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ESC* supernova spectroscopy of non-ESC targets

A. H. Harutyunyan[1,2], P. Pfahler[3], A. Pastorello[4], S. Taubenberger[3], M. Turatto[1], E. Cappellaro[1], S. Benetti[1], N. Elias-Rosa[3], H. Navasardyan[1], S. Valenti[5,6], V. Stanishev[7], F. Patat[5], M. Riello[8], G. Pignata[9], and W. Hillebrandt[3]

[1] INAF – Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, 35122 Padova, Italy
e-mail: avet.harutyunyan@oapd.inaf.it
[2] Dipartimento di Astronomia, Università degli Studi di Padova, Vicolo dell'Osservatorio 3, 35122 Padova, Italy
[3] Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, 85741 Garching bei München, Germany
[4] Astrophysics Research Centre, School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, UK
[5] European Southern Observatory (ESO), Karl-Schwarzschild-Str. 2, 85748 Garching bei München, Germany
[6] Dipartimento di Fisica, Università di Ferrara, via Saragat 1, 44100 Ferrara, Italy
[7] Department of Physics, Stockholm University, AlbaNova University Center, 10692 Stockholm, Sweden
[8] Institute of Astronomy, Madingley Rd., Cambridge CB3 0HA, UK
[9] Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile

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ABSTRACT

Aims. We present the spectra of 36 supernovae (SNe) of various types, obtained by the European Supernova Collaboration. Because of the spectral classification and the phase determination at their discovery the SNe did not warrant further study, and the spectra we present are the only ones available for the respective objects. In this paper we present and discuss this material using a new software for the automated classification of SNe spectra.

Methods. As a validation of the software, we verify the classification and phase estimate reported for these objects in their discovery/classification circulars. For the comparison, the software uses the library of template spectra of Padova-Asiago Supernova Archive (ASA).

Results. For each spectrum of our sample we present a brief, individual discussion, highlighting the main characteristics and possible peculiarities. The comparison with ASA spectra confirms the previous classification of all objects and refines the age estimates. For our software, we determine numerical limits of "safe" spectral classification and the uncertainties of the phase determination.

Key words. supernovae: general – methods: data analysis

1. Introduction

Supernovae (SNe) are the catastrophic events terminating the evolution of different kinds of stars. Two main explosion mechanisms are commonly considered: the core collapse of a massive star and the thermonuclear runaway of a white dwarf accreting material from a companion. Core-Collapse (CC) SNe include several types (SNe II, Ib, Ic, IIn, etc.) while the Thermonuclear SNe are observationally called SNe Ia (see Turatto 2003; Turatto et al. 2007, for reviews).

CC SNe are important tools in understanding the latest epochs of the life of massive stars, the chemical enrichment of galaxies and the star formation history of the universe (e.g. Botticella et al. 2007), while type-Ia Supernovae (SNe Ia), on the account of their high luminosity and homogeneous properties, are considered one of the most accurate distance indicators. Indeed, the measurement of SNe Ia at high redshifts gives the best evidence that we are living in an accelerating Universe (see Perlmutter & Schmidt 2003, and references therein). However, the fact that progenitor systems of SNe Ia and their explosion mechanisms are still debated leaves room for a possible luminosity evolution with redshift, which would undermine the results reported so far. Studies of larger and larger datasets confirmed the existence of rather vast variety of SN Ia properties (e.g. Benetti et al. 2004, 2005).

The European Supernova Collaboration (ESC) was a European Research Training Network (RTN), founded in 2002 with the goal of improving our understanding of SN Ia physics through a detailed study of nearby ($v_{\rm rec} < 6000$ km s^{-1}) SNe Ia. During the following years detailed spectroscopic and photometric monitoring of 15 nearby SNe Ia (plus 1 SN Ic) was carried out. The results for 10 of these objects have already been published in dedicated papers (Benetti et al. 2004; Elias-Rosa et al. 2006, 2008; Pignata et al. 2004b; Kotak et al. 2005; Stanishev et al. 2007; Taubenberger et al. 2006, 2008; Altavilla et al. 2007; Pastorello et al. 2007a,c; Garavini et al. 2007). A number of papers with results on the other objects are in preparation (Pignata et al.; Stanishev et al.; Kotak et al.; Salvo et al.; Kerzendorf et al.; Elias-Rosa et al., in preparation). Using also SNe Ia from this sample, analyses of systematic properties of SNe Ia have been presented in Benetti et al. (2005), Mazzali et al. (2005), Hachinger et al. (2006) and Mazzali et al. (2007).

In order to select RTN target candidates, prompt classification of newly discovered SNe was required. Thereafter some objects became targets of extensive monitoring, many others did not pass the RTN selection criteria and no follow-up observations were triggered. For these SNe only classification spectra are therefore available. In this paper we present spectra of 36 SNe, obtained during the ESC-related programmes, for which follow-up observations were not activated. These data have not been studied or published so far although in some cases, they contain interesting information. In particular, some of these spectra (4) were obtained at or before maximum light when

* European Supernova Collaboration,
http://www.mpa-garching.mpg.de/~rtn

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Table 1. SN sample and observations.

SN	Discovery DD/MM/YY	Acquisition DD/MM/YY	Instrumentation telescope + instrument	Spectral range Å	Resolution[1] Å	Reference IAUC / CBET
2002an	22/01/02	05/02/02	1.82 m Mt.Ekar + AFOSC	3700–7620	25	7805, 7808, 7818, 7828
2002bh	24/02/02	05/03/02	1.82 m Mt.Ekar + AFOSC	4000–7600	26	7837, 7840, 7844
2002cs	05/05/02	07/05/02	TNG + DOLORES	3500–7930	15	7891, 7894
2002dg	31/05/02	15/06/02	ESO NTT + EMMI	3800–9330	10	7915, 7922
2002dm	04/05/02	15/06/02	ESO VLT U4 + FORS2	4290–10 250[2]	12	7921, 7923
2002ej	09/08/02	30/08/02	1.82 m Mt.Ekar + AFOSC	3800–7630	25	7951, 7963
2002hg	28/10/02	02/11/02	CA 2.2 m + CAFOS	3600–8690	12	8004, 8007
2002hm	05/11/02	06/11/02	CA 2.2 m + CAFOS	3500–8700	13	8009
2002hy	12/11/02	15/11/02	ESO 3.6 m + EFOSC2	3500–9820	13	8016, 8019
2003hg	18/08/03	22/08/03	1.82 m Mt.Ekar + AFOSC	3800–7360	24	8184, 8187, 40
2003hn	25/08/03	26/08/03	ESO 3.6 m + EFOSC2	3600–9960	13	8186, 8187
2003ie	19/09/03	22/09/03	1.82 m Mt.Ekar + AFOSC	4000–7440	25	8205, 8207
2004G	19/01/04	21/01/04	CA 2.2 m + CAFOS	3500–8090	14	8272, 8273
2004aq	02/03/04	10/03/04	NOT + ALFOSC	3900–8910	19	8301
2004bs	16/05/04	19/05/04	CA 2.2 m + CAFOS	3800–8650	12	8341, 66, 8344, 8348
2004cc	10/06/04	14/06/04	NOT + ALFOSC	3500–8990	19	8350, 8353
2004dg	19/07/04	21/07/04	1.82 m Mt.Ekar + AFOSC	3800–7780	25	8375, 8376, 8383
2004dk	30/07/04	03/08/04	CA 2.2 m + CAFOS	3500–8750	12	8377, 8379, 8404, 75
2004dn	29/07/04	05/08/04	CA 2.2 m + CAFOS	3800–8690	12	8381
2004fe	30/10/04	02/11/04	NOT + ALFOSC	3500–8900	19	8425, 8426
2004go	18/11/04	07/12/04	1.82 m Mt.Ekar + AFOSC	3800–7580	24	8448, 8450, 8454
2005G	14/01/05	18/01/05	1.82 m Mt.Ekar + AFOSC	3600–7300	24	8465, 8568
2005H	15/01/05	17/01/05	CA 2.2 m + CAFOS	4000–8700	10	8467
2005I	15/01/05	18/01/05	CA 2.2 m + CAFOS	3800–8610	12	8467
2005N	19/01/05	22/01/05	CA 2.2 m + CAFOS	3700–8600	12	8470
2005V	30/01/05	31/01/05	CA 2.2 m + CAFOS	3500–8780	14	8474, 8572
2005ab	05/02/05	09/02/05	1.82 m Mt.Ekar + AFOSC	4250–8070	25	8478, 8479, 8480
2005ai	12/02/05	14/02/05	CA 2.2 m + CAFOS	3800–8700	12	8486, 8487
2005br	28/03/05	25/05/05	ESO VLT U1 + FORS2	4000–9710[2]	12	8516, 156, 8538
2005bs	19/04/05	25/05/05	ESO VLT U1 + FORS2	3800–9290[2]	12	8517, 143, 156, 8538
2005cb	13/05/05	25/05/05	ESO VLT U1 + FORS2	3700–9720[2]	12	8530, 156, 8538
2005ce	28/05/05	29/05/05	NOT + ALFOSC	3400–8800	19	158, 159
2005de	02/08/05	06/08/05	CA 2.2 m + CAFOS	3500–8640	15	8580, 191, 8581, 193
2005dv	04/09/05	09/09/05	CA 2.2 m + CAFOS	3500–8710	12	8598, 217, 218
2005dz	10/09/05	12/09/05	NOT + ALFOSC	3400–8850	19	222, 225
2005kl	22/11/05	24/11/05	CA 2.2 m + CAFOS	4200–8750	12	8634, 300, 305

Notes: [1] measured on the FWHM of the night sky lines when available, otherwise the typical FWHM for the respective telescope-instrument combination is written, [2] obtained by merging two spectra with different spectral coverage.
1.82 m Mt.Ekar + AFOSC – 1.82 m Copernico Telescope + Asiago Faint Object Spectrograph and Camera, Asiago, Italy.
TNG + DOLORES – 3.5 m Telescopio Nazionale Galileo + Device Optimized for the LOw RESolution, La Palma, Spain.
ESO NTT + EMMI – 3.5 m New Technology Telescope + ESO Multi-Mode Instrument, ESO La Silla, Chile.
ESO VLT U1, U4 + FORS2 – 8 m Very Large Telescope, Unit 1, 4 + visual and near UV FOcal Reducer and low dispersion Spectrograph 2, ESO Paranal, Chile.
CA 2.2 m + CAFOS – 2.2 m Calar Alto Telescope + Calar Alto Faint Object Spectrograph, Almería, Spain.
ESO 3.6 m + EFOSC2 – 3.6 m Telescope + ESO Faint Object Spectrograph and Camera (v.2), ESO La Silla, Chile.
NOT + ALFOSC – Nordic Optical Telescope + AndaLucia Faint Object Spectrograph and Camera, La Palma, Spain.

unique information about the physical conditions and chemical structure of the progenitor star can be retrieved.

The spectra have been classified by means of a new automated tool, specifically developed for this purpose, which compares an input spectrum with the spectra of the Padova-Asiago Supernova Archive (ASA), and identifies the best matching template spectrum. In this way it is possible to determine the spectral classification and the age of the new objects. A set of type-Ia SN spectra of ESC objects with good temporal coverage was also used to test and calibrate the software tool.

The structure of the paper is the following: in Sect. 2 we present our SN sample, observations and data reduction techniques. In Sect. 3 the issue of SN spectral classification is addressed, and in Sect. 4 the software is presented. A discussion of individual spectra is done in Sect. 5 and finally the Sect. 6 gives a short summary.

2. SN sample, observations and data reduction

The sample of 36 SNe is presented in Table 1, where the information on instrumental configurations and observational details is also listed. Seven different telescope + instrument combinations have been used for the observations. The last column of the table contains the references for the discovery and the classification circulars (IAUC, CBET) for each object.

All two-dimensional images were pre-reduced (trimmed, overscan, bias and flatfield corrected) with standard IRAF[1]

[1] Image reduction and analysis facility, http://iraf.noao.edu

subroutines. Further data processing was performed using the procedures from the IRAF CTIOSLIT package. In particular, after the optimised extractions performed with the APALL task, the one-dimensional spectra were wavelength-calibrated by comparison with spectra of arc lamps obtained during the same night and with the same instrumental configuration. The wavelength calibration was checked against bright night-sky emission lines. The SN spectra were then flux-calibrated using response curves derived from the spectra of standard stars preferably observed during the same night[2].

In some cases two spectra of the same object observed during the same night in different spectral ranges were merged into a single spectrum to gain a wider wavelength coverage and/or higher signal-to-noise ratio (*SNR*).

3. SN classification

Prompt SN type determination is important in the study of SNe. In particular, the success of extensive and time consuming observational campaigns depends crucially on the proper planning of observations, typically obtained in Target of Opportunity mode. A rapid SN classification is usually performed on the basis of one optical spectrum (usually obtained near maximum light) and in general is quite reliable. In a few cases a definitive classification requires the analysis of the spectral evolution.

In the earliest phase when the SN is optically thick, the photosphere emits a continuum radiation field, while line formation occurs above. The ejecta is expanding and the lines are characterised by P-Cygni (P-Cyg) profiles, an emission peak near the rest wavelength of the line and a blueshifted absorption feature. The emission peak is formed by line scattering into the line of sight of photons emitted by the photosphere and would be symmetrical to the line centre wavelength if there was not the absorption. The absorption is formed by scattering out the line of sight of photospheric photons emitted toward the observer. Since this occurs in front of the photosphere, the absorption is blueshifted (see Jeffery & Branch 1990, for a review of spectra formation).

Type-Ia SNe are classified by the presence of lines of intermediate mass elements such as Si, Ca and S during the maximum light phase and by the absence of H at any time. Type-Ib SNe are spectroscopically classified by the absence of H Balmer and Si II lines and by the presence of He I features, though, as Branch et al. (2002) showed, weak, broad H_α may also be present. Type-Ic SNe are similar, but with the absence of He lines, though some weak contamination of He seems to be common to several type-Ic SNe (Filippenko et al. 1995). Type-II SNe are characterised by strong H Balmer lines.

Most of the SNe fall in one of the above mentioned 4 classes. However, there is an increasing number of peculiar objects, with unprecedented properties and evolution (e.g. SN 2006jc, for which type-Ibn label was coined, Pastorello et al. 2007b, 2008), that do not fit within the scheme above. The current taxonomy of SNe is therefore incomplete, ambiguous and not fully satisfactory (see Turatto et al. 2007, and references therein). In a situation in which the classification criteria are not exhaustive, a conservative approach for SN classification is via comparison with other SNe. With this motivation, our group has developed a tool that compares a given input spectrum with the set of spectra from ASA, a large archive of SN spectra, collected by the members of the group during the last decades.

[2] For a detailed discussion on data reduction techniques see, for instance, Pastorello et al. (2007a).

Table 2. GELATO bins with wavelength ranges and corresponding main spectral features.

Bins	Range Å	SN spectra features Ia	Ib/c	II
1	3504–3792	Ca II	Ca II	Ca II
2	3800–4192	Si II, Ca II	Ca II	Ca II, H_δ
3	4200–4576	Mg II, Fe II	Fe II	Mg II, Fe II, H_γ
4	4584–4936	Fe II	Fe II	Fe II, H_β
5	4944–5192	Fe II	Fe II	Fe II
6	5200–5592	S II	S II, OI	S II
7	5600–5896	Si II, Na I	Na I, He I	Si II, Na I
8	5904–6296	Si II	He I	Si II
9	6304–6800	Fe II	Si II, He I	O I, H_α
10	6808–7904	O I	O I	O I
11	7912–9000	Ca II	Ca II	Ca II

4. SN spectra comparison tool

A few groups (see Blondin & Tonry 2007, for a discussion) have developed software tools for SN spectra analysis. Using different technical approaches from χ^2 minimisation to cross-correlation, these tools aim at different immediate results, from rapid automatic SN spectra classification to quantification of spectral differences. The goal of our software is the quantitative classification of SN spectra by comparison with a large set of template spectra of various SN types at different phase.

The PAdova Supernova Spectra comPARison TOOl (passpartoo) is a collection of software procedures performing automatic comparison of SN spectra. Designed for different purposes and working with slightly different algorithms, all the procedures carry out an automatic comparison of a given (input) spectrum with a set of well-studied SN spectra (templates), in order to find the template spectrum that is most similar to the given one. The first version of the tool was presented in Harutyunyan et al. (2005). In this paper we used the GEneric cLAssification TOol (GELATO), which is a software for objective classification of SN spectra.

One of the major issues to solve is the treatment of reddening, due both to the Galaxy and to the SN host. We wanted our tool to minimise the impact of the reddening on the comparison result with no assumption on the reddening law, which can be very unusual (cf. Elias-Rosa et al. 2006, 2008). To this aim, GELATO divides the input and every template spectrum in a number of separate spectral bins. This approach for spectra comparison was discussed in Riess et al. (1997) and Rizzi (1998) and has the advantage of giving priority to the presence and strength of spectral features. The bins are selected to contain the spectral features most significant for SN classification and dating. The same set of bins is adopted for comparison of spectra of all types with satisfactory results. The current version of GELATO uses 11 bins, 8 of which are from Riess et al. (1997), slightly modified to meet few technical requirements, while 3 have been added to include other spectral features and to enlarge the working spectral range. Table 2 lists the GELATO bins and the corresponding main spectral features.

The GELATO code works as follows: for all the N bins of an input spectrum it computes δ_j, the mean relative distance between the jth bin of the input spectrum and the corresponding bin of the template, scaled in flux to match the input one. This operation is iterated through all the template spectra and the average of δ_j values for each template spectrum is calculated.

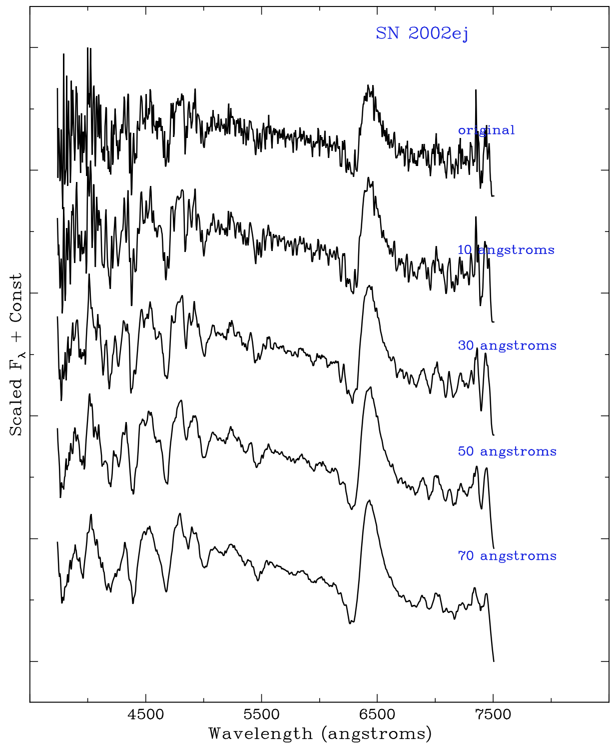

Fig. 1. The original and smoothed spectra of SN 2002ej (Sect. 5). The spectra are in the parent galaxy restframe. The number near smoothed spectra are the corresponding box sizes.

If f_i is the input spectrum at wavelength λ_i and F_i the template spectrum, we define δ_j as follows:

$$\delta_j = \frac{1}{n \cdot \langle f \rangle_j} \sum_{i=1}^{n} |f_i - F_i^{\rm norm}|, \tag{1}$$

where n is the number of spectral elements in the bin, $F_i^{\rm norm}$ is the F_i flux scaled to the input spectrum flux within the given bin, and $\langle f \rangle_j$ is the mean value of the flux in the bin. Then, the average of δ_j values is computed as:

$$\Delta = \frac{1}{N} \sum_{j=1}^{N} \delta_j, \tag{2}$$

where N is the number of bins. The most similar template to the input spectrum is the one that minimises the value of Δ. Before the comparison a boxcar smoothing is performed on all spectra to reduce high-frequency noise components. After tests with artificial noise addition, a box size corresponding to ~40−70 Å is adopted to perform the smoothing. This smoothing is sufficient to remove high-frequency noise components and at the same time preserves the spectral features. Figure 1 shows the original and smoothed spectra of SN 2002ej (cf. Sect. 5).

The software achieves the goal of finding the best fitting archive spectrum to a given input spectrum, through the minimisation of Δ values. However, Δ alone does not describe the quality of the fit, which is necessary for a quantitative comparison of the fits. Thus, we tried to define a quantitative value providing a measure of quality of fits. In general, we noted that the values of Δ computed for the cases of spectra with dominating continuum and weak spectral features are systematically lower than those of spectra having many strong spectral features which can vary in relative intensities and position. To account for this, we weighted the Δ values using coefficients that indicate whether the spectra are more or less feature-rich. We defined the feature-parameter (FP) as follows:

$$\mathrm{FP} = \frac{1}{N} \sum_{j=1}^{N} \frac{1}{n} \sum_{i=1}^{n} \frac{|f_i - F_i^{\rm flat}|}{\langle sp \rangle_j}, \tag{3}$$

where $F_i^{\rm flat}$ is the best fitting straight line to the spectrum in the given bin. Then, for each fit we define the quality of fit (QoF) value by the following expression:

$$QoF = \left(\frac{\Delta}{FP}\right)^{-1}. \tag{4}$$

The QoF allows a numerical estimate of the quality of the fit, which can be used to compare the fits to different SN spectra. Table 4 reports the QoF values of the best fits to our set of spectra. In Fig. 2 the graphical outputs of GELATO for the cases of SN 2002an and 2005bs are presented. In the figures the smoothed versions of the input spectrum (black line) and best fitting template (gray line) together with bin boundaries (dotted lines) are displayed. The Δ value of the fit in the SN 2002an case is smaller than that of the SN 2005bs case (~0.02 and 0.07, respectively), but SN 2005bs has a greater FP (i.e. has more prominent features) than SN 2002an. The resulting QoF is greater for SN 2005bs (~3.3) than for SN 2002an (~1.7), thus according to GELATO the former should be regarded as a better fit than the latter. Further discussion for these spectra can be found in Sect. 5.

We tested the QoF values comparing spectra to different sets of templates. The results combined with visual inspections of the fits showed that $QoF \geq 1.4$ means a high/satisfactory quality of the fit and safe SN type determination, while $QoF < 1$ occurs when the input has no match in the archive. Intermediate values $1 \leq QoF < 1.4$ may result both for fair/good fits with correct type detection or poor fits with incorrect type detection. Further tests will refine the QoF and establish the confidence levels.

We stress that thanks to the above mentioned subdivision in spectral bins, the best fit procedure depends very little on the slope of the continuum, hence reddening. This can be seen, for example, in the SN 2004aq spectrum fit by SN 1991al (Fig. 7d), for which the $QoF = 2.95$, despite the significant difference in SED. To verify this we used the original spectrum of SN 2005bs (see Sect. 5 and Fig. 8j) and progressively reddened it up with two reddening laws ($R_V = 3.1$ and 1.8, Elias-Rosa et al. 2006). Then we searched the best fitting templates with GELATO. Table 3 summarises the results. The best fitting template for all the cases was found to be SN 1996X 31 day after maximum, though with slightly decreasing QoF. The test confirms that GELATO is little sensible to the amount of reddening and to the reddening law.

The second crucial ingredient for the automated spectra classification, besides the software tool, is the availability of an extended archive of spectra. Spectra of all SN types from ASA are used as templates for the comparison procedure. These spectra have been collected by the Padova SN group in the course of several long-term projects devoted to the study of the physical properties of SNe including type-Ia SN spectra obtained by the ESC. The archive has also been enriched with publicly available material from the literature. Table 5 lists the archive content on December 2007. It provides the type, redshift, number spectra and phase range of the spectra for each SN. The information about the types and redshifts of SNe are obtained from the up-to-date version of the Asiago SN catalogue (Barbon et al. 1999).

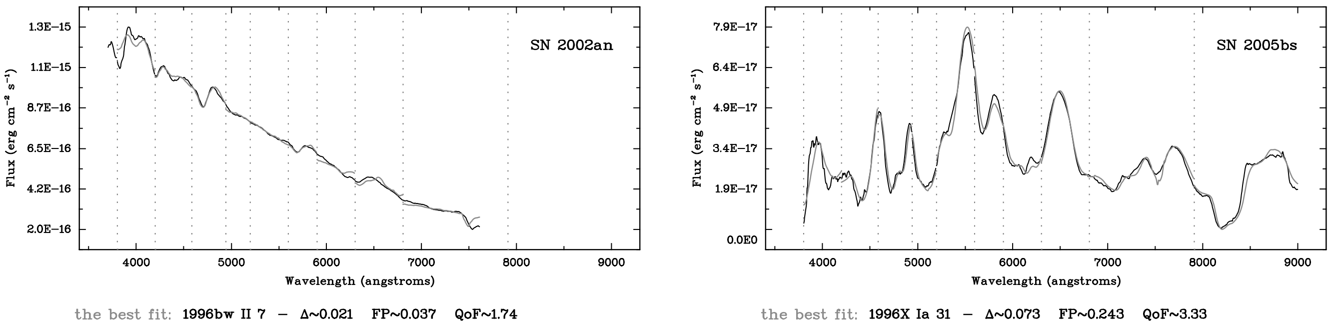

Fig. 2. The graphical output of GELATO for the cases of SN 2002an and SN 2005bs from our sample. The spectra are in the parent galaxy rest frame. The black lines are the input spectra and the gray ones the best fitting template spectra, divided in bins and scaled in flux to match the input spectra in the respective bins.

Table 3. Comparison results for reddened spectra of SN 2005bs.

$E(B-V)$	$R_V = 3.1$		$R_V = 1.8$		Best template
	A_V	QoF	A_V	QoF	
0.0	0	3.3	0	3.3	SN 1996X
0.16	0.5	3.1	0.3	3.1	SN 1996X
0.32	1	2.8	0.6	2.9	SN 1996X
0.48	1.5	2.6	0.9	2.7	SN 1996X
0.64	2	2.3	1.2	2.4	SN 1996X

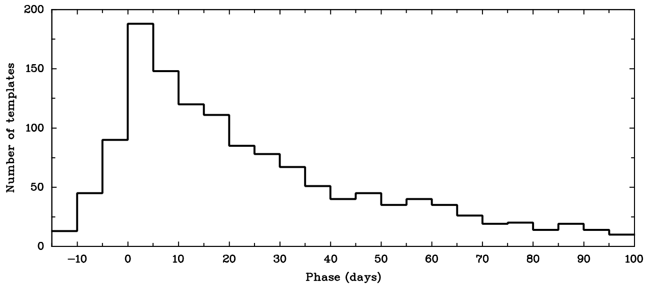

Fig. 3. The phase distribution of the template SN spectra. Typically, the phases are relative to the *B*-maximum for SNe Ia and Ib/c and to the explosion epoch for SNe II.

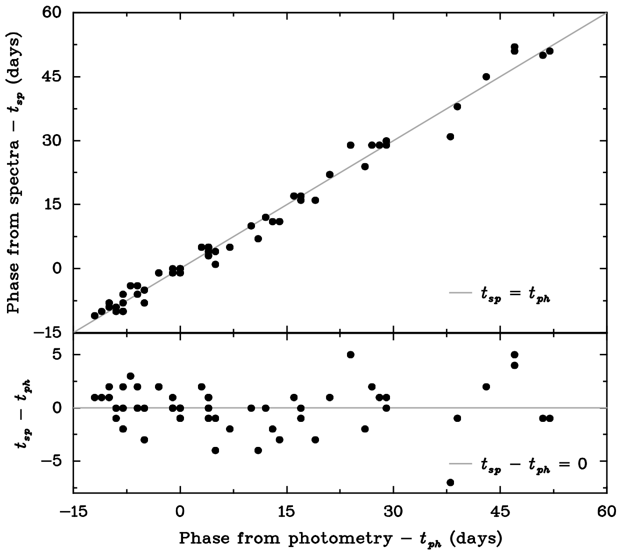

Fig. 4. The phases determined with GELATO compared to the phases from photometry for a sample of type-Ia SNe. In *the bottom panel* are the residuals.

Currently there are spectra of 155 type-Ia (including objects like SN 1991T, 1991bg, 2000cx), 168 type-II (including SNe IIL, IIn, IIb) and 65 type-Ib/c SNe (including hypernovae and objects like 1997dq, 2006jc), for a total database of over 2500 spectra. Figure 3 shows the distribution of the templates on the basis of their phase. As one can see from the figure, the template temporal coverage is good at all phases though, as expected, the number of the template spectra is greater near maximum light.

In general, we adopt as an estimate of the input spectrum age the epoch of the corresponding best fitting template found by GELATO. We carried out several tests to check the ability of GELATO, in combination with ASA to determine the spectral age. To this aim, we used the spectra of a set of well-studied type-Ia SNe 2002bo, 2003cg, 2003du, 2004dt, 2004eo, 2005cf observed by the ESC, for which detailed light curves are available. Each spectrum of these objects was compared with those of a sample of a dozen of template SNe Ia, which include objects spanning the entire range of SN Ia properties (e.g. including SN 1991bg and 1991T). Then, we compared the phases of the best fitting template spectra obtained from the spectral comparison with the phases derived from photometry. The results are plotted in Fig. 4. The plot shows that the two phases are in a good agreement. The difference of the phases has a rms of about 3.1 days in the phase range from 15 to 60 days, while in the range −15 to 15 days it is as small as 1.9 days. The increase of the error with age is expected, because the spectra of SNe Ia change less at late times.

Similar tests done with a set of type-II and type-Ib/c SNe give rms of about 10 days for both samples (see Fig. 5). The errors are larger compared to those of type-Ia SNe due to the heterogeneous behaviour of CC SNe (compared to SNe Ia), to the lack of templates with very good temporal coverage and to the uncertainty in the determination of the explosion epoch for SN II.

5. Individual spectra

The results of the comparison of our set of 36 spectra with the templates are summarised in Table 4, listing for each object the best template, the phase and the QoF. Figures 6–9 show the plots of the spectra of our objects together with their best fitting templates. Spectra are shown in the parent galaxy restframe and are not corrected for extinction. Below we present a short discussion of individual objects.

SN 2002an was found on Jan. 22.52 by Nakano et al. (2002) and classified as a type-II supernova by Benetti et al. (2002a). The spectrum consists of a blue continuum with P-Cyg profiles

Table 4. GELATO's best match templates.

SN	Type	Best match SN template	*QoF*	Template phase (days)	Template spectrum reference	Phase reference
2002an	II	1996bw	1.7	7 *	ASA, Benetti & Turatto (1996)	1995ad, 12d – Pastorello (2003)
2002bh	II	1995V	1.4	8	ASA	Fassia et al. (1998)
2002cs	Ia	2004dt	1.6	–7	Altavilla et al. (2007)	
2002dg	Ib	1998dt	1.7	15 **	ASA	Matheson et al. (2001)
2002dm	Ia	1994ae	9.1	92	ASA	
2002ej	II	1995ad	2.9	24	Pastorello (2003)	
2002hg	II	1999em	2.4	41	Elmhamdi et al. (2003)	
2002hm	II	1998ce	3.8	10 *	ASA, Patat & Turatto (1998)	1995ad, 12d – Pastorello (2003)
2002hy	IIb	2001gh	1.0	11 *	ASA, Altavilla (2001)	1993J, 4d – Barbon et al. (1995)
2003hg	II	1995V	2.1	8	ASA	Fassia et al. (1998)
2003hn	II	1995ad	2.4	10	Pastorello (2003)	
2003ie	II	1998A	1.2	37	Pastorello et al. (2005a)	
2004G	II	1993S	2.4	90 *	ASA	1995ad, 100d – Pastorello (2003)
2004aq	II	1991al	2.9	25 *	ASA	2001du, 18d – Smartt et al. (2003)
2004bs	Ib	1998dt	2.0	17 **	ASA	Matheson et al. (2001)
2004cc	Ic	1994I	1.4	10	Filippenko et al. (1995)	
2004dg	II	2001du	4.8	18	Smartt et al. (2003)	
2004dk	Ic	2004aw	1.4	4	Taubenberger et al. (2006)	
2004dn	Ic	2004aw	1.4	4	Taubenberger et al. (2006)	
2004fe	Ic	1994I	1.9	–3	Filippenko et al. (1995)	
2004go	Ia	1996X	2.2	24	Salvo et al. (2001)	
2005G	Ia	1994D	3.5	11	Patat et al. (1996)	
2005H	II	2002gd	1.0	6	Pastorello (2003)	
2005I	II	2003gd	3.3	101	ASA	Hendry et al. (2005)
2005N	Ib	1990I	2.1	88	Elmhamdi et al. (2004)	
2005V	Ic	2004aw	1.3	22	Taubenberger et al. (2006)	
2005ab	II	1997du	1.5	26 *	ASA, Patat (1997)	
2005ai	Ia	1994D	2.7	24	Patat et al. (1996)	
2005br	Ib	1997X	1.9	40	ASA	1990U, 48d – Piemonte (1996)
2005bs	Ia	1996X	3.3	31	Salvo et al. (2001)	
2005cb	Ic	1994I	2.5	1	Filippenko et al. (1995)	
2005ce	Ib/c	1996aq	2.0	5 *	ASA	1994I, 10d – Filippenko et al. (1995)
2005de	Ia	2005cf	2.8	–5	Garavini et al. (2007)	
2005dv	Ia	2002bo	2.9	0	Benetti et al. (2004)	
2005dz	II	2007T	1.4	4 *	ASA, Benetti et al. (2007)	2002gd, 6d – Pastorello (2003)
2005kl	Ic	2004aw	1.2	4	Taubenberger et al. (2006)	

Notes: phases are relative to the *B*-maximum epoch for type-Ia and Ib/c SNe and to explosion epoch for type-II SNe, * spectral epoch relative to the discovery date. In these cases no reference of the explosion epoch is found and, when available, the second best fitting template spectrum with phase relative to the explosion epoch is reported in the "Phase reference" column, ** relative to the *R*-maximum.

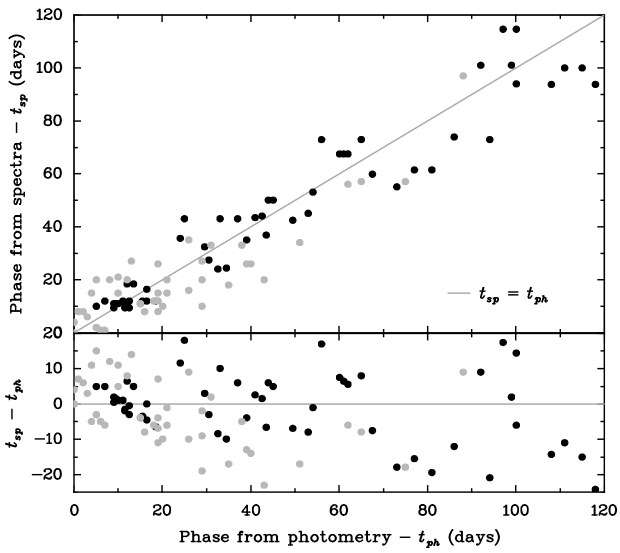

Fig. 5. The phases derived with GELATO compared to the phases obtained from photometry for a sample of type-II (black dots) and type-Ib/c (gray dots) SNe. In *the bottom panel* are the residuals.

of H Balmer and He I λ5876 lines. H_α is almost purely in emission (Fig. 6a). The *QoF* is not high (1.7), which is due to some discrepancies in the fit. In particular H_α is not well fitted. The most similar template spectrum is that of the type-II SN 1996bw obtained 7 days after its discovery (ASA, Benetti & Turatto 1996). For this template the explosion epoch is not estimated. The spectrum of another type-II SN 1995ad 12 days after its explosion (Pastorello 2003) also provides a satisfactory fit. The expansion velocities deduced from the minima of He I λ5876, H_β and H_γ lines are 9300, 9690 and 9800 km s^{-1}, respectively.

SN 2002bh was found on Feb. 24.3 by Ganeshalingam & Li (2002). Benetti et al. (2002b) classified it as a type-II supernova. A broad H_α emission line is the only strong feature in the noisy spectrum. Also, broad He I λ5876, Fe II and H_β features can be identified (Fig. 6b). From the minimum of H_α an expansion velocity of about 12 000 km s^{-1} is derived. The best fit is with the type-II SN 1995V spectrum (ASA) 8 days after the explosion (Fassia et al. 1998). The template spectrum does not match well the blue slope of the spectrum, possibly because of some reddening in the host galaxy.

SN 2002cs was discovered on May 5.5 by Ganeshalingam et al. (2002). The spectrum is that of a type-Ia supernova, and

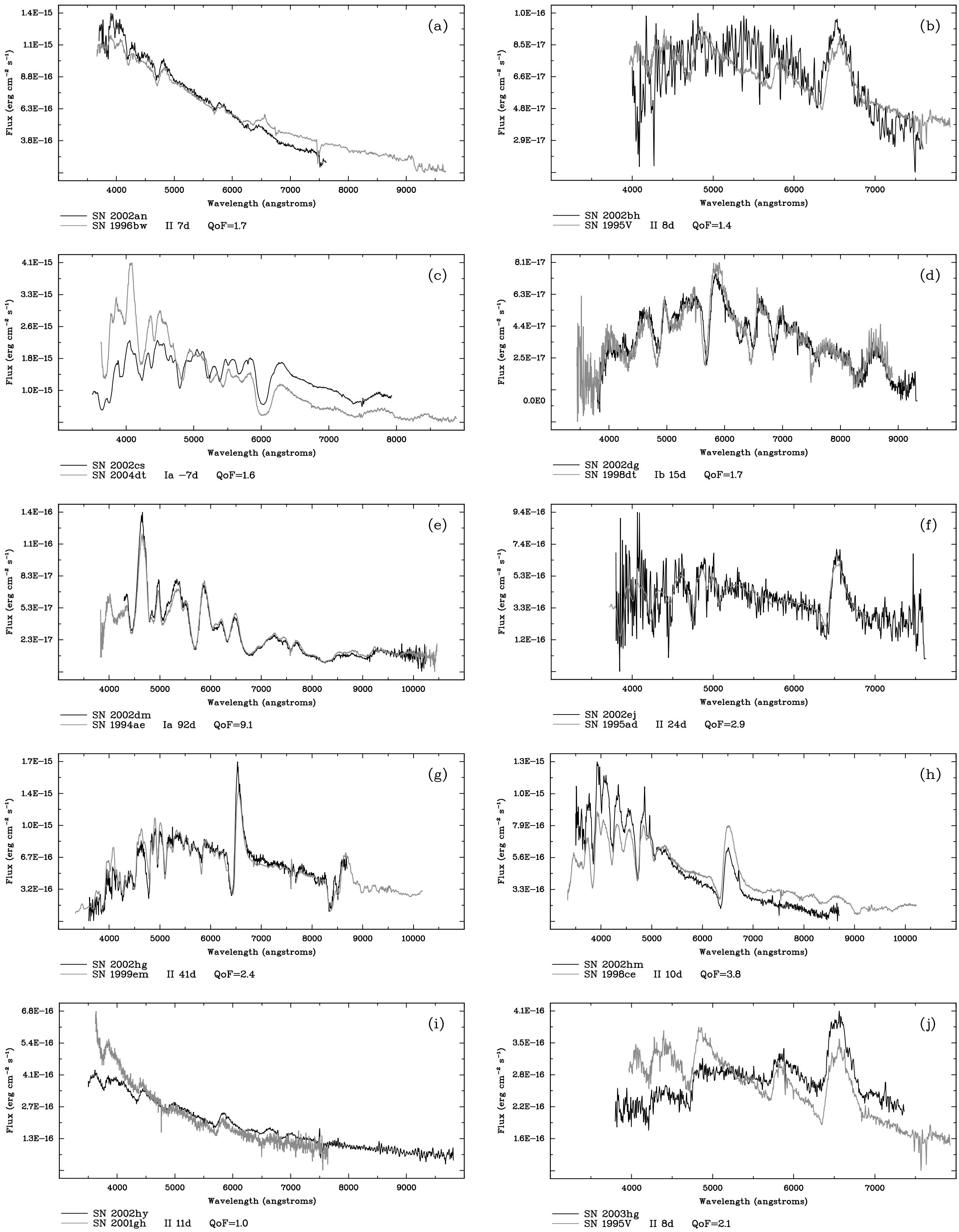

Fig. 6. The comparison of the ESC SN spectra of non-ESC targets with their best fitting templates. The spectra are in the parent galaxy restframe and not corrected for extinction. The black lines are the ESC spectra, while the gray ones display template spectra.

Riello et al. (2002a) gave an age estimate of 2 ± 2 days before maximum light (Fig. 6c). The expansion velocity deduced from the Si II λ6355 minimum is about 15 800 km s^{-1}. Both the expansion velocity and the age estimates are in agreement with those by Matheson et al. (2002). The high expansion velocity may be caused by contamination by a high-velocity component (see Mazzali et al. 2005). High-velocity features are particularly strong and blended with the photospheric components in the SNe that belong to the high velocity gradient (HVG) group (see Benetti et al. 2005). In fact, the closest match we found is

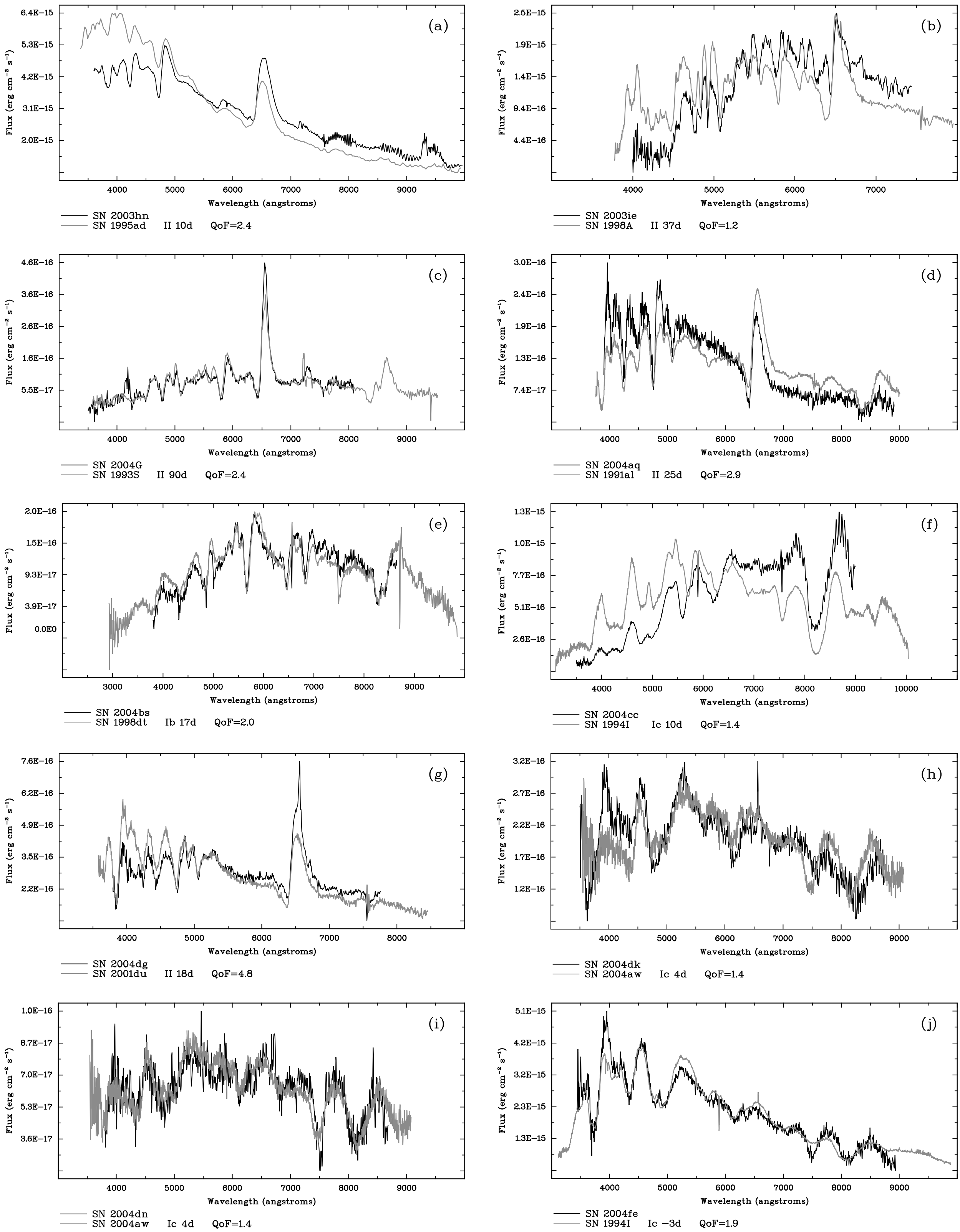

Fig. 7. Same as Fig. 6.

with the HVG SN 2004dt at a phase of −7 days (Altavilla et al. 2007). The shape of the continuum and interstellar absorption Na I D λ5876 feature (in the Galaxy restframe) of the spectrum suggest the presence of significant extinction. The value of $QoF = 1.6$ is mainly due to a mismatch in the line velocity suggesting either an even more extreme case of HVG SN than SN 2004dt or an earlier phase. Because of the first phase determination (−2 ± 2 days instead of −7) SN 2002cs was unfortunately not considered worth of detailed follow-up by the ESC.

SN 2002dg was found on May 31.3 by Wood-Vasey et al. (2002) and classified as a type-Ib supernova 2−3 weeks after maximum by Riello et al. (2002b). The spectrum (Fig. 6d)

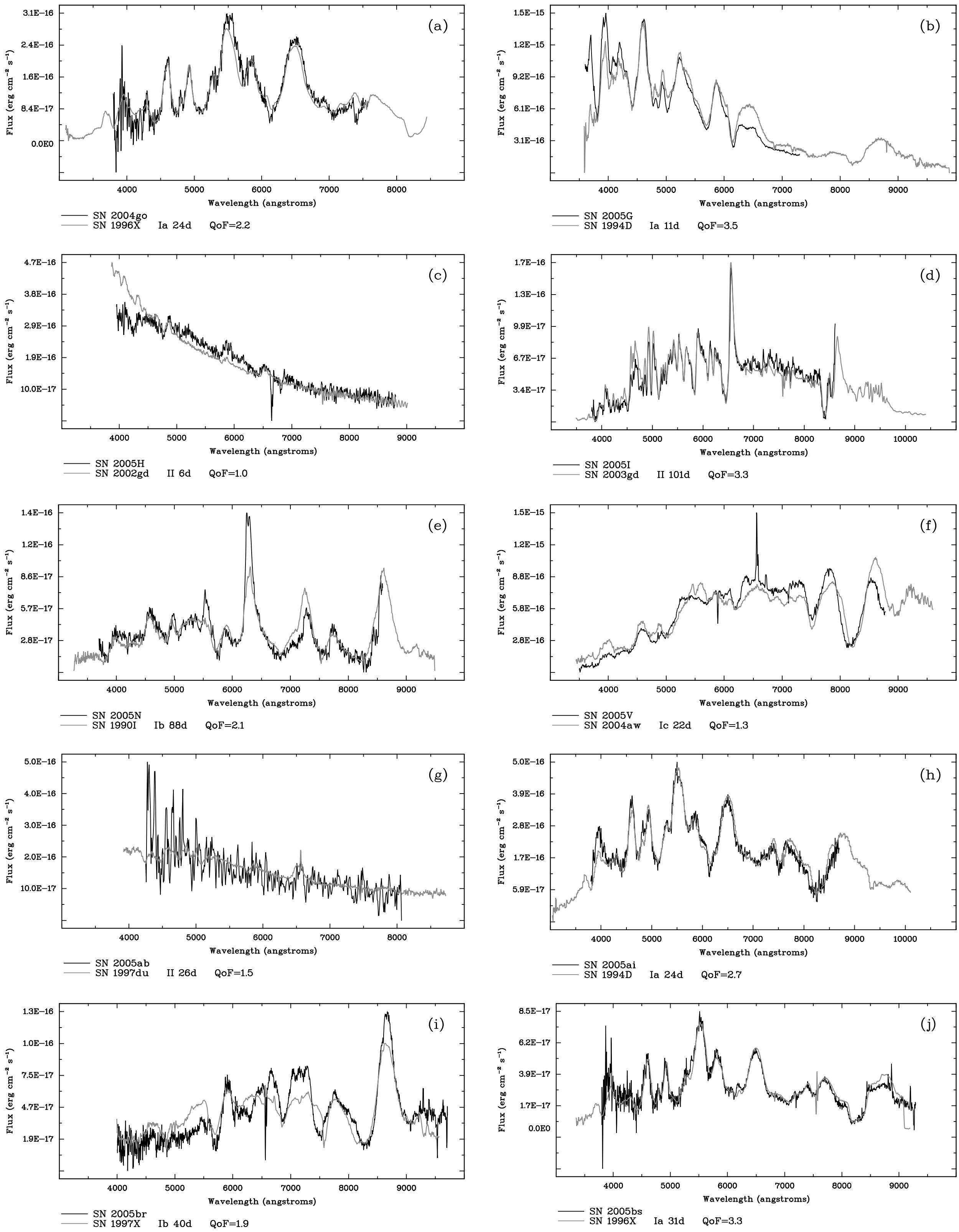

Fig. 8. Same as Fig. 6.

is most similar to that of the type-Ib SN 1998dt at 15 days from *R*-band maximum (Matheson et al. 2001). For SN 2002dg, adopting a recession velocity of 14 000 km s^{-1} derived by Riello et al. (2002b) from the parent galaxy emission lines, the expansion velocities measured from the He I λ5876 absorption minima of the SN 2002dg and 1998dt spectra are 9500 and 10 900 km s^{-1}, respectively. The largest mismatch to the SN 1998dt spectrum is the absorption at 6270 Å (rest frame). If this feature is due to H_α (see Branch et al. 2002), a transitional type-IIb event may be an alternative classification. Inspection of

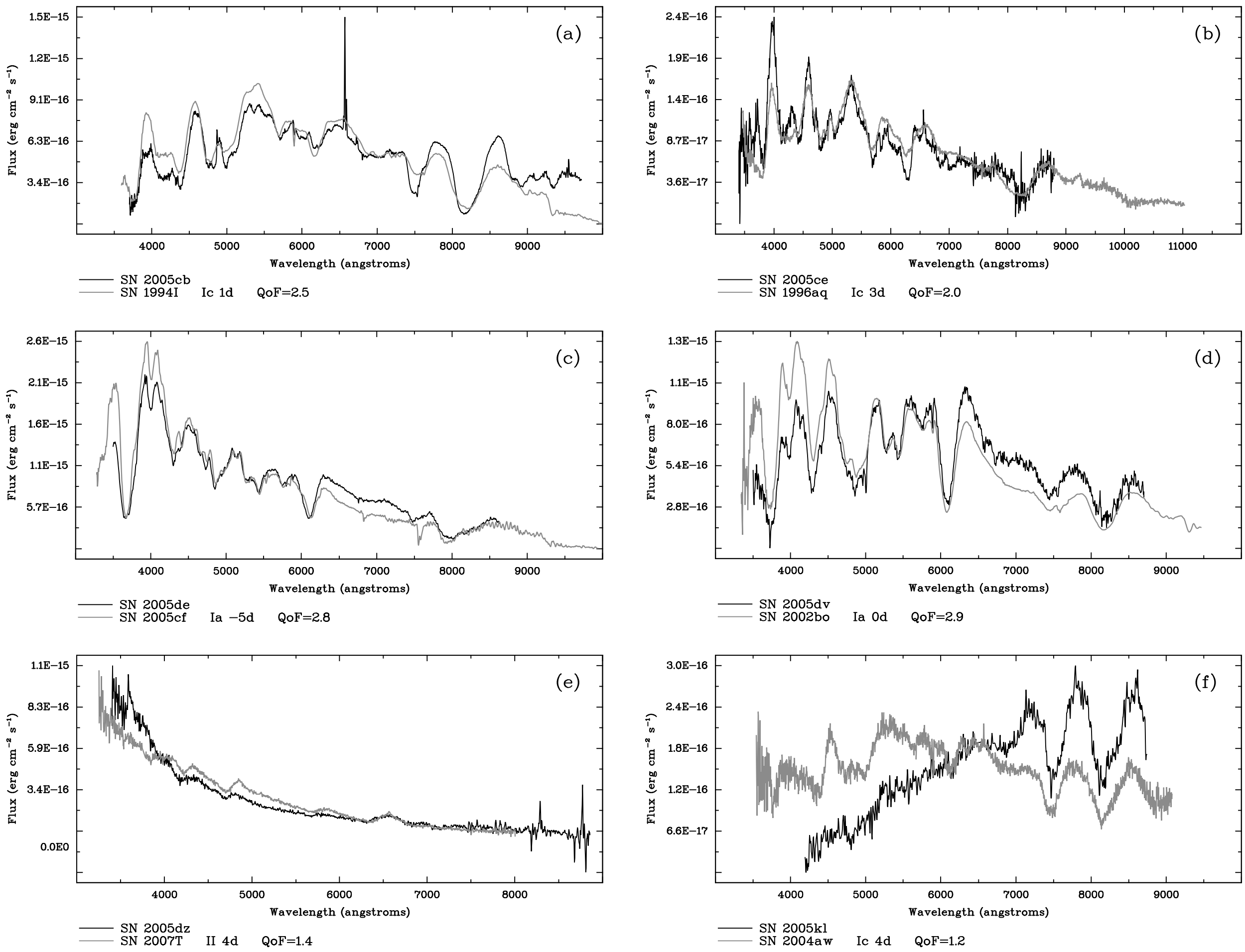

Fig. 9. Same as Fig. 6.

the fit (see Fig. 6) shows that not only the He I features, but also other lines in the spectrum of SN 2002dg are slightly narrower than in SN 1998dt.

SN 2002dm was found on May 4.76 by Sanders (2002), Turatto et al. (2002) classified it as a type-Ia SN, giving a phase estimate of about 50 days after maximum light. The high *SNR* spectrum (Fig. 6e) is almost identical to that of SN 1994ae (ASA) at 92 days after maximum light. The large number of features present in the spectrum and the exceptional resemblance to the 1994ae spectrum lead to the best match among the SNe of the sample (QoF = 9.06).

SN 2002ej was discovered on Aug. 9.11 by Puckett & Kerns (2002) and classified as a type-II supernova two weeks after maximum by Desidera et al. (2002). On the noisy spectrum P-Cyg profiles of H Balmer, Fe II and (possibly) Sc II $\lambda\lambda$5240, 5527, 5658 lines are present (Fig. 6f). The best fitting template (QoF = 2.94) is the one of the type-IIP SN 1995ad at 24 days after explosion epoch (Pastorello 2003). The expansion velocity of SN 2002ej deduced from the minimum of H_α line is about 8070 km s^{-1}.

SN 2002hg was found on Oct. 28.22 by Boles & Schwartz (2002) and classified as a type-II supernova few weeks past maximum light by Pignata et al. (2002a). The spectrum shows strong P-Cyg profiles of H Balmer, Fe II, Ca II (H, K plus IR-triplet), Na I D, O I λ7774, Sc II, Ba II $\lambda\lambda$4934, 6142 lines (Fig. 6g) and is well-fitted (QoF = 2.4) by a type-II SN 1999em spectrum taken 41 days after explosion (Elmhamdi et al. 2003). The expansion velocity of SN 2002hg deduced from the H_α line profile is about 6900 km s^{-1}.

SN 2002hm was detected on Nov. 5.16 by Boles (2002) and classified as a type-II supernova 30 days after maximum light by Pignata et al. (2002b). The rather blue continuum is overimposed by P-Cyg profiles of H Balmer, Fe II, Ca II lines (Fig. 6h). The best fit to this spectrum is provided by the type-II SN 1998ce spectrum at 10 days after discovery (ASA, Patat & Turatto 1998). The SN 2002hm spectrum is also well fitted by SN 1995ad 12 days after explosion (Pastorello 2003), in agreement with the fact the Na I D feature, typical of type-II SNe at more advanced epochs, is not present yet, thus suggesting an earlier phase than that proposed by Pignata et al. (2002b). The expansion velocities deduced from the H_α and H_β absorption minima in the SN 2002hm spectrum are about 9500 and 8100 km s^{-1}, respectively.

SN 2002hy was found on Nov. 12.1 by Monard (2002) and classified as a peculiar type-Ib supernova by Benetti et al. (2002c). The blue continuum is overimposed with strong He I lines at $\lambda\lambda$3889, 4471, 5015, 5876, 6678, 7065 (Fig. 6i). As Benetti et al. (2002c) mentioned, the He I emission peaks are blueshifted on average by 1800 km s^{-1}. Despite the peculiarity of the object, GELATO finds a matching spectrum that contains the He I features with similar line velocity, the SN 2001gh 11 days after discovery (ASA, Altavilla 2001; Valenti 2003). The second best fitting template is the type-IIb SN 1993J at 4 days after explosion (Barbon et al. 1995), which, however, fails to reproduce most of the He I features. SN 2001gh is classified as a type-II SN (Altavilla 2001), but because of the presence of strong He lines both SN 2002hy and SN 2001gh should be considered IIb/Ib events (Elias-Rosa et al., in preparation).

SN 2003hg was discovered on Aug. 18.4 by Moore & Li (2003) and classified as a type-II supernova shortly after explosion (Elias-Rosa et al. 2003). Broad emission lines of H_α (possibly with a boxy profile), and He I λ5876 are present together with absorptions of H_β, and H_γ (Fig. 6j). The best fit to this spectrum is with that of the type-II SN 1995V 8 days after explosion (ASA, the same as in SN 2002bh case). Despite the different SED, most probably due to reddening (in fact, Na I D is present with an equivalent width (*EW*) of about 1.3 Å), the *QoF* is high (2.09).

SN 2003hn was found on Aug. 25.7 by Evans et al. (2003) and classified as a type-II supernova approximately two weeks after explosion by Salvo et al. (2003). The spectrum has a blue continuum and P-Cyg profiles of the H_β, H_γ and He I λ5876 lines. H_α is present almost purely in emission (Fig. 7a). The best match of this spectrum is the type-II SN 1995ad spectrum 12 days after explosion date (Pastorello 2003). The interstellar Na I D absorption feature present in the SN 2003hn spectrum suggests some reddening (EW(Na I D) $\approx$ 0.62 Å, corresponding to a lower limit of $E(B-V) = 0.089$, see Turatto et al. 2003). The expansion velocities for SN 2003hn deduced from the H_β and H_γ lines are of about 8700 and 8200 km s^{-1}, respectively.

SN 2003ie was found on Sept. 19.8 by Arbour & Boles (2003) and classified as a type-II supernova by Benetti et al. (2003). P-Cyg profiles of H_α, H_β, Fe II, Sc II, Na I D and Ba II lines are overimposed on red continuum (Fig. 7b). The expansion velocity deduced from the H_α absorption minimum is about 5500 km s^{-1}. The best fit to this spectrum is with that of the peculiar type-II SN 1998A 37 days after explosion (Pastorello et al. 2005a). Like in SN 1998A the H_α emission shows a significant shift of about 2100 km s^{-1} towards the blue. This effect is seen also in SN 1987A and in other type-II SNe (see Pastorello et al. 2005a, for discussion).

SN 2004G was found on Jan. 19.8 by Nakano et al. (2004) and classified as a type-II supernova about 5 months after explosion by Elias-Rosa et al. (2004a). The best fit to the SN 2004G spectrum (Fig. 7c) is with the type-II SN 1993S 90 days after its discovery (ASA). The spectrum is well-fitted also by the type-II SN 1995ad spectrum 100 days past explosion (Pastorello 2003). The expansion velocities deduced from the H_α and H_β absorption minima are about 6700 and 4900 km s^{-1}, respectively.

SN 2004aq was discovered on Mar. 2.1 by Armstrong & Buczynski (2004) and classified as a type-II supernova one month after explosion by Elias-Rosa et al. (2004b). The spectrum shows P-Cyg profiles of H_α, H_β, Ca II and Fe II lines overimposed on a rather blue continuum (Fig. 7d). The best fit to this spectrum is a type-II SN 1991al spectrum taken 25 days after discovery (ASA). The minima of the H_α and H_β absorption components on the SN 2004aq spectrum are blueshifted by about 7700 and 6600 km s^{-1}, respectively, very similar to those of SN 1991al (7700 and 6500 km s^{-1}). The spectrum of SN 2004aq is also well fitted by that of the type-II SN 2001du 18 days after explosion (Smartt et al. 2003).

SN 2004bs was found on May 16.9 by Armstrong (2004) and classified as a type-Ib supernova about 3 weeks past maximum by Pignata et al. (2004a). The spectrum is dominated by He I λ5876, 6678, 7065 lines with velocities of about 10 800, 10 200 and 10 000 km s^{-1}, respectively (Fig. 7e). Lines of Fe II, O I and Ca II are also present in the spectrum. The best matching template is the type-Ib SN 1998dt (ASA), 17 days after *R*-band maximum (Matheson et al. 2001).

SN 2004cc was found on Jun. 10.3 by Monard & Li (2004) and classified as a type-I supernova by Matheson et al. (2004) and type-Ic supernova one week before maximum by Foley et al. (2004). P-Cyg profiles of Fe II, Na I D (possibly blended with He I λ5876), Si II and Ca II are present on the highly reddened spectrum (Fig. 7f). Strong Na I D interstellar absorption is detected in the host galaxy restframe ($EW \approx 4.1$ Å). The best fit to this spectrum is provided by the type-Ic SN 1994I 10 days after B maximum (Filippenko et al. 1995), although the Na I D (+ He I) absorption and Fe II features in SN 2004cc are bluer (i.e. with a higher expansion velocity) than those of SN 1994I. The deep O I feature in the SN 1994I spectrum in not present in SN 2004cc, making this object rather peculiar.

SN 2004dg was discovered on Jul. 19.8 by Vagnozzi et al. (2004) and classified as a type-II supernova by Elias et al. (2004). The spectrum shows P-Cyg profiles of H_α, H_β, Ca II H&K, Fe II and Ti II lines (Fig. 7g). There is a narrow emission component, probably due to a nearby H II region, on the broad H_α emission profile. The recession velocity deduced from this narrow emission line is of about 1760 km s^{-1}. Adopting this recession velocity, the photospheric velocities deduced from H_α and H_β are about 8420 and 6970 km s^{-1}, respectively. The spectrum of the type-II SN 2001du 18 days from explosion (Smartt et al. 2003) is the best match. Our algorithm provides a very high $QoF = 4.76$, despite a stronger H_α emission in SN 2004dg and a slight difference in SED, probably caused by reddening. In fact, on the noisy continuum a clear Na I D interstellar absorption feature with $EW \approx 1.9$ Å is detected, corresponding to $E(B-V) = 0.29$ (Turatto et al. 2003).

SN 2004dk was found on Aug. 1.2 by Graham & Li (2004a) and classified as a type-Ic supernova by Patat et al. (2004a). P-Cyg profiles of Ca II, Fe II, Na I, Si II and O I lines are present in the spectrum (Fig. 7h). The spectrum is similar to that of the type-Ic SN 2004aw 4 days after B maximum light (Taubenberger et al. 2006), though the O I and Ca II absorption profiles of the SN 2004aw spectrum are significantly bluer than those of 2004dk. The absorption minima of Si II 6355 Å and O I 7774 Å in the SN 2004dk spectrum suggest expansion velocities of about 9200 and 7300 km s^{-1}, respectively. A narrow H_α emission probably due to a nearby H II region is present. The second best fit to this spectrum is by that of SN 1994I 3 days before maximum light (Filippenko et al. 1995), as mentioned in Patat et al. (2004a).

SN 2004dn was discovered on Jul. 29.4 by Graham & Li (2004b) and classified as a type-Ic supernova few days before maximum light by Patat et al. (2004b). Spectral features of Si II, O I and Ca II are clearly visible (Fig. 7i). The expansion velocities deduced from Si II 6355 Å and O I 7774 Å minima are of about 10 500 and 10 200 km s^{-1}, respectively. The best fitting template is again that of the type-Ic SN 2004aw 4 days after maximum (Taubenberger et al. 2006). Having the same best fitting template means that the spectra of SN 2004dn and 2004dk are also similar.

SN 2004fe was discovered on Oct. 30.3 by Pugh et al. (2004) and classified as a type-Ic supernova a few days before maximum by Modjaz et al. (2004). The spectrum (Fig. 7j) shows P-Cyg profiles of Ca II, Fe II, Na I D, and O I lines. The best fitting template spectrum is that of the type-Ic SN 1994I 3 days before B maximum (Filippenko et al. 1995). The absorption at about 6170 Å is probably due to Si II λ6355, while the one at about 6360 Å is possibly either weak H_α or C II λ6580 (see Valenti et al. 2008).

SN 2004go was found on Nov. 18.3 by Li et al. (2004) and classified as a type-Ia supernova 3−4 weeks past maximum by Navasardyan et al. (2004). The expansion velocity deduced from Si II 6355 Å absorption minimum is about 10 200 km s^{-1}. The spectrum (Fig. 8a) is very similar to that of the type-Ia SN 1996X 24 days after maximum light (Salvo et al. 2001). The spectra of SN 1994D (Patat et al. 1996) and 2002bo (Benetti et al. 2004) 24 and 28 days after their *B* band maxima also provide good fits.

SN 2005G was found on Jan. 14.6 by Graham et al. (2005a) and classified as a type-Ia supernova about 10 days past maximum by Navasardyan et al. (2005). Ganeshalingam et al. (2005) report that a spectrum of SN 2005G taken 2 days before ours shows a narrow Si II 6355 Å absorption, a blend of two S II absorptions around 5500 Å and a flux density drop blueward of Ca II H&K lines. The Si II and S II features peculiarities are present in our spectrum as well (Fig. 8b), but we cannot confirm the blue flux decline, because of the limited spectral range. Nevertheless, the spectrum closely resembles (QoF = 3.5) that of the type-Ia SN 1994D 11 days after maximum light (Patat et al. 1996). The blueshift of Si II 6355 Å minimum is of 9600 km s^{-1}.

SN 2005H was found on Jan. 15.2 by Graham et al. (2005b) and classified as a young type-II supernova by Pastorello et al. (2005b). The spectrum is dominated by a blue continuum with overimposed P-Cyg profiles of H_β, Fe II and He I (Fig. 8c). H_α is also present, with broad emission and a shallow absorption. The H_β and He I absorption minima are blueshifted by about 6600 and 6800 km s^{-1}, respectively. The best fitting template to this spectrum is that of the SN 2002gd, a low line velocity Ni-poor SN IIP 6 days after explosion (Pastorello et al. 2004). The featureless spectrum the peculiar line profiles lead, however, to a very low QoF = 1.01.

SN 2005I was discovered on Jan. 15.6 by Graham et al. (2005b). Pastorello et al. (2005b) classified it as a type-II supernova about 3 months after the explosion. The spectrum is characterised by a red continuum and narrow P-Cyg profiles of H_α, H_β, Ca II and Fe II lines (Fig. 8d). The expansion velocities deduced from the H_α minimum is about 4900 km s^{-1}. The best match is with the type-II SN 2003gd spectrum (ASA). Adopting for SN 2003gd the explosion epoch found by Hendry et al. (2005), the template is at an epoch of 101 days from the explosion, in good agreement with the phase estimate by Pastorello et al. (2005b).

SN 2005N was found on Jan.19.6 by Puckett et al. (2005a) and classified as a type-Ib/c supernova in the nebular phase by Taubenberger et al. (2005a). The spectrum shows strong emission lines of Mg I] λ4571, Na I D, [O I] λ6300, 6364, [Ca II] λ7291, 7323 and Ca II (Fig. 8e). The best fit to this spectrum is with the type-Ib SN 1990I spectrum 88 days after maximum light (Elmhamdi et al. 2004), which, however, shows weaker [O I] emissions.

SN 2005V was found on Jan. 30.2 by Mattila et al. (2005) and classified as a type-Ib/c supernova by Taubenberger et al. (2005b). The spectrum shows P-Cyg profiles of Fe II, Na I D, O I and Ca II lines overimposed on a very red continuum (Fig. 8f). A narrow H_α emission line, due to an underlying H II region, is present. The best match of this spectrum is with the type-Ic SN 2004aw 22 days after the maximum light (Taubenberger et al. 2006). The shape of the continuum and the presence of a deep Na I D absorption line (EW = 5.4 Å) in the host galaxy restframe, suggest that SN 2005V is affected by heavy extinction ($E(B-V)$ = 0.9, Turatto et al. 2003). The absorption feature at 6200 Å on the SN 2005V spectrum is most likely due to Si II (possibly blended with H_α). There is no evidence of He I lines.

SN 2005ab was discovered on Feb. 5.6 by Nakano & Kadota (2005). Benetti & Di Mille (2005) classified it as a type-II SN shortly after its explosion. On the very noisy spectrum ($SNR \approx$ 6) a relatively broad (∼5000 km s^{-1}) H_α emission line is present (Fig. 8g). The best fitting template spectrum is that of the type-II SN 1997du 26 days after its discovery (ASA, Patat 1997). The minimum of the H_β line absorption component in the SN 1997du spectrum is blueshifted by about 6900 km s^{-1}. Despite the low *SNR*, the absorptions at about 5770 Å, 5110 Å and 4950 Å seem to be fitted by the SN 1997du absorptions of the Na I D 5892 Å, Fe II 5169 Å and Fe II 5110 Å lines, therefore the phase of SN 2005ab could be more advanced than reported by Benetti & Di Mille (2005).

SN 2005ai was found on Feb. 12.23 by Puckett et al. (2005b) and classified as a type-Ia supernova about one month past maximum light by Taubenberger et al. (2005c). The spectrum is that of a typical type-Ia SN (Fig. 8h), and SN 1994D 24 days after the maximum light (Patat et al. 1996) yields the best match. This spectrum is similar to the spectrum of SN 2004go of the present sample.

SN 2005br was detected on Mar. 28.1 by Monard (2005a) and classified as a type-Ib supernova about 40 days past maximum by Turatto et al. (2005). The reddened spectrum shows features of He I (probably blended with Na I D), O I and Ca II (Fig. 8i). Also, a rather strong ($EW \approx$ 2.6 Å) interstellar Na I D absorption line is detected. The photospheric expansion velocity deduced from He I 5876 Å is about 9000 km s^{-1}. The best fit to this spectrum is achieved with the type-Ib SN 1997X 40 days after discovery (ASA), However, the O I 7774 Å line is shallower (probably contaminated by a telluric feature and less blueshifted) in 1997X. Also, a SN 1990U spectrum (ASA) provides a good fit. Adopting the B maximum epoch given by Piemonte (1996) for SN 1990U, the template spectrum phase is 48 days.

SN 2005bs was found on Apr. 19.1 by Monard (2005b), and Turatto et al. (2005) classified it as a type-Ia supernova. The spectrum (Fig. 8j) resembles very well (QoF = 3.33) that of the type-Ia SN 1996X 31 day after the maximum light (Salvo et al. 2001), in agreement with the estimate by Turatto et al. (2005).

SN 2005cb was found on May 13.22 by Jacques et al. (2005) and classified as a type-Ib/c supernova at about 10 days after maximum by Turatto et al. (2005). P-Cyg profiles of Fe II, Na I D, Si II, O I and Ca II are present in the spectrum (Fig. 9a). The expansion velocities deduced from the minima of Si II and O I features are about 9500 and 11 000 km s^{-1}, respectively. The best fitting template is that of the type-Ic SN 1994I 1 day after B maximum light (Filippenko et al. 1995). SN 2005cb seems to be slightly redder than 1994I at maximum, and has a stronger O I with a higher line velocity.

SN 2005ce was found on May 28.5 by Pugh & Li (2005) and classified as a type-Ib/c supernova a few days after explosion by Stanishev et al. (2005a). The spectrum has a blue continuum with several P-Cyg profiles of Fe II, Ca II lines and moderately weak absorptions at about 5700 Å, 6496 Å, 6850 Å and 7060 Å due to He I, with expansion velocities of about 8980, 8170, 9100 and 9140 km s^{-1}, respectively (Fig. 9b). However, the best fit to this spectrum is provided by the type-Ic SN 1996aq 5 days after discovery (ASA). The spectrum is also similar to that of SN 1994I 10 days after B maximum, though in the SN 2005ce spectrum the O I feature is much weaker (if any). The deep absorption at about 6294 Å is most likely due to H_α (probably blended with Si II and C II λ6580). This is supported by the identification of an absorption at about 4689 Å with H_β. The presence of H_α in various SN Ib/c was suspected (see Branch et al. 2002; Elmhamdi et al. 2006). Usually the H_α line optical depth is small and no apparent H_β is detected, while in this case the H_α feature is strong and there is also some hint of H_β presence. With these identifications the photospheric expansion velocities derived from H_α and H_β lines are of about 12 300 and 10 600 km s^{-1}. Although the best fits found by our programme are with type-Ic SNe, SN 2005ce is a rare and a very interesting example of an intermediate case between a Ib (with possibly some contamination of H) and Ic event.

SN 2005de was discovered on Aug. 2.28 by Lee et al. (2005) and classified as a type-Ia supernova one week before maximum by Wang & Baade (2005). Our spectrum of SN 2005de shows P-Cyg lines of Ca II, Fe II, S II and Si II (Fig. 9c). The Ca II near-infrared triplet seems to be present with two components. This was noted by Wang & Baade (2005) who measured a velocity of about 20 000 km s^{-1} for the bluer component, in agreement with our spectrum where the Ca II absorption minimum is blueshifted by 20 200 km s^{-1}, taking 8579 Å as the wavelength reference for the multiplet. Indeed, this high velocity feature is also present in the best fitting template spectrum of the type-Ia SN 2005cf 5 days before the maximum light (Garavini et al. 2007). Mazzali et al. (2005) find that the presence of high-velocity features is very common, if not ubiquitous, in the early spectra of SNe Ia.

SN 2005dv was found on Sep. 4.8 by Dimai & Dainese (2005) and classified as a type-Ia supernova probably before maximum light by Leonard (2005). The minimum of the Si II λ6355 line is blue-shifted by about 12 600 km s^{-1} suggesting that the phase of the spectrum is near-maximum (Fig. 9d). The best fitting template is that of the type-Ia SN 2002bo at maximum light (Benetti et al. 2004). The fit reproduces all spectral features rather well, though in the blue region the continuum of SN 2005dv spectrum is weaker, probably due to some reddening. This is confirmed by the presence of a Na I D absorption line ($EW \approx 2.3$ Å) in the rest frame of the host galaxy, as noted also by Leonard (2005).

SN 2005dz was found on Sep. 10 by Puckett et al. (2005c) and classified as a young type-II supernova by Stanishev et al. (2005b). The blue continuum of the spectrum is superimposed by broad and shallow P-Cyg profiles of H Balmer and He I λ5876 lines (Fig. 9e). H_α is present mostly in emission. The expansion velocities derived from the H_α and H_β absorptions are about 12 200 and 10 600 km s^{-1}, respectively. The best fitting template spectrum is that of the type-II SN 2007T 4 days after discovery (Benetti et al. 2007), although the expansion velocities of 2007T are smaller. The SN 2005dz spectrum is also similar to that of the type-II SN 2002gd 6 days after explosion (Pastorello et al. 2004).

SN 2005kl was discovered on Nov. 22 by Dimai & Migliardi (2005) and classified as a type-Ic supernova by Taubenberger et al. (2005d). P-Cyg profiles of O I, Ca II and also absorptions due to Si II and Fe II are present in the spectrum (Fig. 9f). The red continuum suggests that the SN is heavily extinguished. The best fitting template is the type-Ic SN 2004aw 4 days after B maximum (Taubenberger et al. 2006), which was also the case for SN 2004dk and 2004dn. The expansion velocity deduced from the Si II absorption is of about 10 000 km s^{-1}.

6. Summary

The European Supernova Collaboration (ESC) was conceived to perform very detailed studies of nearby SNe Ia and carried out extensive follow-up programmes on 15 objects (plus one SN Ic). Integral part of the ESC was a prompt classification programme with ToO observations of selected, newly discovered SNe, with the aim to single out candidates for the following intensive monitoring. In this context several tens of SN candidates were observed which did not meet the ESC requirements as to epoch of discovery and SN type. In this paper we have presented and discussed the spectra of these objects which include 8 type-Ia, 13 type-Ib/c (in 2 cases possibly IIb) and 15 type-II SNe. Each SN spectrum has been analysed by means of a new software tool that compares it with a vast database of SN spectra. For each object we have identified the best fit SN template providing type and a phase estimate. Other information such as the identification of the most prominent spectral features, the expansion velocities of the absorbing layers and possible peculiarities have also been reported.

The comparison with ASA spectra has confirmed the previous classification of all objects. Nevertheless, in some cases the new spectral ages differ from the estimates reported in the original IAU circulars. In the case of SN 2002cs the new determination of the spectral age (−7 days) to be compared to the previous one (−2 ± 2 days), shows the importance of having a reliable and objective classification tool and a complete archive. Had such a tool been available in 2002, SN 2002cs would have become an ESC target for detailed follow-up observations.

The current version of the comparison software, which is now routinely used by the Padova team for the classification of newly discovered SNe, has been presented. In particular, we have discussed the general algorithm and the accuracy of the classification and phase determination. The classification can be considered "safe" when the QoF parameter is larger than 1.4, while for $QoF < 1.4$ the type determination must be done "cum grano salis". Values of QoF smaller than 1 mean that no spectral template similar to the input spectrum is present in the archive. Typical errors in the epoch determination of ±1.9 days have been found for SN Ia in the early, fast evolving phases, while for later epochs the uncertainty rises to 3.1 days. Much larger (about 10 days) is the uncertainty on the epoch determination for CC SNe, because of their heterogeneity and lack of the extensively observed templates.

Although this tool already provides satisfactory results, we plan to implement some refinement for what concerns the quantitative measure of the quality of the fits. The SN research community will have access to the tool through a web-based interface that we plan to develop.

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References

Altavilla, G. 2001, IAU Circ., 7762, 1
Altavilla, G., Stehle, M., Ruiz-Lapuente, P., et al. 2007, A&A, 475, 585
Arbour, R., & Boles, T. 2003, IAU Circ., 8205, 1
Armstrong, M. 2004, Centr. Bur. Electr. Telegr., 66, 1
Armstrong, M., & Buczynski, D. 2004, IAU Circ., 8301, 1
Barbon, R., Benetti, S., Cappellaro, E., et al. 1995, A&AS, 110, 513
Barbon, R., Buondí, V., Cappellaro, E., & Turatto, M. 1999, A&AS, 139, 531
Benetti, S., & Turatto, M. 1996, IAU Circ., 6520, 1
Benetti, S., & di Mille, F. 2005, IAU Circ., 8480, 2
Benetti, S., Altavilla, G., Pastorello, A., et al. 2002a, IAU Circ., 7828, 2
Benetti, S., Altavilla, G., Pastorello, A., et al. 2002b, IAU Circ., 7844, 2
Benetti, S., Altavilla, G., Pastorello, A., et al. 2002c, IAU Circ., 8019, 3
Benetti, S., Navasardyan, H., Pastorello, A., et al. 2003, IAU Circ., 8207, 3
Benetti, S., Meikle, P., Stehle, M., et al. 2004, MNRAS, 348, 261
Benetti, S., Cappellaro, E., Mazzali, P. A., et al. 2005, ApJ, 623, 1011
Benetti, S., Harutyunyan, A., Turatto, M., Cappellaro, E., & Magazzu, A. 2007, Centr. Bur. Electr. Telegr., 837, 1
Blondin, S., & Tonry, J. L. 2007, ApJ, 666, 1024
Boles, T. 2002, IAU Circ., 8009, 1
Boles, T., & Schwartz, M. 2002, IAU Circ., 8004, 2
Botticella, M. T., et al. 2007, A&A, in press
Branch, D., Benetti, S., Kasen, D., et al. 2002, ApJ, 566, 1005
Branch, D., Baron, E. A., & Jeffery, D. J. 2003, Supernov. Gamma-Ray Bursters, 598, 47
Desidera, S., Giro, E., Della Valle, A., et al. 2002, IAU Circ., 7963, 2
Dimai, A., & Dainese, P. 2005, Centr. Bur. Electr. Telegr., 217, 1
Dimai, A., & Migliardi, M. 2005, Centr. Bur. Electr. Telegr., 300, 1
Elias, N., Benetti, S., Navasardyan, H., et al. 2004, IAU Circ., 8376, 2
Elias-Rosa, N., Benetti, S., Marmo, C., et al. 2003, IAU Circ., 8187, 2
Elias-Rosa, N., Pignata, G., Benetti, S., et al. 2004a, IAU Circ., 8273, 2
Elias-Rosa, N., Benetti, S., Stanishev, V., Goobar, A., & Jaervinen, A. 2004b, IAU Circ., 8301, 2
Elias-Rosa, N., Benetti, S., Cappellaro, E., et al. 2006, MNRAS, 369, 1880
Elias-Rosa, N., Benetti, S., Turatto, M., et al. 2008, MNRAS, 384, 107
Elmhamdi, A., Danziger, I. J., Chugai, N., et al. 2003, MNRAS, 338, 939
Elmhamdi, A., Danziger, I. J., Cappellaro, E., et al. 2004, A&A, 426, 963
Elmhamdi, A., Danziger, I. J., Branch, D., et al. 2006, A&A, 450, 305
Evans, R., Bock, G., Krisciunas, K., & Espinoza, J. 2003, IAU Circ., 8186, 1
Fassia, A., Meikle, W. P. S., Geballe, T. R., et al. 1998, MNRAS, 299, 150
Filippenko, A. V. 1997, ARA&A, 35, 309
Filippenko, A. V., Barth, A. J., Matheson, T., et al. 1995, ApJ, 450, L11
Foley, R. J., Wong, D. S., Moore, M., & Filippenko, A. V. 2004, IAU Circ., 8353, 3
Ganeshalingam, M., & Li, W. D. 2002, IAU Circ., 7837, 1
Ganeshalingam, M., Li, W. D., & Armstrong, M. 2002, IAU Circ., 7891, 1
Ganeshalingam, M., Serduke, F. J. D., & Filippenko, A. V. 2005, IAU Circ., 8468, 2
Garavini, G., Nobili, S., Taubenberger, S., et al. 2007, A&A, 471, 527
Graham, J., & Li, W. 2004a, Centr. Bur. Electr. Telegr., 75, 1
Graham, J., & Li, W. 2004b, IAU Circ., 8381, 1
Graham, J., Li, W., Schwartz, M., & Trondal, O. 2005a, IAU Circ., 8465, 1
Graham, J., Li, W., Trondal, O., & Schwartz, M. 2005b, IAU Circ., 8467, 1
Hachinger, S., Mazzali, P. A., & Benetti, S. 2006, MNRAS, 370, 299
Harutyunyan, A., Benetti, S., Cappellaro, E., & Turatto, M. 2005, 1604–2004: Supernovae as Cosmological Lighthouses, 342, 258
Hendry, M. A., Smartt, S. J., Maund, J. R., et al. 2005, MNRAS, 359, 906
Jacques, C., Colesanti, C., Pimentel, E., & Napoleao, T. 2005, IAU Circ., 8530, 2
Jeffery, D. J., & Branch, D. 1990, Supernovae, Jerusalem Winter School for Theoretical Physics, 149
Kotak, R., Meikle, W. P. S., Pignata, G., et al. 2005, A&A, 436, 1021
Lee, E., Ponticello, N. J., Foley, R. J., Puckett, T., & Tigner, J. 2005, Central Bureau Electronic Telegrams, 191, 1
Leonard, D. C. 2005, Central Bureau Electronic Telegrams, 218, 1
Li, W., Yamaoka, H., & Itagaki, K. 2004, IAU Circ., 8448, 2
Matheson, T., Filippenko, A. V., Li, W., Leonard, D. C., & Shields, J. C. 2001, AJ, 121, 1648
Matheson, T., Jha, S., Challis, P., et al. 2002, IAU Circ., 7894, 1
Matheson, T., Challis, P., Kirshner, R., & Penev, K. 2004, IAU Circ., 8353, 2
Mattila, S., Greimel, R., Gerardy, C., & Meikle, W. P. S 2005, IAU Circ., 8474, 1
Mazzali, P. A., Iwamoto, K., & Nomoto, K. 2000, ApJ, 545, 407
Mazzali, P. A., Benetti, S., Altavilla, G., et al. 2005, ApJ, 623, L37
Mazzali, P. A., Röpke, F. K., Benetti, S., & Hillebrandt, W. 2007, Science, 315, 825
Modjaz, M., Challis, P., Kirshner, R., et al. 2004, IAU Circ., 8426, 3
Monard, L. A. G. 2002, IAU Circ., 8016, 1
Monard, L. A. G. 2005a, IAU Circ., 8516, 1
Monard, L. A. G. 2005b, Centr. Bur. Electr. Telegr., 143, 1
Monard, L. A. G., & Li, W. 2004, IAU Circ., 8350, 2
Moore, M., & Li, W. 2003, Centr. Bur. Electr. Telegr., 40, 1
Nakano, S., Sano, Y., Kushida, R., & Kushida, Y. 2002, IAU Circ., 7805, 1
Nakano, S., & Kadota, K. 2005, IAU Circ., 8478, 1
Nakano, S., Kushida, R., Kushida, Y., & Itagaki, K. 2004, IAU Circ., 8272, 1
Navasardyan, H., Turatto, M., Harutunyan, A., et al. 2004, IAU Circ., 8454, 3
Navasardyan, H., Benetti, S., Elias-Rosa, N., Harutunyan, A., & Pastorello, A. 2005, IAU Circ., 8468, 3
Pastorello, A. 2003, Ph.D. Thesis, Univ. Padova
Pastorello, A., Zampieri, L., Turatto, M., et al. 2004, MNRAS, 347, 74
Pastorello, A., Baron, E., Branch, D., et al. 2005a, MNRAS, 360, 950
Pastorello, A., Taubenberger, S., Patat, F., et al. 2005b, IAU Circ., 8467, 2
Pastorello, A., Mazzali, P. A., Pignata, G., et al. 2007a, MNRAS, 377, 1531
Pastorello, A., Smartt, S. J., Mattila, S., et al. 2007b, Nature, 447, 829
Pastorello, A., Taubenberger, S., Elias-Rosa, N., et al. 2007c, MNRAS, 376, 1301
Pastorello, A., et al. 2008 [arXiv:0801.2277]
Patat, F. 1997, IAU Circ., 6776, 1
Patat, F., & Turatto, M. 1998, IAU Circ., 6922, 1
Patat, F., Benetti, S., Cappellaro, E., et al. 1996, MNRAS, 278, 111
Patat, F., Pignata, G., Benetti, S., & Aceituno, J. 2004a, IAU Circ., 8379, 3
Patat, F., Pignata, G., Benetti, S., & Aceituno, J. 2004b, IAU Circ., 8381, 2
Perlmutter, S., & Schmidt, B. P. 2003, Supernov. Gamma-Ray Bursters, 598, 195
Piemonte, A. 1996, Tesi di Laurea, Univ. Padova
Pignata, G., Patat, F., & Turatto, M. 2002a, IAU Circ., 8007, 4
Pignata, G., Patat, F., & Benetti, S. 2002b, IAU Circ., 8009, 2
Pignata, G., Patat, F., Benetti, S., & Harutyunyan, A. 2004a, IAU Circ., 8344, 2
Pignata, G., Patat, F., Benetti, S., et al. 2004b, MNRAS, 355, 178
Puckett, T., & Kerns, B. 2002, IAU Circ., 7951, 2
Puckett, T., George, D., Graham, J., & Li, W. 2005a, IAU Circ., 8470, 1
Puckett, T., Orff, T., George, D., & Crowley, T. 2005b, IAU Circ., 8486, 2
Puckett, T., Pelloni, A., Ponticello, N., et al. 2005c, Centr. Bur. Electr. Telegr., 222, 1
Pugh, H., & Li, W. 2005, Centr. Bur. Electr. Telegr., 158, 1
Pugh, H., Park, S., & Li, W. 2004, IAU Circ., 8425, 1
Riello, M., Benetti, S., Altavilla, G., et al. 2002a, IAU Circ., 7894, 4
Riello, M., Benetti, S., Altavilla, G., et al. 2002b, IAU Circ., 7922, 2
Riess, A. G., Filippenko, A. V., Leonard, D. C., et al. 1997, AJ, 114, 722
Rizzi, L. 1998, Tesi di Laurea, Univ. Padova
Salvo, M. E., Cappellaro, E., Mazzali, P. A., et al. 2001, MNRAS, 321, 254
Salvo, M., Bessell, M., & Schmidt, B. 2003, IAU Circ., 8187, 1
Sanders, E. 2002, IAU Circ., 7921, 1
Schlegel, D. J., Finkbeiner, D. P., & Davis, M. 1998, ApJ, 500, 525
Smartt, S. J., Maund, J. R., Gilmore, G. F., et al. 2003, MNRAS, 343, 735
Stanishev, V., Goobar, A., & Augusteijn, T. 2005a, Centr. Bur. Electr. Telegr., 159, 1
Stanishev, V., Goobar, A., & Naranen, J. 2005b, Centr. Bur. Electr. Telegr., 225, 1
Stanishev, V., Goobar, A., Benetti, S., et al. 2007, A&A, 469, 645
Taubenberger, S., Pastorello, A., & Alises, M. 2005a, IAU Circ., 8472, 3
Taubenberger, S., Pastorello, A., Benetti, S., & Aceituno, J. 2005b, IAU Circ., 8474, 3
Taubenberger, S., Patat, F., Benetti, S., & Alises, M. 2005c, IAU Circ., 8487, 4
Taubenberger, S., Pastorello, A., Mazzali, P. A., Witham, A., & Guijarro, A. 2005d, Centr. Bur. Electr. Telegr., 305, 1
Taubenberger, S., Pastorello, A., Mazzali, P. A., et al. 2006, MNRAS, 371, 1459
Taubenberger, S., et al. 2008, MNRAS, 177
Turatto, M. 2003, Supernov. Gamma-Ray Bursters, 598, 21
Turatto, M., Riello, M., Altavilla, G., et al. 2002, IAU Circ., 7921, 2
Turatto, M., Benetti, S., & Cappellaro, E. 2003, From Twilight to Highlight: The Physics of Supernovae, 200
Turatto, M., Benetti, S., Harutyunyan, A., et al. 2005, Centr. Bur. Electr. Telegr., 156, 1
Turatto, M., Benetti, S., & Pastorello, A. 2007 [arXiv:0706.1086]
Vagnozzi, A., de Pasquale, D., Guerri, F., et al. 2004, IAU Circ., 8375, 1
Valenti, S. 2003, Tesi di Laurea, Univ. Napoli
Valenti, S., Elias-Rosa, N., Taubenberger, S., et al. 2008, ApJ, 673, L155
Wang, L., & Baade, D. 2005, Centr. Bur. Electr. Telegr., 193, 1
Wood-Vasey, W. M., Aldering, G., & Nugent, P. 2002, IAU Circ., 7915, 2

Table 5. The archive SNe and spectra.

SN	Type	Redshift (z)	Number of files	Phase range (days)
1937C	Ia	0.0011	5	8–39
1969L	IIP	0.0016	7	2–61
1974G	Ia	0.0024	1	9
1978K	II	0.0015	2	7683,7687
1979B	Ia	0.0032	5	9–47
1979C	IIL	0.0053	24	5–223
1980K	IIL	0.0002	19	2–95
1980N	Ia	0.0060	1	31
1981B	Ia	0.0060	22	–3–356
1982B	Ia	0.0074	2	3, 28
1983G	Ia	0.0039	6	–1–8
1983N	Ib	0.0017	6	–8–228
1983U	Ia	0.0039	1	14
1983V	Ic	0.0055	3	–9––4
1984A	Ia	–0.0009	12	–7–54
1984E	IIL	0.0041	1	3959
1984L	Ib	0.0051	3	10–61
1985L	IIL	0.0029	2	13, 203
1986E	IIL	0.0037	5	23–5907
1986G	Iapec	0.0018	33	–6–324
1987A	IIpec	0.0011	52	–76–5014
1987B	IInL	0.0085	2	6, 7
1987K	IIb	0.0027	7	0–208
1988A	IIP	0.0051	5	3–444
1988G	Ia	n.a.	1	29
1988H	IIP	0.0066	5	21–874
1988L	Ib	0.0062	8	11–138
1988Z	IIn	0.0222	21	115–3773
1989B	Ia	0.0024	20	–6–348
1989C	IIP	0.0063	3	3–58
1989M	Ia	0.0051	12	20–421
1990B	Ic	0.0075	20	5–148
1990E	IIP	0.0041	21	13–537
1990H	II	0.0053	8	2–27
1990I	Ib	0.0097	24	0–357
1990K	II	0.0053	21	5–475
1990M	Ia	0.0088	8	1–55
1990N	Ia	0.0033	6	–14–246
1990Q	II	0.0064	3	3–299
1990S	IIn	0.0256	1	4
1990U	Ic	0.0079	25	–3–367
1990W	Ib/c	0.0049	10	1–3995
1990aa	Ic	0.0166	20	7–141
1990ah	II	0.0175	1	–84
1990aj	Iac	0.0053	5	42–82
1991A	Ic	0.0107	8	5–96
1991D	Ib	0.0418	14	5–78
1991E	II	0.0240	1	4
1991H	II	0.0180	1	1
1991I	II	0.0360	1	2
1991K	Ia	0.0170	3	70–122
1991L	Ib/c	0.0300	1	13
1991M	Ia	0.0072	9	1–147
1991N	Ic	0.0033	5	5–282
1991S	Ia	0.0550	2	16, 19
1991T	Iapec	0.0058	35	–12–1785
1991ah	IIn	0.0370	3	62–84
1991al	II	0.0100	4	20–28
1991ar	Ib	0.0152	2	14, 30
1991bb	Ia	0.0266	1	45
1991bc	Ia	0.0214	2	19, 49
1991bd	Ia	0.0127	2	16, 46
1991bg	Iapec	0.0030	21	1–203
1991bj	Iapec	0.0182	1	2
1992A	Ia	0.0062	35	–6–406
1992B	Ia	0.0550	1	13
1992C	II	0.0101	9	15–455
1992D	IIn	0.0500	2	7, 33
1992E	Ia	0.0600	2	9, 9
1992G	Ia	0.0053	4	–2–35
1992H	II	0.0060	29	10–403
1992K	Iapec	0.0104	6	45–45
1992O	Ia	0.0370	4	25–25
1992al	Ia	0.0146	1	61
1992ao	II	0.0122	25	4–1382
1992av	Ia	n.a.	1	9
1992ay	IIn	0.0620	1	13
1992ba	II	0.0041	3	3–150
1992bb	Ia	n.a.	2	31, 31
1992bm	II	0.0500	1	–315
1993H	Ia	0.0241	5	1–416
1993J	IIb	–0.0001	39	1–1264
1993K	II	0.0091	13	31–354
1993L	Ia	0.0064	15	16–378
1993M	Ia	0.0901	2	18, 18
1993N	IIn	0.0098	11	32–655
1993S	II	0.0320	2	33, 90
1993T	Ia	0.0881	1	33
1993W	II	0.0180	2	2, 6
1993ad	II	0.0172	11	3–326
1993ae	Ia	0.0190	1	10
1993af	Ia	0.0033	7	–304–318
1993aj	Ia	0.0751	1	14
1994D	Ia	0.0015	42	–11–373
1994I	Ic	0.0015	50	–6–146
1994L	II	0.0068	17	31–356
1994M	Ia	0.0232	3	15–15
1994N	II	0.0098	8	0–265
1994R	II	0.0070	1	10
1994S	Ia	0.0152	1	–4
1994U	Ia	0.0044	1	0
1994Z	II	0.0118	13	2–365
1994ae	Ia	0.0043	13	–6–531
1994ai	Ic	0.0050	8	4–70
1994aj	II	0.0320	30	43–540
1995D	Ia	0.0066	8	–6–364
1995F	Ic	0.0051	5	10–260
1995G	IIn	0.0163	21	2–942
1995H	II	0.0047	6	–10–247
1995J	II	0.0099	1	30
1995M	Ia	0.0520	1	38
1995N	IIn	0.0062	63	4–3374
1995P	Ia	0.0560	1	22
1995R	Ia	0.0237	1	7
1995T	Ia	0.0560	1	8
1995U	Ia	0.0556	1	5
1995V	II	0.0051	16	1–402
1995W	II	0.0113	21	12–780
1995X	II	0.0052	1	28
1995Z	II	0.0158	2	88, 91
1995aa	IIn	0.1900	1	23
1995ac	Iapec	0.0500	8	0–43
1995ad	II	0.0061	23	7–508
1995ae	Ia	0.0689	1	10
1995ag	II	0.0049	2	33,207
1995ak	Ia	0.0227	3	–1–19
1995al	Ia	0.0051	10	–3–166
1995bb	Ic	0.0058	1	18

Table 5. continued.

Table 5. continued.

SN	Type	Redshift (z)	Number of files	Phase range (days)
1995bd	Iapec	0.0154	3	16–19
1996A	II	0.0330	7	10–39
1996D	Ic	0.0158	5	9–214
1996L	IIL	0.0330	16	9–336
1996M	II	0.0200	4	3–61
1996W	II	0.0055	13	8–309
1996X	Ia	0.0068	17	–4–298
1996Z	Ia	0.0076	3	5–269
1996ae	IIn	0.0052	5	7–23
1996al	II	0.0061	48	1–2155
1996an	II	0.0047	18	3–487
1996aq	Ic	0.0053	17	2–270
1996ar	Ia	0.0600	1	3
1996as	II	0.0360	2	3, 3
1996bl	Ia	0.0360	1	–3
1996bo	Ia	0.0175	2	–6, 49
1996bw	II	0.0181	3	7–22
1996bx	Ic	0.0600	1	19
1996cb	IIb	0.0024	19	12–155
1996cc	II	0.0072	6	83–140
1997B	Ic	0.0104	18	1–385
1997C	Ia	0.0227	1	27
1997D	IIpec	0.0052	16	–1–383
1997X	Ic	0.0037	22	5–101
1997Y	Ia	0.0160	4	31–32
1997Z	II	0.0086	5	2–7
1997ab	IIn	0.0125	6	357–777
1997bp	Iapec	0.0083	12	–1–414
1997bq	Ia	0.0094	1	18
1997br	Iapec	0.0069	13	–4–404
1997bs	IIn	0.0024	1	14
1997bt	II	0.0648	1	16
1997by	Ia	0.0453	1	3
1997cn	Iapec	0.0167	3	3–78
1997cr	II	0.0771	2	8,8
1997cw	Iapec	0.0176	9	44–106
1997cy	IIn	0.0642	15	8–635
1997dc	Ib	0.0115	2	6, 32
1997dd	IIb	0.0152	1	17
1997de	Ia	0.0129	1	25
1997dh	Ic	0.0500	1	4
1997dq	Ib/cpec	0.0032	5	6–428
1997ds	II	0.0094	1	8
1997du	II	0.0200	2	26, 35
1997ef	Ib/cpec	0.0118	8	4–102
1997eg	IIn	0.0089	4	76–547
1997ei	Ic	0.0107	1	25
1997ej	Ia	0.0223	2	32, 37
1998A	IIpec	0.0070	10	18–397
1998E	IIn	0.0080	1	374
1998R	II	0.0067	1	36
1998S	IIn	0.0028	5	7–489
1998T	Ib	0.0101	3	3–27
1998V	Ia	0.0174	1	12
1998W	II	0.0119	2	6, 14
1998bn	Ia	0.0061	1	360
1998bp	Ia	0.0106	2	27, 346
1998bu	Ia	0.0031	12	–7–681
1998bw	Ic	0.0085	34	–9–376
1998ce	II	0.0084	1	10
1998cg	Ia	0.1190	1	29
1998co	Ia	0.0182	1	31
1998cv	Ic	0.0270	1	28
1998cx	Ia	0.0197	1	18
1998dg	Ia	0.0082	1	203
1998dh	Ia	0.0089	4	8–58
1998dj	Ia	0.0137	2	4, 52
1998dk	Ia	0.0132	2	29, 31
1998dl	II	0.0047	2	59, 116
1998dm	Ia	0.0065	2	23, 27
1998dn	II	0.0013	2	43, 95
1998dq	Ia	0.0108	1	39
1998dt	Ib	0.0150	7	19–125
1998ee	IIpec	0.0497	1	116
1998es	Iapec	0.0105	3	–2–58
1998et	IIn	0.0404	1	296
1998ew	II	0.0103	1	179
1998fa	IIb	0.0244	5	25–77
1999E	IIn	0.0260	17	8–449
1999J	Iapec	0.0334	1	21
1999P	Ib/c	0.0600	2	6, 7
1999Z	IIn	0.0504	2	31, 115
1999aa	Iapec	0.0149	3	13–50
1999ac	Iapec	0.0095	7	–6–391
1999as	Icpec	0.1270	1	54
1999br	IIpec	0.0034	8	11–99
1999bv	Ia	0.0184	1	5
1999by	Iapec	0.0021	1	183
1999cf	Ia	0.0244	1	13
1999cl	Ia	0.0071	3	16–297
1999cn	Ic	0.0226	3	1–299
1999cw	Ia	0.0124	10	3–397
1999cz	Ic	0.0072	1	15
1999da	Ia	0.0123	1	60
1999dh	II	0.0108	1	22
1999di	Ib	0.0164	3	9–40
1999dk	Ia	0.0152	6	–14–67
1999dn	Ib	0.0094	12	6–379
1999dq	Iapec	0.0145	1	–6
1999eb	IIn	0.0181	7	5–88
1999ec	Iac	0.0092	1	6
1999ee	Ia	0.0114	14	–9–41
1999el	IIn	0.0044	4	18–103
1999em	IIP	0.0024	23	–2–635
1999et	II	0.0163	2	0, 0
1999eu	IIpec	0.0042	4	5–43
1999ex	Ib/c	0.0114	8	–1–13
1999ey	IIn	0.0931	2	4, 25
1999ga	II	0.0047	4	40–441
1999ge	II	0.0188	1	10
1999gi	IIP	0.0020	2	49, 173
1999go	II	0.0148	2	5, 6
1999gt	Ia	0.2740	3	13–13
1999gu	II	0.1470	2	13, 13
2000B	Ia	0.0191	2	10, 19
2000C	Ic	0.0127	5	17–34
2000D	II	0.0172	2	8, 19
2000E	Ia	0.0044	7	14–144
2000H	IIb	0.0130	6	9–66
2000M	II	0.0103	1	5
2000N	II	0.0133	2	5, 9
2000O	Ia	0.0235	2	4, 9
2000P	IIn	0.0074	6	3–506
2000bg	IIn	0.0245	1	4
2000ck	IIpec	0.0268	1	5
2000cm	Ia	0.0072	1	4
2000cn	Ia	0.0235	2	8, 86
2000cu	Ia	n.a.	1	2
2000cx	Iapec	0.0081	5	1–114
2000da	II	0.0244	1	19

Table 5. continued.

SN	Type	Redshift (z)	Number of files	Phase range (days)
2000db	II	0.0023	1	16
2000de	Ib	0.0080	4	13–14
2000dg	Ia	0.0385	1	6
2000dj	II	0.0158	2	7, 8
2000eo	IIn	0.0108	1	10
2000ev	IIn	0.0146	1	1
2000ew	Ic	0.0032	2	65, 109
2000fc	Ia	0.4200	1	9
2000fe	II	0.0141	1	11
2000fp	II	0.3000	1	5
2001N	Ia	0.0210	5	11–57
2001V	Ia	0.0151	3	13–54
2001X	IIP	0.0049	2	129, 468
2001bb	Ic	0.0158	4	18–74
2001bc	II	0.1950	1	8
2001bd	II	0.0961	1	10
2001be	Ia	0.2410	2	9, 9
2001bg	Ia	0.0071	2	3, 11
2001cz	Ia	0.0157	4	1–29
2001dc	IIP	0.0071	3	41–86
2001dk	IIP	0.0180	1	164
2001dr	II	0.0239	1	11
2001du	II	0.0055	1	16
2001ed	Ia	0.0165	1	7
2001eh	Ia	0.0371	17	3–69
2001ep	Ia	0.0130	25	7–103
2001fh	Iapec	0.0130	2	3, 14
2001fv	II	0.0049	2	66, 68
2001fw	Ib	0.0295	1	7
2001ge	Ia	0.2200	1	1
2001gf	Ia	0.1300	2	1, 1
2001gg	II	0.6100	1	1
2001gh	II	0.1600	2	1, 29
2001gi	Ia	0.2000	1	1
2001gj	II	0.2700	1	1
2001ie	Ia	0.0308	1	4
2001ig	IIb	0.0030	1	188
2001io	Ia	0.1900	3	12–12
2001ip	Ia	0.5400	3	12–1433
2001is	Ib	0.0133	2	17, 18
2001it	II	0.0345	1	18
2002A	IIn	0.0096	1	10
2002an	II	0.0129	1	14
2002ap	Icpec	0.0021	38	–7–250
2002bh	II	0.0173	1	9
2002bo	Ia	0.0043	28	–14–367
2002cl	Ic	0.0720	2	14, 14
2002cm	II	0.0871	2	14, 14
2002cn	Ia	0.3020	2	14, 14
2002co	II	0.3180	1	14
2002cr	Ia	0.0094	5	4–46
2002cs	Ia	0.0157	1	2
2002cv	Ia	0.0043	10	–5–26
2002dg	Ib	0.0467	1	15
2002dj	Ia	0.0093	9	2–287
2002dm	Ia	0.0252	1	43
2002du	II	0.2100	1	68
2002ej	II	0.0162	1	21
2002eo	II	0.0204	1	11
2002er	Ia	0.0091	27	–11–582
2002gd	II	0.0090	13	3–111
2002hy	Ibpec	0.0127	1	3
2002ic	Iapec	0.0660	8	16–258
2002ji	Ib/c	0.0049	1	5
2003G	IIn	0.0115	3	15–16
2003J	II	0.0026	1	13

Table 5. continued.

SN	Type	Redshift (z)	Number of files	Phase range (days)
2003L	Ic	0.0213	1	13
2003M	Iapec?	0.0242	5	12–42
2003Z	II	0.0042	12	23–149
2003bg	Icpec	0.0044	1	4
2003cg	Ia	0.0041	40	–8–386
2003dt	Ia	0.0142	1	2
2003du	Ia	0.0064	10	–11–72
2003ei	IIn	0.0268	2	61, 62
2003gd	II	0.0021	7	15–73
2003gs	Iapec	0.0047	2	14, 26
2003hg	II	0.0143	1	4
2003hn	II	0.0039	1	3
2003ie	II	0.0023	1	3
2003jd	Icpec	0.0188	13	0–29
2004G	II	0.0053	1	2
2004aq	II	0.0140	1	8
2004aw	Ic	0.0158	32	1–261
2004dg	II	0.0045	1	2
2004dh	II	0.0194	2	93, 93
2004dj	IIP	0.0004	5	133–157
2004dt	Ia	0.0195	33	–10–354
2004eo	Ia	0.0157	21	2–241
2004et	II	0.0002	5	58–263
2004ex	IIb	0.0174	3	36–85
2004gd	IIn	0.0174	1	39
2004go	Ia	0.0291	1	19
2004gt	Ib/c	0.0055	2	24, 163
2005G	Ia	0.0231	1	4
2005N	Ib/c	0.0163	1	3
2005W	Ia	0.0087	2	1, 15
2005ab	II	0.0154	1	4
2005au	II	0.0182	1	15
2005aw	Ic	0.0133	1	62
2005ay	IIP	0.0027	12	1–308
2005bl	Ia	0.0241	1	33
2005br	Ib	0.0103	1	58
2005bs	Ia	0.0552	1	36
2005cb	Ic	0.0105	1	12
2005cf	Ia	0.0065	31	–12–77
2005cq	Ia	0.3100	1	10
2005cs	IIP	0.0015	17	–1–222
2005ip	II	0.0071	6	3–95
2006G	II/IIb	0.0168	1	25
2006W	IIL	0.0159	1	2
2006X	Ia	0.0053	2	1, 9
2006aj	Ib/c	0.0330	16	–7–10
2006ao	II	0.0299	1	10
2006ca	II	0.0089	1	2
2006gi	Ib	0.0094	1	146
2006gy	IIn	0.0188	3	–31–106
2006gz	Ia	0.0236	17	–13–12
2006jc	Ib/cpec	0.0056	28	3–78
2006ov	IIP	0.0053	2	39, 79
2007C	Ib	0.0056	1	12
2007F	Ia	0.0238	1	2
2007I	Ic	0.0216	1	28
2007R	Ia	0.0308	1	5
2007T	II	0.0135	1	4
2007af	Ia	0.0053	1	67
2007bj	Ia	0.0166	1	2
2007bm	Ia	0.0062	5	2–28
2007bt	IIn	0.0400	1	21
2007bw	IIn	0.1400	1	32
2007fo	Ib	0.0094	1	7