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Shocks in Winds from Accretion Discs and the formation of high energy particles

I. Chattopadhyay & S. K. Chakrabarti

S. N. Bose National Centre for Basic Sciences, Kolkata- 700098, India.

Abstract. We study effects of radiation momentum deposition on jets and outflows from the disks and show that if disks are perturbed, jets could have propagating shock waves which may accelerate particles to observed slopes.

Key words: Astrophysical Jets, Shocks, Synchrotron Radiation

1. Introduction

Astrophysical Jets are assosciated with compact objects (Bridle & Perley, 1984) and are originated from the disc. Matter falling onto a black hole is slowed down by centrifugal pressure occasionally forming a standing or oscillating shock. Hot post-shock flow is puffed up in the form of a torus commonly known as CENBOL (i.e. Centrifugal pressure supported Boundary Layer). Chakrabarti and Titarchuk in 1995 and later Chakrabarti (1997) showed that hard X-rays are emitted by this CENBOL is the source of the hard radiation Recently, Chakrabarti (1999), Das & Chakrabarti (1999), Das et al. (2001) showed that CENBOL can be the base of the outflow. Chattopadhyay & Chakrabarti (2000a, 2000b) showed that momentum deposited by the hot photons from CENBOL onto the outflow results in supersonic jets. Here we study the effect, such as particle acceleration (Blandford, 1990) of shock propagation in these supersonic jets. We also compute the slope of the emitted synchrotron radiation from these accelerated electrons.

2. Method and Results

The photon momentum deposition force (RAMOD ≡Radiation Momentum Deposition force) is calculated by considering the inflow/outflow geometry (cf. Fig. 1 and Eq. 2 of Chattopadhyay & Chakrabarti, 2000c). Figure 1 shows the vector force field of the RAMOD ($\propto 10\dot{M}_{acc}$ where $\dot{M}_{acc} \equiv$ accretion rate). The length of each vector is proportional to the magnitude of RAMOD.

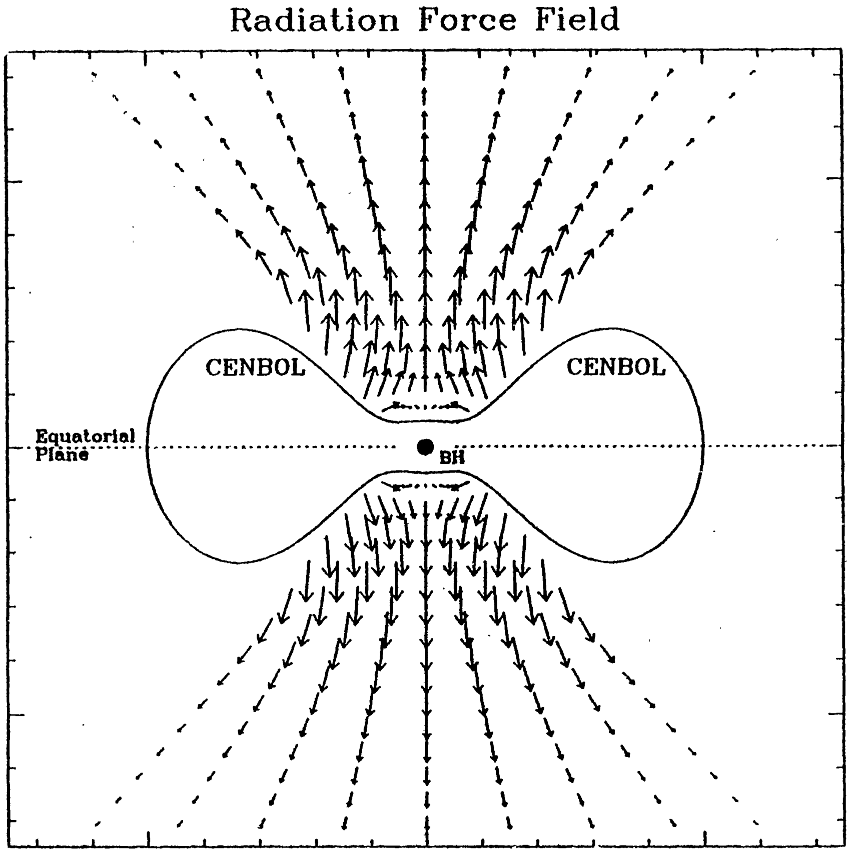

Figure 1. Vector Field for RAMOD. Only the inner part of the disc is shown.

We obtain the solution incorporating RAMOD into the momentum balance equation. Unlike our earlier work, here we solve the time dependent problem using Smooth Particle Hydrodynamics (SPH for brevity. See, Molteni et al. 1998 and references therein). SPH is a 'Lagrangean method'. Difficulties which arise in general in Lagrangean methods for processes more than one spatial dimension is overcome by computing spatial derivatives through interpolation over neighbouring points. Hence basically SPH is an 'interpolation method', where the interpolation points are called 'particles' and are allowed to evolve in time under the influence of governing equations. Figure 2 shows the velocity field of jets coming out of the torus like CENBOL. One can see that close to the horizon though the fluid particles are ejected towards positive z-axis still strong gravity of the black hole sucks in a part of the jets.

We inject perturbations into code. To simulate the effect of flares we randomly increase the initial temperature and let them evolve in time. These perturbations are seen to form propagating shock waves (see Figure 3). We also find the shock front gets

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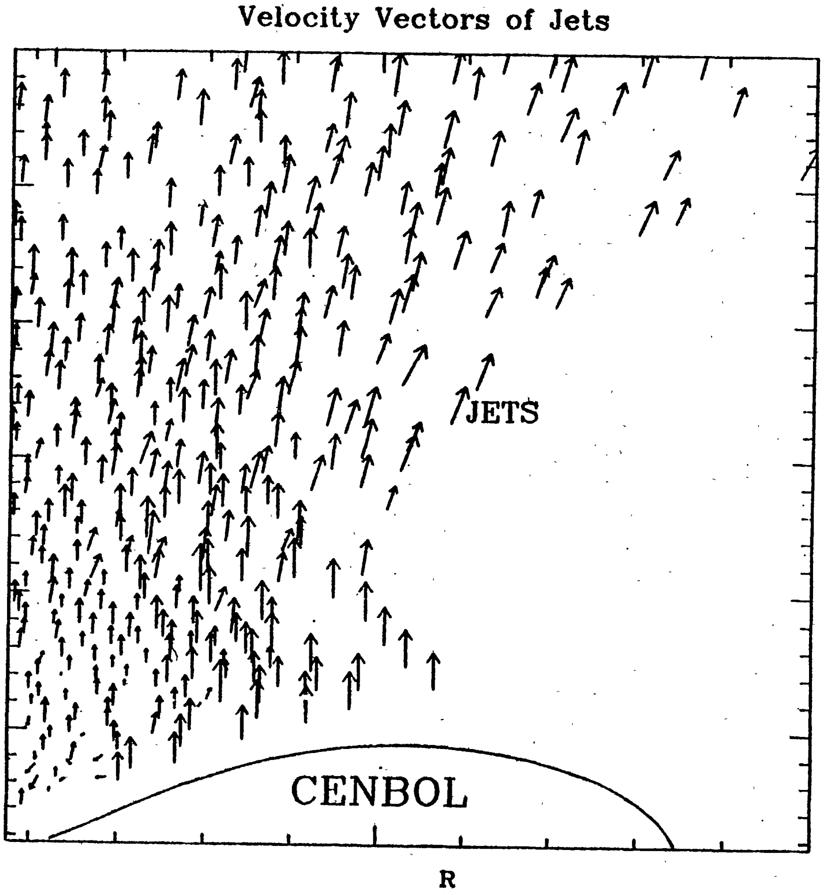

Figure 2. Jets and Inner part of the Accretion disc (CENBOL). The arrows are the velocity vectors.

diffused with time. The transmitted electron distribution function would be a power law in momentum (e.g. Blandford, 1990): $f(p) \propto p^{-s}$. Which depends solely upon the shock compression ratio (R), where, $s = 3R/(R-1)$. The volume spectral emissivity j_ν of synchrotron emission by power-law electron distribution is given by: $j_\nu \propto \nu^{-\alpha}$, where, $\alpha = \frac{s-1}{2}$. The computed compression ratio varies between 2.5 to 1.7, therefore corresponding spectral index for synchrotron radiation varies between 2 to 3.

3. Conclusion

Radiative acceleration of outflows produces supersonic jets. Random perturbations produce multiple non-stationary shocks in jets. The shock gets diffused as it travels the compression ratio varies between 2.5 to 1.7. Power law distribution of the shock accelerated electrons, produces a power-law synchrotron emission whose spectral index depends on compression ratio of the shock and in our case the spectral index varies between 2 to 3.

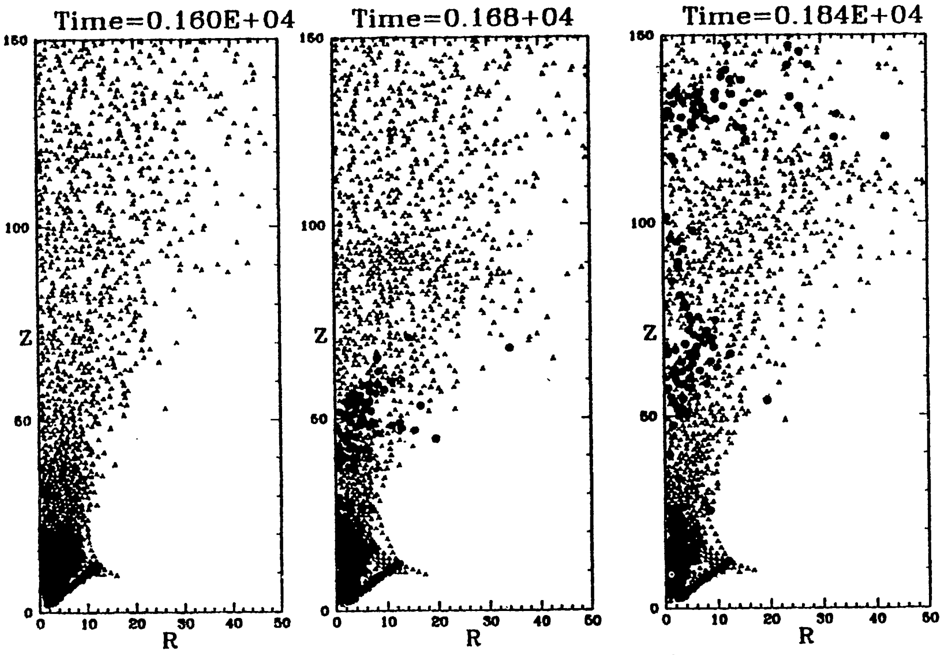

Figure 3. Non-stationary Shock Propagation in Jets. Solid dots represents subsonic particles and skeletal dots represents supersonic particles. Three time steps are shown to represent a moving shock front.

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