GRB–SN CONNECTION IN SAO RAS OBSERVATIONS

A.S. Moskvitin¹, V.V. Sokolov¹, V.N. Komarova *et al.*¹

Abstract. We present the results of SAO RAS 6-m BTA spectral observations of GRBs and XRFs with the signs of SNe: GRB/XRF 060218 (SN 2006aj) and XRF 080109 (SN 2008D). The properties of these events are similar to those of usual core-collapse SNe without GRBs. Some spectral features in the cases of SN 2006aj and SN 2008D may be interpreted as hydrogen and helium traces. This supports an idea of presence of a relic envelope around the progenitor star and the shock break-out effects observed in X-rays, UV and optics.

1 GRB–SN

Work on the search of optical candidates of GRBs started in SAO RAS in 1993. The main aim of this program was to find objects associated with old (archive) bursts with small boxes of localization ($\sim 1 \text{ arcmin}^2$). Because of fast decay of the afterglow brightness and the presence of numerous objects in the error areas the first optical identification with the starforming galaxies was made only in 1997. The next year the GRB follow-up team in cooperation with the Spain team started observing GRB afterglows and their host galaxies (Sokolov 2011).

During recent few years an idea about connection between long-duration GRBs and core-collapse SNe (types Ib and Ic) was supported by numerous observations of such events (Hjorth & Bloom 2011). However, spectroscopically such an association was carried out only for nearby objects. Apparently, in the visible range this can be reliably done for events at redshifts up to $z \sim 0.5$, when the brightness of an SN (especially at maximum) will still dominate in the overall radiation. It would be interesting to compare properties of SNe with and without GRBs. Here the researchers are facing a problem: why some nearby GRBs are not associated with SNe (Della Valle *et al.* 2006)?

In SAO RAS we study the evolution of SNe associated with GRBs (and the XRFs), and also usual core-collapse SNe and usual long-duration GRBs without such a link.

¹ SAO RAS, Russia; e-mail: mosk@sao.ru; sokolov@sao.ru; vkom@sao.ru

Fig. 1. *Left pannel:* the spectra of GRB/XRF 060218 (SN 2006aj) obtained with the BTA since 2.55 ($V_{ph} = V_{HI} = V_{HeI} = 33\,000$ km/s) and 3.55 ($V_{ph} = 18\,000$ km/s; $V_{HI} = V_{HeI} = 24\,000$ km/s) days after the trigger. *Right pannel:* the spectra of XRF 080109 (SN 2008D) obtained with the BTA since 6.48 ($V_{ph} = V_{HeI} = 17\,000$ km/s; $V_{HI} = 23\,000$ km/s) and 27.62 ($V_{ph} = 8\,500$ km/s; $V_{HeI} = 10\,500$ km/s; $V_{HI} = 15\,000$ km/s) days after the trigger.

International photometrical and spectral monitoring of GRBs and SNe (in collaboration with India, USA, Turkey, Spain, etc.) is ongoing in SAO for many years. Follow-up of early phases of SNe and GRBs, explosion asymmetry, wide luminosity range, hosts, and very distant objects are the most interesting tasks for this programs (Moskvitin *et al.* 2010b). In the nearest future we plan to make polarimetrical observations too with the BTA/MANIA.

2 GRB 060218/SN 2006aj and XRF 080109/SN 2008D

One of the most interesting object was the burst GRB/XRF 060218 ($z = 0.1683$) with strong X-ray and UV components (dominating in the first hours) and supernova signs (SN 2006aj). These effects can be explained by interaction between SN shock and a stellar-wind envelope around a massive progenitor star (the “shock breakout” which is also visible at early stages of some SNe).

The object was observed with the BTA 2.55 and 3.55 days after the trigger. The spectra were modelled in the Sobolev approximation with the **SYNOW** code (Branch *et al.* 2003; Elmhamdi *et al.* 2006). The detected detail near $6200\text{ \AA}$ were interpreted as hydrogen line with high velocities: $33\,000$ km/s for the first epoch, and $24\,000$ km/s for the second one (left pannel of Fig. 1, and Sonbaş *et al.* 2008). This may be a sign of stellar-wind envelope around a massive progenitor star.

Another significant event observed at SAO RAS with the BTA was the X-ray flash XRF 080109 associated with SN 2008D. This object was also observed spectroscopically with the BTA. The spectra were modelled with the help of **SYNOW** code to interpret broad features, especially near $6200\text{ \AA}$, and to measure expansion velocities. It was shown that Si II can not fit this absorption because of limitation

Fig. 2. Comparison of properties of usual Ib SNe (Branch *et al.* 2002), SN 2006aj and SN 2008D: expansion velocities of pseudo-photosphere, Helium and Hydrogen.

by the heavier elements such as Fe II. However C II remains a candidate for interpretation of this line (right pannel of Fig. 1, and Moskvitin *et al.* 2010a).

The assumption about the presence of envelopes around progenitor stars is confirmed by agreement between velocities of lines interpreted as hydrogen and helium, and the empiric power-law velocity drop with time for envelopes of classic core-collapse supernovae (Fig. 2, and Branch *et al.* 2002). Detection of a P Cyg profile of the $H\beta$ line in the spectra of optical afterglows of GRBs can be a conclusive argument in favor of this hypothesis (Moskvitin *et al.* 2010a).

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References

- Branch, D., Benetti, S., Kasen, D., *et al.*, 2002, *ApJ*, 566, 1005
- Branch, D., Baron, E.A., & Jeffery, D. J., 2003, chapter in “Supernovae and Gamma-Ray Bursters”, ed. Kurt W. Weiler, *Lect. Notes Phys.* 598, 47 [[astro-ph/0111573](#)]
- Della Valle, M., Chincarini, G., Panagia, N., *et al.*, 2006, *Nature*, 444, 1050
- Elmhamdi, A., Danziger, I.J., Branch, D., *et al.*, 2006, *A&A*, 450, 305
- Hjorth, J., & Bloom, J.S., 2011, Chapter 9 in “Gamma-Ray Bursts”, *Cambridge Astrophysics Series* 51, ed. C. Kouveliotou, R.A.M.J. Wijers & S. Woosley (Cambridge University Press), p. 169 [[arXiv:1104.2274](#)]
- Moskvitin, A.S., Sonbaş, E., Sokolov, V.V., *et al.*, 2010, *Astrophys. Bull.*, 65, 132 [[arXiv:1004.2633](#)]
- Moskvitin, A.S., Fatkhullin, T.A., Sokolov, V.V., *et al.*, 2010, *Astrophys. Bull.*, 65, 230 [[arXiv:1008.0773](#)]
- Sokolov, V.V., 2011, submitted to *BASI* [[arXiv:1111.1406](#)]
- Sonbaş, E., Moskvitin, A.S., Fatkhullin, T.A., *et al.*, 2008, *Astrophys. Bull.*, 63, 228 [[arXiv:0805.2657](#)]