INCLINATION EFFECTS FOR KERR DISKS

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The 'Big Bump', the most striking feature in the continuum energy distributions of quasars, extends through the optical, ultraviolet and, probably, soft x-ray bands. We model the Bump with a blackbody accretion disk [1,2] around a Kerr black hole, taking relativistic inclination effects into account [3,4].

Orientation Effects: An observer at $\mu = \cos\theta$ to the disk axis who assumes the source to be spherically symmetric derives an 'effective luminosity' $L(\nu, \mu)$. From each radius in the disk light travels along null geodesics to the observer with combined gravitational and Doppler orbital redshift g. We integrate over the geodesics to find the orientation dependent luminosity of the Kerr disk [5],

$$L(\nu, \mu) = 2 \int \int_0^1 g^4 J(\nu/g, r) T(g, r, \mu) dg dA$$

where the transfer function $T(g, r, \mu)$ contains the focussing effects. T can be thought of as the factor by which the observer gets the total luminosity wrong; in the Newtonian case $g = 1$ and $T = 2|\mu|$.

Numerical results: We choose a black hole with the 'canonical' angular momentum parameter $a = 0.998$, mass $M = 8 \times 10^8 M_\odot$ and an accretion rate $\dot{M} = 1.1\ M_\odot/\mathrm{yr}$. This corresponds to $L_{Bol} = 10^{46}$ erg/s $= 0.1 L_{Edd}$. The resulting spectrum are very similar to those in [3]. The edge-on spectrum is much harder than face-on and intermediate spectra, and the ultraviolet to soft x-ray color is much more sensitive to inclination than the optical colors.

The Quasar Color-Color Diagram: The infrared ($1 - 2\mu$m), optical ($4000 - 8000Å$), and ultraviolet ($1000 - 2000Å$) color-color diagram, Fig. 1, compares the computed disk colors with that of actual quasars from our energy distribution survey. The dotted line shows the colors of a pure power law of various slopes. It turns out that for $\mu \geq 0.25$ the locus of pure disk colors can be described by a one-parameter family of spectra; if

$$S = \log(L/f_L^2) + \zeta(\mu)(\mu - 1) = 42.23 + 2\log(M/10^6 M_\odot) - \log(\dot{M}) + \zeta(\mu)(\mu - 1),$$

constant S describes an empirical locus of nearly constant spectral shape. Here L is the bolometric luminosity in erg/s, $f_L = L/L_{Edd}$ is the fraction of Eddington luminosity, and $\zeta \sim 2.5$ is a weak function of μ . Note that for a face-on Eddington-limit disk, $S = \log(L)$. Although the edge-on ($\mu = 0$) spectra have different colors, we retain the same function S to parameterise them. The solid lines on the left of the diagram represent the colors of a Kerr disk for edge-on and face-on inclinations, labelled with the value of the S parameter. At low S, face-on disks tend to the colors of a power law of energy index 1/3 (marked as point P). At higher S, the flattening of the spectrum at the peak begins to affect the colors and make them redder. Edge on disks tend to power law of index close to 1 at low S, marked as point Q. By mixing in various fractions a powerlaw of energy index 1 the colors are moved to within the observed quasar locus, illustrated for one value of S by the dashed lines.

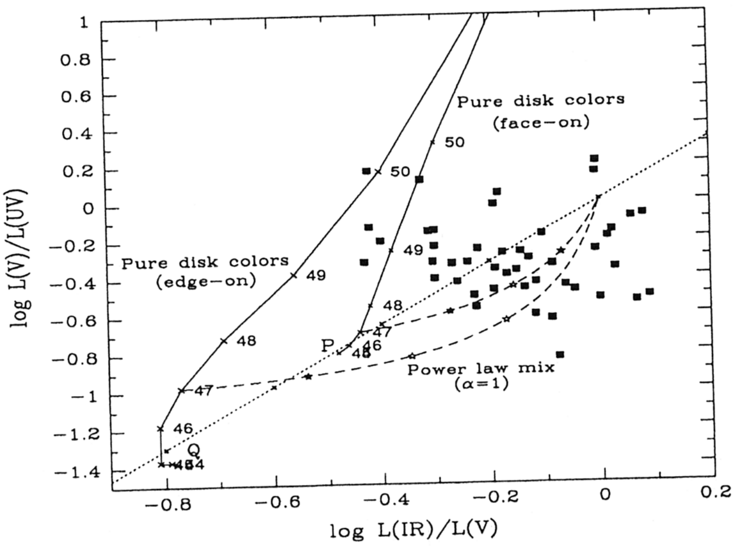

Fig. 1: Quasar IR−VIS−UV Color−Color Diagram

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