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Astronomers Link Gamma-Ray Bursts to Supernovas

By DENNIS OVERBYE

Alien space wars and antimatter comets are but two of the more exotic explanations that have been proffered in the last three decades for the flashes of high-energy radiation known as gamma-ray bursts that have appeared sporadically in the cosmic night, tantalizing and frustrating astronomers.

An only slightly more prosaic theory has taken hold among astronomers in recent years: that these violent flashes are the yowls of giant stars imploding, perhaps into black holes, the inky gravitational sinks that swallow light and all else.

Now there is evidence that those astronomers are right, at least about some of the bursts. On March 29 a gamma-ray burst was detected that went off unusually near Earth — a mere two billion light-years away — prompting a deluge of observations that discerned the unmistakeable hint of a supernova explosion, the cataclysm in which a massive star ends its life, in the debris of the burst.

"There should no longer be doubt in anybody's mind" that gamma-ray bursts and supernovas are connected, said Dr. Thomas Matheson, of the Harvard-Smithsonian Center for Astophysics in Cambridge, Mass.

Dr. Stan E. Woosley, an astrophysicist at the University of California at Santa Cruz, said, "It looks like a black hole was born that day." Dr. Woosley is an author of a series of three papers on the burst by an international array of astronomers that appeared yesterday in Nature.

In interviews, astronomers described the results as the "smoking gun" they had long suspected must be there connecting the two most violent phenomena in nature.

"It's just ironclad now," said Dr. Donald Lamb, an astrophysicist at the University of Chicago.

In a commentary accompanying the Nature papers, Dr. Peter Meszaros, an astronomer at Pennsylvania State University, called the recent work "a watershed event." Dr. George Ricker, a gamma-ray astronomer at the Massachusetts Institute of Technology, said the detailed observations of this burst would serve as a template for theorists for years to come. "It's a very lucky event for us," Dr. Ricker said.

Gamma-ray bursts have led astronomers on a merry chase since the 1960's, when they were accidentally discovered by satellites intended to look for nuclear tests on Earth.

Efforts to understand these bursts were hampered at first because they last only a few seconds or minutes and do not repeat. The satellites that detected them could not fix their locations in the sky precisely enough for astronomers to link them to particular stars or galaxies.

It was not until 1997, using coordinates relayed from the Dutch-Italian satellite Beppo-Sax, that astronomers found a visible afterglow to one burst in a galaxy seven billion light-years away, establishing these flashes as some of the most violent events in the universe.

Then on March 29, the High Energy Transit Explorer, operated by NASA and a multinational collaboration led by the Center for Space Reseach at M.I.T., recorded a blast in the constellation Leo and sent its coordinates to a network of astronomers.

Whereas most gamma-ray bursts had been traced to galaxies typically 10 billion light-years away, the afterglow from this one was so bright that the astronomers joked about its casting shadows, said Paul Price, a graduate student at Mount Stromlo Observatory in Australia, who was among the first to identify the glow and who is the lead author of one of the Nature papers.

"Up close and personal with a cosmic explosion," as Dr. Price put it in an e-mail message. The result was that the burst afterglow could be studied in unprecedented detail.

A crucial breakthrough came when Dr. Krzysztof Stanek and Dr. Matheson, of the Center for Astrophysics, and Dr. Peter Garnavich of the University of Notre Dame, aided by astronomers around the world recording observations 12 nights in a row, discovered the spectral signature of a supernova peeking out from the fading afterglow about a week after the burst. It was the first direct evidence that at least some gamma-ray bursts come from supernovas. Their results were published earlier this month in the online edition of Astrophysical Journal Letters.

Significantly, both this supernova and one in 1998 were of a type known as Ic, which seem to involve certain very massive stars, giving support to what is termed the "collapsar" model of bursts.

Under this theory, Dr. Woosley said, the story begins with a rapidly aging rotating star, perhaps 30 times the mass of the Sun. When the core of such a star, made of iron, finally collapses of its own weight, it creates a black hole or a dense neutron star in its middle.

Material trying to fall onto this object forms a hot swirling disk and a narrow jet, which shoots out of the star in six or seven seconds. The gamma rays are formed when this jet, moving at nearly the speed of light, plows into material in interstellar space, forming a "fireball" of magnetic fields and high-energy particles.

Meanwhile, the rest of the star blows up as a supernova, but for a few days that violence is masked by the greater fury of the gamma-ray fireball that surrounds it.

"We can't see inside until it fades," Dr. Woosley said.

The new papers both validate and complicate this picture, the astronomers say. In one, Dr. Makoto Uemura, an astronomer at Kyoto University, and his colleagues report that the afterglow from the March 29 burst did not fade steadily in its first few hours. Rather it rose and fell in brightness sporadically. These "bumps" in the light curve could provide important clues to the nature of gamma-ray bursts, Dr. Uemura said in an e-mail message.

One possibility, he explained, is that the black hole, the central engine of the burster, sputters, emitting jets in more than one puff, which then catch up to each other in the outer world and collide, "refreshing" the fireball.

The connection between the supernova and the March 29 gamma-ray burst has been strengthened by the observations reported in another paper by several astronomers led by Dr. Jens Hjorth of the University of

Copenhagen. They concluded that the gamma-ray burst and the supernova explosion occurred within two days of each other, eliminating models in which the star's collapse happens in two stages.

The spectral data also suggest that the supernova associated with this gamma-ray burst was unusually violent, with gas flying outward at 36,000 kilometers a second, "faster than a supernova has ever been seen to expand," Dr. Woosley said.

How some stars attain such savage explosive energies and the rapid spins needed to power the jets are mysteries that await elucidation. The Hubble Space Telescope will be able to study the afterglow from the March 29 event for another year, astronomers say, and radio telescopes might be able to track it longer. A new satellite known as Swift, designed to hunt and study the bursts, is scheduled to be launched this winter.

"My head is spinning," Dr. Lamb said.