SUPERCRITICAL ACCRETION AND ITS POSSIBLE RELATION TO QUASARS AND RADIO SOURCES

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This paper reviews some of the properties of supercritical accretion which make it a possible model for the quasar optical central source and for producing the jet in radio sources. Some of the problems with this scenario can be remedied with alternative, but related, models.

The model supposes that material is accreting at a rate $\dot{M}$ onto a black hole of mass $M_8=M/10^8\ M_\odot$ with energy conversion efficiency ε and is producing luminosity $L=\varepsilon\dot{M}c^2$. "Standard" accretion theory is assumed: 1) a substantial fraction of L is converted into heat and radiated thermally and 2) the ratio of the free-fall time to the heating time $\alpha < 1$ (Shakura and Sunyaev 1973, hereinafter SS). (If magnetic dynamos and reconnection participate in the heating, then a limit on the field strength can be found by noting that the ratio of magnetic to total energy density $\alpha_m < \alpha$ [SS].) In order for ε to be a substantial fraction, the infall velocity must be small ($\sim \alpha$ times the free-fall speed) as would occur in a disk or in a spherical distribution of occasionally-colliding clouds orbiting the hole. Supercritical accretion occurs when the outward radiation pressure at a radius r due to electron scattering ($\kappa_{es}L/4\pi r^2c$) exceeds that of gravity (GM/r^2), i.e. when $\dot{M}$ exceeds $\dot{M}_{cr} \equiv 4\pi GM/\kappa_{es}c\varepsilon = 0.22\ \varepsilon^{-1}\ M_8\ M_\odot yr^{-1}$, where $\kappa_{es}=\sigma_T\ m_p^{-1}$ is the electron scattering opacity. Some or most of the accreting matter is expected to be driven away from the black hole when $\dot{m} \equiv \dot{M}/\dot{M}_{cr} > 1$.

The new result we note is that standard accretion theory cannot reproduce the optical spectrum of a quasar <u>unless</u> the accretion is nearly critical or supercritical. It is well-known that quasars have "non-thermal", steep optical spectra, often suggested to be synchrotron emission, with a low energy cut-off of 10^{14} Hz (3μ) or less. This cannot occur unless the emitting region is optically thin to both free-free and synchrotron self-absorption down to this frequency. Figures 1 and 2, however, show that optical thinness of the accreting material occurs only for a limited range of α, $\dot{m}$, and M. (Calculations are taken from SS for $\dot{m} < 1$ and Meier 1981 for $\dot{m} > 1$. For $\dot{m} \ll 1$ optical thickness to free-free is a density effect and for $\dot{m} \gg 1$ it is due to the large <u>geometrical</u> thickness of the disk. Optically thinness to synchrotron

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occurs only when the disk is geometrically large, i.e. $\dot{m}$ or M large.) We conclude that necessary (but not sufficient) conditions to fit quasar spectra are rapid heating ($\alpha \sim 1$), nearly critical accretion ($\dot{m} > 0.1$), and a supermassive black hole ($M > 10^{5-6} M_{\odot}$).

FIGURE 1

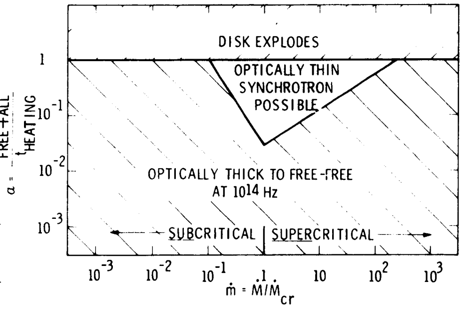
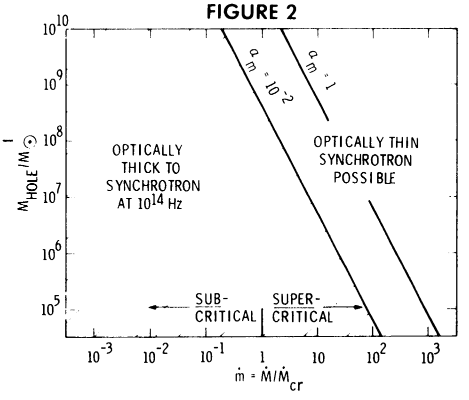


FIGURE 2



Other properties make supercritical accretion an interesting model (see Meier 1981 for details). If the optical emission is synchrotron, the lack of polarization must be explained (see, e.g., R. Moore in this symposium). The moderate optical depths to electron scattering expected here ($\tau_{es} \sim 1\text{-}10$) provide a natural de-polarization mechanism. In addition, if $\alpha \sim 1$, X-rays are produced and, if $\dot{m} > 1$ also, the ejected wind has velocities up to 0.3c, similar to quasar broad absorption and emission line widths. Finally, the geometrically thick supercritical disk has evacuated funnels along the rotation axis and hence the symmetry for collimating jets (see Abramowicz and Piran 1980, Begelman and Meier 1981, and reviews in this volume by Thorne, Rees, and Shklovsky).

One problem with this model is that constant velocity outflow does not fit the quasar absorption or emission line profiles. However, the model may provide the wind needed in the Scott, Christiansen, Weymann, and Schiano (1981) ablated cloud model for the broad absorption profiles. Another problem is that low luminosity ($< 10^{43}$ erg s^{-1}) objects with no strong optical component (e.g., Cen A, M 87) still seem to be ejecting jets. This implies that either jets can be ejected even when the accretion is subcritical or that their hole masses are below $10^5\ M_{\odot}$. Disks thickened by gas, rather than radiation, pressure are a possible mechanism for producing subcritical jets (see Rees, this volume).

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