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A scientific first:

A Supernova Explosion is Observed in Real Time

Including a tell-tale flash of radiation preceding the event

An ordinary observation with NASA's Swift research satellite recently led to the first real-time sighting of a star in the process of exploding. Astronomers have surveyed thousands of these supernova explosions in the past, but their observations have always begun some time after the main event is underway. The information gained from catching a supernova at the very onset is already being hailed as the "Rosetta Stone" of star explosion, and it is helping scientists to form a detailed picture of the processes involved.

A typical supernova is preceded by the burn-out of a massive star. When the nuclear fuel at its core runs out, the star collapses under its own weight. The resulting body, now known as a neutron star, is so dense that one teaspoonful of its core material weighs as much as all the humans on earth. This extreme compression is followed by a rebound, creating a shock wave that bounces off the surface of the newly-formed neutron star and rips through its outer, gaseous layers. These layers are ejected, flying off the surface in rapidly expanding shells.

For the last four decades, astronomers have theorized that the explosion is preceded by a burst of x-ray radiation that lasts for several minutes. For the first time, that burst was actually seen – all previous observations had taken place when the star was already an expanding shell of debris, days or even weeks after the explosions' start. Both luck and the Swift satellite's unique design played a role in the discovery. In January of this year, Drs. Alicia Soderberg and Edo Berger of Princeton University, USA, were using the satellite, which measures gamma rays, X rays and ultraviolet light, to observe another supernova in a spiral galaxy in the Lynx constellation, 90 million light-years from Earth. At 9:33 EST, they spotted an extremely bright five-minute X-ray burst and realized it was coming from another location within the same galaxy.

The Princeton scientists immediately assembled a team of 15 research groups around the world to investigate, including Prof. Eli Waxman and Dr. Avishay Gal-Yam of the Weizmann Institute's Physics Faculty. Gal-Yam performed measurements and calculations that enabled the scientific team to cancel out the various disturbances that affect astronomical data, such as radiation-absorbing interstellar dust, which skews observed measurements. The shock-wave eruption and X-ray generation

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of this supernova explosion went exactly according to the theoretical model that Waxman and Prof. Peter Meszaros of Penn State University had developed earlier. The data showed that the explosion – known as supernova 2008D – is a relatively common type of supernova, and not a rare supernova involving jets of gamma ray radiation.

Already, the observation has provided scientists with valuable new information on supernovae, including the dimensions of the exploding star, the structure of its envelope and the properties of the shock wave that hurls off the star's outer envelope. As they continue to analyze the data, the scientists believe it may help them to solve some of the outstanding puzzles surrounding these types of explosion. For instance, according to mathematical calculations of the forces involved in neutron star collapse, the bouncing shock wave should stall out before it manages to eject the stellar envelope. Clearly, this is not what happens in nature, but clues found in the Swift observations may help researchers to correct the model.

Now that they have observed a supernova from the pre-explosion stage, the scientists are not only gaining a better understanding of the little-understood processes that make these stars explode, they hope their knowledge of the x-ray emissions will enable them to catch more stars that are right on the brink of becoming supernovae.

Prof. Eli Waxman is Head of the Benoziyo Center for Astrophysics and the Albert Einstein Minerva Center for Theoretical Physics.

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