Optical Transients

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Abstract: We outline and discuss the recent results of optical searches for counterparts to gamma-ray burst sources as well as related problems.

1 Introduction

The searches for optical counterparts to GRB proceed in three directions, namely as searches for: (1) **Flashing counterparts** (Optical transients–OT; either real-time or archival), (2) **Fading counterparts** (OT; follow-up searches), and (3) **Quiet counterparts.** The general problem is, however, that the nature of and even the distance to GRB is unknown. Hence we actually do not know what are we looking for. This should be always taken into account during evaluation of data in all mentioned directions. Here we discuss the first two categories.

2 Searches for flashing counterparts

2.1 Archival searches

One important but not obvious assumption must be done in these analyses, namely that the GRB/OT are recurrent. Alternatively, we can estimate limits for luminosities and/or recurrencies. The recent situation in the field of archival searches (i.e. using archival astronomical plates) can be summarized as follows:

- Several very good candidates (and blue faint possible counterparts) have been detected with strong evidence for reality and light amplitudes $\gg 10^{m}$ (Hudec et al. 1994a,b, Vrba et al. 1994a,b).
- The recurrence, if any, is > 1 yr (in agreement with γ-ray data).
- Archival astronomical plates are advantageous for these searches, especially for monitoring of particular GRB positions. Up to 20 000 h of exposure are available for particular positions. This would be hardly possible with other methods, e.g. modern monitoring with electronic detectors would for the same fraction of monitoring time require about 34 yr (assuming 100 nights per year and 5 hours per night), i.e. almost the full active life of one astronomer.
- The two best studied OT seems to be very colored (Hudec et al. 1994a,b)

- Coincidence of OT with QSO has been found in one case, close to the GRB position (Vrba et al. 1994a,b). A question naturally arises, namely whether or not are (at least some) QSOs sources of OT, and whether are (at least some) GRB related? The problem is in (still) large sizes of GRB error boxes as well as in the high QSO average density. At least one QSO is expected to be located in typical error box.

2.2 Real-time searches

The simultaneous optical data for GRB are extremely important because no assumption for trigger recurrency and/or delayed emission is necessary in this case. Up to now, real-time optical data are available for ~ 50 GRB but mainly with very limited sensitivity ($< 3^m$ for 1-sec events) and response limited to red light only (> 400 nm). The previous and recent results in this direction can be summarized as follows:

- No optical emission (> 400 nm) above mag ~ 5 (1 sec duration assumed) or $Lg/Lo > 100\ldots300$ has been detected for **a few** GRB. The faintest limit (320) exists for GRB 830313 (Hudec, 1993).
- No optical emission (> 400 nm) above magnitudes 0 ...3 (1 sec duration assumed) or $Lg/Lo > 0.1\ldots10$ has been detected for **many** (~ 50) GRB. These limits have been obtained mainly at the Ondřejov Observatory on meteor sky patrol plates within the framework of *GRO*-related programs (e.g. Hudec 1993, Greiner et al. 1993, 1994, 1995 and Hudec et al. 1995a)
- One can speculate whether the non-detection of simultaneous optical emission is due to (i) absence of brighter optical emission, (ii) the delayed optical emission, or (iii) the optical emission dominates in blue (this would be in agreement with results from archival searches revealing at least two reliable optical flashing candidates with extremely colored light). However, the limits recently available are still too poor even for this speculation: optical accompanying emission with $Lg/Lo \sim 100$ would remain undetectable almost in all cases. However, it should be mentioned that the time delays between optical and gamma ray emission cannot be fully excluded regarding the lack of knowledge of related physical processes. Moreover, the recently suggested possible link between OT and QSOs, and perhaps even with GRB (Vrba et al. 1994a,b), if confirmed, would result in natural expectation of delays (already known for some processes inside of QSO's, e.g. Robson et al. 1993 and von Linde et al. 1993).

3 Follow-up searches, burst alert

This category of searches for optical GRB emission is strongly related with recent achievements in satellite programs such as *GRO-BATSE*, *BACODINE*, *COMPTEL*, etc. The newly operated *BACODINE* system distributes the GRB data to ground-based observers within 0.3 to 30 sec after events (Barthelmy et al. 1994b). The optical burst alert data go usually significantly deeper than real–time data mentioned in the previous section. The present situation can be summarized as follows:

- No optical emission (> 320 nm) has been detected at times ~ hrs to ~ days after GRB down to $15\ldots20^m$ (e.g. Barthelmy et al. 1994a, Boer et al. 1994, Castro-Tirado et al. 1994, Kippen et al. 1994, Krimm et al. 1994, and Hudec et al. 1995b).
- One of the main problems of theses searches is the relatively high background of (mainly unknown) variable stars at a rate of ≥ 1 for a typical GRB error box area provided with current programs (*BACODINE*, *BATSE*), which are of the order of several or even several tens of degrees (Hudec & Wenzel 1995).
- The detection of these (unknown) variable stars can be used as a measure of the reliability of the method used (Hudec & Wenzel 1995).
- The variable objects found in some GRB error boxes are probably not related to GRB events but are probably newly discovered variable stars. However, we have to analyse and to classify them to avoid any kind of possible misinterpretation of real candidates.
- More than one (and better $\gg 1$) frame/plate is necessary for each trigger to avoid misinterpretation of emulsion/CCD false triggers and for comparison.

4 Strategy for the future

4.1 Archival searches

One of the main problems of past archival searches was the relatively large size of investigated GRB error boxes resulting in the not quite negligible probability that the objects found inside are just a random coincidence. A much better situation is in the case of new IPN3 error boxes with areas of order of a few arcmin^2 in the best cases (Hurley et al. 1994). Another improvement in archival searches should be the use of plates from several plate collections to increase the amount of monitoring hours available for the particular position. Then fractions of the total monitoring time available for one GRB may reach up to 2 yr and/or even more, significantly increasing the probability that the related OT will be detected if there is measurable optical emission (as already mentioned, these analyses, however, require an assumption about trigger recurrency).

4.2 Real-time searches

There are almost no simultaneous optical data except those from the Ondřejov photographic network. A more sensitive all-sky or at least very wide-field patrol service is not available at the present. The *ETC* camera (Vanderspek et al. 1994) is more sensitive (magnitude limit 8.5 for 5-sec flashes) but with a limited FoV (0.75 sr). While the Ondřejov photographic patrol has monitored about 7 000 steradian-hours during the 2.5 yr period 1991–1993, the *ETC* has monitored only about 600 steradian-hours. A promising approach is to build a double CCD monitor with large FoV and significantly better limiting magnitude than currently available photographic programs, preferably as a network (Hudec & Soldán 1995).

4.3 Burst alert searches

Here only a few papers have been published so far and the majority of obtained data is still in evaluation. It seems however to be clear that simultaneous data and/or data taken immediately (i.e. within 1 hr) after the trigger are provided only by both photographic (e.g. Hudec 1993, Greiner et al. 1993, 1994, 1995 and Hudec et al. 1995a) and CCD (e.g. Vanderspek et al. 1994 and Krimm et al. 1994) patrol experiments so far. The minimal delay in burst alert searches with larger instruments is still 5 hr or even more. There are many reasons for such delays. Initially, the GRB data were becoming available with delays of order of ~ hrs but now they are available much faster. The *BACODINE* system (Barthelmy et al. 1994b) provides a very fast response. However, the optical burst alert data usually still have delays of order of hours or even more. One of the reasons is that the position of the trigger is unobservable at the time of the trigger (daytime or below the horizon) and the observers have to wait several hours. Another reason for delay is the presence of humans in the loop. Robotic telescopes with automated response to incoming information would significantly improve the delays between GRB and optical observations (see also Hudec & Soldán 1995).

In general, it is clear that more and better optical data are needed. Further, there is an obvious need for very sophisticated classification of detected triggers to exclude false events and to verify real OT.

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