On the Nature of Soft X-ray Weak QSOs (SXW QSOs)

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X-ray emission is a universal property of QSOs, but there is a large dispersion in the strength of the X-rays relative to other wavelengths.

Significant population of SXW QSOs; $\gtrsim 20$ times weaker than usual in soft X-rays (e.g. Laor et al. 1997)

- Internal absorption?
- Unusual intrinsic SEDs?
- Extreme X-ray or optical variability?

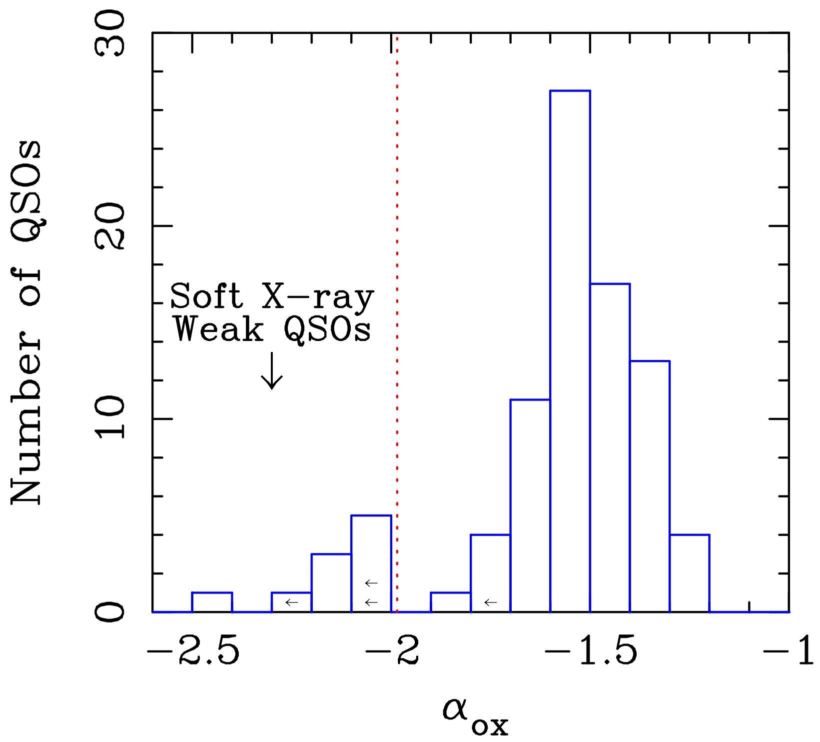
Uniform, systematic study

- Determine the origin of soft X-ray weakness *in general*.
- Discover any relations between SXW QSOs, BAL QSOs and X-ray warm absorber QSOs.
- Correlations between soft X-ray weakness and other observables.

SXW QSO Selection and Sample

Select all SXW QSOs from the $z < 0.5$ BQS (87 QSOs).

- Want a well-defined sample for general SXW QSO conclusions.
- High-quality, uniform data available in the literature and archives.
- Calculated high-quality α_{ox} values for all 87 QSOs.
- Usually ROSAT; also ASCA and Einstein when needed
- 83 detections, 4 upper limits; much better than previous studies



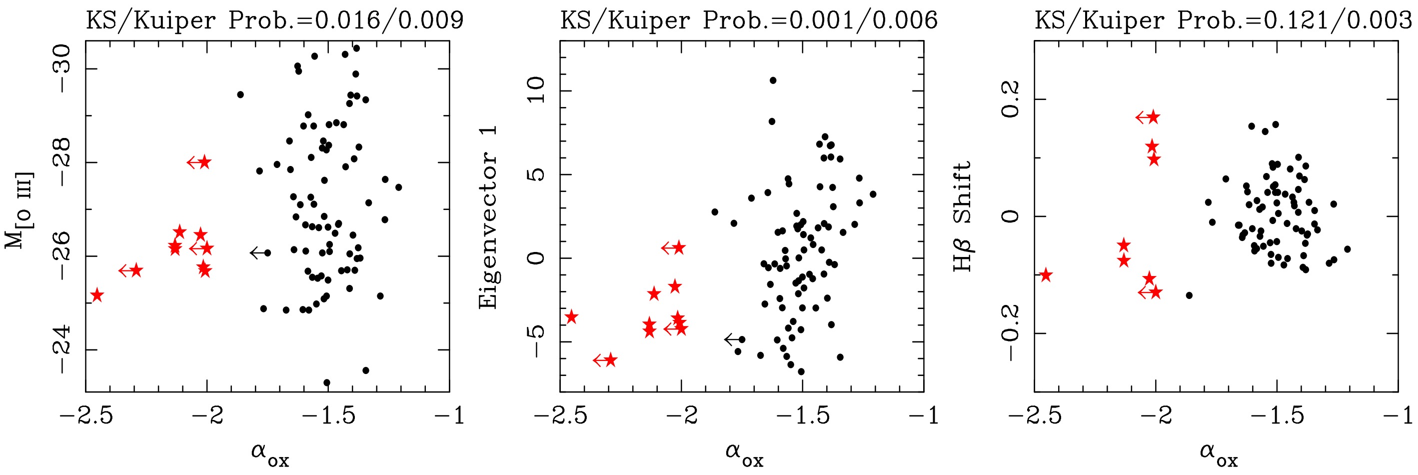
Resulting SXW QSO sample

- Find 10 SXW QSOs with $\alpha_{ox} < -2$ ($>$ 25 times weaker than usual in soft X-rays); $\approx$ 11% of optically selected QSO population
- 9 radio-quiet SXW QSOs and 1 radio-loud

Continuum and Line Properties

Look for α_{ox} correlations and systematic differences of SXW QSOs

- Continuum and line properties from Boroson & Green (1992); optical continuum polarization; α_{opt}; radio structure
- C IV absorption in 55 objects with coverage (HST, IUE)



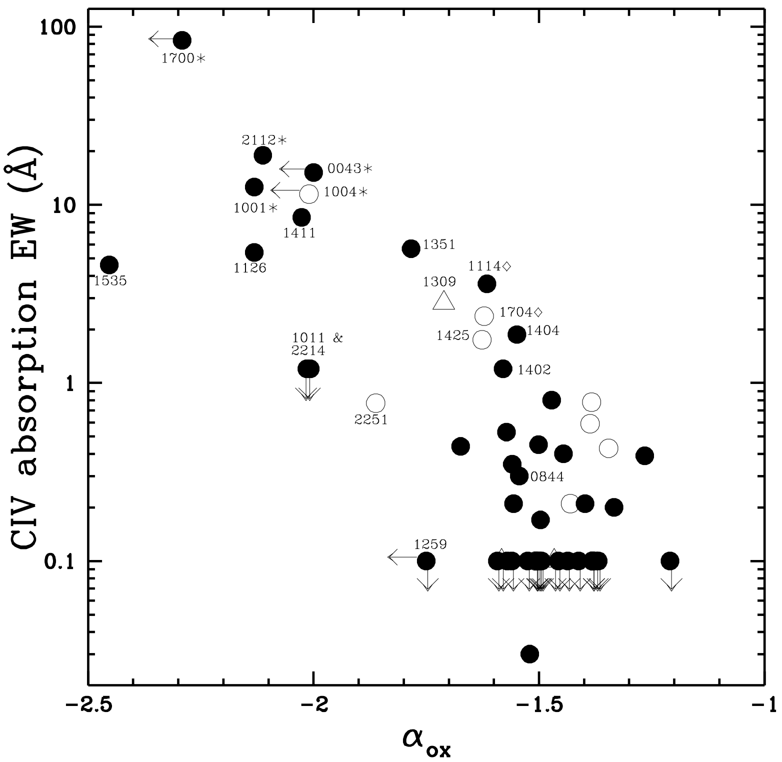
Similarities and differences between SXW QSOs and non-SXW QSOs

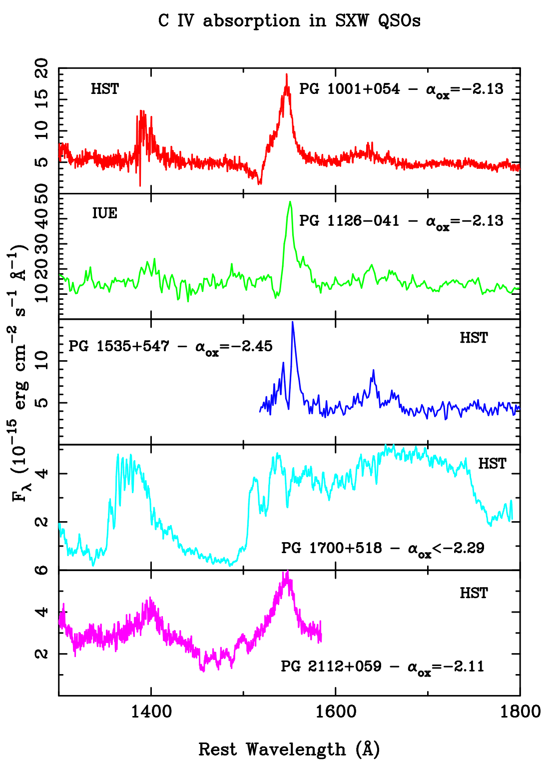
- Consistent: M_V, z, R, α_{opt}, polarization, Hβ FWHM
- Consistent: EWs of Hβ, He II, Fe II
- Inconsistent: Low [O III] luminosities, negative eigenvector 1, 'peaky' Hβ line profiles, large Hβ line shifts

Ultraviolet Absorption Properties

Soft X-ray weak QSOs show greatly enhanced UV absorption.

- Most have C IV absorption EW > 4 Å.
- $\alpha_{\rm ox}$ and C IV absorption EW are strongly correlated.
- Our one object with a broad-band X-ray detection shows heavy X-ray absorption. Two other ASCA nondetections.





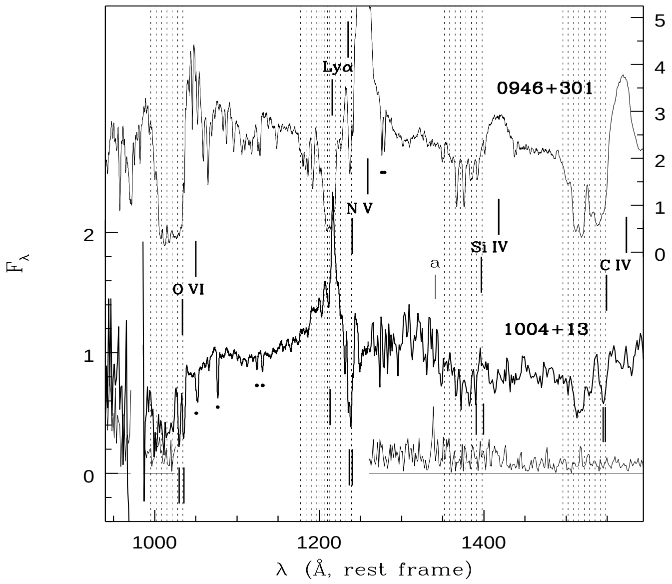
- 5 BAL QSOs in the $z < 0.5$ BQS—3 previously known and 2 new ones (one new BAL QSO is radio loud!). BAL QSOs lie at the extreme of the $\alpha_{\rm ox}$/C IV EW correlation.
- Other interesting objects

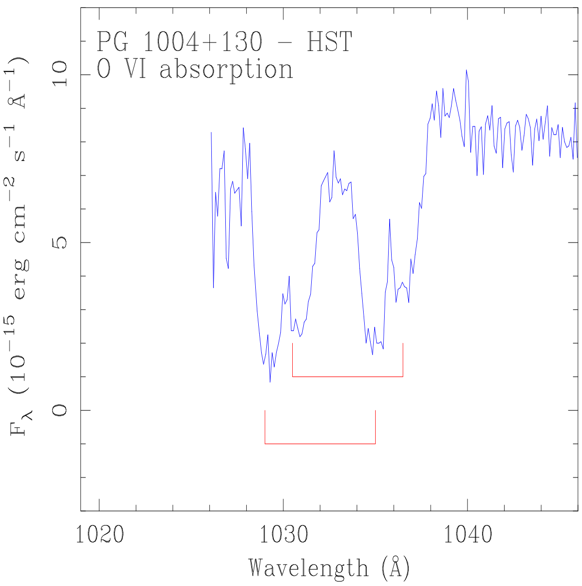
PG 1004+130 (PKS 1004+13)

Wills, Brandt & Laor, ApJL, submitted

Basic properties, history, and our results

- $z = 0.240$, $V = 15.2$, $\alpha_{\rm ox} < -2.01$, $\log R = 2.32$ (radio loud and lobe dominant)
- First noted to be soft X-ray weak by Elvis & Fabbiano (1984). They suggested that a strong BBB was causing the unusual $\alpha_{\rm ox}$.
- Broad absorption troughs are seen in O VI, N V, Si IV and C IV with velocities up to ~ 10000 km s^{-1}. Balnicity is 850 km s^{-1}. Also strong associated absorption.





- Strong and broad N V absorption can explain the anomalously weak Lyα emission line.
- Can use radio structure as orientation indicator. Suggests that BAL flow is at large inclination to the central engine axis.

Conclusions and Future Work

The origin of soft X-ray weakness in QSOs.

- We find highly suggestive evidence that heavy absorption is the primary cause of soft X-ray weakness in QSOs.
- We can argue against unusual SEDs based on line EWs.
- We can argue against extreme variability using historical data.

Additional conclusions

- Practical implication: Selection by soft X-ray weakness is $\gtrsim 80\%$ effective at finding low-redshift QSOs with strong and interesting UV absorption. Much more effective than other methods.
- BAL incidence is consistent in $z < 0.5$ BQS and LBQS.
- SXW QSOs generally have low [O III] luminosities (cf. low-ionization BAL QSOs). Suggests soft X-ray weakness is at least partially linked to an *intrinsic* property.
- SXW QSOs lie toward the negative end of Boroson & Green eigenvector 1. High $\dot{M}/\dot{M}_{\rm Edd}$, as has been postulated for NLS1 objects? Accretion at high $\dot{M}/\dot{M}_{\rm Edd}$ might drive a stronger outflow (e.g. Blandford & Begelman 1999).

For More Information

Please contact Niel Brandt (`niel@astro.psu.edu`). A paper describing these results has been submitted to *The Astrophysical Journal*.

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