The spiral galaxy, NGC 4725, photographed by the 100-inch telescope at Mt. Wilson. The picture on the left shows the galaxy before the supernova explosion. At right the arrow indicates the supernova.

Search for Supernovae

by Fritz Zwicky

Supernovae are cosmic explosions which, at maximum brightness, radiate away as much energy every day (in the form of light and corpuscular radiation) as the sun does in a hundred million years.

Studies of these phenomena may be of great importance for views on the evolution of stars and stellar systems, the nature of neutron stars, and the origin of cosmic rays. Also, there is the possibility that data on supernovae may be used to calibrate distances to the very periphery of the visible universe.

The original supernova search began at Caltech in 1933 and continued until 1942, when the war—and the work load—forced its abandonment. In 1956 it was decided to renew the search for supernovae through the cooperative effort of several observatories, such as Palomar, Lick, and Steward in this country, and Berne in Switzerland. This international enterprise, of which I am director, is largely financed by funds from the National Science Foundation and from the Swiss National Science Fund.

From this combined effort, a dozen supernovae have been found in the last few years. (Only about 60 have been recorded in history.) Two of the most important ones were discovered by a collaborator in my group, Dr. M. L. Humason (who retired in June 1957 as a staff member of the Mount Wilson and Palomar Observatories).

Existence of the supernova phenomenon was first clearly proved from observations at the Palomar Observatory in 1937, with the aid of the 18-inch Schmidt telescope. With this instrument, specifically built for the supernova search, Dr. J. J. Johnson (then research fellow in astrophysics) and I, discovered 19 supernovae in the period from September 1936 to January 1942. This investigation showed that, on the average, one supernova flares up in a normal galaxy about once in 360 years.

It was also found, from the analysis of the light curves and of the spectra, that there are several types of supernovae. The two most prominent are designated as types I and II.

Perhaps the most important result to come from this study was the conclusion, drawn first in 1937 (long before the H-bomb experiments) that the supernova phenomenon is caused by a stupendous *nuclear fusion chain reaction.*

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Type I supernovae are the brightest known so far. Their spectra, which consist of ill-defined bands, have completely defied interpretation in spite of concerted efforts by the world's best spectroscopists. This failure to understand the origin of even one single feature in the spectrum of the brightest supernovae is one of the reasons the search for supernovae was resumed a few years ago.

In some cases the decline in luminosity (as seen in blue light only) of type I supernovae is approximately exponential for periods of several hundred days, starting from 50 to 100 days after maximum. This means that the photographic magnitude increases linearly with time.

During the past few years, some observers have published data indicating that the photographic brightness of supernovae of type I, regardless of absolute brightness, declines by one magnitude every 52 days. This supposition induced a number of investigators to propose that the light curves of supernovae of type I can be explained by assuming that the decay of some radioactive isotope (Californium 254, for instance) is responsible for the emission of light by the gas clouds expelled by the supernova. This theory has proved to be incorrect because the decay rates of supernovae of type I, found so far, are not all the same; they lie in the range from 28 to 52 days.

From our extended search with the 18-inch Schmidt telescope on Palomar Mountain, between 1936 and 1941, it was found that supernovae of type II are intrinsically fainter than those of type I. In contradistinction to the spectra of those of type I, the spectra of type II supernovae seem to show considerable similarity with the spectra of some of the common novae. In fact, Dr. R. L. Minkowski (staff member of the Mount Wilson and Palomar Observatories) obtained strong evidence, from the widths of the emission lines of hydrogen, that gas clouds are being ejected with velocities between 5000 and 7000 km/sec.

Two new supernovae

The first of the two important new supernovae discovered by Dr. Humason last June appeared next to a spiral arm, and slightly within an absorbing lane, of the giant spiral galaxy, NGC 7331. This object is probably the brightest supernovae of type II ever found. Its apparent magnitude was +12.5 and its absolute photographic magnitude was estimated as about −17 (or about 600 millions times brighter than the sun).

Fortunately, Dr. J. L. Greenstein (Caltech professor of astrophysics and staff member of the Mount Wilson and Palomar Observatories) and Dr. Minkowski were at hand to repeatedly photograph the spectrum of this explosion. As a result of their efforts, it was clearly established that the spectrum is actually similar to that of some common novae – as Minkowski's spectra had indicated 20 years ago. The gas clouds, which are ejected at a velocity of about 6000 km/sec instead of only 1000 km/sec – as in common novae – seem to be of unexpectedly large mass.

Contrary evidence

Also, not only were the emission lines of the Balmer series of hydrogen photographed, but emission lines of other elements such as helium and highly ionized carbon could be identified as well. There is no indication, however, that heavier elements were ejected in any great abundance, which is clearly contrary to the idea advocated by Professor Fred Hoyle (now visiting professor of astronomy at Caltech, from Cambridge University) and others, that supernovae populate interstellar space with the heavier elements.

The second bright supernova discovered by Dr. Humason made its appearance in an open barred spiral galaxy which may be a member of the large Virgo cluster of galaxies. This supernova was of type I and, spectacularly enough, at maximum it was several times as bright as the entire galaxy of stars in which it occurred. Its apparent photographic magnitude at maximum was about +13.5.

The two newly discovered supernovae have temporarily disappeared from sight. Early in 1960, when the respective constellations come into reach of our telescopes again, we hope to be able to photograph them at later stages of their development. Then we may be able to determine the physical characteristics of the tail ends of their light curves by photographing them in several colors. This should enable us to establish the necessary data for the use of supernovae as distance indicators to the most remote parts of the universe which can be reached with present telescopic equipment.