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Shocks in two-temperature advective accretion flow around black holes

I. K. Dihingia[1]*, S. Das[1] and S. Mandal[2]
[1]*Indian Institute of Technology Guwahati, Guwahati, India*
[2]*Indian Institute of Space Science and Technology, Thiruvananthapuram, India*

Abstract. We study a two-temperature, viscous accretion flow around the Schwarzschild black hole. We obtain global transonic accretion solutions (GTAS) that include stationary shock waves considering various radiative cooling mechanisms, namely Bremsstrahlung, Synchrotron and Compton cooling processes, respectively. We observe that GTAS severely depends on the cooling efficiencies as the dynamics of the dissipative accreting matter is governed by the accretion rate ($\dot{m}$, in Eddington unit).

Keywords : accretion, accretion disc – black hole physics – shock waves

1. Introduction

Accretion process on to a black hole seems to be a useful mechanism to produce high energy radiation. In particular, it successfully explains the spectral state transitions and the outflow activities which are commonly observed for black hole sources (Frank et al. 2002). In an accretion disc, when matter accretes on to a black hole, if the ion-electron collision timescale becomes larger than the infall timescale, the disc fail to sustain a single temperature throughout the disc, instead a two-temperature disc is formed. Earlier, Eardley et al. (1975); Shapiro et al. (1976) constructed a two-temperature disc model to explain the observed spectrum from Cygnus X-1. Recently, Mandal and Chakrabarti (2005) adopted a two-temperature accretion disk model and studied the spectral properties of a stationary black hole considering shock location in a parametric way. In this work, for the first time, we self-consistently calculate the global shocked accretion solutions of a dissipative flow around a stationary black hole.

2. Result and Discussion

We present two shocked accretion solutions for flows having viscosity $\alpha = 0.01$ and accretion rate $\dot{m} = 0.01$ and $\dot{m} = 0.006$. To obtain these solutions, we inject matter

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*email: `i.dihingia@iitg.ernet.in`

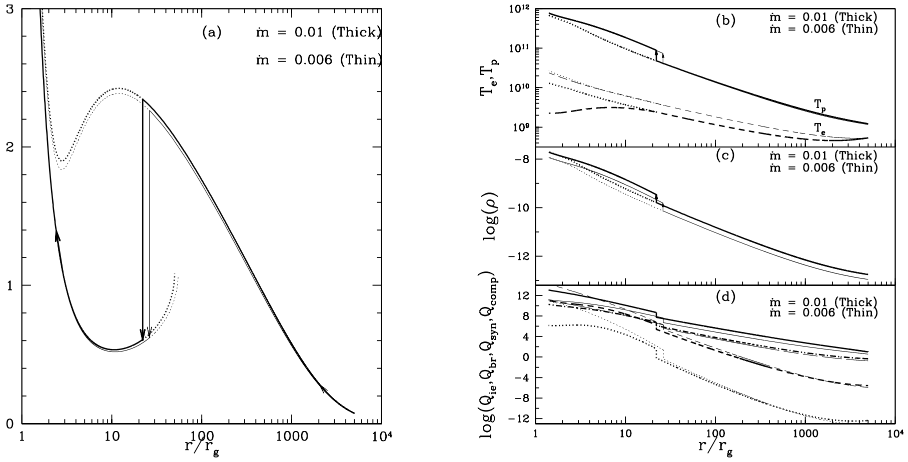

Figure 1. Variation of (a) Mach number, $M = v/a$ (v and a are flow velocity and sound speed), (b) Electron temperature (T_e) and proton temperature (T_p), (c) density (ρ) and (d) Coulomb coupling $\mathrm{Q_{ie}}$ (solid), Bremsstrahlung cooling $\mathrm{Q_{br}}$ (dot-dashed), Synchrotron cooling $\mathrm{Q_{syn}}$ (dashed), and Compton cooling $\mathrm{Q_{comp}}$ (dotted) with radial distance r. Here, thin and thick curves are for $\dot{m} = 0.006$ and 0.01, respectively.

from the outer edge of the disc at $r^{\rm edge} = 5000r_g$ (r_g is the Schwarzschild radius), with angular momentum $\lambda^{\rm edge} = 8.223$, and electron temperature $T_e^{\rm edge} = 5.365{\times}10^8 K$. For $\dot{m} = 0.006$, shock forms at $26.24r_g$. When accretion rate is increased as $\dot{m} = 0.01$, the shock front proceeds towards the black hole at $22.06r_g$ (see Fig. 1a). This is due to the fact that when $\dot{m}$ is increased, post-shock pressure decreases because of the increase of cooling efficiency and therefore, shock has to move forward while maintaining the pressure balance across it. Since the post-shock matter is hot and dense compared to the pre-shock flow (see Fig. 1b-c), high energy radiations are mainly produced from the inner part of the disc. On the other hand, pre-shock matter is responsible to produce relatively soft-radiations. Solutions of these kind are very much promising in order to explain the spectral states of the black hole candidates. Discussion on such issue is beyond the scope of this paper and will be reported elsewhere.

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