XMM-NEWTON OBSERVATIONS OF THE LAOR ET AL. SAMPLE OF PG QUASARS

C.Brocksopp[1], R.L.C Starling[2], P.Schady[1], K.O.Mason[1], E.Romero-Colmenero[3], and E.M.Puchnarewicz[1]

[1]Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Dorking, Surrey RH5 6NT
[2]Astronomical Institute "Anton Pannekoek", University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam
[3]South African Astronomical Observatory, PO Box 9, Observatory 7935, Cape Town

ABSTRACT

We present *XMM-Newton* EPIC and OM observations of the Laor et al. sample of the Palomar Green quasars. A power-law provides a reasonable fit to the 2–5 keV region of the X-ray spectra; extrapolation of this power-law to the full *XMM*/EPIC range reveals a soft excess below 2 keV in most objects. A single power-law provides a poor fit to the full range and instead a broken power-law is used. We show that the low- and high-energy components of this broken power-law are tightly-correlated ($r = 0.97$, to within 99% confidence), suggesting a common origin. This result places important constraints on attempts to fit the soft X-ray emission with a thermal model. Finally, preliminary study of the broad-band (optical–X-ray) spectral energy distribution suggests that accretion disc models are not able to represent the soft X-ray region of the spectrum, adding support to the conclusion that the soft X-ray emission may be non-thermal in origin.

Key words: Multiwavelength; Quasars; SED.

1. INTRODUCTION

The Laor et al. (1997) sample of PG quasars is a subset of the optically-selected Bright Quasar Survey which, in order to create a sample which is complete and representative of most quasars in terms of their X-ray properties, has been further constrained by redshift ($z \leq 0.4$) and column density ($nH_{Gal} < 1.9 \times 10^{20}$). *ROSAT* observations in the 0.2–2.0 keV range were obtained and presented by Laor et al. (1997). We have used *XMM-Newton* to update the *ROSAT* observations, providing a much wider X-ray spectral coverage (0.3–10.0 keV, although we note that we were able to use only 0.7–10.0 keV for the MOS cameras due to calibration problems at low energy), higher energy resolution and a high S/N ratio, and also providing simultaneous optical and UV data from the Optical Monitor.

We note that full details of the results of this study are presented in Brocksopp et al. 2005.

2. RESULTS

We find that a simple absorbed power-law is a good fit to the 2–5 keV region of the spectrum and that extrapolation to low energies reveals the presence of a soft excess in most objects. Such a power-law provides a poor fit to the full *XMM*/EPIC range (0.3–10.0 keV). Instead we use a broken power-law plus Galactic absorption and iron line, which is a successful fit to the spectra in most cases. Four of the quasars show evidence for additional (presumably intrinsic) absorption. Twelve of the sources show evidence for an iron line, but with low significance ($< 2\sigma$) in most cases. An example of one of the fits, for PG 1115+407, is shown in the top left corner of Fig. 1.

We have plotted various combinations of spectral parameters and line and continuum luminosities for comparison with the plots in Laor et al. (1997). We confirm the correlations found by these authors. But our most significant correlation is the extremely tight relationship (Spearman rank correlation coefficient, $r = 0.97$ to $> 99\%$ confidence) between the photon indices of the low- and high-energy components of the broken power-law. There are a number of discrepant points (labeled in the bottom left panel of Fig. 1 but we find that these objects are atypical, containing a warm absorber and/or are labelled as "X-ray weak" by Laor et al. (1997). The bottom left panel of Fig. 1 shows an expanded view of the same plot, with the best-fit straight line drawn through the points.

In addition to the EPIC X-ray spectra, we have obtained *XMM*/OM data for each of the Laor et al. quasars. All optical–X-ray broad-band spectra have been plotted and a sample plot (again for PG 1115+407) is shown in the top right panel of Fig. 1. The spectrum is in the observed-frame of the quasar, the vertical dotted line represents the position of the Lyman break and all points have been corrected for Galactic absorption.

Also plotted are four accretion disc models; best-fit

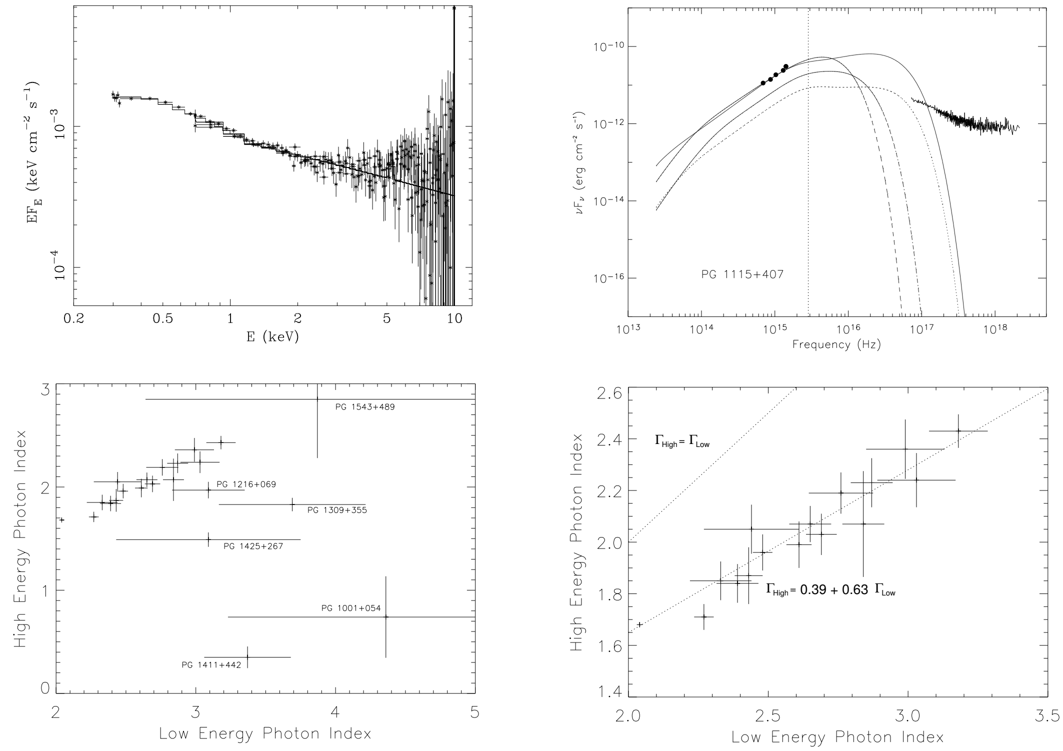

Figure 1. Top row: Sample EPIC (left) and OM–EPIC (right) spectra for one of the Laor et al. quasars, PG 1115+407. Both are plotted in νF_ν-space (or equivalent) in the observed-frame of the quasar. The EPIC spectrum is over-plotted by an absorbed broken power-law model. The broad-band spectrum is over-plotted by four accretion disc models: best-fit Kerr (solid), best-fit Schwarzschild (dashed), published mass Kerr (dotted), published mass Schwarschild (dot-dashed), all of which have been fit to the OM data-points. The vertical dotted line represents the Lyman limit. Bottom row: The tight correlation ($r = 0.97$) between the high- and low-energy photon-indices of the broken power-law for each quasar in the sample. The discrepant points in the left-hand plot are mainly those which contain warm absorbers and/or defined as "X-ray weak" (Laor et al., 1997). The right-hand plot shows an expanded view of the same correlation and the equation of the best-fit straight line through the points.

Kerr (solid line), best-fit Schwarzschild (dashed line), best-fit Kerr using published mass estimate (dotted line) and best-fit Schwarzschild using published mass estimate (dot-dashed line). These models are modified Czerny & Elvis (1989) accretion disc curves (Siemiginowska et al. 1995) and are parametrised in terms of black hole mass, angle of inclination and mass accretion rate (Kerr models) or luminosity (Schwarzschild models). They have been fit to the OM photometry alone and the best fit obtained by minimising χ^2.

In all cases we find that the disc models which fit the OM data most successfully are not able to represent the soft X-ray excess. We also find that fitting the disc model predicts masses which are significantly different from the estimates published in the literature; indeed a number of the published masses provide very poor fits to the OM data. In general the Schwarzschild models provide better fits than the Kerr models. Furthermore some of the Kerr models overpredict the soft-X-ray flux (e.g. PG 1402+261).

3. CONCLUSIONS

By using simple phenomenological models to fit these data, we are able to place important constraints on which physical models are appropriate for describing the spectra of the Laor et al. sample of quasars. The tight correlation between the low- and high-energy components of the broken power-law suggest that both components are produced in the same region of the system and by the same emission mechanism. This would appear to rule out thermal disc emission, particularly given the failure of the disc models to represent the soft X-ray excess in the SEDs above. Instead models invoking non-thermal mechanisms should be used. Detailed investigation of these alternative models will be the subject of future work, including consideration of the radio emission and jet models often used to describe the SEDs of black hole X-ray binaries.

REFERENCES

Brocksopp C., Starling R.L.C., Schady P., Mason K.O., Romero-Colmeno E., Puchnarewicz E., 2005, MNRAS in press (astroph/0510776)

Czerny B., Elvis M., 1987, ApJ, 321, 305

Laor A., Fiore F., Elvis M., Wilkes B., McDowell C., 1997, ApJ, 477, 93

Siemiginowska A., Kuhn O., Elvis M., Fiore F., McDowell J., Wilkes B.J., 1995, ApJ, 454, 77