Explaining the global X-ray Baldwin effect with XMM-Newton

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The strong correlation between the intrinsic spectral slope $\Gamma$ in X-rays and the amount of Compton reflection $\Omega/2\pi$
The $\Omega/2\pi - \Gamma$ correlation is explained by Comptonization of AGN accretion disc photons

the larger the solid angle $\Omega/2\pi$ subtended by the reflector and the stronger the luminosity $L_{\text{UV}}$ of soft photons is:

- the greater is the cooling by seed photons incident on the plasma
- the lower is the plasma electron temperature $\Theta = kT_e/mc^2$
- the steeper are the X-ray photon indices $\Gamma$
- the weaker is the X-ray luminosity $L_x$
- the lower are the $\alpha_{\text{ox}}$ values
Accretion states and Comptonizing coronal parameters

- Super-Eddington
- radiation driven outflows with $\tau >> 1$
- cool corona
- photon trapping
- weak and steep Comptonized X-ray emission
- standard disk
- sub-Eddington
- hot corona
- strong and flat Comptonized X-ray emission

$$\Gamma = \ln \tau / \ln (1 + 4\Theta)$$
$$L_{\text{corona}} = f(\Theta, \tau)$$
XMM-Newton simulations of AGN accretion states and Comptonized plasma parameters

Super-Eddington
low $\Theta$
$\Gamma = (5.1+0.1)$

Eddington limit
medium $\Theta$
$\Gamma = (2.4+0.1)$

Sub-Eddington
high $\Theta$
$\Gamma = (1.7+0.1)$

The strong the UV emission, the weaker the X-ray emission which is the X-ray Baldwin effect.
LBQS 0102-2713 as an extreme for AGN accretion states and Comptonized plasma parameters

UV disc emission
$L = (6.2 \pm 0.2) \times 10^{47}$ erg s$^{-1}$
$L/L_{edd} = 17.9^{+33.0}_{-11.5}$

Comptonized UV photons
soft X-ray emission
$\Gamma(90\%) = 3.4 - 4.7$
$kT(90\%) < 5.6 - 10.2$ keV
LBQS exhibits one of the steepest soft photon indices

joint fit to the XMM-Newton and ROSAT data

observed photon index

$\Gamma(90\%)$
- M1 3.4-4.0
- M2 3.5-4.0
- PN 3.8-4.3
- ROSAT 3.7-4.7

mean value

2.3 with large scatter
- ROSAT Walter, Fink$^{93}$
- Chandra Green$^{08}$
- SDSS, PSS Vignali$^{03}$
- Brandt, Just$^{07}$
- Shemmer$^{04}$
- Strateva$^{07}$
LBQS 0102-2713: XMM-Newton, Swift, ROSAT data

accretion disc spectrum + local Comptonized emission
LBQS 0102-2713: Luminosity, Mass and Eddington ratio

**LUMINOSITY:**
$L = (6.2 \pm 0.2) \times 10^{47} \text{ erg s}^{-1}$

the most luminous quasar in the local universe?

**MASS:**
$M = (2.5^{+4.3}_{-1.6}) \times 10^{8} \text{ M}_{\odot}$

**EDDINGTON RATIO:**
$L/L_{edd} = 17.9^{+33.0}_{-11.5}$ one of the highest Eddington ratios measured so far

![Bolometric luminosity as a function of $z$](image)
LBQS 0102-2713: Comparison with mean quasar SED

X-ray weakness
- low plasma temperature
- steep $\Gamma$
The UV line emission is comparable to quasar composites and LBQS is NOT intrinsically X-ray weak.

The X-ray weakness is explained by the Comptonization of accretion disc photons.

Rest frame EW values:

- Ly$\beta$ + O VI = 12 Å measured
- Ly$\alpha$ + N V = 70 Å measured

Quasar composites:
- Brotherton 11 Å
- Zheng 16 Å
- Vanden Berk 9 Å
- York90, HST FOS

Instrumental setups:
- Ly$\beta$ + O VI
- Ly$\alpha$ + N V
Super-Eddington accretion produce radiation-driven outflows with significant Thomson depth $t \gg 1$ (e.g. Abramowicz88, Kawashima09), and such outflows Compton up-scatter photons, making the hard emission component the steep soft X-ray photon indices $\Gamma$ translate in Compton $y$ parameters ranging between $y = (0.05 \text{ and } 0.08)$ as $y = 4 \Theta \times \tau$ and assuming a lower limit for $\tau$ of 1, the upper limit for $\Theta = kT_e/mc^2$ ranges between 0.01 and 0.02, corresponding to low electron temperatures ranging between 5.6 and 10.2 keV.
An qualitative explanation for the global X-ray Baldwin effect

strong UV disc emission results in X-ray weakness
Summary

the larger the solid angle $\Omega/2\pi$ subtended by the reflector and the stronger the luminosity $L_{\text{UV}}$ of soft photons is:

- the larger is the radiation-driven outflow (feedback)
- the greater is the cooling by seed photons incident on the plasma
- the lower is the plasma electron temperature $\Theta = kT_e/mc^2$
- the steeper are the X-ray photon indices $\Gamma = \ln \tau / \ln (1 + 4\Theta)$
- the weaker is the X-ray luminosity $L_x = f(\Theta, \tau)$
- the lower are the $\alpha_{\text{ox}}$ values

which generally explains the global X-ray Baldwin effect