Is there a super way to make black holes?

Gabi Perez

Illustration of the binary system GRO J1655-40 shows an ordinary star circling a disk of material surrounding a black hole.

Twisting space like a pretzel and sucking in everything around it—even light—a black hole can seem like a notion that's hard to swallow. Although weighty evidence has convinced most astronomers that these gravitational monsters indeed exist, scientists are still unsure how they form.

According to one theory, stars more than 10 times as massive as the sun succumb quietly to gravity after burning up their nuclear fuel. They collapse under their own weight to become black holes.

In a second model, the demise of these stars unfolds less directly. First, they explode as supernovas, hurling their outer layers into space and leaving behind a dense, burned-out remnant called a neutron star. Debris from the explosion then falls back onto the neutron star, turning it into a black hole.

Theorists have spotlighted the supernova scenario because it may explain the origin of mysterious flashes of high-energy radiation, or gamma-ray bursts (SN: 7/10/99, p. 28). Now, observations of a star that closely orbits a suspected black hole strongly support the supernova model of black hole formation, researchers report in the Sept. 9 NATURE.

Rafael Rebolo of the Institute of Astrophysics of the Canary Islands in La Laguna, Spain, and his colleagues examined the composition of the atmosphere of an ordinary star, about twice the sun's mass, that circles a suspected black hole more closely than Mercury orbits our sun. Residing some 10,000 light-years from Earth, the pair of objects is known as GRO J1655-40 or Nova Scorpii 1994.

Using the Keck I Telescope on Mauna Kea in Hawaii, the team found that the star's outer layers contain oxygen, magnesium, silicon, and sulfur in abundances 6 to 10 times those found in the sun. That's a puzzle because the relatively lightweight star would never have reached the internal temperature, greater than 3 billion kelvins, required to forge high concentrations of these elements. In contrast, the star's massive companion could easily have generated them before it became a black hole.

If the companion had collapsed directly into a black hole, the material would have remained locked inside. However, if the heavyweight had first exploded as a supernova, ejecting the elements into space, its lower-mass partner could have captured them.

"This is, to our knowledge, the most direct evidence ever found for a link between a supernova and black hole formation," Rebolo and his colleagues assert.

"There's no other way I can think of that you could actually have an enhancement [of the four elements] except to say that the star that just became a black hole must have first blown up and injected that enriched material into the companion star," says John J. Cowan of the University of Oklahoma in Norman.

Another possibility, enrichment via a wind blown from the massive star, doesn't work, he says. A wind would contain a variety of materials, including iron, but the star shows enhancement by only the elements likely to be released in a supernova explosion, Cowan notes.

"These are fascinating observations," says Stan Woosley of the University of California, Santa Cruz, but he adds that he would like to see a detailed supernova model that explains the observed abundance pattern. Woosley has championed the supernova–black hole model to explain gamma-ray bursts.

One complication is the star's proximity to its partner. Before becoming a black hole about a million years ago, the latter was a star 25 to 40 times the mass of the sun. Its outer layers would have enveloped the smaller star.

The evidence suggests, however, that such direct contact played only a minor role in altering the star's atmosphere, Rebolo says. For example, nitrogen, which would have been plentiful in the outer layers of the black hole's predecessor, has relatively low abundance in the low-mass companion.

Rebolo holds that black holes may arise either through supernova explosions or direct gravitational collapse. His team plans to search for the supernova signature in other black hole systems. —*R. Cowen*

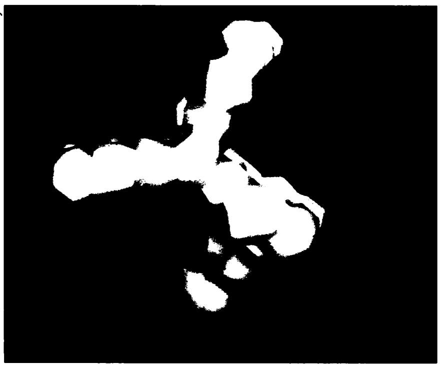
Molecular motors spin slowly but surely

Two groups of scientists have built from scratch the first working single-molecule motors: one powered by light and heat and the other by chemical reactions. The synthesized molecules both incorporate ratcheting mechanisms, which allow them to spin—albeit very slowly—in a single direction.

The organic molecule designed by researchers at the University of Groningen in the Netherlands and Tohoku University in Sendai, Japan, rotates via a four-step process. "We irradiate it with ultraviolet light, and one half rotates [180°] with respect to the other half," explains Groningen's Ben L. Feringa.

Next, the molecule relaxes into a lower-energy conformation. Feringa and his colleagues then shine UV light on the molecule again, spinning it another 180°. Finally, heating it to 60°C enables the molecule to readjust and assume its original shape, so the researchers can begin the process again.

Kelly



A one-way molecular motor consists of a three-bladed fan (white) attached to a ratcheting mechanism (blue).

The molecule's corkscrew shape allows it to spin in only one direction. To get a motor that rotates in the other direction, Feringa says, the researchers simply constructed its mirror image.

To make their motor, T. Ross Kelly and his colleagues at Boston College in Chestnut Hill, Mass., have taken a different approach. They attached a triptycene molecule, which looks like a three-bladed fan, to a helicene molecule, which acts as a ratcheting mechanism.

By performing a series of chemical reactions, the researchers can cause one of the blades to brush past the ratchet, turning the fan 120°. By modifying the chemical structure of all three blades, they hope to create a fan that will spin continuously, Kelly says.

Their molecule may lead to greater understanding of the biological motors that exist in living organisms, such as the ones that power flagella (SN: 2/7/98, p. 86) and cilia, says Kelly. "There's probably a parallel between the way ours works and the way nature's works," he suggests.

The two groups report their findings in the Sept. 9 NATURE.

Will such motors find their way into tiny machines? "The science that has been conceived and carried out by Kelly and Feringa is science at its very best," says J. Fraser Stoddart of the University of California, Los Angeles. "What will become of it? No one knows. That mystery is part and parcel of the excitement of it all." —*C. Wu*