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BVRI lightcurves of supernovae SN 2011fe in M101, SN 2012aw in M95, and SN 2012cg in NGC 4424

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HIGHLIGHTS

- Densely populated, high precision lightcurves of three recent and bright SNe.
- It is easy to anticipate these SN will be intensively studied as template cases.
- A new, robust method to combine SN photometry from different telescopes is devised.
- A correction is suggested to zero-points of relations providing absolute B mag.
- Light- and color-curves and bolometric lightcurves are discussed.

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ABSTRACT

Accurate and densely populated BVR_CI_C lightcurves of supernovae SN 2011fe in M101, SN 2012aw in M95 and SN 2012cg in NGC 4424 are presented and discussed. The SN 2011fe lightcurves span a total range of 342 days, from 17 days pre- to 325 days post-maximum. The observations of both SN 2012aw and SN 2012cg were stopped by solar conjunction, when the objects were still bright. The lightcurve for SN 2012aw covers 92 days, that of SN 2012cg spans 44 days. Time and brightness of maxima are measured, and from the lightcurve shapes and decline rates the absolute magnitudes are obtained, and the derived distances are compared to that of the parent galaxies. The color evolution and the bolometric lightcurves are evaluated in comparison with those of other well observed supernovae, showing no significant deviations.

1. Introduction

Most supernovae are discovered at cosmological distances. Rarely do they become as bright as SN 2011fe, a type Ia supernova that recently erupted in M101 and peaked at $B = 9.9$. In recent times, particularly bright supernovae were SN 1937c (a type Ia in IC 4182, peaking at $B = 8.7$; Schaefer, 1996), SN 1972e (type Ia in NGC 5253, peaking at $B = 8.6$; Branch et al., 1983), SN 1993j (type II in M81, reaching $B = 10.8$; Lewis et al., 1994), and of course SN 1987a (a type II in LMC, peaking at $B = 4.6$; Hamuy et al., 1988). Such bright SNe are subject to "all-out" observing campaigns, and the great amount of data collected over a wide range of wavelengths make them critical tests for models. The quest for the ultimate set of observational data on well observed supernovae may go on for years or decades after the event, with increasingly finer and more sophisticated comparisons, homogenization, re-calibration, and merging of independent sets of data (Clocchiatti et al., 2011 have only recently obtained what they termed the "ultimate" lightcurve of SN 1998bw, a key supernova that together with SN 2003dh provided the first solid evidence of the connection between supernovae and Long-Soft gamma-ray bursts).

The aim of this paper is to present our rich set of accurate BVR_CI_C photometric measurements of SN 2011fe, covering 342 days, augmented by similar photometry of other two recent and bright supernovae, SN 2012aw (type IIP) and SN 2012cg (type Ia), whose monitoring was stopped by solar conjunction while they were still in their early decline stages.

It is known (e.g., Suntzeff et al., 1988; Clocchiatti et al., 2011) that time dependent differences in the lightcurves of supernovae obtained by different authors are the results of slightly different local realizations of the standard photometric passbands combined

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with the profoundly non-stellar character of supernova spectra (dominated by time-variable strong absorption and emission). An enhancing feature of our set of BVR_CI_C photometric measurements is that they have been independently and in parallel obtained with several different telescopes equipped with different CCD cameras and BVR_CI_C filter sets, all adopting the same accurate photometric sequences calibrated by Henden et al. (2012) on equatorial (Landolt, 1983, 1992) standards. Combining data from different telescopes into a single, merged, densely populated lightcurve effectively improves upon the disturbing effects of differences in the local realizations of a common photometric system, offering a merged lightcurve which should be a closer match to the *true* lightcurve than any local realization.

2. Observations

BVR_CI_C photometry of the three program supernovae was obtained with several robotic, remotely or manually controlled telescopes operated by ANS Collaboration. Technical details of this network of telescopes running since 2005, their operational procedures and sample results are presented by Munari et al. (2012). Detailed analysis of the photometric performances and measurements of the actual transmission profiles for all the photometric filter sets in use is presented by Munari and Moretti (2012).

Additional BVR_CI_C measurements of SN 2011fe and SN 2012aw were obtained at the Astrokolkhoz Observatory in New Mexico with K35, a 35 cm remotely operated telescope which houses a set of Astrodon BVR_CI_C multi-layer dielectric filters.

All measurements were carried out with aperture photometry, the long focal length of the telescopes and the smoothness of galaxy background around the three supernovae not requiring the use of PSF-fitting.

All photometric measurements of SN 2011fe and SN 2012aw were carefully tied to the local BVR_CI_C sequences calibrated by Henden et al. (2012) against (Landolt, 1983, 1992) equatorial standards. A similar sequence was established around SN 2012cg and adopted by all ANS Collaboration telescopes monitoring this supernova. The adopted transformation equations between local realizations (small letters) and the standard system (capital letter) take the usual form:

$$
\begin{aligned}
B &= b + \alpha_b \times (b - v) + \gamma_b \\
V &= v + \alpha_v \times (v - i) + \gamma_v \\
R_C &= r + \alpha_r \times (v - i) + \gamma_r \\
I_C &= i + \alpha_i \times (v - i) + \gamma_i \\
B - V &= \beta_{bv} \times (b - v) + \delta_{bv} \\
V - R_C &= \beta_{vr} \times (v - r) + \delta_{vr} \\
V - I_C &= \beta_{vi} \times (v - i) + \delta_{vi}
\end{aligned}
\qquad (1)
$$

where α, β, γ, δ are constants describing the instantaneous realization of the standard system. Their values, range of variability, and dependence upon filters, detectors, telescope, and atmosphere for ANS telescopes are discussed in Munari and Moretti (2012).

The median value of the total error budget (defined as the quadratic sum of the Poissonian error on the supernova and the formal error on the transformation from the local to the standard system) for the data collected on the three supernovae is 0.011 mag for B, 0.007 in V, 0.010 in R_C, 0.016 in I_C, and 0.010 mag for $B - V$, 0.011 in $V - R_C$, and 0.018 in $V - I_C$. Colors and band magnitudes are obtained separately during the reduction process, and are not derived one from the other.

3. The lightcurve merging method (LMM)

The spectra of supernovae are dominated by broad emission and absorption features and are completely different from the black-body like spectra of normal field stars used in transforming the local photometry to the standard system. Local realizations of the photometric system include different atmospheric and filter transmission, detector sensitivity, efficiency of the optics. On normal stars (like those making the photometric comparison sequence) all these effects are collectively corrected for by the transformation Eq. (1), provided that the local realization is sufficiently close to the standard system (i.e., α_λ are close to 0.0, and β_λ close to 1.0). The spectra of supernovae, strongly dominated by broad and intense absorptions and emissions, are completely different from the black-body like spectra of normal field stars, and the Eq. (1) transformations can only partially compensate for the differences between the local and the standard systems.

The situation is illustrated in Fig. 1, where the measured transmission profiles for the B and V band filters in use with ANS Collaboration telescopes are overplotted with a flux-calibrated spectrum of SN 2012cg which was obtained on 2012 June 16.875 UT with the Asiago 1.22 m telescope of the University of Padova, operating at 2.31 Å/pix over the 3300–8100 Å range. These filters come from different manufacturers and are of both the multi-layer dielectric type (profiles plotted in blue) and the classical sandwich of colored glasses (profiles plotted in red), typically built according to the standard recipe of Bessell (1990). Some of the profiles shown in Fig. 1 are for brand-new filters, others for filters in long use at the telescopes and showing clear aging effects (see Munari and Moretti (2012) for a detailed discussion).

The lightcurves of the same supernova obtained with different telescopes will therefore show offsets among them, and these offsets will be time-dependent following the spectral evolution of the supernova. An example is shown in Fig. 2 (middle panel), where our V-band data on SN 2011fe from different telescopes are compared. Which of these lightcurve is the correct one? There is no *a priori* argument to prefer one or another, all of them referring to the same photometric calibration sequence, using the same extraction software, suffering from similar and very low formal errors.

The closest representation of the *true* lightcurve appears to be a proper combination of all these individual lightcurves, effectively averaging over different observing conditions and instrumentation. To combine them into a merged lightcurve, we assume that all

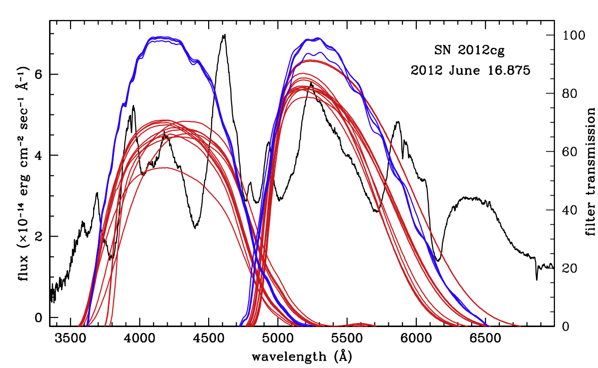

Fig. 1. A spectrum of SN 2012cg with overplotted the measured transmission profiles of many B and V filters from different manufactures (from Munari and Moretti, 2012). Red curves refer to common filters made with sandwiches of colored glasses, blue curves to multi-layer dielectric filters. The different amount of transmitted absorption and emission features is evident (expecially on the red wing of V filter passband), which account for the unavoidable differences in the photometry obtained with different telescopes even if a given SN is measured against the same identical photometric sequence. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

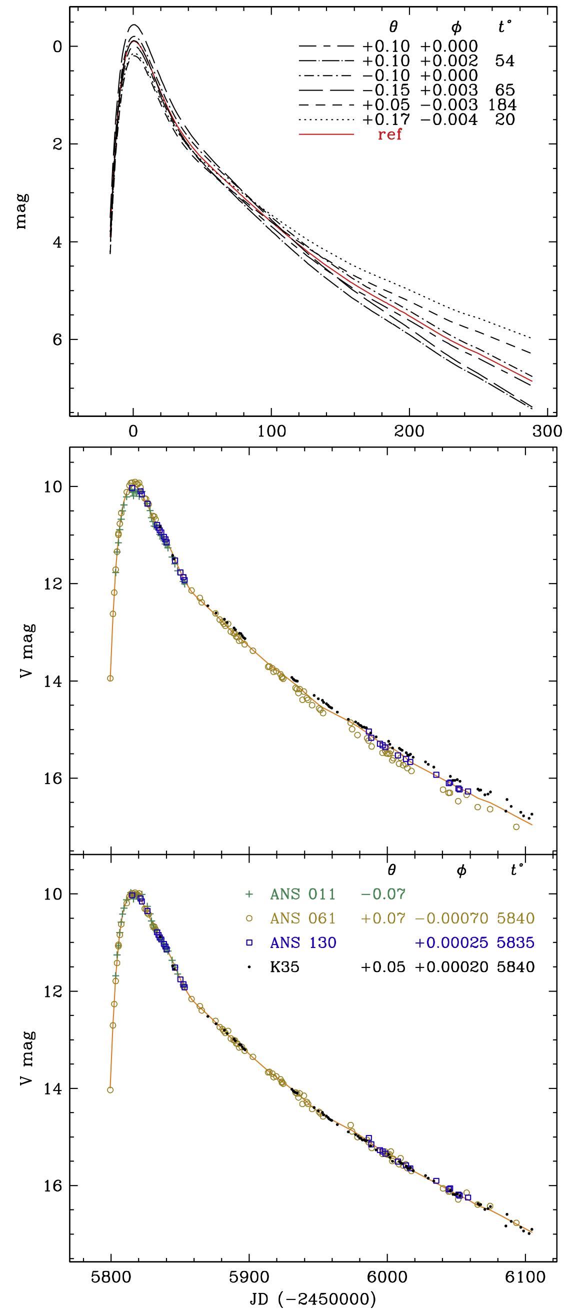

Fig. 2. Example of the lightcurve merging method (LMM) described in Section 3. *Top:* These lightcurves are the results of shifting (by θ) and stretching (by ϕ) around the pivot points (t°) the ordinates (magnitudes) of the reference ligthcurve (ploted in red). *Middle:* our source *V*-band observations for SN 2011fe, where different colors and symbols identify different telescopes. *Bottom:* our merged *V*-band lightcurve of SN 2011fe after application (by the given quantities) of the LMM shift and pivot stretching method. The orange line (the same in both the middle and bottom panels) is a spline fit to the *merged lightcurve* $\mathrm{mag}(\lambda)_{i,j}$ (cf. Eq. (3)). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

individual lightcurves from different telescopes are exactly the same one, affected only by an offset in the ordinate zero-point and a linear stretch of the ordinates around a pivot point:

$$\mathrm{mag}_{i,j}(\lambda) = \mathrm{mag}^*_{i,j}(\lambda) + \theta_j(\lambda) + \phi_j(\lambda) \times [t_{i,j}(\lambda) - t^\circ_j(\lambda)] \quad (2)$$

where $\mathrm{mag}^*_{i,j}(\lambda)$ is the *i*th magnitude value in the λ photometric band from the *j*th telescope, $\mathrm{mag}_{i,j}(\lambda)$ is the corresponding value in the merged lightcurve, $\theta_j(\lambda)$ is the amount of zero-point shift and $\phi_j(\lambda)$ is coefficient of the linear stretching around the $t^\circ{}_j(\lambda)$ pivot point. The stretch is therefore a linear function of time difference with the reference $t^\circ{}_j(\lambda)$ epoch.

The optimal values for $\theta_j(\lambda), \phi_j(\lambda)$ and $t^\circ{}_j(\lambda)$ are derived by a χ^2 minimization of the difference between the observed points and those defining the merged lightcurve:

$$\chi^2 = \sum_i \sum_j \frac{[\mathrm{mag}^*_{\mathrm{i,j}}(\lambda) - \mathrm{mag}_{\mathrm{i,j}}(\lambda)]^2}{[\epsilon_{i,j}(\lambda)]^2} \quad (3)$$

where *j* sums over the different telescopes, *i* over the individual measurements of each telescope, and $\epsilon_{i,j}(\lambda)$ is the total error budget of each measurement. The effect of shifting and stretching around a pivot point the ordinate values of a given lightcurve is illustrated in the top panel of Fig. 2. The application of the method to the actual data we obtained for the three supernovae is illustrated in the middle and bottom panels of Fig. 2, using the *V*-band observations of SN 2011fe as an example. The reduction of the dispersion around a common lightcurve is evident when comparing the middle and bottom panels of Fig. 2. The coefficients for the other bands, colors, instruments and supernovae considered in this paper are similarly small.

Notice that the LMM method to construct a merged lightcurve from observations obtained with different telescopes *does not stretch* the resulting lightcurve in flux (compare how the orange line, the same curve in both panels, goes through the data in the middle and bottom panels of Fig. 2), nor time (the method acts only on the individual magnitude values, not the associated time tag). Therefore, the LMM method does not interfere with the application of popular time- and brightness-stretching methods used to estimate the absolute magnitude of a supernova by comparison with a sample of template ligthcurves (see below).

Our merged BVR_CI_C photometry for the three program supernovae is listed in Tables 1–3, and presented in the Figs. 3, 5, 6 and 7. All together, we present 236 BVR_CI_C data sets for SN 2011fe, 108 for SN 2012aw, and 27 for SN 2012cg.

4. Results

4.1. SN 2011fe

The type Ia SN 2011fe was discovered in M101 at $g = 17.35$ on 2011 Aug 24.164 UT by the Palomar Transient Factory (Nugent et al., 2011a), only ~11 h after it exploded (on Aug 23.71, Nugent et al., 2011b). From archival HST images, Li et al. (2011) excluded a luminous red giant as a companion star to the progenitor of SN

Table 1
Our merged BVR_CI_C photometry for SN 2011fe (the table is published in its entirety in the electronic edition of New Astronomy. A portion is shown here for guidance regarding its form and content).

SN	JD (−2450000)	*B*	*V*	R_C	I_C	Tel.
...	...	...	...	...	...	...
2011fe	5844.2325	12.635	11.362	10.989	10.677	ANS 11
2011fe	5844.5647	12.575	11.476	11.061	10.740	K 35
2011fe	5845.5631	12.669	11.547	11.109	10.774	K 35
2011fe	5846.2354	12.717	11.504	11.104	10.768	ANS 11
2011fe	5846.2861	12.758	11.515	11.144	10.747	ANS 130
2011fe	5848.2254	12.817	11.644	11.277	10.923	ANS 11
2011fe	5850.2832	12.976	11.758	11.424	11.040	ANS 130
2011fe	5852.2221	12.953	11.865	11.513	11.202	ANS 11
2011fe	5852.2358	12.958	11.897	11.569	11.278	ANS 61
2011fe	5852.2830	13.091	11.857	11.528	11.173	ANS 130
2011fe	5853.2102	13.105	11.914	11.591	11.280	ANS 11
2011fe	5853.2676	13.105	11.920	11.603	11.247	ANS 130
...	...	...	...	...	...	...

Table 2
Our merged BVR_CI_C photometry for SN 2012cg.

SN	JD (−2450000)	B	V	R_C	I_C	Tel.
2012cg	6072.3727	13.035	12.893	12.711	12.582	ANS 157
2012cg	6072.3967		12.852		12.492	ANS 11
2012cg	6073.4303	12.849	12.636	12.480	12.392	ANS 157
2012cg	6074.3370	12.761	12.539	12.344	12.320	ANS 11
2012cg	6076.3644	12.485	12.310	12.097	12.073	ANS 157
2012cg	6078.3677	12.298	12.146	11.929	11.951	ANS 157
2012cg	6080.3689	12.223	12.026	11.890	11.859	ANS 157
2012cg	6084.3318	12.184	11.975	11.801	11.855	ANS 11
2012cg	6084.3666	12.219	11.954	11.821	12.051	ANS 157
2012cg	6086.3389	12.234	12.079		12.032	ANS 11
2012cg	6088.3801	12.347	12.066	11.878		ANS 157
2012cg	6090.3679	12.492	12.141	11.994	12.232	ANS 157
2012cg	6093.3861	12.787	12.300	12.179	12.189	ANS 11
2012cg	6094.3868	12.860	12.327	12.170	12.576	ANS 11
2012cg	6094.4045	12.826	12.319			ANS 157
2012cg	6095.3845	12.921	12.371		12.578	ANS 11
2012cg	6096.3720	13.046	12.454	12.322	12.522	ANS 157
2012cg	6097.3697	13.127	12.533	12.405	12.418	ANS 157
2012cg	6098.3503	13.261	12.524		12.740	ANS 11
2012cg	6100.3713	13.467	12.640	12.541	12.498	ANS 157
2012cg	6101.3818	13.583	12.745		12.460	ANS 11
2012cg	6105.3752	13.939	12.854	12.554	12.374	ANS 157
2012cg	6113.3878	14.577	13.258			ANS 157
2012cg	6116.3744	14.637	13.424			ANS 157

Table 3
Our merged BVR_CI_C photometry for SN 2012aw (the table is published in its entirety in the electronic edition of New Astronomy. A portion is shown here for guidance regarding its form and content).

SN	JD (−2450000)	B	V	R_C	I_C	Tel.
...	...	...	...	...	...	...
2012aw	6009.3037	13.502	13.352	13.196	13.082	ANS 61
2012aw	6009.3514	13.498	13.387	13.186	13.091	ANS 157
2012aw	6009.4240	13.449	13.342	13.193	13.078	ANS 130
2012aw	6009.4519	13.481	13.366	13.186	13.126	ANS 11
2012aw	6009.7358	13.525	13.364	13.204	13.096	K 35
2012aw	6010.3456	13.492	13.343	13.169	13.059	ANS 157
2012aw	6010.3598	13.508	13.333	13.176	13.068	ANS 61
2012aw	6010.4744	13.456	13.325	13.162	13.047	ANS 61
2012aw	6010.5456	13.475	13.329	13.162	13.036	ANS 130
2012aw	6010.7187	13.476	13.342	13.178	13.057	K 35
...	...	...	...	...	...	...

2011fe, a conclusion supported by sensitive X-ray and radio non detection during early evolution (Horesh et al., 2012; Chomiuk et al., 2012). Analysis of early-time optical spectra was reported by Parrent et al. (2012), ultraviolet data from Swift satellite by Brown et al. (2012), and polarization of optical light by Smith et al. (2011). Being the first close type Ia supernova detected in the CCD era, SN 2011fe will undoubtedly become the best observed thermonuclear supernova, well into its nebular stage, and a stringent test for theoretical models.

We began our photometric monitoring of SN 2011fe on 2011 August 25.891, less than a day after the announcement of discovery was posted by Nugent et al. (2011a). We have obtained 236 independent BVR_CI_C runs, the last on 2012 August 1.404 UT, covering 342 days. We began when the SN was still 4.4 mag below maximum, and continued until it declined by 7.2 mag below it. Table 4 lists the time and brightness of the optical maximum from our observations, both as observed and as corrected for the $E_{B-V} = 0.025 \pm 0.003$ reddening found by Patat et al. (2011) to affect SN 2011fe. In correcting for the reddening we have adopted a standard $R_V = 3.1$ reddening law (Fitzpatrick, 1999) and the reddening relations of Fiorucci and Munari (2003) appropriate for the observed colors.

Our epochs and magnitudes at maximum brightness are somewhat different from those listed by Richmond and Smith (2012), who presented BVR_CI_C photometry covering the first 180 days of SN 2011fe evolution. The differences are probably due to the preliminary AAVSO comparison sequence that they used, based on only three stars, of similar colors and much redder ($B-V$ = +0.63, +0.68, +0.84) than the supernova at maximum brightness ($B-V$ = −0.08). This forced Richmond and Smith to adopt the values of α_b, α_v, α_r, α_i in the transformation equations Eq. (1) above from unrelated observations of a single Landolt (1992) field, and use the three AAVSO stars around SN 2011fe only to constrain the zero-points γ_b, γ_v, γ_r, γ_i in the same equations. Appreciably closer to our Table 4 are the values obtained by Tammann and Reindl (2011) from analysis of photometry collected by AAVSO members, covering the first 75 days of SN 2011fe lightcurve.

The absolute magnitude of type Ia supernovae is related to the shape of their lightcurves, with Phillips (1993) noting how the intrinsic brightness is inversely proportional to the speed of decline. The most used calibrations of the relation between absolute brightness and rate of decline are probably the Δm_{15}, MLCS and stretch methods. The Δm_{15} method is based on the magnitude difference between maximum light and 15 days past it (Hamuy et al., 1996; Phillips et al., 1999). The MLCS method (Riess et al., 1996; Riess et al., 1998) fits the observed lightcurve to a set of template lightcurves built from a set of well observed and calibrated supernovae. The stretch method (Perlmutter et al. (1997),Goldhaber et al., 2001) derives the decline speed and therefore the absolute magnitude by stretching the scale on the time axis of the lightcurve to fit a reference lightcurve. Prieto et al. (2006) presented a new technique that is a combination of the Δm_{15} and MLCS methods. Their calibration of the absolute magnitude at maximum takes the form:

$$M_\lambda(max) = a_\lambda + b_\lambda(\Delta m_{15} - 1.1) \quad (4)$$

where $\lambda = B, V, R_C, I_C$. Our determination of Δm_{15} in the B, V, R_C, I_C bands is given in Table 4, together with the resulting distances to SN 2011fe.

The distance derived from Δm_{15} in the V, R_C, I_C bands are tightly grouped around the mean value $<(m-M)_\circ> = 29.34 \pm 0.02$, which is very close to the $(m-M)_\circ = 29.39 \pm 0.04$ distance to M101 derived by Suntzeff (1996) from HST observations of stars at the tip of the RGB by Sakai et al. (2004) and Rizzi et al. (2007). The distance obtained from Δm_{15} in the B band is significantly less, by 0.23 mag, but close to the distance $(m-M)_\circ = 29.05 \pm 0.13$ that Shappee and Stanek (2011) derived for M101 from HST observations of Cepheid variables. We will see in the next paragraph, that a similar situation exists with SN 2012cg, where the Prieto et al. (2006) relations for V, R_C, I_C provide comparable distances, while in the B band the distance is less by 0.22 mag. This suggests a possible revision of zero-points of Prieto et al. (2006) for the B band:

$$M_B(\max) = -19.550 + 0.636 \times (\Delta B_{15} - 1.1) \quad (5)$$

for the $E_{B-V} \leqslant 0.06$ low reddening case, and

$$M_B(\max) = -19.511 + 0.753 \times (\Delta B_{15} - 1.1) \quad (6)$$

for the $E_{B-V} > 0.06$ case. At least for SN 2011fe and SN 2012cg, adding −0.225 mag to the zero-points would bring the distance derived from B band into agreement with those obtained from the V, R_C, I_C bands. It is worth noticing that both these supernovae are close to $\Delta B_{15} = 1.1$, so changing the slope instead of the zero-points would not cure the systematic shift between the distance in B and that derived in the V, R_C, I_C bands. The absolute magnitude of SN 2011fe corresponding to the $(m-M)_\circ = 29.34$ distance modulus is $M_B = -19.55$. The secondary maximum in the I_C band was fainter by 0.46 mag and occurred 28.0 days later, both values being well

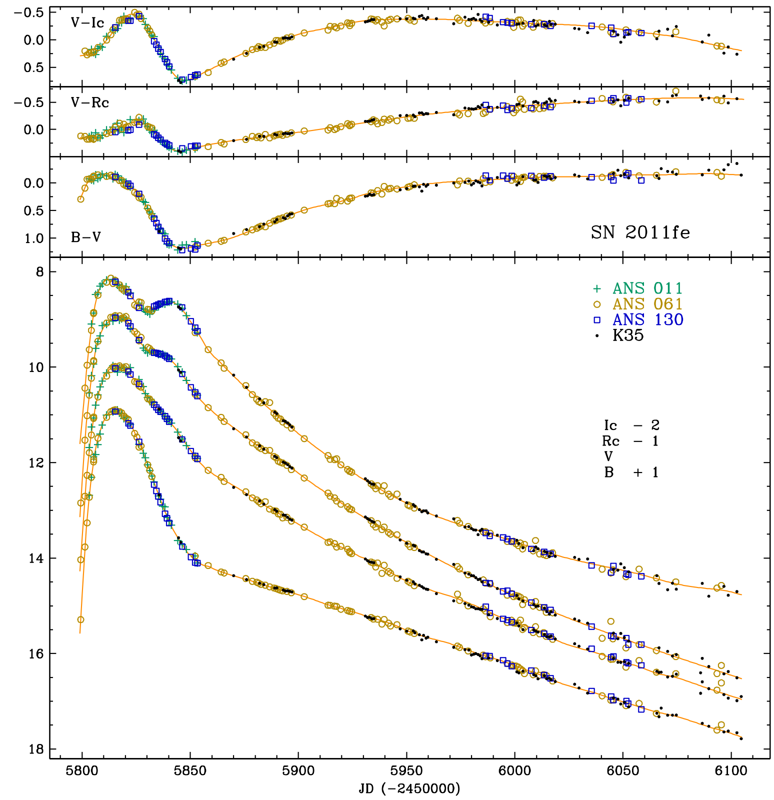

Fig. 3. *BVR*$_C$*I*$_C$ light- and color-curve of SN 2011fe from our data in Table 1. Different colors and symbols identify the telescopes used to monitor the supernova. The curves are spline fits to the data drawn to guide the eye.

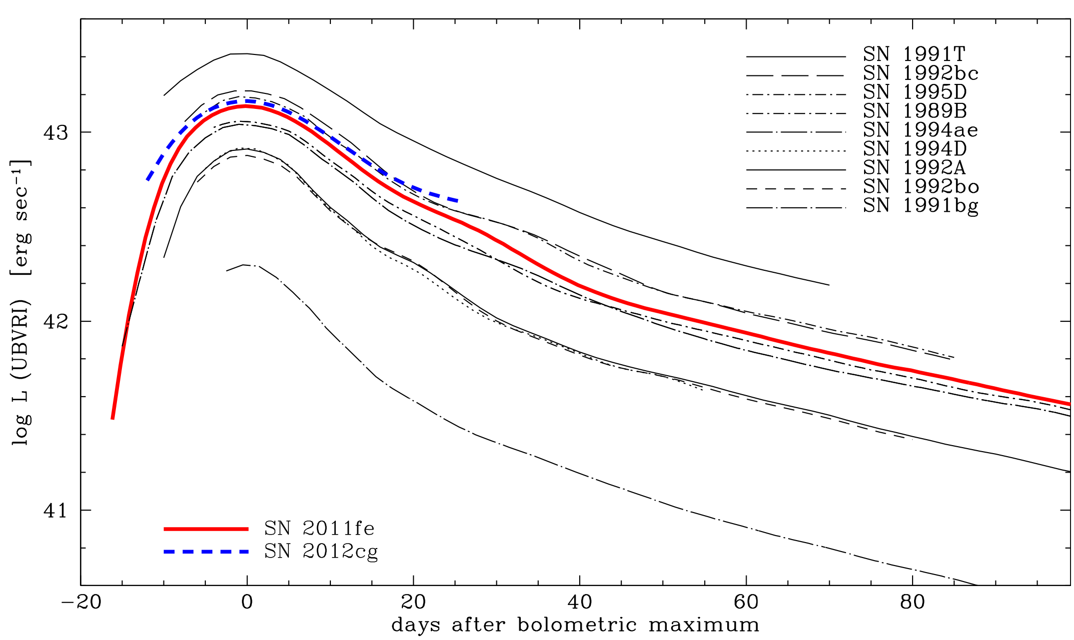

Fig. 4. Bolometric lightcurves of SN 2011fe and SN 2012cg (obtained by summing the reddening corrected flux in *UBVR*$_C$*I*$_C$ bands) compared to those of well observed objects from Contardo et al. (2000). The *U* data are obtained from observed *B* values and adding the parametrized *U*–*B* color evolution from Nobili and Goobar (2008).

within the range observed for type Ia supernovae (e.g., Leibundgut, 2000).

The bolometric curve of SN 2011fe is presented in Fig. 4, where it is compared to the bolometric evolution of a sample of well observed type Ia supernovae compiled by Contardo et al. (2000). All the bolometric lightcurves in Fig. 4 are obtained by adding the flux observed in the *UBVR*$_C$*I*$_C$ bands, which is a close approximation of the *true* bolometric lightcurve (obtained integrating the flux over the whole wavelength range), given the evidence that about 80% of the bolometric luminosity of a typical SN Ia is emitted over the optical range (Suntzeff, 1996). We did not observe SN 2011fe in the *U* band, but obtained it from our *B*-band data and

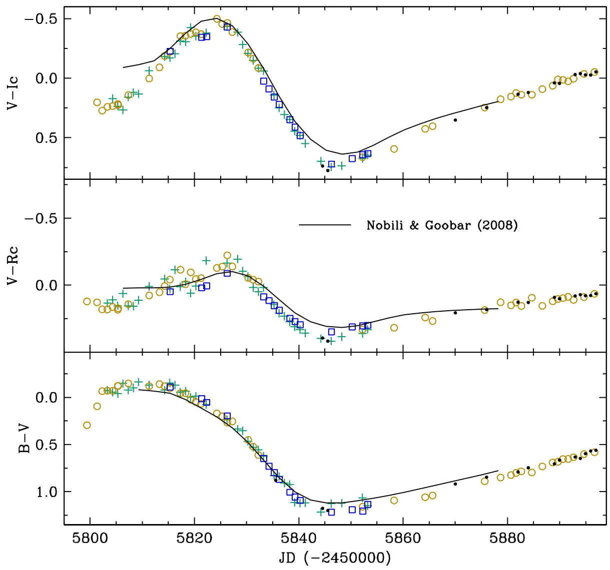

Fig. 5. Comparison of the color evolution of SN 2011fe with the parameterized color evolution of Nobili and Goobar (2008), over-plotted as a curve.

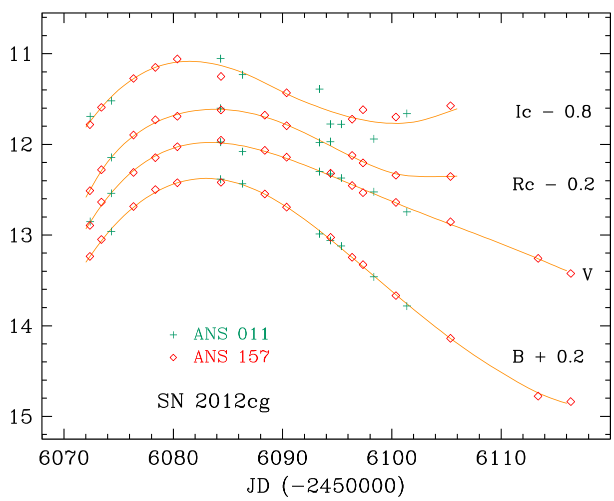

Fig. 6. BVR_CI_C lightcurve of SN 2012cg from our data in Table 2. Different colors and symbols identify the telescopes used to monitor the supernova. The curves are spline fits to the data drawn to guide the eye.

the $U-B$ average color evolution of type Ia supernovae as given by Nobili and Goobar (2008). This is a safe procedure because U band is a marginal contributor to the optical flux, and SN 2011fe followed the typical B–V, V–R_C and V–I_C color evolution of type Ia supernovae (see Fig. 5). The shape of the bolometric lightcurve nicely follows the progression with absolute magnitude presented by Contardo et al. (2000). The maximum of the bolometric luminosity is reached $\sim$18.2 days past the beginning of eruption as determined by Nugent et al., 2011b, close to the 18.03 ± 0.24 days found by Ganeshalingam et al. (2011) as the mean value for spectroscopically normal type Ia supernovae.

4.2. SN 2012cg

SN 2012cg was discovered in NGC 4424 on 2012 May 17.22 UT by Kandrashoff et al. (2012) during the Lick Observatory Supernova Search (LOSS), and soon spectroscopically identified as a type Ia supernova caught well before optical maximum. An X-ray observation with Swift obtained 1.5 days after the discovery failed to detect emission from the supernova (Margutti and Soderberg, 2012). Post-discovery inspection of MASTER-Kislovodsk images of NGC 4424 obtained on May 15.790, reveals the supernova was at that time already present at a magnitude $\sim$19 (Lipunov and Krushinsky, 2012).

We began our observations of SN 2012cg on May 24.873 UT, 9 days before B maximum, and continued them for 44 days. We obtained a total of 27 BVR_CI_C measurement data sets.

The time and brightness of SN 2012cg at maximum are given in Table 5. The B-band maximum corresponds to June 4.5 UT. Marion et al. (2012) similarly found the maximum to have occurred around June 4. The indication by Silverman et al. (2012) of a B-band maximum occurring on June 2.0 ± 0.75 cannot be easily reconciled with our observations.

The Δm_{15} decline rates of SN 2012cg in Table 5 are somewhat slower than those of SN 2011fe, suggesting an intrinsically brighter target. By correcting for a $E_{B-V} = 0.18$ reddening (as suggested by Marion et al., 2012; Silverman et al., 2012), we obtain from VR_CI_C a distance modulus of $(m-M)_\circ = 30.95$. This is quite close to the $(m-M)_\circ = 30.91$ obtained for NGC 4424 from the Tully–Fisher relation by Cortés et al. (2008). The corresponding absolute magnitude for SN 2012cg would be $M_B = -19.55$, the same as found above for SN 2011fe, in spite of the slower decline rates. The bolometric lightcurve of SN 2012cg plotted in Fig. 4 peaks at a luminosity close to that of SN 2011fe on June 4.75, but the rising and declining time are slower than those of SN 2011fe. Silverman et al. (2012) modeled the early rise in magnitude of SN 2012cg following the usual expanding fireball approach, and by extrapolation estimated that the supernova explosion occoured on May 15.7–0.02. Our bolometric lightcurve reaches its maximum 20.0 days later.

4.3. SN 2012aw

SN 2012aw was discovered by P. Fagotti on Mar 16.86 UT on images of M95 taken at his private observatory when it was at $R_C \sim 15$ (CBET 3054), and was classified from spectra as a type IIP supernova by Itoh et al. (2012) and Siviero et al. (2012). We began our observations on Mar 17.91 UT, a week before maximum was reached in the B band, and continued them for 91 days, collecting 108 BVR_CI_C measurement data sets.

Freedman et al. (2001) obtained from observation of Cepheids a distance to the parent M95 galaxy of $(m-M)_\circ = 30.0$–0.1. While the Milky Way reddening toward M95 is low ($E_{B-V} = 0.028$, Schlegel et al. (1998), the amount local to SN 2012aw seems to be relevant. Fraser et al. (2012) identified on archival HST and ground-based images the supernova progenitor as a star of V–26.7, appearing red in color and suffering from a large extinction ($E_{B-V} > 0.8$), whereas the SN itself does not appear to be significantly extinguished, a fact that Fraser et al. interpret as evidence for the destruction of pre-existing, circumstellar dust during the SN explosion. This conclusion is shared by Van Dyk et al. (2012) that found the progenitor to be a red-supergiant of $M_{bol} = -8.3$, being extinguished by $A_V \sim 3.1$ mag.

Our photometry shows a long lasting, flat maximum in VR_CI_C bands, distinctive of type IIP supernovae, which is expected to last about a hundred days (Doggett and Branch, 1985), i.e., longer than our monitoring period. The maximum in the B band was reached on Mar 24.1 UT at $B = 13.487$, providing an absolute magnitude of $M_B = -16.4$ (correcting for the Milky Way reddening but not for any residual reddening from dust local to the SN). The β^B_{100} decline parameter, as defined by Patat et al. (1994), is 2.67, right in the middle of their distribution for type IIP supernovae, and β^V_{100} is 0.63. The rate of decline at the center of the decline branch

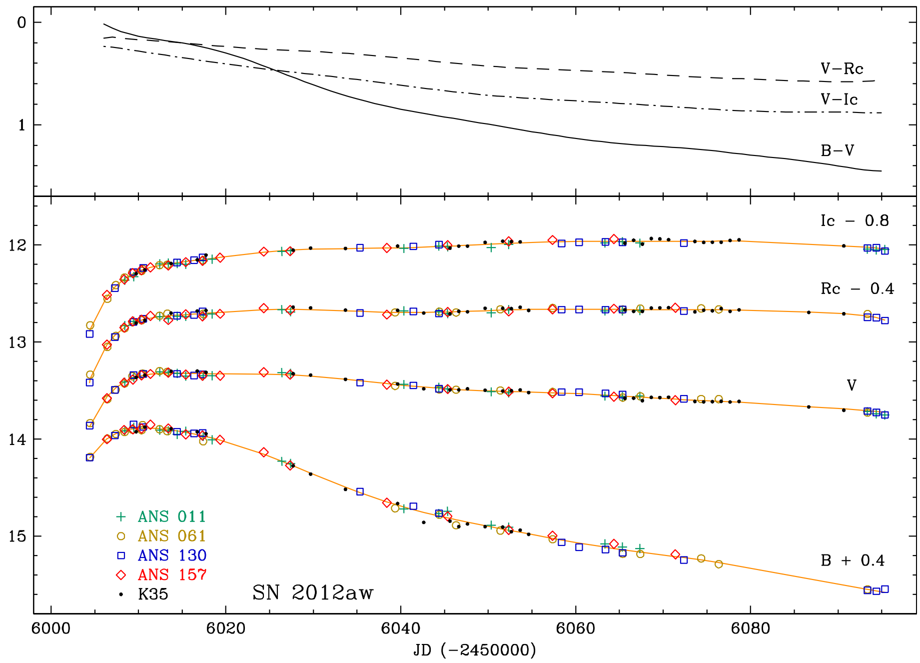

Fig. 7. *BVR*$_C$*I*$_C$ light- and color-curve of SN 2012aw from our data in Table 3. Different colors and symbols identify the telescopes used to monitor the supernova. The curves are spline fits to the data drawn to guide the eye.

Table 4
Time and brightness of SN 2011fe at maximum. The fourth column gives the decline in magnitude 15 days past maximum. The last two columns list the brightness at maximum and the distance modulus corrected for $E_{B-V} = 0.025$ reddening, adopting the standard $R_V = 3.1$ extinction law and Prieto et al. (2006) calibrations of Δmag_{15}.

Band	Maximum		Δm_{15}	$E_{B-V} = 0.025$	
	UT (−2450000)	Mag		(Mag)$_\circ$	$(m-M)_\circ$
Primary maximum					
B	5815.29	9.893	1.108	9.785	29.11
V	5816.00	9.976	0.695	9.895	29.38
R_C	5817.05	9.928	0.753	9.863	29.30
I_C	5812.59	10.168	0.602	10.123	29.33
Secondary maximum					
I_C	5840.26	10.624		10.579	

Table 5
Time and brightness of SN 2012cg maximum. The fourth column gives the decline in magnitude 15 days past maximum. The last two columns list the brightness at maximum and the distance modulus corrected for $E_{B-V} = 0.18$ reddening, adopting the standard $R_V = 3.1$ extinction law and Prieto et al. (2006) calibrations of Δmag_{15}.

Band	Maximum		Δm_{15}	EB-V =0.18	
	UT (−2450000)	Mag		(Mag)$_\circ$	$(m-M)_\circ$
B	6083.0	12.176	1.039	11.399	30.73
V	6083.4	11.979	0.569	11.391	31.02
R_C	6083.8	11.813	0.652	11.347	30.92
I_C	6081.5	11.884	0.625	11.543	30.92

before the inflection point was $\Delta B = 0.035$ mag day^{-1}, and $\Delta B = 0.015$ mag day^{-1} at the center of the plateau phase. At the time of *B* maximum, the observed colors of SN 2012aw were B–V = +0.146, V–$R_C = +0.174$, V–$I_C = +0.290$. They monotonically evolved toward redder colors during the time covered by our observations, as typical for type IIP supernovae.

The maximum in *V* band was reached at *V*=13.321 on Mar 27.2 UT, and the mean decline rate from then to the end of our monitoring (82 days later) is 0.0050 mag day^{-1}. Over the period of our observations in Fig. 7, the R_C lightcurve is best describe as *flat* (within ±0.02 mag of) once the initial rise was completed, and the I_C as showing a minimal curvature indicative of a ill-defined, broad maximum around May 24, two months past the *B*-band maximum. A similar delay in the I_C maximum and the flat appearance of the R_C lightcurve during the initial hundred days was observed by Elmhamdi et al. (2003) for supernova type IIP 1999em in NGC 1637.

Our lightcurve of SN 2012aw does not show a brightness *spike* around *B*-band maximum as reported by Elmhamdi et al. (2003) for the type IIP supernova 1999em brightness, and by Ruiz-Lapuente et al. (1990) for type IIP supernova 1988a. These spikes in the earliest portion of the recorded lightcurve were attributed to the supernova ejecta slamming onto circumstellar material originated by mass loss from the progenitor during the immediate pre-supernova phase. The reality of these spikes is however dubious, given the discussion in Section 3 about the differences between local realizations of a common photometric system. The lightcurve of 1999em around maximum brightness was compiled by Elmhamdi et al. assembling few data points from different telescopes, mostly contributing a single observation. Similarly, the lightcurve of SN 1988a was compiled by Ruitz-Lapuente et al. from visual estimates by different observers, each one contributing only sparse data, and the reality of the supposed spike rests entirely on only two visual estimates, that come from a single observer that did not provide other data on this supernova and whose consistency with the other observers therefore cannot be tested.

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