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On Shock Conditions in Black-Hole Accretion[1]

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Abstract. We study the effects of different shock conditions upon shock properties, such as their location and strength. We find that it is very important to include the effects of radiative energy loss in the shock front.

Accretion flows onto black holes must be transonic. Due to general relativistic effects, there can exist more than one sonic point for the flow. In this case, shocks may form. Shocks change the basic temperature structure of the accretion disk and may be responsible for many astrophysical phenomena observed in active galactic nuclei, such as soft X-ray production and time variability.

Almost all authors who have studied shocks in accretion flows have adopted one of the two kinds of approximations to the flow: adiabatic or isothermal. In the adiabatic case, besides mass-flux and momentum-flux conservation and the constraint that the flow must pass through both the inner and the outer sonic points, one usually selects energy-flux conservation as the last shock condition. However the width of a realistic shock front does not equal zero, so energy loss must occur from the upper and the lower surfaces of the shock to the surrounding medium. Thus energy flux must not be conserved and it should somewhat decrease. So instead of using $[T^{tr}]_+ = [T^{tr}]_-$, in the present paper we introduce a phenomenological expression

$$[T^{tr}]_+ = f[T^{tr}]_-. \tag{1}$$

Here T^{tr} is the tr component of the energy-momentum tensor $T^{\mu\nu}$ and $f \leq 1$. The subscripts '$-$' and '$+$' denote the values before and after the shock, respectively. In the isothermal case, the generally adopted shock condition is temperature invariance. This is not realistic either; the temperature of the flow should rise somewhat after the shock, so we use

$$b_+^2 = g b_-^2 \tag{2}$$

to replace the generally adopted condition, $b_+^2 = b_-^2$, where b is the sound speed and $g \geq 1$.

Figures 1a and 1b show the variation of the shock's location and strength with different values of f in the adiabatic case, respectively, where the parameters used are (a) the specific total energy $E = 1.0005$, and (b) the specific angular momentum $l = 3.7576$. Figures 2a and 2b show the variation of the

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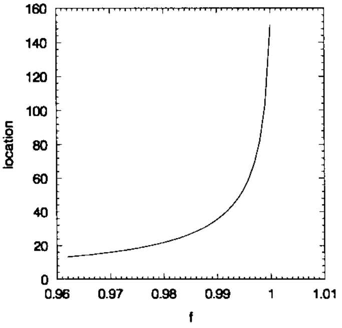

Fig.1a

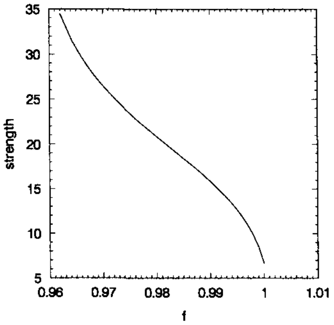

Fig.1b

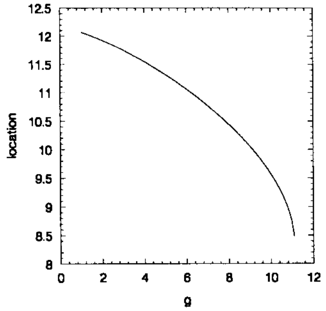

Fig.2a

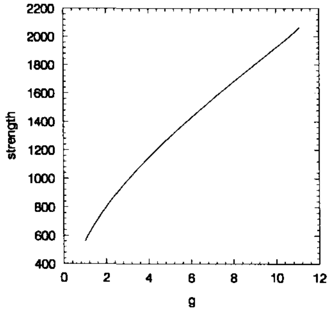

Fig.2b

shock's location and strength with different values of g in the isothermal case, respectively, where the parameters used are (a) the square of the sound speed $b^2 = 0.0001666$ and (b) the specific angular momentum $l = 3.7576$. In the Figures, the shock's location is in units of the black-hole mass ($G = c = 1$), and the shock's strength is defined as the ratio of the Mach number before the shock to that after the shock. From these figures, we can obviously see the influence of different shock conditions upon the results.