Mem. S.A.It. Vol. 74, 934

Memorie della

An Intermediate Redshift Supernova Search at ESO: SN Rate first estimate*

Giuseppe Altavilla[1,2]

[1] INAF - Astronomical Observatory of Padova, Vicolo dell'Osservatorio 5, I-35122 Padova, Italy
[2] Department of Astronomy, University of Padova, Vicolo dell'Osservatorio 2, I-35122 Padova, Italy

Abstract. We present the preliminary results of our Supernova Search at intermediate redshift. We observed periodically several fields, surveying about two square degrees in each run at the MPG/ESO2.2 m, and the candidates were checked by spectroscopic observations at VLT. 21 Supernovae have been observed with $z \leq 0.6$, with a distribution peak at about $z \sim 0.2$. We found both Thermonuclear SNe (type Ia) and Core Collapse SNe (type II-Ib/c), almost in equal proportions (10 type II, 9 type Ia, 1 type IIn and 1 type Ic). Our preliminary estimate of the SN rate at redshift ~ 0.2 is: SNR(Ia)=$0.17^{+0.17}_{-0.15}$, SNR(CC)=$0.25^{+0.25}_{-0.22}$.

Key words. Supernovae: general

1. Introduction

The observation of Supernovae (SNe) may provide valuable information for studying the stellar evolution, the kinematics and enrichment of the interstellar matter. SNe can give useful hints in the study of pulsars, cosmic rays, neutrinos, gravitational waves, gamma-ray bursts. Also type Ia SNe are reliable cosmological distance indicator.
The supernova rate (SNR) is strongly linked to the star formation rate (SFR): because of the short lifetime of massive progenitors ($M > 8M_{\odot}$), Core Collapse SNe (CCSNe) are correlated with the instantaneous SFR while type Ia SNe, originating in evolved binary system, can give information about the long term star formation history. The SNR is also one of the key parameters in the theories of galactic chemical evolution. The local SNR for different SN classes and morphological galaxy types is reasonably well known (Cappellaro et al. 1999), but the SN frequency at higher redshift is still rather uncertain. Two pioneering works (Pain et al. 1996; Hardin et al. 2000), were based on three and four SNe respectively. In a more recent study Pain et al. (2002) have presented the results based on a sample of 38 type Ia SNe.

Here we present the preliminary results of our Supernova Search at intermediate red-

Send offprint requests to: Giuseppe Altavilla, altavilla@pd.astro.it
* Based on observations collected at the European Southern Observatory, Chile
Correspondence to: Vicolo dell'Osservatorio 5, I-35122 Padova, Italy

Table 1. SNe spectroscopically confirmed

SN	type	z	IAUC	SN	type	z	IAUC	SN	type	z	IAUC
1999ey	IIn	0.09	7310	2001be	Ia	0.24	7615	2001io	Ia	0.19	7780
1999gt	Ia	0.27	7346	2001ge	Ia	0.22	7762	2001ip	Ia	0.54	7780
1999gu	II	0.15	7346	2001gf	Ia	0.10	7762	2002cl	Ic	0.07	7885
2000fc	Ia	0.42	7537	2001gg	II	0.61	7762	2002cm	II	0.09	7885
2000fp	II	0.30	7549	2001gh	II	0.16	7762	2002cn	Ia	0.30	7885
2001bc	II	0.19	7615	2001gi	Ia	0.20	7762	2002co	II	0.32	7885
2001bd	II	0.10	7615	2001gj	II	0.27	7762	2002du	II	0.21	7929

Type	Ia	Ib/c–II
N.	9	12
z_{min}	0.10	0.07
z_{max}	0.54	0.61

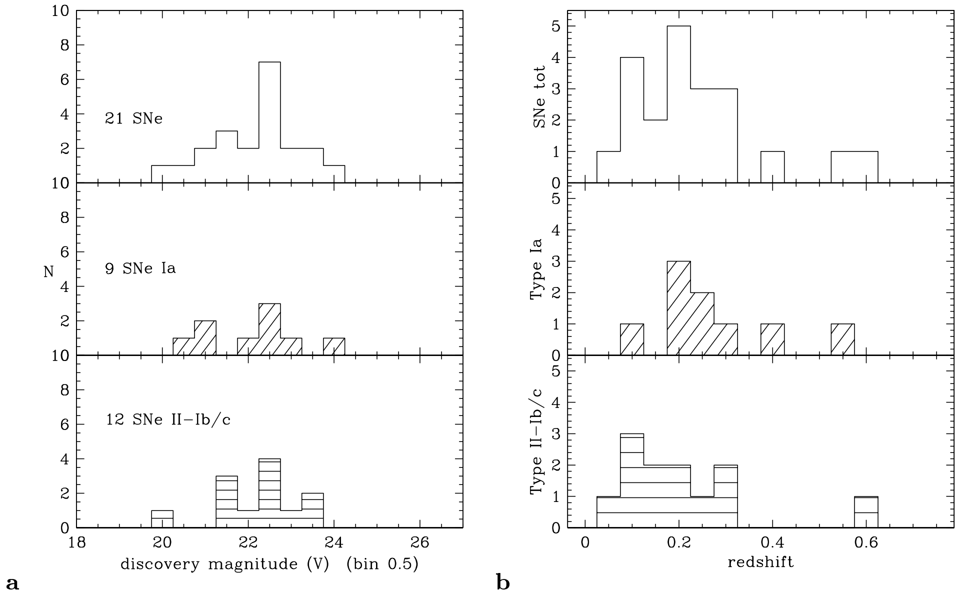

Fig. 1. (**a**) V magnitude distribution and (**b**) redshift distribution of the 21 SNe spectroscopically confirmed. Upper panels: type Ia SNe + CCSNe; middle panels: type Ia SNe; lower panels: CCSNe

shift ($z \sim 0.2$), aimed to determine the SNR of both CCSNe and type Ia SNe.

2. Observational data and preliminary results

The search was performed using the MPG/ESO 2.2 m telescope equipped with the Wide Field Imager. Because of the faint magnitudes of the candidates, the spectroscopic classification and follow–up was performed with ESO VLT + FORS1/2.

21 fields were surveyed for a total effective searched area of ~ 5.1 square degrees. Among the ~ 100 reliable candidates, we confirmed spectroscopically 21 supernovae

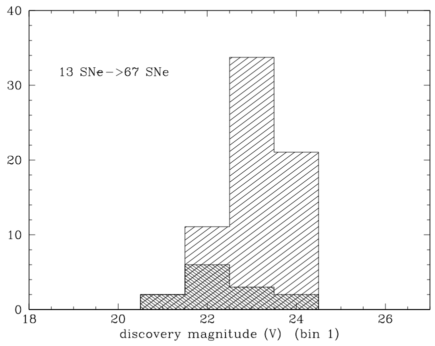

Fig. 2. Magnitude distribution of 13 SNe of the subsample of classified SNe (double shaded histogram) and magnitude distribution of all the candidates (single dashed histogram)

(9 type Ia, 10 type II, 1 type IIn and 1 type Ic), with redshift up to $z = 0.6$ (Table 1) and V magnitude at discovery ranging in the interval 20–24 (Fig.1a). We found CCSNe and type Ia SNe in almost equal proportion but, as expected, due to their brighter absolute magnitude, the latter ones are on average at higher redshift than the former ones (Fig.1b).
The observational strategy, the data reduction and storage are described in details in the contribution by M. Riello, in these proceedings.

2.1. SN rate

To estimate the SN rate in SNu ($1SNu = 1SN(100yr)^{-1}(10^{10}L_{B\odot})^{-1}$) we need to count the number of SNe exploded in the total "control time" of a distance limited volume of the Universe containing a known integrated luminosity $L_{B\odot}$. The control time of a single observation is the interval of time during which a SN at a given distance is brighter than the magnitude limit of the search. The magnitude limit depends on the seeing, on the transparency of the sky, even on the position in the frame and in general is different for each observation. On the other side the SN apparent magnitude depends on the distance, on the luminosity at maximum and the evolution for its particular SN type. First we considered type Ia SNe. To estimate the control time we calculated the expected SN light curves at different redshifts, taking into account K correction and time dilatation. In this preliminary analysis we considered a subsample of the search, including 13 SNe found from April 2001 to April 2002. Before this date we did not have VLT time available and spectroscopic confirmation was possible only for very few bright candidates. We divided the observed volume in redshift bins and computed the integrated galaxy luminosity in each bin after the counts of Lilly et al. (1991), Maddox et al. (1990), Metcalfe et al. (1995). We adopted $H_0 = 75kms^{-1}Mpc^{-1}$ and an Einstein-De Sitter cosmology.
A severe bias was introduced because only the brighter candidates could be observed due to limited observational time allocated for spectroscopy. After observation $\sim 70\%$ of the candidates turned out to be SNe, while the other $\sim 30\%$ turned out to be AGNs-QSOs with redshift in the range $0.3 < z < 2.3$. In order to take into account the bias in the magnitude of the spectroscopically confirmed candidates, we compared their magnitude distribution with that of all the candidates detected (Fig.2). The comparison of the two distributions gives us the correction factors to apply to the confirmed candidates counts. To compute the SNR we need to derive the redshift distribution of the SN candidates from the magnitude distribution. Actually, the magnitude distribution results from the spread in redshift and the phase of the candidates. If the epoch of explosions were known, it would be possible to derive the redshift from the observed apparent magnitude. Unfortunately the epochs are not known, so we derived several distributions assuming different phases. The SNR(Ia) was then computed as the average of the rates derived from the different redshift distributions. In this contribu-

Table 2. SNe Rate (SNu^{a})

redshift	Total # of SNe	Rate Ia	Ib	II	reference
< 0.01	137	$0.20^{+0.06}_{-0.06}$	$0.08^{+0.04}_{-0.04}$	$0.40^{+0.19}_{-0.19}$	Cappellaro et al. 1999
~ 0.10	4	$0.25^{+0.27}_{-0.16}$			Hardin et al. 2000
~ 0.20	5[b]	$0.20^{+0.20}_{-0.18}$		$0.27^{+0.28}_{-0.25}$	present work
~ 0.40	3	$0.46^{+0.51}_{-0.35}$			Pain et al. 1996
~ 0.55	38	$0.51^{+0.15\,c}_{-0.13}$			Pain et al. 2002

[a] scaling as $(H_0/75)^2$
[b] we considered 3 type Ia and 2 type II of our subsample (13 SNe) with redshift $0.15 < z < 0.25$
[c] model E (Einstein De Sitter Universe)

tion we restricted the computation to the range $0.15 < z < 0.25$, since for SNe at these distances the distribution corrections mentioned above are negligible ($< 5\%$). Considering the ratio between the number of type Ia SNe and the CCSNe and the ratio between the control time of the two classes, we can calculate the CCSNe rate SNR(CC) from the value obtained for the type Ia SNe. The derived rates agree within the errors, with the values found in literature (Cappellaro et al. 1999; Hardin et al. 2000; Pain et al. 1996, 2002) (Table 2.1). We find a ratio SNR(CC)/SNR(Ia)=1.35 somewhat smaller than the value derived for the local universe SNR(CC)/SNR(Ia)=2 (Cappellaro et al. 1999) but similar to the value SNR(CC)/SNR(Ia)=1.12 derived before the correction for internal absorption (Cappellaro et al. 1993).

3. Conclusion and future work

We presented the SN sample produced by our SN search and a first preliminary estimate of the SNR, for both type Ia and CCSNe. The work for the inclusion of the whole sample and a more accurate treatment of all selection effects is in progress.

Acknowledgements. This work has been financially supported by the Italian Ministry for University and Research through grant Cofin/2001.

References

Cappellaro, E., Evans, R., Turatto, M., 1999, A&A 351, 459
Cappellaro E. et al., 1993 A&A 268, 472
Pain R. et al., 1996, ApJ 473, 356
Hardin D. et al., 2000, A&A 362, 419
Pain R. et al., 2002, ApJ 577, 120
Lilly, S.J., Cowie, L.L., Gardner, J.P., 1991, ApJ 369, 79
Metcalfe N. et al., 1995, MNRAS 273, 257
Maddox S.J. et al., 1990, MNRAS 247, 1