ASTRONOMY

Exploding Stars

Once in Five or Six Centuries a Star Will Explode Releasing Energy 100,000,000 Times That of Sun

ONCE in every five or six centuries one of the billions of stars in the Milky Way explodes with an output of energy approximately 100,000,000 times that of the sun.

These explosions represent the most titanic sudden releases of energy that have been observed in the universe. The last to be observed in this star system occurred 369 years ago, and another 200 years may pass before man will see again with the naked eye a bright star shining at noon day.

But the Milky Way is only one among thousands of systems each having billions of stars. In each one of these systems there is such a star explosion about once in every 500 years. Observations of these during the past five years have enabled astronomers of the Mount Wilson Observatory of the Carnegie Institution of Washington and the California Institute of Technology to open up a new chapter in observational astronomy—the astronomy of the most spectacular phenomena in the universe.

More Frequent Type

There is another type of star explosion fairly frequent and well-known, the normal nova, or new star. The stars are normally extremely stable balls of glowing gas. But each year one star in a few thousand million suddenly becomes unstable, swells up and blows off its cover, and then subsides into a state of partial collapse. Within our own galactic system of several thousand million stars, ten or twenty flare up each year to maximum luminosities of about 100,000 times that of the sun and then slowly fade until, years later, they approximate their original brightness. Only a few of these are actually noticed and still fewer are near enough to be conspicuous. Occasionally, when this happens to one of the nearer stars and the outburst is especially bright, the event may be described as spectacular. Five times during the twentieth century we have seen bright, naked-eye novae. They appeared in 1901, 1918, 1920, 1925, and 1934.

But these normal novae explosions, after all, are as fire crackers to big guns when they are compared with the thousand fold greater phenomena of the supernovae which the Mount Wilson astronomers are now studying.

Supernovae outbursts presumably occur in our own star system once in every four or five centuries. It is reasonably certain that none has taken place during the three centuries since telescopes have become available. However, there are at least two earlier records of outbursts which were almost certainly supernovae —in the years A.D. 1572 and 1054.

The supernova of 1572 flared up in the constellation of Cassiopeia to rival the planet Venus in brightness. It was visible in full daylight. The position of the strange object was measured with unusual precision by Tycho Brahe, the Danish astronomer, who startled the world by proving that the new star lay above the moon in the supposedly changeless regions of the heavens. It faded and was lost from sight about eighteen months after its first appearance. Since telescopes were then unknown its subsequent history remains a mystery. The region has been examined carefully with the great telescopes available today. There are many faint stars within the area. Any one of them might represent the final stage of the supernova. It seems likely that, if any remnant of the outburst still survives, it is more than 100,000,000 times fainter than the maximum luminosity during its explosion.

Visible for Months

The only other record is from China. In A.D. 1054, Chinese astronomers observed a new star which remained visible for several months near the star Zeta Tauri. In this general region of the sky is an object known as Messier 1, a mass of gas about one-sixth the apparent diameter of the moon, known as the Crab Nebula. This object is expanding. If the present rate has remained constant the expansion must have started eight or nine centuries ago. The expanding cloud may be the remnant of the ancient supernova. A few years ago a reference to this star was found in an old Japanese chronicle, where it was compared with the planet Jupiter. A few months ago two Dutch Oriental students discovered other records, including a rather detailed account of the outburst in a Chinese history of the Sung dynasty. The position was described in considerable detail and agrees quite well with that of the Crab Nebula.

The spectrum of the gas cloud indicates that the rate of expansion is about 800 miles per second. Its distance is about 5,000 light years. Thus it can be calculated that its maximum luminosity must have been of the general order of that of 300,000,000 suns, very definitely in the class of supernovae.

At the center of the Crab Nebula are two faint stars. One is a yellow star which, because of its proper motion, evidently is not associated with the gas clouds but merely happens to be in the line of sight. The other is so abnormal that it is believed to be what is left of the supernova itself after nine centuries. It is a blue star about 400,000,000 times fainter than at its maximum brightness in 1054. Its present luminosity is just about that of the sun. Its spectrum, somewhat difficult to observe against the bright background of the cloud, appears to be that of a very hot, highly collapsed star, an extreme case of the so-called "white dwarfs."

One in Andromeda

In 1885 a star appeared near the nucleus of the great spiral star system in the constellation of Andromeda which was approximately one-tenth as bright as the system itself. This system undoubtedly contains several billions of stars. It is of the same order of magnitude as the great Milky Way system itself. Calculations by Mount Wilson astronomers now show that this outburst must have reached a maximum brightness approximately 100,000,000 times that of the sun.

This conclusion was reached about 1924. During the next twelve years the probable significance of bright novae was generally recognized but little progress was made in their investigation. The difficulty lay in the extreme rarity of the outbursts and the chance nature of the discoveries. During all this period only one outburst actually was observed in a distant nebula.

A systematic search on a modest scale was started at Mount Wilson in 1929. A watch was begun of the Virgo cluster, a compact group of a few hundred nebu-

lae most of which could be recorded on a single plate. It was seven years before the first outburst occurred. This leisurely progress emphasized the need of a well planned, large scale investigation and this was started in 1936 in collaboration with Professor Zwicky of the California Institute of Technology. An intensive systematic search for bright novae was initiated.

In 1937 Dr. Zwicky made the first of his long list of discoveries. As the novae were discovered, their light curves, distances and spectra were investigated at Mount Wilson. The differences between these bright novae and normal novae were so pronounced that it was apparent quite early that they represented distinct types. Subsequent developments established the validity of the distinction.

Nineteen Since 1937

Since 1885, thirty-seven supernovae have been observed in thirty-three stellar systems. Since 1937, nineteen have been recorded, of which seventeen were discovered by Dr. Zwicky or his assistant. Before this survey the frequency of supernovae could only be surmised from the fact that six outbursts accidentally had been found in the Virgo cluster of about 300 nebulae in thirty-one years. Dr. Zwicky's calculations now show that one can be expected about once every five centuries per average nebula — which checks well with the observed frequency of their appearance in the Milky Way.

Supernovae have appeared in nebulae of all types, and show no pronounced preference for any particular types. This fact may be significant because the types of nebulae presumably represent an evolutional sequence. On this assumption, the instability leading to the outbursts does not seem to be associated with any particular periods in the life history of stellar systems.

Another significant fact is the appearance of supernovae in elliptical nebulae which, in general, do not contain supergiant stars or even the brighter giant stars. This fact seems to dispose of a suggestion once made that normal novae may represent explosions of ordinary stars and supernovae the explosions of supergiants.

The studies to date have enabled Mount Wilson astronomers to divide supernovae into two major groups which differ radically in their spectra, maximum luminosities, and the patterns of their light curves.

The two are thus described by Dr. Edwin Hubble of the Mount Wilson staff: "In Group One the form of the light curves is similar in general to that of normal novae. The stars seem to blaze out a million fold or more within the space of a few days. The average maximum, of the order of 100,000,000 suns, is comparable to the total luminosity of an average stellar system. Following maximum the stars fade rapidly at first. Then, after a few weeks, they fade slowly and steadily, losing about one-third of their light each month.

"An outburst which occurred in August, 1937, in a dwarf stellar system about 3,000,000 light years from the earth, may be described as an example. The supernova blazed out to a maximum of about 600,000,000 suns, nearly 100 times brighter than the nebula itself. This maximum is the brightest definitely recorded. The star faded in the usual manner and was last photographed about two years after its discovery. It was then about a half million times fainter than at the maximum.

"The amount of energy suddenly released by the explosion is suggested by the fact that the supernova radiated in one day as much photographic energy as the sun has radiated in 1,500,000 years. When the spectra finally are interpreted they evidently will furnish important new information concerning the behavior of matter under extreme conditions far beyond the scope of terrestrial laboratories.

"The spectra are radically different from those of any other known phenomena. Not a single one of the major features has yet been identified. The only recognizable features are two relatively narrow bands in the red which are believed to represent oxygen lines. These bands do not appear until five or six months after maximum.

"Supernovae of Group Two reach a maximum of the order of 10,000,000 suns, and present spectra that resemble those of normal novae on an enhanced scale. A typical example is an outburst that occurred last May in a giant stellar system at a distance of five or six million light years. It blazed up to a maximum of about 30,000,000 suns, or about one-seventh the total luminosity of the nebula. After maximum it began to fade but the rate of fading over the first several weeks was slower than that found for Group One. Later the star faded more rapidly until it reached the usual normal curve, which it followed thereafter.

"The spectrum was recorded from maximum to 76 days after maximum. The first record showed the continuous spectrum of a very hot star. Emission bands appeared four or five days after maximum, as in the case of normal novae, and indicated a velocity of expansion of the order of nearly 4,000 miles a second. All the major features in the photographic region have been identified and the story is reasonably clear. It seems to be the story of a normal nova on a gigantic scale."

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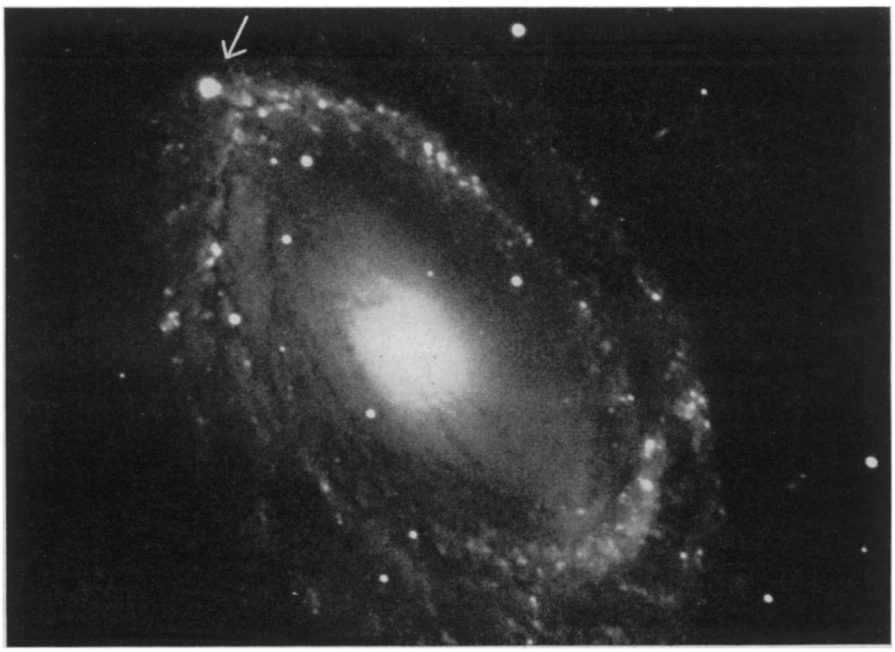

SUPERNOVA

The arrow points to a great exploding star in the spiral galaxy NGC 4725—one of the most spectacular phenomena in the universe.