Recent Trends in the Study of Compact Objects (RETCO-II): Theory and Observation
ASI Conference Series, 2015, Vol. 12, pp 91–92
Edited by Indranil Chattopadhyay, Anuj Nandi, Santabrata Das and Samir Mandal

Shocks in magnetically supported accretion flow around black holes

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Abstract. We investigate a single-temperature, magnetized accretion disk around a Schwarzschild black hole. The global transonic accretion solutions including Rankine-Hugoniot (RH) shocks are studied in the presence of synchrotron cooling. We study the shock properties in terms of plasma β ($= p_{gas}/p_{mag}$, where p_{gas} and p_{mag} represent the gas pressure and magnetic pressure) at the outer edge of the disk (β_{edge}) and accretion rate ($\dot{m}$, in Eddington unit).

Keywords : accretion, accretion discs — black hole physics — hydrodynamics — (magneto-hydrodynamics) MHD — shock waves

1. Introduction

Magnetic fields are ubiquitous in the astrophysical environment that play an important role in accretion disks. Following an approach similar to Oda et al. (2007), we investigate a single-temperature, magneto-fluid model for accretion disk around a Schwarzschild black hole. We consider synchrotron cooling mechanism as energy dissipation process following Shapiro and Teukolsky (1983). The sonic point analysis and RH shock conditions are employed following the treatment of Das S. (2007); Sarkar et al. (2015). In this work, we use $2G = M_{BH} = c = 1$, where G, M_{BH} and c are the gravitational constant, mass of the black hole and speed of light, respectively.

2. Results and Discussion

Fig. 1 (a) shows the plot of Mach number with logarithmic radial distance when flows are injected at the outer edge ($x_{edge} = 1000$) with angular momentum $\lambda_{edge} = 2.4113$,

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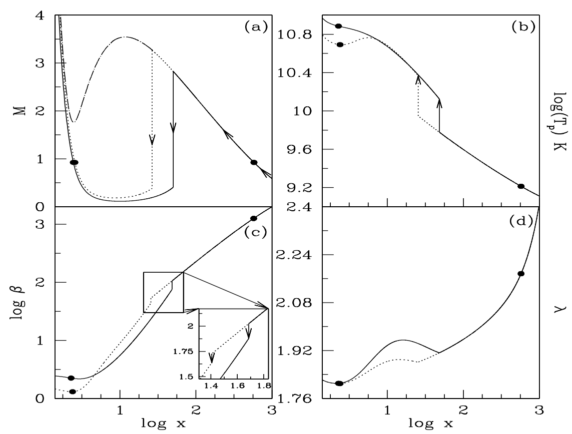

Figure 1. Variation of various flow variables with radial distance along with shock solutions in the cooling and cooling free limits. See text for details.

$\beta_{edge} = 2000$ and $\alpha_B = 0.02$ (ratio of Maxwell stress and the total pressure). The vertical arrows indicate the shock transition. The solid curve shows the shock solution in the absence of cooling and the shock is formed at $x_s = 48.47$. When the cooling is turned on, the shock moves forward for accretion rate $\dot{m} = 0.0151$ and forms at $x_s = 25.49$ as shown by the dotted curve. Cooling effectively reduces the post-shock pressure and thus the shock moves closer to the black hole to maintain pressure balance. Panels (b), (c) and (d) in Fig. 1 represent the variation of proton temperature $\log(T_p)$, $\log(\beta)$ and angular momentum λ respectively with logarithmic radial distance corresponding to the shock solutions as in Fig. (1a). When cooling is included, the temperature profile is reduced in the post-shock region as in panel (b). The plasma β profile in panel (c) shows a decreasing trend as the flow is accreted towards the black hole. β value drops during the shock transition resulting the post-shock region more magnetically dominated. In addition, cooling makes the inner part of the disk magnetically more dominated as compared to cooling free case. Cooling affects the β profile and consequently the angular momentum distribution is also affected as shown in panel (d). Hence, we conclude that the plasma β parameter seems to play an important role in deciding the shock dynamics.

References

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