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Rapid Communication

Optical follow up of the GRB 990123 source from UPSO, Nainital

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Abstract. The CCD magnitudes in Johnson *BV* and Cousins *R* photometric passbands are determined for the optical transient of GRB 990123. These observations have been taken approximately 12 hours after trigger of the gamma-ray burst. BVR photometric light curves are obtained by combining the published data with the present measurements. They indicate that the flux decay constants in *BV* and *R* passbands are almost the same. Its value is 1.1 ± 0.06. Such decay is quite consistent with the fireball models for the optical transient.

1. Introduction

After launching of the Italian-Dutch satellite BeppoSAX in mid-1996, it has been possible to obtain position of Gamma-ray Burst (GRB) with an accuracy better than 3-5 arc minutes within hours of occurance. The follow up observations of relatively long lasting afterglows in X-ray, optical and radio regions have now therefore become routine. Such multi-wavelength observations have contributed significantly to our understanding of GRB sources.

Piro et al., (1999) reported a very bright GRB on 23 January 1999 at UT 09:46:59. Within 3.5 hour after the burst trigger time, Odewahn et al., (1999) discovered a R = 18th magnitude object not present in the Digital Sky Survey that was tentatively identified as the GRB optical counterpart. Based on images obtained much earlier, Akerlof & McKay (1999) discovered a rapidly fading object at $\alpha = 15^h25^m30.^s34$, $\delta = +44°45'59.5''$ (J2000), consistent with the position of the optical transient reported by Odewahn et al., (1999). Within 10 minutes, the luminosity of the optical transient varied from V = 11.82 to 14.53 mag after peaking at V = 8.95 mag just after the first exposure. These spectacular events led Djorgovski et al., (1999) to suggest that GRB 990123 is lensed by a foreground galaxy. This scenario is not supported by the absorption line spectroscopic redshift measurements by Kelson et al. (1999) and Hjorth et al. (1999). They found that the value of redshift for optical transient is 1.60. A more extended discussion on this topic can be seen in Andersen et al. (1999).

We started optical observations of the optical transient at Nainital approximately 12 hours after the trigger of the burst under a long term collaborative programme between Danish, German, Indian, Italian, Mexican and Spanish astronomers coordinated by one of us (AJCT). Successful optical observations have been carried out in UBVRIJK on 24 January 99, and in UBVRI from 25-30 January 99, at ground-based observatories (0.8-m IAC80, 1.5-m TCS, 2.2-m CAHA, 2.5-m NOT and 3.5-m CAHA) under this collaboration, in addition to observations from the U.P. State Observatory (UPSO), Nainital. The photometric results of the UPSO observations are presented here. The decay light curves are presented in BVR photometric passbands by combining them with the data published in GCN Observational reports.

2. Observations and data analysis

The CCD photometric monitoring of the optical transient was carried out for 3 nights during January 1999 from 23 to 25 using 104-cm Sampurnanand telescope located at UPSO, Nainital. The optical transient could be monitored typically for about 3 hours in a night. One pixel of the 1024 × 1024 size CCD chip mounted at the f/13 Cassegrain focus of the telescope corresponds to 0.38 arcsec, and the entire chip covers a field of ~ 6′ × 6′ on the sky. Except for the night of 23/24 January 1999, others were of photometric quality. Exposures upto maximum of 20 minutes were generally given. In order to improve the S/N ratio of the optical transient, the data have been binned in 2 × 2 $pixel^2$ and also two or more images of a filter have been stacked after correcting them for bias, non-uniformity in the pixels and cosmic ray events. Exposure times for the stacked images were generally more than 40 minutes.

As the optical transient was generally quite faint on the stacked images, DAOPHOT profile-fitting technique was used for the magnitude determination. These magnitudes were calibrated using differential photometric techniques and standards given by Nilakshi et al., (1999). The results derived in this way are given in Table 1. One can note that the good photometric sky conditions at Nainital enabled us to observe the optical transient till it was as faint as $V \sim 22$ mag with an accuracy of 0.10 mag using a telescope of aperture 1 m.

Table 1. *BV R CCD* magnitudes of the optical transient of GRB 990123. Errors are primarily based on the S/N ratio.

Time in UT	Filter	Exposure in minutes	Magnitude
Jan 99 23.958	*B*	30 × 1, 20 × 1	20.31±0.08
Jan 99 24.000	*R*	20 × 2	19.61±0.03
Jan 99 24.940	*R*	20 × 3	20.83±0.05
Jan 99 24.987	*B*	20 × 3	21.71±0.11
Jan 99 25.028	*V*	20 × 1	21.08±0.15
Jan 99 25.940	*R*	20 × 2	21.34±0.10
Jan 99 25.990	*V*	20 × 3	21.89±0.10

3. Results and discussions

Table 1 shows the results of our photometric observations in Johnson *BV* and Cousins *R* passbands. In order to study the photometric light curve of the optical transient of GRB 990123 we have combined our measurements with the data published by various groups in the GCN Observational reports. All photometric measurements have been put on the same calibration scale, using the magnitudes of the reference stars given by Nilakshi et al., (1999). In this way we have been able to take care of the errors arising due to different calibrations.

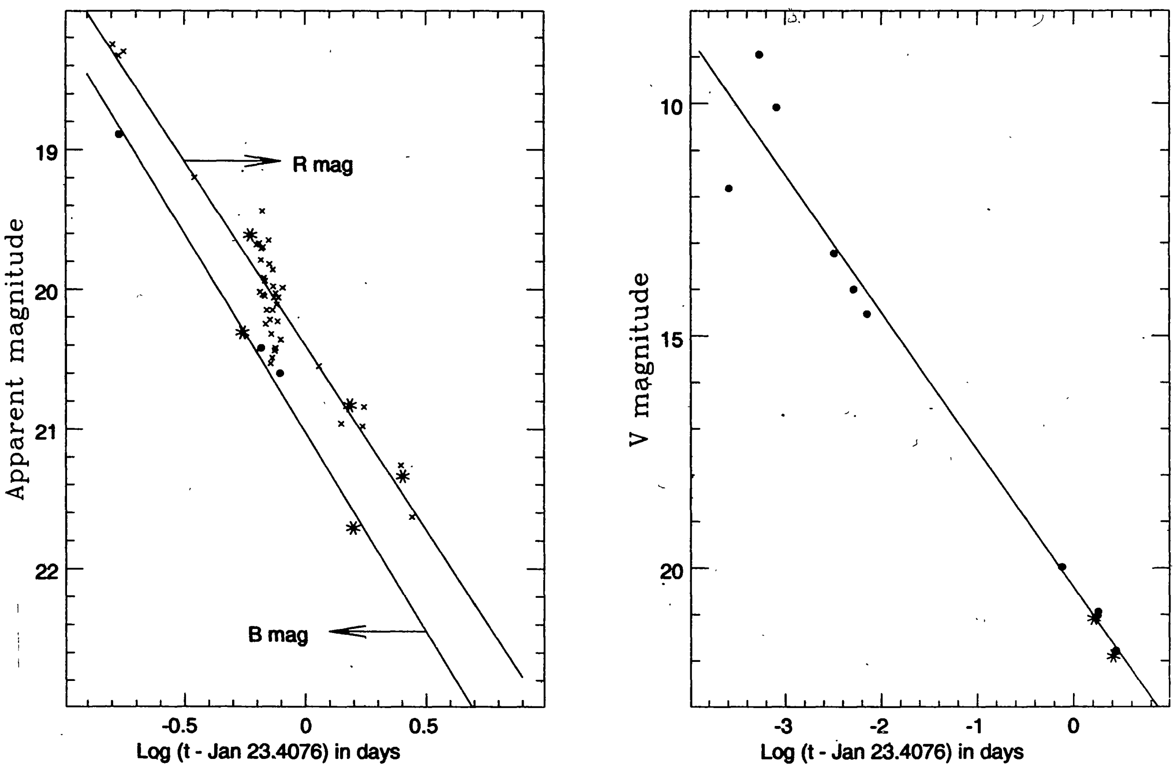

Figure 1. *BV R* photometric light curves of the optical transient of GRB 990123. Starred points are from UPSO, Naini Tal. Other points are taken from GCN Observational reports (see text). Crosses and filled circles in the left panel of the diagram are *R* and *B* magnitudes respectively while *V* magnitudes are shown as filled circles in the right panel of the diagram.

Fig 1 shows the light curve in V, B and R photometric passbands. The UPSO observations have been identified in these plots. The X-axis is log $(t - t_0)$ where t is the time of the observation and t_0 is the time of the trigger of GRB event. All times are measured in units of days. The light curves have not yet flattened.

The decay of previous optical transients associated with GRBs appears to be well characterized by a power law $F(t) \propto (t - t_0)^{-\alpha}$, where $F(t)$ is the flux of the optical transient at time t in days and α is the decay constant. Assuming this parametric form and by fitting least square linear regressions to the observed magnitudes as function of time, we obtained following relations for the B, V and R magnitudes

$$B(t) = (21.02 \pm 0.12) + (2.8489 \pm 0.17) log(t - t_0)$$

$$V(t) = (20.44 \pm 0.18) + (2.8314 \pm 0.05) log(t - t_0)$$

$$R(t) = (20.40 \pm 0.22) + (2.6487 \pm 0.13) log(t - t_0)$$

These lines are also plotted in Fig. 1. It can be seen that the UPSO observations, within $1 - \sigma$ errors, follow the above linear relations. The B and R light Curves are obtained only during fading phase of the optical transient, while the V light curve contains both brightening and decaying phase of the GRB. In fact, the brightest three points are during the trigger phase, within 35 seconds after the start of the event. We have therefore excluded these three points while deriving the decay relation in V. However, their inclusion will not change the value of decay constant significantly. The correlation coefficients of these linear relations are always greater than 0.9. This indicates that assumption of power-law decay for the optical flux of the optical transient associated with GRB 990123 is justified. Allowing for the factor -2.5 involved in converting flux to the magnitude scale, the values of flux decay constants are 1.14 ± 0.07, 1.13 ± 0.02 and 1.06 ± 0.05 for the B, V and R passbands respectively. In K-passband, the value of decay constant has been found to be 1.14 ± 0.08 by Bloom et al., (1999). Thus, we conclude that the flux decay constants are independent of wavelengths at least in the range of 0.4 to 2.5 micron. This is in agreement with the decays noted in earlier optical transients. These decay rates are remarkably similar to those reported for previous optical transients (see Kulkarni et al., (1998). Such decays are quite consistent with the synchrotron emission models.

4. Conclusions

In gamma-rays the GRB 990123 was one of the top 2 percent of bursts. In the optical it reached 9th magnitude during the burst itself. These properties of the GRB 990123 have led to the suspicion that this event was extra strong because of gravitational lensing. A consequence of this lensing hypothesis is image splitting. The same burst would arrive at different times, with the time difference proportional to the image separation (e.g., Turner 1999). One would therefore expect a repeat of the GRB and its afterglow. The gamma-ray burst may easily be missed (earth occultation etc.) but its afterglow would be visible for a few days. We are therefore continuing our observations of the optical transient in R passband.

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