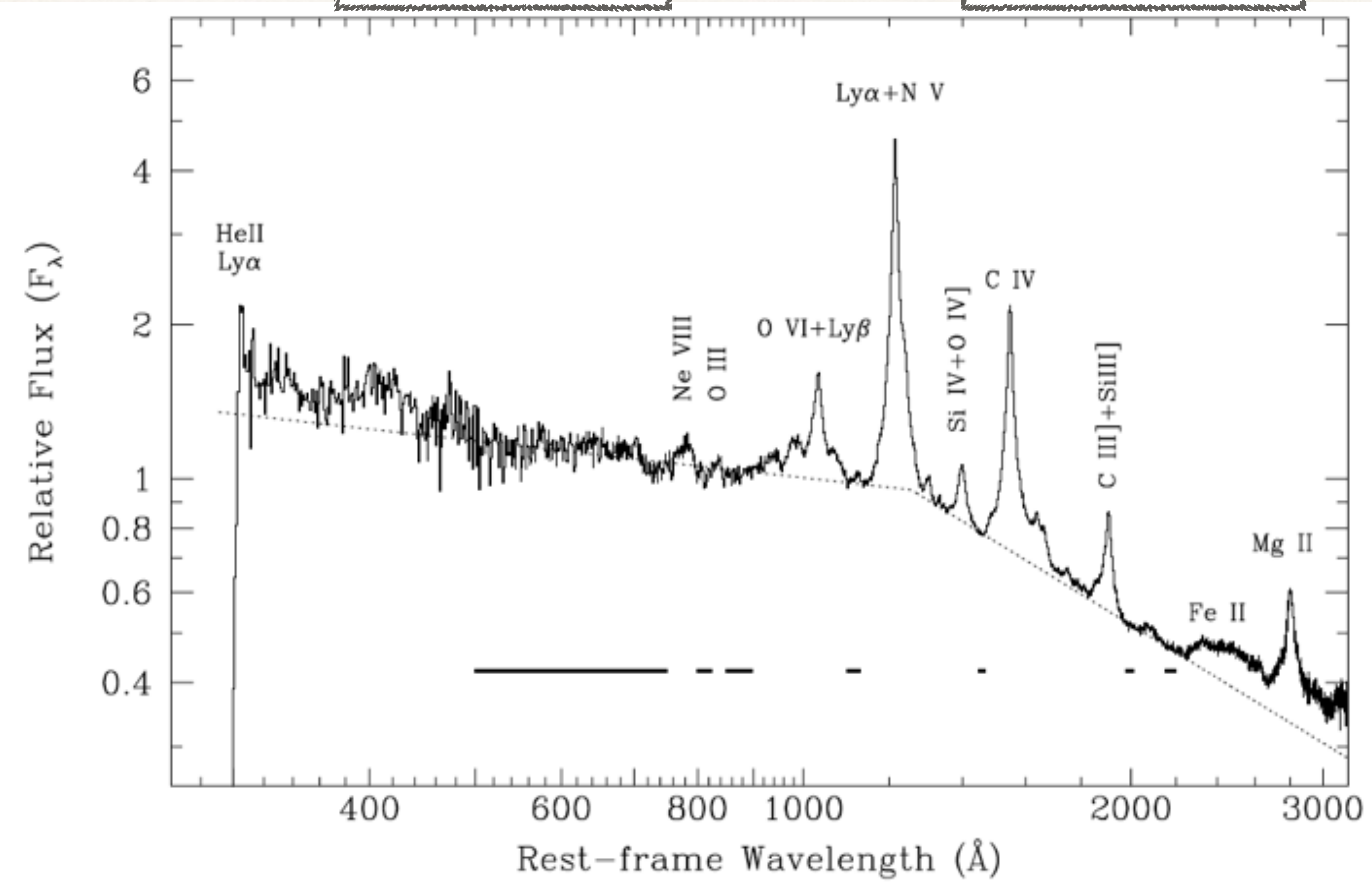
Elvis+94, Richards+06, Krawczyk+13, Shang+11, Elvis+12

UV spectra of BH accretion disks

Telfer+2002 (HST, >340 citations):
184 QSOs at ⟨z⟩~1.2 (~20 QSO z>2), break at ~ Lyα

α_{EUV} = -1.57

α_{NUV} = -0.72



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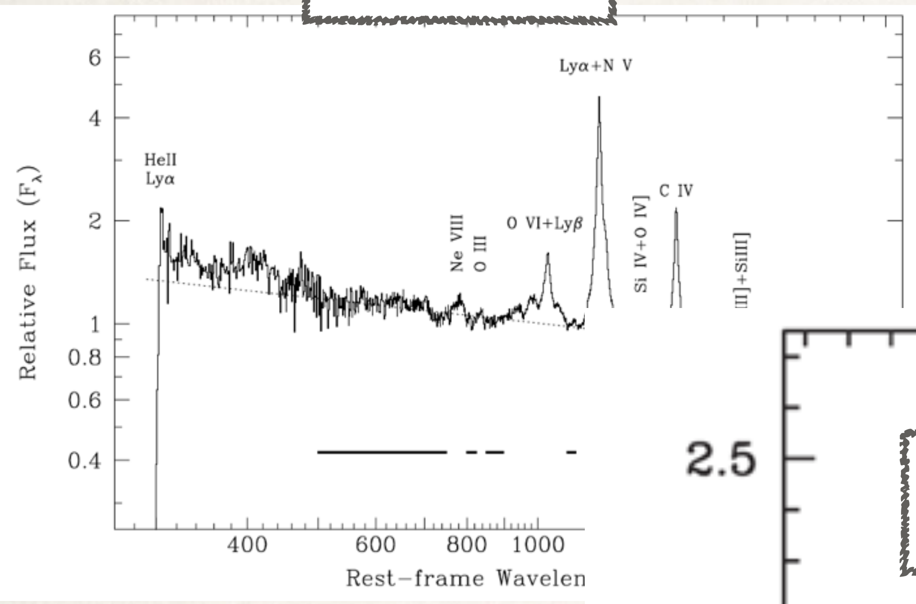
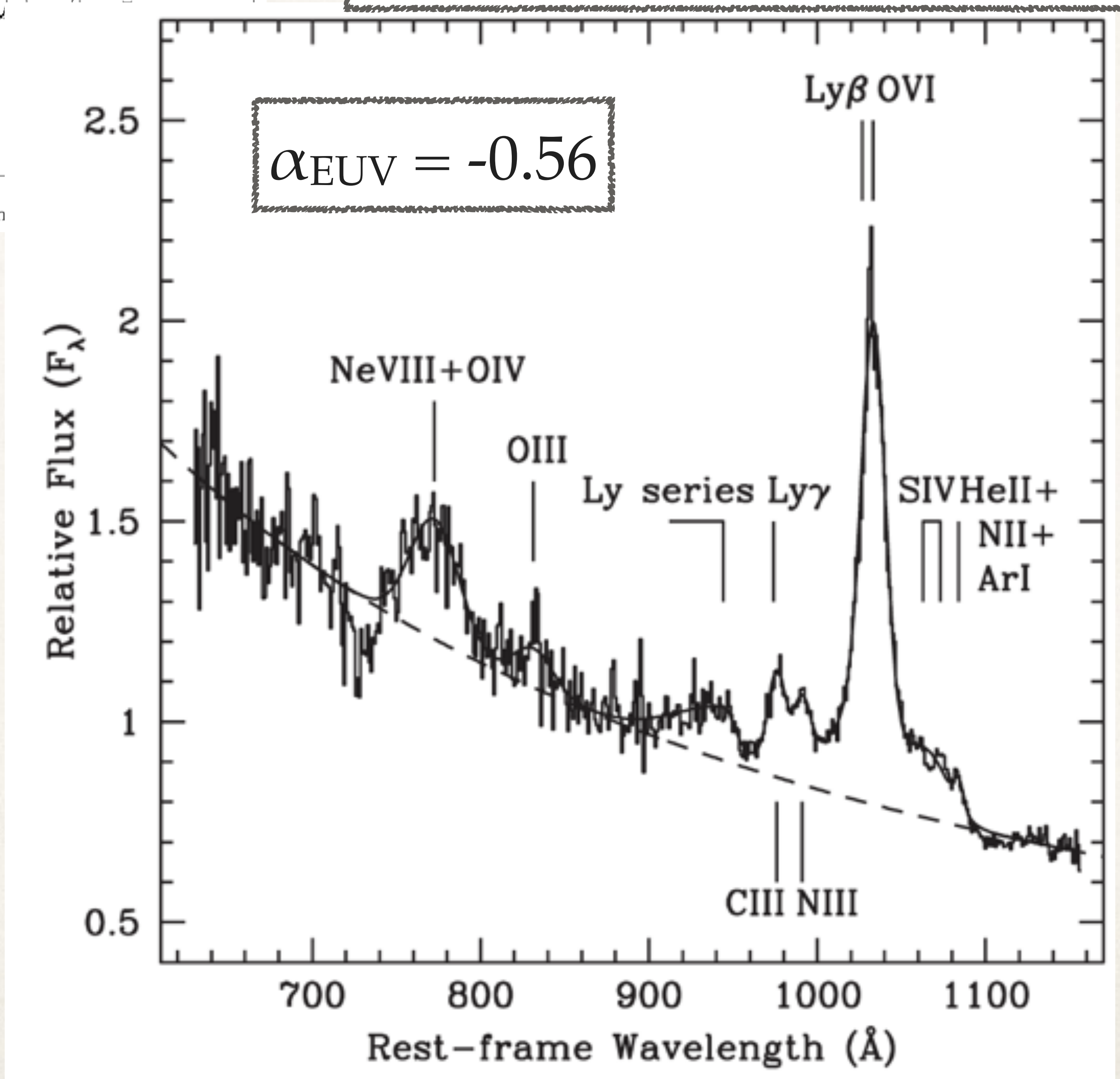


Scott+2004 (FUSE):
85 QSOs at ⟨z⟩~0.1 (z≲0.67), no break

α_{EUV} = -0.56



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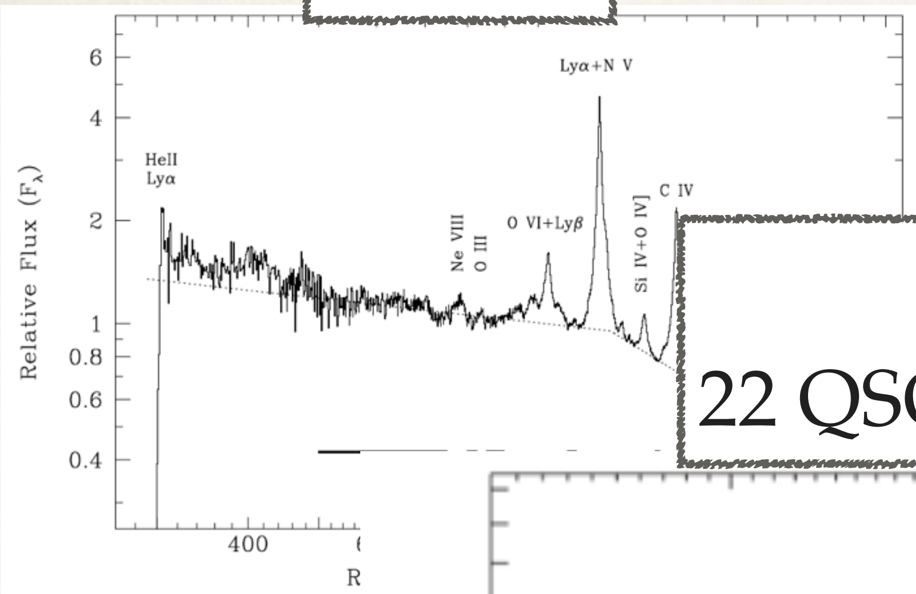


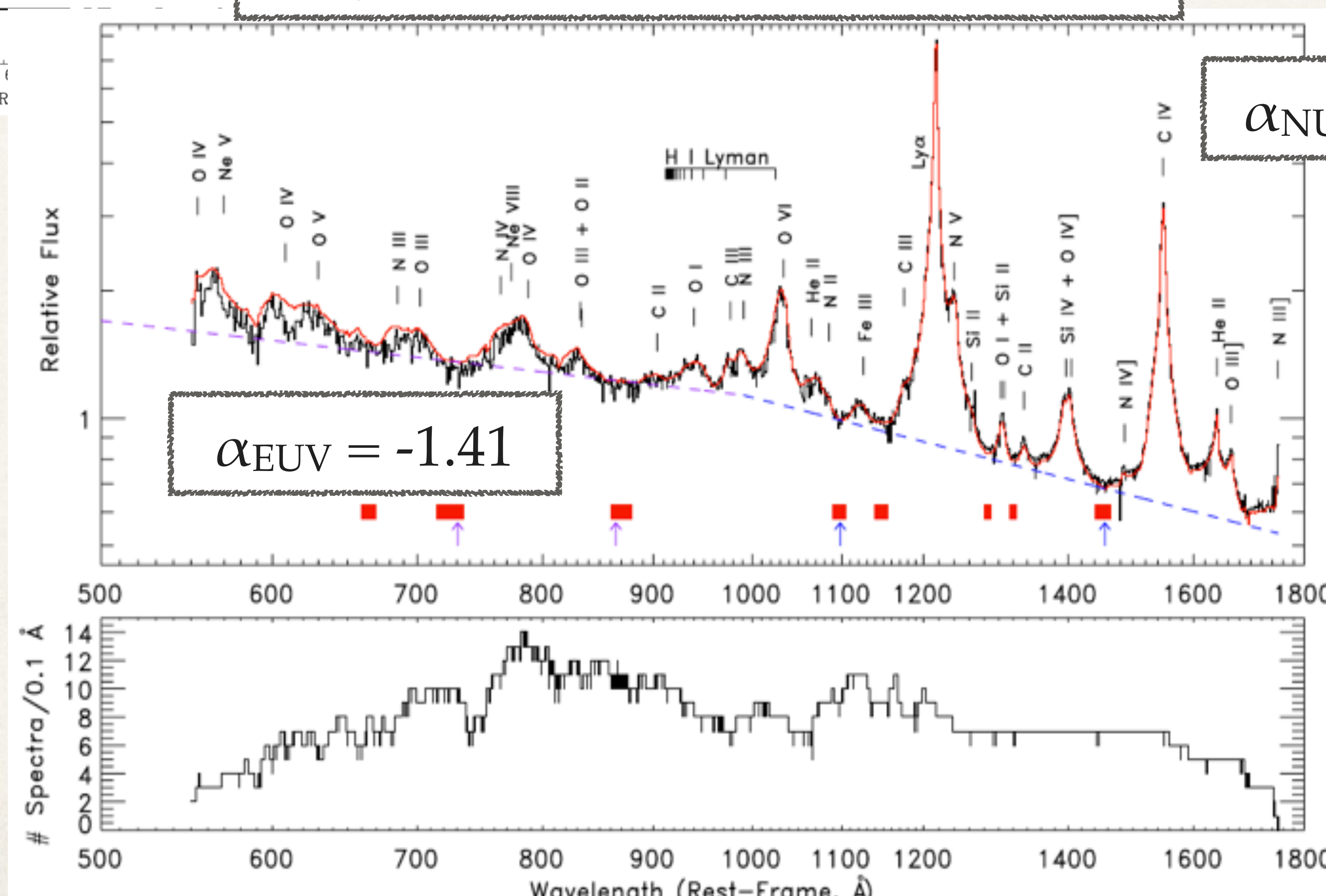
Scott+2004

Shull+2012 (COS):

22 QSOs at ⟨z⟩~0.5, break at ~1000 Å

α_{NUV} = -0.68

α_{EUV} = -1.41



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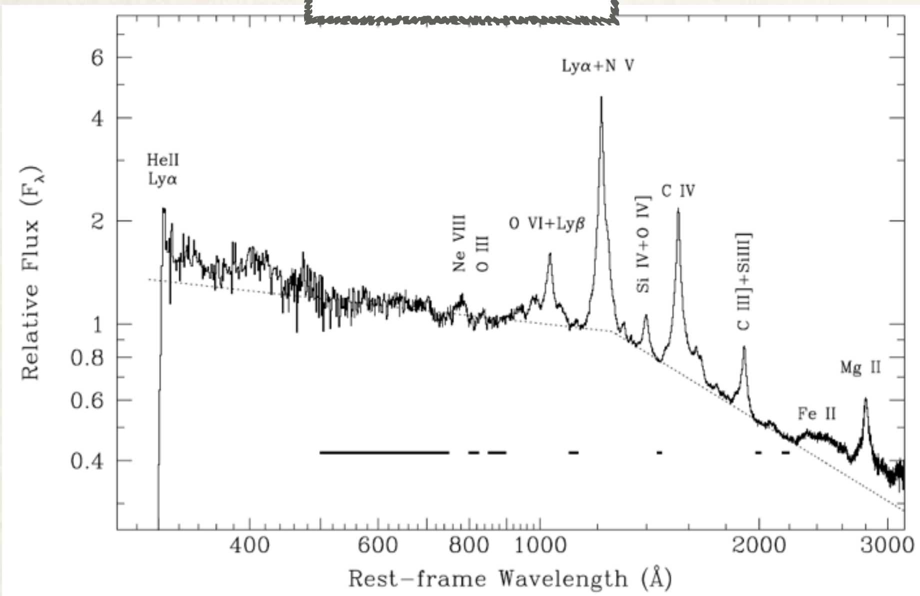

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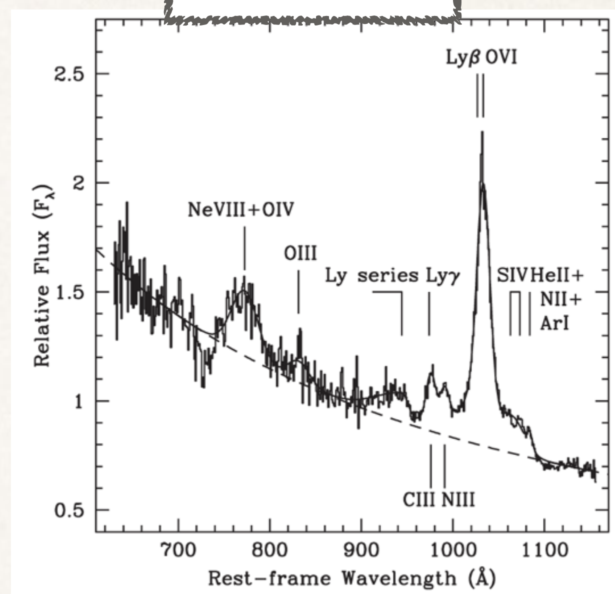

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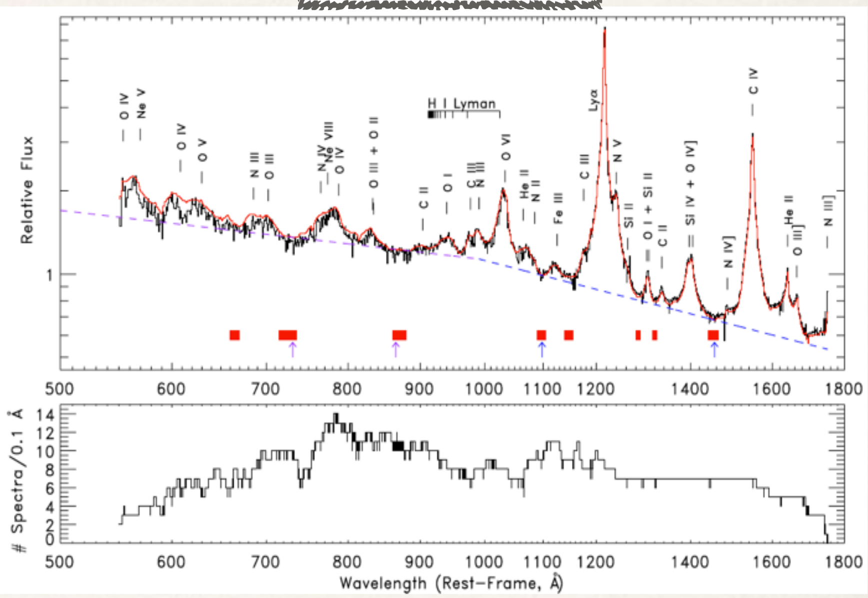


- Expect a break in the UV (black body) which depends on BH mass (and on how the IGM correction is done)
- Expect less massive BH to be hotter

Understanding the spectrum of BH AD

If one assumes:

- AGN luminosity derived by accretion
- Particle erg dissipated locally at distance r and optically thick medium: black body
- Virial theorem

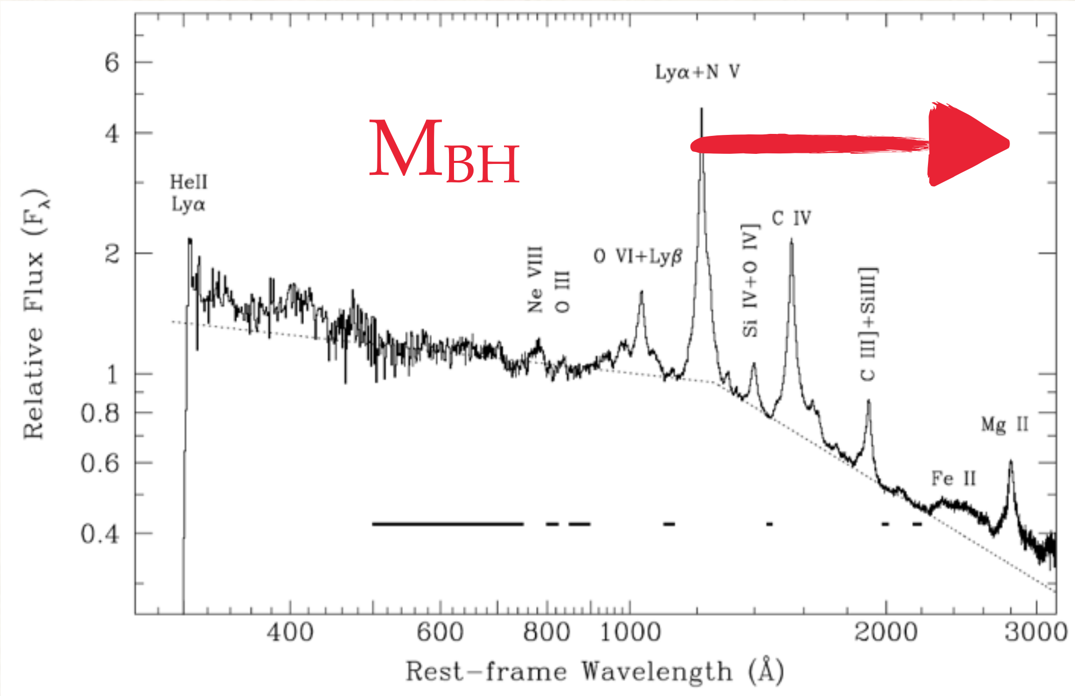
$$T = \left(\frac{GM\dot{M}}{4\pi\sigma r^3}\right)^{1/4} \sim 6.3\times10^5 \left(\frac{\dot{M}}{M_E}\right)^{1/4} M_8^{-1/4} \left(\frac{r}{R_S}\right)^{-3/4}$$

$r = 3\,R_S$; λ=0.1 ; $M_{BH} = 10^6\,M_\odot \Rightarrow T \sim 5.0\times10^5$ K

$r = 3\,R_S$; λ=0.1 ; $M_{BH} = 10^8\,M_\odot \Rightarrow T \sim 1.5\times10^5$ K

The disc temperature decreases as the black hole mass increases

We expect to see the location of the break changing as a function of M_{BH}



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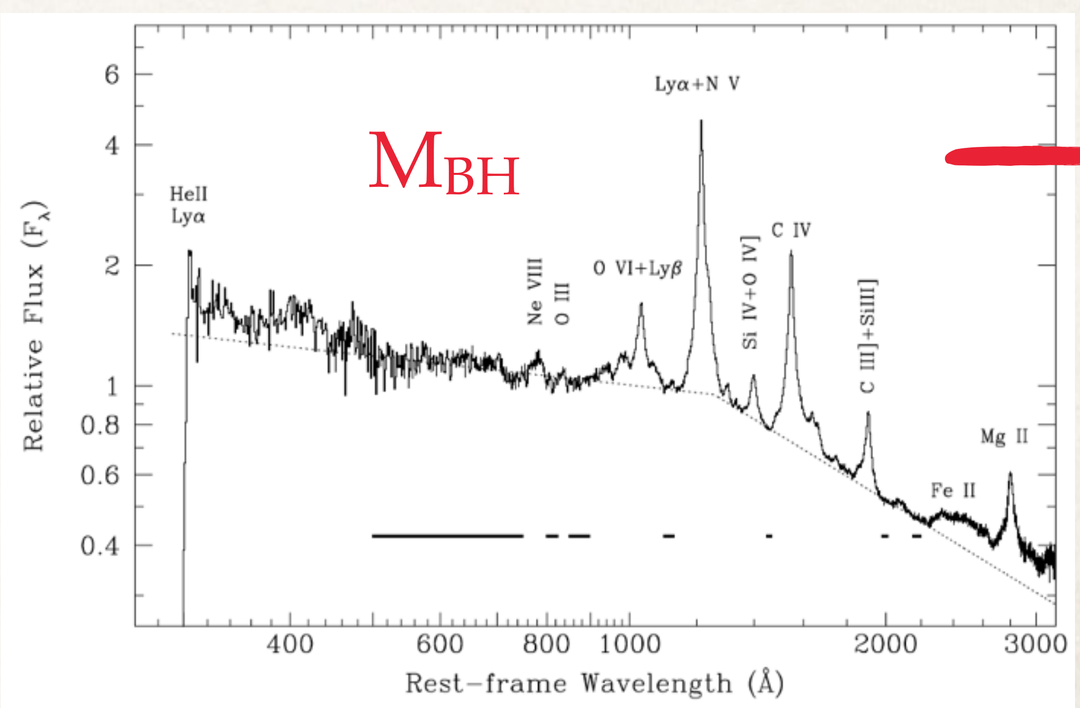
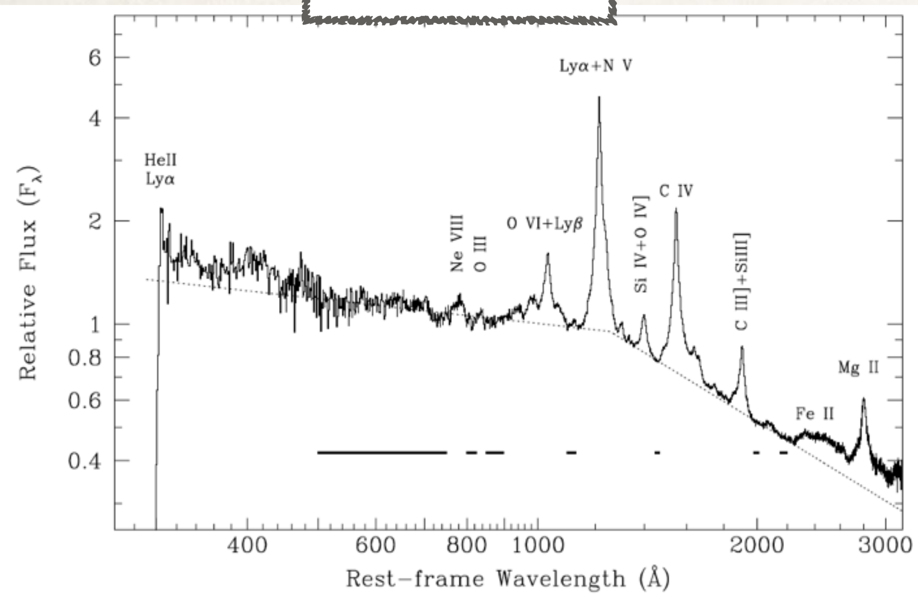


UV spectra of BH accretion disks

Telfer+2002



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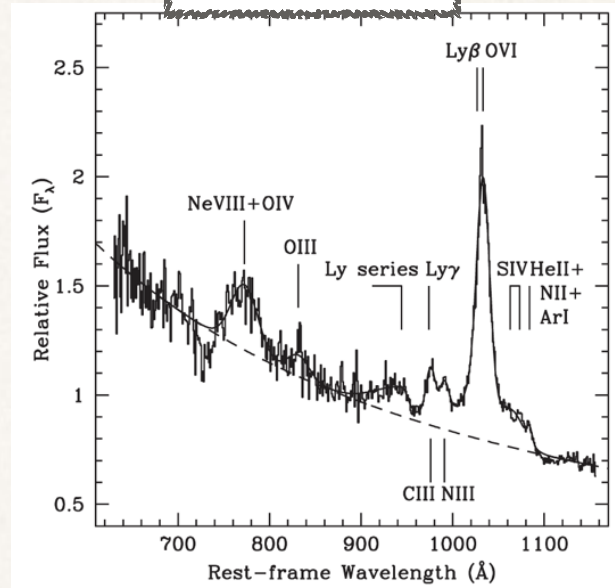
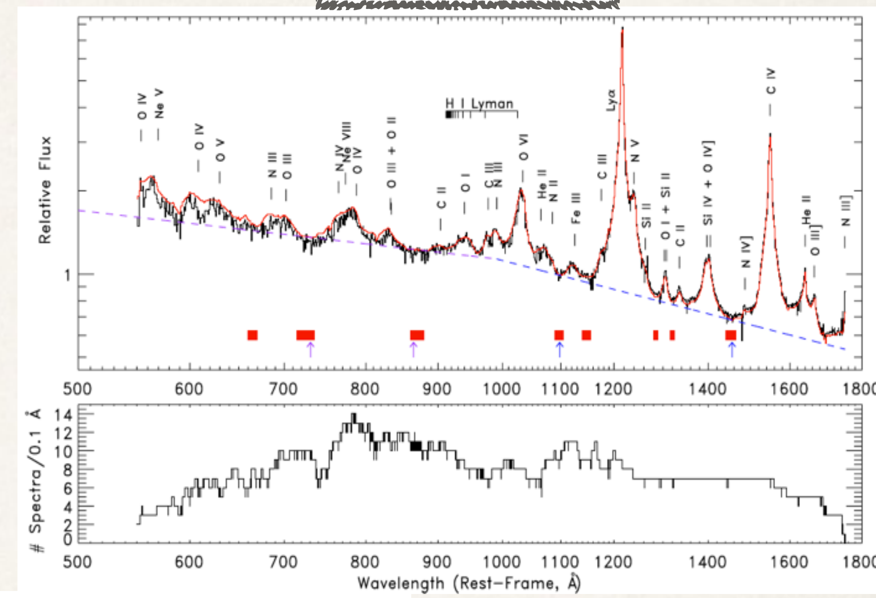
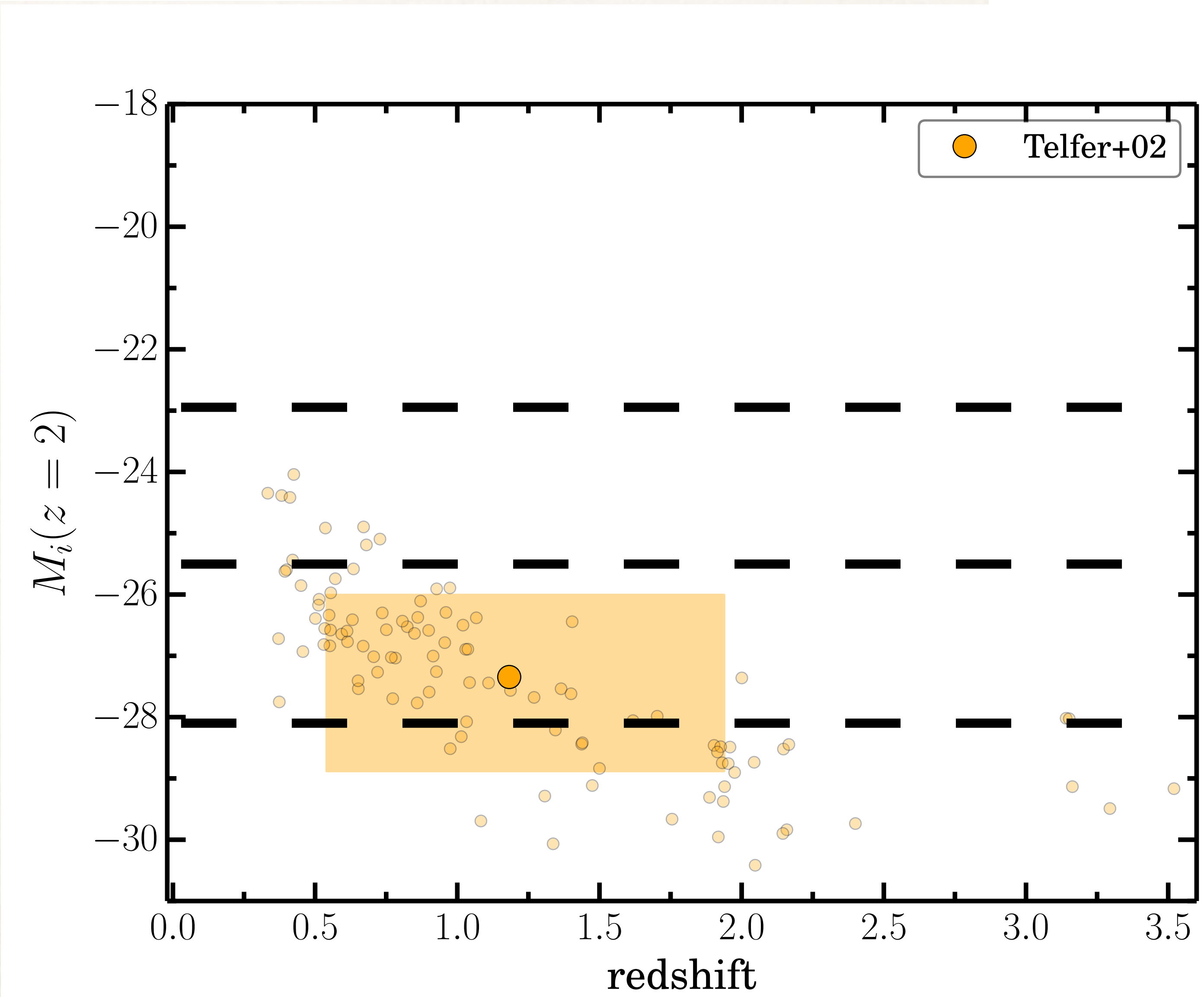


Shull+2012





$M_{BH} \sim 10^7\ M_\odot$

$M_{BH} \sim 10^8\ M_\odot$

$M_{BH} \sim 10^9\ M_\odot$

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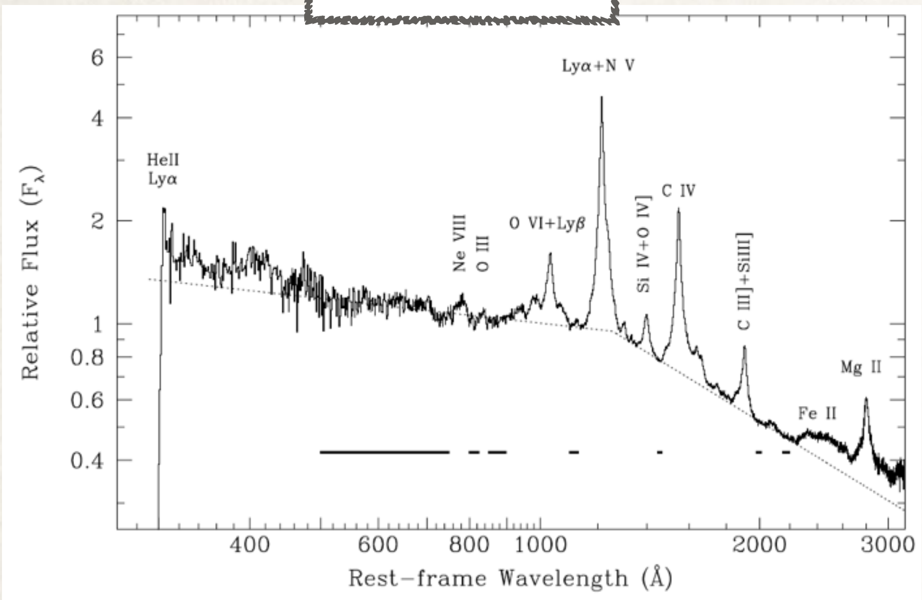

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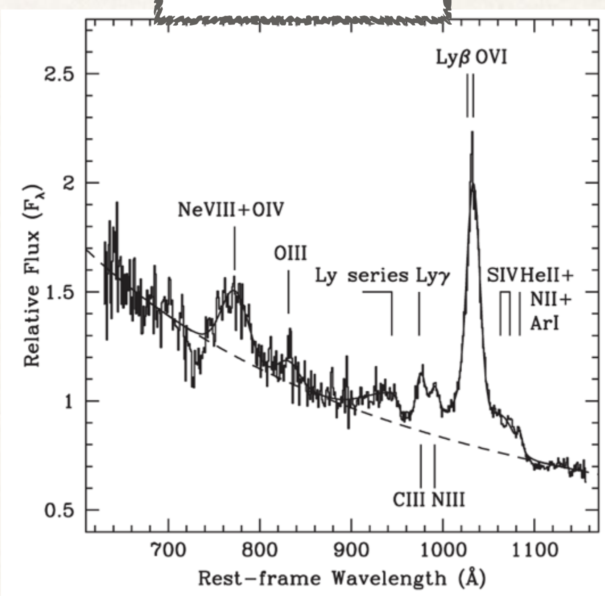

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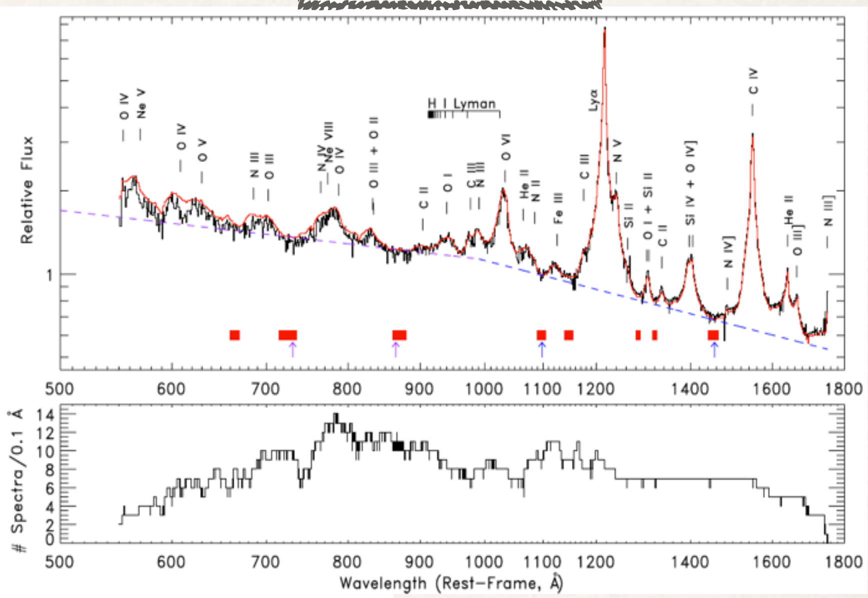

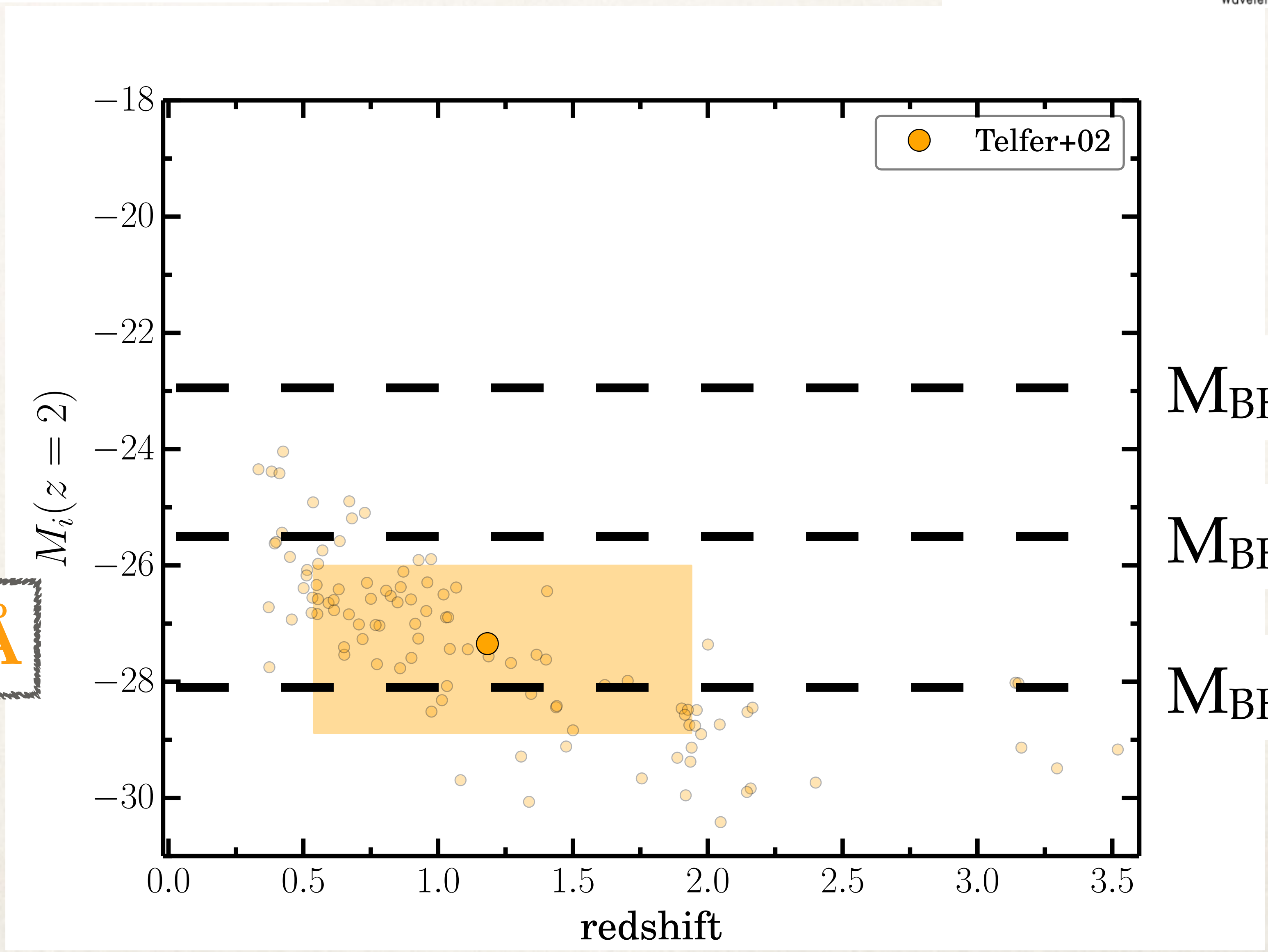

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Break at ~1100Å

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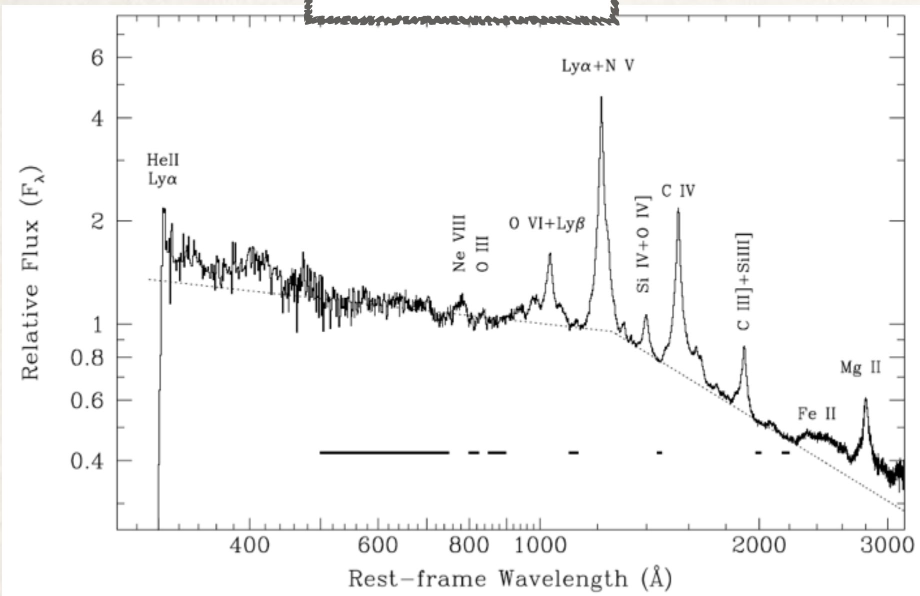

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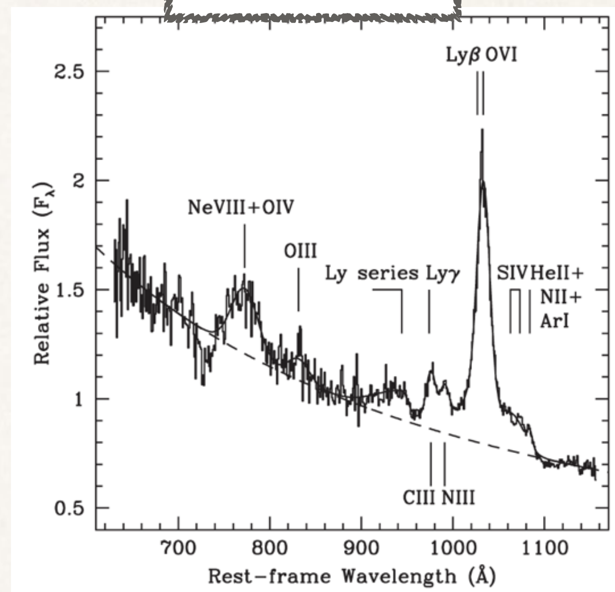

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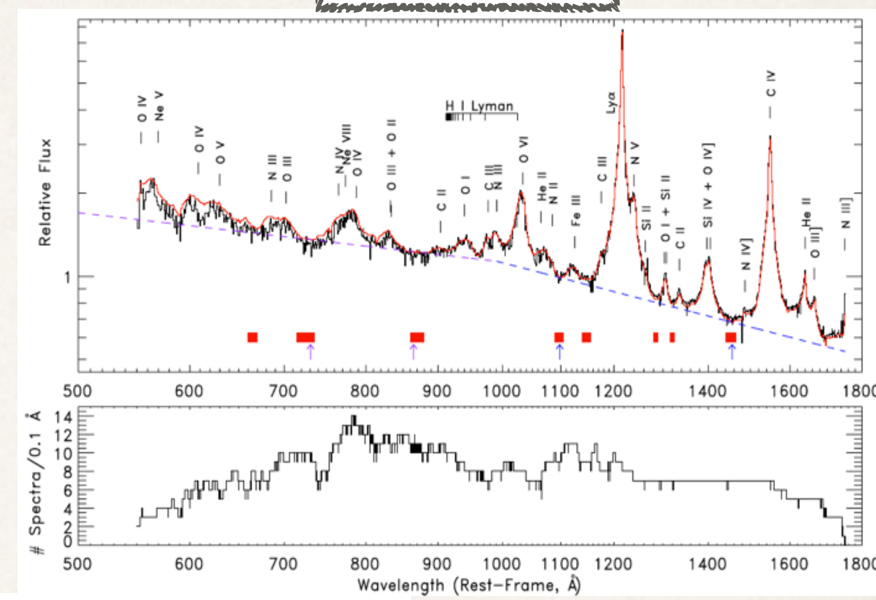
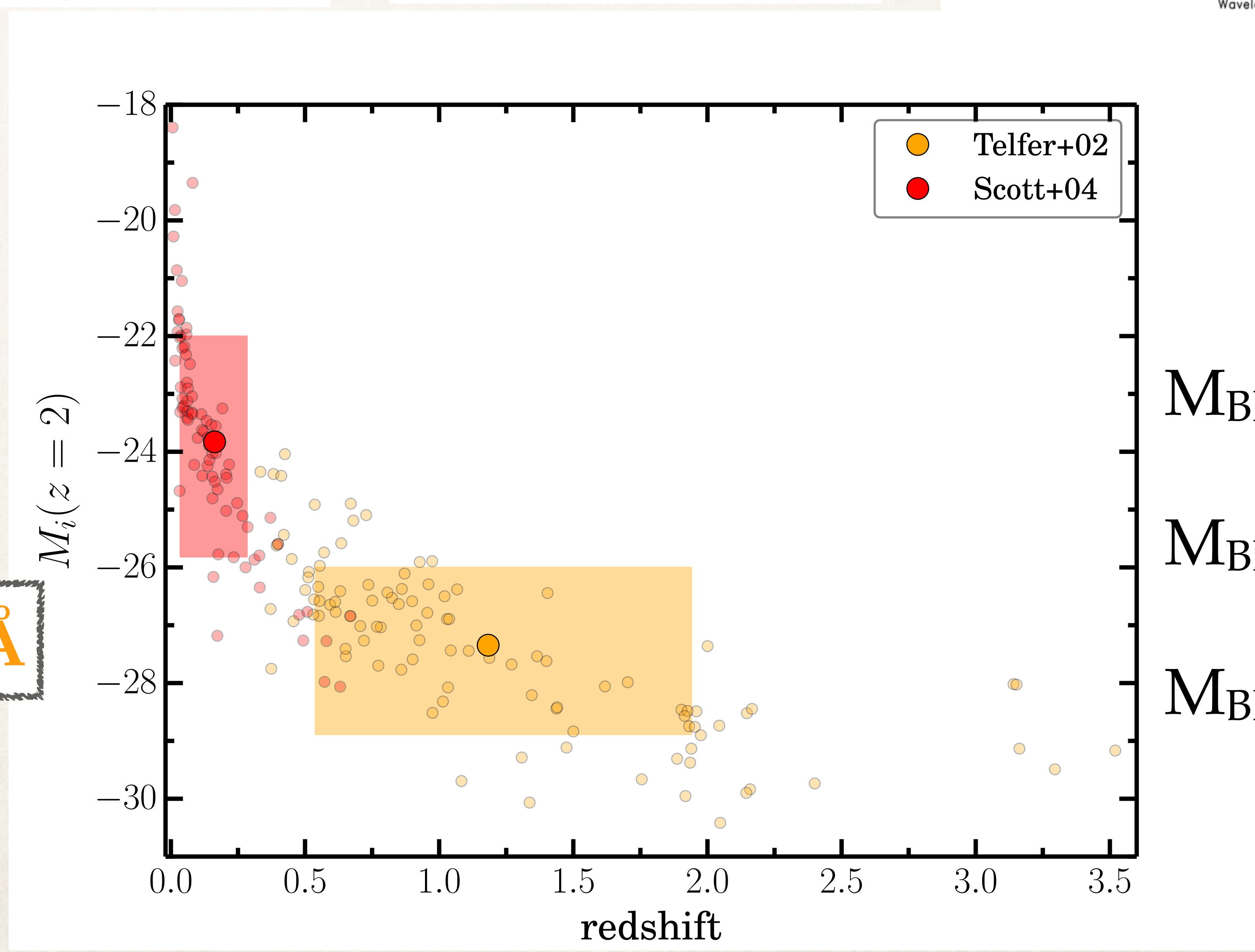


No break

Break at ~1100Å



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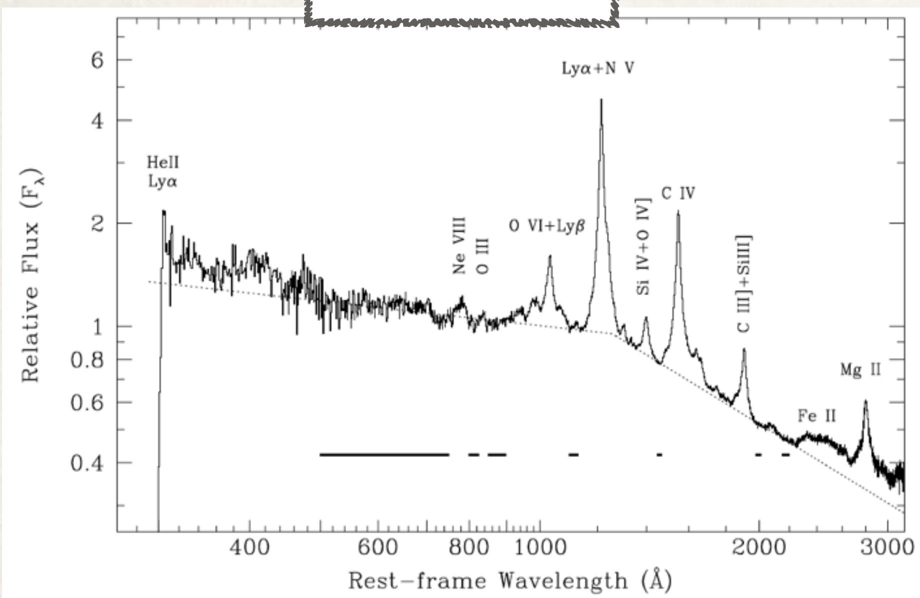

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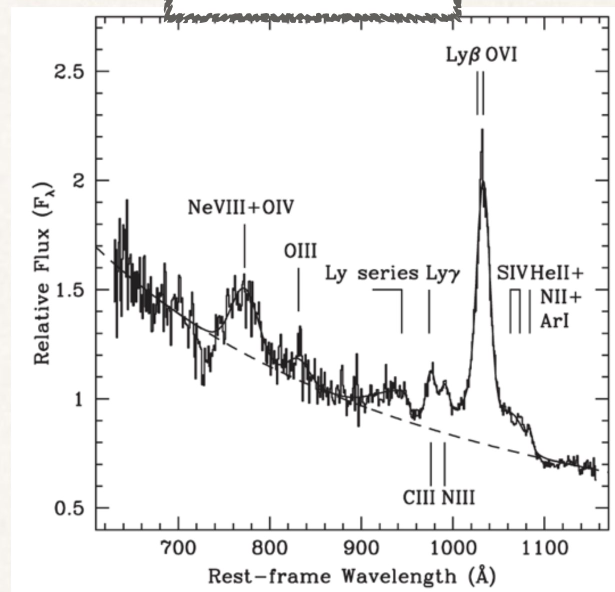

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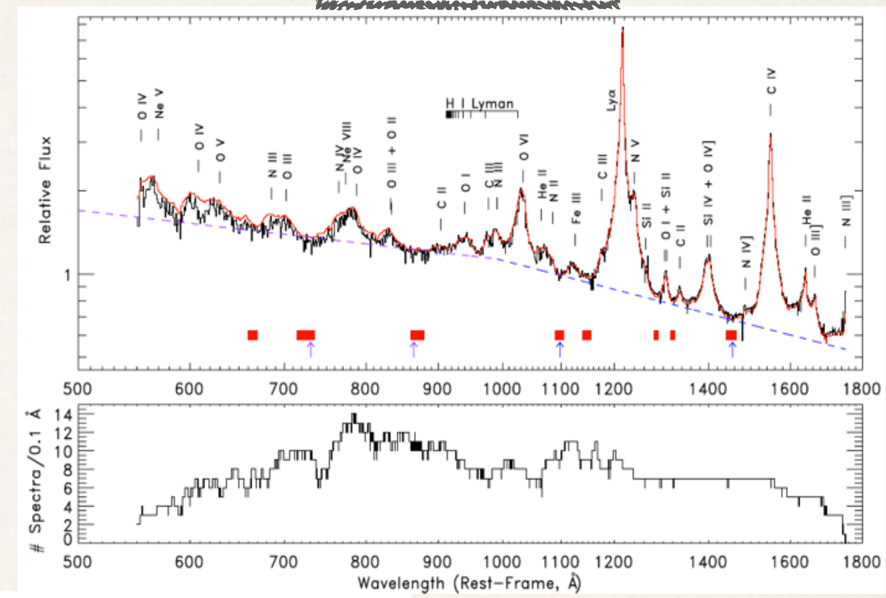
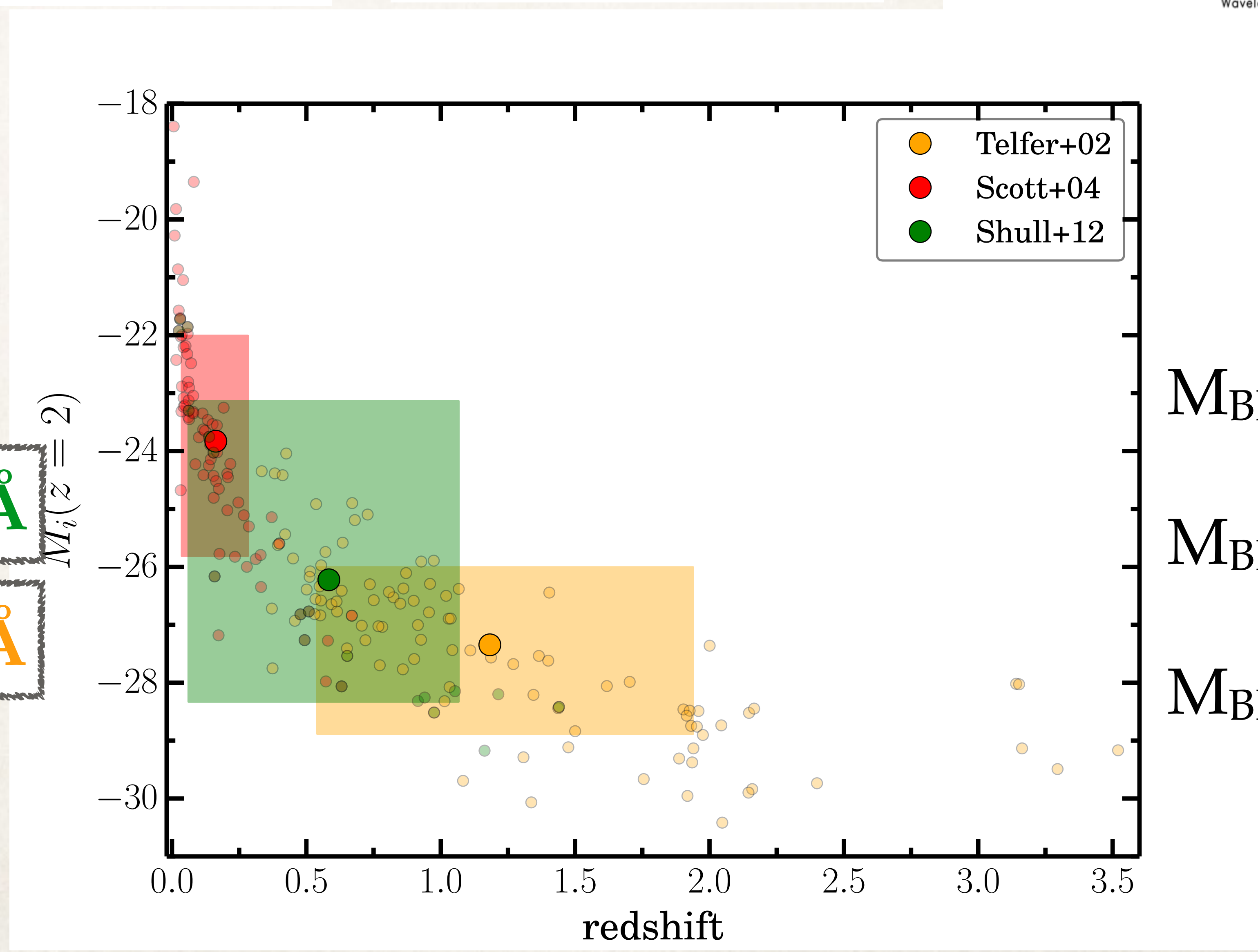


No break

Break at ~1000Å

Break at ~1100Å



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UV spectra of BH accretion disks

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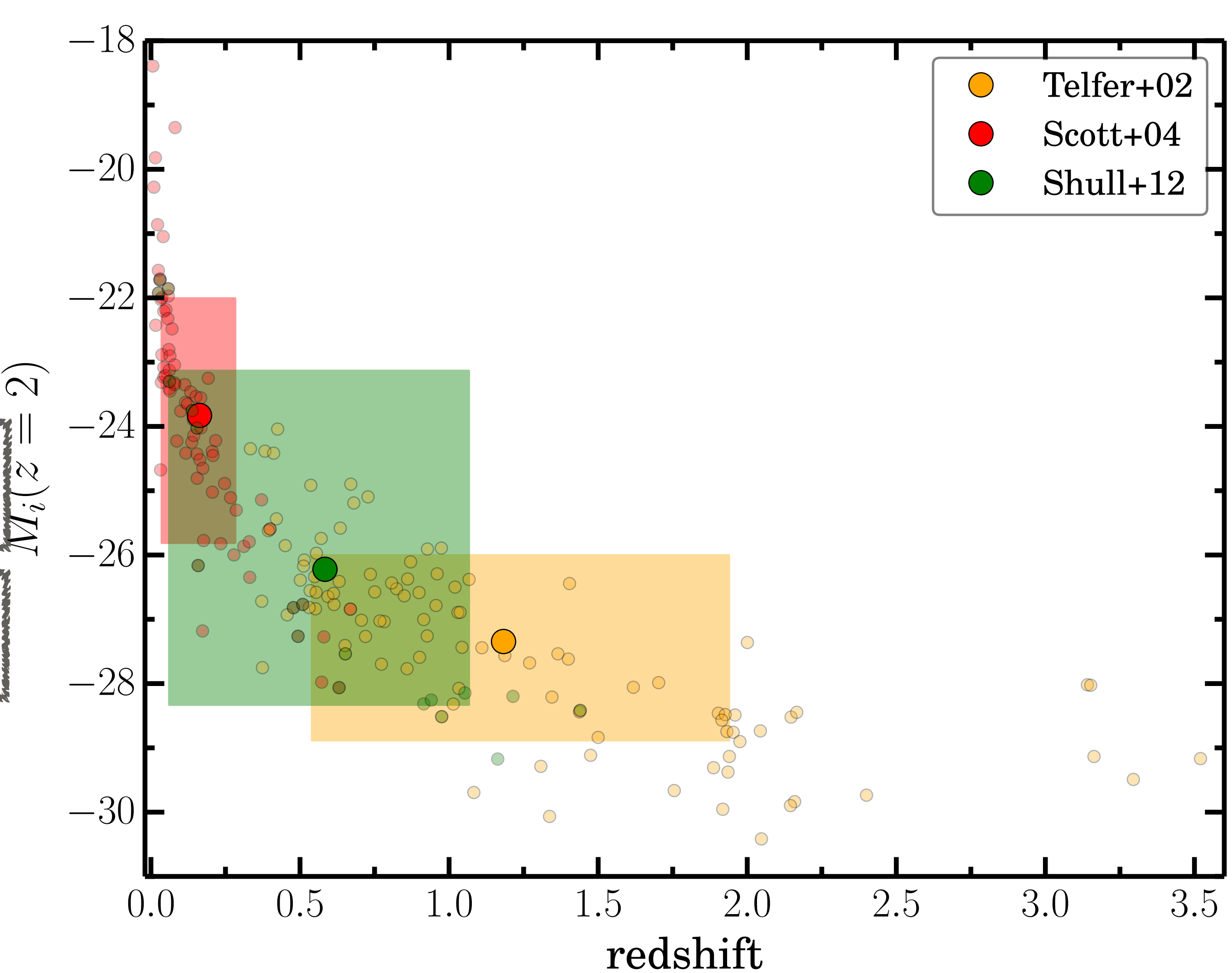
$T \sim L^{1/4} M_{BH}^{-1/2}$

The thermal disk peaks further into the blue for small M_{BH}

No break

Break at ~1000Å

Break at ~1100Å



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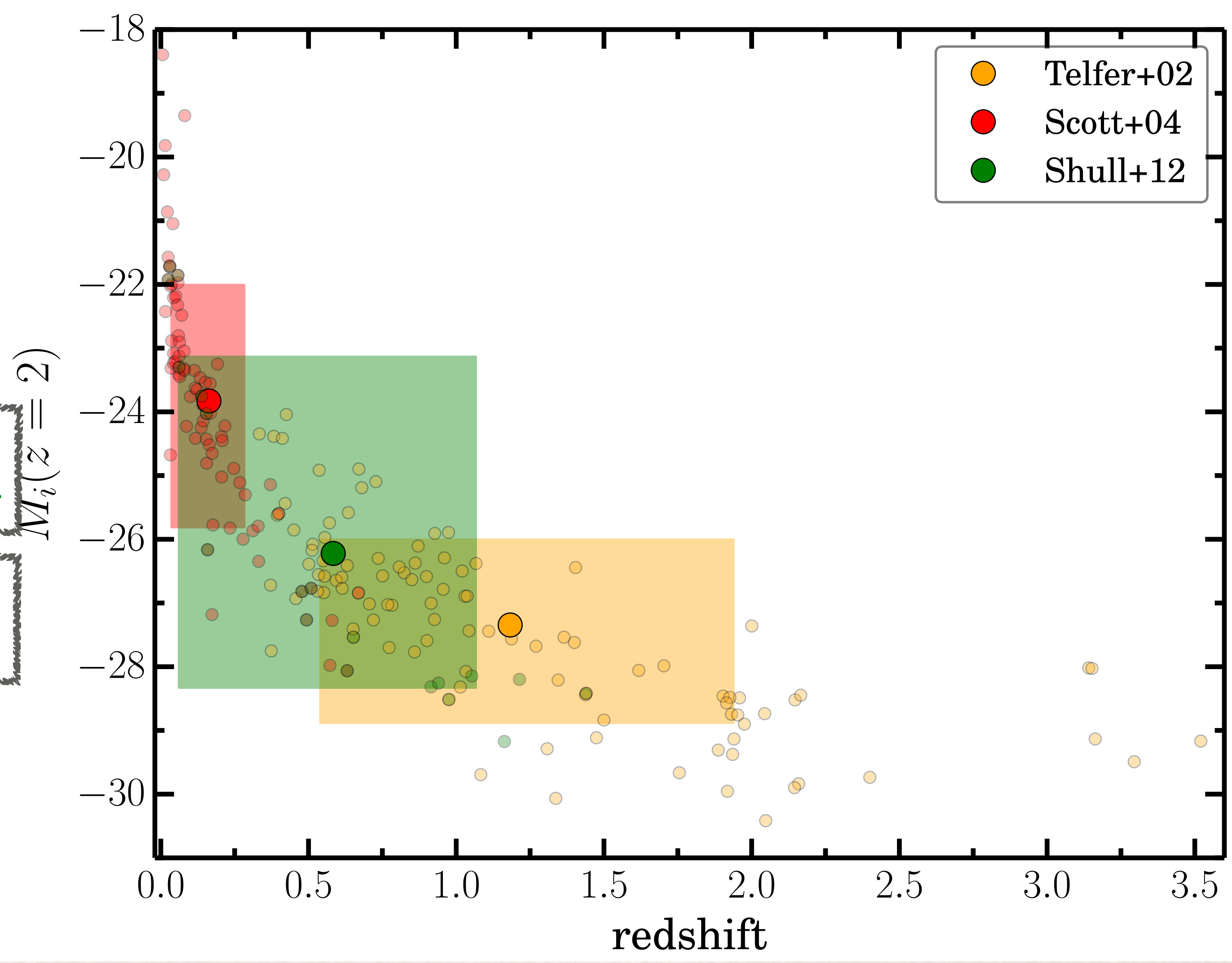
The thermal disk peaks further into the blue for small M_{BH}

maybe we are seeing the expected transaction, but…

No break

Break at ~1000Å

Break at ~1100Å



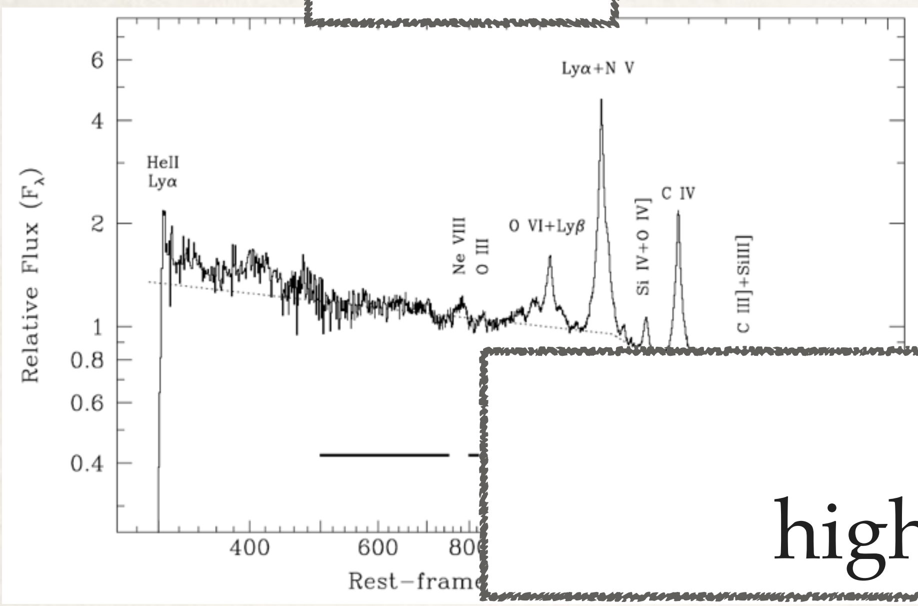
$M_{BH} \sim 10^7 M_\odot$

$M_{BH} \sim 10^8 M_\odot$

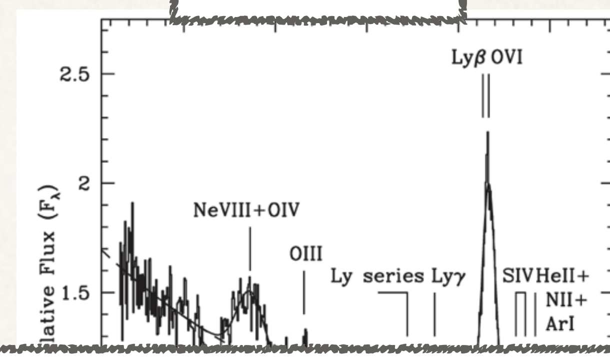
$M_{BH} \sim 10^9 M_\odot$

UV spectra of BH accretion disks

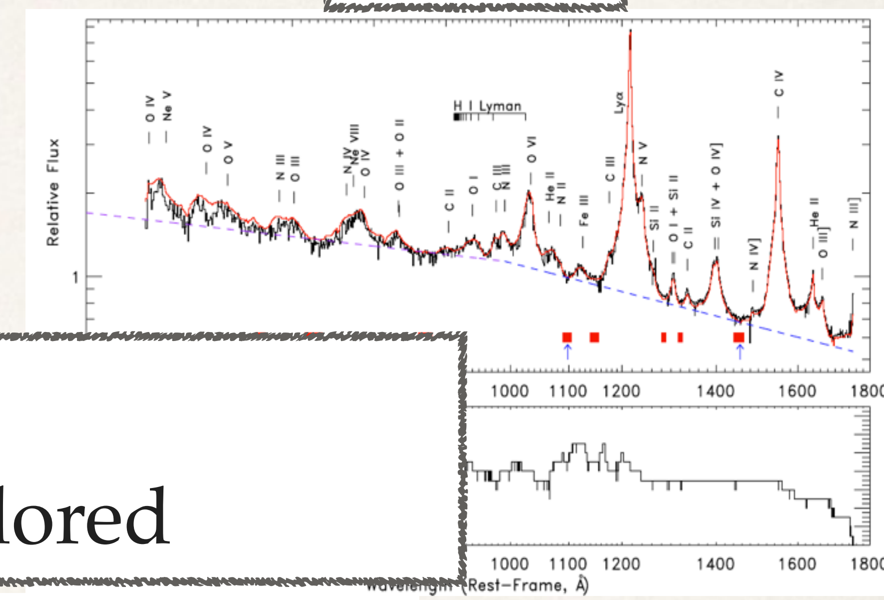
Telfer+2002



Scott+2004

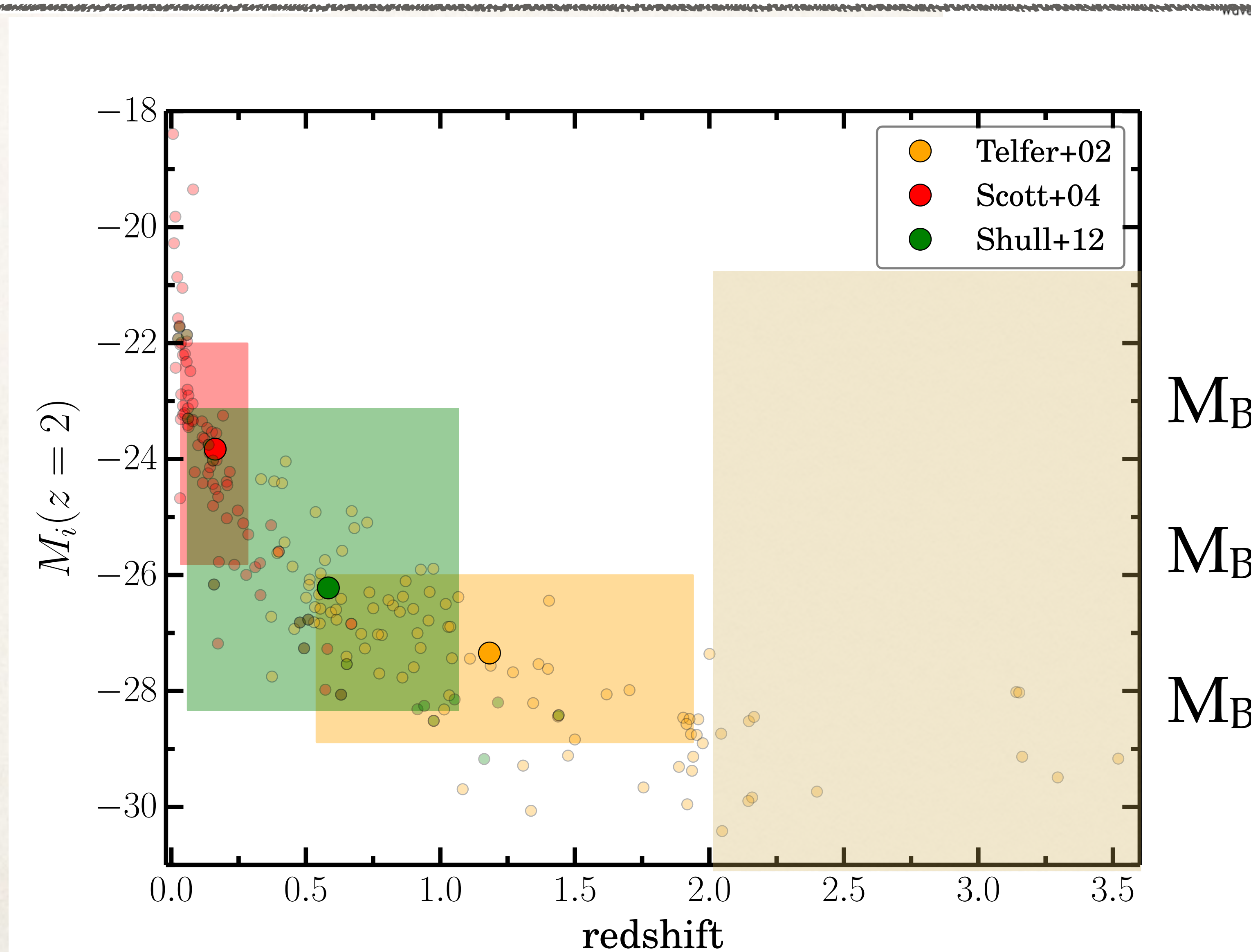


Shull+2012



<20 QSOs at z>2

high redshift poorly explored



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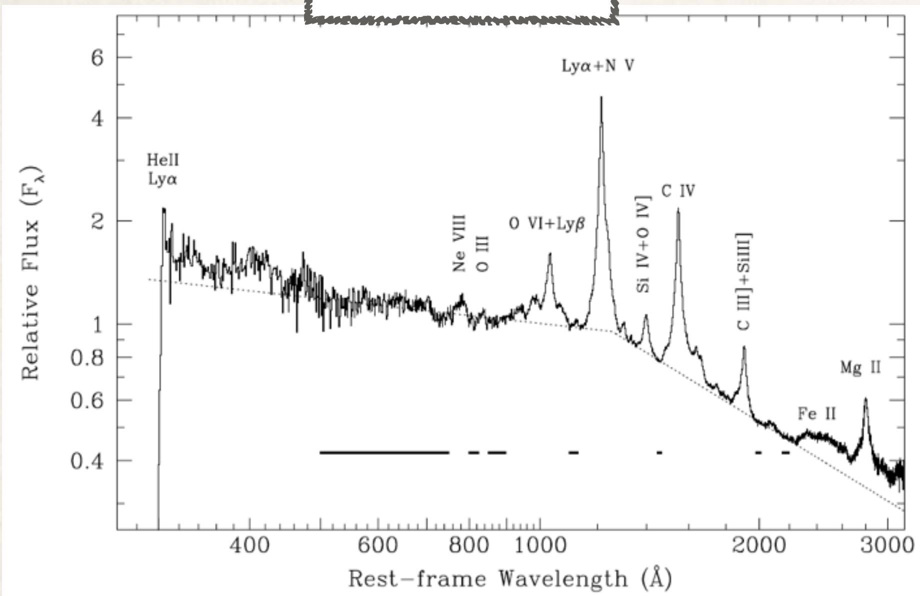
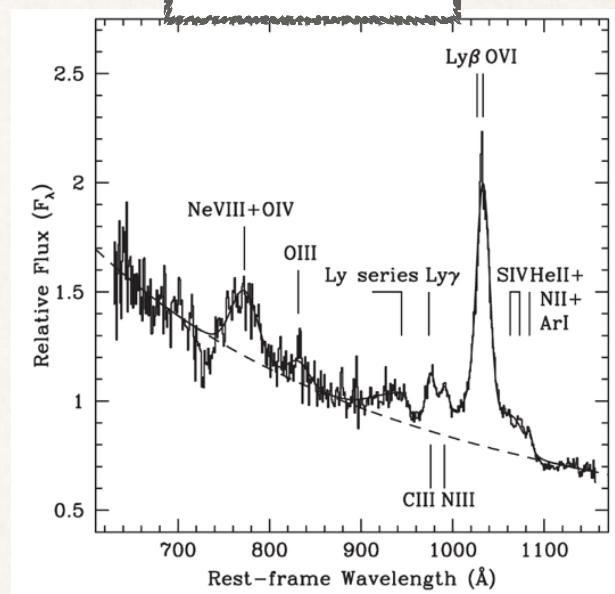
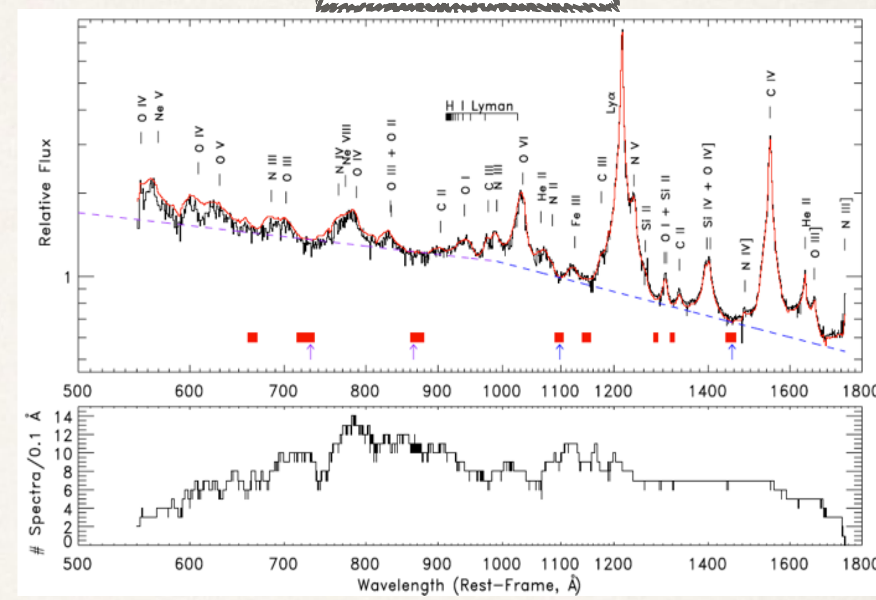


Scott+2004



Shull+2012



- The most massive BH (redshift > 2) poorly explored
- Previous works used overly simplistic and outdated models for the IGM correction
- Highly biased samples. Took whatever they find from the HST/FUSE archives which tend to be the UV brightest and hence bluest objects

BH growth at high z

- Construct for the first time the UV composite for QSO at redshift > 2
- State-of-the-art IGM correction: proper estimate of the uncertainties
- Clear sample selection

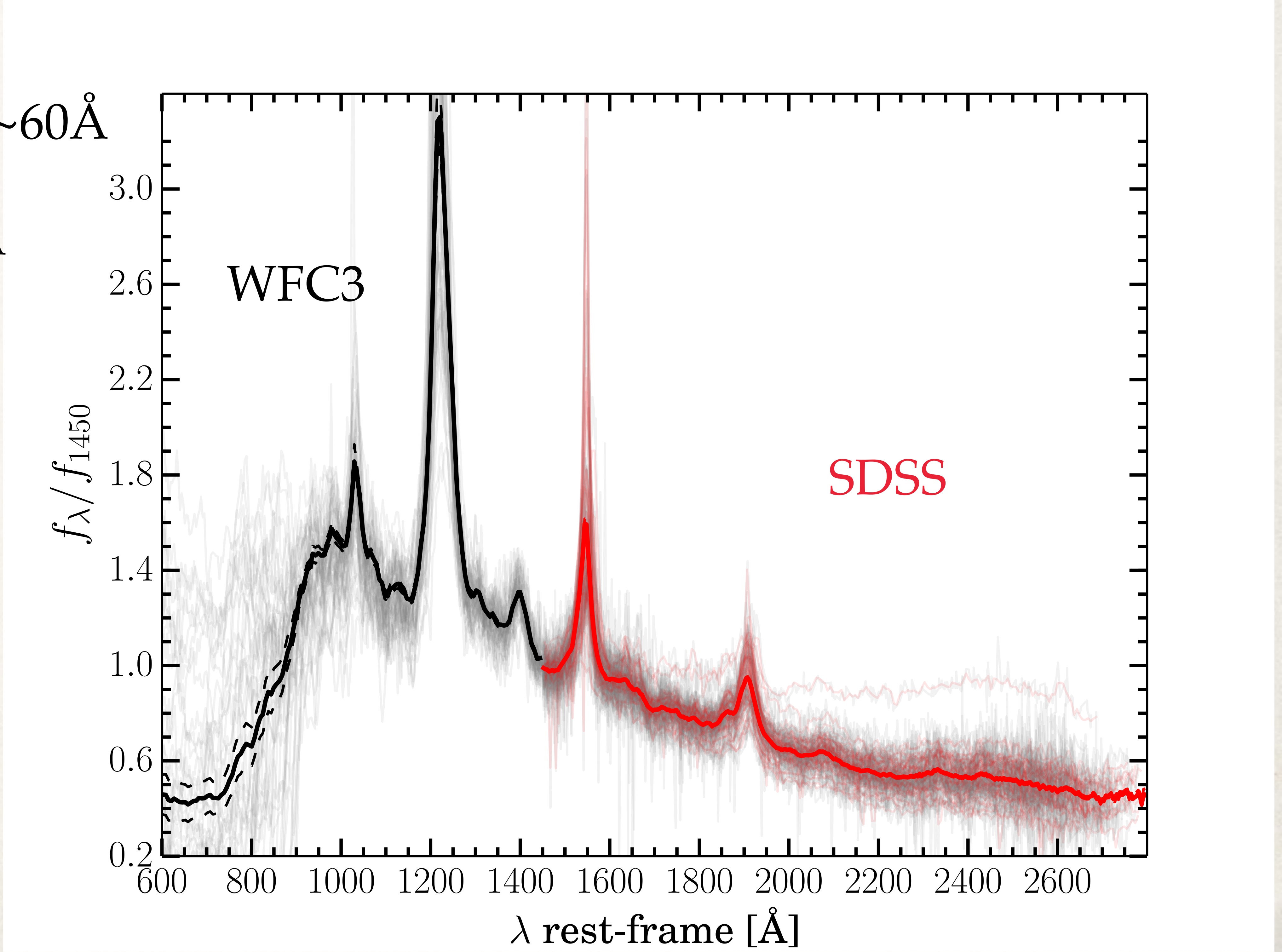
The sample

53 SDSS QSOs with g<18.5 mag; 2.28 < z < 2.60; <z>~2.44 observed with WFC3/UVIS-G280 grism Cycle 17

λ_{obs}=2000-6000 Å

λ=2500Å FWHM~60Å

S/N~30 at 1350 Å



O'Meara+11,+13

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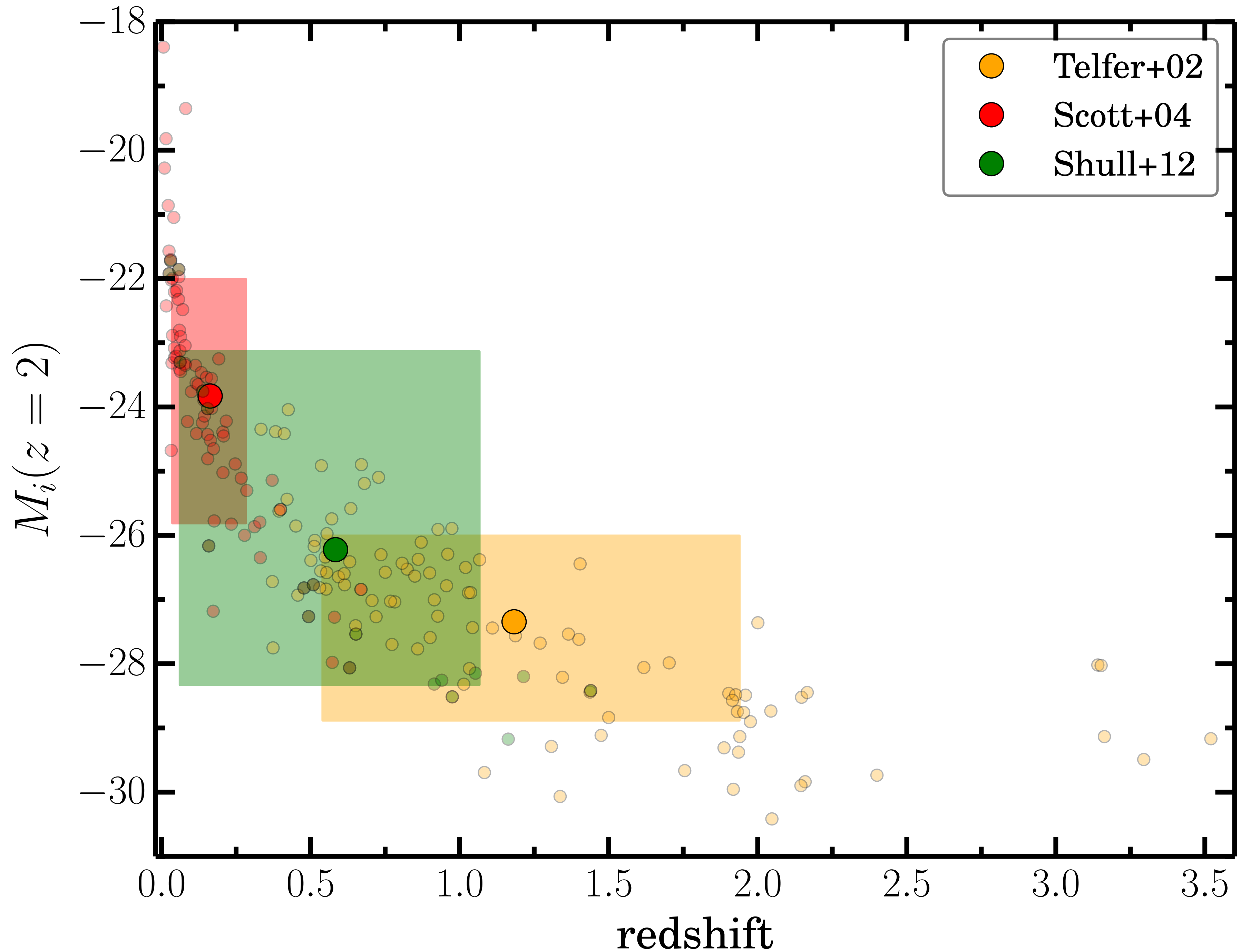

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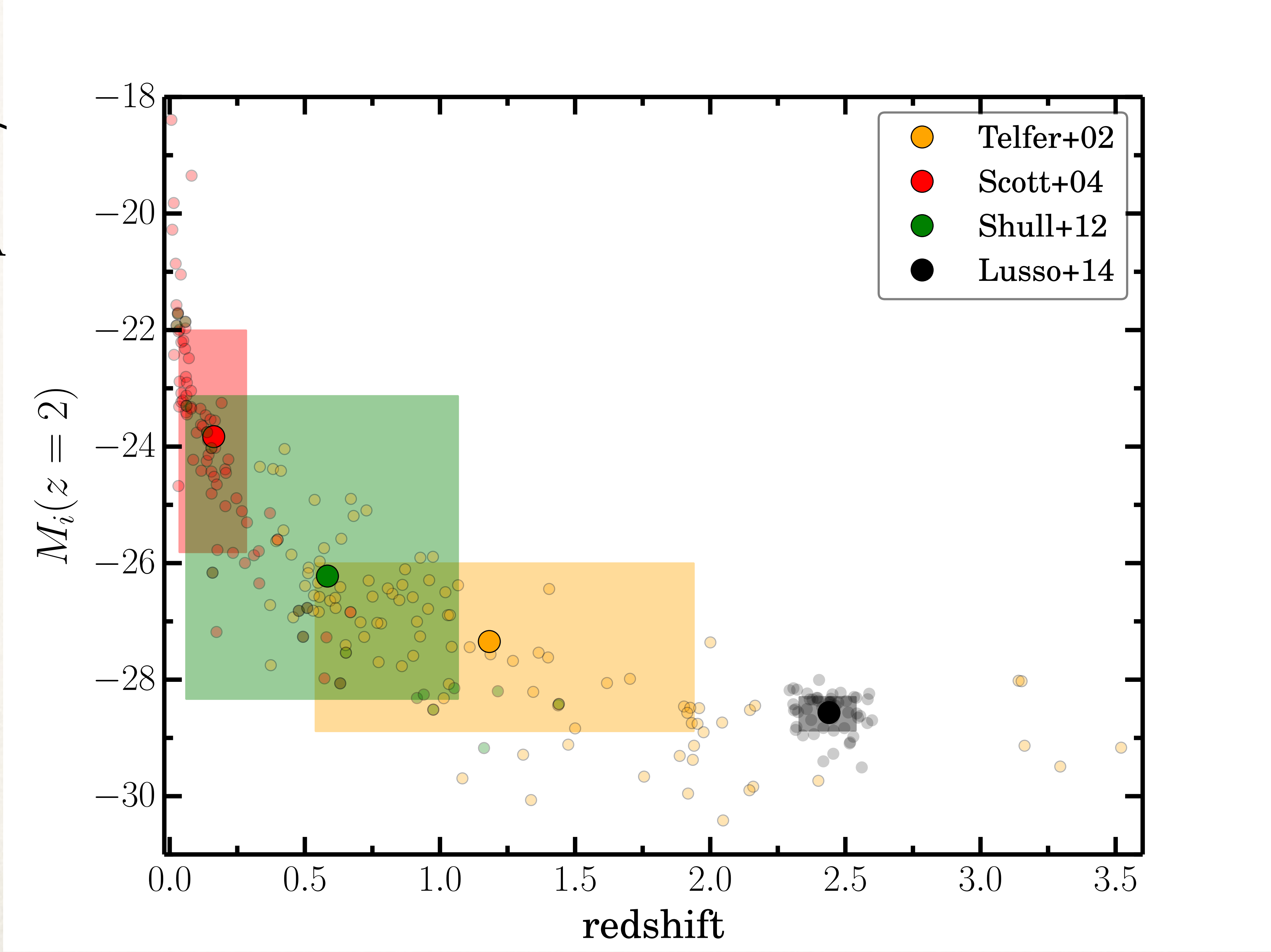

O'Meara+11,+13

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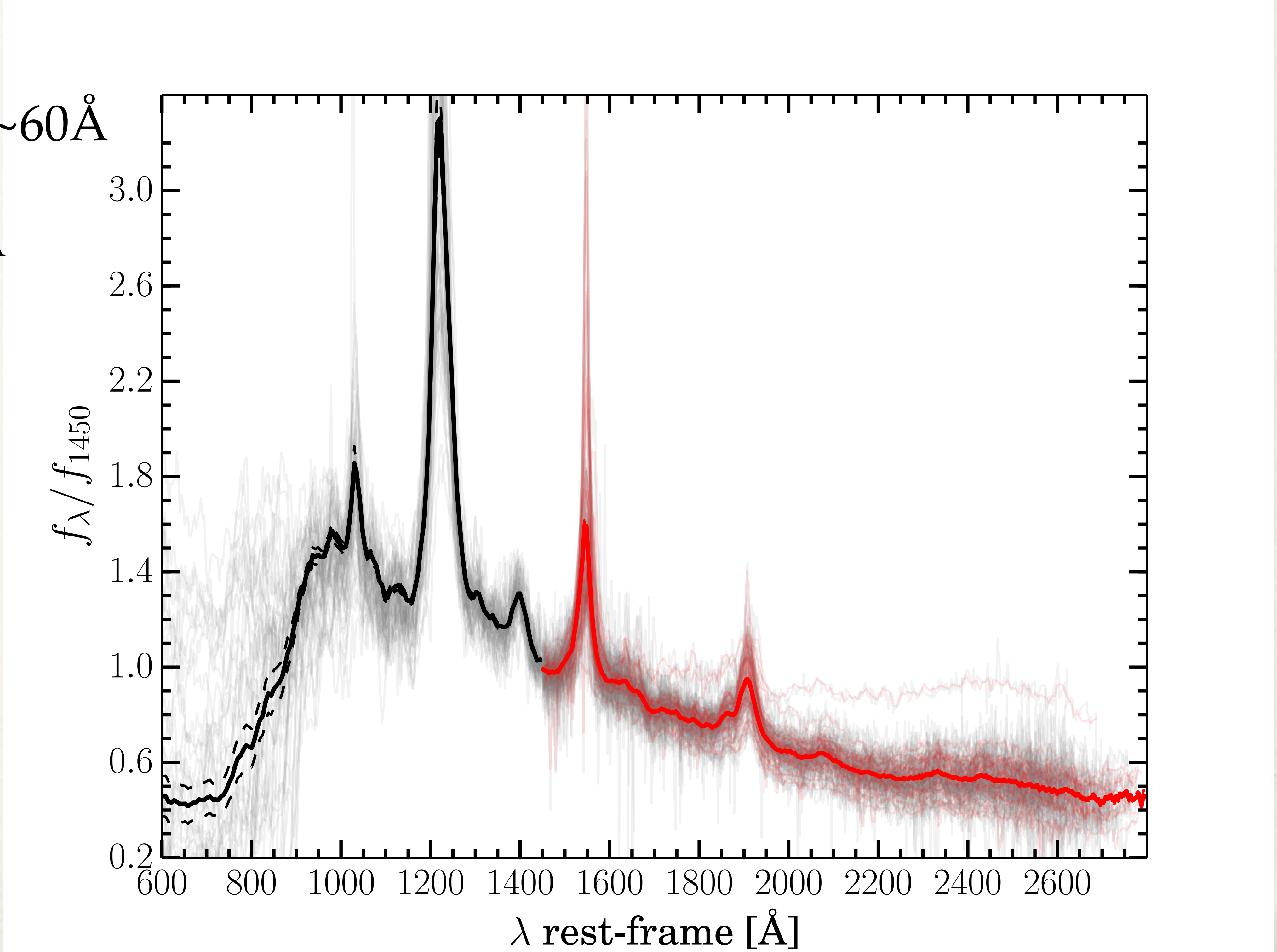
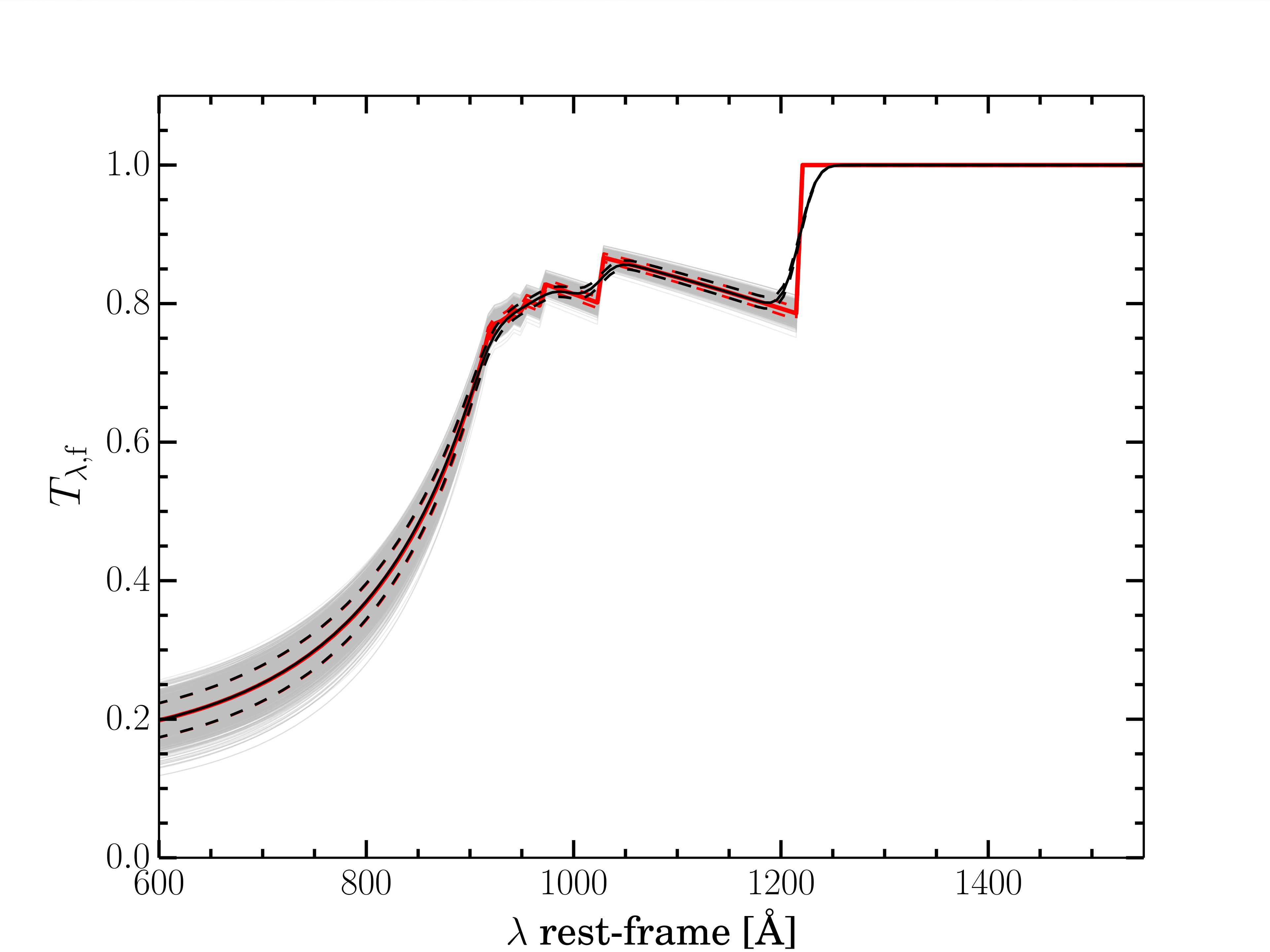


O'Meara+11,+13

IGM absorption correction

10000 IGM transmission curves for a suite of different column densities via MCMC (calibrated from absorption lines)



IGM absorption correction

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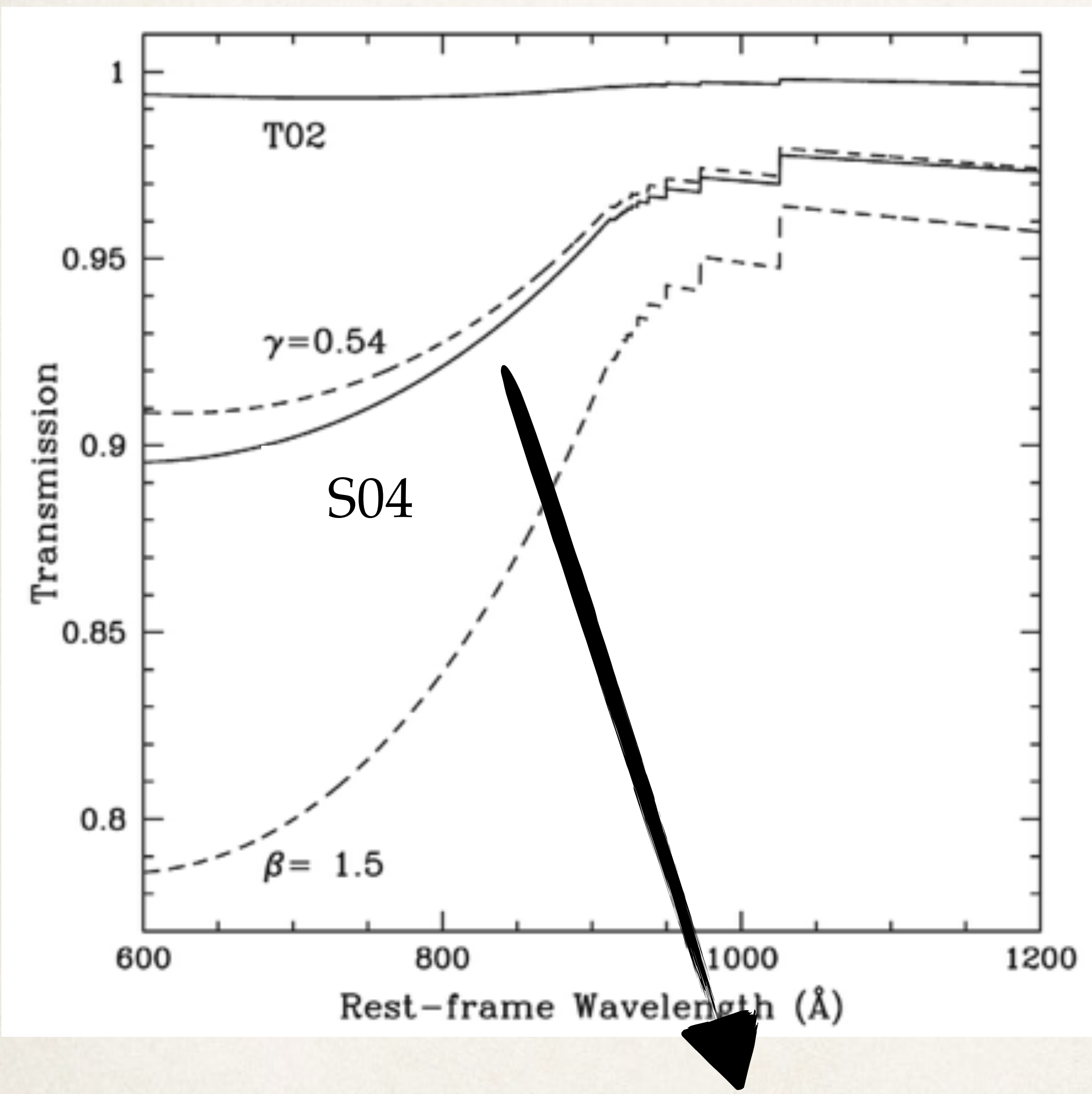
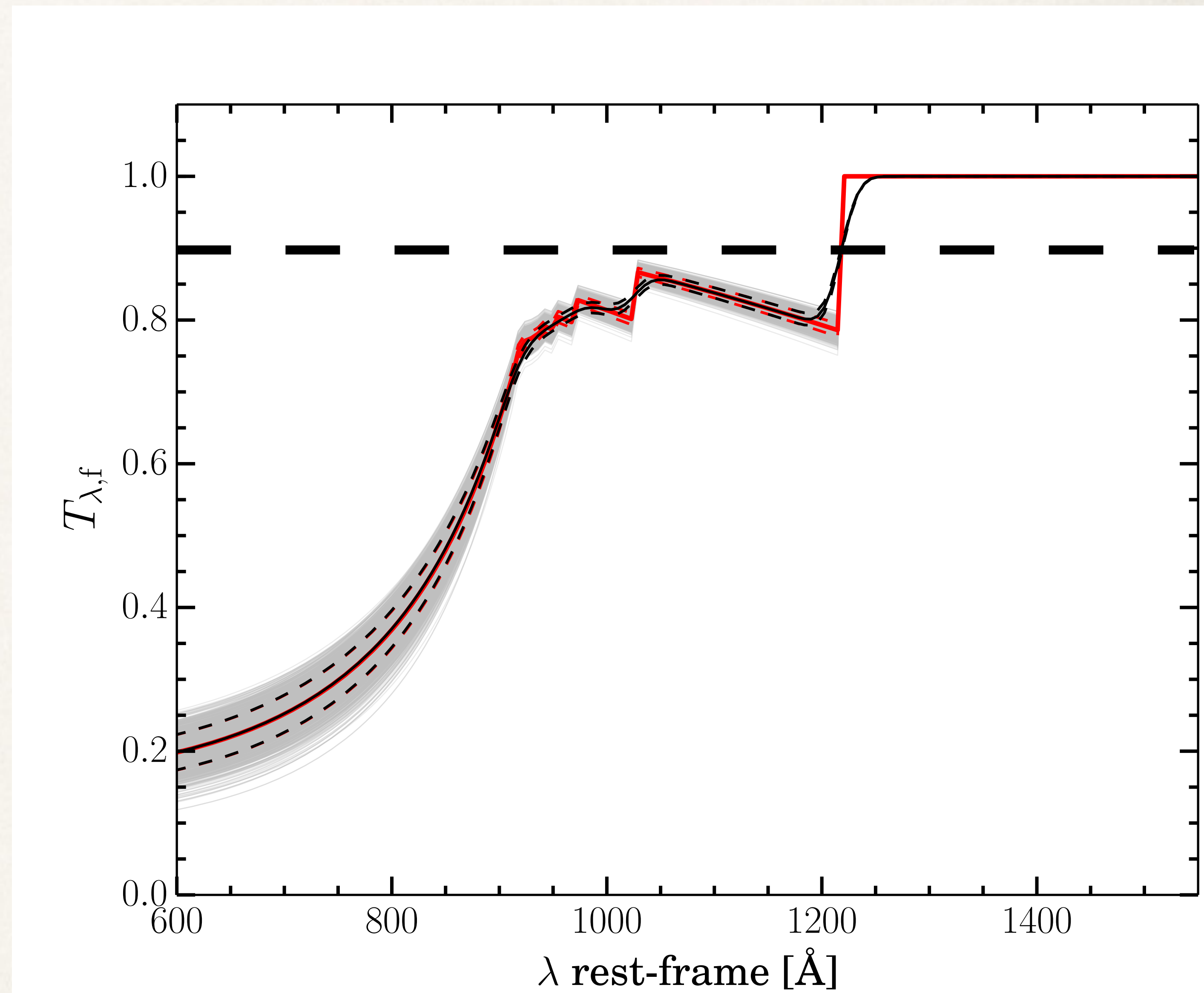
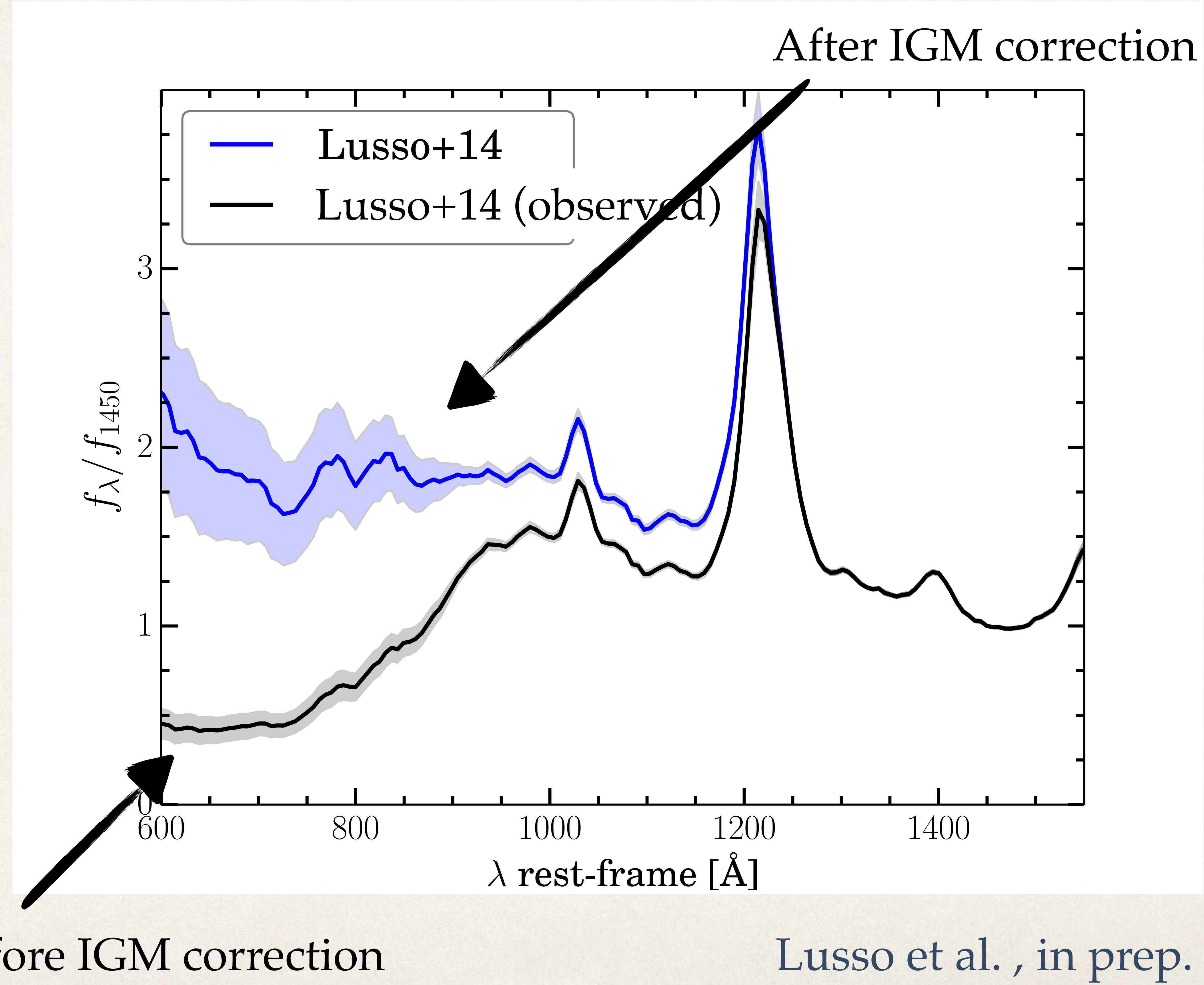




single correction for a broad range of redshift and models outdated

UV quasar composite

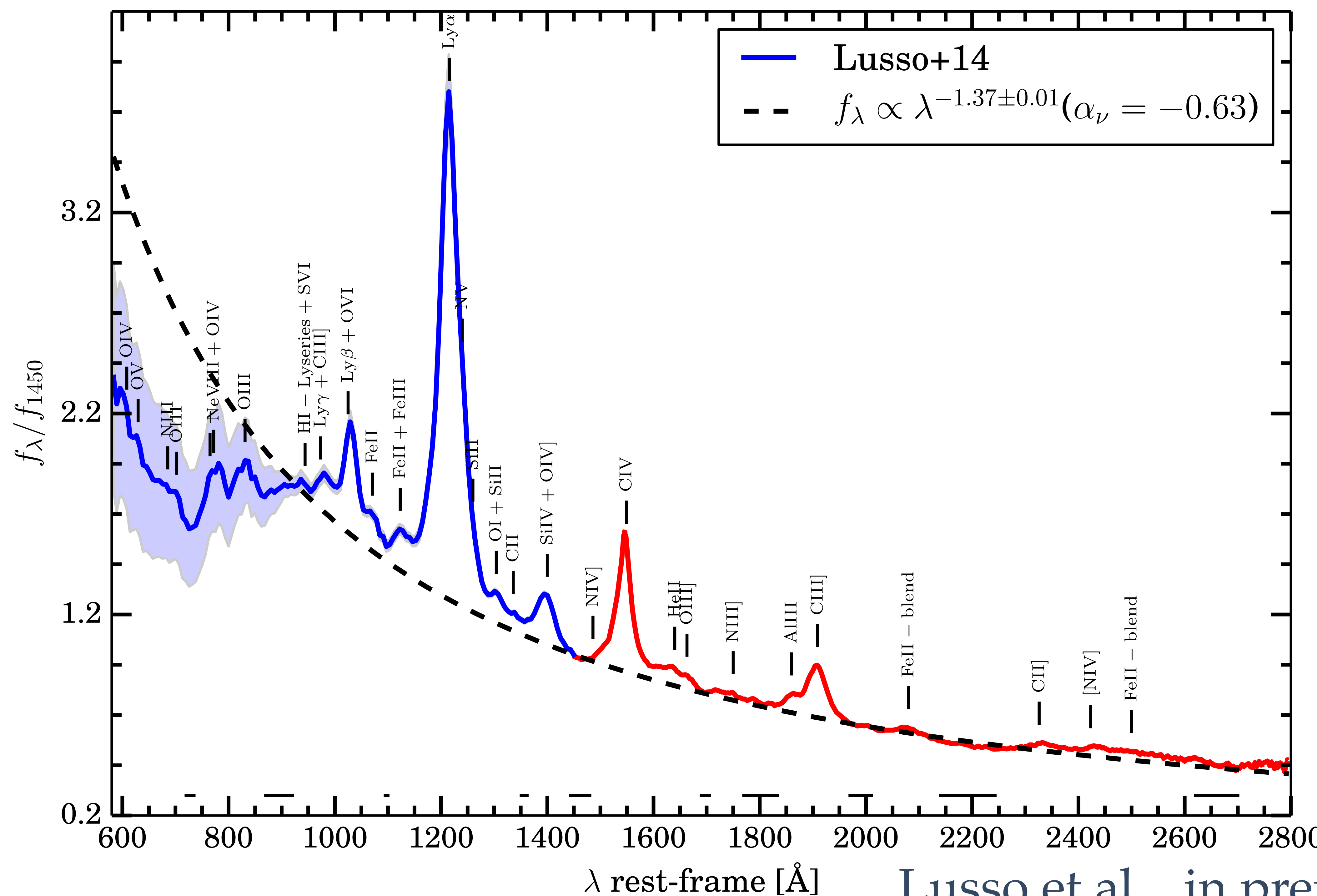


Lusso et al. , in prep.

UV quasar composite: continuum fit

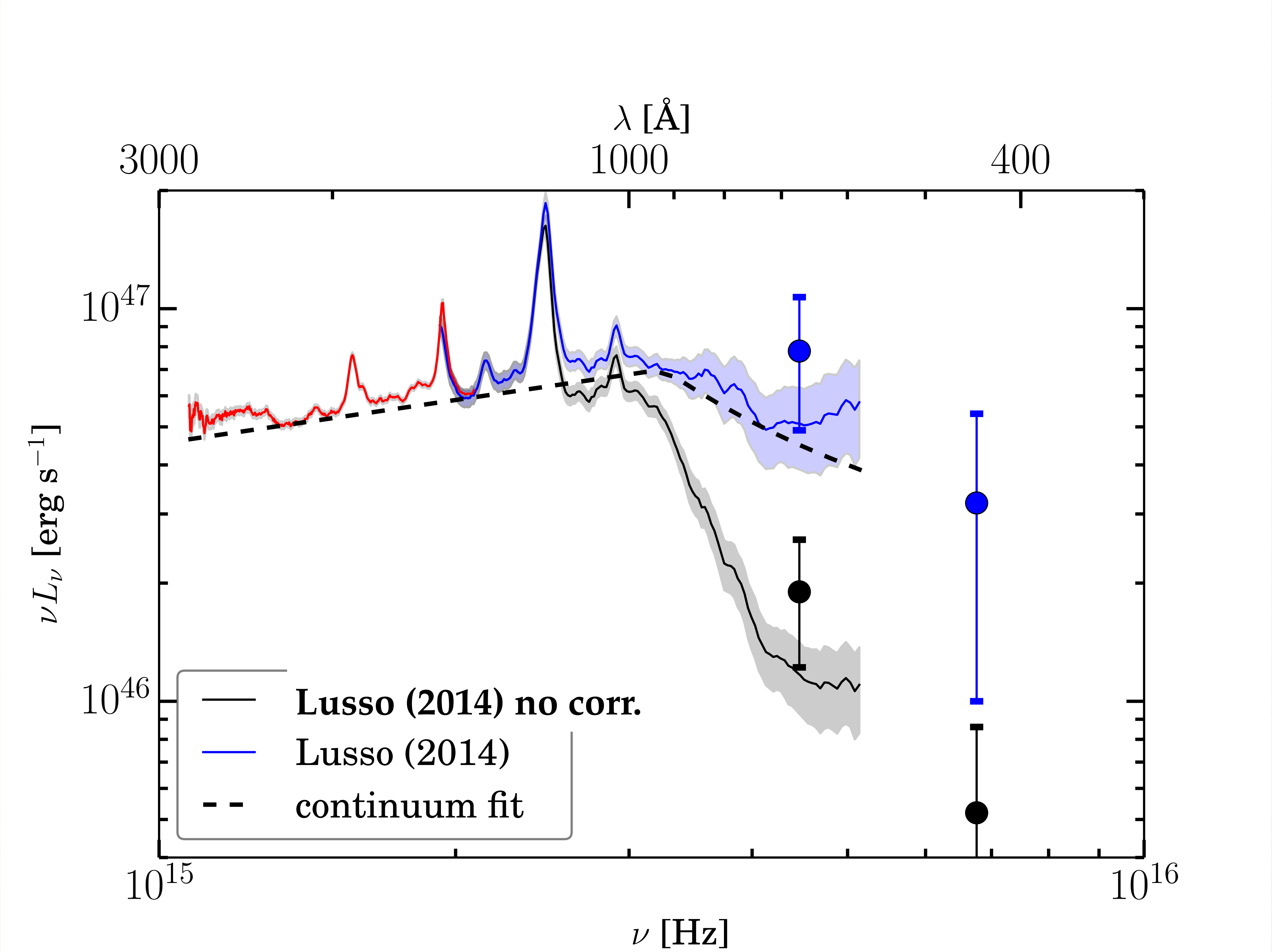
α_{EUV} ~ -1.9 α_{NUV} = -0.63 ± 0.01

λ_{break}=922.18 ± 31.15 $f_\lambda \propto \lambda^{-1.37\pm0.01} \exp[-(\lambda_c - \lambda)/\lambda_f]$

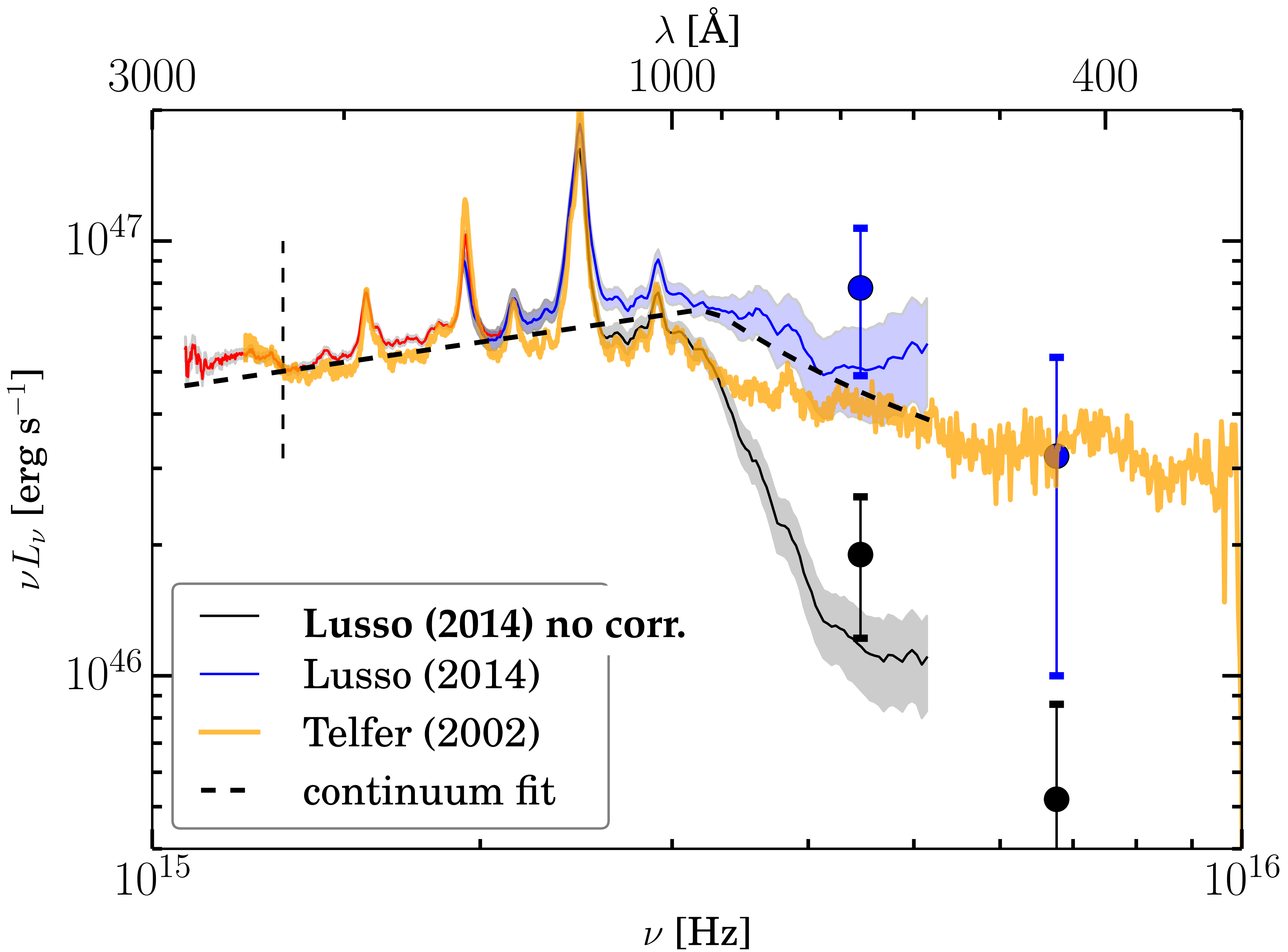


Lusso et al. , in prep.

UV quasar composite: comparison



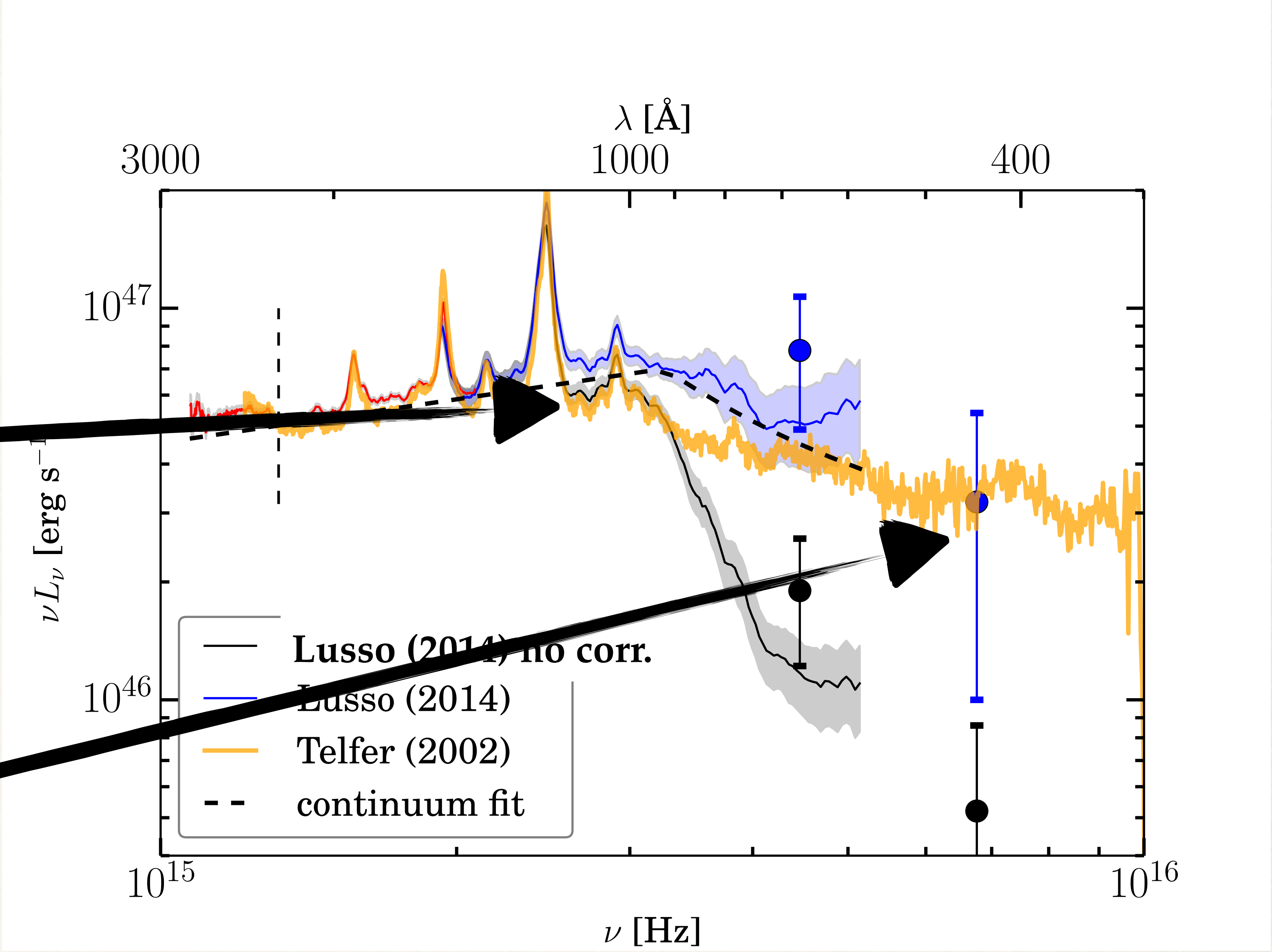
UV quasar composite: comparison



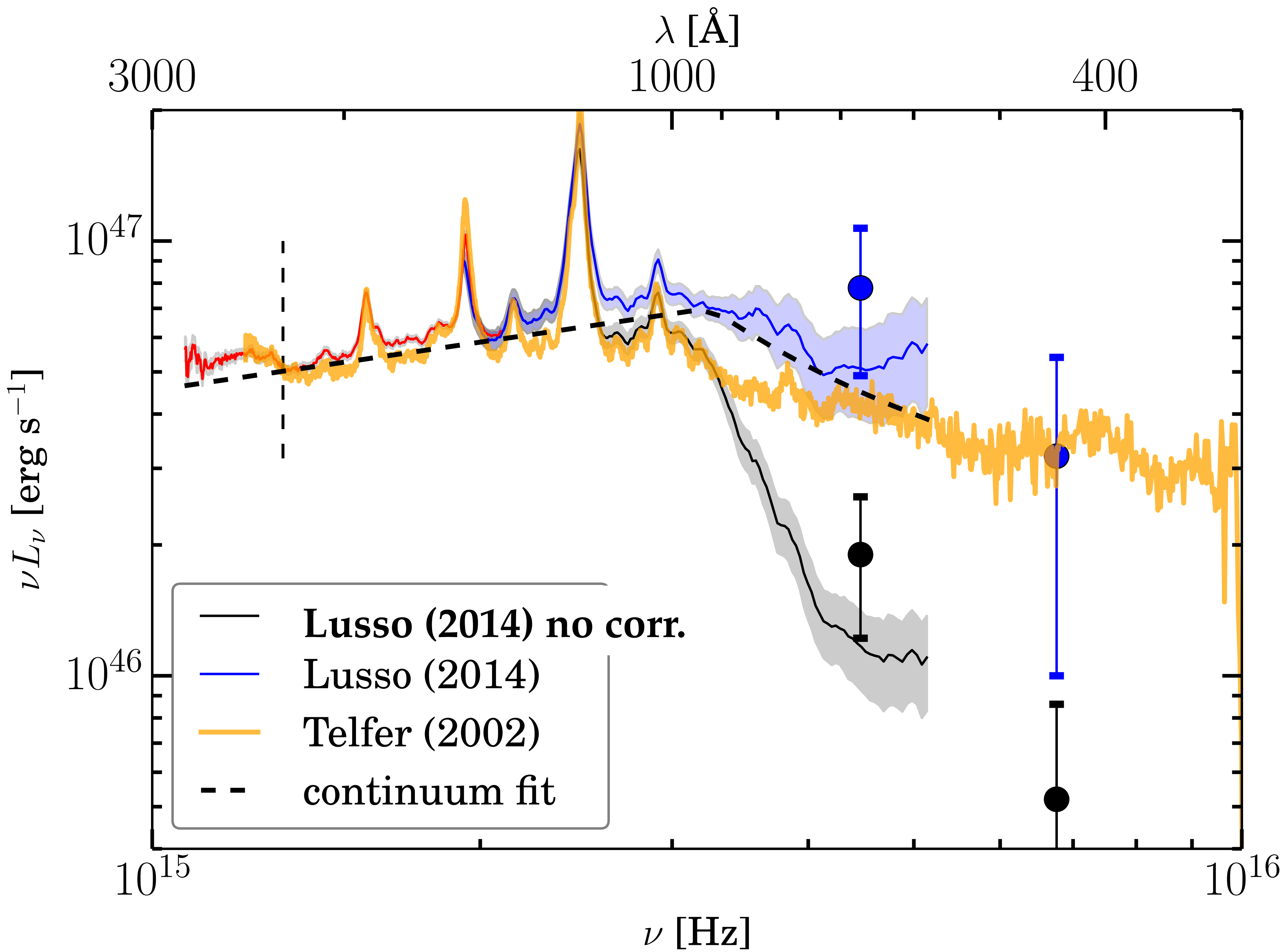
UV quasar composite: comparison

IGM correction employed by **Telfer+02** less than 1% over the whole composite, BUT

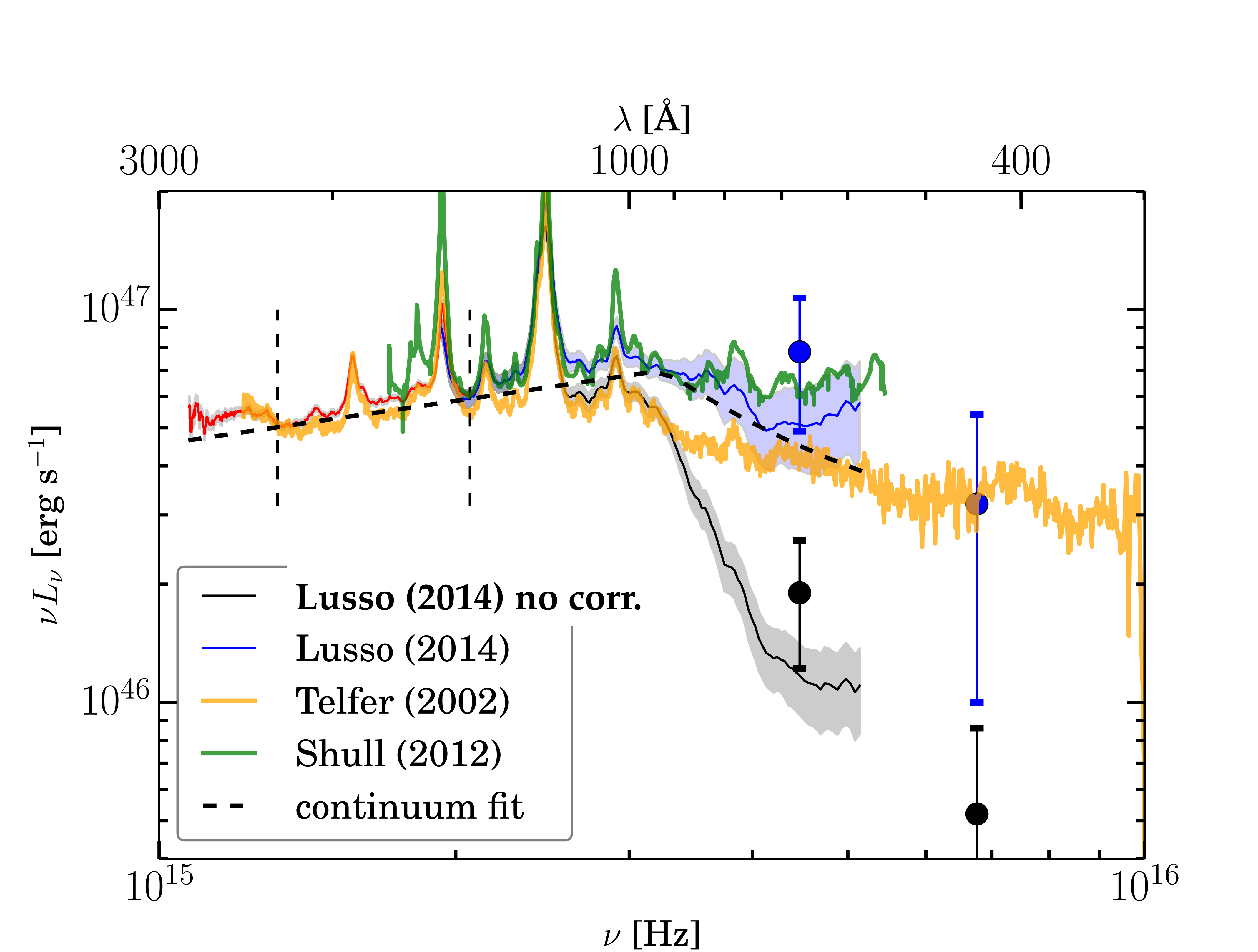
1. in the forest the correction should be >5% AND
2. at λ<600 (where there are <<20 z>2 quasars contributing) the correction is >>1% (~80%)!!



UV quasar composite: comparison



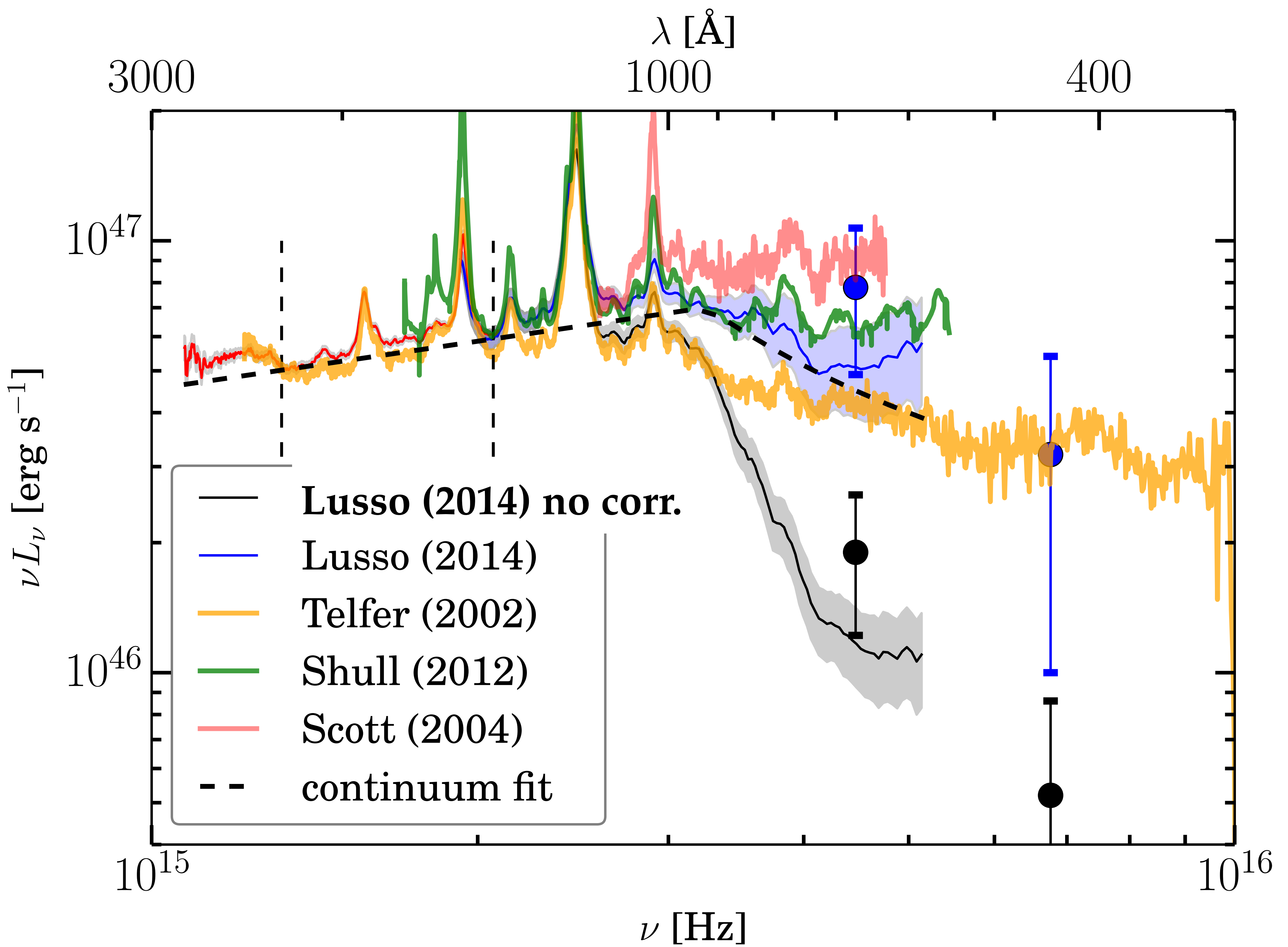
UV quasar composite: comparison



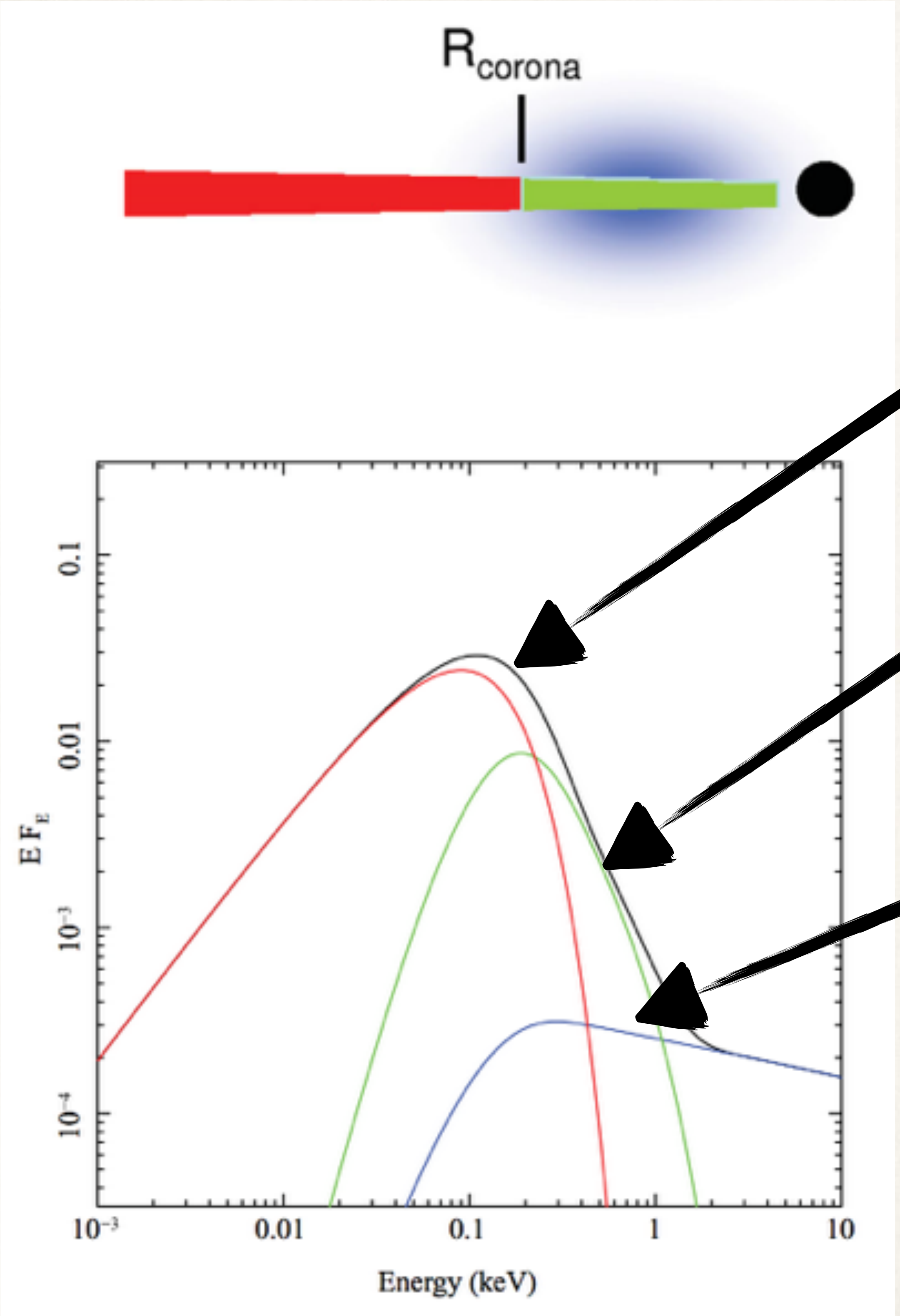
UV quasar composite: comparison

Softer EUV slope (α_{EUV}~-1.9) than **Scott+04** (α_{EUV}~-0.56)

and **Shull+12** (α_{EUV}~-1.41)



Accretion disk models



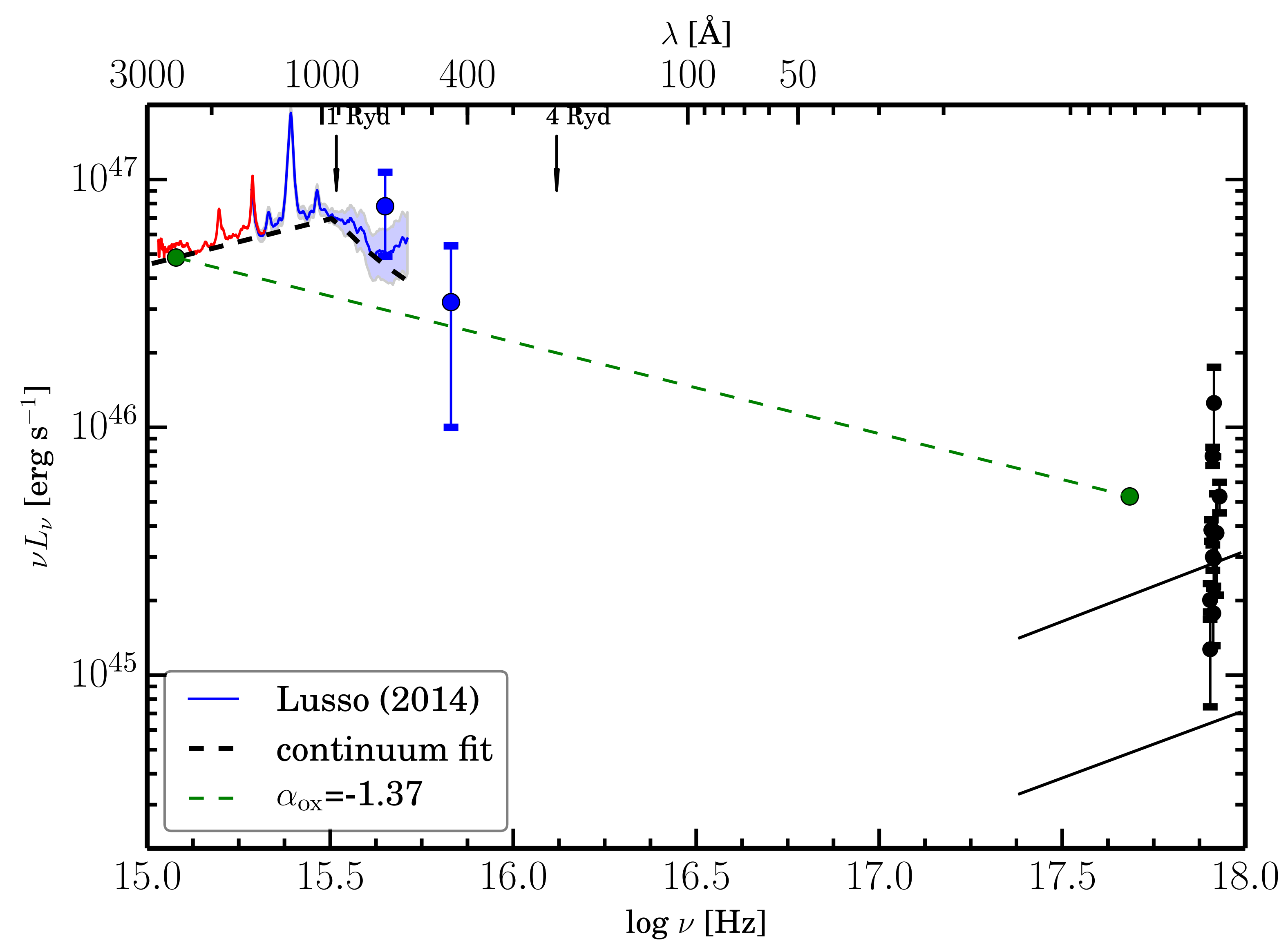
Done+12

Outer disk (Red) which emits as a (colour T corrected) BB

Inner disk (Green) where the emission is Compton upscattered

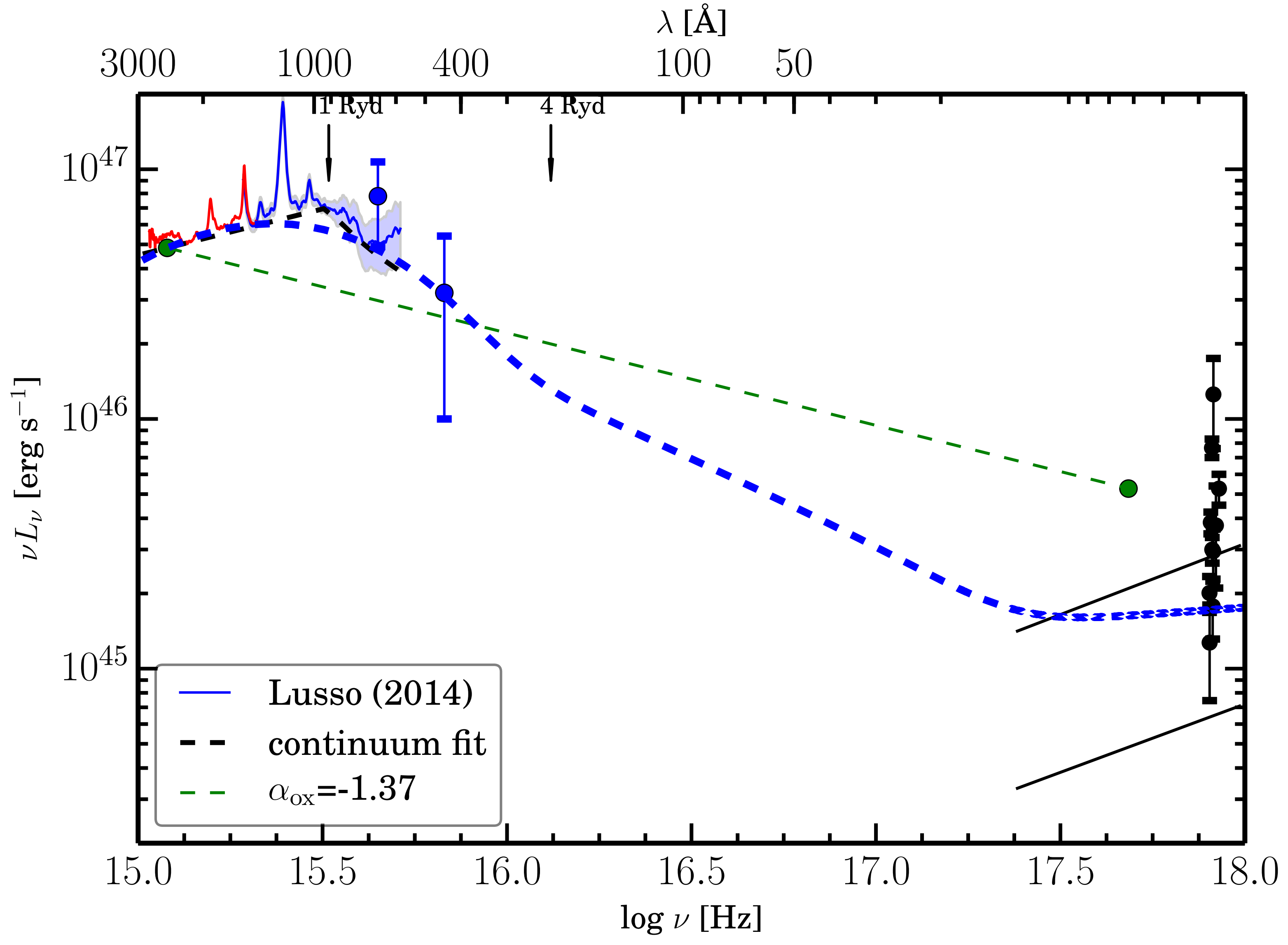
X-ray Corona (Blue) where also a fraction of the emission is Compton upscattered (power-law tail at high energies)

Accretion disk models



Accretion disk models

DATA {
$M_{BH} = 6 \times 10^9 M_{\odot}$
$\lambda_{Edd} = 0.35$
$\Gamma = 1.9$
(a=0.8)



Accretion disk models

DATA
{
$M_{BH} = 6 \times 10^{9}\ M_{\odot}$

$\lambda_{Edd} = 0.35$

$\Gamma = 1.9$

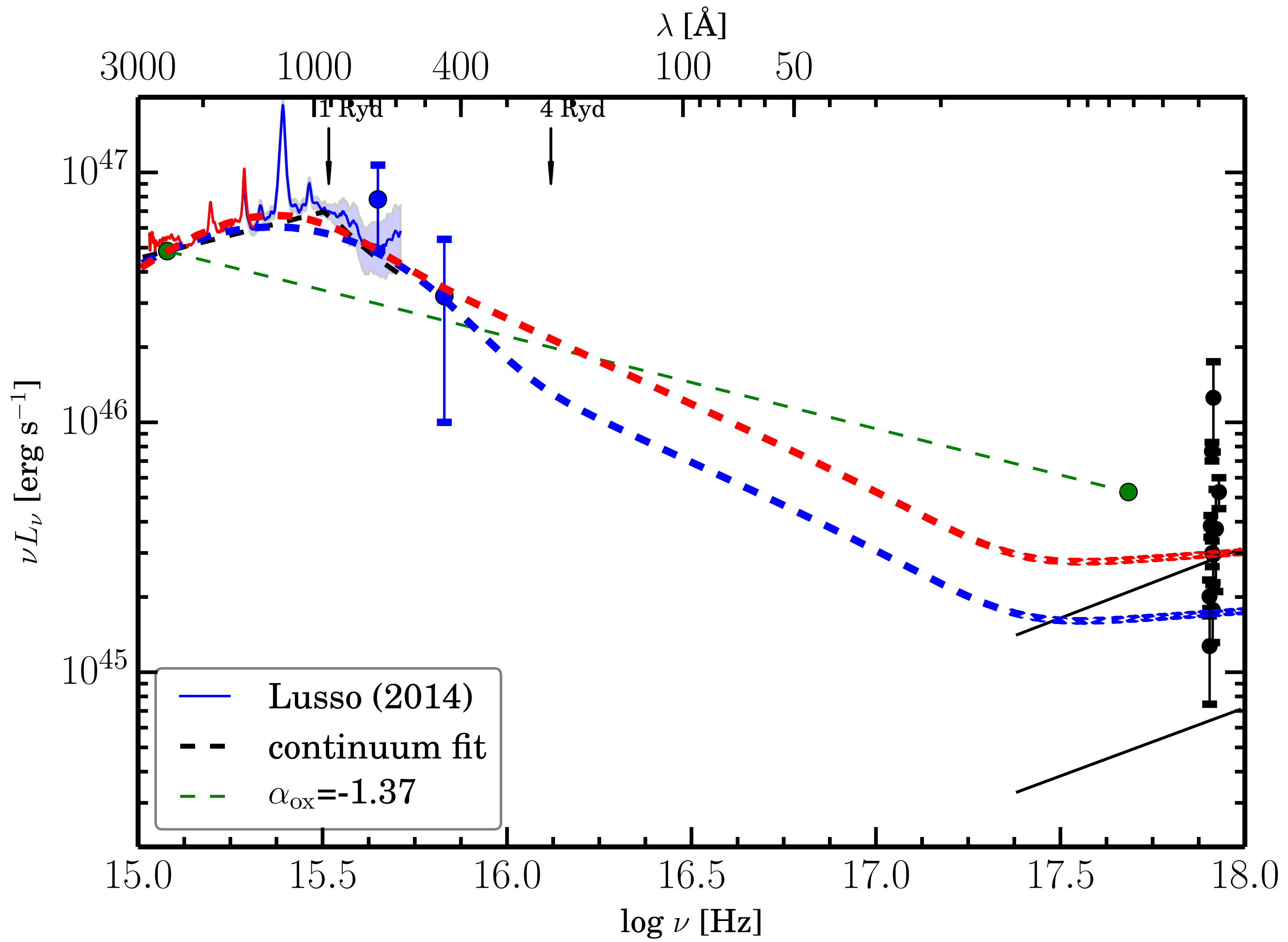
(a=0.8)

$M_{BH} = 1.2 \times 10^{10}\ M_{\odot}$

$\lambda_{Edd} = 0.17$

$\Gamma = 1.9$

(a=1.0)



Accretion disk models

DATA {

$M_{BH} = 6 \times 10^9 M_\odot$

$\lambda_{Edd} = 0.35$

$\Gamma = 1.9$

(a=0.8)

$M_{BH} = 1.2 \times 10^{10} M_\odot$

$\lambda_{Edd} = 0.17$

$\Gamma = 1.9$

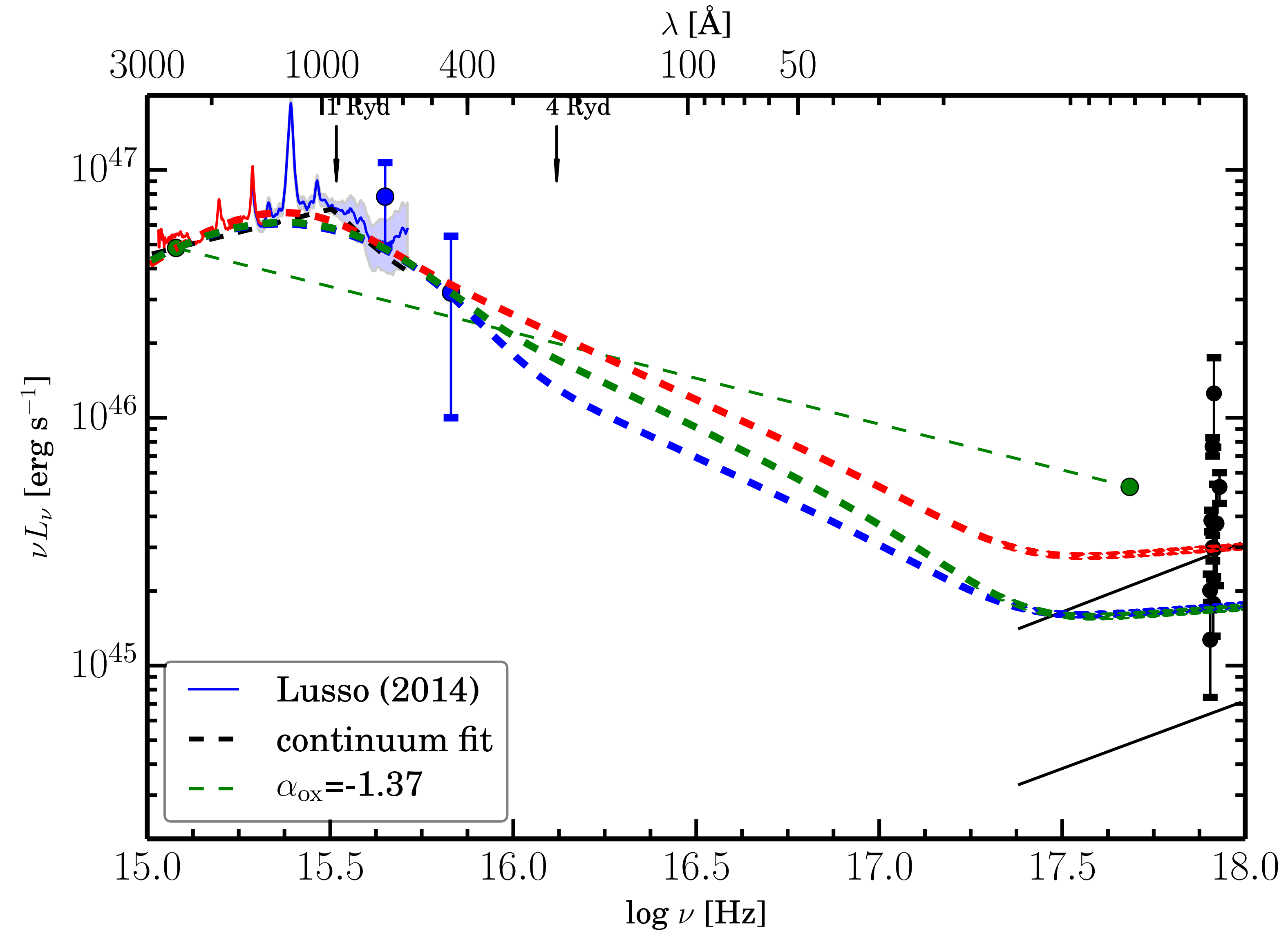
(a=1.0)

$M_{BH} = 3 \times 10^9 M_\odot$

$\lambda_{Edd} = 0.70$

$\Gamma = 1.9$

(a=0.3)



Conclusions

- Current estimates of AGN SEDs do not properly take into account absorption by neutral hydrogen
- First UV quasar composite at redshift higher than 2 with proper IGM absorption correction
- Softer EUV continuum than low luminous/low redshift (low M_{BH}) quasar samples
- The peak of the BBB does not depend on M_{BH} only (but BH spin is also involved)