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NUMERICAL SIMULATIONS OF ADVECTIVE ACCRETION DISKS AROUND BLACK HOLES

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Radial velocity of accretion flow approaches the velocity of light on the horizon of a black hole. Thus a black hole accretion is necessarily supersonic and therefore sub-Keplerian close to the horizon. Hence, independent of heating and cooling processes, a black hole accretion must deviate from a standard Keplerian disk. These disks are called the advective disks (Chakrabarti, 1996a). We present here the results of numerical simulations of all possible types of such disks.

Two parameter (specific energy $\mathcal{E}$ and specific angular momentum λ) space of 1D flow can be classified (Chakrabarti, 1989; Chakrabarti & Ryu, 1996) in 'SA' (shocks in accretion), 'SW' (shocks in winds), 'NSA' (no shocks in accretion), 'NSW' (no shocks in winds), 'I' (inner sonic point only), 'O' (outer sonic point only)and 'I*' and 'O*' (incomplete flows through inner and outer sonic points). See Fig. 1a. The region N has no solution. Fig. 1b shows examples of solutions (Molteni, Ryu & Chakrabarti, 1996; Eggum, in preparation) from 'SA', 'I' and 'O' regions where we superpose analytical (solid) and numerical simulations (short dashed curve is with SPH code and medium dashed curve is with TVD code; very long dashed curve is with explicit/implicit code). The agreement is excellent.

In presence of cooling effects, shocks from 'SA' oscillate (Fig. 2a) when the cooling timescale roughly agrees with postshock infall time scale (Molteni, Sponholz & Chakrabarti, 1996). The solid, long dashed and short dashed curves are drawn for $T^{1/2}$ (bremsstrahlung), $T^{0.4}$ and $T^{0.75}$ cooling laws respectively. In the absence of steady shock solutions, shocks for parameters from 'NSA' oscillate (Fig. 2b) even in the absence of viscosity (Ryu, Chakrabarti & Molteni, 1997).

The oscillation frequency and amplitude roughly agree with those of quasi-periodic oscillation of black hole candidates. When the flow starts from a cool Keplerian disk flow simply becomes sub-Keplerian before it enters through the horizon. Fig. 3a shows this behaviour where the ratio of $\lambda/\lambda_{Keplerian}$ is plotted. When the flow deviates from a hot Keplerian disk, it may develop a standing shock (Fig. 3b) (Molteni et al. 1997).

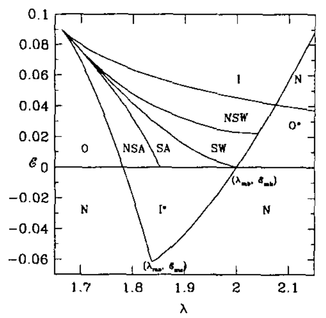

Fig. 1a.

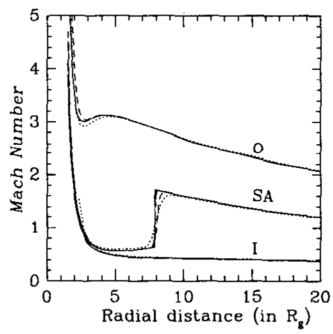

Fig. 1b.

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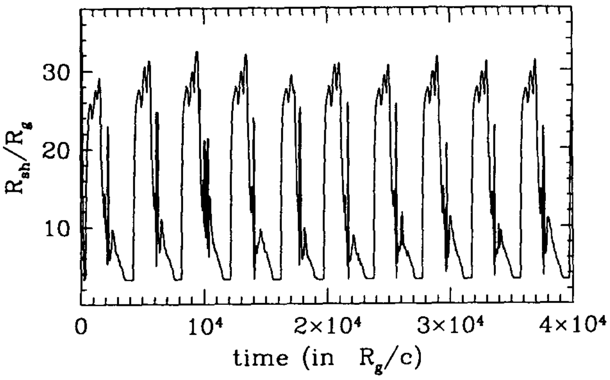

Fig. 2a.

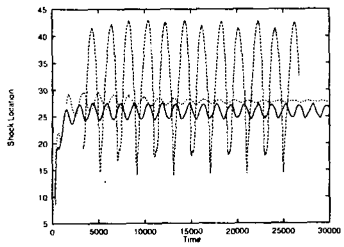

Fig. 2b.

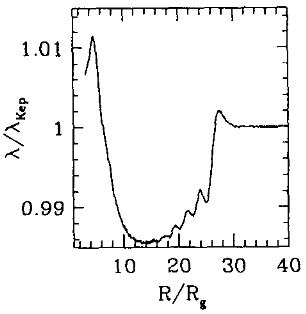

Fig. 3a.

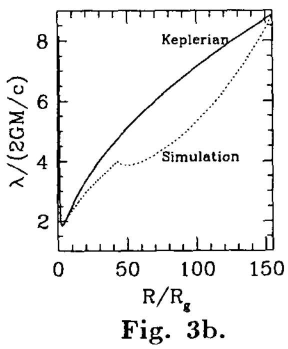

Fig. 3b.