Optical/UV/soft X-ray quasar spectra: Models vs. observations

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OPTICAL/UV/SOFT X-RAY QUASAR SPECTRA: MODELS vs. OBSERVATIONS.

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ABSTRACT

We compare the optical to soft X-ray spectral energy distribution of six bright low-redshift (0.048<z<0.155) radio-quiet quasars with models of quasars where the soft excess is interpreted in terms of (a) optically thick thermal emission from the innermost region of an accretion disk in Schwarzschild and Kerr geometries, (b) reprocessing from ionized gas. Pure disk models even in a Kerr geometry cannot easily reproduce the observed optical to soft X-ray energy distribution. The range of parameters which give reasonable predictions is narrow: high inclinations, high accretion rates and central black hole mass $\sim 10^8 M_{\odot}$. We consider modifications of the disk models: 1) an underlying power law component extending from the infrared ($3\mu m$) to the X-ray; 2) reprocessing of hard X-rays. The modified models can explain the optical-UV and soft X-ray observations. Free-free models are discussed by Fiore in these Proceedings.

1. Data

The X-ray data are taken from Fiore et al. (1994a), where the ROSAT observations were fitted by two power laws and thermal bremsstrahlung plus power law models. IR, optical and UV observations are from Elvis et al. (1994) and Fiore et al. (1994b).

2. Accretion Disk Models

We consider a geometrically thin accretion disk around a supermassive ($10^6 - 10^8 M_{\odot}$) black hole, with accretion rates: 0.01 - 1.0 $\dot{M}_{Edd}$ and the efficiency η: 0.08 for non-rotating and 0.324 for rotating black hole.

(1) Accretion disks in Schwarzschild geometry, unless supplemented by a hot corona, systematically underpredict the soft X-ray emission.

(2) Accretion disk models in a Kerr geometry cannot reproduce the optical-UV slope for the range of parameters for which they can match the observed soft X-ray color. They are too steep (Fig.1).

(3) Only high inclination, high accretion rate, $M_{bh} = 10^8 M_{\odot}$ models can reproduce simultaneously the observed soft X-ray color and UV luminosity. Models with lower mass can reproduce the soft X-ray color but underpredict the UV luminosity (Fig.2). Models that could account for the soft X-ray color tend to overpredict the soft X-ray luminosity.

3. An IR-to-X-ray Underlying Power Law

When a power law (Elvis et al. 1986, Carleton et al. 1987) extending between

IR (3μm) and the X-rays with $\alpha_{IRX} = 1.25$ ' was added to the accretion disk spectra:

(1) the model can reproduce both the soft X-ray and the optical-UV colors (Fig.3);

(2) the 3μm and 0.4keV luminosities predicted by the models appeared in the observed range.

4. Comments on Disk Irradiation

Recent models of an accretion disk illuminated by an external X-ray source (Ross & Fabian, 1992; Matt et al. 1993) shows that the X-ray spectrum flattens with respect to accretion disk models. Reflection could well be an important component in the 0.2-2 keV region. For low accretion rates (corresponding to $\frac{L}{L_{Edd}} = 0.15$), and low ionization parameters, many lines are present in the soft X-ray band (O VIII Kα, Fe XVII&XVIII Lα lines). For higher accretion rates ($\frac{L}{L_{Edd}} = 0.30$) the line strength is much reduced. The limits on the emission line strength found in Fiore et al. (1994a) argue for high accretion rates ($\frac{L}{L_{Edd}} \sim 0.3$).

Also the outer regions of the disk which contribute to the optical-UV part of the spectrum can be modified by irradiation. Irradiation may cause the flattening of the spectrum as well as the wide range of observed optical-UV slopes.

4. Conclusions

We compared the observed optical-UV to soft X-ray spectral energy distribution of a sample of six radio-quiet, low-redshift quasars with the predictions of Big Blue Bump and soft X-ray component models.

(1) Assuming a physical link between the Big Blue Bump and the soft X-ray component, free-free (in general emission from ionized plasma) models can explain the observed soft X-ray color and the mean optical-UV color, but not the soft X-ray color and the spread in optical-UV color (Fiore these Proceedings).

(2) Pure disk models even in a Kerr geometry do not seem to have the required flexibility to account for the observed spread in optical-UV and soft X-ray slopes and luminosities. The flat soft X-ray component slope found by the PSPC requires high inclinations and high accretion rates, which overestimate the soft X-ray luminosity, when producing the correct UV luminosity.

(3) The model with an underlying power law component extending from the infrared ($3\mu m$) to the X-ray added to accretion disk emission, can explain *both* the optical-UV and soft X-ray slopes and luminosities *and* the observed $3\mu m$ luminosity.

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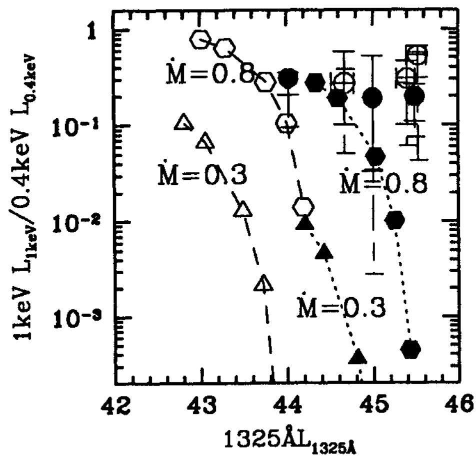

Figure 1. The Soft X-ray color plotted against the optical-UV color. Filled and open circles with error bars identify the quasars, the dashed errors bars indicate the error resulting from a power law plus free-free fit. Dashed lines identify accretion disk models in a Kerr geometry. Filled hexagons and triangles indicate disk inclinations, $\mu = \cos\theta = 1, 0.75, 0.5, 0.2, 0.1$ (soft X-ray color increases with inclination) with $M = 10^8 M_\odot$, accretion rates 0.3 L_{Edd} and 0.8 L_{Edd} respectively. Open hexagons and triangles identify disk models with $M = 10^7 M_\odot$ for the same inclinations and accretion rates.

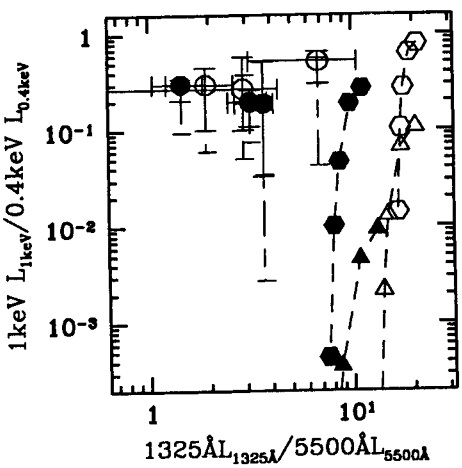

Figure 2. The soft X-ray color vs. the 1325Å luminosity. Filled exagons and triangles identify accretion disk models (Kerr) with $M_{bh} = 10^8 M_\odot$ and open exagon and triangles $M_{bh} = 10^7 M_\odot$ with accretion rates: $\dot{M} = 0.3\dot{M}_{crit}$, $\dot{M} = 0.8\dot{M}_{crit}$ and μ=1; 0.75; 0.5; 0.2; 0.1.

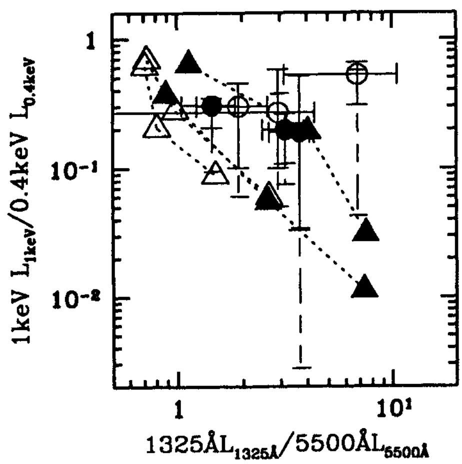

Figure 3. The soft X-ray vs. the optical-UV color. Filled triangles identify accretion disk plus power law models with $M_{bh} = 10^8 M_\odot$ and $\dot{M} = 0.3\dot{M}_{crit}$, μ=0.5 and four values of the power law normalization. The power law slope is fixed to 1.25. Open triangles the same for $M_{bh} = 10^7 M_\odot$.