Dependence of equivalent width of quasar emission lines on UV spectral index, quasar luminosity and BH mass

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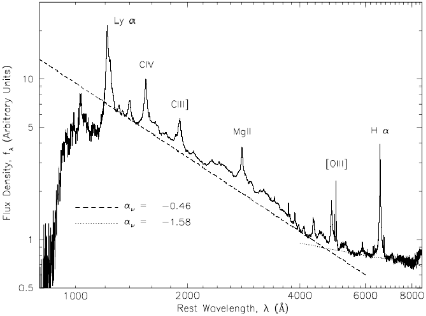
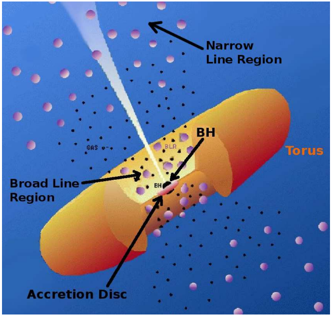
General view



Composite spectra of the quasars from Vanden Berk et al., 2001



Model of AGN

- "Big Blue Bump" and (quasi-) power-law continuum $\Longrightarrow$ thermal emission of accretion disc
- broad and narrow emission lines $\Longrightarrow$ surrounding clumped gas
- broad absorption lines ($\sim$15–20%) $\Longrightarrow$ gas flows outward centre
- Lyα,...–forests (absorption) $\Longrightarrow$ intergalactic H I etc.

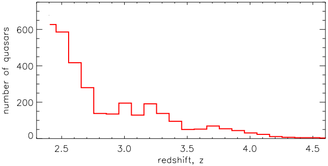
Characteristics and dependencies between them

Baldwin effect: anticorrelation of the continuum luminosity l_ν at 1450 Å and the equivalent width of C IV (1549 Å) emission line (and others).

Characteristics	Dependence	Origin
EW–L	**YES** (Baldwin effect)	proximity of the studied regions. (Lyα, Si IV+O IV, C IV, Mg II, Al III,...)
L–α_λ	**NO***	unknown
EW–α_λ	?	?
M$_{BH}$–α_λ	?	?

* – from Ivashchenko, Sergijenko & Torbaniuk, MNRAS, 2013.

The sample



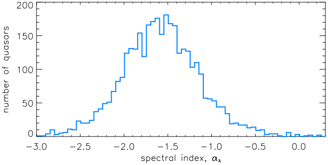
redshift distribution of the sample of quasars.

3535 QSO

SDSS DR7

$R \approx 2000$

$2.3 < z < 4.6$

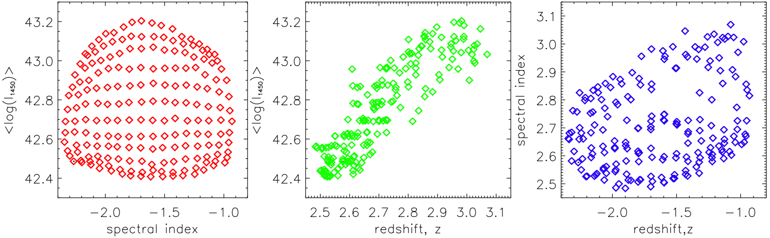


Spectral index distribution of the sample of quasars.

192 composite spectra:

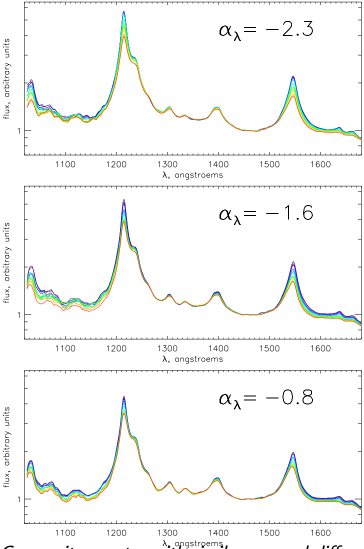
$$\alpha_\lambda = -2.3 \ldots -0.8 \quad (\Delta\alpha_\lambda = 0.1),$$

$$\langle \log(l_{1450}) \rangle = 42.2 \ldots 43.4 \quad (\Delta\langle \log(l_{1450}) \rangle = 0.1)$$

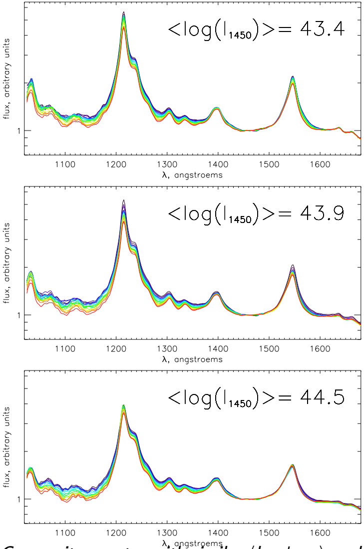


Dependence between values $\langle z \rangle$ and $\langle \log l_{1450} \rangle$ of subsamples and α_λ of composite spectra.

Compilation of the composite spectra



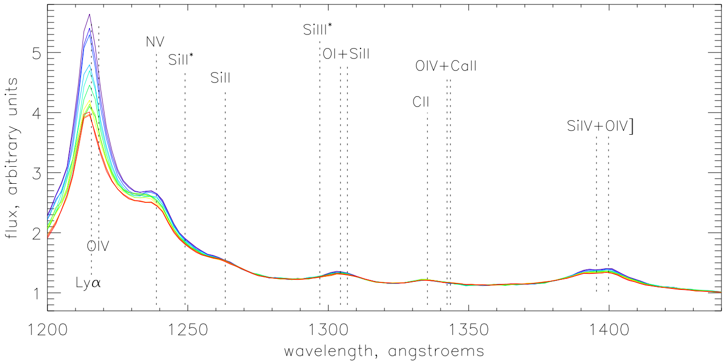
Composite spectra with similar α_λ and different $\langle \log l_{1450} \rangle$.



Composite spectra with similar $\langle \log l_{1450} \rangle$ and different α_λ.

The wavelength ranges

1215–1285 Å	Lyα+O IV+N V+Si II*+Si II
1290–1320 Å	Si III*+O I+Si II
1320–1350 Å	C II+O IV+Ca II
1350–1430 Å	Si IV+O IV]



12 composite spectra with similar spectral indices ($\alpha_\lambda = -2.2$) with lines identified.

Calculation of EW

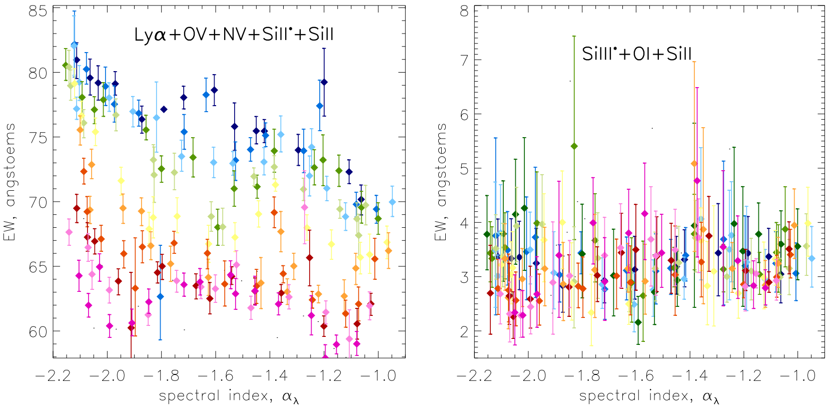
- the wavelength ranges were fitted with the smallest possible number of emission lines (using `IDL lmfit`):

$$f(\lambda) = b + \sum_k a_k \exp\left[-\frac{(\lambda - \lambda_k^0)^2}{2w_k^2}\right], \tag{1}$$

$$f(\lambda) = c \cdot \lambda^{\alpha_\lambda} + \sum_k a_k \exp\left[-\frac{(\lambda - \lambda_k^0)^2}{2w_k^2}\right]; \tag{2}$$

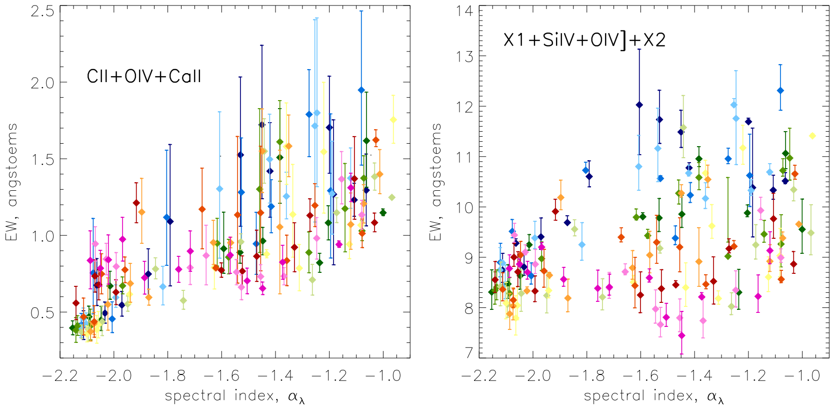
  - finding of λ_k^0 and initial parameters (b/c, a_k, w_k);
  - with fixed λ_k^0 finding of parameters b/c, a_k, λ_k^0, w_k;
- calculation of equivalent width (compute integrals of obtained functions describing individual lines or sets of lines).

Equivalent widths and dependencies $EW - \alpha_\lambda$, $EW - L$



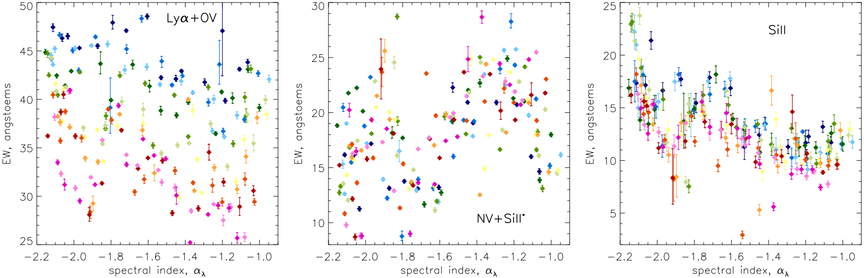
Dependence of equivalent width of quasar emission lines on UV spectral index for superposition of lines within the wavelength ranges 1215–1285 Å, 1290–1320 Å (colour shows the change of the luminosity)

Equivalent widths and dependencies $EW - \alpha_\lambda$, $EW - L$



Dependence of equivalent width of quasar emission lines on UV spectral index for superposition of lines within the wavelength ranges 1320–1350 Å, 1350–1430 Å (colour shows the change of the luminosity)

Equivalent widths and dependencies $EW - \alpha_\lambda$, $EW - L$



Dependence of equivalent width of quasar emission lines on UV spectral index for superposition of lines within the wavelength ranges 1215–1285 Å (colour shows the change of the luminosity).

Calculation of M_{BH}

Calculation of virial mass of central supermassive BH for 3535 individual quasars and composite spectra (using C IV emission line):

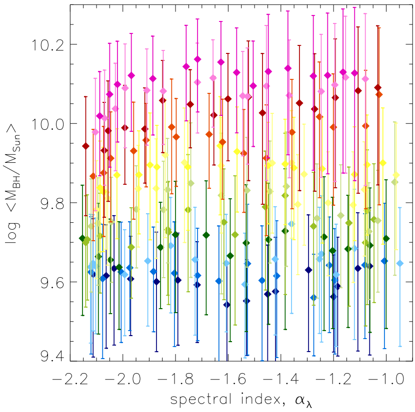
$$\lg\left(\frac{M_{BH}}{M_\odot}\right) = a + b\lg\left(\frac{\lambda L_\lambda}{10^{44}\,erg\ s^{-1}}\right) + 2\lg\left(\frac{W}{km\,s^{-1}}\right), \tag{3}$$

$$L_\lambda = 4\pi D_{phot}^2 F_\lambda, \tag{4}$$

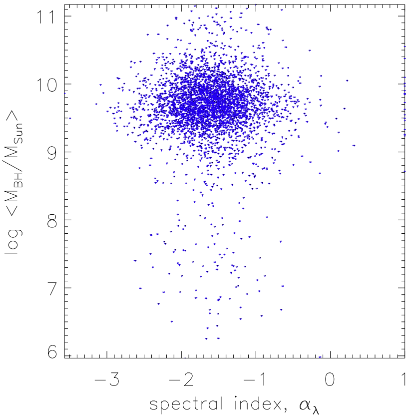
$$D_{phot} = \frac{c(1+z)}{H_0}\int_0^z \frac{dt}{\sqrt{\Omega_\Lambda + \Omega_M(1+t)^3}}, \tag{5}$$

- F_λ and L_λ – flux and luminosity, W – full width at half minimum (FWHM) of C IV (1549 Å); D_{phot} – photometric distance, z – redshift of the quasar;
- $H_0 = 67.74 \pm 0.78$ km s^{-1} Mpc^{-1}, $\Omega_\Lambda = 0.692 \pm 0.010$, $\Omega_M = 0.308 \pm 0.010$ (Planck+WP+BAO from Planck Collaboration, 2015);
- calibration parameters $a = 0.66$ and $b = 0.53$ for C IV from Shen et al., 2011.

The diagrams α_λ-M_{BH}



Mass of quasar's BH – spectral index α_λ diagram (colour shows the change of the luminosity)



Mass of quasar's BH – spectral index α_λ diagram for 3535 individual quasars.

Conclusions

1. there is EW–α_λ dependence for those lines for which Baldwin effect is observed (for some lines we have inverse dependence (Lyα+O V+N V+Si II*+Si II) and for others (C II+O V+Ca II and X1+Si IV+O IV]+X2) this dependence is direct);
2. there is no EW–α_λ dependence for those lines for which Baldwin effect is not observed (Si III*+O I+Si II);
3. the separation of Lyα+O V+N V+Si II*+Si II lines shows that Baldwin effect and EW–α_λ dependence exists only for Lyα+O V and Si II, while for N V+Si II* those effects doesn't exists;
4. there is no dependence between α_λ and virial mass of the BH.

Characteristics	Dependence	Origin
EW–L	**YES** (Baldwin effect)	proximity of the studied regions. (Lyα, Si IV+O IV, C IV, Mg II, Al III,...)
L–α_λ	**NO**	**unknown**
EW–α_λ	**YES**	**unknown** for those lines for which Baldwin effect is observed
M_{BH}–α_λ	**NO**	**unknown**