SPECTRA OF AGN ACCRETION DISKS — PRELIMINARY RESULTS

H. A. Scott
Lawrence Livermore National Laboratory, L17
P. O. Box 808
Livermore, California 94550, USA

S. L. O'Dell
Space Science Laboratory, ES65
NASA Marshall Space Flight Center
Huntsville, Alabama 35812, USA

After the suggestion (Shields 1978) that some AGN emission might arise in an opaque accretion disk around a supermassive compact object, several papers (*e.g.*, Malkan and Sargent 1982; Malkan 1983; Bechtold *et al.* 1987) have interpreted the flat ultraviolet continuum ("big blue bump") observed in many AGN spectra, in terms of such a model. The early calculations approximated the radiation locally emergent from the accretion disk as blackbody; the more recent calculations (*e.g.*, Czerny and Elvis 1987; Wandel and Petrosian 1988) have treated this emission as (electron-scattering) modified (possibly comptonized) blackbody.

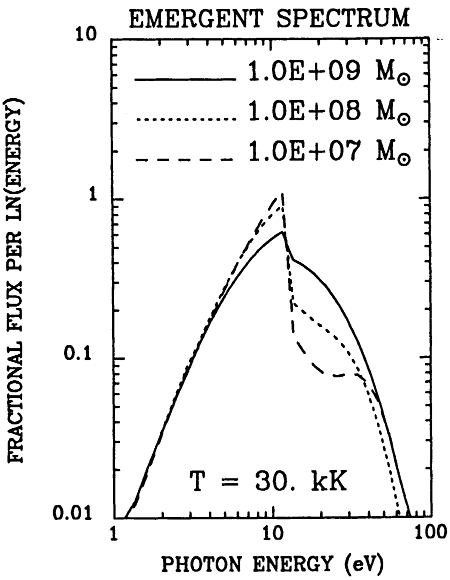
To investigate potentially important accretion-disk phenomena — *e.g.*, the strength of atomic edges and lines (*cf.* Kolykhalov and Sunyaev 1984; O'Dell 1986), communication between various parts of the disk (*cf.* O'Dell, Scott, and Stein 1987; Pacharintanakul and Katz 1980), and non-LTE effects (possibly enhanced by photo-ionization from above) — it is necessary to solve self-consistently for the hydrostatic structure and radiation field, much as one would for a stellar atmosphere. In several respects, the accretion-disk problem is more difficult: Energy generation, *via* viscous dissipation, occurs throughout the atmosphere; the gravitational acceleration changes with altitude; and concavity of the photosurface couples different regions of the disk. Furthermore, for parameters characteristic of AGN accretion disks, much of the inner disk is radiation-pressure dominated. In this case, the standard alpha-viscosity (viscous stress $f_\varphi = \alpha P_{tot}$) model (Pringle and Rees 1972; Shakura and Sunyaev 1973; Novikov and Thorne 1973) is unstable (Lightman and Eardley 1974; Shakura and Sunyaev 1976; Lin and Shields 1986).

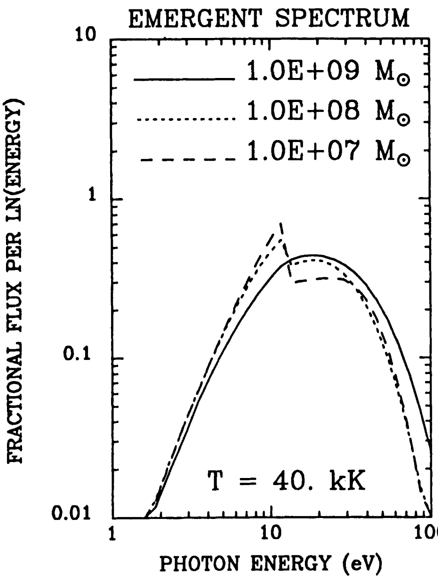
We are developing a numerical code to calculate self-consistently the structure and emergent spectra of thermal accretion disks, using a complete-linearization method (*e.g.*, Mihalas 1978), suitably modified to handle accretion disks. Currently, the code computes the local (single-atmosphere) vertical structure and emergent spectrum of a geometrically thin (plane-parallel), bi-alpha-viscosity (viscous stress $f_\varphi = \alpha_{gas}P_{gas} + \alpha_{rad}P_{rad}$) accretion disk. At present, we assume entirely radiative vertical energy transport, local thermodynamic equilibrium (LTE), and coherent scattering (hence, no comptonization). Comptonization is negigible for the models we consider; indeed, it is seldom significant in *stable* AGN accretion disks (*cf.* Wandel and Petrosian 1988).

Here we present results for a beta-viscosity disk — *i.e.*, for $\alpha_{rad} = 0$ and $\alpha_{gas} = \beta$, such that $f_\varphi = \beta P_{gas}$. In contrast with the α disk, the β disk is stable and quite opaque (Lightman and Eardley 1974). The figures below show locally emergent spectra for a pure-hydrogen β disk (with $\beta = 1$), for effective temperatures (a) $T_{eff} = 30\,kK$ and (b) $T_{eff} = 40\,kK$, at a radius $R = 10\,R_g$ (gravitational radius $R_g \equiv GM/c^2$), from a central mass M. For the smaller M, the Lyman discontinuity is quite prominent in absorption, particularly at the lower T_{eff}. The weakening of this feature with increasing M, corresponds to a similar behavior in stellar atmospheres as $log\, g$ approaches the minimum value

D. E. Osterbrock and J. S. Miller (eds.), Active Galactic Nuclei, 257–258.

allowed (a *local* Eddington limit) for a given T_{eff}. The resemblance of the computed accretion-disk spectra with those of pure-hydrogen stellar atmospheres with similar (Rosseland-mean) photosurface gravities $log\, g$, follows because β disks are sufficiently opaque that most of the (viscous) energy generation occurs below the photosurface and the gravitational acceleration changes little over the relatively narrow transition region.





By fixing both the mass-scaled radius $r \equiv R/R_g$ and the effective temperature T_{eff}, the mass-accretion rate $\dot{M} \sim M^2$, so that the Eddington-scaled mass-accretion rate $\dot{\mu} \equiv \dot{M}c^2/L_E \sim M$. Thus for a given T_{eff}, the Eddington-scaled luminosity L/L_E of a low-central-mass β disk is less than that of a high-central-mass one. (For the values used here, $[L/(10^{45} erg/s)] \approx [M/(10^9 M_\odot)]^2$.) The calculated spectra then suggest that, for a β disk of characteristic temperature $T_{eff} \approx 35\, kK$, Lyman-continuum absorption would be quite prominent in the less luminous AGNs, but much less so in the more luminous AGNs (operating near the Eddington limit). Observed AGN spectra rarely show Lyman discontinuities at the emission redshift of the AGN.

We began this research under NSF grant AST 83-16228, while in the Physics Department, Virginia Tech.

REFERENCES

Bechtold, J., Czerny, B., Elvis, M.,Fabbiano, G., and Green, R. F. 1987, *Ap. J.*, **314**, 699.
Czerny, B., and Elvis, M. 1987, *Ap. J.*, **321**, 305.
Kolykhalov, P. I., and Sunyaev, R. A. 1984, *Adv. Space Res.*, **3**, 249.
Lightman, A. P., and Eardley, D. M. 1974, *Ap. J. (Letters)*, **187**, L1.
Lin, D. A. C., and Shields, G. A. 1986, *Ap. J.*, **305**, 28.
Malkan, M. A. 1983, *Ap. J.*, **268**, 582.
Malkan, M. A., and Sargent, W. L. W. 1982, *Ap. J.*, **254**, 22.
Mihalas, D. 1978, *Stellar Atmospheres, Second Edition* (San Francisco: W. H. Freeman).
Novikov, I., and Thorne, K. S. 1973, in *Black Holes*, ed. C. DeWitt and B. S. DeWitt (New York: Gordon & Breach).
O'Dell, S. L. 1986, *Pub. A. S. P.*, **98**, 140.
O'Dell, S. L., Scott, H. A., and Stein, W. A. 1987, *Ap. J.*, **313**, 164.
Pacharintanakul, P., and Katz, J. I. 1980, *Ap. J.*, **238**, 985.
Pringle, J. E., and Rees, M. J. 1972, *Astr. Ap.*, **21**, 1.
Shakura, N. I., and Sunyaev, R. A. 1973, *Astr. Ap.*, **24**, 337.
Shakura, N. I., and Sunyaev, R. A. 1976, *M.N.R.A.S.*, **175**, 613.
Shields, G. 1978, *Nature*, **272**, 706.
Wandel, A., and Petrosian, V. 1988, *Ap. J. (Letters)*, **329**, L11.