THE SHAPE OF SOFT X-RAY SPECTRA OF QUASARS

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1. INTRODUCTION AND SAMPLE

Several lines of evidence suggest that the x-ray spectra of quasars are not simple, exact power laws: 1. when Wilkes and Elvis (1987) analyzed quasars as power laws they found an absorption less than that due to our galaxy; 2. the mean 0.3 to 3.5 keV spectral index is steeper than the mean for the 2 to 20 keV range; 3. although several lines of evidence argue that AGN provide a significant portion (perhaps all) of the x-ray background, the diffuse background spectrum does not agree with the x-ray power-law indices measured for quasars or Seyfert galaxies. Schwartz and Tucker (1988) have suggested that all the above conflicts are reconciled if the slope in the Log(flux density) vs. Log(energy) plot flattens continuously with increasing energy. In this paper we utilize one particular parameterization suggested for the flux density, which we call the "log-slope" model:

$$f(E) = K\ E^{-a+b\,log\,E}$$

where f is the flux density, K a normalization parameter which is not of interest here, and a and b are the two parameters of our fit.

In this paper we present preliminary results of applying this fit to the same set of data from 33 quasars which have previously been discussed by Wilkes and Elvis (1987) in terms of single power law fits. Wilkes and Elvis previously rejected the single power law model because it fits to a smaller amount of absorption than is inferred from the 21cm measurements of galactic hydrogen column density. The analysis here differs primarily in that we do not fit a galactic column density, but instead use 21cm measurements by Stark et al. (from Wilkes and Elvis), together with the cross sections given by Morrison and McCammon (1983).

2. RESULTS

Table 1 summarizes our fits. We give the total χ^2 values for the power-law and log-slopes shapes, respectively. The log-slope fits have one fewer degree of freedom, for each of the 33 sources. We test the following 3 hypotheses: 1. all sources are fit by a power-law model, 2. all sources are fit by a log-slope model, and 3. that a log-slope model does NOT improve the fit relative to a power law. There are 249 degrees of freedom for the single power law, thus the value $\chi^2 = 336.7$ forces rejection of hypothesis 1 at $> 99.99\%$ confidence. Hypothesis 2 is allowed at just the 2.3% level (i.e., rejected at 97.7% confidence). The most important result for our work is the evidence to reject hypothesis 3. If hypothesis 2 is accepted, the $\Delta\chi^2 = 76.8$ for 33 degrees of freedom for all $b = 0$, thus such a point lies outside the 4.3σ confidence contour. However, eliminating the 6 largest $\Delta\chi^2$ values brings

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Table 1. Fits of Power Law, $E^{-\alpha}$, and Log-Slope, $E^{-a+b\,log\,E}$, to Quasar X-ray Spectra.

	Chi-Squared Value:				
33 Objects:	Power Law	Log-Slope	α	a	b
SUMS:	336.70	259.90			
MEANS:	10.20	7.88	0.951	0.933	0.379
RMS:			0.437	0.451	0.584
Error of MEAN:			0.077	0.080	0.103

$b = 0$ within the 90% confidence region. An F-test of the difference of the two χ^2 values rejects no improvement at about 95% confidence.

This conclusion depends sensitively on the fact that we fix N_H. If N_H were added as a free parameter the improvement would only be $\Delta\chi^2 = 28.2$ for 33 d.o.f. The fit of (α,N_H) vs. (a, b) improves χ^2 by 10. The unphysically low values of N_H (as noted by Wilkes and Elvis) are masking the effect of the $b\ log\ E$ term, given the relatively few energy channels and E/ΔE$\sim$ 1 resolution for the Einstein IPC.

3. CONCLUSIONS

1. Using measured values of galactic hydrogen and calculated cross sections based on universal abundances, the log-slope shape is preferred to the exact power law shape.
2. The mean values found for a and b, with the uncertainty calculated as the rms divided by the square root of 33, includes the region of Figure 1 in Schwartz and Tucker which allows simultaneous fit of the 2-20 keV AGN spectra (Mushotzky 1984) and also (with suitable high energy cutoff) of the observed x-ray background spectrum in the 2-40 keV region.
3. The numerical form of the log-slope model is suggested by models of (inverse) Compton scattering in optically thick environments (cf. Lightman and White 1988). However, other parametric representations that allow flattening with increasing energy would most likely also be allowed by the present IPC data.

References

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