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Discovery of the heavily obscured supernova 2002cv

A. Di Paola[1], V. Larionov[2,3], A. Arkharov[4], F. Bernardi[1,6], A. Caratti o Garatti[1], M. Dolci[5], E. Di Carlo[5], and G. Valentini[5]

[1] INAF – Osservatorio Astronomico di Roma (OAR), via Frascati 33, Monte Porzio Catone, Roma, Italy
[2] Astronomical Institute of St. Petersburg University, St. Petersburg, Petrodvorets, Universitetsky pr. 28, 198504 St. Petersburg, Russia
[3] Isaac Newton Institute of Chile, St. Petersburg Branch
[4] Central Astronomical Observatory, St. Petersburg, Russia
[5] INAF – Osservatorio Astronomico di Teramo (OACT), Teramo, Italy
[6] Università di Roma *Tor Vergata*, Roma, Italy

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Abstract. On the 13th of May 2002, supernova 2002cv was discovered using a near-infrared camera working at the AZT-24 1.1 m telescope at Campo Imperatore (AQ-Italy). After the infrared detection a simultaneous photometric follow-up was started at optical wavelengths. The preliminary results confirm a heavily obscured object with a $V - K$ color not lower than 6 mag, making SN 2002cv the most reddened supernova ever observed. This finding, along with the recent discovery of another obscured supernova, suggests a critical revision of the rates known to date. The estimate of the visual extinction and the light curves are provided here. These latter indicate that our SN 2002cv observations are the earliest available for a type-Ia supernova at IR wavelengths.

Key words. supernovae: general – supernovae: individual: SN2002cv – infrared: galaxies

1. Introduction

The AZT-24 telescope of the Campo Imperatore Observatory[1] (a cooperation among Rome, Teramo and Pulkovo Observatories) is mainly used for photometric studies of variable sources at near infrared (NIR) wavelengths. During the follow-up of the supernova 2002bo (Cacella et al. 2002), discovered on 2002 March 9 in the spiral galaxy NGC 3190, a new source appeared ~28″ to the North and ~10″ to the West of the galactic nucleus (Larionov et al. 2002) at $10^{\rm h}18^{\rm m}03\overset{\rm s}{.}68$ and $+21°50'06\overset{''}{.}2$ (J2000). Our discovery images of this supernova, called SN 2002cv, are presented in Fig. 1.

A more detailed analysis of the images obtained during the days preceding May 13, that is the discovery date, has shown that the outburst became visible between May 6 and May 9, though at the limit of detectivity, thus preventing us from a prompt detection of the new supernova. The maximum in our NIR light curves was observed between the 20th and the 22nd of May ($J = 14.77 \pm 0.05$ on MJD 52414.5 ± 0.5, $K = 13.92 \pm 0.07$ on MJD 52416.8 ± 0.5).

As soon as the object was discovered, a simultaneous follow-up was started at optical wavelengths using the Schmidt telescope of the Campo Imperatore Observatory and the TNT telescope of the Teramo Observatory.

Since our first discovery IAU Circular and the preparation of this text, 4 additional IAU Circulars were published about SN 2002cv. In the first of them, Li (2002) reports the failed localization of SN 2002cv using the KAIT telescope[2] that observed NGC3190 at optical wavelengths (B, V, R and I) both before and after the discovery. In the second Meikle & Mattila (2002) provide a preliminary classification of the supernova as type-Ia by means of the UKIRT telescope NIR spectroscopy; this classification is confirmed in the fourth Circular by Filippenko et al. (2002).

2. Instrumentation

The observations at NIR wavelengths were obtained by using the 1.1 m telescope and the SWIRCAM camera (D'Alessio et al. 2000) at the Campo Imperatore Observatory (AQ-ITALY) located 2150 m a.s.l. SWIRCAM is based on a Rockwell PICNIC array having 256 × 256 pixels with a size of 40 μm, that corresponds to 1.04″ on the sky. Standard broad band filters (J, H, K and Ks) are available as well as some narrow band filters and low resolution grisms ($R \approx 270$) for IJ and HK spectroscopic observations.

Send offprint requests to: A. Di Paola,
e-mail: dipaola@mporzio.astro.it

[1] see http://www.mporzio.astro.it/cimperatore/WWW/

[2] see http://astro.berkeley.edu/~bait/kait.html

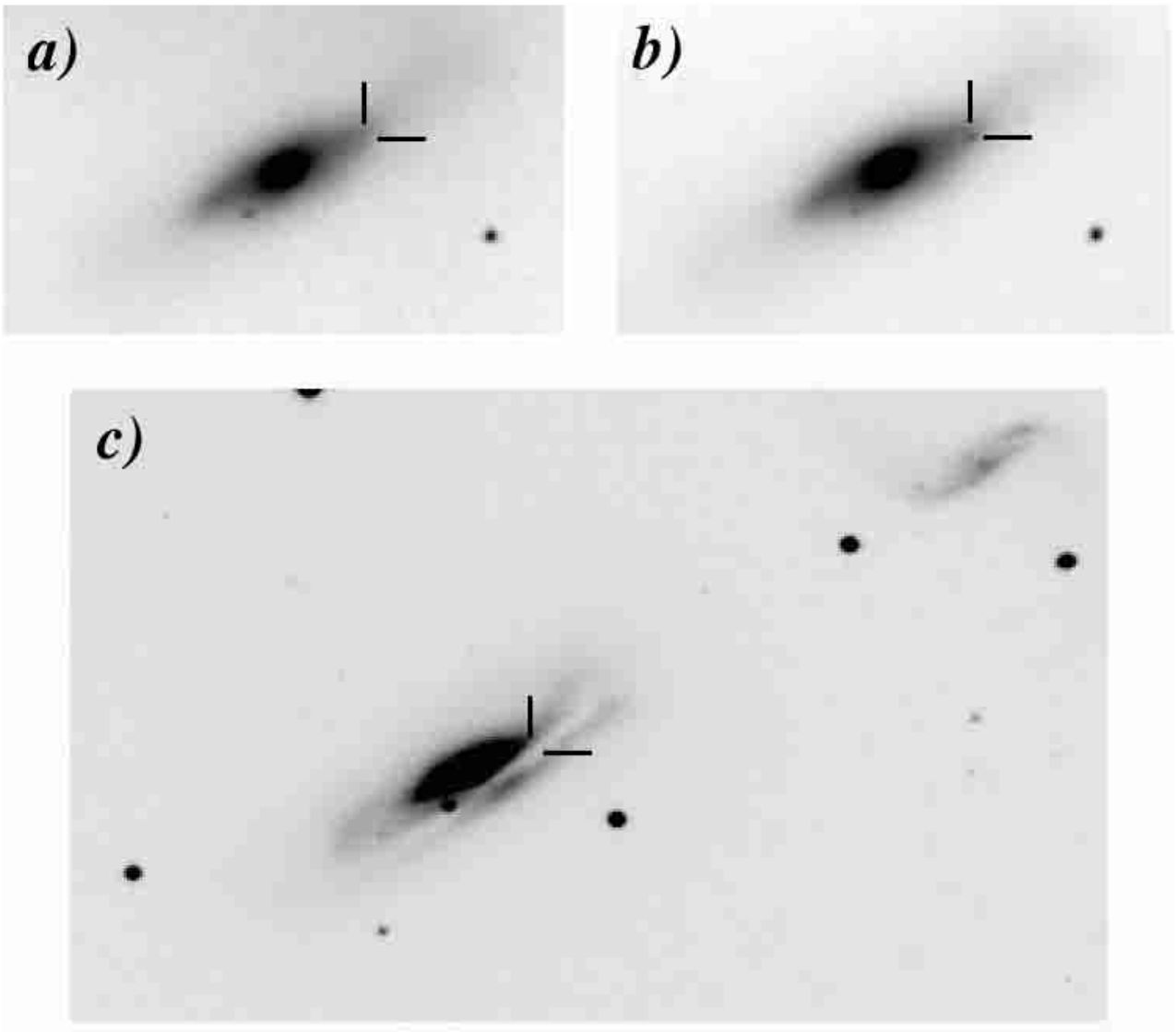

Fig. 1. The *K*-band images obtained with AZT-24 telescope before **a)** and after **b)** SN 2002cv discovery. Panel **c)** contains the *V*-band image obtained with the Schmidt telescope on May 15th (after the outburst) with no detectable object at the SN location.

The 60/90/180 cm Schmidt telescope at Campo Imperatore was used for optical follow-up. It is equipped with an optical CCD camera (ROSI) using a 2048×2048 pixels, back illuminated, thinned array from Marconi Ltd. (Pedichini et al. 2000) featuring 1.5″ per pixel on the sky. Johnson broad band optical filters are available via a filter jukebox especially designed for Schmidt telescopes focal station.

The TNT is an F/14 Ritchey-Chrétien 72 cm telescope located at the Teramo Observatory at about 300 meters a.s.l., equipped with Tektronic TK512 CB1-1 front illuminated 512×512 pixels CCD camera and standard Johnson filters.

3. Observations and results

At NIR wavelengths, during the first 20 days of observations we were able to acquire detailed light curves in *J*, *H* and *K* bands with very good signal-to-noise ratio (error bars are shown in Fig. 2). At the same time *V*, *R* and *I* band images were obtained both from the Schmidt and TNT telescopes.

It was immediately clear that SN 2002cv was heavily obscured since it could not be detected in *V*-band images which reach the 22nd magnitude on the sky and the 20th on the galaxy disk (Fig. 1). This fact is supported by the existence of a strong dust lane passing across the SN location which is measured from IR images.

NIR images were obtained by 6 on-source ditherings with a 10″ radius, as well as by side sky images. Both were processed using the *Preprocess* package (Di Paola 2000). The sky images were combined using 2-D median composition to eliminate stars. The resulting sky frame was subtracted from each target image before flat-fielding and co-adding the dithered images. Because of the difficulties caused by the galactic disk gradient just through the SN image, we decided to perform plain aperture photometry providing galaxy subtraction. Galaxy images without the SN are available from images acquired before the SN 2002cv outburst, during the SN 2002bo follow-up.

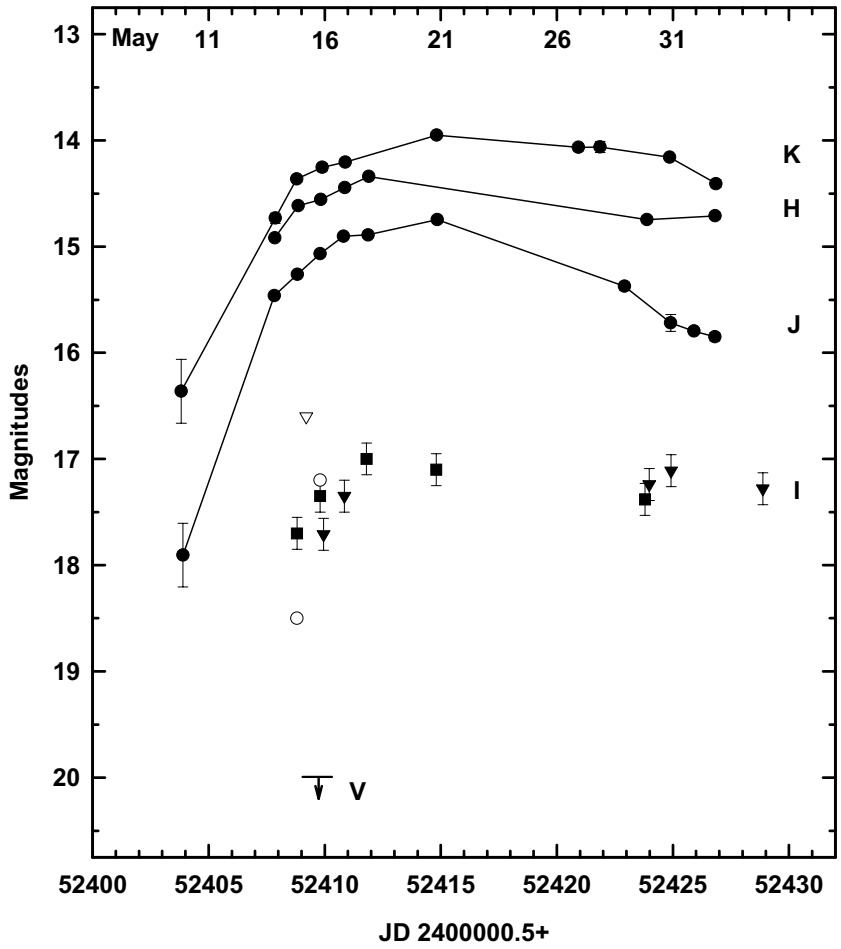

Fig. 2. The preliminary light curves obtained during first 23 days of SN 2002cv monitoring. Filled circles, connected with straight lines, refer to AZT-24 NIR observations (one-sigma error bars are shown; in most cases they are smaller than the symbol size). Filled squares – TNT *I* band data, filled triangles – Campo Imperatore Schmidt telescope data, open triangle – MMT data and open circles – Nickel Telescope Lick Observatory data (the last two from Larionov et al. 2002). *V*-band upper limit, from Campo Imperatore Schmidt telescope, is also shown.

The error estimates are derived from the composition of the statistical errors on the supernova and the standards measurements.

At optical wavelengths the Schmidt telescope images were also dithered on a larger circle (5′). Only for *I*-band images it was necessary to calculate a sky image on the basis of the same target images, just to subtract the fringes pattern. In any case all the images were flat-fielded and co-added before proceeding with profile fitting photometry.

Unfortunately at optical wavelengths we have not a library image as deep as those we obtained after SN 2002cv discovery. This implies that the galaxy subtraction technique cannot be applied and the accuracy of the photometry is affected by the uncertainty in galaxy background contribution. This contribution has been locally approximated by a second degree surface fitted on the region surrounding the SN. The Landolt standards were used for field photometric calibration.

Each TNT image was reduced by using standard bias subtraction and flat-field normalization techniques. The photometric measurements were performed by adopting a point-spread function (PSF) fitting with the ROMAFOT package implemented in the MIDAS software. In order to derive more accurate relative photometry of the supernova with respect to two comparison stars located in the same field, we have properly accounted for the host galaxy luminosity profile. This was done during the fitting procedure by adopting a tilted plane approximation for the diffuse background emission. The calibration to the standard system was performed by using two nearby standard stars from the Landolt catalogue.

All the available values are reported in the Fig. 2 light curves (a further analysis will be published in a forthcoming paper). From the plot it is clearly visible that SN 2002cv was discovered while its brightness was still increasing, about 11 days before the IR maximum. According to Meikle & Mattila (2002) and Filippenko et al. (2002) SN 2002cv is a type-Ia. If this classification will be confirmed, these observations will represent the earliest NIR measurements available of such type of supernovae.

4. Discussion

It appears clearly from the near-infrared light curves and *V*-band non-detection that supernova 2002cv is heavily obscured. It is possible to evaluate the reddening basing on available measurements and on the assumption it is a type-Ia supernova. We employ average optical–IR light curves from

Nugent et al. (2002) and standard galactic dust extinction law (Rieke & Lebofsky 1985).

From Fig. 2 we use MMT and Nickel Telescope data coupled with our NIR simultaneous observations to obtain $I - K$ and $R - K$ colour indexes ($R \approx 19^{\rm m}$ from MMT observations on May 15). The resultant colour excesses correspond to values of A_V in the range $7\overset{\rm m}{.}4$ to $8\overset{\rm m}{.}3$, while V band non-detection at $20^{\rm m}$ level sets a consistent lower limit of $A_{\rm V} \geq 7\overset{\rm m}{.}0$. Another estimate of the extinction may be derived from the SN absolute magnitude at maximum. Since from our observations the J-band maximum is better defined than others, we can obtain an estimate of A_J using the SN apparent magnitude, the typical absolute magnitude of type Ia supernovae in the J-band from Meikle (2000) and the distance modulus (DM) for the galaxy. DM can be estimated both from NGC 3190 redshift ($z = 0.00424$, see Heraudeau & Simien 1998) and from Tully-Fisher method (see Tully 1988): the two values are respectively 31.46 ± 0.2 and 31.76. In the following we will then use 31.6 ± 0.3. Then:

$$A_J = m_J - M_J - DM = 14.8 + 19.0 - 31.6 = 2.2 \pm 0.3.$$

The accuracy depends mostly on the absolute magnitude and on the DM uncertainty. Using A_J, the A_V value is obtained from the extinction law:

$$A_V = A_J/0.282 = 7.8 \pm 1.0$$

and confirms the previous estimates.

At a lower accuracy level, A_V can be estimated also using H and K bands maxima. In these cases the results are $A_V = 7.7 \pm 2.3$ and $A_V = 10.0 \pm 3.6$ respectively.

Definitely we estimate $A_V = 7.9 \pm 0.9$, thus SN 2002cv is really the most reddened supernova ever observed.

If the complete light curves will support the hypothesis of SN 2002cv to be overluminous supernova as suggested by its affinity with SN 1991T (Li 2002; Filippenko 2002), then it strengthens the Howell (2001) correlation between the host galaxy morphological type (NGC 3190 is classified as a SA(s)a late type galaxy) and the supernova type-Ia luminosity.

We note that the observing of two supernovae simultaneously in the same galaxy is supposed to be a very rare event according to the actual supernova-rate estimates. This fact and the fact that this object and SN 2001db (see Maiolino et al. 2002) are invisible to most of the currently working supernova search programs, seem to suggest that those supernova-rates need to be significantly revised.

5. Conclusions

1. We present preliminary light curves of the supernova 2002cv we have discovered in NGC 3190 galaxy.
2. The supernova outburst appeared above magnitude $J = 18$ between the 6th and 9th of May, and reached its maximum on May 20, making 2002cv the earliest supernova Ia observed at NIR wavelengths.
3. The color index $V - K \gtrsim 6$ mag makes this supernova the most reddened ever observed.

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