# Discovery of the Optical Afterglow for GRB030323

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**Abstract** GRB030323 is a distant ($z$ = 3.371) Gamma-Ray Burst (GRB) with an optical afterglow. The afterglow was discovered by AAVSO members and was the first afterglow discovered through the AAVSO International High Energy Network. This paper describes the discovery and provides a finding chart and a light curve of the afterglow.

## 1. Introduction

Since this is the first discovery made through the AAVSO International High Energy Network, a little background is in order.

Pam Kilmartin began variable star observing as an amateur while at Auckland University in the 1970s. Alan Gilmore began variable star observing for the Variable Star Section of the Royal Astronomical Society of New Zealand (RASNZ) in 1959. Since then, they moved to Mt. John in 1980 to become observer-technicians. In 1996, Alan was appointed Mt. John Superintendent. Pam chairs the Small Bodies Nomenclature Committee of IAU Division III and is also secretary of the RASNZ; Alan compiles the RASNZ's monthly Newsletter. They primarily observe southern variables (RCBs and RVTs) and NEOs.

Mount John University Observatory (MJUO) is operated by the University of Canterbury, and is located on the South Island of New Zealand, near Lake Tekapo. The 0.6m Optical Craftsman (OC) telescope at MJUO was delivered in 1970. Its mechanical construction has been revamped by the University's mechanical workshop in Christchurch. For several decades, it was primarily used for photoelectric photometry. In 1974 a second 0.6m telescope from Boller and Chivens was delivered, and has been used with a large CCD array for gravitational microlensing work, as well as for GRB observing.

Pam and Alan were recipients of one of the CCD cameras purchased by the AAVSO thanks to a grant from the Curry Foundation , an ST-9e from Santa Barbara Instruments Group (SBIG). Since the OC telescope is a classical Cassegrain working at f/16 (common with photoelectric telescopes), the plate scale is too large for the ST-9e to have much of a field of view. Garry Nankivell and Nigel Frost designed and built a focal reducer, using an existing Kowa photographic lens along with a purchased Edmunds achromat. The focal reducer changes the OC from f/16 to f/6.4, providing a 9x9arcmin field with the ST-9e. A picture of the 0.6m telescope, focal reducer and CCD is shown in Figure 1.

Several GRB fields were observed with the OC/focal reducer system prior to GRB030323, but the optical system was not yet optimized. GRB030323 was the first burst observed where the optical system was working properly.

The AAVSO High-Energy Network originated at the AAVSO 2000 Spring Meeting (Huntsville, AL), where a High-Energy Astrophysics Workshop for Amateur Astronomers was given. Conceived as a GRB follow-up network and funded by the Curry Foundation, along with support from NASA Marshall Space Flight Center, NASA Center for Space Science, and Sonoma State University, the Network has evolved into a more general High-Energy Network to encompass other AAVSO programs on Blazars and polars. A PowerPoint presentation by A. Price on the Network can be found on the AAVSO website (URL: http://www.aavso.org/observing/programs/hen/grb.shtml).

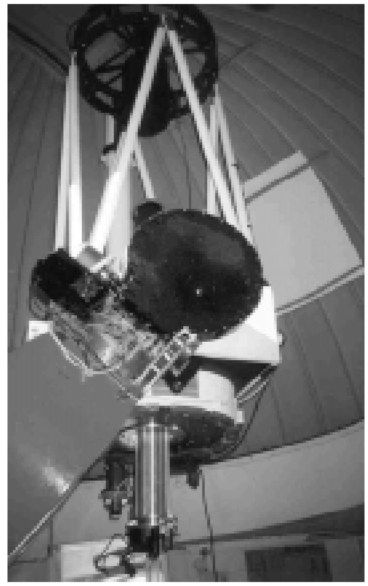

Figure 1. The MJUO Optical Craftsman 0.6m telescope. The long cylinder at the back end of the telescope is the focal reducer, with the SBIG ST-9e camera below it.

## 2. Discovery

A long (26 second), faint gamma-ray burst occurred on March 23, 2003 (therefore called GRB030323). This burst was detected by the HETE satellite FREGATE instrument (trigger 2640) at 21:56:57.60 UT. While the on-board spacecraft software can often calculate the position of a gamma-ray burst, this was not the case for GRB030323. A ground analysis by the MIT team of the simultaneous Wide X-Ray Monitor (WXM) detection yielded an error circle centered at $11^h\ 06^m\ 54^s$ –21° 51' 00" (J2000) and with error diameter of 36 arcmin. This analysis was distributed at 02:55:11 UT on March 24, about 5 hours after the burst. Further refinements to the WXM error circle were made at 04:23:48 UT, and finally a Soft X-ray Camera (SXC) localization was disseminated at 05:28:51 UT, with center coordinates $11^h\ 06^m\ 06^s$ –21° 54' 20" J2000; this is an error trapezoid with height of 4 arcmin and area about 71 $arcmin^2$. At 21:33:01 on March 25, a GRB Coordinated Network (GCN; Barthelmy 2003) notice by Graziani *et al.* (2003) was posted giving the details of the gamma-ray and x-ray light curves. The error boxes are shown in Figure 2.

Unfortunately, the localization was posted at almost the same time as another gamma-ray burst, GRB030324 (Donaghy *et al.* 2003). Most professionals concentrated on GRB030324 as its localization was near the celestial equator (easily visible from both hemispheres), the localization was posted only seconds after the burst, had a smaller error circle, and was supported by ground analysis about an hour later to give an even smaller error circle. Many GCN notices for GRB030324 were posted by observatories around the world, but no optical afterglow was discovered to quite faint limits.

Henden (2003) acquired *BVRcIc* field calibration for GRB030323 by interrupting his continuous monitoring of the GRB030324 field. Kilmartin and Gilmore observed the field of GRB030323 from MJUO with the OC telescope and the ST-9e SBIG CCD camera provided by the AAVSO. These observations were unfiltered, with exposure times of 60 seconds. Ten such frames were combined and compared against the ESO DSS-2 red and infra-red images. A stationary object on the CCD image stack had no DSS-2 counterpart, and was observed to fade. They reported the discovery and provided accurate coordinates to the AAVSO International High-Energy Network at 030324 1308 UT, about 15 hours after the burst. Following careful analysis, the discovery was finally announced to the community by Gilmore *et al.* (2003). The location of the afterglow with respect to the spacecraft error boxes is shown in Figure 2.

Further confirmation was made by Smith *et al.* (2003) using the ROTSE-IIIB system at McDonald Observatory and by Monard (2003) of the AAVSO network. Vreeswijk *et al.* (2003) observed the optical afterglow using the VLT Unit-4 with the FORS2 spectrograph. An hour exposure yielded a redshift of $z = 3.371$, the third most distant GRB afterglow discovered.

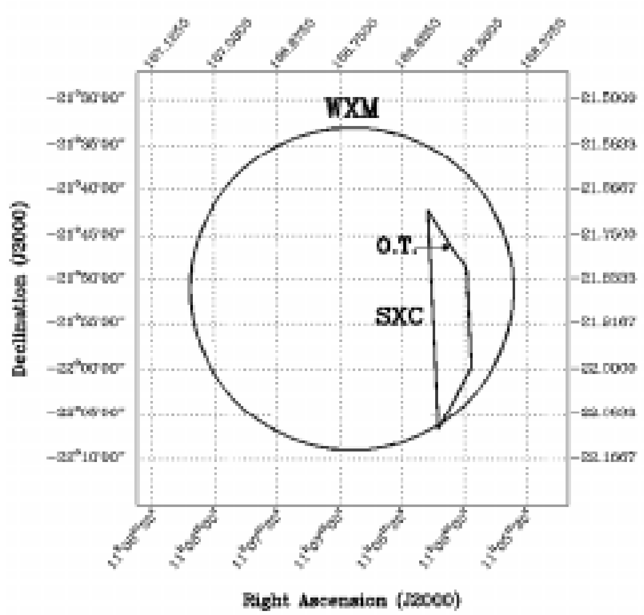


Figure 2. The sky map showing the location of the HETE WXM and SXC error boxes, along with the location of the optical transient. Taken from Graziani *et al.* (2003).

## 3. Observations and light curve

The optical transient position, based on UCAC-2, is $11^{h}\ 06^{m}\ 09^{s}.40\ -21^{\circ}\ 46'\ 13''.4$ J2000 with errors less than 100mas in each coordinate. A finding chart for the optical transient was posted with the discovery GCN. Figure 3 shows a slightly improved version of that finding chart. Most of the objects in the field are galaxies, as can be seen with the deeper and better resolution Gemini image posted by Castro Cern *etal.* (2003). This complicates photometry since uncrowded stars are necessary for any field calibration. A *BVRcIc* all-sky calibration of the field was given by Henden (2003).

Figure 4 shows the photometry for the burst as collected by Vreeswijk *et al.* (2004), with additional unfiltered photometry from Smith *et al.* (2003), Gilmore *et al.* (2003), and Li *et al.* (2003). The available photometry is fairly sparse, due to the concentration by professionals on another burst during the first day along with the arrival of the localization announcement after European sites were able to observe. The first data point is from ROTSE-3, 8 hours after the burst. The light curve has the typical power-law fading behavior, with possible break near two days. More details regarding this light curve and its interpretation can be found in Vreeswijk *et al.* (2004).

The discovery of the afterglow and early posting of the coordinates by Gilmore *et al.* (2003) led to the triggering of a Target of Opportunity program by Vreeswijk *et al.* (2003). Without the help from AAVSO members, a redshift for this afterglow may not have been possible.

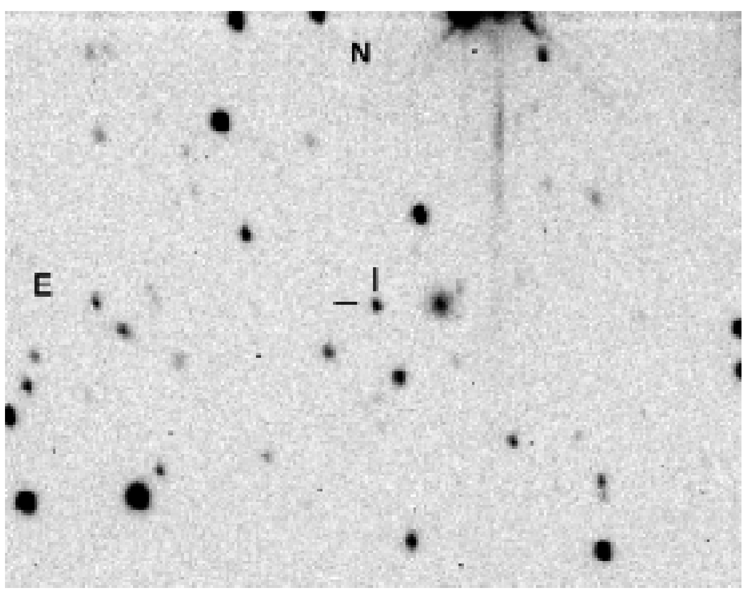


Figure 3. The field of GRB030323. Image taken with the NOFS 1.0m telescope on 030324 with an *Rc* filter. Field of view is 3x4arcmin, with the afterglow marked.

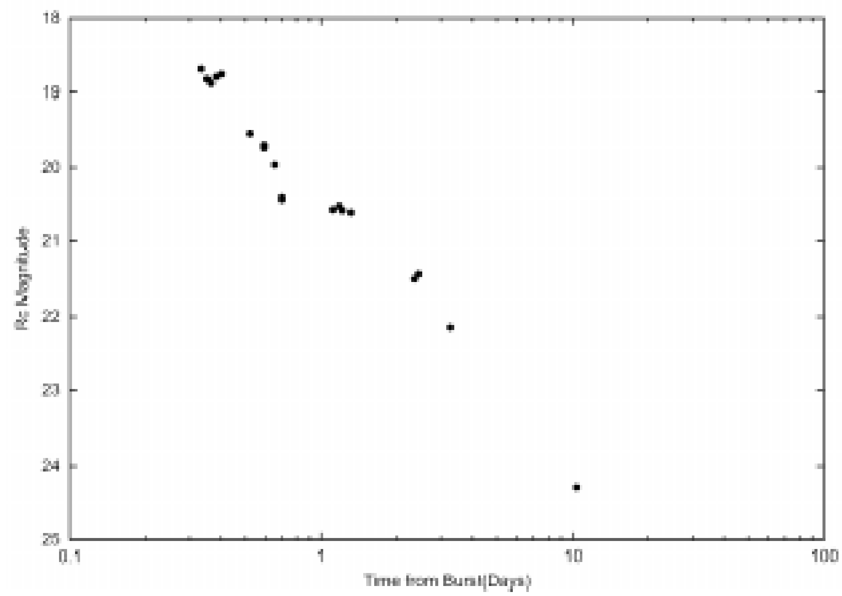


Figure 4. The *Rc* light curve for GRB030323. Additional early-time unfiltered data are included after adjustment onto the *Rc* system.

## 4. Acknowledgements

These observations would not have been possible without the generous contributions from the Curry Foundation, both for supplying the CCD camera used at MJUO as well as funding the AAVSO International High Energy Network. We also appreciate the generous support of SBIG for providing the CCD cameras at reasonable cost. This paper made use of the Digital Sky Survey as provided through the ESO on-line interface at http://archive.eso.org/dss/dss.

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