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GRO: Black Hole Models for Gamma-Ray Bursts

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"Black Hole Models for Gamma-Ray Bursts"

Jacob Shaham, Principal Investigator

The Burst and Transient Source Experiment (BATSE) on board the Compton Gamma Ray Observatory (CGRO) has established that the distribution of gamma ray bursts (GRBs) is isotropic but bound in the radial direction (Meegan et al. 1992). This finding suggests that GRBs are either cosmological (see Hartmann 1993; Paczynski 1994 for an overview) and/or that they originate in an extended halo of our Milky Way Galaxy (e.g., Eichler and Silk 1992; Hartman 1992; Li and Dermer 1992). The implied luminosities and the observed variability of the GRBs on time scales as short as one millisecond suggest that they originate on a compact object. We are currently investigating the possibility of creating GRBs from accretion flows on to black holes.

The mechanism of initial energy release in the form of a burst is not understood yet. We are trying to find out the typical time scales involved in this energy release and the initial distribution of photons as a function of energy. It is very likely that a realistic model will have to include the effects of the spacetime geaometry (in the case of Kerr black holes it is only axisymmetric) and the inhomogeniety in the photon density porduced by the effects of gravity. However as a first step we are formulating the problem in the Minkowski spacetime for a homgenious and isotropic burst. It would not be difficult to incorporate the effects due to the spacetime curvature later on.

However,quite independent of the above facts, Galactic halo sources must involve the formation of opaque electron-positron-photon plasma which is generally known as a fireball, as is the case with the cosmological GRB sources (Meszaros and Rees 1993; Meszaros et al., 1993; Narayan et al., 1992 for example). For these Galactic halo models, observed rise times and luminosites imply that, if they are in thermal equilibrium (which is not the case, as is evident from the non-thermal nature of the spectrum) then they would be optically thick to Compton scattering (which dominates over the pair production opacity) with an average optical depth of a few hundered. But it seems very likely that initially we will have many more high energy photons compared to Planck distribution and in that case pair opacity can not be neglected.

For an arbitrary initial distribution of photons, we are formulating the equations of relativistic kinetic theory for non-equilibrium plasmas (de Groot et al., 1980) which can take into accoun various particle creation and annihilation processes (such as pair production and annihilation reactions and bremsstrahlung and double Compton scattering etc.) and various scattering processes (Svensson 1982). We plan to consider, in our analysis, the finite medium radiative transfer effects as well. The resulting system is very complex to be handled analytically. Therefore we are planning to develop Monte carlo techiniques, to compute various quantities of interest, analogous to those developed by Ramaty and Meszaros (1981) and Zdziarsky (1980) etc.

We will first consider a homogeneous and isotropic non-equilibrium relativistic plasma which is confined to a sphere of a fixed radius R and has a given initial distribution of photons and particles which we characterize by some one parameter family of functions. In our model,involving Kerr black holes,the initial photon distribution could arise from Compton-Penrose process (Piran and Shaham,1977) in the accreting plasma near the Kerr horizon. We also include baryon concentration N_b in our calculation. We define a fictitious temperature T as the temperature of an equilibrium plasma which has the same energy density. We consider the range 25 $KeV \leq kT \leq 10\ MeV$ where k is the Boltzmann constant. This temperature range spans both Galactic and cosmological GRBs. For such a plasma we study the equilibrating and radiative processes to estimate the relaxation and cooling time scales and the emergent spectrum. We plan to study the influence of the baryon concentration on these quantities. Then we plan to do a similer analysis for a freely expanding plasma to understand the interplay between the expansion time scale and the previous ones and obtain the emergent spectrum. Finally we will consider the effects due to curvature of the black hole and try to couple our initial conditions to those existing near accreting black holes.

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