THE SPECTRUM OF MASSIVE THIN ACCRETION DISKS: THEORY AND OBSERVATIONS

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1.Theory

We have made detailed calculations of the structure and the spectrum of massive, geometrically thin "bare" accretion disks. The calculations are for an α-disk with various assumptions on the viscosity law. The radiative transfer was treated with the Eddington approximation for an atmosphere with a vertical temperature gradient. All significant sources of opacity, for $T>10^4$K, are included, and all models are found to be optically thick throughout. Spectral modifications due to electron scattering (modified blackbody and comptonization) are not significant in most cases. The requirement of a geometrically thin accretion disk forces a limit of $L<0.3L_{ed}$ on the accretion rate. Several previous disk calculations violate this limit (Malkan 1983, Czerny & Elvis 1987, Bechtold et al. 1987) and their results are questionable. The surface temperature is close to the effective temperature, even for regions where electron scattering effects are significant. This is due to the vertical temperature gradient and is in contradiction to earlier findings. The angular distribution of the ionizing flux is strongly influenced by general relativistic effects, and can be very different for various disks.

2.Observations

We have compared the theoretical spectra with quasars observations, some of which are nearly simultaneous and some from the paper by Elvis et al. (1986). The fitting was done by minimizing the chi square with respect to three parameters: the accretion rate, the central mass, and the disk inclination (for nonrotating and rotating black holes). This procedure enables us to deduce the significance level of the fit, and the allowed range for the fitted parameters. Only points at $\lambda<1\mu$ were used in the fitting process.

A power law was subtracted from the data prior to the fitting. Its slope was chosen by the following process: the longest available IR point, which doesn't show a turnover, was chosen as a pivot point, and the slope which allowed the best fitting model was adopted. This slope was always steeper than the slope obtained from the IR data only, but usually by less than 0.15 dex. Fittings done with a significantly steeper slope were always worse. This result is surprising since apriori one would not expect these 2 independent methods to yield similar results. The residual IR flux above the power law can be attributed to thermal dust emission, free-free emission from the BLR, or both. Attempts to fit the 3μ flux with dust and no underlying power law gave very unsatisfactory results. The steepening of the fitted IR slope is relevant to attempts to connect this slope with the IR-X slope.

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Fittings with a rotating B.H. spectrum are usually better than those for a nonrotating one. This is due, at least partly, to the larger number of different spectral forms available in this case. Varying the inclination angle changes the spectrum significantly for a rotating B.H., while in a nonrotating case it only shifts the intensity with almost no change of form. The allowed range of the fitted parameters is very large. This can be seen in fig.1 which gives a projection of the allowed volume in the three-dimensional parameter space on the mass vs. accretion rate plain. This reflects the nonuniqeness of the disk spectrum, where different combinations of mass and accretion rate give similar results (see fig.2), over the limited range of frequencies available. The number of continuum points used in the fit is not crucial but the overall frequency range is. The soft X-ray flux and slope usually cannot be fitted without assuming some reprocessing of the "bare" disk spectrum.

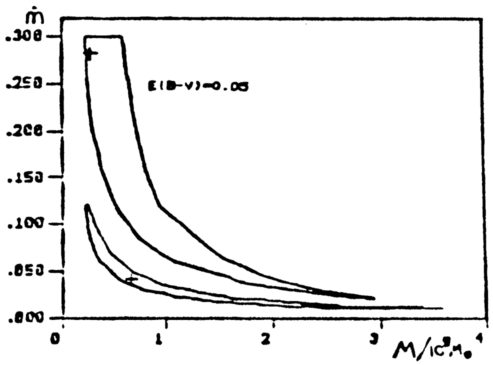

Fig. 1

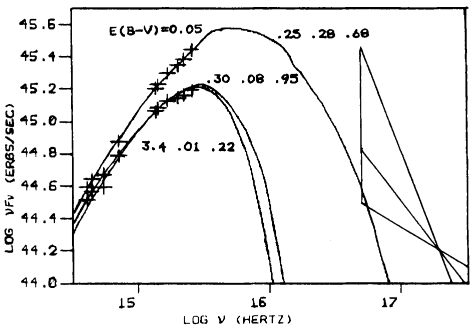

Fig. 2

Fig. 1: Projection of the 90% confidence region in M (B.H. mass) m (accretion rate in units of the Eddington accretion rate) and μ (disk inclination) on the M m plain, for the object 1211 +143. Note the very large range in M, m allowed.

Fig. 2: Various fittings to the spectrum of 1211 +143 with a power law of -1.24 subtracted. The numbers represent M_9, m and μ, the IPC spectrum is shown on the right (from Bechtold et al. 1987). Note the great difference in extrapolation for E(B-V)=0.05.

Extinction, internal to the quasar, can have a significant effect on the spectrum and the fitted parameters, as can be seen in fig.1. It also affects dramatically the extrapolated spectrum, as shown in fig.2. This can help attempts to explain the soft X-ray flux as part of a thin disk spectrum. Extinction of up to E(B-V)=0.05 usually gives satisfactory fits, but more reddening is not compatible with a thin disk spectrum.

Fitting attempts failed only in one object out of 10, at a significance level above 99%, another one was just acceptable on the 95% level, and the rest could not be rejected even on a 80% significance level.

3.References

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