RECENT STUDIES IN SUPERNOVA RATES

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Abstract

A summary is presented of the present state of estimating supernova frequencies, drawn from the 1991 review paper by van den Bergh and Tammann.

1. Introduction

Knowledge about the rates at which supernovae appear in different types of galaxies is important for a number of reasons in astrophysics and cosmology.

The supernovae (SN) rate largely determines the structure, kinematics, and composition of the interstellar medium. The evolution of elliptical galaxies may also depend on the SN rate in these objects. The SN rates affect our estimates of the cosmic-ray flux, the birth rates of pulsars, runaway stars, X-ray binaries, neutron stars, and possibly black holes. And the detection of gravitational waves will depend upon the frequency of core-collapse supernovae in the nearby universe.

2. Brief History of SN Rates

Perhaps the earliest determination of SN rates was Zwicky's 1938 estimate of one SN every 460 years per galaxy. By 1969, the rate was estimated to be one every 300 years.

Then it was noticed that rates in different types of galaxies were not the same, and that the SN rate depended on the luminosity of the galaxy. So, an "average galaxy" luminosity value had to be defined. This value is now considered to be 10 billion (10^{10}) suns in blue light.

The estimated frequency rose to about one supernova every twenty years in a galaxy like our own.

Also, it was thought that type 1 supernovae were much more common than type 2. We now know, however, that the opposite is the case. Not only are supernovae of type 1 less frequent, but this class is now subdivided into type 1a, type 1b, and possibly type 1c. Types 1b and 1c together are about as frequent as type 1a overall.

In the 1970's and even into the early 1980's, estimates of the SN rate were made using samples of galaxies in which it was simply assumed that all supernovae had been found. But the galaxies under review did not comprise a distance-limited sample. Also, continuous surveillance of many of these galaxies was lacking. As a result, there was no evidence to support the belief that all supernovae had in fact been seen in these galaxies.

In recent years the number of supernovae being found and analyzed is increasing dramatically, and will soon reach a total of 1000 discoveries. But this increase has not helped our understanding of SN rates as much as one might think because most of these discoveries have been made by accident, or in situations where the galaxies being searched do not belong to a well-defined and well-chosen sample.

So, in fact, only about 100 nearby supernovae, which have been found as a result of systematic searches of well-defined samples of galaxies, are useful for determining proper SN rates.

3. Requirements for a Statistical Study

There are certain requirements for a statistical study of galaxy observations in order to arrive at a useful estimation of supernova frequencies.

1. The total number of supernovae that have occurred in the galaxies in question during the period must be known. If not, then the resulting supernova rates will be a lower limit only.
2. The galaxies which will be included in the statistical analysis must be chosen before any supernova information is examined. In a photographic survey, for example, it can be very hard to tell which galaxies appearing on the photo are actually contributing to the statistics, unless the galaxies have already been chosen. Useful galaxy samples will always represent a compromise between small distance (to maximize completeness of supernovae discoveries) and sample size.
3. The control times will determine the distances of galaxies chosen. A supernova will be visible in a galaxy only for a certain period of time, depending upon its distance. Each observation of each galaxy represents a certain surveillance time, which will vary according to which type of supernova is being considered. This raises a number of issues that will not be discussed here.

Three sets of galaxy samples have been used most recently. These are:

1. all galaxies within a radius which includes the Virgo cluster. Even at this distance, and certainly beyond it, loss of type 2 supernovae could be sufficient to affect the statistics.
2. the galaxies covered photographically at Asiago Observatory since 1959. This search has produced 51 supernovae, but the sample does not include any known examples of type 1b. Photographic searches have their own peculiar difficulties.
3. the Shapley-Ames galaxies covered visually by Evans between November 1980 and October 1988. This search produced 24 supernovae, but the limiting magnitude of the search was a rough average estimate, and is not known precisely.

Resulting supernova frequencies per hundred years for different types of galaxies which have luminosities of 10 billion suns in blue light are given in Table 1 (van den Bergh and Tammann 1991).

Table 1. Supernova frequencies per hundred years for galaxies having luminosities of 10 billion suns in blue light.

Galaxy Type	*1a*	*1b*	*2*	*Total*
E - SO$^+$	0.98	-	-	0.98
SO/a, Sa	0.49	0.04	0.17	0.70
Sab, Sb	0.49	0.27	1.35	2.11
Sbc, Sd	0.49	0.77	3.93	5.19
Sdm, Im	0.49	0.91	4.21	5.61
Am	-	-	-	6.3*

* not corrected for internal absorption
$^+$ Large errors apply to the E - SO estimates.

Reference

van den Bergh, S., and Tammann, G. 1991, *Annual Review of Astronomy and Astrophysics,* **29**, 363.