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R. E. GRIFFITHS
H. GURSKY
D. A. SCHWARTZ
J. SCHWARZ

Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, Massachusetts 02138

H. BRADT
R. E. DOXSEY

Massachusetts Institute of Technology, Center for Space Research, Cambridge, Massachusetts 02139

P. A. CHARLES
J. R. THORSTENSEN

University of California, Space Sciences Laboratory, Berkeley, California 94720

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Interpretation of tails of X-ray bursts

ALCOCK AND HATCHETT[1] recently proposed that the tails of X-ray bursts[2,3] observed during burst decay (time scales typically tens of seconds) are due to the small-angle scattering of the original pulse of X rays on interstellar dust grains. To produce the desired tails, and obey constraints set by optical interstellar reddening data, their model uses grains with a typical size of $\sim 3\ \mu m$. Here we give four independent reasons which rule out their model (see also ref. 3).

(1) Bursts from one source in general are similar to one another[2,4]. However, a burst is sometimes detected with a tail much longer (already pointed out by Alcock and Hatchett) or shorter than is typical for that source. This has been observed for example in bursts from MXB1837+05 (SAS-3, unpublished data) and MXB1728−34 (ref. 5) where the minimum duration of the tails was a few seconds, the maximum ~ 100 s.

Because of the low interstellar reddening of the globular cluster NGC6624, Alcock and Hatchett conclude that the tails of the bursts from MXB1820−30 in this cluster cannot be explained by their model but are intrinsic to the source. Additional evidence for this conclusion is contained in a series of bursts from MXB1820−30, reported by Clark *et al.*[6]. The tails in the bursts became gradually shorter and the last few bursts showed hardly any tails at all. (The tail duration gradually decreased from ~ 25 s to < 10 s). Therefore, a large part of the tails in bursts from these sources must be intrinsic to the source.

(2) Different kinds of bursts are emitted by MXB1730−335 (Rapid Burster)[7]. Besides the Type I bursts, the Rapid Burster also emits Type II bursts, whose spectral evolution is very different in that the softening during burst decay is much less pronounced than in the Type I bursts[7,8]. If the mechanism proposed by Alcock and Hatchett were to explain the tails of the Type I bursts such softening tails should also be observed after these Type II bursts, but they are not.

(3) Furthermore, in spite of the large distance and interstellar reddening[15] of MXB1730–335 a superposition of 12 small Type II bursts by Ulmer *et al.*[16] shows that these bursts do not have tails longer than ~ 2s. This observation alone shows that the tails caused by interstellar scattering have a duration $\lesssim 2$s for the Rapid Burster.

(4) According to Alcock and Hatchett the optical depth τ_X for scattering of X rays on 3-μm grains has to be small. Hence, the energy observed in the tails of X-ray bursts is proportional to τ_X (see their equation (16)). We make the reasonable assumption that the distribution of the large grains follows that of the small ones (which are responsible for the interstellar reddening). Most of the heavy elements in the interstellar medium are probably locked up in grains[9]. Therefore, according to this model, one would expect a positive correlation between the relative strength of the burst tails and the interstellar absorption. The latter is commonly expressed in terms of the equivalent interstellar column density of hydrogen N_H. We tested this prediction by comparing the observed values of N_H, as obtained from fits to the burst spectra[4] with the ratio ε of the energy in the burst tails to the total burst energy. In those cases where optical evidence is available on the interstellar reddening (MXB1659−29; 1735−44 and the galactic centre burst sources)[10–12] good agreement exists with these N_H values, using a relationship between N_H and E_{B-V} (see refs 13 and 14). It is somewhat ambiguous to determine where the tails start, but this is of no consequence; the range of values of N_H is at least a factor of 10, and this is much larger than the uncertainties introduced by the above ambiguity.

There is no correlation between ε and N_H for the 10 burst sources studied previously[4]. The values of ε for the sources with $N_H \leq 10^{22}\ cm^{-2}$ range from 0.35 to 0.65. For sources with $N_H > 10^{23}\ cm^{-2}$, ε ranges from 0.3 to 0.5. These results clearly exclude that the tails are the result of grain scattering, because in that case we would expect values of ε to be approximately proportional to N_H.

It may be argued that, as dust particles approximately midway between the burst source and the observer dominate the scattering mechanism, this lack of correlation reveals local concentrations of dust around some of the burst sources. In that case the typical value of the 'non local' column density is $\lesssim 10^{22}\ cm^{-2}$, corresponding to interstellar extinction values of $\lesssim 4$ mag. According to Alcock and Hatchett this is insufficient to produce a significant observable effect.

The model of Alcock and Hatchett (although it may work at different time scales and lower intensity levels) does not account for the observed tails of X-ray bursts. These tails are predominantly intrinsic to the X-ray burst mechanism.

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JAN VAN PARADIJS
WALTER H. G. LEWIN

Department of Physics and Center for Space Research, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

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