# A Novel Kind of Nova

A singular sort of nova, an explosion by a solo star, is proposed as an explanation for Nova Cygni 1975

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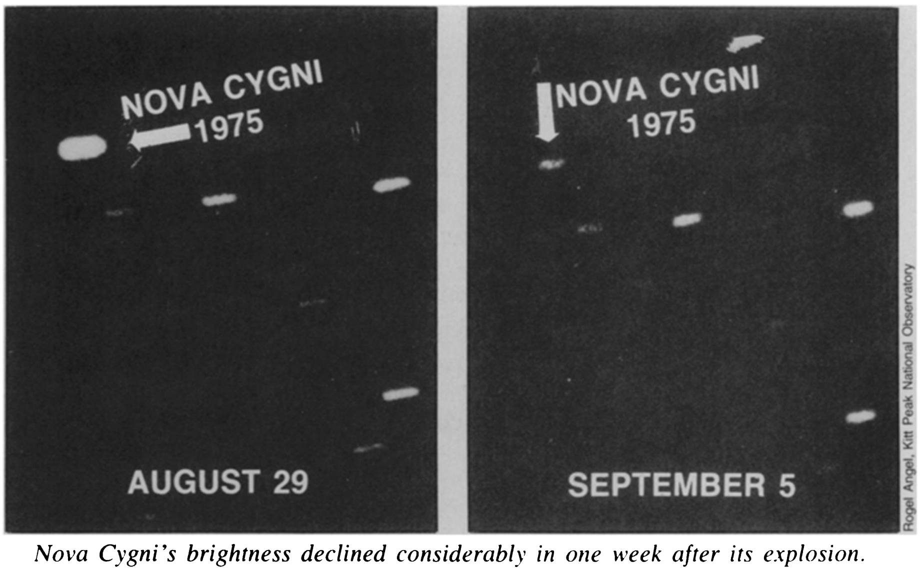
When Nova Cygni 1975 first exploded on Aug. 29, 1975, it looked so un-nova-like to observers at the Hamburg Observatory that they suggested it might be a supernova. It was certainly unusual. Reaching a maximum brightness of 1.79 magnitude, brighter than all but about 30 stars in the sky, it was the brightest nova in three decades, and it appeared to show the greatest increase in brightness of any nova observed. Yet as more and more observation reports came in during the days after Aug. 29, the supernova suggestion was rejected. It looked like a nova. Still, there was something a little strange.

By the time the American Astronomical Society met in Chicago in December 1975, Nova Cygni's rise and fall had been well observed and a lot of data were in. Speaking at the meeting, J. S. Gallaher of the University of Minnesota suggested that in view of the data recorded, Nova Cygni was in fact an unusual kind of nova with certain resemblances to a supernova, a nova outburst taking place in a single star. Now, in the Aug. 15 ASTROPHYSICAL JOURNAL LETTERS he and five other astronomers (S. G. Starrfield of Arizona State University, J. W. Truran of the University of Illinois at Urbana-Champaign, W. M. Sparks of the Goddard Space Flight Center in Greenbelt, Md., P. Strittmatter of the University of Arizona and H. M. Van Horn of the University of Rochester) present a recension of the evidence on Nova Cygni to show that it does fit the model of a new class of single-star novas.

This goes contrary to previous opinion on the subject of novas. In 1955, the late Otto Struve proposed, and since then astronomers have generally believed, that all novas occur in close binary systems. One member of such a binary is a white dwarf star. The white dwarf's gravity draws matter, mostly hydrogen, from its companion star. The result is that the white dwarf develops an envelope rich in hydrogen, a prime fuel for thermonuclear reactions, and that richness eventually results in a runaway reaction, a thermonuclear explosion of the white dwarf's outer layers.

The trigger of a supernova lies within the star. An elderly star—it doesn't have to be in a binary system—runs out of thermonuclear fuel. The heat produced by the thermonuclear reactions no longer supports the bulk of the star. The star collapses under its own gravitation. The collapse generates energy that eventually triggers an explosion of the star.




*Nova Cygni's brightness declined considerably in one week after its explosion.*

To compare, a nova involves the outer layers of the star and leaves a more or less intact core. A supernova involves most of the star's mass. It leaves behind a dead core (a neutron star or black hole) and scatters a nebulous remnant through the surrounding space, a remnant that can continue to glow for a millenium or more.

Earlier this year, Starrfield, Sparks and Truran reported at a symposium of the International Astronomical Union that they had calculated a model for the occurrence of a nova on the basis of the astrophysics of white dwarfs. It gives some details about the sort of white dwarf that can have a nova explosion. White dwarfs draw their main energy from a rather advanced nuclear burning cycle, the carbon-nitrogen-oxygen cycle. Because of the nature of the CNO cycle, the material of the white dwarf's outer layers must have something like five times as much carbon, nitrogen and oxygen as the sun (which is a rather typical star) to give a characteristic nova outburst. The luminosity of the white dwarf before the outburst must be low, between a thousandth and a hundredth that of the sun. After the outburst, the star can become a relatively stable star of large radius (about a million kilometers or more) and high temperature, 30,000°K. (The steady high temperature can be reconciled with the observed rapid decline in visual brightness, because the energy gradually shifts to shorter and less visible wavelengths as the radiation from the remnant core of the star comes to dominate that from the shell.) These features have been seen in a number of observed novas.

How do the observed facts of Nova Cygni 1975 compare with these models? Nova Cygni lies directly in the galactic plane (galactic longitude 90°, galactic latitude −0.1°), and for that location, the reddening of its light by interstellar dust indicated a distance of about one kiloparsec or more. Taking 1.5 kiloparsecs for the sake of argument, Starrfield and collaborators estimate Nova Cygni's maximum absolute visual magnitude at −9.5. This is bright for a nova, but not unique; the nova CP Puppis in 1942 may have gone as high as −10.5 magnitude. The graph of Nova Cygni's increase and decline in brightness looks like that of Type I supernova, but it ran its course about five times as fast as a Type I supernova. The greater speed indicated that less matter was ejected than a supernova would have ejected, and in fact, infrared observations of Nova Cygni indicate that the matter ejected amounted to about a ten-thousandth the mass of the sun. The range of velocities with which the ejected matter flew away, between 1,300 and 2,500 kilometers per second, is also characteristic of a fast nova.

As it turns out, Nova Cygni fits the Starrfield-Sparks-Truran model quite well. Its rise in luminosity (15 to 18 magnitudes) is extreme but within the limits of the model. Its brightness curve is very similar to the theoretical one calculated from their model, and its brightness before the explosion indicates that it started from a single white dwarf with a luminosity between a hundredth and a thousandth of the sun's luminosity or even less.

What is unusual about all this is that the model's predictions differ in a few respects from those of observed fast novas. For one example, the brightness curve of a typical fast nova exhibits a sharp spike instead of the rounded maximum predicted by the model and seen in Nova Cygni. The discrepancies appear presumably because the Starrfield-Sparks-Truran model ignored the effects of a nova's supposed binary companion on the nova's behavior. This is the kicker: A model that only approximates the behavior of a binary nova fits Nova Cygni very closely, and so Starrfield, Truran, Gallagher, Sparks, Strittmatter, and Van Horn conclude that Nova Cygni is what the model represents: a nova occurring in a star without a binary companion, a phenomenon astrophysicists had not believed could exist.

But can it exist? The main reason for supposing that novas happen in binary systems is to provide a source for the accretion of matter that causes the fuel imbalance that triggers the explosion. Supernovas happen without outside intervention, but a nova needs help. The only source of such help for a free-standing white dwarf is the clouds in interstellar space.

Can a white dwarf accrete enough matter from interstellar space to trigger a nova explosion during the time it takes to cool to a thousandth of the sun's luminosity? Truran, Starrfield, Sparks and S. Wyatt argue in a yet unpublished paper that there is a one-in-a-hundred chance that a white dwarf can accrete a ten-thousandth of the sun's mass in this way during a few billion years. This is the kind of time it would take a pure carbon white dwarf with a total mass equal to the sun's to cool to a luminosity equal to a thousandth of the sun's, which is the theoretical starting point for the nova. Furthermore it has been shown that such a star would have convective processes that would mix the hydrogen accreting from interstellar space with the star's own matter to produce the enhancement of carbon, nitrogen and oxygen necessary to make the explosion.

So Strittmatter and co-authors conclude, "It appears, therefore, that all the conditions necessary for a nova eruption can, with reasonable probability, be realized on an isolated white dwarf and that the association of nova-like events with close binary systems may not be unique." So it seems astrophysics has a new class of nova to consider. □