A STATISTICAL STUDY OF THE RELATIONSHIP BETWEEN X-RAY, OPTICAL AND RADIO LUMINOSITY FOR A SAMPLE OF QSOs

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ABSTRACT. Our statistical study finds that the X-ray luminosity, l_x, for an average QSO of given optical luminosity, l_o, is an increasing function of radio luminosity, l_r. An average QSO of given l_o and l_r has higher l_x if the radio spectrum is flat than if it is steep. The correlation between l_x, l_o and l_r appears to be improved if l_r refers only to core emission, l_{rcore}. Assuming an average radio-loud QSO is a radio-quiet QSO with a separate component which produces l_{rcore} and l_{xcore}, l_{xcore}/l_{rcore} is larger if the core is that of a QSO with extended radio structure than if that of a compact flat-spectrum QSO.

Various authors have found that samples of QSOs exhibit a dependence of X-ray luminosity, l_x, on optical luminosity, l_o, of the form

$$\log l_x = \log(A l_o^\alpha) \tag{1}$$

(The logarithm of the function is given to illustrate that the regression analysis is for $\log l_x$ rather than l_x). Different QSO samples have given values of α between ≈ 0.5 and ≈ 0.9 (e.g., Avni and Tananbaum 1986, and references therein). However, it has also been pointed out that the X-ray luminosity of QSOs is influenced by their radio luminosity, l_r (e.g., Kembhavi, Feigelson and Singh 1985; and references therein). We have studied this dependence by applying eq. [1] to a sample of 227 QSOs divided into 3 subsamples in bands of $\log(l_r/l_o)$. Our fits use the Detections and Bounds method of Avni et al. (1980). Luminosities refer to monochromatic source-frame values at 5 GHz, 2500 Å and 2 keV for l_r, l_o and l_x, respectively. The X-ray measurements were made with the Einstein Observatory Imaging Proportional Counter. The radio and optical data were taken from many published sources. We find that all 3 subsamples can be fit with the same value of α, but the normalization, A, increases with increasing $\log(l_r/l_o)$. Furthermore, we find that, for the 114 QSOs in our 2 subsamples of highest $\log(l_r/l_o)$, i.e., those QSOs we define as radio-loud, A is greater for objects with flat radio spectra (FRS) than for objects with steep radio spectra (SRS).

For investigative purposes, we have chosen a model with a simple dependence of l_x on both l_o and l_r,

$$\log l_x = \log(K l_o^\alpha l_r^\beta) \tag{2}$$

For our FRS QSO sample, we find that the sigma of the Gaussian distribution of the residuals for a fit to eq. [2] is significantly smaller than that for a fit to eq. [1], with $\alpha \approx \beta \approx 0.45$. This suggests a connection between the radio luminosity and at least some of the X-ray luminosity for these objects. FRS QSOs are core compact, and the report of $\approx 75\%$ VLBI visibility for objects of this type (Zensus, Porcas and Pauliny-Toth 1984) suggests their radio cores are typically ≤ 20 pc. For our SRS QSO sample, $\alpha \approx 0.45$, whereas β is smaller but still greater than zero. We have divided the 46 objects in our SRS sample on the basis of radio morphology. Our SRS-Compact sample is populated by 16 objects. These are an interesting group for study because their radio structure is typically complex, with structure on all scales between ≈ 10 pc and ≈ 10 kpc (e.g., Pearson and Readhead 1984). Unfortunately, our 16 objects have an insufficient spread in l_r for conclusions to be drawn. Our SRS-Extended sample is populated by 24 objects. For these objects, when l_r refers only to the luminosity within ≈ 30 kpc ($H_o = 50$ km s^{-1} Mpc^{-1}; $q_o = 0$) of the core, l_{rcore}, the fit to eq. [2] appears to be improved, although statistical uncertainties prevent a strong statement.

In order to investigate physical mechanisms, we have fit the samples to a functional form which separates the dependence on optical and radio luminoisty,

$$\log l_x = \log(Al_o^\alpha + Bl_r^\beta) \tag{3}$$

We find that the term in l_o for the FRS sample is consistent with that for the radio-quiet sample (for the radio-quiet sample, the term in l_r is assumed to be negligible). This implies that we may consider a radio-loud QSO as a radio-quiet QSO with a separate component which produces l_{rcore} and a contribution to l_x, which we can call l_{xcore}. This applies also to the SRS-Extended objects, when l_r refers only to l_{rcore}. A value of $\beta \approx 0.88$ fits both the FRS and SRS-Extended (core radio) samples. We then find that the ratio of B for the SRS-Extended (core radio) to FRS samples is 5.5±3.6 (90% errors). This means that the ratio l_{xcore}/l_{rcore} is larger if the core is that of a QSO with extended radio structure than if that of a compact flat-spectrum QSO. This could be interpreted as due to relativistic beaming depressing the X-ray relative to core-radio luminosity in FRS but not SRS QSOs. This is in qualitative agreement with the prediction of the unified scheme of Orr and Browne (1982), although our results do not imply a sufficiently large effect to be in quantitative agreement.

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