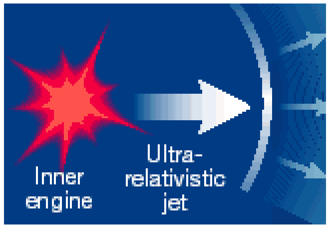

Birth of a Black Hole is Messy, New Observations Suggest

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The almost instant detection of a powerful deep-space energy burst, and the rapid follow-up by 33 telescopes around the world, has provided compelling evidence for the explosive birth of a black hole.

The aftermath appeared to be very messy, said astronomers who watched the event's energy output decline more slowly than had ever been seen before.

The observations were the most detailed ever made of a faraway explosive event known as a gamma-ray burst, or GRB. A study of the data, collected over several weeks, strengthens the connection between mysterious GRBs and even more mysterious black holes.

Hidden process

One way to make a black hole, theorists agree, is to explode a very massive star. In one of these supernova events, outer portions of the star are flung into space. Some material falls back, however, and collapses into a sphere so dense that nothing, not even light, can escape.

In recent decades, astronomers have observed mysterious gamma-ray bursts coming from all directions of the sky and mostly from outside our galaxy. Studies have gradually tied the bursts to the so-called collapsar model of black hole formation. Also, research last year made a strong connection between supernovae and gamma-ray bursts.

Still, the engine driving a GRB is not known with certainty. Researchers think gamma rays and other forms of radiation, including X-rays, visible light and radio waves, are generated prodigiously as the black hole swallows additional incoming gas and dust in sloppy fashion.

More important, fresh jets of energetic particles are created by the new setup. They zoom out along the axis of rotation of the star or the resultant black hole and blast through slower-moving material that's expanding away in waves from the site of the initial explosion.

The jets move at a significant fraction of the speed of light, speeds astronomers call relativistic. When they collide with the bubbles of material, shock waves heat the material. Gamma rays and light are unleashed, theory holds.

But there are loose ends in all these theoretical connections, not the least of which is the fact that the initial moments of gamma-ray bursts have gone largely unobserved in most wavelengths. Significant optical flashes have largely eluded astronomers.

New approach

Unlike previous gamma-ray observatories, NASA's High-Energy Transient Explorer (HETE) was designed to relay its observations to Earth in real time, instead of just once per orbit.

When HETE detected a gamma-ray burst called GRB 021004 last October, a worldwide alert went out within 11 seconds. Just more than three minutes later an automated Japanese telescope, at the Institute for Physical and Chemical Research, detected an optical counterpart to the burst. Within minutes, the explosion was recorded by the Palomar 48-inch Oschin Telescope and the Near Earth Asteroid Tracking (NEAT) camera.

Soon, telescopes all over the planet, and even NASA's space-based Chandra X-ray Observatory, were pointed at the event, which occurred in a galaxy several billion light-years away (which means that the explosion actually occurred billions of years ago and its light had just arrived at Earth).

The fading optical afterglow was monitored continuously for several weeks until it ended. The initial hours proved most compelling.

"What we have observed is a very slow decay of the optical emission for the first half-hour to 2 hours after the burst," said the study's leader, Derek Fox of Caltech. "This implies continuing energy input to the shock regions of the afterglow at these times, meaning that either the GRB's central engine is continuing to operate, or that the explosion itself was a 'dirty' explosion that ejected debris with a wide range of velocities."

Either explanation, Fox told *SPACE.com*, is a natural fit with collapsar models.

The results will be detailed in the March 20 issue of the journal *Nature*.

Fox noted that this was only the second burst to be caught so quickly by optical telescopes, so the slow decay of output may turn out to be a common feature.

"The main thing we can say for certain now, that we did not know before, is that a gamma-ray burst cannot be conceived of as a single monolithic explosion," Fox said. "Rather, it seems there is some intrinsic 'messiness' to the event -- either in the sense that the engine continues to burble for some time afterwards, or in the sense of the explosion itself being dirty, that is, having slow-moving as well as highly-relativistic debris."

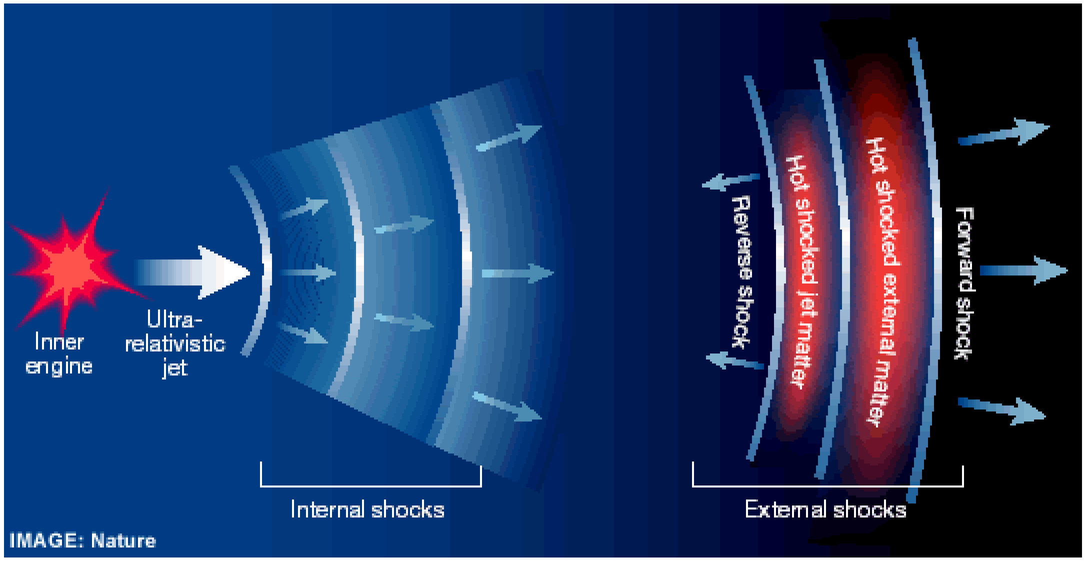
Mysteries remain

"The results are exciting, but perplexing," said Tsvi Piran of the Hebrew University in Israel. Piran was not involved in the research but wrote an analysis of it for *Nature*.

Piran said the early afterglow faded "much more slowly than had been predicted" and exhibited significant "wiggles" or flashes as it wound down. A non-uniform structure in the jets that create the gamma rays had long been predicted, Piran said, and "this may be the first evidence for its existence."

Despite the new observations, gamma-ray bursts remain largely mysterious, Fox said. Even the link between black hole formation and the bursts is not yet proven.

"At their very core, GRBs are likely to remain mysterious for a very long time," he said. "Even if we determine that GRBs are produced by collapsars, we will still be at a loss to say, for certain, what the engine of the process is. Is it the inflow of the gases from the star feeding the black hole, is it nuclear reactions in these gases, as they are crushed and heated, or is it, possibly, the spin of the black hole itself?"



Some internal engine, perhaps the collapse of a massive star, fuels a relatavistic jet of particles that collides with material to produce shock waves, and reverse shocks. This heats the material and produces light and gamma rays.