start gathering a shroud of hydrogen and helium, the gases that make up the outer layers of the giant planets. Saturn's core, being farther from the sun, would have grown more slowly and drawn in less gas. By the time the gas dissipated, Saturn would have ended up with one third of the mass of Jupiter and one tenth of the internal pressures.

Saturn's lower internal pressures, Stevenson suggests, would in turn have allowed more of its helium to separate from hydrogen—a pressure-sensitive process. The result would have been a separate, helium-rich shell rotating around the planet's core. Because the shell would be electrically conductive at the pressures of Saturn's deep interior, it would be able to put its own stamp on the magnetic field generated in the core. The core's magnetic dynamo could be generating a tilted field, as conventional theory would call for, but the conductive shell might nullify any part of the field not symmetric about the rotation axis.

The wild tilts of the magnetic fields generated by Uranus and Neptune may be more a matter of chance events in the planets' infancies. Uranus seems to have taken a heavy, off-center hit by one of the larger planetesimals falling into it; that would explain why it is spinning on its side. A giant impact might also have mixed the growing planet's rocky core just enough to eliminate the density differences that drive convective flows. Because convection is what powers the dynamos that generate magnetic fields, Stevenson speculates that the task of generating a field would be left to a spherical, convecting shell surrounding the core. And the more complex geometry of convection in a shell could explain the two planets' tilted, highly complex fields.

In the inner solar system, says Stevenson, "the profound question, of course, is why doesn't Venus have plate tectonics [unlike Earth]?" The crucial factor, says planetary climatologist James Kasting of Pennsylvania State University, was probably Venus' position 40 million kilometers closer to the sun, where sunlight is twice as intense. Of the pair, only Earth was able to cool after its formation, with two consequences that could have been crucial to initiating plate tectonics. The cooling boosted the density of Earth's crust and made it more prone to sink into the interior, driving plate motions at the surface. And water vapor in the atmosphere condensed into permanent oceans, where the water could be carried into Earth's interior by sinking plates, providing a lubricant for plate motion. On Venus, in contrast, the surface remained hot and buoyant, and the water vapor in its atmosphere gradually broke down and was lost to space, closing off the possibility of plate tectonics.

These examples of "psychoanalyzing" the planets—explaining their adult characteristics through their childhood experiences—are only a few of the cases that could be tackled by comparative planetology. Why does Mercury have an iron core twice as massive, relative to its size, as any other rocky planet? Again, a chance impact early on may be to blame. Mercury could have formed an iron core of conventional proportions and then had much of its outer rocky mantle blasted away by one of the last and largest planetesimal impacts.

How can Neptune sustain 1400-kilometer-per-hour winds—faster than Jupiter's—when it is so far from the sun, whose heat powers atmospheric circulation? One hypothesis holds that less solar energy means less small-scale turbulence, which can slow global wind systems. How could Mars—now more than 50°C below freezing—have been warm enough in its early days to have water flowing on its surface? Perhaps geothermal heat played a role.

To Moustafa Chahine, chief scientist at the Jet Propulsion Laboratory and a co-chair of the comparative planetology meeting, such questions are a sign that it's time to adopt a mindset diametrically opposed to the one that was prominent in the past. Instead of looking to the other planets for answers about Earth, he says, it's time to draw on the understanding of the most intensively studied processes on Earth to help sort out the stunning differences among the planets. Chahine and his colleagues are now developing a joint NASA–National Science Foundation program embodying this "contrasting" version of comparative planetology. With only nine planets to study, it would never do to leave Earth out of the picture. As Stevenson puts it, half jokingly: "To make more progress, we need more planets."

**–Richard A. Kerr**

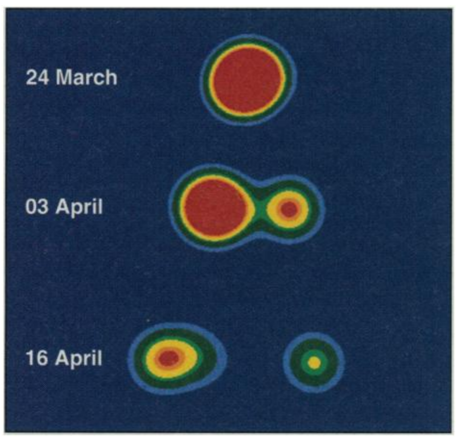
ASTRONOMY

# Micro-Quasars Found in Our Galaxy

THE HAGUE—You wouldn't want to get too close to a quasar, but astronomers would love to get a better view of these enigmatic beasts. Seen only in the farthest reaches of the universe, quasars shine thousands of times more brilliantly than entire galaxies and spew radio-emitting jets of material out to distances of hundreds of thousands of light-years. Only the gravitational pull of black holes weighing as much as millions of suns, most astronomers believe, could supply enough power to explain these displays. But, forced to observe quasars at a safe distance, astronomers have remained largely in the dark about their inner workings.

Now a discovery announced at the International Astronomical Union (IAU) meeting here and a subsequent finding reported in an IAU circular suggest that small-scale counterparts of quasars lie within our own galaxy, conveniently close for study. The clue was a phenomenon characteristic of some quasars: They seem to fling out clumps of material at greater than the speed of light. The effect is thought to be an optical illusion, produced when the quasar's jet is pointed in the general direction of Earth. The cosmic speed limit isn't violated, but the effect requires that the material actually be moving at very close to light speed.

Last week, radio astronomers reported such "superluminal" jets emerging from two x-ray–emitting objects in our own galaxy, implying that the inner workings of these x-ray sources may resemble those of quasars. "These findings are extremely important because they provide a clear link between x-ray [sources] in our galaxy and distant quasars," says Rashid Sunyaev of the Space Research Institute in Moscow. And that, says Gerald Fishman of the Marshall Space Flight Center in Huntsville, Alabama, qualifies these nearby sources as "two of the most exciting objects discovered in recent years."



MIRABEL AND RODRIGUEZ/NATURE

**Pushing the limit.** Blobs of radio-emitting gas race outward from GRS 1915+105 at an apparent speed greater than that of light.

Astronomers had already suspected a distant kinship between quasars and some galactic x-ray sources, because both classes of objects are thought to be powered in roughly the same way. The x-ray sources are believed to be binary star systems in which one star has collapsed into a small black hole or a compact neutron star. This stellar cinder greedily bolts chunks of its companion, just as the massive central black hole of a quasar drags in matter from its surroundings. Most of this matter spirals inward, gets fiercely heated by friction, and gives off x-rays.

But now it seems that, as in quasars, some mysterious mechanism also shoots out material from the poles of the compact object in high-speed jets, visible at radio wavelengths. Felix Mirabel of the Centre d'Etudes de Saclay, near Paris, and Luis Rodriguez of the Autonomous National University in Mexico City spotted the first of these superluminal jets near a source called GRS 1915+105, located just 40,000 light-years from Earth. GRS 1915+105 was discovered in 1992 when the French-Russian GRANAT satellite detected its highly variable x-ray emission. A few months later, Mirabel and Rodriguez began mapping the radio-emitting material around GRS 1915+105 with the Very Large Array (VLA) in New Mexico. Follow-up observations in 1993 hinted that part of the radio source had shifted across the sky. But at the time, the radio emissions were too dim for astronomers to be sure.

Last March, however, the radio emissions brightened dramatically, and Mirabel and Rodriguez were able to track two blobs of material racing away from a central source at an apparent speed 25% faster than light. At the IAU meeting and in a paper in yesterday's issue of *Nature*, the researchers estimated that the ejected material is actually moving at 92% of the speed of light, and they put its mass at about a third that of the moon. Accelerating it, say Mirabel and Rodriguez, would have required the power of 100 million suns, suggesting that even a quasar in miniature is a formidable thing.

As news of that finding spread this summer, astronomers began to look for other x-ray sources in the galaxy that might be performing similar feats. Just last week, radio astronomers hit pay dirt. Using the VLA to study X-ray Nova Scorpii, an x-ray source that itself was spotted only a month ago by NASA's orbiting Compton Gamma Ray Observatory, Robert Hjellming of the National Radio Astronomy Observatory tracked two rapidly diverging jets. Derek McKay and Michael Kesteven of the Australia Telescope National Facility then estimated that the source lies just 11,000 light-years from Earth, which implies that the jets are flying apart at more than the speed of light.

Nova Scorpii's distance, about a quarter of the distance to the earlier source, along with its strong radio emission, about 10 times more intense, suggest it may be an even better place to study a quasar in miniature. By merging data collected at radio telescopes in Australia, South Africa, California, and Hawaii using a technique known as Very Long Baseline Interferometry (VLBI), researchers hope to make high-resolution radio maps that might reveal clues to the workings of this micro-quasar—and its much bigger brothers.

**–Ray Jayawardhana**

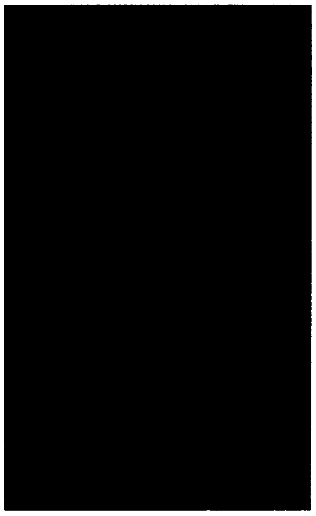
*Ray Jayawardhana is a science writer in Cambridge, Massachusetts.*

MATERIALS SCIENCE

# Making Molecular Filters More Reactive

Organic chemists are on the verge of something big in the manufacture of molecular strainers called zeolites. These nanoscopic filters, used widely by industry, have traditionally been made from porous crystals of inorganic materials such as silicon and aluminum. But zeolites made of organic materials could open up an exciting new range of applications in areas including drug manufacture. Before this can happen, however, organic chemists must be able to control the size of the pores in the zeolite—and so far they've only been able to make extremely small pores.

At last week's American Chemical Society (ACS) conference in Washington, D.C., however, a team led by Jeffrey Moore, an organic chemist at the University of Illinois (UI) at Urbana-Champaign, and Stephen Lee, an inorganic solid state chemist at the University of Michigan (UM) at Ann Arbor, reported making organic zeolites out of large molecules with preformed pores. When these ring-shaped molecules stacked up, they formed channels as large as 17 angstroms in diameter—more than twice the width of the earlier organic record. The discovery opens the door to making organic zeolites with even larger pores, simply by increasing the size of the holes in the prefab building blocks.



JEFFREY MOORE

**Straining for bigger size.** Computer image of organic zeolite with 17-angstrom pores shows the oxygen *(red)* and carbon *(green)* atoms used in its construction.

"It's very interesting," says Galen Stucky, a professor of chemistry and materials at the University of California, Santa Barbara. "Historically, inorganics have been used [to make zeolites] because their cost is cheap and you can make them in bulk quantities. But the thing you have with organics is the potential to make small variations [in the building blocks] to control the chemistry of the framework."

The zeolite construction crew started to make their prefab pores using molecules that look like the spokes and hubs of a child's Tinker Toy set. The spokes were rigid acetylene molecules and the hubs, ring-shaped benzenes. UM synthetic chemists Jinshan Zhang and Ziyan Wu connected these chemical Tinker Toys one by one into a hexagon, with benzene hubs at the corners, joined by acetylene spokes. Finally, Zhang and Wu added hydroxyl groups to the outside of each hub; these groups can form hydrogen bonds to join one hexagonal pore to a neighboring one.

When the researchers placed these hexagonal pores in a solution of ethanol and methanol, the hydrogen bonds drew neighboring hexagons together to form a two-dimensional honeycomb pattern. Intermolecular forces caused additional layers to stack up, creating a solid crystal with channels 8 angstroms in diameter. Using similar starting materials, the group also fashioned a more complex 3D building block that led to their second organic zeolite with 17-angstrom channels.

With their new organic zeolites in hand, the UI/UM team plans to join reactive molecules to the inside of the pores, giving their strainers highly specific binding properties that can't be built into inorganic zeolites. One such possibility, says Moore, is adding molecules such as amino acids that preferentially bind to one of a pair of mirror-image, or chiral, molecules. Such left- or right-handed molecules are commonly used as drugs, and pharmaceutical manufacturers must separate such nearly identical twins, as in many cases one molecule is therapeutic while its mirror image is either ineffective or toxic. And currently, the most widely used process for separating left- and right-handed versions of the same molecule requires several chemical stages.

The trick in developing such filters, says chemist Thomas Bein of Purdue University in West Lafayette, Indiana, "will be to add functional groups without affecting self-assembly of the crystal." Unlike inorganic zeolites, in which molecules are held together with rugged covalent bonds, organic zeolites are glued with relatively weak intermolecular forces and hydrogen bonds. And the same reactivity that makes the functional groups candidates for placement inside the pores could potentially affect how the molecules interact. The fragility of these bonds also means that organic filters won't replace inorganic zeolites in high-temperature applications, such as breaking apart the large hydrocarbons in crude oil into the smaller ones used in gasoline. But if organic chemists can manage to add these groups, they'll have a field of zeolite applications all to themselves.

**–Robert F. Service**