Proceedings of the Indiana Academy of Science
(1987) Volume 97 p. 435-440.

Historical Supernovae

Theresa A. Nagy
Department of Physics
Indiana State University
Terre Haute, Indiana 47809

Abstract

Throughout recorded history, records of unusual and interesting astronomical events have been made with varying degrees of reliability. The earliest observations of comets date back to the 23rd century B.C., but with doubtful authenticity. The first reliable record of a comet was in the year 1095 B.C. The class of objects known as supernovae, visible to the naked eye, have only eight reliable recorded events. The last event took place on February 23, 1987. The other seven verified supernovae occurred in the years AD 185, 393, 1006, 1054, 1181, 1572 and 1604. An historical/scientific discussion of these eight super-explosions will be presented which will identify the characteristics of this exclusive category of astronomical objects.

Introduction

Early views of the universe were typically centered on the belief that the sea of visible stars was constant and unchanging—the Aristotelian view of celestial perfection. The human eye as a sensor can detect less than 10,000 of the millions of known stars in our universe. Optical aids were not available until the early 1600s and thus the view of the universe was very limited—with few exceptions. These exceptions were "new" stars originally dubbed *nova*. This paper deals with the correlation of historical records with actual data from the remnant of a given explosion.

In 1885 a new star was discovered near the center of the Andromeda galaxy (M31) by Ernst Hartwig at the Dorpat Observatory in Russia. Heber D. Curtis recognized the importance of this new star which was brighter than all other known novae. This discovery started the search for other, very bright novae. In 1934, Walter Baade and Fritz Zwicky presented a classic paper in which a new term was introduced into the field of astronomy—*supernova*. (The 1885 event in the Andromeda galaxy was the first supernova detected outside the Milky Way galaxy and now about a dozen are seen (*not* naked eye) each year in other galaxies.) They plotted the number of novae occurring in nearby galaxies within the past hundred years versus their absolute magnitudes. The resultant histogram showed a distinct bimodal grouping—the more numerous fainter group (absolute magnitudes $+13$ to $+16$) and a brighter group (absolute magnitudes $+7$ to $+10$). The histogram showed us events in the absolute magnitude range $+10$ to $+13$. Those in the brighter group were dubbed the "supernovae" to distinguish them from those in the fainter "novae" group.

Supernovae Types

Novae and supernovae are two types of objects listed in the General Catalogue of Variable Stars as eruptive stars. While the eruptive event is taking place, a history of the variation in the amount of light versus time can be made. This light signature is known as a *light curve*. The two most common types of supernovae light curves are known as Types I and II, as shown (1) in Figures 1 and 2. Type I supernovae are characterized by one major outburst of light followed by a gradual exponential decay (typically lasting up to 300 days from the time of the initial outburst). These

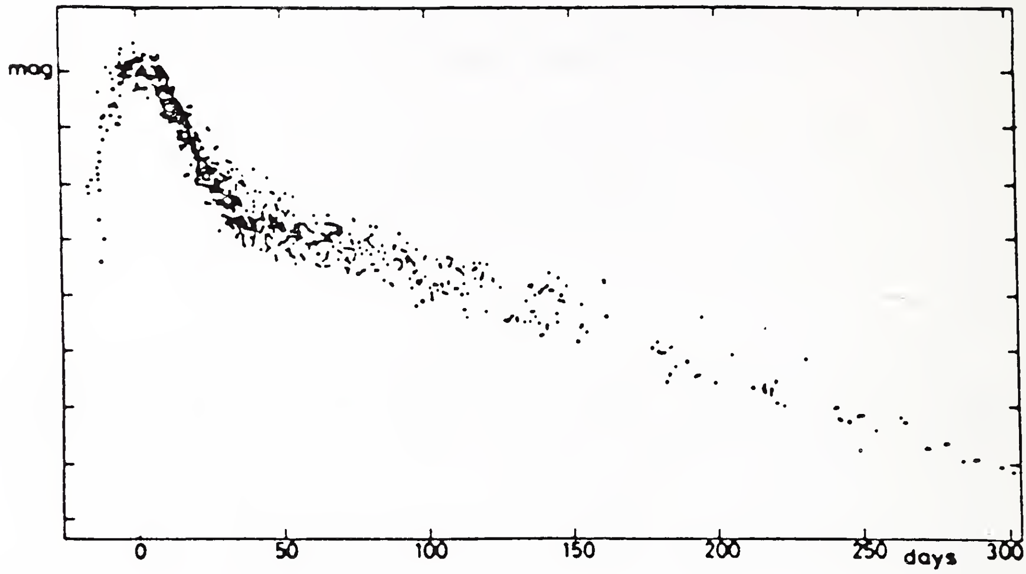

FIGURE 1. Composite light curve from 38 Type I supernovae.

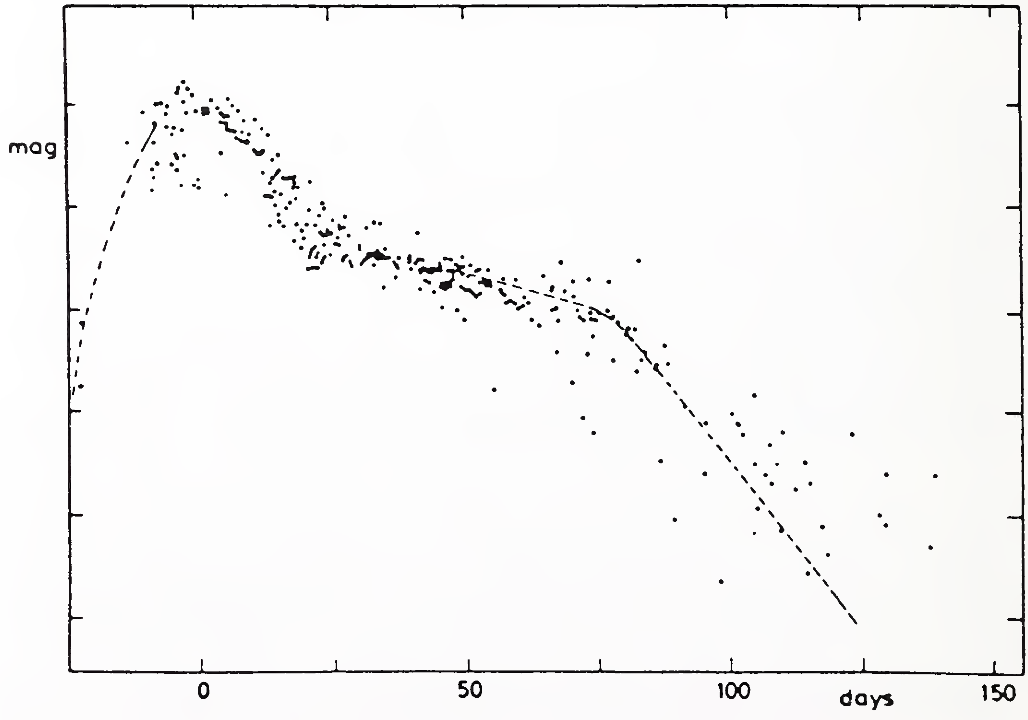

FIGURE 2. Composite light curve from 13 Type II supernovae.

events are thought to arise in double star systems where one component pulls material from the other, thus making it unstable. Type II supernovae are characterized by an initial outburst of light which is not as violent but with several secondary outbursts for the first 75 days followed by a very rapid decrease in the light output. The vertical axes of both figures are in magnitudes, in which the scale varies from brightest (top) to faintest (bottom). In addition to their light variation signatures, the two types of supernovae vary in another important aspect. The spectra of these events show that the Type II supernovae have strong emission lines of hydrogen (Balmer lines) and strong absorption lines of ionized calcium. The Type I supernovae do not have emission lines of hydrogen but do show strong absorption lines of ionized silicon and iron. Type I supernovae occur in all galaxy types whereas Type II supernovae are confined to galaxies that show strong evidence for ongoing star formation (e.g., the arms of spiral galaxies).

Supernovae Remnants (SNRs)

The four principal observable remnants of a supernova are (1) a pulsar, (2) an expanding optical nebulosity, (3) a region of radio emission and (4) an extended X-ray source. Very few SNRs exhibit all four remnant types but the region of radio emission appears to be common to all events. The intensity of the radio emission increases with increasing wavelength—non-thermal radiation caused by the synchrotron mechanism. In a synchroton, electrons are accelerated to very high speeds in a magnetic field. In a supernova, the electrons of low energy emit radiation at radio wavelengths and exhibit a high degree of polarization, a property verified in data from SNRs.

Source of Historical Records and Candidates

Historical records of astronomical events with enough information to reconstruct and locate the events are mainly from three countries in the far east—China, Japan and Korea. The main source of data is from the Chinese and is limited to the year 213 BC and later, for it was in that year that the "burning of the books" took place by direction of the emperor Ch'in Shih-huang. The Han dynasty (202 BC - AD 220) established an astronomical office as part of a special subdepartment within the Ministry of State Sacrifices. This Astronomical Bureau had two major functions: (1) to maintain an accurate calendar and (2) to observe and interpret celestial portents. The official establishment of the Astronomical Bureau marked the beginning of organized acquisition of astronomical data that has survived.

The term K'o-shing was used to describe "guest stars" or "visiting stars". This term appears to be synonymous with novae and supernovae, but the term sometimes is associated with motion and thus occasionally used to describe a comet. The two thousand years of written records describing bright "guest stars" contain approximately 75 objects. However, if the restraint that only the ones visible for at least five months (thus eliminating comets) is imposed, the list is reduced to only 20 objects. These 20 then represent the historical records of the novae that were bright enough to be seen as naked-eye objects. Distribution studies of supernovae in other galaxies shows that they tend to be constrained to the galactic plane. Thus, if the further restriction of limiting the list of candidates to only those objects which lie close to the galactic plane (galactic latitude (b) less than 25 degrees) then the list is reduced to the seven events given below. the apparent magnitude (m) at maximum light and the distance to the remnant (d) in light years.

TABLE 1. Historical Supernovae Candidates.

Year	*Duration*	*b*	*m*	*d*
AD 185	20 months	15°	−4	6500
AD 393	8 months	0°	−1	—
AD 1006	several years	+15°	−10	4200
AD 1054	22 months	−5°	−5	6500
AD 1181	185 days	0°	0	28000
AD 1572	16 months	0°	−4	10000
AD 1604	12 months	+5°	−3	26000

Around AD 275 the Astronomer Royal of China estimated from early star maps that there were 283 star groups (asterisms) of 1464 stars. Later figures vary but these figures are fairly representative. The Chinese historical records relate the event with respect to the recognized asterisms. By comparison, there are today 88 recognized constellations whose boundaries are set by the International Astronomical Union.

AD 185

The event of AD 185 was reported to be "within" the asterism Nan-men, the two bright stars Alpha and Beta Centauri. A survey of this region yields four candidate (2) supernova remnants. To have a SNR correlated with the reported event, the radio, X-ray and optical evidence must yield a SNR within 5000 light years and less than 2000 years old. The SNR that lies directly on a line between Alpha and Beta Cen is *not* that SNR, but the one that lies about two degrees south of the line fulfills both criteria (and is the only one of the four candidates to do so). Thus, the remnant associated with the SN of AD 185 is RCW 86 (G315.4-2.3).

AD 393

The event of AD 393 meets all of the criteria with respect to visibility and galactic position; however, the historical records place the event in the asterism *Wei* (a portion of the constellation Scorpius) and covers an area greater than 40 square degrees. This area has been surveyed a number of times and there are seven known (3) remnants "within" this asterism. Unfortunately, because the asterism covers so large an area, any unambiguous SNR identification is not possible. Since it was observed for such a long period (eight months), it was almost certainly a supernova, but the other half of the puzzle cannot be completed with any certitude. Thus, this event will have to be dropped from the final list of historical supernovae.

AD 1006

The event of AD 1006 occurred in a fairly populated portion of the sky, but it also represents the brightest of the events in the historical records. This brightness was fortunate in that it provided important limits on the search area for its remnant. A record has survived from a Benedictine monastary at St. Gallen in the Alpstein mountains in Switzerland. The importance of this sighting is that it sets a southern declination limit on an otherwise fairly large search area. The southern limit is defined by the limited visibility of the monks from St. Gallen because of the restricted southern view (2). This southern limit defines the preferred search area and yields only one eligible candidate (2) — PKS 1459-41. Because candidate meets all other criteria, another case can be closed with considerable confidence.

AD 1054

One of the most famous objects in the sky is the Crab Nebula (M1). The new star in AD 1054 occurred in a very uncluttered portion of the sky near the star Zeta Taurus. The only SNR in the vicinity is the Crab Nebula (2). This is a very easy identification match and is unambiguous.

AD 1181

The event of AD 1181 represents the third supernova recorded by the Sung dynasty astronomers (AD 1006, AD 1054 and AD 1181). This event also marks the transition event—by the time of the next visible supernova in 1572, European astronomy well surpassed that of the Far East. The AD 1181 event occurred in a very cluttered region in the vicinity of the constellation Cassiopeia. Convincing evidence exists for

3C 58 being the SNR and there is no other remnant in the vicinity that could correspond. There is a great deal of confusion in the correlation of the historical records with a known SNR. The confusion results from the critical interpretation of a single word in the historical records. Thus, the correlation is listed as probable.

AD 1572

The event of AD 1572 appeared shortly after the publication of Copernicus' *De Revolutionibus Orbium Coelestium* (AD 1543). The Renaissance was well under way in Europe and scientific progress was rapid, whereas the Chinese and Korean scientific expertise was relatively unchanged over the centuries. The light from the supernova arrived at Earth during the time of the Danish astronomer Tycho Brahe (AD 1546-1601). Brahe was an extremely careful observer who recorded the position of the supernova with respect to nine reference stars in Cassiopeia and with respect to Polaris. The positional measurements of Brahe were accurate to within about one arc minute. (By comparison, many of his contemporaries recorded measurements that are accurate to only about half a degree.) Brahe's records also yield an unambiguous Type I supernova event. The SNR 3C 10 has been positively identified at optical, radio and X-ray wavelengths. The correlation of the supernova to the SNR was a much easier task with the precise positional information provided by Brahe.

AD 1604

Just 32 years after the supernova of 1572, the last pre-telescopic (astrononical use of the telescope dates from around 1609) supernova was discovered. Brahe died in AD 1601 (just three years prior to the event) but his student and successor, Johannes Kepler (Ad 1571-1630), made detailed observations of the supernova of 1604. As with SN 1572, the supernova of 1604 was a Type I event. Apparently the new star was detected almost simultaneously by astronomers in Europe and the Far East. Kepler was not the first one to detect the supernova but was the one who made precise measurements both of its position (error of less than one arc minute) and its brightness. Japanese historical records fail to include either this supernova or the one of AD 1572.

SN 1987A

On February 23, 1987 the light from a supernova that erupted 160,000 years ago reached Earth. This is the first naked-eye supernova since the event in AD 1604 and the first since the advent of telescopes. Unlike the six historical supernovae described above, this supernova occurred not in our Galaxy but in one of our neighboring galaxies—the Large Magellanic Cloud (LMC), 160,000 light years from Earth.

This event has caused supernova researchers to rethink some basic theoretical assumptions. Prior to this event the progenitor star was always thought to be a red supergiant. Identification of the progenitor star is difficult in the very cluttered region of the LMC, but it is thought that it was a blue supergiant (which is smaller than a red supergiant). This could explain why the event was not as bright as expected. The spectra distinctly show, lines of hydrogen. Thus the event is a Type II. However, the light curve in the first 20-30 days does not match other Type II light curves (mainly because it did not become as bright as expected).

Thus far, the event 1987A has produced energy at optical, ultraviolet and X-ray wavelengths. Gamma rays are expected to reach Earth in a few months. The event also led to the birth of neutrino astronomy with the recording of a neutrino burst at Earth (eight bursts were recorded in the United States and eleven in Japan). It is too soon for a SNR—but soon, another SNR will be correlated with this naked-eye supernova.

Summary

Only six events survive the rigid constraints as outlined, yielding a very probable or a certain link between the historical records and a known supernova remnant. The radio remnants correlated with these six survivors are given in Table 2. The historical records provide important data, for they place a limit on the age of the remnant and aid in identifying the correct candidate among multiple candidates in a cluttered field. A supernova is the result of an explosion of a certain type of star. The amount of energy released is typically 10^{51} SI units (equivalent to about 10^{28} one-megaton hydrogen bomb explosions). It is a fairly rare event and apparently only seven have been naked-eye objects as viewed from planet Earth.

TABLE 2. Historical SN-SNR Correlations.

SN	*Radio Remnant Identifications*
AD 185	G315.4-2.3 (RCW 86)
AD 1006	G327.6+14.5 (PKS 1459-41)
AD 1054	G184.6-5.8 (Ml)
AD 1181	G130.7+3.1 (3C 58)
AD 1572	G120.1+1.4 (3C 10)
AD 1604	G4.5+6.8 (3C 358)

Literature Cited

1. Barbon, R., Ciatti; F. and Rosino, L. 1974. In Supernova and Supernova Remnants. Reidel, Holland.
2. Clark, D.H. and Stephenson, F.R. 1977. The Historical Supernovae. Pergamon Press, Oxford, 233 p.
3. Clark, D.H. 1984. Superstars. McGraw-Hill, New York, 216 p.