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Classification of Supernovae and Their Rates

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Abstract. Classification of supernovae (SNe) includes different physical and phenomenological classes. Physically, there are two main classes of supernovae: SNe Ia representing the thermonuclear explosion of a white dwarf in a close binary system (CBs), and core-collapse SNe resulting in the gravitational collapse of massive stars. Stripped-envelope SNe Ib/c represent a particular class of core-collapse supernovae. They occur with stars stripped of their hydrogen/helium envelope in CBs and/or due to the strong stellar wind. We present the recently determined rates for different classes of SNe found in literature, and try to estimate the rates for stripped-envelope SNe, including hypernovae (SNe Id).

1 Classification of Supernovae

Classification of supernovae (SNe) includes different physical and phenomenological classes. Physically, there are two main classes of supernovae: SNe Ia representing the thermonuclear explosion of a white dwarf in a close binary system (CBs), and core-collapse SNe resulting in the gravitational collapse of massive stars. Stripped-envelope SNe Ib/c represent a particular class of core-collapse supernovae. They occur with stars stripped of their hydrogen/helium envelope in CBs and/or due to the strong stellar wind.

Historically, classification of supernovae (SNe) began by recognizing SNe I, with no hydrogen lines, and SNe II which do show hydrogen in their spectra (see Figure 1). SNe II make a quite heterogeneous class and can be further classified as SNe II-L whose light curves linearly decrease after maximum, and SNe II-P with a plateau on the light curves, due to the recombination of H. Newer classes are IIb with low H and IIn showing narrow emission lines and are probably interacting with dense circumstellar medium (CSM). There are also peculiar SN II like the well known SN 1987A.

A rather homogeneous class SN I was shown later to consist of two spectroscopically and photometrically distinct subclasses: Ia which were only located in ellipticals, and Ib found in HII regions and spiral arms, which strongly suggested that their progenitors were massive young stars with their H envelopes stripped. The third subclass, SNe Ic, discovered later, show no helium lines either, and thus corresponds to the massive stars stripped of their H and He envelopes. Recently there were three supernovae with very broad lines discovered:

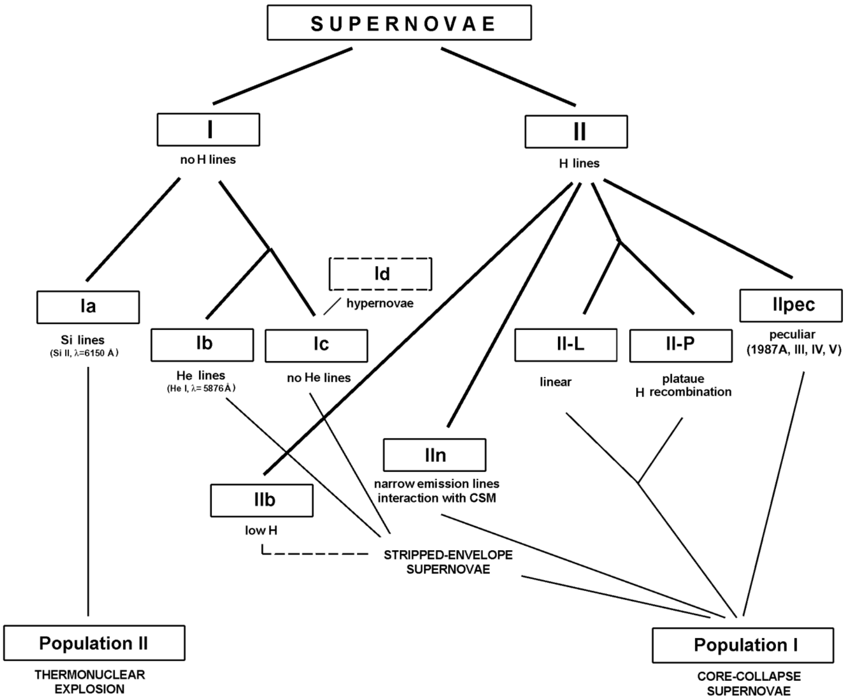

Figure 1. Classification of supernovae.

SN 1997ef, 1998bw, 2002ap. These high expansion velocity *i.e.* high energy SNe might form a new subclass Id corresponding to the hypernovae (possibly connected to the gamma-ray bursts). For more details, on core-collapse SNe particularly, see *e.g.* [1].

2 Supernova Rates

An important information about supernovae is their rate. Supernova rate (SNR) for a given SN and galaxy type is defined as:

$$\nu = \frac{N}{T} \ \text{[SNu]}, \tag{1}$$

where N is the number of SNe discovered in a given sample of galaxies during the total control time T, and supernova unit is 1 SNu = SNe per 10^{10} luminosity of Sun per century. Total control time incorporates galaxy luminosity as a normalization factor, since it has been shown that it correlates with the SNR, and the probability of SN detection depending on the photometric properties of SN type in question [2,3]. The recently determined supernova rates [3] are given in the Table 1. The rates scale with h^2 where h is the Hubble constant in units 75 km/s Mpc^{-1}. In the last two columns we have tried to estimate the rates for stripped-envelope SNe, which were lumped together as type Ib/c in previous studies. In the last row we included SNe Id.

Table 1. Supernova rates in SNu for different galaxy and SN types [3]. The last and last but one column shows the SN Ib to Ic, and the SN Id to Ic ratios found in this study.

Galaxy type	ν [SNu] Ia	Ib/c	II	$N_{\rm Ib}/N_{\rm Ic}$	$N_{\rm Id}/N_{\rm Ic}$
E–S0	$0.18 \pm 0.06\ h^2$	$< 0.01h^2$	$< 0.02h^2$	–	–
S0a–Sb	$0.18 \pm 0.07\ h^2$	$0.11 \pm 0.06\ h^2$	$0.42 \pm 0.19\ h^2$	0.92	–
Sbc–Sd	$0.21 \pm 0.08\ h^2$	$0.14 \pm 0.07\ h^2$	$0.86 \pm 0.35\ h^2$	0.45	–
Others*	$0.40 \pm 0.16\ h^2$	$0.22 \pm 0.16\ h^2$	$0.65 \pm 0.39\ h^2$	0.42	–
All	$0.20 \pm 0.06\ h^2$	$0.08 \pm 0.04\ h^2$	$0.40 \pm 0.19\ h^2$	0.55	0.04

*Others include types Sm, Irregulars and Peculiars.

The main assumption in our analysis is that SN Ib/c/d relevant observational properties (above all average absolute magnitude) are similar, so that for this initial study we can take the number of recorded SNe N as an indicator of SNR. This is of course unjustified preassumption for all SN types, since *e.g.* luminous SN Ia would be favored and faint SNe II would be missing from some randomly chosen sample, but it may be to a certain extent valid for the stripped-envelopes. As a database we used the October 2004 version of the Asiago Supernova Catalogue [4]. A cutoff at redshift $z = 0.03$ has been induced to make the results consistent with the rates in the local universe.

The final results are shown in the form of histogram in Figure 2. As it is already well known, the majority of supernovae are the core-collapse SNe, while SN Ia

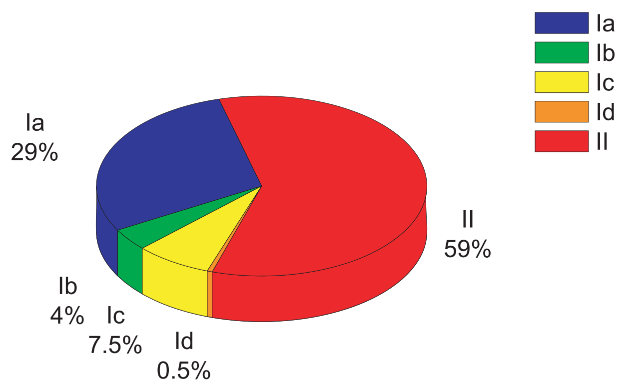

Figure 2. Overall relative rate estimates for different types of supernovae.

make about 30 per cent. Our main emphasis is on stripped-envelope SNe. It can be noticed that there is a dominance of SNe Ic among the stripped-envelopes. The reason may be physical, but this may also be a selection effect if SNe Ic prove to be intrinsically brighter. Under previous assumptions, based on three hypernova candidates, the SN Id make at most 5 per mill of all SNe.

Acknowledgments

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