

# GRB afterglow studies at the Nordic Optical Telescope\*

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**Abstract.** Using the 2.56-m Nordic Optical Telescope (NOT) on La Palma we have observed most of the known optical afterglows to gamma-ray bursts (GRBs). We here briefly report on the discoveries of the optical afterglows of two recent SAX GRBs (GRB 980519 and GRB 980613) and the detection of their host galaxies. GRB 980519 was bright upon discovery ( $R \approx 20$ ) and occurred in a faint ( $R \approx 26$ ) galaxy whereas GRB 980613 was faint upon discovery ( $R \approx 23$ ) but occurred in a bright galaxy ( $R \approx 23$ ). Both host galaxies may show signs of interaction. GRB 980519 led to the earliest reported optical identification to date. We describe our continued efforts to produce optical identifications soon after optical observations have begun.

**Key words:** cosmology: observations — gamma-rays: bursts

## 1. Introduction

The 2.56-m Nordic Optical Telescope located on La Palma is an almost ideal telescope for rapid response observations because of its good seeing, its flexibility and the constant availability of an optical imager. We have conducted a GRB ToO programme for several years and have imaged most known optical afterglows to gamma-ray bursts (GRBs). In May 1997 we obtained images of GRB 970508 3 hours after the BATSE trigger (Jaunsen et al. 1997) and later found the first evidence for a flattening of the power law decay of the light curve, indicative of the presence of a host galaxy (Pedersen et al. 1998). More recently, NOT has contributed to observations of GRB 980329 (Palazzi et al. 1998) and GRB 980703 (Castro-Tirado et al. 1999). In this contribution we describe our discoveries of two recent SAX GRBs, namely GRB 980519 and GRB 980613.

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\* Based on observations made with the Nordic Optical Telescope, operated on the island of La Palma jointly by Denmark, Finland, Iceland, Norway, and Sweden, in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias.

## 2. Discovery of optical afterglows

### 2.1. GRB 980519

The afterglow of GRB 980519 was discovered at NOT less than 9 hours after the burst occurred as a rapidly fading  $R \sim 19.5$  source that was not present in the Digital Sky Survey (Fig. 1). A GCN circular announcing the position of the optical transient (OT) (Jaunsen et al. 1998) was issued less than 6 hours after the first NOT images were obtained, making it the earliest reported GRB OT discovery to date (December 1998). We obtained a high-quality multi-colour lightcurve showing that the OT brightness decayed with a power-law exponent of  $\alpha = -2.0 \pm 0.1$ . An optical spectrum of the OT was also obtained. These results will be reported elsewhere.

### 2.2. GRB 980613

In the discovery image for the OT associated with GRB 980613 (Fig. 2), obtained 16.5 hours after the burst (Hjorth et al. 1998), the OT was 3.5 mag fainter ( $R \approx 23$ ) than that of GRB 980519. Consequently, very little is known about the spectral and decay properties of this system which was the faintest burst detected so far by SAX (Costa et al. 1998). However, the location of the OT/GRB led to the discovery of the host galaxy (Fig. 2) and its redshift,  $z = 1.096$  (Djorgovski et al. 1999).

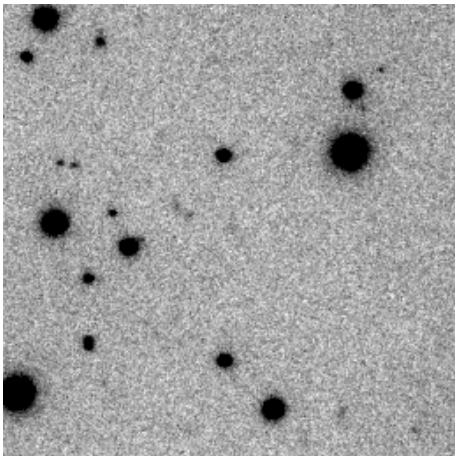
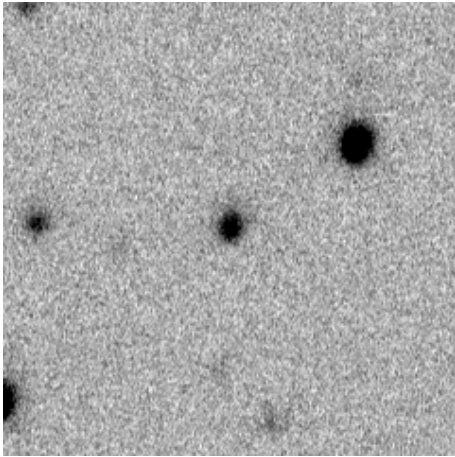
## 3. Host galaxies

### 3.1. GRB 980519

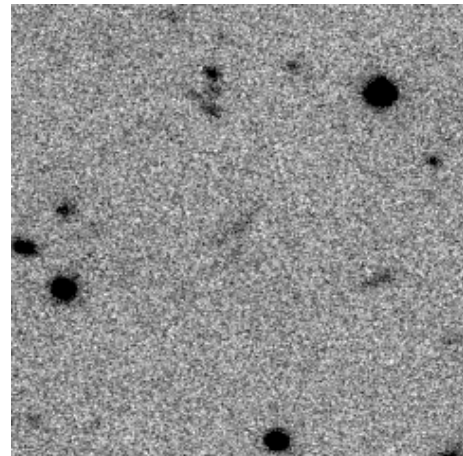
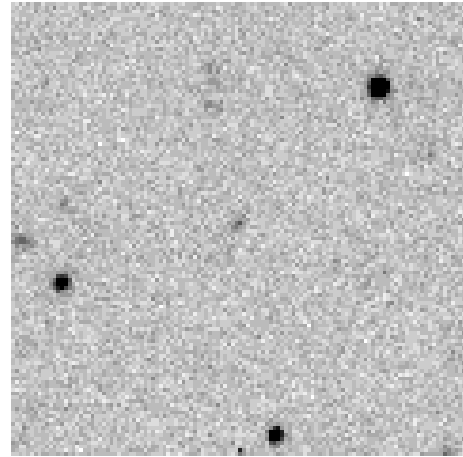
High-resolution (seeing  $\sim 0''.5$ ) late-time imaging is shown in Fig. 1. At the location of the OT a faint  $R \approx 26$  source is seen. The expectation that the OT is fainter than this leads us to suspect that we are seeing the host galaxy, possibly with a small contribution from the OT. It appears from Fig. 1 that this galaxy may be part of an interacting system, possibly powering a star burst. Alternatively, the galaxy is an irregular system consisting of several sub-clumps with detectable star formation.

### 3.2. GRB 980613

A fairly large and bright host galaxy has been observed with Keck-II (Djorgovski et al. 1998) and NOT. Figure 2



**Fig. 1.** GRB 980519. The upper panel shows the discovery image of the OT (V). The lower panel shows the host galaxy, including a possible contribution from the OT (R). North is up, east is to the left. The images are  $45'' \times 45''$



**Fig. 2.** GRB 980613. The upper panel shows the discovery image of the OT (R). The lower panel shows the host galaxy imaged after the OT had faded away (R). North is up, east is to the left. The images are  $45'' \times 45''$

shows the very blue ( $R \sim 23.4 \pm 0.2$ ,  $R-I < 0$ ) edge-on disk host galaxy with a companion galaxy nearby. The position of the OT coincides with the centre of the host. The host is of significantly larger angular extent than any other known GRB host galaxy, so it will be possible to obtain detailed information about the host's morphology.

#### 4. Rapid response strategy: Streamlining

Rapid identification of the afterglows to GRB is essential for their localisation and for the characterisation of their early properties and evolution. We are currently streamlining the identification procedures to minimise overhead. We have set up procedures for generation of web pages containing all relevant information about a given GRB error box. We have implemented automatic transfer of data, pipeline processing of the images, including basic reductions and astrometry, and are currently developing procedures for automatic calibration and object matching. Our current goal is to be able to issue a GCN circular with a

short list of candidate OTs within a few hours after an image (which allows an OT detection) has been obtained.

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