X-RAY TO INFRARED CONTINUA OF OPTICALLY SELECTED QUASARS

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ABSTRACT. X-ray to infrared continuum data for nine optically selected (PG) quasars show a form which can be simply described in terms of two components — a power law of slope ~1 joining smoothly the 1-10 μm infrared with the 0.1-10 keV x-ray points and superimposed on this, a 'big bump' of optical-uv emission. The 'big bump' can be interpreted as thermal emission from an accretion disk. In a unique case where this 'big bump' extends to soft x-rays the accretion disk parameters can be constrained interestingly.

1. INTRODUCTION

Wilkes and Elvis (this meeting) present the results of an survey of the soft x-ray spectra of quasars using the *Einstein* Observatory IPC. These results show a diversity of slopes in x-ray power-law index, contrasting with earlier work (Mushotzky 1984). To interpret these indices in physical terms it helps greatly to know how the x-ray continuum joins up with the ultraviolet to infrared (UVOIR) spectrum. We have therefore started a program to determine the UVOIR shape of all the quasars that have good IPC x-ray spectra. Here we show the results for the first nine quasars. They are all uv-excess selected quasars from the Bright Quasar Survey (Schmidt and Green 1983). A full report of these results will be presented in Elvis et al. (1986), Bechtold et al. (1986), and Czerny, B., et al. (1986, in preparation).

2. CONTINUUM DISTRIBUTION

The energy distribution (log νf_ν vs. log ν) for the best determined continuum distribution (PG1501+106, Mkn 841) is shown in Figure 1. The 'bow-tie' shape in the x-ray band shows the range of allowed slopes.

The luminosity distribution across the entire five decade range of frequency is remarkably uniform (a horizontal line in Figure 1 would have equal luminosities per decade). The energy distribution of Figure 1 is similar to that of all the other quasars in the distribution (except PG1211+143, see below). These continua could be interpreted in many ways, the simplest however is to divide the distribution into just 2 components: a power law of slope ~1.0 in the

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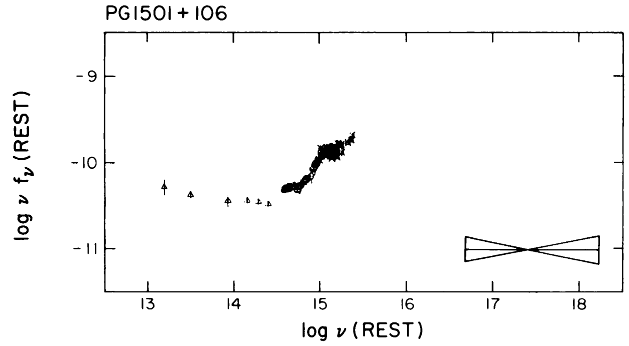
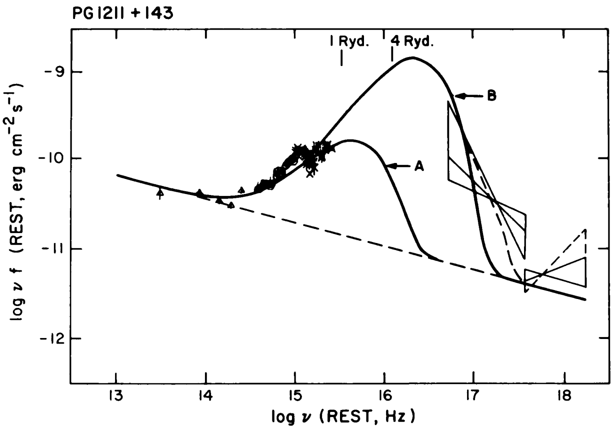
Figure 1.



infrared extending without a break into the soft x-ray region; and a 'big bump' in the optical-ultraviolet superimposed on this power-law. (The 'small bump' in Figure 1 has been shown convincingly to be due to Balmer continuum and FeII emission, see Wills, Netzer, and Wills 1985.) This two component description is the same as that proposed by Shields (1978) and Malkan and Sargent (1982) but extended now into the 0.1-10 keV x-ray range.

One unique quasar is particularly important. PG1211+143 has a very steep ($\alpha_E \sim 2.2$) soft x-ray spectrum and a flatter ($\alpha_E < 1.2$) hard x-ray spectrum. No other quasar in the Wilkes and Elvis IPC survey has such a steep soft spectrum. Its uniqueness may be related to its L_x/L_{opt} ratio which is the largest in the PG sample (Tananbaum et al. 1986). Figure 2 shows its x-ray to infrared energy distribution.

Figure 2.



It is natural to apply the same 2-component decomposition as for the other quasars by assuming the steep soft x-ray component to be the high frequency extension of the 'big bump'.

3. THE POWER-LAW

The data do not require that a single power-law extends from 10 μm to

10 keV. They are however consistent with this simple interpretation. The coincidence of $\alpha_{IR} \approx \alpha_x \approx \alpha_{IR-x} \approx 1.0$ must certainly be explained in some way. In both the infrared and the x-ray bands there are ambiguities which could easily remove this connection (e.g., IR dust emission, two-component x-ray spectra).

If we adopt a single power-law as a working hypothesis there are several mechanisms which could produce it: (1) Direct synchrotron emission; (2) 'Unsaturated Comptonization' of a arbitrary infrared seed spectrum (e.g., Ipser and Price 1983); (3) Inverse Compton x-rays up-scattered from the 1-10 μm infrared; (4) A pair-production cascade spectrum (see Novikov, this meeting). There is no immediate way of deciding between these possibilities. Infrared and x-ray polarization and broad-band variability studies seem to offer the best hope.

4. THE 'BIG BUMP'

Although the nature of the big bump is not decided the possibility that it is due to the integrated thermal emission of an accretion disk is an attractive one. Since the steep soft x-ray spectrum of PG1211+143 gives us a new constraint on the 'big bump' spectrum we have taken the accretion disk idea as, again, a working hypothesis to see what parameters it would imply for PG1211+143.

We used the simplest optically thick, geometrically thin disk models at a constant cos i = 0.5 inclination. This model turns out not to be self-consistent but it does allow a first look at the problem and possibilities. More sophisticated models are now being investigated by B. Czerny.

Figure 3.

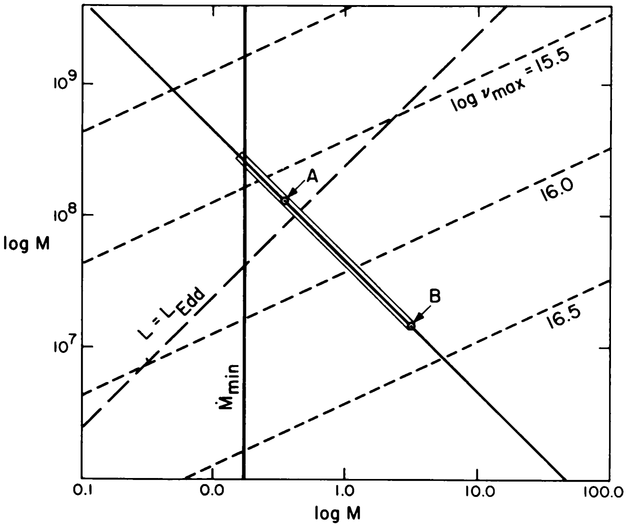


Figure 3 shows how the uv luminosity and the peak in νf_ν constrain the central mass and accretion rate for PG1211+143. The points labelled A and B correspond to the models shown in Figure 2 and illustrate the extreme range of allowed models. If the soft x-rays are really from the hot inner edge of a disk then model B is more appropriate. Model B however is ~20 times super-Eddington. Such a disk will be puffed-up by radiation pressure and so the thin disk approximation will not apply. However any model that is more realistic than a black body approximation will be less super-Eddington, probably by quite a large factor.

We can also use the optical-infrared break at ~1 μm to limit the outer radius of the disk to be at least ~.005 parsec. This may be interesting in limiting the value of the viscosity parameter α to prevent the break-up of the disk. It also makes clear that the 1-year timescale of ultraviolet variability which we see in the IUE data cannot be due to a global change in the accretion rate fed through the disk. This is simply because the viscous timescale at the outer radius we measure is already ~50,000 years. This imposes a low pass filter on any variation in accretion rate.

At the high energy end better x-ray spectra are sorely needed. Even the steep slope we measured is too flat to be explained with a simple disk model. We propose that the disk might be embedded in a hot (~80 keV) Compton scattering atmosphere. However the too flat slope might be an artifact of our low resolution ($\Delta E/E$ ~1) IPC spectrum.

4. CONCLUSIONS

Truly broad-band studies of quasars are clearly a valuable, even necessary, tool for understanding the quasar continua. We are now extending our study to include all quasars with good x-ray spectra. The new continua will include IRAS far-infrared data to look for the limits of the 'power-law' and accurate galactic N_H values to allow better x-ray slope determinations.

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DISCUSSION

Bregman : Could the X-ray emission have varied and you have observed PG 1211+143 in a bright state ?

Elvis : Of course. We are monitoring PG 1211+143 with EXOSAT so we will soon know if it varies a lot. Whatever state it was in, it still had a very soft spectrum.

Burbidge : You have described ways in which you can explain the continuum observations by disk accretion models. Can you tell me which critical observations might rule out disk accretion models ?

Elvis : Strong variability on timescales much too short for dynamical timescales would be one way. Grey shift changes in the entire 'big bump' would, I think, be another. The constancy of the break point at 1 μm between IR power-law and the big bump may also be a problem since a disk should have very different relative amplitudes as a function of inclination angle.