TRANSPORT OF RADIATION & ENERGETIC PARTICLES IN ACCRETION FLOWS*

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ABSTRACT. The equations describing the transport of suprathermal charged particles and electromagnetic radiation across accretion flows onto compact objects are solved analytically, including the effect of shocks in the flows. These solutions indicate (a) accretion flows with shocks accelerate particles very efficiently upto ultra-relativistic energies. (b) the emergent spectra of electromagnetic radiation from such flows reproduce the observed spectra of quasars from the infrared to the hard X-ray region.

1. MATHEMATICAL FORMALISM

We consider an idealised spherically symmetric supersonic accretion flow with a shock transition at $r=r_s$. Parametrising the velocity at $r>r_s$ as $V=-V_o(r/r_s)^{-\alpha}$ and the diffusion constant $\kappa_{rr}=\kappa_o(r/r_s)^{\beta} \times (p/p_o)^{\gamma}$, the transport equation for the distribution function of energetic particles (and quanta reads)

$$-\kappa_o\left(\frac{p}{p_o}\right)^{\gamma}\frac{1}{r^2}\frac{\partial}{\partial r}\left[r^2\left(\frac{r}{r_s}\right)^{\beta}\frac{\partial f}{\partial r}\right]-V_o\left(\frac{r}{r_s}\right)^{-\alpha}\frac{\partial f}{\partial r}+\frac{1}{3}V_o\frac{1}{r^2}\frac{\partial}{\partial r}\left[r^2\left(\frac{r}{r_s}\right)^{-\alpha}\right]p\frac{\partial f}{\partial p}=0.$$

Defining σ through $V(r=r_s-\varepsilon) = V_o(1-3\sigma^{-1})$, the boundary conditions at $r=r_s$ may be written as

$$-\kappa_o\left(\frac{p}{p_o}\right)^{\gamma}\frac{\partial f}{\partial r}+\kappa_-(r_s,p)\frac{\partial f_-}{\partial r}+\frac{V_o}{\sigma}p\frac{\partial f}{\partial p}=N(4\pi p_o r_s)^{-2}\delta(p-p_o),\quad f(r_s,p)=f_-(r_s,p),$$

where N is the total number of particles injected per second, and $\kappa_-(r,p)$ and $f_-(r,p)$ are the downstream diffusion coefficient and distribution function, respectively. Analytic solutions for $\alpha+\beta=1$ and for

* Discussion on p.424

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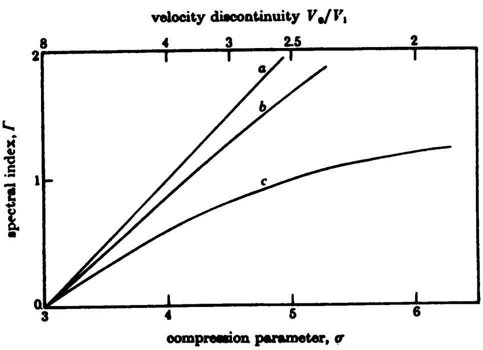
$\alpha+\beta=2$ (applicable to photons) are obtained; these exibit power law behaviour $f \approx p^{\Gamma}$. With $\eta= r_s V_o/\kappa_o$

Γparticle $= \alpha\{1+(1+\beta)\eta^{-1}\}, (\alpha+\beta)=1$; Γphotons $=\sigma\{1-2\beta\, \eta^{-1}(\frac{1}{3}\sigma-1)\}, (\alpha+\beta)=2$

The observed radiated power will have an index $\Gamma_i=\Gamma_{ph}+3$. These are shown in figs.1,2.



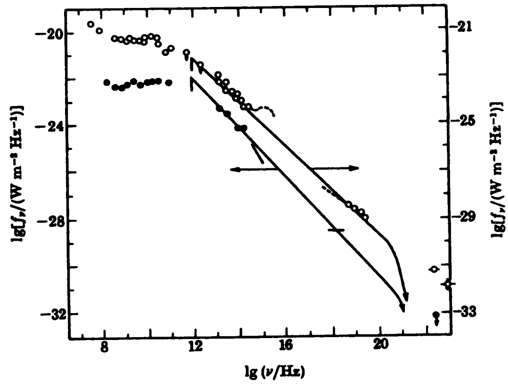


Fig.1. Γ_{ph} from IR to hard x-rays Typical η=20-100, σ=4-5 (a) $\eta=\infty$ (b) η=30 (c) η=10.

Fig.2. Fits to 2 quasars (1)3C120 (●) (2)3C272 (0). Γ_1=0.97, η_1=30, σ_1=4.05; Γ_2=1.07, η_2=30, σ_2=4.22.

Comparison between planar and accretion shocks under astrophysical conditions

Planer Shocks	Accretion Shocks
1) Shock dissipates its energy.	Shock is continuously supplied with energy by the accretion flow.
2) Particle acceleration occurs only at the shock	Particle acceleration every where since ∇.V. is negative.
3) Acceleration rather inefficient since only particles crossing the shock front are accelerated.	Particles are convected into the shock and are accelerated efficiently.
4) Source of injection of superthermal particles & photons at the shock not clear.	Strong post shock turbulence can be a good injector.

Also, it is instructive to compare the spectral index, Γ obtained by us (R.Cowsik and M.A.Lee, Proc. Roy. Soc. Lond. A383, 409, 1982) with that obtained by Payne and Blandford (MNRAS, 194, 1033, 1981) without any shock in the flow: $\Gamma = -3\beta^{-1}(1+\beta)$. The hardest spectrum they get is for $\beta = 2$ ($\Gamma = 9/2$) and for free-fall $\beta= 3/2$, $\Gamma = 5$. Both these spectra are too steep to reproduce the spectra of quasars. One may conclude shocks are important in giving the requisite hardness to the emergent spectra.

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