BRIGHT BURSTS AND THE GRB DISTANCE SCALE

J-L. ATTEIA
Centre d'Etude Spatiale des Rayonnements
BP 4346, 31029 Toulouse Cedex, France

Abstract. We discuss the use of selected characteristics of the burster population (e.g. the distribution of peak fluxes, or durations) to derive the GRB distance scale within the framework of cosmological models. The effects of the cosmological expansion on GRBs are briefly noted and it is shown that intrinsic GRB properties may strongly complicate the search for (and the interpretation of) purely cosmological effects. In this context, bright GRBs provide a sample of reference; they are almost free of cosmological influences and they have been studied for a long time. We also emphasize the need for a GRB distance indicator which could be used for individual events; several recent studies suggest that such a quantity may exist.

Key words: Gamma Ray Bursts

1. The GRB Number-Intensity Distribution

Following the first observations of BATSE (Meegan et al., 1992), it was proposed that cosmological sources could explain both the observed isotropy of GRBs on the sky and the apparent deficit of faint bursts. This paper discusses some of the difficulties related to the determination of the burster distance in the framework of cosmological models. Its scope is limited to review several critical issues but none is discussed in detail. The emphasis is put on the interplay between intrinsic burst properties and cosmological effects which makes difficult the interpretation of cosmological tests (e.g. Band, 1994).

In the cosmological paradigm, the GRB Number-Intensity distribution is the clue to their cosmological origin, and many authors proposed to use it to derive the distance to the sources (e.g. Mao and Paczyński, 1992; Piran, 1992; Wasserman, 1992; Fenimore et al., 1993; Wickramasinghe, 1993; Emslie and Horack, 1994; Mészáros and Mészáros, 1995). Integral Number-Intensity distribution of gamma-ray bursts observed by BATSE and PVO is displayed on Fig. 1 (Fenimore et al., 1993).

The bright end of the curve has the slope $-1.5$ expected for sources homogeneously distributed in a Euclidean space. Assuming that this is not a coincidence, this strengthens the geometrical interpretation of the GRB Number-Intensity distribution and demonstrates that nearby bursters are in a region of space where cosmological effects are negligible.

The faint end on the other hand, clearly shows a deficit of bursts. It should be noted that the rapid departure of the observed curve from the slope $-1.5$ restrains the width of the luminosity function of the bursts detected by BATSE (because the Number-Intensity distribution of bursters with a broad
range of luminosities is the average of many curves flattening at different intensities, and would exhibit a much softer transition from slope $-1.5$ to $-0.8$ than is actually observed).

The observations are well fit by a simple cosmological model ($\Lambda = 0$, $\Omega = 1$, no evolution) with the assumption that GRBs are standard candles with identical power law spectra. A simple model of this type allows the determination of the luminosity of the sources ($L_0$), of their spatial density ($N_0$), and of the redshift of the most distant bursters ($z_{max}$). In the case of the combined distribution of BATSE and PVO, Fenimore et al. (1993) find $L_0 = 6 \times 10^{50} \, h_{75}^{-2} \, \text{erg s}^{-1}$, $N_0 = 22 \, h_{75}^{3} \, \text{GRB Gpc}^{-3} \, \text{yr}^{-1}$ and $z_{max} = 0.8$. The average distance of the brightest sources is also provided by the model. This is an important parameter because bright bursts often have small error boxes which can be efficiently searched for quiescent counterparts.

Alternatively, it may be claimed that the GRB Number-Intensity distribution is dominated by their intrinsic luminosity function, all the sources being at approximately the same distance. The main difficulty with this interpretation is that the slope of the bright end of the curve is $-1.5$ just by chance.