Observational Properties of Type II Plateau Supernovae

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Summary. We present spectroscopic and photometric data of a sample of Type II plateau Supernovae, covering a wide range of properties from the ^{56}Ni rich, high luminosity events (e.g. SN 1992am) to the low-luminosity, ^{56}Ni poor SNe (e.g. SN 1997D). We provide an observational framework to analyze correlations among observational data, physical parameters and progenitors characteristics of Type II supernovae.

1 The Sample of SNe II-P

Type II plateau Supernovae (SNe II-P) are considered a heterogeneous group of core-collapse events sharing a very wide range of physical properties. Despite their variety of observational parameters (e.g. early- and late-time luminosity, expansion velocity, continuum temperature), recent studies highlight tight correlations among their physical parameters [6, 10]. However, in these works the low-luminosity tail of the SNe II-P distribution was poorly sampled. Zampieri et al. [these Proceedings] have recently investigated such correlations, including also low-luminosity events. Our sample was selected in such a way to cover a large range in luminosity and line velocity, preferably among SNe II-P discovered at very early stages. We selected a few well studied SNe from literature and unpublished data from the Padova-Asiago SN Archive. Most of them have long-duration plateaux, but also events with relatively short plateaux (SNe 1992H and 1995ad) and spectroscopic evolution of a normal SN II-P, were considered. SNe from our archive have been observed either in spectroscopy and photometry from a few days after their discovery to the nebular phase, when the main output of energy comes from the radioactive decays. The sample includes 6 Ni poor ($< 10^{-2} M_\odot$) SNe, 5 intermediate Ni mass ($1-5\times10^{-2} M_\odot$) SNe and five Ni rich ($> 7\times10^{-2} M_\odot$) events.

In Table 1 we list the main data about the selected SNe (see also Ramina, Laurea Thesis, 2003, unpublished and references therein). When the distance

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Table 1. Main data of the selected SNe II-P

SN	μ	A_V	t_0 (JD)	ref.($\star$)	SN	μ	A_V	t_0 (JD)	ref.($\star$)
1969L	29.84	0.20	2440550.5	[2]	1996an	31.50	0.16	2450222	[9]
1987A	18.49	0.60	2446849.82	SAAO	1997D	31.29	0.07	2450361	[13, 1]
1992H	32.48	0.33	2448661	[3]	1999br	31.19	0.08	2451278	[5, 8]
1992am	36.74	0.44	2448799	[12]	1999em	29.47	0.31	2451476	[4, 7]
1992ba	30.91	0.19	2448883.2	[5, 9]	1999eu	31.08	0.09	2451394	[8]
1994N	33.34	0.13	2449451	[8]	2001dc	32.85	1.28	2452056	[8]
1995ad	32.02	0.11	2449981	[9]	2002gd	33.09	0.22	2452552	[9]
1996W	31.95	0.70	2450180	[9]	2003Z	31.93	0.13	2452665	[9]

($\star$) Reference for spectro-photometric data

modulus μ is obtained from the host galaxy recession velocity, H_0 has been assumed to be equal to 65 km s^{-1} Mpc^{-1}. The total extinction reported in Table 1 is the sum of the host galaxy reddening and the Galactic contribution, from [11]. More details on the estimated distances and interstellar extinction are in Ramina [Laurea Thesis, 2003, unpublished].

1.1 Faint SNe II-P

SN 1997D [13, 1] is the prototype of a homogeneous group of CC-SNe with unique observational properties. The light curves, showing flat plateaux lasting $\sim 90-110$ days, are underluminous at all epochs, and their spectra, redder than "typical" SNe II-P, show strong and narrow P-Cygni features indicating very small expansion velocities (~ 1000 km s^{-1} at the end of the plateau phase, see Fig. 1). In [8, 14] other similar SNe were discussed (SNe 1994N, 1999br, 1999eu and 2001dc). The database has been recently enriched by the discovery of a well representative event, SN 2003Z, extensively monitored at TNG[1]. This SN provides a very good example of the spectro-photometric evolution of low-luminosity SNe (see Fig. 2). The SN was observed both in spectroscopy and photometry during the photospheric phase, and observations during the nebular phase, useful to estimate the ^{56}Ni mass, are still in progress. Preliminary late-time photometry suggests that SN 2003Z ejected 0.006 $M_{\odot}$ of ^{56}Ni. We suggest that low-luminosity events may occur with relatively high frequency.

The observed properties of the faint CC-SNe are consistent with very small ejected ^{56}Ni mass ($< 10^{-3}$ $M_{\odot}$) and low explosion energy ($\ll 10^{51}$ erg, [14]). This suggests high-mass progenitors ($M_{MS} > 20 - 25 M_{\odot}$) for which significant fall-back might have occurred ([14] and Zampieri et al., these Proceedings).

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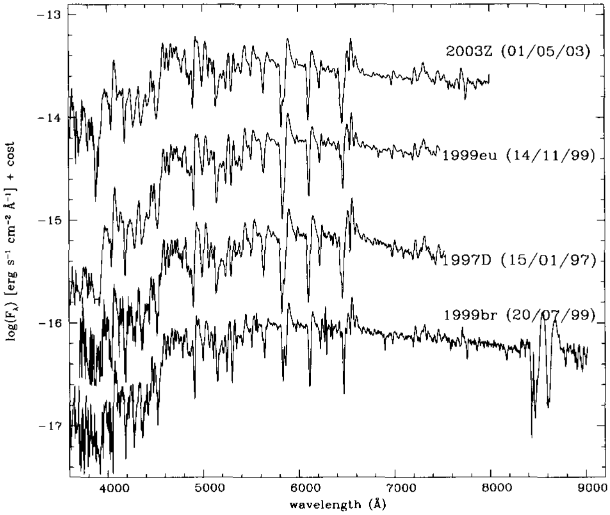

Fig. 1. Spectra of low-luminosity SNe II-P at $\sim$ 100 days after the explosion.

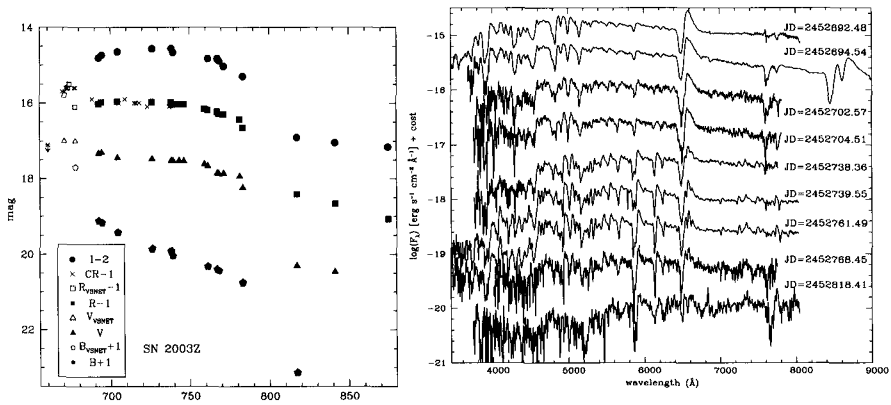

Fig. 2. Photometric and spectroscopic evolution of the low-luminosity SN 2003Z. Unfiltered measurements and VSNET (*http://vsnet.kusastro.kyoto-u.ac.jp/vsnet/*) data are also reported.

1.2 Normal SNe II-P

The sample contains also a number of "normal" and high luminosity events covering a large range of physical properties (e.g. Ni mass, explosion energy, ejected mass). Even if we observe a large spread both in luminosity ($2 - 20 \times 10^{42}$ erg s^{-1}) and in expansion velocity ($3000 - 5000$ km s^{-1} at the beginning of recombination), these SNe never show the extreme properties of SN 1997D and other faint events. Zampieri et al. (these Proceedings) suggest that the

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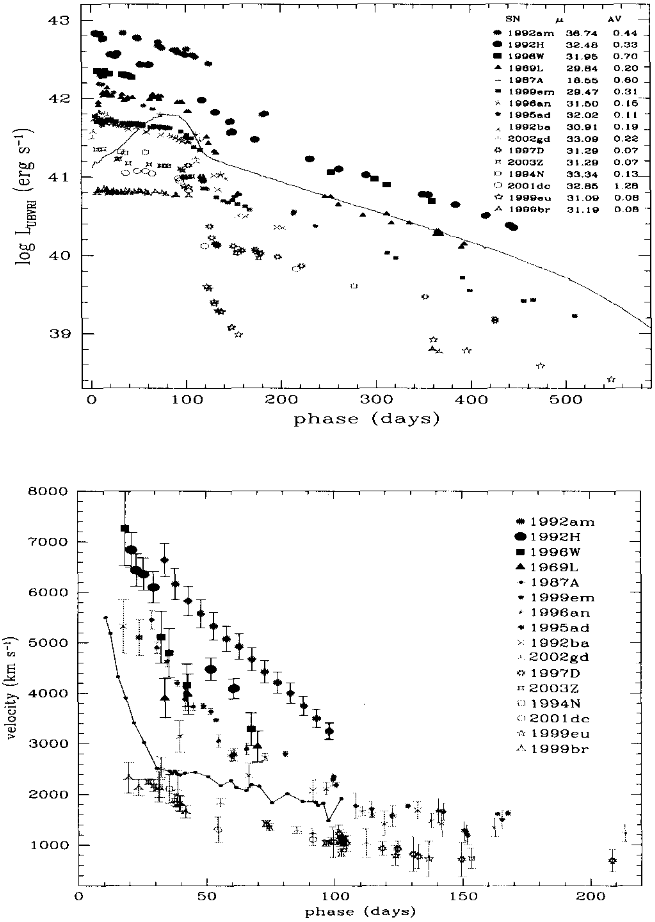

Fig. 3. Top: Luminosity evolution of our selected sample of SNe II-P. Bottom: expansion velocities obtained from the blueshift of the minimum of Sc II lines. Adopted colors are: red for faint 1997D-like SNe, magenta for intermediate-luminosity SNe, black for normal and high luminosity events; blue (solid line) is SN 1987A.

ejected envelope mass is in the range $12 - 26$ $M_{\odot}$, with no definite tendency to vary with the other SN parameters.

Peculiar is the case of SN 2002gd, well observed during the plateau, then lost behind the sun. The plateau luminosity is relatively high, but the expansion velocity deduced from the P-Cygni minima of spectral lines is small, close to that of faintest SNe II-P. This SN was recently observed and our preliminary photometry suggests an unusually strong post-plateau luminosity decrease. We may explain it with a very low amount of ejected ^{56}Ni

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($< 10^{-3}M_{\odot}$). Or, alternatively, dust formation into the ejecta might absorb the light at optical wavelengths, leading us to underestimate the ^{56}Ni mass. Because of its peculiar behavior, more late-time observations are required to better understand this event before any systematic analysis of its properties can be performed.

2 The Heterogeneous Family of SNe II-P

A comparison among the pseudo-bolometric light curves for the SNe II-P of our sample is shown in Fig. 3. The light curves appear to be heterogeneous in shape and luminosity at all epochs. In particular the exponential tails are powered by very different amounts of ^{56}Ni ($0.002 - 0.3$ $M_{\odot}$). It is remarkable that the low-luminosity SNe are fainter at all stages than all other SNe shown in Fig. 3.

Also the evolution of the expansion velocity, obtained measuring the blueshift of the minimum of the Sc II lines (see Fig. 3) shows a large spread at all epochs, ranging from 3300 km s^{-1} for SN 1992am [12] to about 1000 km s^{-1} for SN 1999br at ~100 days after explosion. A similar spread is present also in the evolution of the continuum temperature. This suggests, in accordance with [6], that plateau luminosity, Ni mass, continuum temperature, expansion velocity and explosion energy are correlated, from the high values of physical parameters of the luminous SNe 1992H and 1992am to the exceptionally small ones for the faint SNe (see discussion in Zampieri et al., these Proceedings).

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