MILLIMETRE OBSERVATIONS OF GAMMA-RAY BURSTS AT IRAM

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Abstract. Since 1997, and following our detection of the first mm afterglow, we have followed-up 70 GRBs, mainly with the IRAM's Plateau de Bure Interferometer, what can be considered as the IRAM Legacy GRB Sample. 66 events were observed at 3 mm, with 19 of them being detected (with another 3 having marginal detections). 32 GRBs were followed up at 1 mm, with 6 of them being detected. Redshifts for the GRB afterglows lie in the range $z = 0.03$ –8.3, with measured flux densities (at 3 mm) varying between 0.25 and 60 mJy (but usually < 1.5 mJy) with first observations taking place around 1–2 days after the GRB. Forward shock emission explains the observations with the exception of one particular case (GRB 090423 at $z = 8.2$) for which reverse shock emission is required.

1 Introduction

Since 1997, following our detection of the first millimeter (mm) afterglow (GRB 970508. Bremer *et al.* 1998) we are conducting pioneering mm observations

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of GRBs with the IRAM's Plateau de Bure Interferometer (PdBI) in the French Alps.

Observations at these wavelengths are most essential due to the following reasons: i) Negligible absorption effects (like gamma-rays), *i.e.* dark or ultra- high- z bursts can be detected; ii) The peak of the GRB synchrotron spectrum peaks in the mm range; iii) No self-absorption effects (as seen at lower-frequencies); iv) Negligible interstellar scintillation effects (as seen at lower-frequencies); v) The peak of the GRB afterglow emission takes hours-days to cross the mm band; vi) PdBI is the only Northern Hemisphere observatory nowadays that has the sensitivity high enough to detect the mm afterglow emission for a considerable number of events (and perhaps even for detecting the forward emission too in some cases); vii) A logistics advantage: the flexibility of PdBI due to the fact that is a service observatory (with no observers present at the time of executing their programs) makes it easy to reschedule a target of opportunity (ToO) program.

This work enlarges the IRAM sample previously discussed (de Ugarte Postigo *et al.* 2012) as it does include additional datasets and the details can be seen in Castro-Tirado *et al.* (2013).

2 Observations and results

We have mainly used the PdBI (Guilloteau *et al.* 1992), located at 2550 m a.s.l. in the Haute Alpes (France). It is the most sensitive observatory in the Northern Hemisphere operating at millimetre wavelengths (0.8, 1.2, 2 and 3 mm). In 1996 is started observations with 5 antennae, increasing to 6 as of 2002. New generation receivers were installed in 2007. In fact, the wideband correlator WIDEX, installed in 2010, has significantly increased the number of detections due to its superb sensitivity. Additional observations were carried out on a very few cases with the 30 m IRAM antenna at Pico Veleta (2920 m a.s.l.) in Sierra Nevada (Spain).

Following our 16 yr study of GRB afterglows, the main results are the following ones:

1. The number of follow-ups amounted to 70, with 19 detections of mm afterglows achieved at 3 mm, 6 detections at 1 mm, with 4 of the events being simultaneously detected at 1 and 3 mm.
2. Redshifts for the GRB afterglows lie in the range $z = 0.03$ – 8.3 , with measured flux densities (at 3 mm) varying between 0.25 and 60 mJy (but usually < 1.5 mJy) with first observations taking place around 1–2 days after the GRB. We have detected 2 (out of 3) GRBs at $z > 6$: GRB 050904 ($z = 6.3$) and 090423 ($z = 8.3$). On the lower redshift end, we have detected the low- z , faint GRB 090108 / SN 2008D ($z = 0.03$).
3. Amongst the long-duration class, we have detected four dark GRBs: GRB 051022 (associated with a $z = 0.809$ galaxy), GRB 090404 (whose galaxy is not properly identified), GRB 111215A (associated with a galaxy in the range $1.8 < z < 2.5$) and GRB 120624B.

Fig. 1. The observed light curves and upper limits for 64 events observed at 3 mm as described in this work, with 18 of detected (black circles, filled) and 45 undetected (grey upside down triangles, empty). GRB 070610 and GRB 110328A are excluded as they have a different physical origin.

3 Conclusions

Millimetre observations are a powerful tool for gaining a better understanding of the GRB physics, especially the highly extinguished events and very high redshift bursts. The 23 GRBs detected imply a 32% success rate (for this non-blind sample). Millimetre observations are not affected by high- z or extinction and usually can lead to sample the synchrotron peak in the spectrum as well as detecting the tail of the prompt emission and the forward shock in one case (GRB 090423 at $z = 8.3$).

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