Searching for supernovae

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1. Introduction

Supernovae (SN) are extremely violent explosions marking the end, sometimes a new beginning, of a star or star system. For a few weeks, a supernova might outshine its home galaxy.

They are rare events compared to human life spans, but quite numerous on a cosmic time-scale. The last recorded supernova in our Milky Way was the SN of 1604, discovered by Kepler. Since a galaxy, like the Milky Way, is expected to produce about one SN per century, we are due for a few....

To find a SN now, it is better to look beyond our Milky Way. A well-planned search program is of utmost importance to achieve success.

2. Types of supernovae

There are two main types of supernovae :

2.1. SNe of type II: the ultimate implosion of heavy stars

This happens to a heavy star when the fusion process is halted because the core has run out of fuel. The collapse follows since no internal pressure is produced in the core to counter the gravitational forces of the immense layers around it. This is a very energetic event with most of the energy dissipated via neutrinos.

The fate of the core is to become a neutron star or black hole. The outcome is dictated by the initial mass of the star.

2.2. SNe of type Ia: an overweight white dwarf in a binary system

This happens when an accreting white dwarf (WD) reaches a critical mass (Chandrasekhar limit) and its internal structure is no longer able to hold up the gravitational pressure.

Although other scenarios are possible (like the merging of two WDs), the more-or-less identical starting parameters cause the majority of type Ia SNe to reach the same peak brightness and to produce similar light curves.

Despite the lower energy release of this type of SN, the optical brightening exceeds that of type II SNe by a factor of five, about two full magnitudes. This will allow us to see them further away.

For both those reasons SNe Type Ia are ideally suited as standard candles for measuring vast distances in the Universe via optical means. Other types of SN mainly include the types Ib and Ic, which are thought to be versions of type II. How often and where these different types occur depends on the home galaxy.

3. Host galaxy parameters

In addition to the galaxy's visual (*V*) or blue band (*B*) brightness, the following are important parameters for selecting galaxies to monitor for SN events:

Co-ordinates

Without accurate knowledge of the equatorial co-ordinates (RA and Dec) it is not possible to find the galaxy or to position it on the CCD image.

Co-ordinates are also used to eliminate from the program those galaxies that are too far North or to allow for a lower or higher weight for selection for certain seasons (eg open skies during the winter on the high-veld).

Distance

Sometimes given in Mpc (1 megaparsec = 3.26 million light years) but most often as the measured recession speed (km s^{-1}), the distance gives an indication of the peak brightness that SNe will reach.

The following equation will give a good measure of the expected visual magnitude:

$$m_v \text{ (type II)} = 13.3 + 2.5 \log (d/10)^2$$

with d the distance in Mpc, and

$$m_v \text{ (type Ia)} = m_v \text{ (type II)} - 1.9$$

Unfortunately, accurate distances to galaxies are only known for a few nearby ones, including those of the Virgo cluster.

It is however possible, after years of studying galaxy images, to acquire a feel for distances, based on the texture of mainly the spiral arms. Such derived distances will only be approximate.

Galaxy size

This parameter can refer to the dimensions in arcmin that the galaxy is seen from here, but when expressed as an absolute luminosity, it refers to the active star mass in the galaxy.

The latter is given in units of 10^{10} solar luminosities for some nearby galaxies in the Nearby Galaxies Catalogue, but those values are inaccurate to various degrees.

An approximate value can be derived from the distance and the total galaxy magnitude.

Morphology

Certain types of galaxies tend to produce more SNe than others.

Galaxies with ongoing star formation (bright spiral arms) will produce fair amounts of type II SNe.

The Hubble 'tuning fork' diagram shows different lines for spiral galaxies with and without a bar. As far as statistics on SN production rates are concerned, there is no particular difference between them.

Elliptical and lenticular galaxies, where star formation is thought to have stopped, are not likely to produce SNe of type II and related types.

Typical SN rates (an average derived from several recent publications) are given in the table below, where $L_\odot$ refers to the total luminosity of the galaxy, expressed in solar luminosities:

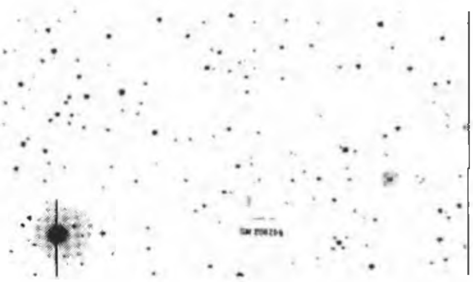
Galaxy type	**Type Ia [a]**	**Type II [a]**
E	0.15	-
L / S0	0.2	-
Sa	0.2	0.3
Sb	0.22	0.7
Sc	0.22	1.1
Sd	0.22	0.9
Sm	0.22	0.8
Irr	0.4	0.9

[a] per 10^{10} $L_\odot$ per 100yr

Inclination

Galaxies lying face-on to us show more detail and SN light will be less attenuated. Side-on galaxies might be more appealing on photographs but often hide SNe. This also applies to our own Milky Way, which looks like a very nearby side-on galaxy.

SN 2002cr in NGC 5468.



SN 2002bq in ESO 373-G005.

Target programs

In order to maximize the chances for detecting SNe, it is necessary to consult diverse catalogues and select target galaxies on the basis of good properties for SN production. The observing site and equipment determine the limiting magnitude and hence the maximum distance from which SNe can be seen.

The ideal galaxy for a search would be a large, nearby, face-on galaxy of type Sc. M83 (NGC 5236) is a perfect example of this. Although some more remote (CCD program) galaxies are probably larger still, it is difficult to accurately quantify them.

The present approach at the Bronberg Observatory is to select galaxies within 10 Mpc for the visual program only, and those beyond 20 Mpc for the CCD programs. Galaxies in-between those distance limits might appear in both programs.

By considering all the relevant parameters, it is possible to compose a table of all candidate galaxies and to derive the number of expected SNe of both types (Ia and II) and the expected maximum brightness at which they will occur.

For the visual program a point system was devised in order to list those galaxies from best to worst, with the distance as an important factor. A program is then composed by selecting the best 250 or so. A point system was not applied for the CCD program.

Information on galaxies and SNe

Galaxy catalogues

Nearby Galaxies Catalogue (NBG) (1988) R. B. Tully. Cambridge University Press.

Third Reference Catalogue of Bright Galaxies (RC3) (1991) G. de Vaucouleurs, A. de Vaucouleurs, H. G. Corwin, Jr., R. J. Buta, G. Paturel, P. Fouque.

The following parameters are given in these catalogues: co-ordinates, *B* brightness of galaxy, apparent size (arcmin), inclination and recession speed (actual Mpc distance in Tully). The catalogues can be searched via the Vizier site at [http://adc.gsfc.nasa.gov/viz-bin/VizieR].

SN websites and links

[http://www.rochesterastronomy.org/snimages/]
[http://cfa-www.harvard.edu/cfa/ps/lists/RecentSupernovae.html]
[http://www.supernovae.net/isn.htm]