Optical and Infrared Photometry of the Type Ia Supernovae 1991T, 1991bg, 1999ek, 2001bt, 2001cn, 2001cz, and 2002bo

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ABSTRACT

We present optical and/or infrared photometry of the Type Ia supernovae SN 1991T, SN 1991bg, SN 1999ek, SN 2001bt, SN 2001cn, SN 2001cz, and SN 2002bo. All but one of these supernovae have decline rate parameters $\Delta m_{15}(B)$ close to the median value of 1.1 for the whole class of Type Ia supernovae. The addition of these supernovae to the relationship between the near-infrared absolute magnitudes and $\Delta m_{15}(B)$ strengthens the previous relationships we have found, in that the maximum light absolute magnitudes are essentially independent of the decline rate parameter. (SN 1991bg, the prototype of the subclass of fast declining Type Ia supernovae, is a special case.) The dispersion in the Hubble diagram in JHK is only $\sim$0.15 mag. The near-infrared properties of Type Ia supernovae continue to be excellent measures of the luminosity distances to the supernova host galaxies, due to the need for only small corrections from the epoch of observation to maximum light, low dispersion in absolute magnitudes at maximum light, and the minimal reddening effects in the near-infrared.

[19]The National Optical Astronomy Observatory is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

Subject headings: supernovae, individual (SN 1991bg, SN 1999ek, SN 2001bt, SN 2001cn, SN 2001cz, SN 2002bo) – techniques: photometric

1. Introduction

Since the discovery of a precise relationship between the absolute magnitude at maximum light and decline rate (Phillips 1993), Type Ia supernova light curves have become the most accurate method to measure luminosity distances to objects at cosmological distances. The standard measure of the decline rate in the notation of Phillips, $\Delta m_{15}(B)$, is the number of magnitudes that a Type Ia supernova declines in the 15 days after the time of B-band maximum. $\Delta m_{15}(B)$ is now one of many methods used to calibrate absolute magnitudes of Type Ia SNe (supernovae). These include a modification of the $\Delta m_{15}(B)$ method to incorporate BVI data by fitting discrete templates (Hamuy et al. 1996; Phillips et al. 1999; Prieto, Rest & Suntzeff 2005); a similar multi-color technique using a continuous set of multi-color templates with the important additions of a self-calibrated error model (Riess, Press & Kirshner 1996; Jha 2002); and a method that parameterizes the BV light curves by "stretching" the time axis to fit any given light curve set to a single template set (Perlmutter et al. 1997). Finally, Wang et al. (2003) have shown that useful information such as reddening can be derived from plots of the filter by filter magnitudes vs. the photometric *colors* (instead of vs. time), using data from the month after maximum light. All these techniques rely on fitting optical multi-color light curves to a template set which includes a single parameter which is independently correlated to the intrinsic luminosity of the SN.

Until recently Type Ia SNe were primarily observed through the BV and RI_{KC} (Kron-Cousins) bands. Jha (2002) has added the U filter to the light curve sets and presents $UBVRI$ data for 44 objects. The U-band data are particularly important for cosmology, because many high-redshift SNe are measured in the R- and I-bands, which may correspond to rest frame U-band light curves depending on the redshift. The U-band light curves are sensitive to the the metallicity of the progenitor if the U-band light curve is measured before maximum light (Höflich, Wheeler, & Thielemann 1998; Lentz et al. 2000).

The compilation of near-IR (infrared) light curves of Type Ia SNe has been slow due to a lag in IR detector technology with respect to optical CCD detectors and the lack of telescopes dedicated to IR observations. The Caltech infrared group (Elias et al. 1981, 1985) presented the first extensive observations of Type Ia SNe in the near infrared. A complete summary of IR observations obtained through 1998 is given by Meikle (2000).

In their Fig. 6 Elias et al. (1985) show an H-band Hubble diagram and comment that

Type Ia SNe at maximum light may be good standard candles. Meikle (2000) analyzed the IR data available four years ago and used Cepheid determinations of the distances to eight galaxies which have hosted Type Ia SNe, concluding that the dispersion in absolute magnitude 14 days after T(B_{max}) was ≈0.15 mag over the decline rate range $0.87 \leq \Delta m_{15}(B) \leq 1.31$. Krisciunas et al. (2004a) presented the first Hubble diagrams for Type Ia SNe based on JHK magnitudes at maximum light. Their data indicate that there are no obvious decline-rate relations in the near-IR if we consider the objects with $\Delta m_{15}(B) \lesssim 1.7$. Thus, rather than standardizable candles, Type Ia SNe *at maximum light* are excellent standard candles. The dispersions in the absolute magnitudes at maximum light are roughly ± 0.15 mag for the near-IR JHK bands. The near-IR data have the extra advantage that extinction by interstellar dust is up to an order of magnitude less at IR wavelengths compared to optical bands (Cardelli, Clayton, & Mathis 1989). Even for objects significantly reddened at optical wavelengths, the extinction corrections are small in the IR, thus eliminating a previously serious potential source of random and systematic error in the distance determinations.

There are other advantages to using the near-IR magnitudes in conjunction with the optical ones. In our Papers I through V we discussed the use of the V *minus* near-IR loci for Type Ia SNe. Except in the unusual case of SN 2000cx (Paper IV) we found that the unreddened loci of $V-J$ or $V-H$ allowed the determination of A_V with smaller random errors and less worry about systematic errors. This is because: 1) unreddened Type Ia SNe appear to exhibit predictable V *minus* near-IR color curves, allowing us to derive sensible color excesses for objects which are reddened; and 2) the total extinction A_V is equal to these color excesses to a factor of about 1.3. Thus we can use, say, $V-H$, as a method of measuring A_V without introducing a significant uncertainty due to a non-standard extinction law. Since R_V can be as low as 1.8 (see Paper I for a discussion of SN 1999cl), serious systematic errors of distance can result if one uses only optical data and assumes $R_V = 3.1$ to convert $E(B-V)$ into A_V.

A final advantage to the use of colors such as $V-J$ or $V-H$ can be made by appealing to our experience with measuring stellar effective temperatures (Blackwell et al. 1990; Bessell, Castelli, & Plez 1998). A color based on two filters close in wavelength such as $B-V$ is a very sensitive function of T_{eff} but also the metallicity of the photosphere. A color such as $V-K$ is also sensitive to metallicity, but because of the very large wavelength difference between the bands, the effect of temperature is much larger making the metallicity effect secondary. We are far from understanding the continuum formation of complicated non-hydrogen NLTE photosphere of a Type Ia SN, but the observed range in color and ionization seen at maximum light can be explained by a simple temperature sequence where the more luminous SNe are hotter (Nugent et al. 1995). If this were true, by using a color such as $V-H$, which may be a less complicated function of T_{eff} rather than $B-V$, we may be able to uncover a clearer relationship between the observed colors and the underlying physical temperature and luminosity.

Since 1999 we have been engaged in regular monitoring of bright Type Ia SNe (typically $V_{max} < 15.5$), at Cerro Tololo Inter-American Observatory (CTIO) and Las Campanas Observatory (LCO) with the goal to construct a near-IR Hubble diagram with a sample of 30 Type Ia SNe. We are motivated by the success of the Calán/Tololo SN survey (Hamuy et al. 1993b) which published a similar number of optical light curves of Type Ia SNe. Given the importance of high redshift SNe for cosmology, i.e. evidence for a non-zero cosmological constant (Riess et al. 1998; Perlmutter et al. 1999; Tonry et al. 2003; Knop et al. 2003), a well-calibrated sample of nearby SNe studied in the near-infrared will allow us to better understand the dereddened properties of the population of Type Ia SNe, and ultimately allow us to better anchor the distant sample to the nearby one.

This is the sixth in a series of data papers on optical and infrared photometry of Type Ia supernovae (SNe). We have already presented data on SN 1999aa, SN 1999cl, and SN 1999cp (Krisciunas et al. 2000, Paper I); SN 1999da, SN 1999dk, SN 1999gp, SN 2000bk, and SN 2000ce (Krisciunas et al. 2001, Paper II); SN 2001el (Krisciunas et al. 2003, Paper III); SN 2000cx (Candia et al. 2003, Paper IV); and SN 1999ee, SN 2000bh, SN 2000ca, and SN 2001ba (Krisciunas et al. 2004b, Paper V). Jha (2002) has presented other optical data for SN 1999aa, SN 1999cl, SN 1999gp, SN 2000ce, and SN 2000cx. Extensive optical photometry of SN 1999ee has been presented by Stritzinger et al. (2002). Li et al. (2001b) presented data for SN 2000cx.

Here we present optical and/or near-IR photometry of the Type Ia supernovae SN 1991T, SN 1991bg, SN 1999ek, SN 2001bt, SN 2001cn, SN 2001cz, and SN 2002bo. Three of these objects were discovered by one of us (RC) as part of an ongoing SN search with a 0.3-m f/2.7 telescope sited at Réunion Island (latitude = S 21°06′, longitude = E 55°36′). Except for SN 1991bg, the group of supernovae presented in this paper has a $\Delta m_{15}(B)$ decline rate close to the median value for all Type Ia SNe. In that sense, this is a "normal" group of Type Ia supernovae which should be representative of the average population.

2. Observations

2.1. Photometric Calibration

We used Landolt (1992) standards for the calibration of our optical photometry. The field star magnitudes were derived from aperture photometry in the IRAF environment.[20] Typically, we derive the photometry of the SNe themselves using point spread function (PSF) magnitudes using DAOPHOT (Stetson 1987, 1990). When necessary, we first performed image subtraction using templates taken after the SNe have faded away. Some of our subtractions were carried out with a script based on Andrew Phillips' IRAF package PSFMATCH, while others were carried out using a script written by Brian Schmidt and based on the algorithm of Alard & Lupton (1998).

Except for the case of SN 1991bg, we calibrated the IR magnitudes of the field stars near the SNe using the near-IR standards of Persson et al. (1998) and observations from the LCO 1-m telescope. We have found that the Two Micron All Sky Survey (2MASS) magnitudes of field stars brighter than 15th magnitude are, on average, 0.03 mag brighter than the derived J_s, H, and K_s photometry on the system of Persson et al. With this offset we were able to assess the quality of the photometry of the field stars if they were observed by us on few photometric nights.

The photometry of the local standards is given in Tables 1 and 2. The finding charts are shown in Figures 1a through 1e.

Photometry of a given SN, obtained with multiple telescopes, shows systematic differences from telescope to telescope. Often this amounts to several hundredths of a magnitude, but once a SN begins to enter the nebular phase two to three weeks after maximum light, these systematic differences can amount to several tenths of a magnitude. In Papers III, IV, and V we used a method of spectroscopically-based filter corrections to correct the photometry for the non-stellar spectral energy distributions of the SNe and the differences of the filter transmission curves of the filters in different instruments. The problem of bringing the photometry of Type Ia SNe onto a standard system was discussed by Suntzeff (2000), and a correction - the "S-correction" method - was given in Stritzinger et al. (2002); the reader should consult this paper for the definition of the linear transformations. We have found, for example, comparing YALO and CTIO 0.9-m B-band photometry of Type Ia SNe, that starting some 30 days after the time of B-band maximum there is a systematic difference

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of 0.07 mag owing to the filter differences. In the V-band the systematic differences are 0.05 mag, but with the opposite arithmetic sense. Without taking this into account YALO photometry gives $B-V$ colors 0.12 mag different in the tail of the color curve. This clearly makes a significant difference if one derives a $B-V$ color excess from photometry at this epoch. As found by Krisciunas et al. (2003) in the case of SN 2001el, these systematic differences can be largely eliminated by correcting the photometry to the system described by Bessell (1990).

The applications of S-corrections to date have only reduced the systematic errors of the photometry taken on different telescopes, not eliminated them. Elias (2003) suggests that these theoretical corrections are never as good as one would hope due to the difficulty of measuring the instrument/filter/detector system efficiencies and that the real S-corrections should be calculated empirically as the observed differences of the photometry obtained with different telescopes and instruments. However, there are very few SNe which have been well sampled with multiple telescopes, so we cannot yet set up appropriate look up tables.

In Figs. 2 and 3 we show optical filter corrections to the Bessell (1990) system, while in Fig. 4 we show IR corrections from the YALO filters to the system of Persson et al. (1998). The trends in these figures are not precise, and it is very important to get spectral atlases of other SNe to see if the S-corrections of other SNe approximate what we find in the cases of SNe 1999ee, 2001el, and 2002bo.

The filters and CCDs used in the CTIO 1.5-m CCD camera are nominally the same as those in the 0.9-m camera. We have assumed that the S-corrections derived for the $UBVRI$ filters are the same for the two cameras.

Our principal goal with the photometry of the five supernovae of mid-range decline rates discussed in this paper is to derive color excesses (i.e. E(B−V), giving extinction corrections) and infrared magnitudes at maximum light. The photometry *presented in the tables* includes the color corrections based on observations of standard stars. For further analysis we have applied the S-corrections and K-corrections to all our data where possible, the one exception being the Steward IR data for SN 1999ek where we do not have a good prescription for the system throughputs. In the case of SN 2002bo we explicitly list the S-corrections (Tables 12 and 13). The IR K-corrections are based on spectra of SN 1999ee and are given in Paper V.

We have used a new program to carry out the Δm_{15} analysis (Prieto, Rest & Suntzeff 2005), which is a variant on the method given in Phillips et al. (1999). The $BVRI$ light curves of a given SN are fitted simultaneously, minimizing a χ^2 statistic constructed as the difference between the data and the model (i.e. templates in each filter plus magnitudes at maximum), weighted by the uncertainties in the data and model. The parameters of the fit (unknown variables) are: the time of B-band maximum, the magnitudes at maximum in each filter ($BVRI$), the value of Δm_{15}, and the total reddening $E(B-V)_{total}$.[21] The host reddening is simply the total reddening minus the Galactic reddening given by Schlegel, Finkbeiner & Davis (1998). The new $\Delta m_{15}(B)$ code uses the same 6 templates based on 7 objects that were used by Phillips (1993), Hamuy et al. (1996), and Phillips et al. (1999), along with the well-sampled light curves of 8 Type Ia SNe observed more recently. The code adopts K-corrections similar to those described by Hamuy et al. (1993a). In contrast to previous versions of Δm_{15} analysis, the Prieto code allows for a continuous variation of Δm_{15}. The analysis produces a covariance matrix, allowing us to calculate the 1-σ statistical uncertainties of the parameters.

2.2. SN 1991T

SN 1991T is the prototype of the slowly declining Type Ia SNe. Phillips et al. (1999) give $\Delta m_{15}(B) = 0.94 \pm 0.05$ for this object. While SN 1991T was originally considered significantly overluminous (Riess, Press & Kirshner 1996), Gibson & Stetson (2001) recently obtained a Cepheid distance to the host galaxy, NGC 4527. Their distance modulus of $m - M = 30.562 \pm 0.085$ mag indicates that this object has optical absolute magnitudes at maximum *comparable* to Type Ia SNe with mid-range decline rates.

Data of Lira et al. (1998) indicate that the B-band maximum of SN 1991T occurred on 1991 April 29.2 UT (JD 2,448,375.7). Menzies & Carter (1991) reported JHK data taken on April 17.96 UT, some 11.2 days prior to $T(B_{max})$. Menzies (2004, private communication) indicates that these measurements were taken with a 0.75-m telescope at South African Astronomical Observatory and a single channel photometer giving a 36 arcsec diameter beam. The instrument looked at two sky patches approximately 3 arcmin north and south of the SN location.

Harrison & Stringfellow (1991) have previously reported JHK photometry of SN 1991T obtained on 1991 June 22 UT with the Australian National University's 2.3-m telescope at Siding Spring. Here we report two previously unpublished nights of ANU 2.3-m infrared

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[21] Effectively, the code gives total reddening. It assumes that the Galactic reddening from Schlegel, Finkbeiner & Davis (1998) is correct. Arce & Goodman (1999) discuss possible systematic errors in the Galactic reddening of Schlegel et al. But if the Schlegel et al. reddening used by us is systematically too *large* by a certain amount, then our derived value of the host galaxy reddening should be systematically too *small* by exactly the same amount. This is to say that there should be no systematic error in our effective value of total reddening, which is what we desire most for accurate supernova distances.

data (see Table 3), taken 5.05 and 6.10 days after T(B_{max}). These observers used a single channel InSb detector, 10 arcsec diameter beam, and a 20 arcsec chop in the north-south direction. Finally, we note that these data are on the MSSSO infrared standard system. For subsequent calculations we have slightly corrected them to the system of Elias et al. (1982) using the linear transformations given by McGregor (1994).

Given that these previously unpublished data were taken within 10 days of the presumed time of the IR maxima, we can then use the templates of Paper V and the Cepheid distance of the host to estimate the absolute magnitudes at maximum. We adopted E$(B-V)_{Gal}$ = 0.022 mag from Schlegel, Finkbeiner & Davis (1998) and E$(B-V)_{host}$ = 0.14 ± 0.05 (Phillips et al. 1999). With R_V = 3.1, A_V = 0.50 mag. Standard Cardelli, Clayton, & Mathis (1989) extinction parameters then give A_J = 0.14, A_H = 0.10, and A_K = 0.06 mag.

2.3. SN 1991bg

SN 1991bg is the prototype of the rare fast declining Type Ia SNe. According to Li et al. (2001a), only 16 percent of Type Ia SNe discovered in a distance-limited survey are like SN 1991bg. The fast decliners are intrinsically red at maximum light compared to mid-range and slow decliners and lack the secondary maximum in the I-band light curves. They are subluminous by 2 to 3 magnitudes in the V- and B-bands. The fast decliners are probably explosions of C-O white dwarfs yielding the smallest amounts (≈ 0.1 $M_{\odot}$) of ^{56}Ni (Stritzinger & Leibundgut 2004, and references therein).

Filippenko et al. (1992) and Leibundgut et al. (1993) give optical CCD photometry of SN 1991bg. The maximum brightness in V occurred on 1991 December 14.7 UT (JD2,448,605.2). The time of B-band maximum is not as well contrained by the fewer B-band data, but if SN 1991bg behaved like SN 1999by, an equally fast decliner (Garnavich et al. 2004), then the B-band maximum of SN 1991bg probably occurred about 2 days prior to T(V_{max}). We will assume that T(B_{max}) occurred at JD2448603.2. For the purpose of calculating absolute magnitudes we assume a distance modulus of $m - M$ = 31.32 ± 0.11 (Tonry et al. 2001) for NGC 4374 (the host of SN 1991bg), which is based on the method of Surface Brightness Fluctuations (SBF's).

Porter et al. (1992) presented an AAS poster discussing five nights of JHK data and the bolometric light curve of SN 1991bg. However, Alain Porter died in 1993 and the data were never published. We have acquired the raw data used by Porter for the critical 3 nights near maximum light taken by Stanford, Eisenhardt, & Dickinson (1995). The data were taken with the Kitt Peak National Observatory 1.3-m telescope using the Simultaneous Quad-color

Infrared Imaging Device (SQIID). This camera contained four low quantum efficiency 256 $\times$ 256 PtSi arrays. The plate scale on the 1.3-m telescope was 1.36 arcsec per pixel. SQIID took simultaneous $JHKL'$ images, but the L' images were not saved.

We used images obtained by Stanford et al. to characterize the non-linearities of SQIID. We calibrated SN 1991bg directly using bright IR standards of Elias et al. (1982) on the photometric night of 15 December 1991 and determined the JHK magnitudes of field stars A and J of Leibundgut et al. (1993). We confirmed that no color terms need to be used for the determination of the J and K data with SQIID, but there is a substantial color term for H, namely -0.261 ± 0.053, scaling $H - K$. This is in agreement with the value found by Stanford et al. (see their §3).

We list the JHK magnitudes of stars A and J in Table 2. In Table 3 we give the JHK photometry of SN 1991bg derived from SQIID images. The two remaining nights of the Porter data in the J-band were obtained by E. Lada et al. (2004 private communication) in January of 1992 but are not included in our paper. Porter et al. (1992) state that SN 1991bg faded by three magnitudes in the J-band in the month after maximum light.

2.4. SN 1999ek

SN 1999ek was discovered in UGC 3329 by Johnson & Li (1999) from images taken on 1999 October 20.5 (JD 2,451,472.0) and 21.4 UT at α = 05:36:31.6, δ = +16:38:18 (equinox 2000), at 11.7 arcsec west and 12.1 arcsec south of the core of UGC 3329. Strolger et al. (1999) reported that spectra taken on October 25 and 26 UT indicated that SN 1999ek was a Type Ia SN at or near maximum light. Jha et al. (1999) report that a spectrum taken on October 30.46 UT confirms the SN typing and age with respect to maximum.

This supernova, located at a Galactic latitude of -8 degrees, has a large Galactic reddening according to Schlegel, Finkbeiner & Davis (1998) at E$(B - V)$ = 0.561 mag. We note that Arce & Goodman (1999) find that for $A_V > 0.5$ mag, the Schlegel, Finkbeiner & Davis maps overestimate the reddening by a factor of 1.3 to 1.5.

All our optical data of SN 1999ek were obtained with the CTIO 0.9-m telescope. Our image subtraction templates were obtained with the CTIO 1.5-m telescope on 2001 November 12 UT. The JH infrared templates were obtained with the LCO 1-m telescope on 2000 November 17 UT.

Our IR data of this object were obtained with the 1.2-m telescope of the Fred L. Whipple Observatory at Mt. Hopkins, Arizona (1 night), the YALO 1-m at CTIO (7 nights) and the

Steward Observatory 2.3-m at Kitt Peak (5 nights). The Steward data were obtained with a 256 × 256 HgCdTe NICMOS detector (Rieke et al. 1993). We found that the images could not be flattened and sky-subtracted well. As a result, the Steward data should be considered only approximate (± 0.08 mag). In Table 4 we give the internal errors of the photometry.

In Tables 4 and 5 we give the optical and IR data of SN 1999ek. We took no K_s-band imagery of this field with the LCO 1-m, and the one night of FLWO imagery was not photometric. We have opted to use the K-band values of the nearby field stars from 2MASS to calibrate the single night of K-band data of SN 1999ek.

In Fig. 5 we show the optical and IR light curves of SN 1999ek. We include some optical photometry of Jha (2002) which is consistent with our data at the 0.01 mag level at JD 2,451,487.

Using the light curve fitting code of Prieto, Rest & Suntzeff (2005) we derive $E(B-V)_{total} = 0.76 \pm 0.05$ mag for SN 1999ek. The implied host reddening is $E(B-V)_{host} = 0.76 - 0.56 = 0.20$ mag. The implied total extinction is $A_V = 2.37 \pm 0.16$ mag, assuming $R_V = 3.1$ for both components of reddening.

Using the unreddened $V-H$ locus for mid-range decliners (Paper V, Table 14), we derive $E(V-H) = 1.83 \pm 0.05$ mag for SN 1999ek using only the LCO infrared data. This gives $A_V = 2.25 \pm 0.12$ mag. Thus, in the case of SN 1999ek, the method of combining optical and IR photometry for mid-range decliners discussed in Papers I, II, III, and V gives a value of A_V consistent with the Δm_{15} method.

2.5. SN 2001bt

SN 2001bt was discovered by Chassagne (2001a) from images taken on 2001 May 24.0 (= JD 2,452,053.0) and 24.9 UT. It is located at α = 19:13:46.8, δ = −59:17:23 (equinox 2000), 14.1 arcsec west and 17.1 arcsec north of the nucleus of IC 4830. From a spectrum obtained on May 26 UT with the LCO 2.5-m telescope Phillips & Krisciunas (2001) deduced that SN 2001bt was a Type Ia SN at or near maximum.

Tables 6 and 7 contain our photometry of SN 2001bt itself. Fig. 6 shows the optical and IR photometry of SN 2001bt.

The data obtained with the LCO 2.5-m telescope have much smaller internal errors than the data from the YALO 1-m telescope at a comparable epoch near maximum light. Our values of the maximum IR magnitudes of SN 2001bt hinge much more on the LCO photometry, for which no filter corrections are necessary as well, to place the data on the filter system of Persson et al. (1998).

2.6. SN 2001cn

SN 2001cn was also discovered by Chassagne (2001b) from images of 2001 June 11.95 (= JD 2,452,072.45) and 12.85 UT. It is located at α = 18:46:17.8, $\delta = -65$:45:42 (equinox 2000), 2.6 arcsec west and 17.9 arcsec south of the nucleus of IC 4758. Candia et al. (2001) report that a spectrum obtained by D. Norman and K. Olsen on June 14.3 UT with the CTIO 1.5-m telescope showed that SN 2001cn was a Type Ia SN near maximum light.

Tables 8 and 9 contain our photometry of SN 2001cn itself. Fig. 7 shows the optical and IR photometry of SN 2001cn.

2.7. SN 2001cz

Yet another SN was discovered by Chassagne (2001c) from images taken on 2001 July 4.64 (= JD 2,452,095.14) and 5.61 UT. SN 2001cz is located at α = 12:47:30.2, $\delta = -39$:34:48 (equinox 2000), 0.6 arcsec west and 31.4 arcsec south of the nucleus of NGC 4679. Pastorello et al. (2001) obtained a spectrum on July 12.01 UT with the Danish 1.54-m telescope at La Silla, finding the new object to be a Type Ia SN within 2 d of maximum light. Tables 10 and 11 contain our photometry of SN 2001cz itself. Fig. 8 shows the optical and IR photometry of SN 2001cz.

In Fig. 1d we mark a previously unknown RR Lyrae star. Its V magnitude ranges from 16.20 to 16.72, and its period is 0.6405 d. For more details see Krisciunas et al. (2004c). According to Schlegel, Finkbeiner & Davis (1998), the Galactic reddening in the direction of NGC 4679 is $E(B-V) = 0.092$. Assuming $R_V = 3.1$, the V-band extinction is then 0.285 mag. With $\langle V \rangle = \frac{1}{2}$ (V_{max} + V_{min}) + 0.07 (Smith 1995, p. 27), and adopting a mean absolute magnitude $M_V = +0.7$ (Layden et al. 1996), the distance to the new RR Lyr star is roughly 12.9 kpc. It is located some 5 kpc above the Galactic plane.

2.8. SN 2002bo

SN 2002bo was independently discovered by Cacella & Hirose (2002) on 2002 March 9 UT. Nakano et al. (2002) give a position of α = 10:18:06.5, δ = +21:49:42 (equinox 2000), some 11.6 arcsec east and 14.2 arcsec south of the nucleus of the SA galaxy NGC

3190. Kawakita et al. (2002) and Benetti et al. (2002) obtained spectra on March 9 and 10, respectively, which showed that SN 2002bo was a Type Ia SN 10 to 12 days before maximum. According to NED, the heliocentric redshift of NGC 3190 is 1271 km s^{-1}, or $z = 0.0042$, a very nearby galaxy.

NGC 3190 is a member of the Leo III group (Garcia 1993). Tonry et al. (2001, their Table 1) determined SBF distances of two possible members of this group. They obtained $m - M = 32.66 \pm 0.18$ for NGC 3193 and $m - M = 31.86 \pm 0.24$ for NGC 3226. From dynamical information Benetti et al. (2004) obtained a distance modulus for SN 2002bo of 31.67 mag on a scale of $H_0 = 65$ km s^{-1} Mpc^{-1}. Correcting to an $H_0 = 72$ scale, this becomes $m - M = 31.89$, close to the measured SBF distance modulus of NGC 3226, but in significant disagreement with the distance modulus of NGC 3193.

A similar distance estimate can be obtained by using the flow model of Tonry et al. (2000). One uses the Supergalactic coordinates of NGC 3190 to calculate the flow velocities along the vector towards the galaxy. A distance is recovered when the flow velocity matches the radial velocity of the galaxy with respect to the Cosmic Microwave Background. For SN 2002bo we find $v_{flow} = v_{CMB}$ at a distance modulus of 31.69 on the $H_0 = 78.4$ scale of Tonry et al.. This is equivalent to a distance modulus of 31.87 on an $H_0 = 72$ scale, corresponding almost exactly to the SBF distance modulus of NGC 3226 on the same scale. We will adopt the distance modulus for NGC 3226, 31.86 ± 0.24, as the distance modulus to SN 2002bo. The equivalent recession velocity in the CMB frame would be 1696 km s^{-1}.

For the CTIO 0.9-m data we used images of 2003 January 3 UT as image subtraction templates. For the CTIO 1.5-m data we used subtraction templates obtained with that telescope on 2003 January 30 UT. All the YALO 1-m data are derived from PSF magnitudes without image subtraction templates.

Without S-corrections the U-band photometry of SN 2002bo obtained with the YALO, CTIO 0.9-m and 1.5-m telescopes shows systematic differences up to 0.4 mag due to the lack of ultraviolet response below 3500Å in the SITe CCDs on the CTIO telescopes. If we calculate S-corrections based on our best knowledge of the U-band filters for the CTIO and the YALO telescopes, we still find small differences between the two filter systems. To improve the fits, we shifted the two filter functions until we matched the color terms from synthetic photometry of spectrophotometric standards with color terms obtained from actual broad-band photometry of stars. We found we needed to shift the nominal CTIO 0.9-m U-band filter profile 40 Å to shorter wavelengths. The ANDICAM U-band filter profile had to be shifted 30 Å toward longer wavelengths. The color term, based on actual photometry of stars, as opposed to synthetic photometry, is $+0.107 \pm 0.010$ (scaling $U - B$) for the CTIO 0.9-m telescope and -0.084 ± 0.020 for YALO.

Benetti et al. (2004) give MJD = 52356.0 ± 0.5 ≡ Julian Date 2,452,356.5 as the time of T(B_{max}) for SN 2002bo. From CTIO data only we obtain T(B_{max}) = JD 2,452,356.5 ± 0.2, in agreement with the value of Benetti et al..

In Tables 12 and 13 we present our optical and IR photometry of SN 2002bo. In Fig. 9 we show the optical and IR light curves of SN 2002bo, including the data of Benetti et al. (2004). Szabo et al. (2003) have also published 11 nights of VRI data for SN 2002bo.

The premaximum data of SN 2002bo do not fit our JHK templates very well, the data being roughly 0.3 mag fainter than the template (see Fig. 10). However, it should be noted that our templates are based on very few data points obtained more than a week before T(B_{max}). Still, because we actually measured this SN at maximum, we do not need to use our templates to determine what the observed maxima were.

In Fig. 11 we show the V *minus* near-IR color curves of SN 2002bo. We also plot the unreddened loci for mid-range decliners (Papers I and V), adjusted by the implied color excesses to minimize the reduced χ^2 values of the fits. The reader will notice immediately that the loci based on other objects do not fit these color curves very well, especially around day 10. The reduced χ^2 values range from 2 to 4, and the data fail to match the templates by up to 0.3 mag at 10 days after T(B_{max}).

The implied values of A_V are 0.71 ± 0.16 from E($V-J$), 0.64 ± 0.09 from E($V-H$), and 0.51 ± 0.08 from E($V-K$). While these three values are statistically equal, within the errors (the weighted mean being 0.59 ± 0.06), the color excesses listed in Fig. 11 do not *increase* from $V-J$ through $V-K$, as they ought to. The optical photometry of SN 2002bo indicates that $E(B-V)_{total} = 0.39 \pm 0.02$, implying $A_V = 1.21$ *if* $R_V = 3.1$. Conversely, if the host galaxy extinction is $A_{V,host} = 0.59 - 3.1 \times 0.025 = 0.51$ [using $E(B-V)_{Gal}$ from Table 15], and $E(B-V)_{host} = 0.365$, it follows that $R_{V,host} = 1.40$. This would imply very non-standard dust in the host galaxy. We feel it is most likely that the odd implied color excesses of SN 2002bo are due to its having abnormal unreddened colors.

From spectroscopic evidence Benetti et al. (2004) suggest that the unusually low temperature of SN 2002bo, the presence of high-velocity intermediate-mass elements and the low abundance of carbon at early times indicates that the silicon burning in this object penetrated to much higher layers than in more normal Type Ia SNe. Whatever the physical explanation, the spectral energy distributions (SEDs) in the V- and near-IR bands were considerably different than other Type Ia SNe we have studied. As a result there may be *no* color index that can be used to obtain a reliable value of A_V for this unusual object.

2.9. Spectral Observations

Spectral observations were obtained for three of the program supernovae. A log of the observations is given in Table 14. For the spectra taken with the CTIO 1.5-m telescope, the facility Cassegrain spectrograph was used with two grating setups. The gratings have the following specifications listed as (lines per mm, blaze, resolution at 5000 Å, Ångströms per pixel): grating 09, (300, 4000 Å, 7.3 Å, 2.88 Å px^{-1}); grating 13, (150, 5000 Å, 14 Å, 5.7 Å px^{-1}). The CCD is a Loral 1200 × 800 pixel detector with excellent ultraviolet response. The detector fringes redward of 8000 Å. Although the wavelength coverage using grating 13 covers more than an octave, we did not use an order blocking filter to remove the blue contamination from first order red. These spectra will be contaminated by blue light longward of 6600 Å. Because of flexure in the spectrograph, wavelength calibration spectra were taken at every slew position. We observed spectrophotometric standards from the lists of Hamuy et al. (1992, 1994). The supernovae were observed through 2 and 10 arcsec slits, and the standards through a 10 arcsec slit. The slit length was roughly 4 arcmin.

The data were reduced to fluxes with the SPECRED package in IRAF. The CCD data were bias subtracted, trimmed, and flat-fielded using either dome flats or twilight spectra. In the case of the twilight spectra, the solar lines were removed by filtering. The data were wavelength calibrated to an accuracy of ≈0.1 pixel residual in the fit. The underlying galaxy spectra was removed by interpolating the galaxy flux across the position of the supernova. The spectra were brought to an absolute flux scale with reference to the Hamuy et al. spectrophotometric standards and standard extinction tables. To cover the full ultraviolet range, the table of fluxes of the standard stars was extrapolated to 3100 Å by fitting a quadratic function over the range 3300 to 3650 Å. The small slit data were corrected to the flux scale of the 10 arcsec observations. Not all the nights were photometric, so the flux scale should be considered as a relative scale.

We present the spectra in Fig. 12. We also include two spectra of SN 1999ee which were observed on the same nights as SN 1999ek but not included in the Hamuy et al. (2002) study of that supernova. We also include two earlier time spectra of SN 1999ee from Hamuy et al. (2002) to provide a spectral sequence of a normal Type Ia over the epoch of observations of our program supernovae. From a comparison of the features of the SNe shown in Fig. 12 with spectra given by Filippenko (1997), we find that the program supernovae were caught within a week of T(B_{max}).

3. Discussion

Using the infrared light curve templates of Paper V, which indicate IR maxima about 3 days prior to T(B_{max}), we find that SN 1991T, the prototype of the slowly declining Type Ia supernovae, had implied IR absolute magnitudes at maximum quite comparable to our sample of slow decliners and mid-range decliners. The IR data given by Menzies & Carter (1991), obtained 11.2 days prior to T(B_{max}), are between 1.1 and 1.8 magnitudes brighter than our templates. Either their measurements included a significant amount of host galaxy light, or the behavior of this object long before T(B_{max}) was different than any object studied to date.

While the observations of SN 1991bg presented here and those of SN 1999by by Höflich et al. (2002) and Garnavich et al. (2004) do not allow us to constrain fully the IR maxima of these two objects, because of the rarity of the fast declining Type Ia SNe and the paucity of IR data on these objects, some comments are in order. Firstly, SN 1999by was observed close enough to maximum light that we can derive *H*- and *K*-band maxima for SN 1999by. The *J*-band maximum of SN 1999by was likely no more than 0.1 mag brighter than the observation made 2 days prior to T(B_{max}). Likewise, the *JHK* observations of SN 1991bg 0.85 days after T(V_{max}) must have been less than 0.1 mag from the IR maxima. Thus, we can compare the luminosities and intrinsic colors of two fast decliners (with essentially zero host reddening) with the larger number of Type Ia SNe of mid-range and slow decline rates. The case of SN 1986G, which had $\Delta m_{15}(B)$ almost as large, is complicated by its substantial and uncertain reddening (see Krisciunas et al. 2004a, and references therein).

In Fig. 13 we show the colors at maximum of the better sampled objects shown in Fig. 12 of Krisciunas et al. (2004b) along with the near-maximum colors of SNe 1991bg and 1999by. The purpose of this graph is merely to demonstrate the intrinsic redness of the fast decliners in the V *minus* near-IR color indices. Fig. 16 of Garnavich et al. (2004) shows the $B - V$ colors at maximum vs. $\Delta m_{15}(B)$ and also demonstrates that Type Ia SNe with $\Delta m_{15}(B) \gtrsim 1.7$ exhibit much redder colors than Type Ia SNe with lesser decline rates.

In Table 15 we summarize the basic data for the five SNe with mid-range decline rates presented in this paper. Listed are: the velocity of recession with respect to the Cosmic Microwave Background radiation (using the NED velocity calculator for objects with redshift greater than 3000 km s^{-1}), the time of *B*-band maximum, the decline rate $\Delta m_{15}(B)$, and the Galactic and host contributions of the $B-V$ color excess. We assumed values of E$(B-V)_{Gal}$ from Schlegel, Finkbeiner & Davis (1998). In Table 15 the values of E$(B-V)_{host}$ are derived from optical data alone.

In Table 16 we give the apparent magnitudes at maximum for the objects discussed in this paper and their extinction-corrected values. We adopt the values of A_λ / A_V = 0.282, 0.190, and 0.114 for the J-, H-, and K-bands, respectively, given by Cardelli, Clayton, & Mathis (1989) in their Table 3, column [5].

In Fig. 14 we show the Hubble diagrams of Type Ia SNe for the near-IR JHK bands, adding objects from this paper to Fig. 2 of Krisciunas et al. (2004a). In Fig. 15 we show the JHK absolute magnitudes at maximum light versus the redshift for Type Ia SNe of mid-range and slow decline rates. There is no obvious trend, indicating that the absolute magnitudes are uniform to a look back time of 0.5 Gyr. Fig. 16 shows the JHK absolute magnitudes at maximum light versus the decline rate parameter $\Delta m_{15}(B)$. As found by Krisciunas et al. (2004a), the absolute magnitudes show no obvious correlations with the optical decline rate parameter until we consider the fastest decliners. Thus, Type Ia SNe with $\Delta m_{15}(B) \lesssim 1.7$ can be considered standard candles at maximum light in the near-IR. We note that in spite of the peculiarities of the light curves and implied color excesses of SN 2002bo, the small *infrared* extinction corrections and the uniformity of IR absolute magnitudes at maximum give this object IR absolute magnitudes similar to "normal" Type Ia SNe.

In Table 17 we give the mean absolute magnitudes of our growing sample of Type Ia SNe and the 1-σ distribution widths. This is an update of the corresponding table of Krisciunas et al. (2004a). None of the numbers has changed significantly.

Not only is the extinction much lower in the near-IR compared to the rest frame optical bands, but we can use the JHK infrared templates to derive the maximum magnitudes if data are taken in the time frame of −12 to +10 days with respect to T(B_{max}). If the implied distances of high redshift SNe derived from *rest frame* J- or H-band photometry are in agreement with the distances derived from rest frame UBV photometry, that will increase our confidence in the adopted extinction corrections. Also, it will give us confidence that Type Ia SNe that exploded billions of years ago are fundamentally the same type of objects we now observe in nearby galaxies.

Because Type Ia SNe are standard candles in the near-IR, except for the objects with the largest possible decline rates, it would be ideal if high-redshift supernovae are observed in the $H-$ or $K-$bands so that we might exploit the advantages of observing these important objects at least in the rest frame J-band. The IR bandpasses are closer to notch filters[22] than the optical bands, and we would expect that the K-corrections should be small at "magic" redshifts where the J band redshifts to the effective wavelength of H or K, or the H band redshifts to K. This happens at z=0.33 ($J \Rightarrow H$, H_{max} = 21.8), z=0.73 ($J \Rightarrow K$,

[22]Having filter profiles with flat tops and minimal wings.

K_{max} = 23.1), and z=0.30 ($H \Rightarrow K$, K_{max} = 21.8) for the LCO system of Persson et al. (1998). It is unlikely that ground-based telescopes can reach the K-band detection at z=0.73, but the H-band detection of S/N=15 at z=0.3 is roughly one hour on an 8-m telescope in good conditions. With a few supernovae sampled roughly 4 times near maximum light, the effects of acceleration could be easily seen in the rest-frame J-band magnitudes.

4. Conclusions

In this paper we have provided optical and/or infrared photometry of the Type Ia supernovae SN 1991T, SN 1991bg, SN 1999ek, SN 2001bt, SN 2001cn, SN 2001cz, and SN 2002bo.

The previously unpublished near-IR data of SN 1991T are important because SN 1991T is the prototype of the slowly declining Type Ia SNe. These data were obtained close enough to T(B_{max}) that they allow us to estimate the absolute magnitudes at maximum of this object. Just as Gibson & Stetson (2001) found regarding the optical absolute magnitudes at maximum, we find that SN 1991T had IR luminosities at maximum comparable to other, spectroscopically normal, objects.

Also, because of the importance of SN 1991bg as the prototype of the fast declining Type Ia SNe, we felt it was worthwhile to re-reduce and publish the few infrared data near the epoch of maximum light without further delay. We also do this to honor our late colleague Alain Porter. Within the errors, SN 1991bg had a decline rate equal to that of SN 1999by. The absolute magnitudes near maximum light in the IR of these two objects were essentially the same, and roughly half a magnitude fainter than Type Ia SNe of mid-range and slow decline rates.

Benetti et al. (2004) have shown that SN 2002bo exhibited unusual SEDs. As a result, we cannot confidently derive a value of the extinction (A_V) toward this object, because we cannot compare its colors to other objects with similar SEDs which are known to be unreddened. Four objects presented in this paper have optical and IR light curves which are like many "normal" Type Ia SNe.

We have used a new program to carry out the Δm_{15} analysis for the $BVRI$ data (Prieto, Rest & Suntzeff 2005). As one can see in the corresponding figures, the derived light curve templates fit the $BVRI$ data very well.

Following up the work of Krisciunas et al. (2004a,b), we derived the extinction-corrected apparent (and absolute) magnitudes of five new mid-range decliners in the near-IR and confirmed that there is no apparent dependence of the absolute magnitudes at maximum versus the decline rate or the redshift for Type Ia SNe with $\Delta m_{15}(B) \lesssim 1.7$. The rms scatter of the absolute magnitudes is roughly ± 0.15 mag in the JHK bands. Thus, an individual object can give a distance good to ± 7 percent.

We made use of the NASA/IPAC Extragalactic Database (NED), the SIMBAD database, operated at CDS, Strasbourg, France, and the Two Micron All-Sky Survey (2MASS). We thank the Space Telescope Science Institute for the following support: HST GO-07505.02A; HST GO-08177.06 (the High-Z Supernova Team survey); HST GO-08641.07A was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555. We thank STScI for the salary support for P.C. from grants GO-09114 and GO-09421. We thank Stefano Benetti and Peter Meikle for many useful discussions about SN 2002bo and for sharing their optical and IR spectra. K.K. thanks LCO and NOAO for funding part of his postdoctoral position. Support for this work was provided to M.H. by NASA through Hubble Fellowship grant HST HF-01139.01A, awarded by the Space Telescope Science Institute. J. L. P. and N. B. S. thank Armin Rest for the idea of a continuous $\Delta m_{15}(B)$ parameterization. We thank Lisa Germany for making the mosaics of the LCO 2.5-m images of SN 1999ek.

We thank Michael Merrill and Richard Joyce for useful discussions relating to the reduction of the SN 1991bg data obtained with SQIID; and Gajus Miknaitis for help with reading two rather old data tapes.

We are grateful for access to telescopes at Cerro Tololo Inter-American Observatory, Kitt Peak National Observatory, Las Campanas Observatory, Steward Observatory, and the Fred L. Whipple Observatory.

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This preprint was prepared with the AAS LaTeX macros v5.2.

Table 1. Optical Photometry of Supernova Field Stars

SN field	star	U	B	V	R	I	N[a]
1999ek	1	···	14.766 (0.007)	13.909 (0.011)	13.361 (0.006)	12.807 (0.006)	3
...	2	···	15.863 (0.009)	15.017 (0.009)	14.463 (0.006)	13.902 (0.009)	3
...	3	···	17.117 (0.013)	16.276 (0.011)	15.723 (0.007)	15.168 (0.009)	3
...	4	···	14.266 (0.007)	13.460 (0.009)	12.935 (0.006)	12.408 (0.008)	3
...	5	···	13.592 (0.006)	12.855 (0.010)	12.374 (0.009)	11.878 (0.011)	3
...	6	···	16.106 (0.006)	14.600 (0.010)	13.761 (0.006)	12.979 (0.006)	3
...	7	···	14.420 (0.007)	13.661 (0.010)	13.169 (0.006)	12.674 (0.007)	3
...	8	···	16.249 (0.006)	15.325 (0.008)	14.729 (0.006)	14.128 (0.006)	3
...	9	···	15.492 (0.006)	14.168 (0.011)	13.387 (0.006)	12.635 (0.008)	3
...	10	···	15.273 (0.008)	14.196 (0.009)	13.525 (0.006)	12.877 (0.006)	3
2001bt	1	15.964 (0.068)	15.326 (0.006)	14.424 (0.005)	13.918 (0.012)	13.509 (0.005)	2
...	2	16.840 (0.076)	15.988 (0.011)	14.938 (0.009)	14.339 (0.012)	13.828 (0.003)	2
...	3	15.937 (0.068)	15.852 (0.007)	15.257 (0.007)	14.881 (0.013)	14.553 (0.007)	2
...	4	···	17.155 (0.007)	16.288 (0.017)	15.799 (0.016)	15.402 (0.007)	2
...	5	15.870 (0.068)	15.427 (0.004)	14.622 (0.005)	14.165 (0.011)	13.778 (0.007)	2
...	6	15.505 (0.066)	14.463 (0.004)	13.333 (0.003)	12.710 (0.011)	12.167 (0.006)	2
2001cn	2	15.372 (0.011)	15.004 (0.006)	14.393 (0.004)	13.674 (0.007)	14.284 (0.059)	4
...	3	16.145 (0.009)	15.698 (0.007)	14.891 (0.004)	14.037 (0.007)	14.445 (0.063)	4
...	4	16.556 (0.011)	16.174 (0.008)	15.522 (0.004)	14.769 (0.008)	15.418 (0.064)	4
...	5	16.577 (0.013)	15.982 (0.011)	14.925 (0.006)	13.792 (0.012)	13.944 (0.068)	4
...	6	16.415 (0.011)	16.020 (0.009)	15.399 (0.006)	14.639 (0.011)	15.157 (0.061)	4
...	7	17.378 (0.011)	16.629 (0.010)	15.457 (0.005)	14.056 (0.010)	···	4
...	8	17.495 (0.015)	17.083 (0.011)	16.401 (0.005)	15.611 (0.010)	···	4

Table 1—Continued

2001cz	1	15.490 (0.015)	15.031 (0.003)	14.173 (0.003)	13.696 (0.004)	13.265 (0.004)	7
...	2	14.907 (0.014)	14.716 (0.003)	13.990 (0.004	13.568 (0.005)	13.166 (0.003)	7
...	3	17.004 (0.018)	16.784 (0.006)	16.027 (0.003)	15.575 (0.003)	15.153 (0.003)	7
...	4	17.306 (0.021)	16.946 (0.007)	16.136 (0.004)	15.672 (0.004)	15.245 (0.004)	7
...	5	16.985 (0.017)	16.965 (0.007)	16.278 (0.004)	15.848 (0.003)	15.431 (0.004)	7
...	6	15.970 (0.018)	15.882 (0.004)	15.195 (0.003)	14.784 (0.004)	14.394 (0.003)	7
2002bo	1	15.715 (0.034)	15.252 (0.016)	14.435 (0.012)	14.000 (0.015)	13.597 (0.014)	7
...	2	19.643 (0.119)	18.529 (0.021)	17.213 (0.019)	16.391 (0.020)	15.666 (0.023)	5
...	3	15.938 (0.028)	15.691 (0.016)	14.929 (0.013)	14.492 (0.018)	14.076 (0.015)	7
...	4	13.250 (0.019)	13.046 (0.017)	12.414 (0.015)	12.066 (0.015)	11.703 (0.015)	3
...	5	15.224 (0.038)	15.072 (0.024)	14.366 (0.020)	13.970 (0.025)	13.613 (0.021)	3
...	6	16.253 (0.041)	16.291 (0.021)	15.644 (0.019)	15.278 (0.023)	14.922 (0.021)	4

[a]The number of nights of calibration measurements for a given star. Values in parentheses in this table (and others) are 1-σ error bars.

Table 2. Infrared Photometry of Supernova Field Stars

Field	star	J/J_s	H	K/K_s[a]	N_{obs}[b]
1991bg	A	11.803 (0.010)	11.164 (0.008)	11.002 (0.028)	1 1 1
...	J	10.822 (0.005)	10.585 (0.005)	10.574 (0.011)	1 1 1
1999ek	2	13.128 (0.006)	12.738 (0.008)	12.649 (0.022)	5 6 0
...	3	14.371 (0.015)	13.978 (0.005)	13.805 (0.044)	5 6 0
...	IR1	14.049 (0.012)	13.302 (0.004)	13.100 (0.028)	5 6 0
2001bt	1	12.878 (0.005)	12.492 (0.010)	12.380 (0.009)	2 2 2
2001cn	IR1	13.771 (0.013)	13.100 (0.011)	...	1 1 0
...	3	13.478 (0.010)	13.108 (0.009)	13.046 (0.029)	1 1 1
...	4	14.328 (0.012)	14.011 (0.012)	13.929 (0.037)	1 1 1
...	7	13.196 (0.010)	12.542 (0.009)	12.394 (0.027)	1 1 1
...	8	15.170 (0.016)	14.781 (0.017)	...	1 1 0
2001cz	6	13.846 (0.055)	13.547 (0.011)	13.481 (0.027)	2 1 1
2002bo	1	13.051 (0.009)	12.688 (0.008)	12.676 (0.035)	4 4 4

[a]The K-band values for the 1999ek stars are from 2MASS.

[b]Number of nights of observations that were used to determine the weighted means, for each of the three filters.

Table 3. Infrared Photometry of Type Ia Supernova Prototypes

Object	UT Date	JD[a]	J	H	K	Notes[b]
SN 1991T	1991 Apr 17	364.46	11.73	11.16	10.93	1
...	1991 May 4	380.75	12.45 (0.09)	12.44 (0.10)	12.28 (0.10)	2
...	1991 May 5	381.80	12.58 (0.10)	12.29 (0.10)	12.19 (0.10)	2
...	1991 Jun 22	429.86	14.97 (0.30)	13.72 (0.14)	13.71 (0.25)	2,3
SN 1991bg	1991 Dec 15	606.05	13.49 (0.03)	13.45 (0.04)	13.49 (0.05)	4
...	1991 Dec 16	606.06	13.51 (0.03)	13.44 (0.03)	13.41 (0.05)	4
...	1991 Dec 17	607.05	13.59 (0.04)	...	...	4

[a]Julian Date *minus* 2,448,000.

[b]1 = Menzies & Carter (1991); may include a significant amount of host galaxy light. 2 = data on MSSSO IR system (McGregor 1994). 3 = Harrison & Stringfellow (1991). 4 = data on Caltech IR system (Elias et al. 1982).

Table 4. Optical Photometry of SN 1999ek

JD[a]	B	V	R	I
478.840	18.061 (0.023)	17.401 (0.018)	16.901 (0.015)	16.557 (0.016)
478.840	18.048 (0.021)	17.378 (0.016)	16.883 (0.015)	16.569 (0.015)
479.836	17.987 (0.041)	17.362 (0.035)	16.778 (0.023)	16.479 (0.027)
479.840	17.925 (0.037)	17.351 (0.036)	16.770 (0.024)	16.520 (0.032)
480.758	18.070 (0.070)	17.324 (0.058)	16.760 (0.055)	16.574 (0.079)
480.758	17.984 (0.082)	17.339 (0.060)	16.856 (0.058)	16.573 (0.072)
481.785	17.938 (0.016)	17.250 (0.015)	16.807 (0.015)	16.574 (0.015)
481.789	17.930 (0.023)	17.278 (0.015)	16.820 (0.015)	16.580 (0.015)
483.863	17.955 (0.015)	17.250 (0.015)	16.817 (0.015)	16.675 (0.016)
483.867	17.913 (0.014)	17.240 (0.015)	16.824 (0.015)	16.681 (0.015)
484.734	17.968 (0.014)	17.243 (0.015)	16.834 (0.015)	16.705 (0.015)
484.738	17.983 (0.014)	17.268 (0.015)	16.850 (0.015)	16.699 (0.015)
485.801	17.998 (0.029)	17.300 (0.043)	···	16.751 (0.016)
485.805	18.034 (0.057)	17.291 (0.023)	16.816 (0.015)	16.795 (0.023)
486.824	18.069 (0.014)	17.275 (0.015)	16.875 (0.015)	16.788 (0.015)
486.824	18.062 (0.015)	17.284 (0.015)	16.870 (0.015)	16.765 (0.015)
487.812	18.108 (0.014)	17.325 (0.015)	16.902 (0.015)	16.851 (0.016)
487.812	18.103 (0.016)	17.317 (0.015)	16.901 (0.015)	16.814 (0.017)
488.813	18.182 (0.014)	17.364 (0.015)	16.978 (0.015)	16.917 (0.015)
489.762	18.289 (0.019)	17.394 (0.021)	17.032 (0.020)	16.961 (0.024)
489.766	18.258 (0.018)	17.410 (0.019)	17.044 (0.016)	16.966 (0.024)
490.844	18.358 (0.014)	17.455 (0.015)	17.128 (0.015)	17.096 (0.023)
490.848	18.374 (0.017)	17.468 (0.015)	17.138 (0.017)	17.058 (0.019)
492.859	18.552 (0.018)	17.583 (0.015)	17.301 (0.015)	17.223 (0.018)
492.871	18.541 (0.051)	17.562 (0.024)	17.298 (0.029)	17.222 (0.023)
493.812	18.668 (0.016)	17.647 (0.015)	17.354 (0.015)	17.287 (0.018)
493.828	18.672 (0.017)	17.654 (0.015)	17.350 (0.015)	17.230 (0.018)
501.848	19.654 (0.026)	18.116 (0.016)	17.547 (0.016)	17.175 (0.016)
501.852	19.671 (0.031)	18.131 (0.018)	17.526 (0.015)	17.162 (0.017)
503.695	20.384 (0.208)	18.300 (0.022)	17.663 (0.016)	···

Table 4—Continued

504.707	20.057 (0.176)	18.248 (0.025)	17.614 (0.017)	17.065 (0.016)
506.778	20.308 (0.206)	· · ·	· · ·	· · ·
508.836	20.312 (0.134)	18.518 (0.027)	17.722 (0.018)	17.075 (0.015)

[a]Julian Date *minus* 2,451,000.

Table 5. Infrared Photometry of SN 1999ek

JD[a]	J	H	K	Telescope[b]
473.99	· · ·	16.414 (0.115)	16.544 (0.076)	1
477.67	16.150 (0.039)	16.079 (0.040)	· · ·	2
477.80	16.124 (0.020)	16.281 (0.018)	· · ·	3
478.69	16.097 (0.050)	16.136 (0.050)	· · ·	2
481.82	16.209 (0.019)	16.331 (0.020)	· · ·	3
483.78	16.415 (0.023)	16.464 (0.038)	· · ·	4
484.81	16.436 (0.024)	16.485 (0.024)	· · ·	4
485.78	16.539 (0.024)	16.405 (0.163)	· · ·	4
486.82	16.908 (0.068)	16.676 (0.135)	· · ·	4
487.79	16.778 (0.023)	16.648 (0.025)	· · ·	4
488.80	16.935 (0.022)	16.645 (0.029)	· · ·	4
489.84	17.134 (0.023)	16.525 (0.031)	· · ·	4
497.66	17.819 (0.081)	16.455 (0.070)	· · ·	2
503.64	17.563 (0.065)	16.296 (0.059)	· · ·	2
504.67	17.441 (0.088)	16.253 (0.073)	· · ·	2

[a]Julian Date *minus* 2,451,000.

[b]1 = FLWO 1.2-m; 2 = Steward Observatory 90-inch; 3 = LCO 2.5-m; 4 = LCO 1-m.

Table 6. Optical Photometry of SN 2001bt

JD[a]	*B*	*V*	*R*	*I*	Telescope[b]
2055.78	16.260 (0.023)	16.096 (0.009)	15.817 (0.015)	· · ·	2
2061.90	15.577 (0.014)	15.414 (0.006)	15.212 (0.010)	15.305 (0.015)	2
2061.82	15.571 (0.011)	15.414 (0.007)	15.210 (0.016)	15.289 (0.013)	1
2064.77	15.522 (0.039)	15.319 (0.019)	15.147 (0.073)	15.359 (0.042)	1
2067.83	15.668 (0.012)	15.317 (0.008)	15.155 (0.018)	15.460 (0.014)	1
2070.82	15.856 (0.019)	15.393 (0.011)	15.266 (0.026)	15.567 (0.019)	1
2073.92	16.197 (0.030)	15.553 (0.018)	· · ·	15.760 (0.035)	1
2076.86	16.503 (0.020)	15.733 (0.008)	15.663 (0.023)	15.909 (0.025)	1
2079.89	16.945 (0.030)	15.967 (0.017)	15.778 (0.028)	15.880 (0.035)	1
2082.75	17.306 (0.021)	16.112 (0.011)	15.809 (0.022)	15.771 (0.019)	1
2085.74	17.689 (0.048)	16.301 (0.026)	15.869 (0.042)	15.761 (0.039)	1
2088.70	17.937 (0.033)	16.451 (0.019)	16.006 (0.031)	15.747 (0.031)	1
2091.68	18.156 (0.045)	16.678 (0.017)	16.144 (0.031)	15.794 (0.026)	1
2094.81	18.410 (0.178)	16.875 (0.047)	· · ·	16.044 (0.079)	1
2096.78	· · ·	16.978 (0.035)	16.529 (0.070)	16.238 (0.063)	1
2097.67	18.529 (0.088)	17.102 (0.028)	16.566 (0.051)	16.200 (0.043)	1
2101.75	18.574 (0.161)	17.409 (0.061)	· · ·	16.493 (0.105)	1
2106.64	18.791 (0.088)	17.438 (0.041)	17.005 (0.067)	16.733 (0.061)	1
2115.86	18.904 (0.039)	17.663 (0.014)	17.285 (0.025)	17.055 (0.030)	1
2122.67	18.923 (0.099)	17.823 (0.027)	17.453 (0.060)	17.345 (0.084)	1
2123.65	18.920 (0.051)	17.869 (0.011)	17.507 (0.024)	17.403 (0.027)	1
2128.75	19.121 (0.077)	17.958 (0.041)	17.626 (0.060)	17.605 (0.062)	1
2131.76	19.014 (0.041)	18.048 (0.013)	17.750 (0.025)	17.762 (0.042)	1

[a]Julian Date *minus* 2,450,000.

[b]1 = YALO 1-m; 2 = CTIO 1.5-m.

Table 7. Infrared Photometry of SN 2001bt

JD[a]	*J*	*H*	*K*	Telescope[b]
2061.81	15.472 (0.029)	15.695 (0.061)	15.562 (0.078)	1
2061.85	15.420 (0.015)	15.645 (0.020)	15.399 (0.026)	2
2064.76	15.342 (0.073)	15.895 (0.160)	15.629 (0.275)	1
2068.83	16.163 (0.041)	16.120 (0.051)	···	2
2069.83	16.291 (0.036)	16.163 (0.045)	15.653 (0.030)	2
2070.81	16.244 (0.051)	16.087 (0.091)	15.944 (0.208)	1
2073.92	17.029 (0.118)	16.226 (0.190)	15.860 (0.217)	1
2076.86	17.168 (0.071)	16.221 (0.114)	15.875 (0.126)	1
2079.89	17.010 (0.088)	16.048 (0.143)	15.776 (0.151)	1
2082.75	17.051 (0.062)	15.930 (0.094)	···	1
2088.70	16.649 (0.042)	15.669 (0.066)	15.743 (0.096)	1
2091.67	16.435 (0.037)	15.783 (0.065)	15.827 (0.102)	1
2094.80	16.633 (0.089)	15.934 (0.199)	···	1
2096.78	16.733 (0.081)	16.077 (0.130)	···	1
2097.66	16.785 (0.047)	16.156 (0.079)	···	1
2101.70	17.355 (0.163)	16.254 (0.251)	17.003 (0.538)	1
2106.63	17.677 (0.078)	16.578 (0.123)	17.276 (0.259)	1
2115.84	18.052 (0.116)	16.942 (0.184)	···	1
2122.65	18.904 (0.234)	17.227 (0.342)	···	1
2123.63	18.747 (0.149)	17.275 (0.221)	···	1
2128.73	19.428 (0.277)	17.450 (0.401)	···	1

[a]Julian Date *minus* 2,450,000.

[b]1 = YALO 1-m; 2 = LCO 2.5-m.

Table 8. Optical Photometry of SN 2001cn

JD[a]	U	B	V	R	I	Telescope[b]
2075.85	···	15.559 (0.013)	15.312 (0.008)	15.162 (0.011)	15.470 (0.013)	2
2075.84	···	15.639 (0.014)	15.289 (0.007)	15.182 (0.016)	15.479 (0.016)	1
2076.80	15.716 (0.057)	15.611 (0.022)	15.332 (0.013)	15.196 (0.020)	15.524 (0.022)	2
2076.85	···	15.631 (0.023)	15.312 (0.015)	15.204 (0.024)	15.582 (0.024)	1
2077.79	15.805 (0.059)	15.676 (0.023)	15.365 (0.013)	15.233 (0.020)	15.573 (0.023)	2
2078.80	15.868 (0.062)	15.759 (0.022)	15.410 (0.013)	15.300 (0.019)	15.650 (0.023)	2
2079.73	···	15.785 (0.015)	15.411 (0.010)	15.350 (0.019)	15.757 (0.018)	1
2082.71	···	16.099 (0.008)	15.556 (0.005)	15.556 (0.008)	15.989 (0.010)	1
2085.71	···	16.425 (0.009)	15.765 (0.005)	15.739 (0.010)	16.084 (0.033)	1
2088.67	···	16.822 (0.011)	15.930 (0.006)	15.817 (0.010)	16.041 (0.014)	1
2091.65	···	17.173 (0.019)	16.103 (0.005)	15.865 (0.008)	15.941 (0.010)	1
2094.81	···	17.532 (0.020)	16.264 (0.005)	15.929 (0.010)	15.874 (0.015)	1
2096.72	···	17.729 (0.059)	16.394 (0.033)	15.972 (0.049)	15.809 (0.061)	1
2097.71	···	17.800 (0.021)	16.435 (0.009)	16.007 (0.015)	15.836 (0.029)	1
2101.72	···	18.086 (0.018)	16.724 (0.010)	16.232 (0.017)	15.903 (0.017)	1
2104.67	···	18.275 (0.018)	16.901 (0.006)	16.435 (0.011)	16.085 (0.011)	1
2106.67	···	18.379 (0.016)	17.029 (0.006)	16.569 (0.011)	16.262 (0.017)	1
2114.86	···	18.667 (0.026)	17.378 (0.010)	16.995 (0.025)	16.787 (0.027)	1
2117.81	···	18.664 (0.033)	17.461 (0.012)	17.071 (0.023)	16.903 (0.081)	1
2122.62	···	18.763 (0.071)	17.634 (0.030)	17.201 (0.047)	17.117 (0.053)	1
2123.61	···	18.757 (0.035)	17.613 (0.011)	17.255 (0.019)	17.141 (0.020)	1
2127.67	···	18.846 (0.075)	17.747 (0.038)	17.399 (0.057)	17.309 (0.061)	1
2130.76	···	18.897 (0.056)	17.763 (0.030)	17.463 (0.044)	17.408 (0.066)	1

Table 8—Continued

2140.72	···	19.057 (0.054)	18.059 (0.022)	17.794 (0.035)	17.774 (0.046)	1
2156.71	···	19.127 (0.080)	18.546 (0.040)	18.278 (0.077)	18.361 (0.111)	1

[a]Julian Date *minus* 2,450,000.

[b]1 = YALO 1-m; 2 = CTIO 0.9-m.

Table 9. YALO Infrared Photometry of SN 2001cn

JD[a]	J	H	K
2075.84	15.899 (0.028)	16.084 (0.062)	15.667 (0.095)
2076.84	16.171 (0.046)	16.144 (0.071)	15.684 (0.099)
2079.73	16.561 (0.044)	16.088 (0.077)	15.829 (0.104)
2082.71	17.011 (0.035)	16.164 (0.058)	···
2085.69	17.379 (0.059)	16.039 (0.095)	···
2088.67	17.191 (0.036)	15.907 (0.056)	···
2091.64	17.130 (0.036)	15.829 (0.057)	···
2094.74	16.959 (0.036)	15.873 (0.071)	···
2096.72	16.842 (0.040)	15.707 (0.069)	···
2097.69	16.831 (0.034)	15.665 (0.054)	···
2101.70	16.560 (0.031)	15.792 (0.052)	···
2104.66	16.629 (0.029)	15.895 (0.048)	···
2106.66	16.796 (0.030)	16.072 (0.049)	···
2114.84	17.716 (0.085)	16.606 (0.136)	···
2117.47	17.896 (0.079)	16.808 (0.128)	···
2122.60	18.273 (0.153)	16.887 (0.232)	···
2123.60	18.400 (0.103)	16.905 (0.156)	···
2127.66	18.401 (0.135)	17.445 (0.216)	···
2130.76	18.855 (0.193)	17.449 (0.301)	···

[a]Julian Date *minus* 2,450,000.

Table 10. Optical Photometry of SN 2001cz

JD[a]	U	B	V	R	I	Telescope[b]
2097.50	15.297 (0.045)	15.740 (0.037)	15.682 (0.034)	15.489 (0.040)	15.474 (0.037)	2
2101.53	···	15.465 (0.012)	15.307 (0.006)	15.202 (0.015)	15.304 (0.013)	1
2104.47	···	15.436 (0.016)	15.240 (0.010)	15.136 (0.018)	15.378 (0.017)	1
2106.47	···	15.474 (0.010)	15.264 (0.006)	15.160 (0.014)	15.432 (0.013)	1
2112.53	···	15.843 (0.022)	15.449 (0.013)	15.450 (0.028)	15.767 (0.028)	1
2114.48	···	15.957 (0.018)	15.535 (0.012)	15.555 (0.023)	15.885 (0.022)	1
2117.48	···	16.237 (0.014)	15.735 (0.006)	15.721 (0.018)	16.081 (0.017)	1
2123.47	···	16.944 (0.021)	16.061 (0.009)	15.855 (0.022)	15.973 (0.025)	1
2128.48	···	17.488 (0.070)	16.291 (0.019)	15.931 (0.033)	15.872 (0.032)	1
2130.49	···	17.694 (0.040)	16.432 (0.024)	16.008 (0.039)	15.826 (0.036)	1
2137.49	···	18.203 (0.085)	16.858 (0.012)	···	···	1
2144.48	···	18.462 (0.041)	17.195 (0.008)	16.767 (0.033)	16.462 (0.025)	1
2151.49	···	18.608 (0.040)	17.457 (0.018)	17.136 (0.031)	16.801 (0.033)	1
2155.51	···	18.623 (0.164)	17.591 (0.045)	···	···	1

[a]Julian Date *minus* 2,450,000.

[b]1 = YALO 1.0-m; 2 = CTIO 0.9-m

Table 11. YALO Infrared Photometry of SN 2001cz

JD[a]	*J*	*H*	*K*
2101.52	15.404 (0.061)	15.730 (0.126)	15.397 (0.132)
2104.46	15.499 (0.061)	15.879 (0.121)	15.607 (0.130)
2106.46	15.623 (0.064)	15.996 (0.121)	15.685 (0.148)
2112.52	16.580 (0.120)	16.023 (0.216)	15.759 (0.258)
2114.47	16.806 (0.085)	16.153 (0.155)	15.805 (0.172)
2117.46	17.163 (0.099)	16.155 (0.168)	16.062 (0.187)
2123.46	17.477 (0.125)	15.882 (0.198)	15.785 (0.208)
2128.47	17.029 (0.091)	15.646 (0.155)	15.642 (0.177)
2130.48	16.833 (0.079)	15.646 (0.140)	15.704 (0.161)
2137.49	16.540 (0.102)	15.722 (0.188)	···
2144.47	17.020 (0.078)	16.220 (0.143)	···
2151.47	17.664 (0.098)	16.574 (0.173)	···

[a]Julian Date *minus* 2,450,000.

Table 12. Optical Photometry of SN 2002bo[a]

JD[b]	U	ΔU	B	ΔB	V	ΔV	R	ΔR	I	ΔI	Telescope[c]
345.67	16.248 (0.094)	[0.047]	15.797 (0.016)	−0.073	15.264 (0.013)	0.015	14.910 (0.017)	0.000	14.876 (0.026)	0.030	1
346.68	15.759 (0.086)	[0.047]	15.431 (0.009)	−0.069	14.940 (0.011)	0.014	14.582 (0.011)	0.000	14.536 (0.023)	0.023	1
350.56	14.381 (0.064)	[0.073]	14.397 (0.020)	−0.030	14.069 (0.010)	0.003	13.812 (0.011)	0.005	13.805 (0.013)	−0.003	2
350.66	14.655 (0.071)	[0.047]	14.484 (0.022)	−0.040	14.099 (0.010)	0.017	13.840 (0.016)	−0.010	13.784 (0.011)	0.001	1
354.65	14.313 (0.081)	−0.095	14.136 (0.014)	−0.038	13.706 (0.009)	0.027	13.556 (0.013)	−0.015	13.621 (0.010)	−0.029	1
358.64	14.448 (0.099)	−0.135	14.126 (0.010)	−0.041	13.577 (0.013)	0.028	13.501 (0.015)	−0.014	13.699 (0.019)	−0.064	1
360.65	14.351 (0.074)	0.170	14.127 (0.047)	−0.007	13.638 (0.040)	0.000	13.508 (0.030)	0.005	13.749 (0.030)	−0.005	3
361.66	14.412 (0.074)	0.170	14.205 (0.040)	−0.004	13.659 (0.040)	−0.001	13.488 (0.030)	0.005	13.784 (0.030)	−0.006	3
362.62	14.837 (0.073)	−0.107	14.308 (0.012)	−0.031	13.654 (0.010)	0.032	13.574 (0.012)	−0.015	13.864 (0.032)	−0.102	1
366.62	15.298 (0.069)	−0.118	14.658 (0.025)	−0.026	13.815 (0.014)	0.036	13.818 (0.026)	0.009	14.144 (0.033)	−0.140	1
370.55	15.838 (0.098)	−0.130	15.098 (0.013)	−0.023	14.068 (0.014)	0.040	14.047 (0.032)	0.028	14.297 (0.034)	−0.138	1
373.60	15.810 (0.064)	0.179	15.390 (0.020)	0.021	14.349 (0.014)	−0.023	14.180 (0.011)	0.008	14.349 (0.010)	−0.003	2
376.58	16.710 (0.114)	−0.147	15.758 (0.031)	−0.020	14.413 (0.015)	0.047	14.123 (0.029)	0.039	14.098 (0.038)	−0.111	1
381.58	17.225 (0.157)	−0.162	16.293 (0.028)	−0.072	14.658 (0.011)	0.052	14.237 (0.022)	0.024	14.045 (0.013)	−0.088	1
385.57	17.606 (0.249)	−0.174	16.587 (0.054)	−0.080	14.896 (0.027)	0.056	14.438 (0.026)	−0.001	14.066 (0.015)	−0.070	1
389.58	17.621 (0.215)	−0.185	16.858 (0.039)	−0.078	15.218 (0.022)	0.056	14.745 (0.014)	−0.009	14.346 (0.013)	−0.060	1
390.53	···	···	16.875 (0.046)	−0.076	15.270 (0.019)	0.055	14.805 (0.014)	−0.008	14.429 (0.015)	−0.059	1
397.48	···	···	17.112 (0.057)	−0.067	15.548 (0.016)	0.052	15.169 (0.015)	−0.005	14.874 (0.014)	−0.047	1
400.54	···	···	17.147 (0.013)	−0.062	15.660 (0.015)	0.050	15.285 (0.018)	−0.001	14.976 (0.012)	−0.041	1

[a]The corrections are to be *added* to the data. This transforms the data to the filter system of Bessell (1990). Values in square brackets could be in error by as much as 0.1 mag.

[b]Julian Date *minus* 2,452,000.

[c]1 = YALO 1-m; 2 = CTIO 0.9-m; 3 = CTIO 1.5-m.

Table 13. YALO Infrared Photometry of SN 2002bo[a]

JD[b]	J	ΔJ	H	ΔH	K	ΔK
345.69	14.590 (0.030)	0.033	14.637 (0.039)	−0.024	14.765 (0.071)	0.002
346.68	14.442 (0.057)	0.036	14.493 (0.029)	−0.024	14.635 (0.059)	0.002
350.66	13.806 (0.084)	0.048	13.956 (0.028)	−0.026	13.977 (0.041)	0.010
354.65	13.619 (0.023)	0.061	13.907 (0.026)	−0.029	13.862 (0.041)	0.021
358.64	13.852 (0.030)	0.059	14.103 (0.030)	−0.032	13.984 (0.074)	0.037
362.62	14.262 (0.029)	−0.005	14.251 (0.023)	−0.035	14.214 (0.051)	0.055
366.62	15.044 (0.099)	−0.069	14.382 (0.054)	−0.038	14.482 (0.070)	0.037
370.55	15.472 (0.054)	−0.086	14.276 (0.023)	−0.043	14.259 (0.061)	0.024
376.58	15.186 (0.075)	−0.081	14.020 (0.032)	−0.064	14.090 (0.103)	0.006
381.58	14.828 (0.047)	−0.076	13.890 (0.020)	−0.070	13.931 (0.040)	−0.011
385.57	14.756 (0.043)	−0.073	14.005 (0.029)	−0.052	14.101 (0.052)	−0.008
389.57	14.905 (0.025)	−0.086	14.122 (0.027)	−0.021	14.370 (0.048)	0.001
390.53	14.973 (0.038)	−0.091	14.307 (0.027)	−0.015	14.530 (0.050)	0.001
397.48	15.731 (0.075)	−0.124	14.663 (0.037)	0.030	14.910 (0.071)	0.002
400.54	15.835 (0.037)	−0.125	14.839 (0.030)	0.033	15.158 (0.092)	0.002

[a]To transform the data in columns 2, 4, and 6 to the photometric system of Persson et al. (1998) one *adds* the corresponding corrections in columns 3, 5, and 7.

[b]Julian Date *minus* 2,452,000.

Table 14. Table of spectral observations

Object	Telescope[a]	Grating	UT Date	Age[b]	Exptime[c]	Observer(s)
SN 1999ee	1	09	25.09 Oct 1999	+7.5	2400	C. Smith
...	1	13	25.18 Oct 1999	+7.6	1800	C. Smith
...	1	13	31.03 Oct 1999	+13.4	3600	R. Leiton, S. Pizarro
SN 1999ek	1	13	25.37 Oct 1999	−5.2	1200	C. Smith
...	1	13	26.30 Oct 1999	−4.2	5400	P. Ugarte
...	1	13	30.33 Oct 1999	−0.2	3600	R. Leiton, S. Pizarro
...	1	13	01.32 Nov 1999	+1.8	3600	R. Leiton, S. Pizarro
SN 2001bt	2	grism	26.37 May 2001	−7.6	600	M. Phillips
SN 2001cn	1	09	14.30 Jun 2001	+3.4	1800	D. Norman, K. Olsen
...	1	09	22.31 Jun 2001	+11.2	600	J. Huchra

[a]1 = CTIO 1.5-m; 2 = LCO 2.5-m.

[b]Number of days in observer's frame since T(B_{max}).

[c]Total exposure time in seconds.

Table 15. Useful Data for Supernovae

SN	v_{CMB}[a]	T(B_{max})[b]	$Bmax$	$Vmax$	$Rmax$	$Imax$	$\Delta m_{15}(B)$	$E(B-V)_{Gal}$[c]	$E(B-V)_{host}$
1999ek	5278	1482.04 (0.11)	17.91(0.01)	17.25(0.01)	16.88(0.01)	16.56(0.01)	1.17 (0.03)	0.561	0.203 (0.046)
2001bt	4332	2063.43 (0.22)	15.51(0.02)	15.30(0.02)	15.17(0.02)	15.16(0.02)	1.18 (0.03)	0.065	0.256 (0.018)
2001cn	4628	2071.56 (0.15)	15.40(0.01)	15.27(0.01)	15.20(0.01)	15.26(0.01)	1.15 (0.02)	0.059	0.165 (0.014)
2001cz	4900	2103.93 (0.12)	15.38(0.01)	15.27(0.01)	15.20(0.01)	15.28(0.01)	1.05 (0.03)	0.092	0.123 (0.017)
2002bo	1696	2356.50 (0.20)	14.02(0.02)	13.47(0.01)	13.61(0.01)	13.55(0.02)	1.12 (0.03)	0.025	0.365 (0.014)

[a]Recession velocity in km s^{-1} with respect to the Cosmic Microwave Background radiation.

[b]Julian Date *minus* 2,450,000.

[c]From Schlegel, Finkbeiner & Davis (1998); but see *caveat* from Arce & Goodman (1999).

Table 16. Infrared Apparent Magnitudes at Maximum and Extinction-Corrected Values[a]

SN	A_V	J_{max}	J_{corr}	H_{max}	H_{corr}	K_{max}	K_{corr}	$N_{J,H,K}$[b]
1999ek	2.37(16)	16.16(07)	15.49(08)	16.30(08)	15.85(09)	16.32(08)	16.05(08)	11,12,1
2001bt	1.06(06)	15.48(04)	15.20(04)	15.69(06)	15.50(06)	15.48(05)	15.37(05)	6,6,5
2001cn	0.69(04)	15.61(08)	15.41(08)	15.90(11)	15.77(11)	15.58(12)	15.50(12)	3,3,3
2001cz	0.67(05)	15.49(06)	15.30(06)	15.78(12)	15.65(12)	15.53(13)	15.45(13)	4,4,4
2002bo	1.21(04)	13.55(07)	13.21(07)	13.94(03)	13.71(03)	13.89(04)	13.75(04)	6,6,6

[a]Values in parentheses are uncertainties in hundredths of a magnitude.

[b]Number of data points prior to $t' = +10$ d in "stretched time".

Table 17. Mean Absolute Magnitudes of Type Ia SNe at Maximum[a]

Filter	$\langle$M$\rangle$	σ_x	χ^2_ν	N
J	−18.61(03)	± 0.131	1.29	22
H	−18.28(03)	± 0.148	1.52	21
K	−18.44(03)	± 0.145	0.99	20

[a]For objects with $\Delta m_{15}(B) \lesssim 1.7$.

Fig. 1.— Finding charts for the supernovae: a) SN 1999ek; b) SN 2001bt; c) SN 2001cn; d) SN 2001cz; and e) SN 2002bo. The object labelled "var" in Fig. 1d is a previously unknown RR Lyr star; see Krisciunas et al. (2004c).

Fig. 2.— S-corrections for B-band data (top graphs) and V-band data (bottom graphs). These corrections place the data from the YALO 1-m and CTIO 0.9-m telescopes on the system of Bessell (1990). We used spectra of SNe 1999ee (circles), 2001el (triangles), and 2002bo (squares). Given the different spectral energy distributions of these three supernovae, we would not expect the S-corrections to be identical.

Fig. 3.— Similar to Fig. 2, but S-corrections for R and I.

Fig. 4.— S-corrections for the infrared bands. The corrections place the data obtained with the YALO 1-m telescope on the photometric system of Persson et al. (1998). The filled-in circles correspond to data derived using ("normal") spectra of SN 1999ee, while the squares correspond to S-corrections obtained from spectra of the "abnormal" SN 2002bo.

Fig. 5.— Optical and IR light curves of SN 1999ek. Four nights of data from Jha (2002) are plotted as diamond-shaped symbols.

Fig. 6.— Optical and IR light curves of SN 2001bt. Data points with errors greater than 0.15 mag have the error bars shown. The infrared data from the LCO 2.5-m telescope, which are notably more accurate than the data from the YALO 1-m telescope, are shown as diamond-shaped symbols. The YALO optical data contain filter corrections to the filter system of Bessell (1990), while the YALO infrared data are corrected to the system of Persson et al. (1998). The data are K-corrected, but rescaled in the time axis by $1+z$ so that the Julian Dates match the dates of observation.

Fig. 7.— Optical and infrared light curves of SN 2001cn. The optical data obtained with the CTIO 0.9-m telescope are shown as filled in circles. All the other data were obtained with the YALO 1-m telescope. As in Fig. 6 the optical data are S-corrected, K-corrected, and the Julian Dates are rescaled by $1+z$ to match the dates of observation.

Fig. 8.— Optical and infrared light curves of SN 2001cz. As in Figs. 6 and 7 the optical data are S-corrected, K-corrected, and the Julian Dates are rescaled by $1+z$ to match the dates of observation.

Fig. 9.— Optical and IR light curves of SN 2002bo. The $UBVRI$ data from Cerro Tololo are represented by filled-in circles, and include filter corrections to the system of Bessell (1990). The other optical data are from Benetti et al. (2004). The infrared data include the

corrections to the photometric system of Persson et al. (1998).

Fig. 10.— Photometry of five Type Ia SNe compared to *JHK* templates given in Paper V. Symbols: circles = SN 1999ek; squares = SN 2001bt; triangles, point up = SN 2001cn; diamonds = SN 2001cz; and triangles, point down = SN 2002bo. The time axis values are stretched according to factors determined from $\Delta m_{15}(B)$. We show the error bars if they are greater than ± 0.10 mag. For SN 1999ek we do not plot the data from Steward Observatory.

Fig. 11.— *V minus* near-IR color curves of SN 2002bo. The fourth order polynomials are the unreddened loci of mid-range decliners from Paper I, offset by the indicated color excesses. These color excesses imply values of A_V considerably different than one obtains from $E(B-V)$. This is further evidence to the actual spectra presented by Benetti et al. (2004) that SN 2002bo had an unusual SED over time.

Fig. 12.— Spectral atlas of SN 1999ek, SN 2001bt, SN 2001cn, and SN 1999ee (top to bottom). The top two spectra of SN 1999ee are taken from Hamuy et al. (2002). The vertical scale is given in logarithmic units of ergs s^{-1} cm^{-2} $Å^{-1}$, but includes arbitrary offsets for presentation. The SN 1999ee spectra cover a range of −7 to +13.4 days with respect to $T(B_{max})$. The absorption feature at ≈ 7600 Å in some of the spectra is the Fraunhofer A band, due to molecular oxygen in the Earth's atmosphere.

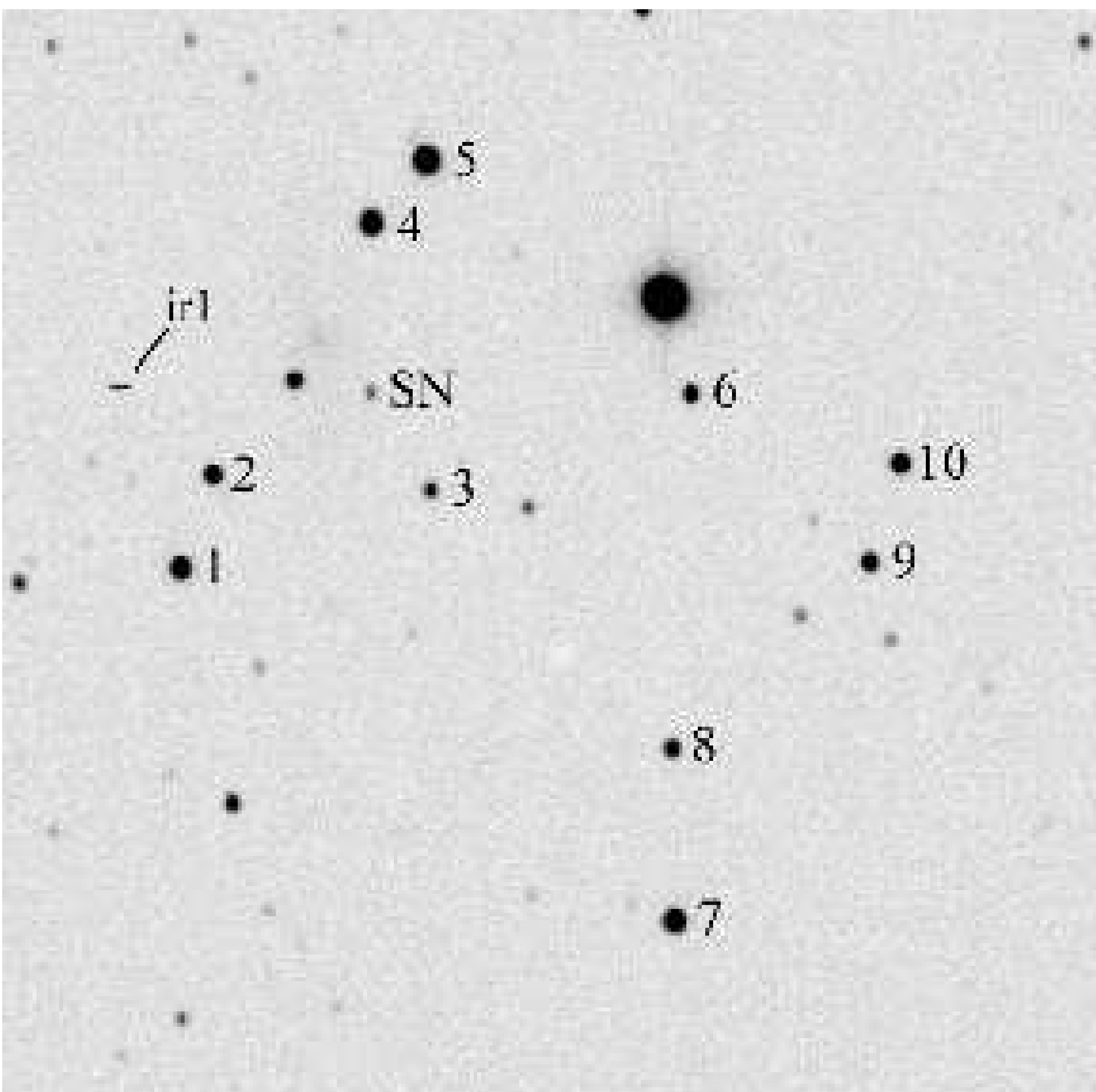
Fig. 13.— Dereddened pseudo-colors at maximum light vs. the decline rate parameter $\Delta m_{15}(B)$. The values of $\Delta m_{15}(B)$ and the extinction-corrected IR maxima are given in Tables 15 and 16 of this paper and in Table 1 of Krisciunas et al. (2004a). The filled-in dots correspond to the better sampled objects shown in Fig. 12 of Krisciunas et al. (2004b). The data of SN 1999by (left-pointing triangle in each sub-figure) correspond to dereddened colors at an epoch 2 days prior to $T(B_{max})$ for $V-J$ and $V-H$; for $V-K$ the epoch was 3 days prior to $T(B_{max})$. For SN 1991bg (right-pointing triangle in each sub-figure) the data correspond to an epoch 0.85 days after $T(V_{max})$.

Fig. 14.— Hubble diagrams of Type Ia SNe. We have added 8 objects to Fig. 2 of Krisciunas et al. (2004a). The triangles correspond to objects which are not far enough to be in the smooth Hubble flow. Their equivalent velocities are determined from direct measures of the distances to the hosts, on the $H_0 = 72$ km s^{-1} Mpc^{-1} scale of Freedman et al. (2001). SN 2002bo is represented by downward pointing triangles. Filled-in circles correspond to objects discussed by Krisciunas et al. (2004a) which are in the smooth Hubble flow. Squares correspond to new objects which are in the smooth Hubble flow. The points at $v_{CMB} = 933$ km s^{-1} (the Cepheid distance of NGC 4527 times $H_0 = 72$) correspond to SN 1991T. The right- and left-pointing triangles correspond to SNe 1991bg and 1999by, respectively, which

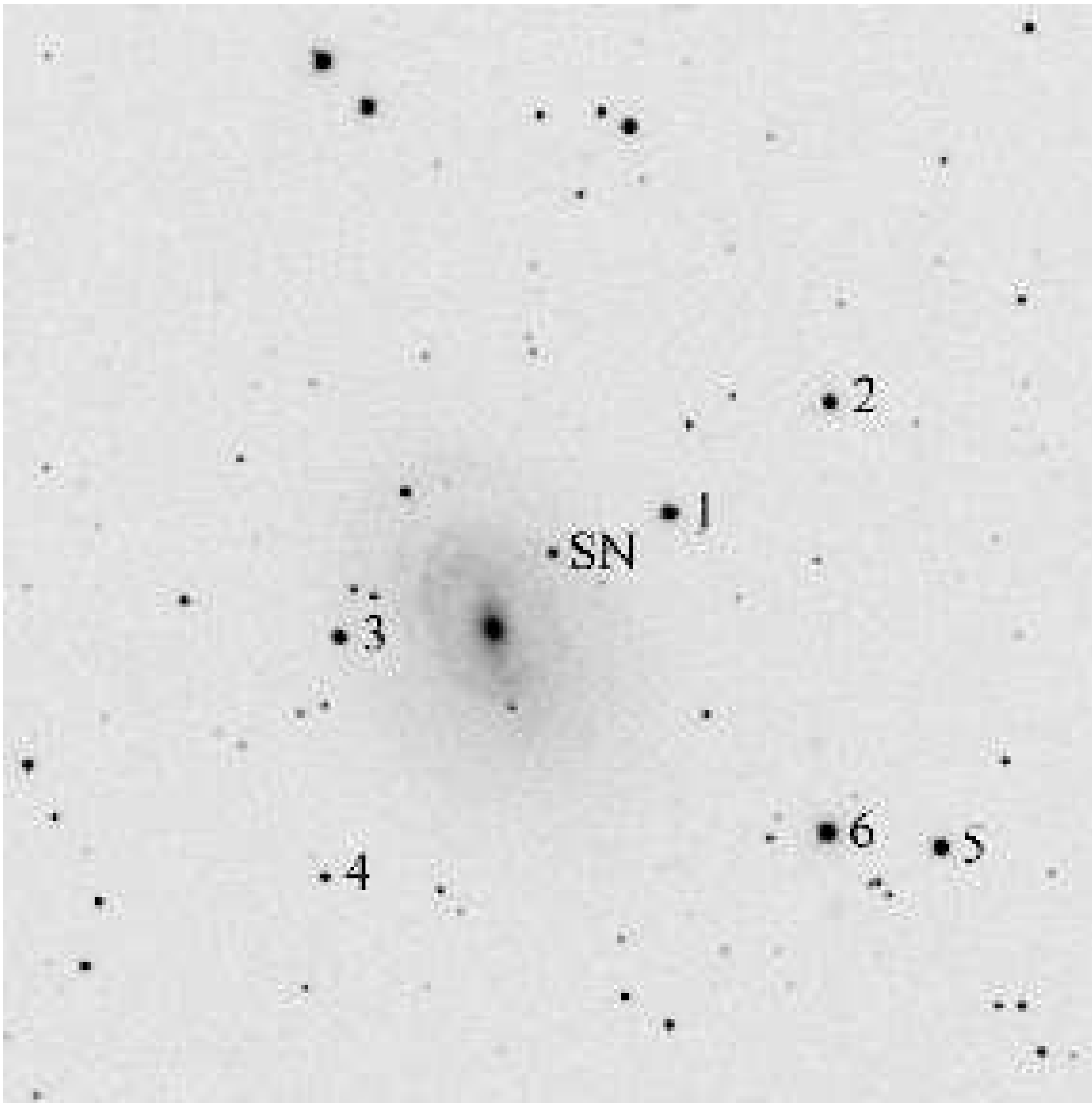
are subluminous.

Fig. 15.— Absolute magnitudes of Type Ia SNe at maximum (with $\Delta m_{15}(B)$ in the range 0.8 to 1.7) as a function of the logarithm of the redshift. There is no obvious trend as a function of z. The symbols are the same as in Fig. 14.

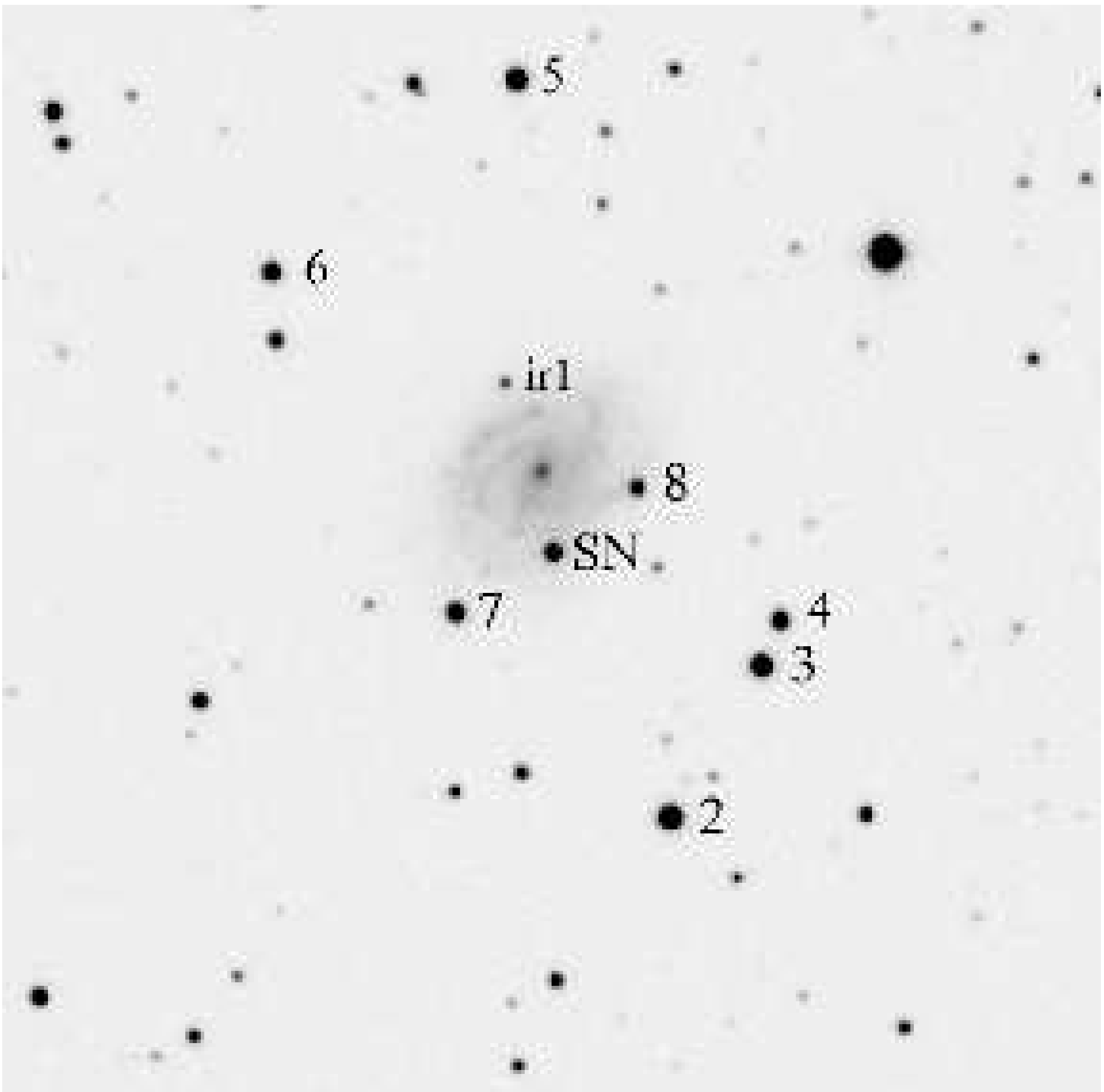
Fig. 16.— Absolute magnitudes of Type Ia SNe at maximum on the $H_0 = 72$ km s^{-1} Mpc^{-1} scale, as a function of $\Delta(m)_{15}(B)$. We have added 8 objects to Fig. 3 of Krisciunas et al. (2004a). The symbols are the same as in Fig. 14.



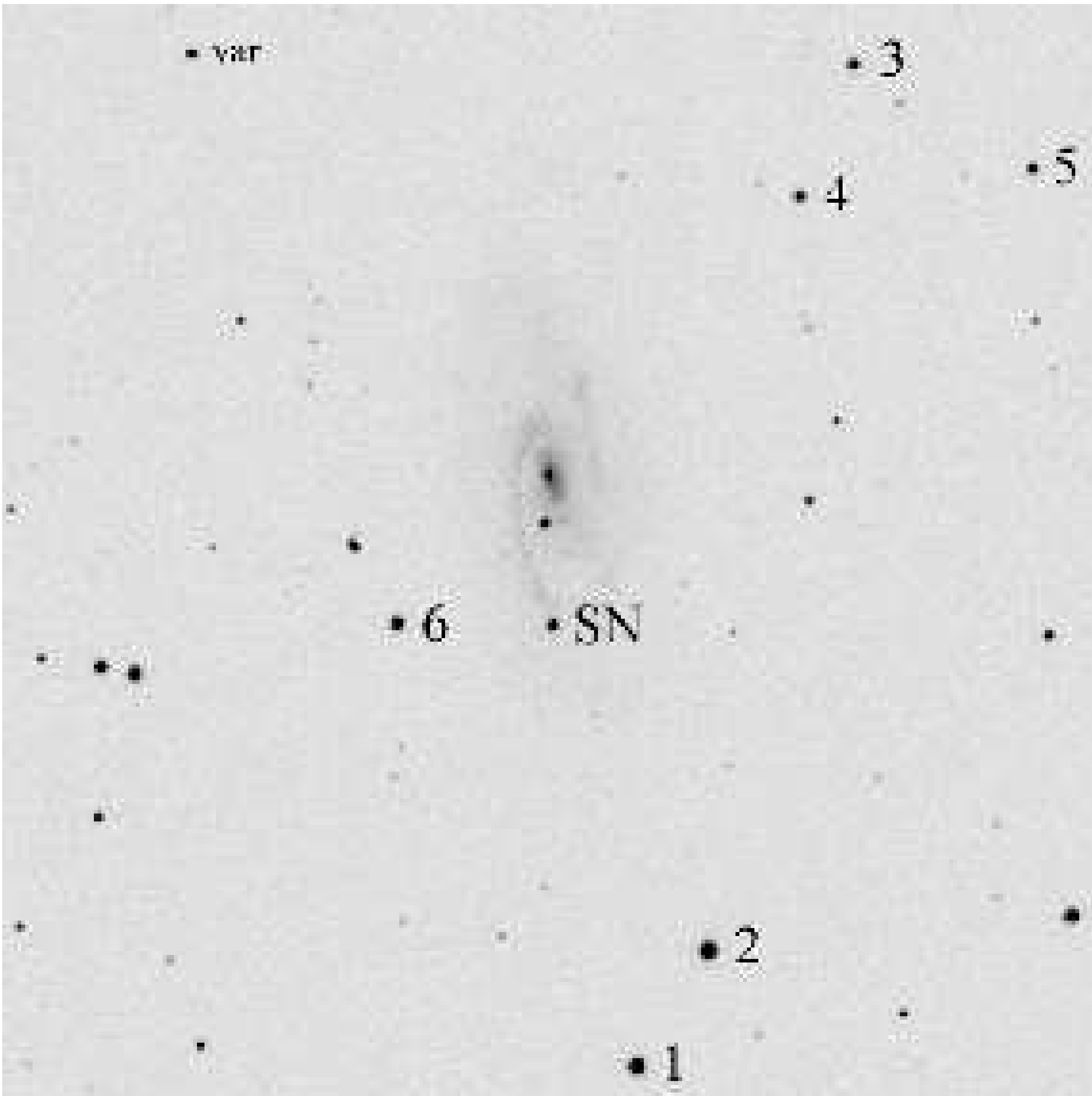
Krisciunas *et al.* Fig. 1a



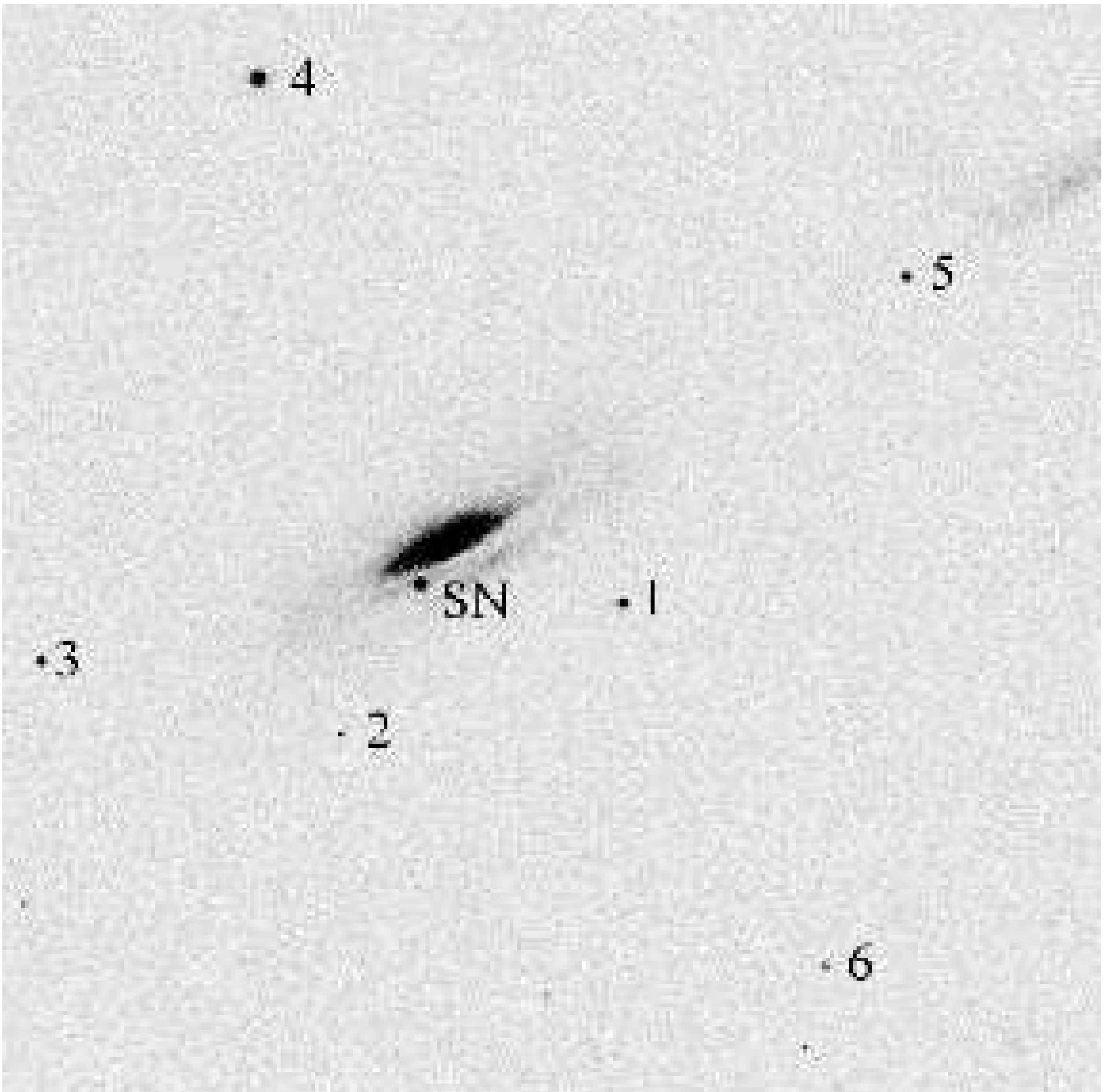
Krisciunas *et al.* Fig. 1b



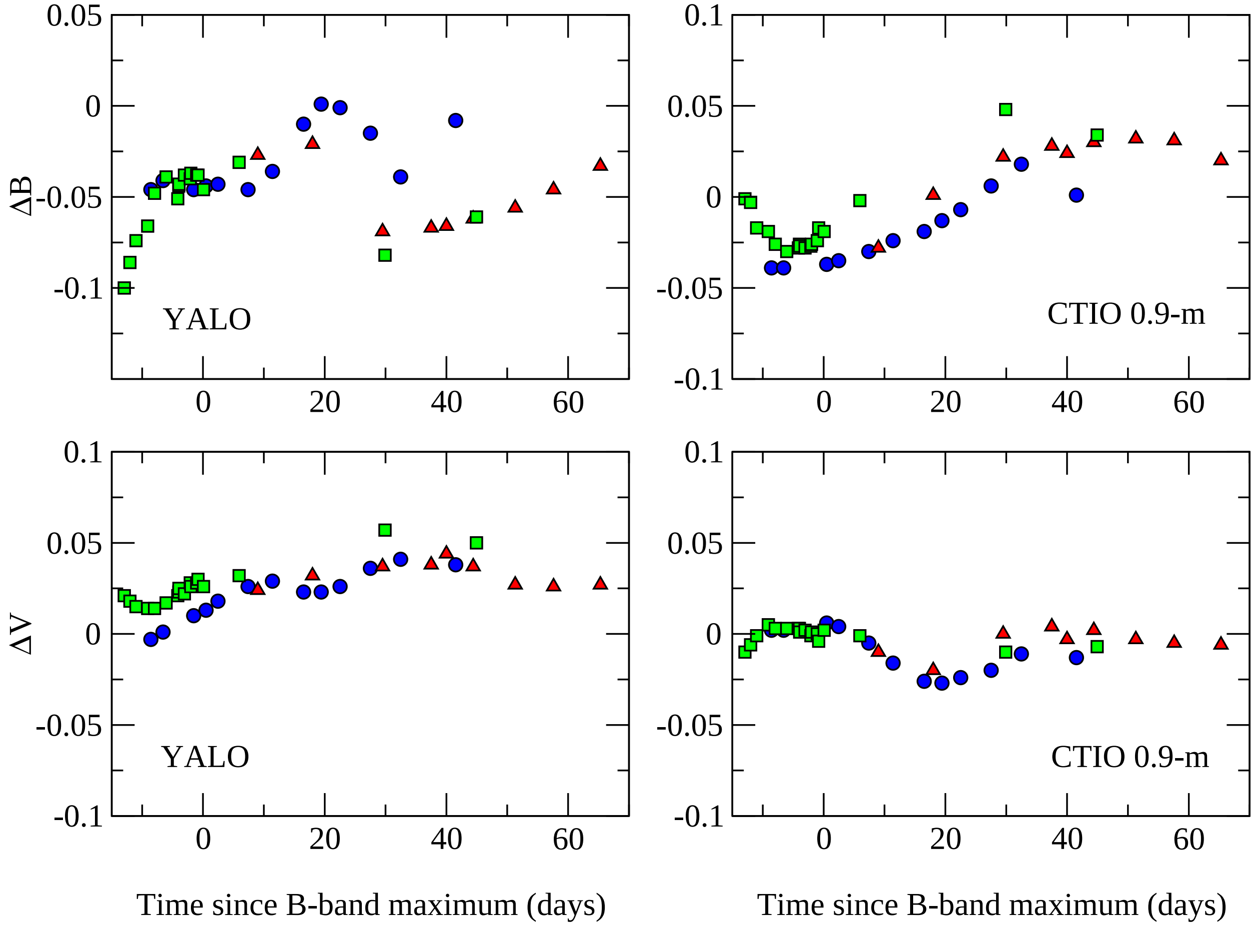
Krisciunas *et al.* Fig. 1c



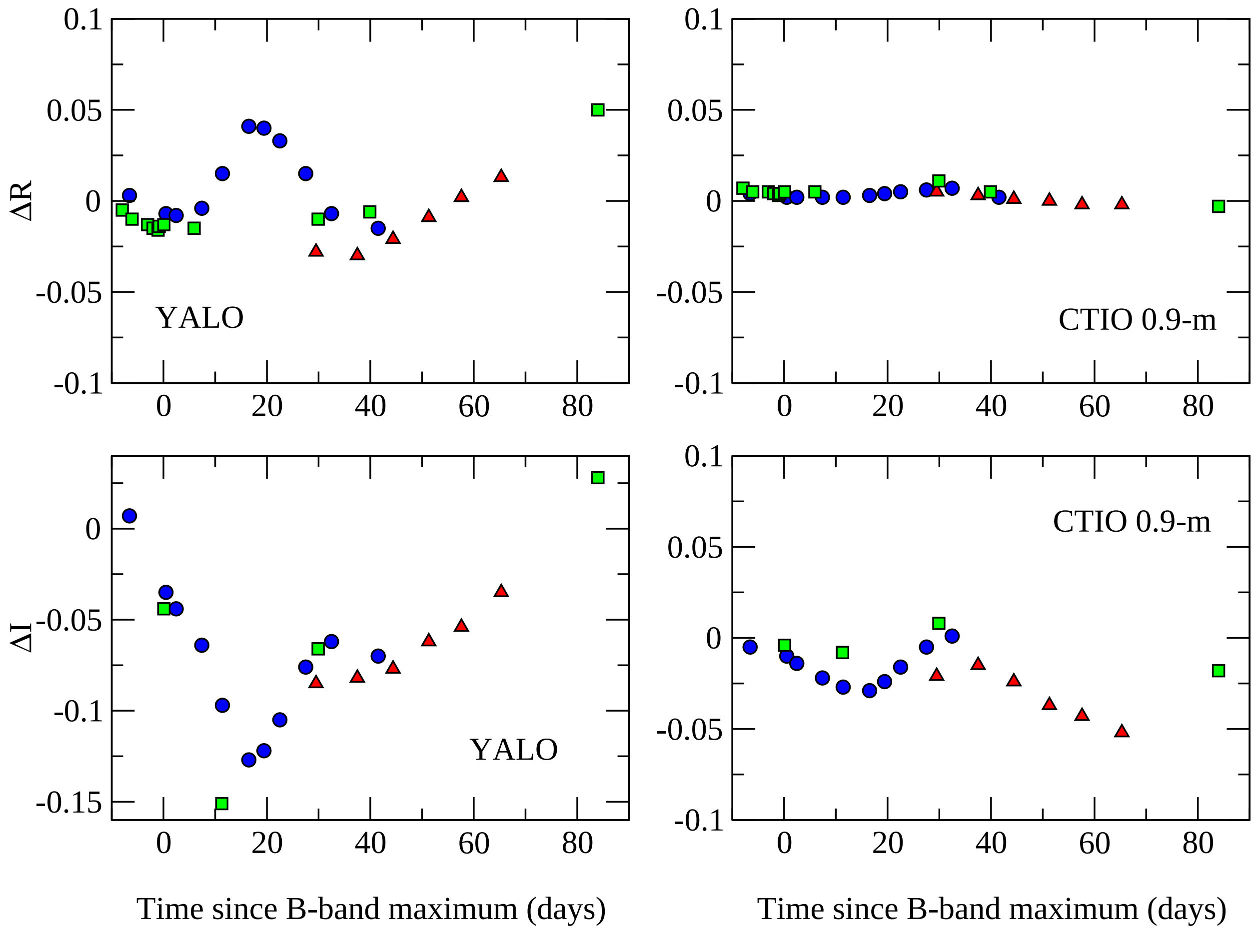
Krisciunas *et al.* Fig. 1d



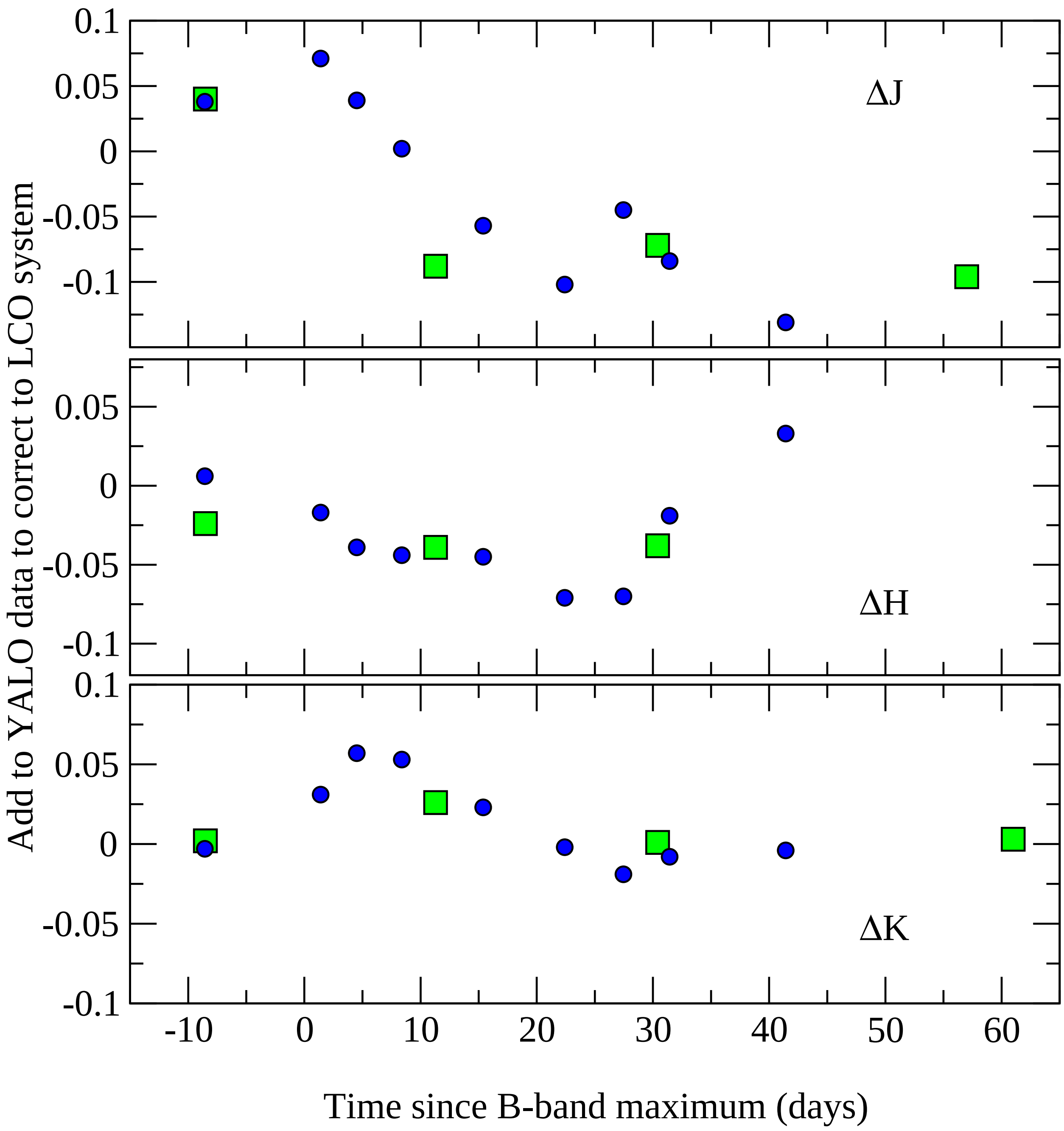
Krisciunas *et al.* Fig. 1e



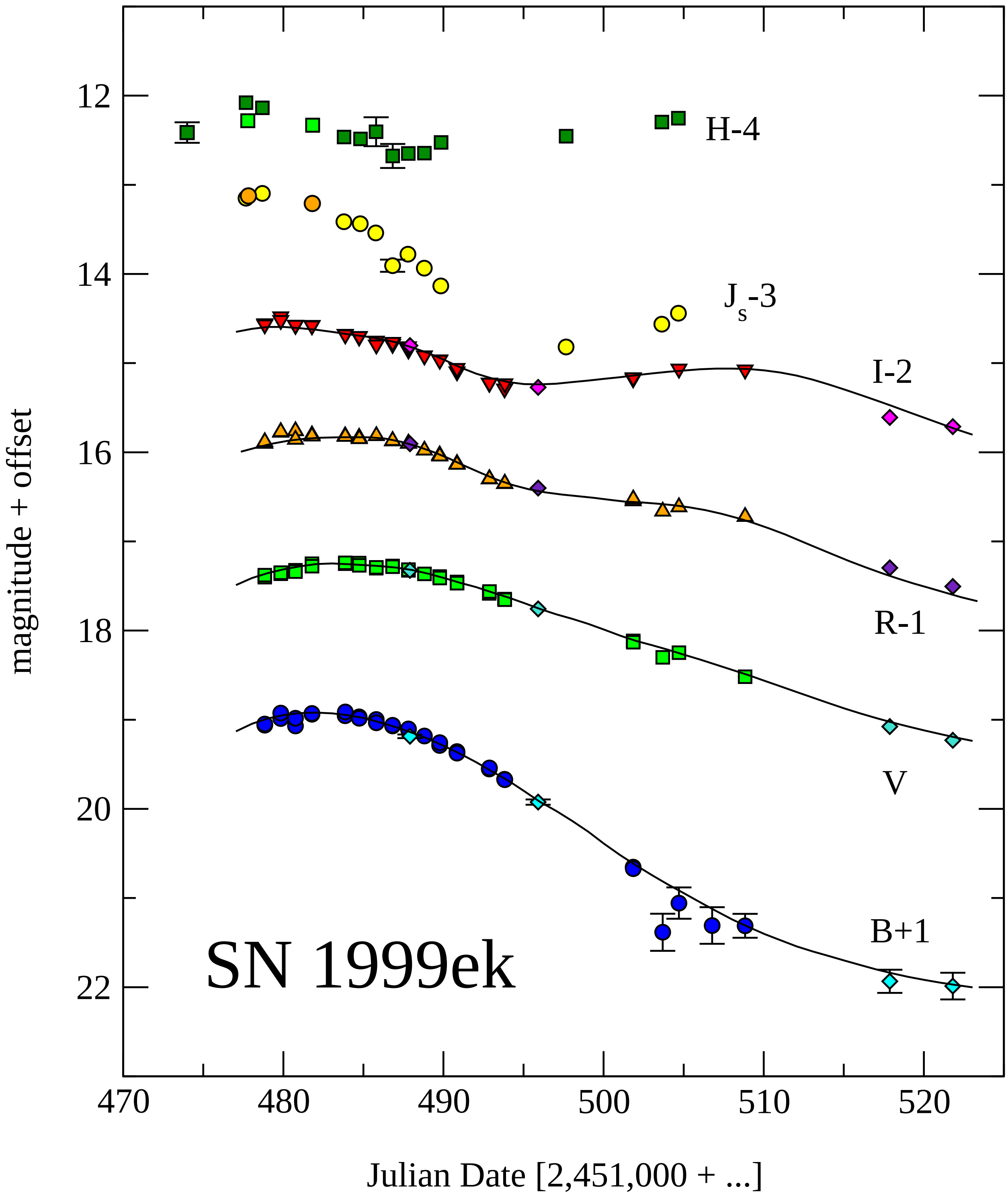
Krisciunas *et al.* Fig. 2



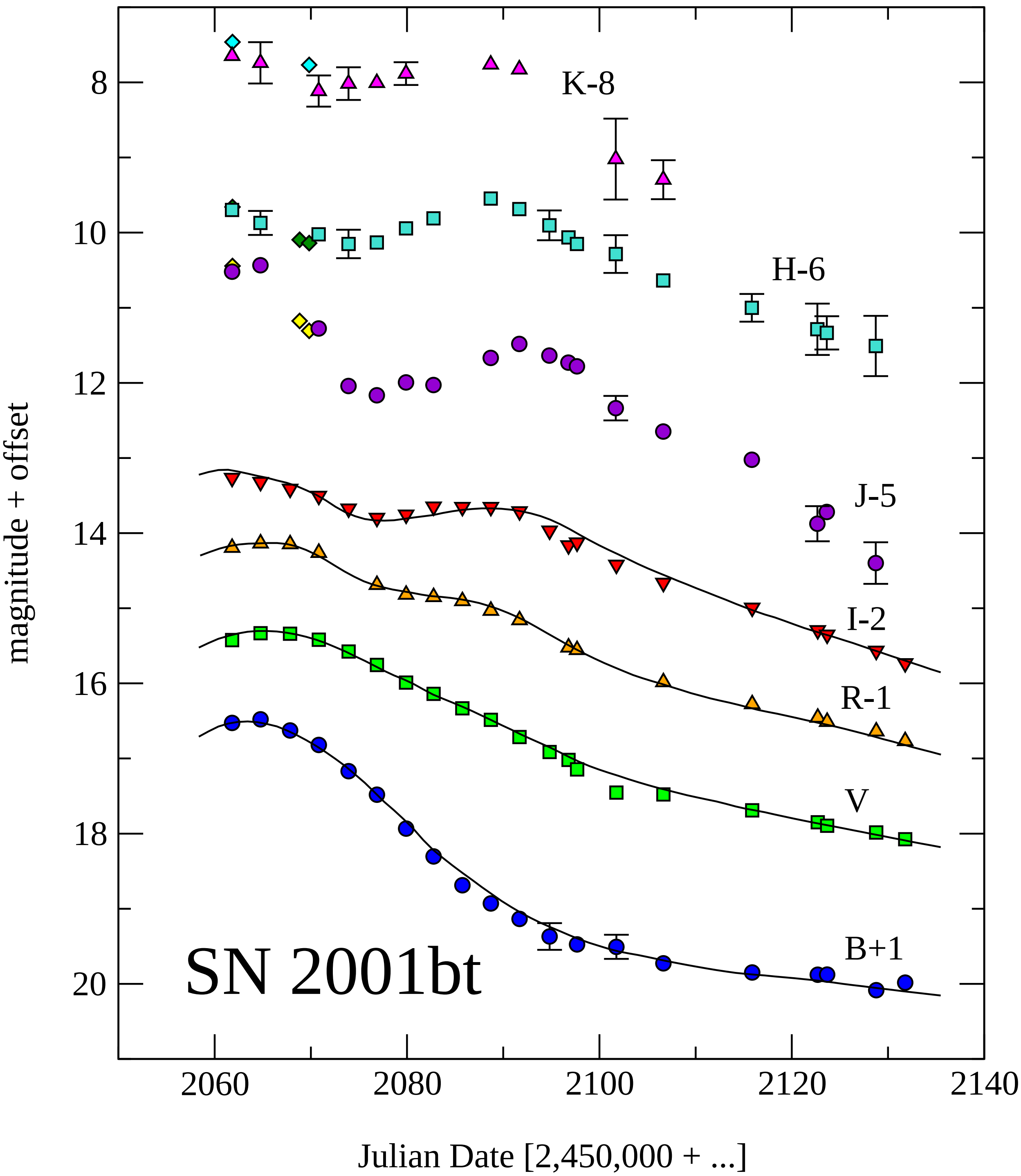
Krisciunas *et al.* Fig. 3



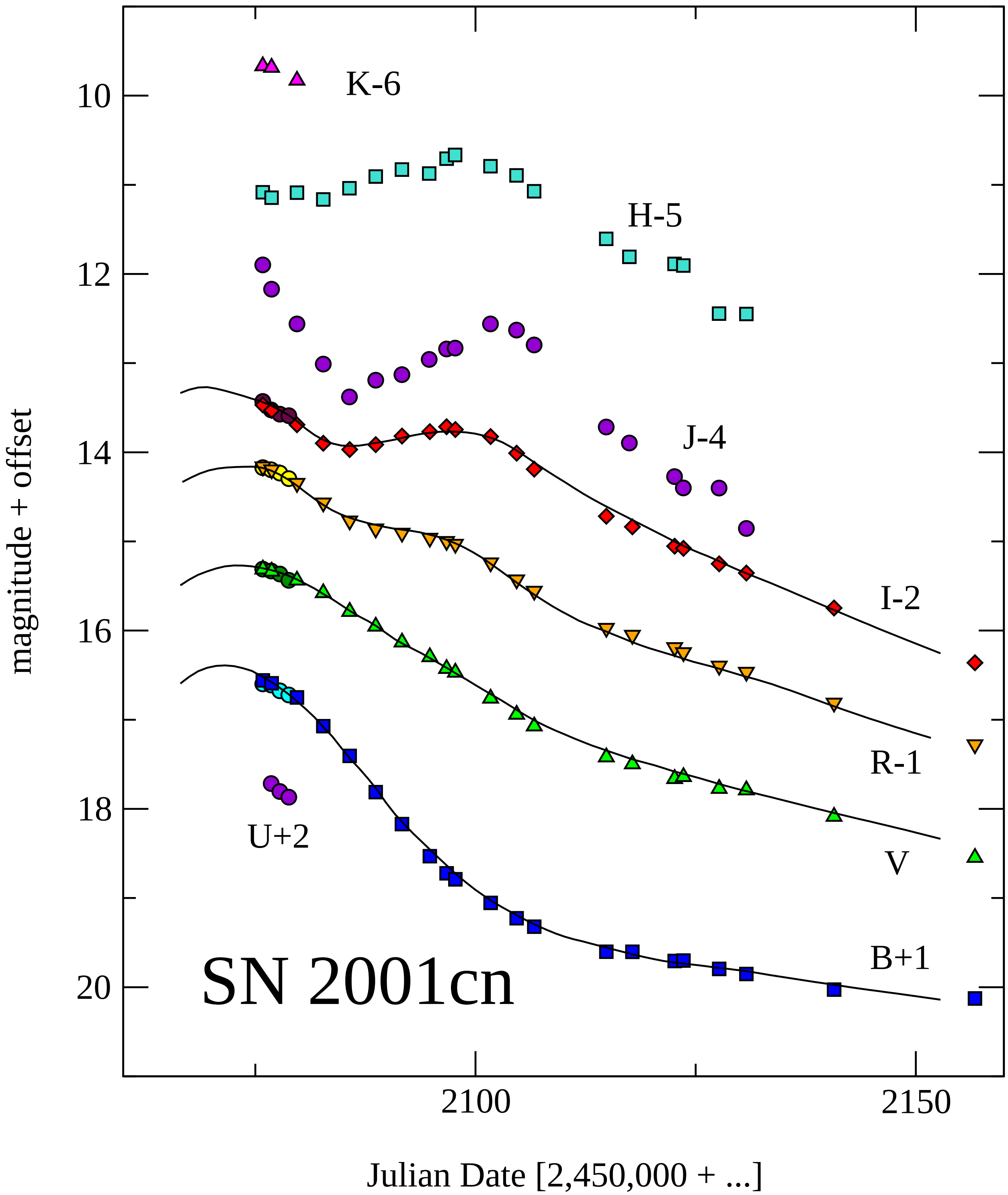
Krisciunas *et al.* Fig. 4



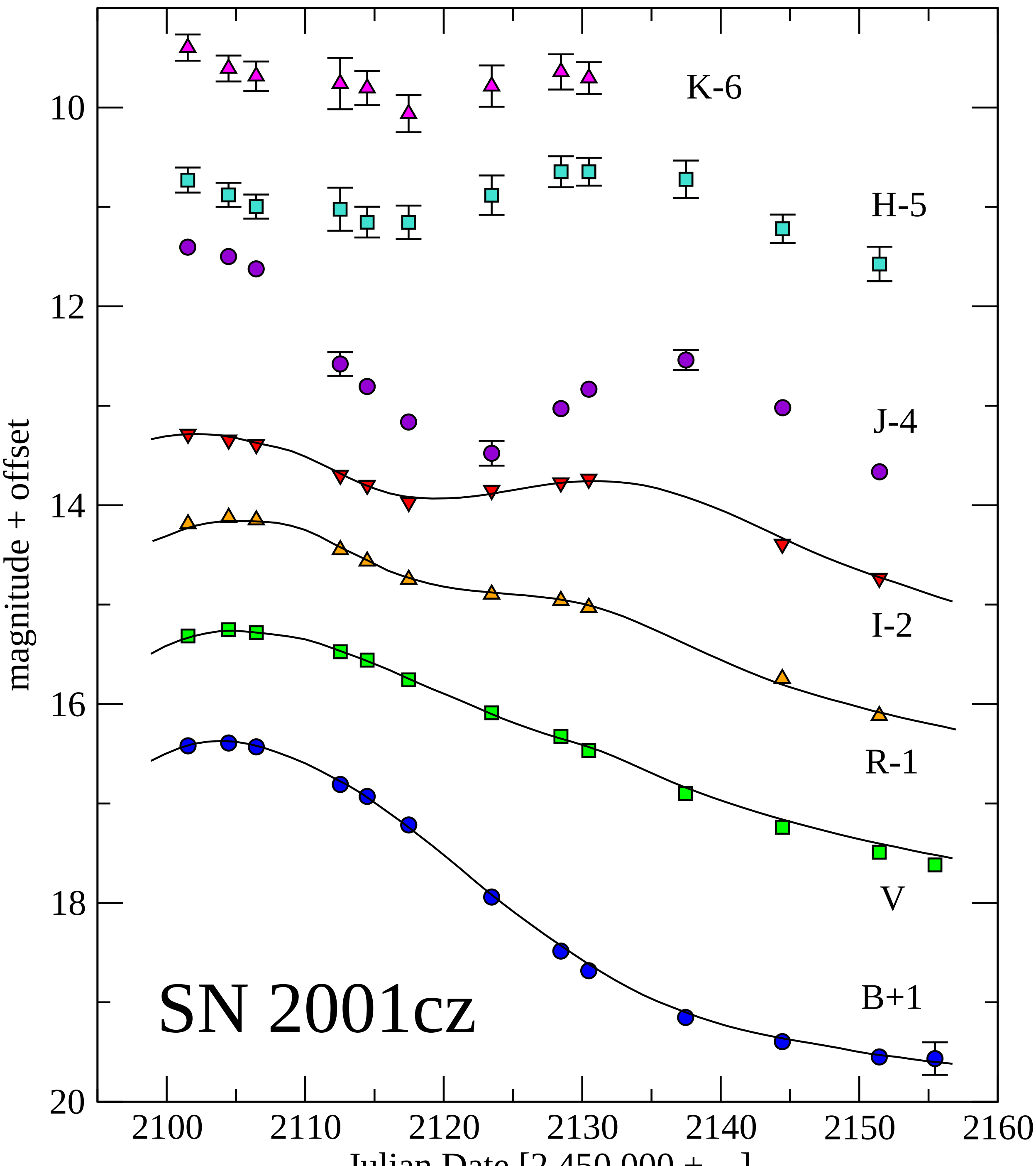
Krisciunas *et al.* Fig. 5



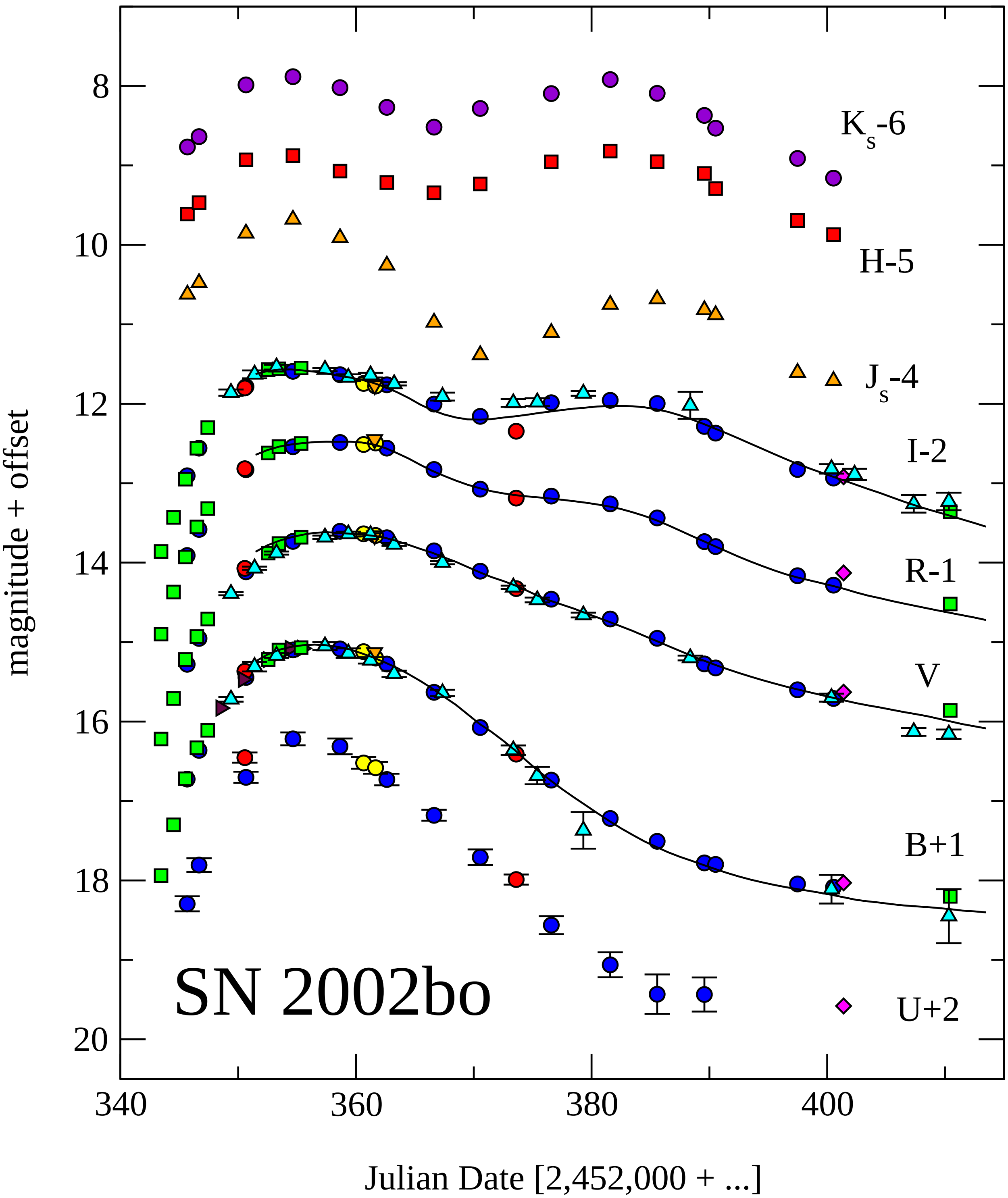
Krisciunas *et al.* Fig. 6



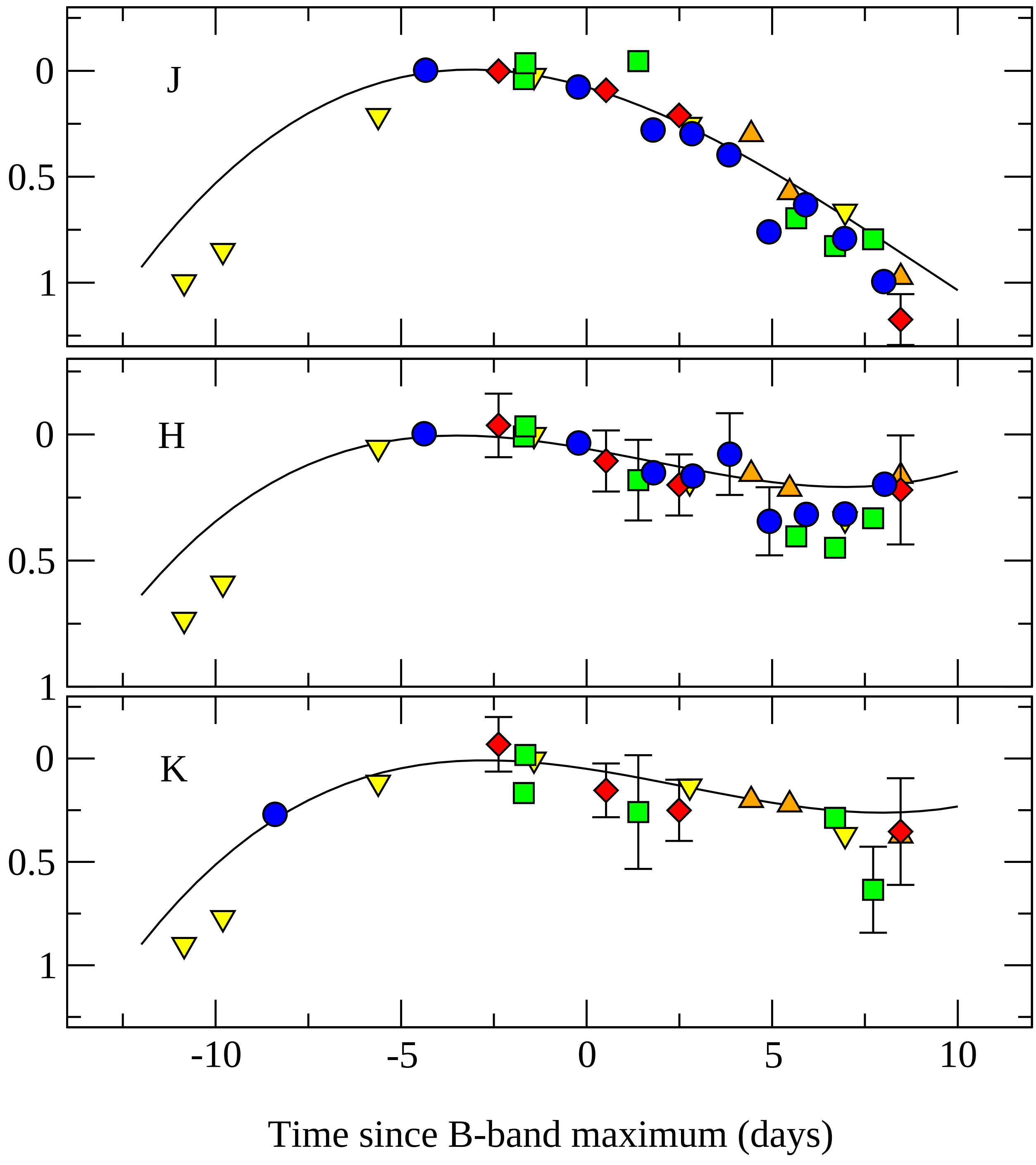
Krisciunas *et al.* Fig. 7



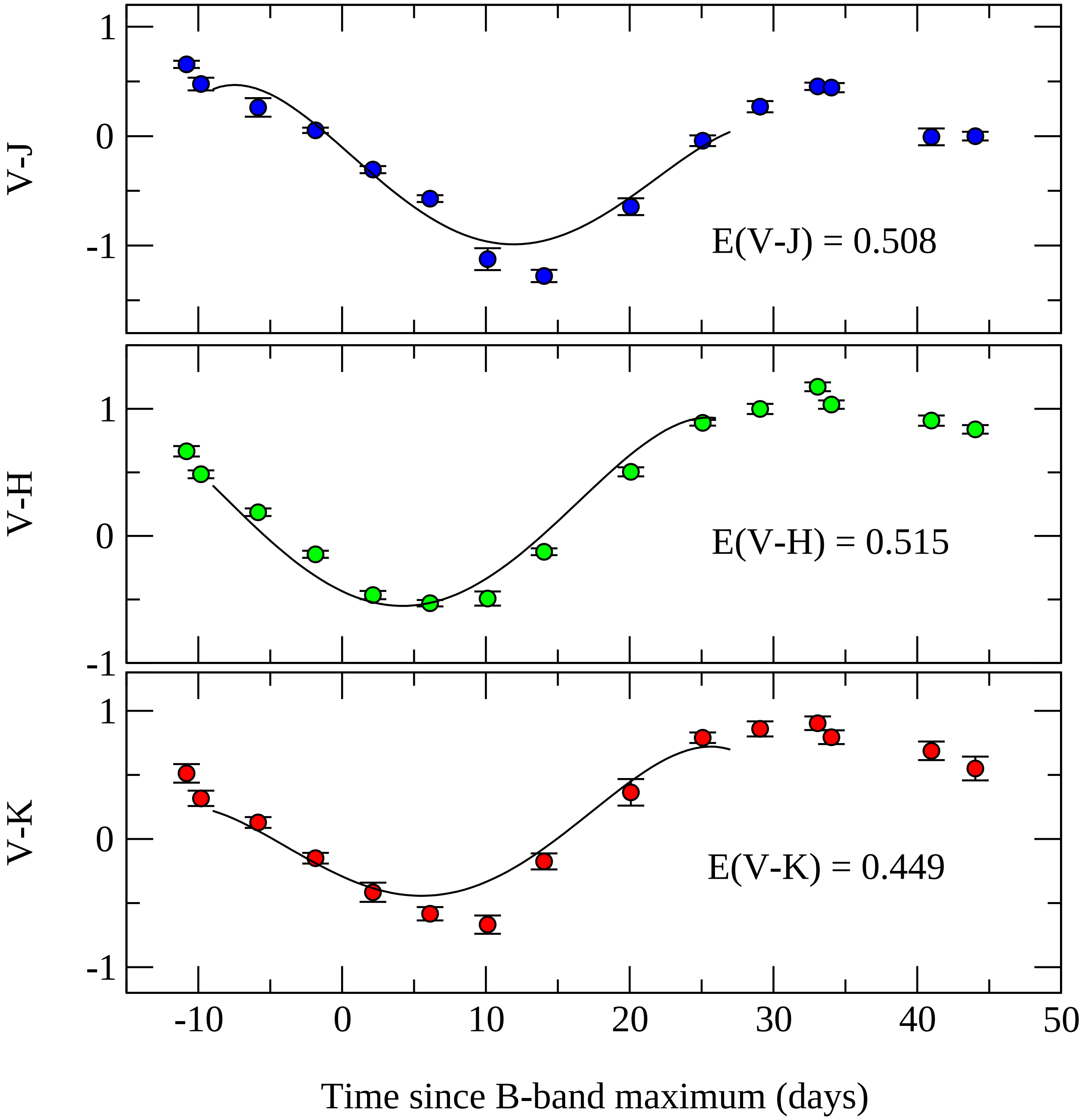
Krisciunas *et al.* Fig. 8



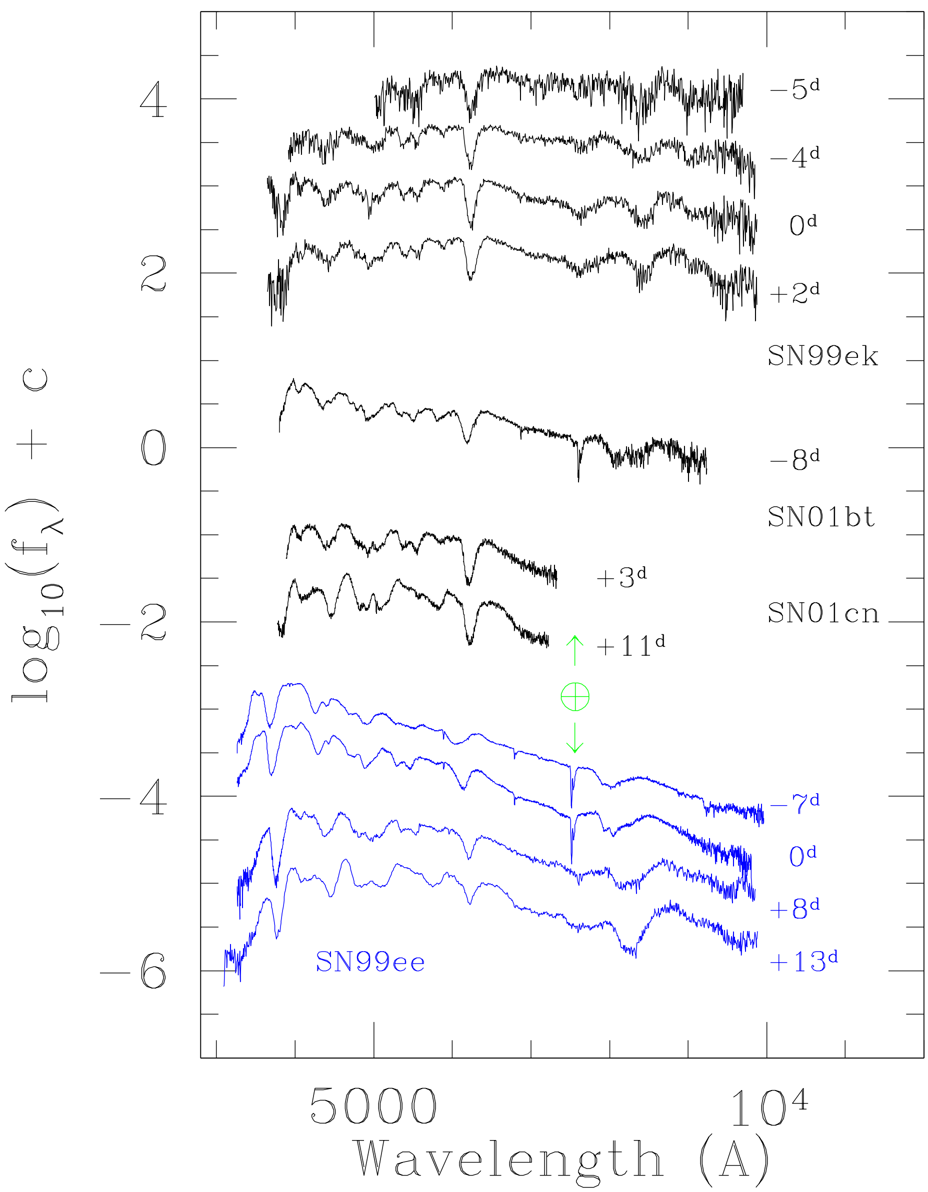
Krisciunas *et al.* Fig. 9



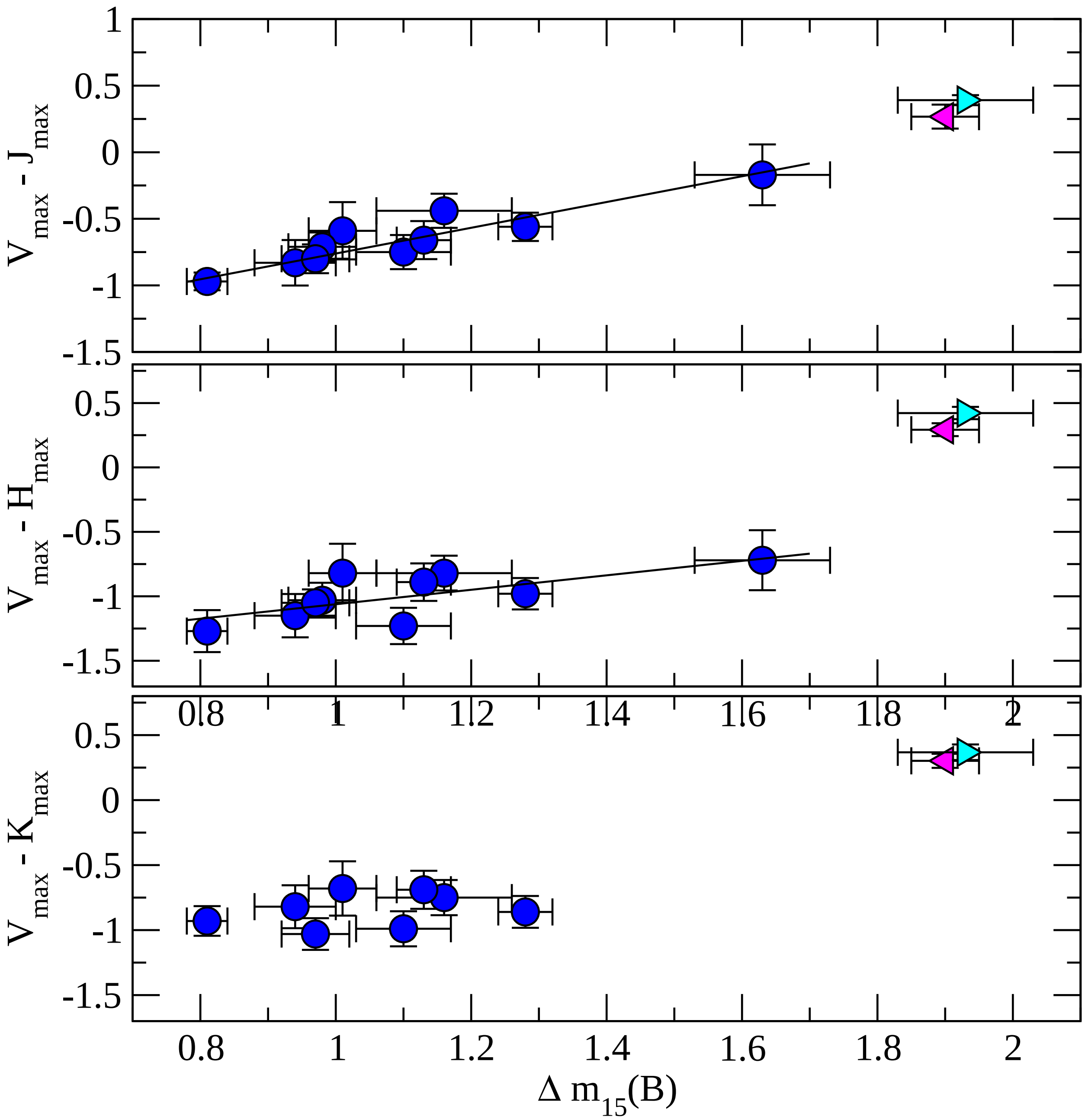
Krisciunas *et al.* Fig. 10



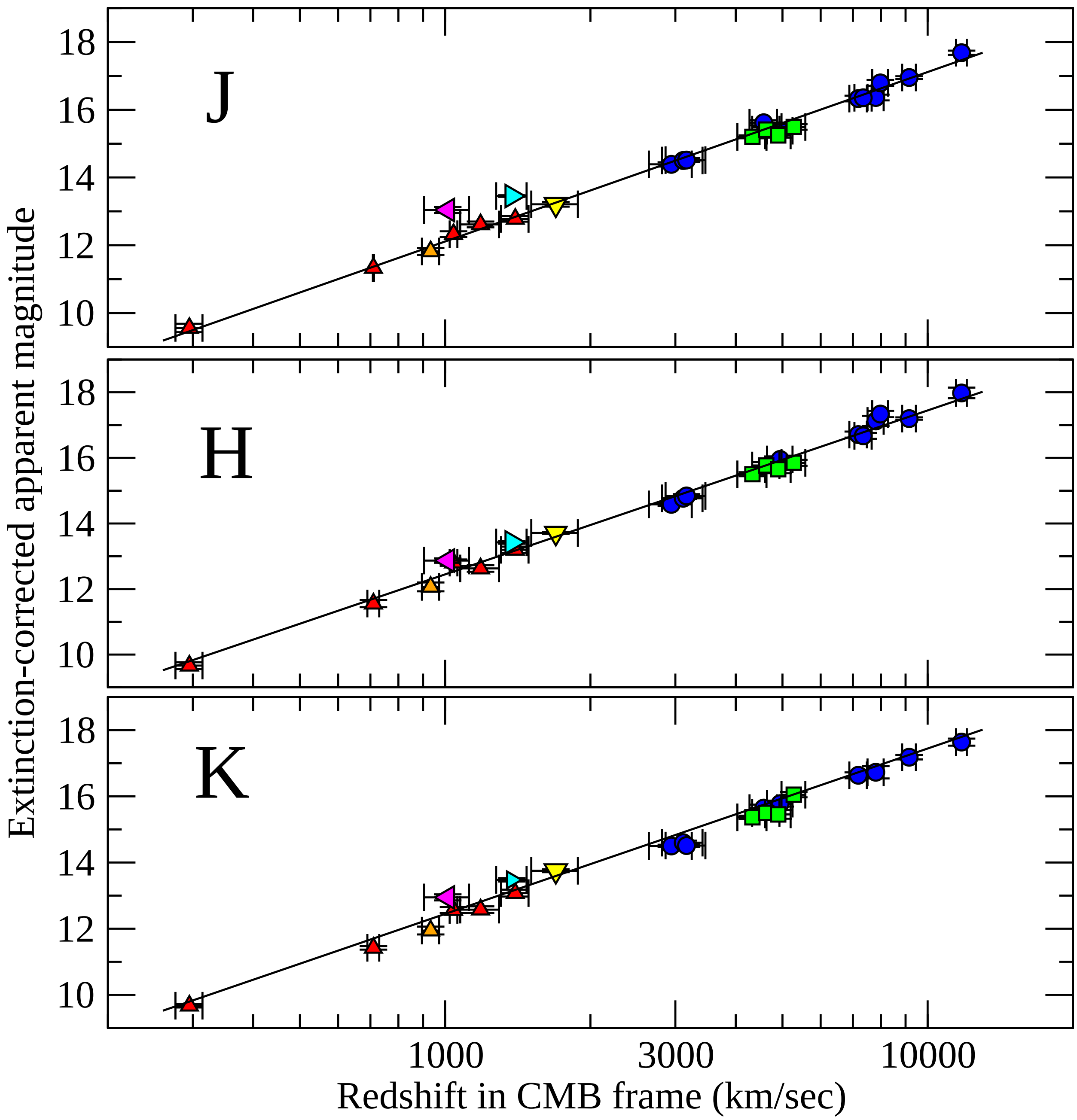
Krisciunas *et al.* Fig. 11



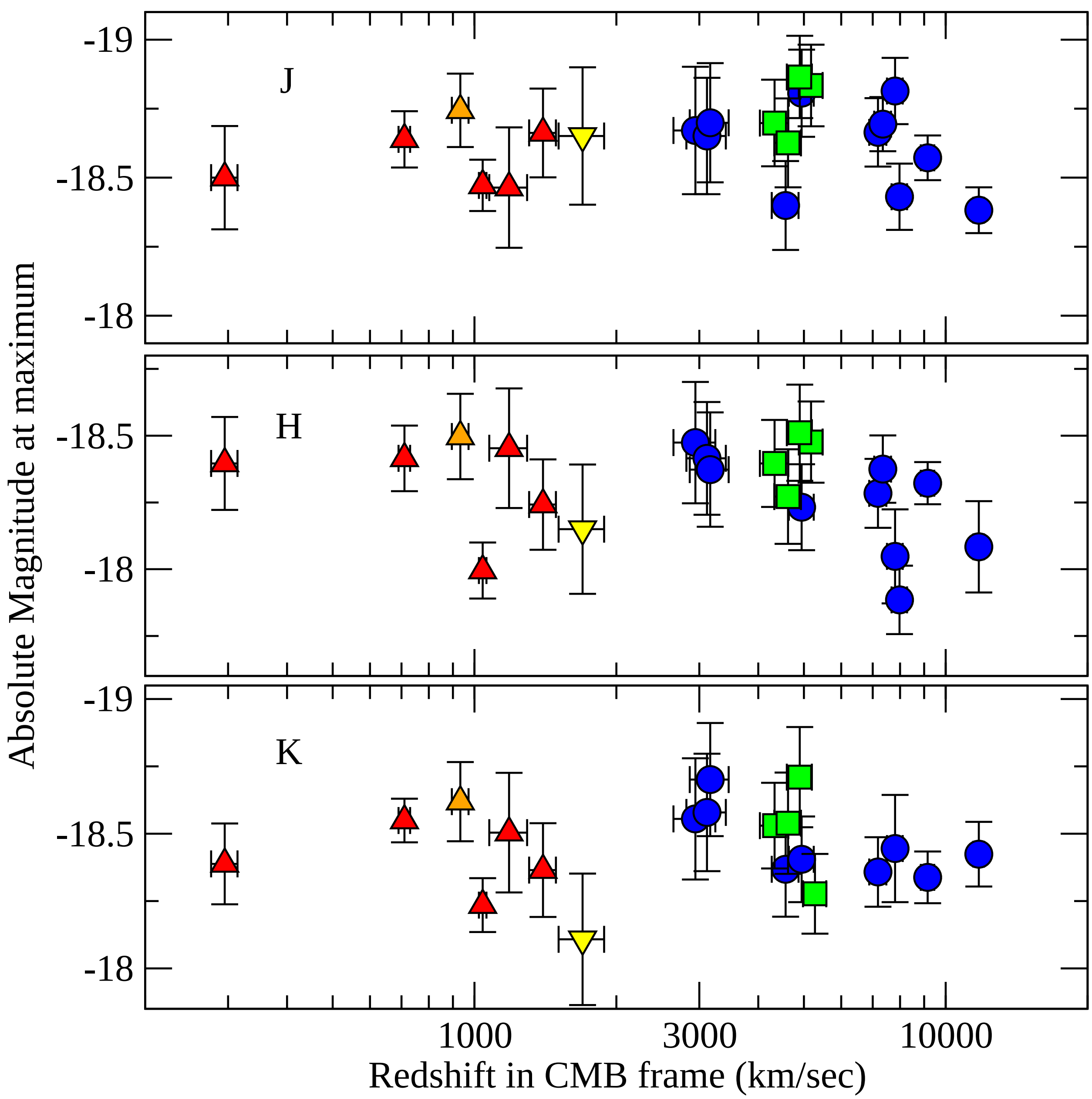
Krisciunas *et al.* Fig. 12



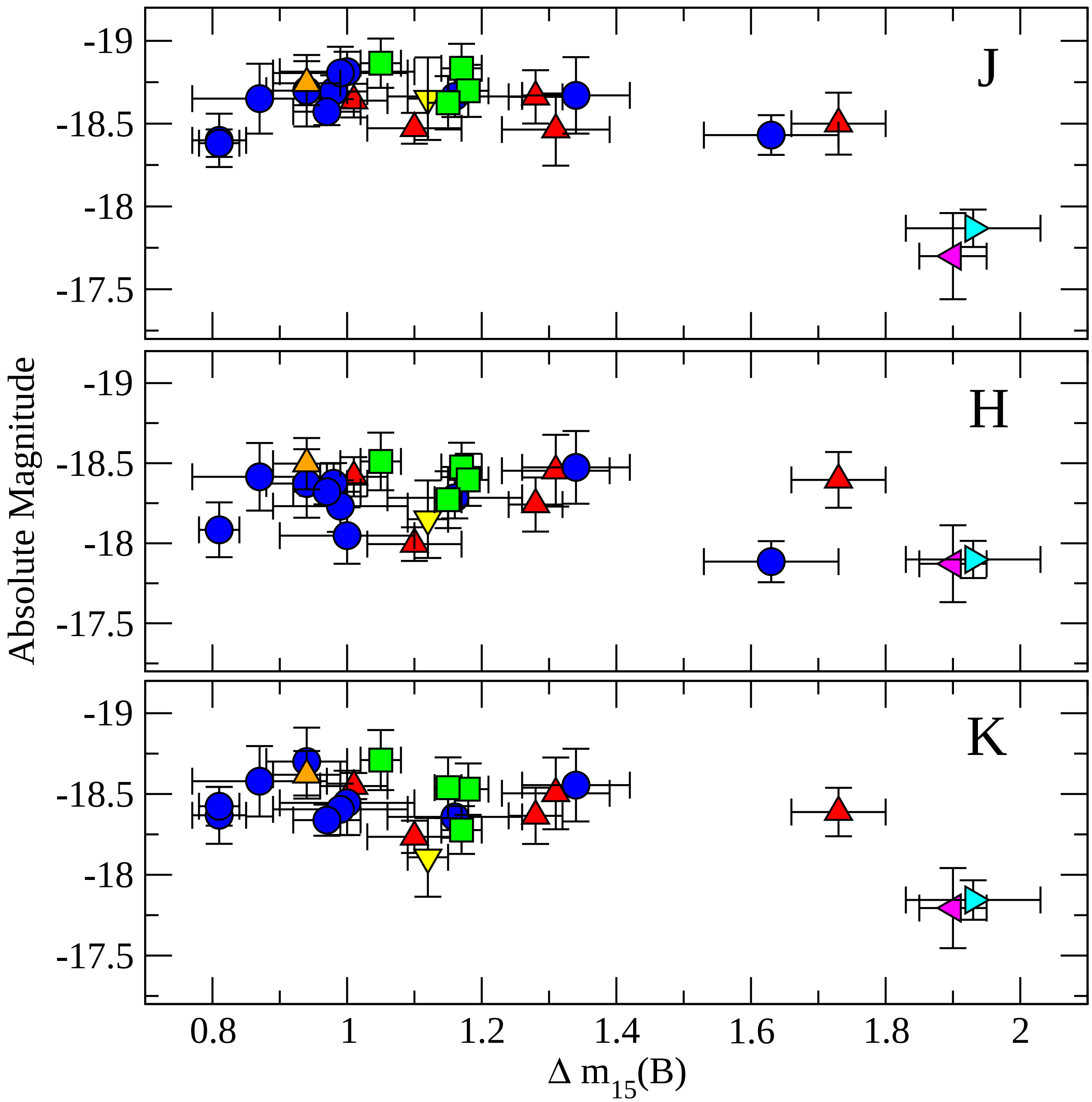
Krisciunas *et al.* Fig. 13



Krisciunas *et al.* Fig. 14



Krisciunas *et al.* Fig. 15



Krisciunas *et al.* Fig. 16