APS MEETING

Mapping a Galaxy's Hungry Heart

Astronomers have long believed that some of the brightest objects in the universe are driven by hunger. The distant beacons known as quasars, for example, are thought to be galaxies that harbor vast black holes sucking in gas and heating it to incandescence as they swallow it. Closer to home lie "active" galaxies with brilliant nuclei that may also be set alight by black holes devouring material. Now astronomers have taken a first step toward learning how one of these putative black holes feeds itself.

At the American Physical Society meeting last week in Washington, D.C., Johns Hopkins University astronomer Julian Krolik described early results from a technique for mapping the clouds of gas that are thought to whirl around the "central engine" of an active galaxy. Theorists picture the engine as a black hole nestled at the center of a rapidly spinning disk of infalling gas, rather like a marble at the center of a doughnut. "The big question," says Krolik, "is how does material that is to be accreted get in there?"

That's where the new technique comes in, by promising to show how the clouds of gas are distributed around the central engine of an active galaxy and whether they flow inward—or are driven outward by deeper processes. "It's a step along the way to the greater goal of understanding the dynamics of quasars," says astrophysicist Roger Blandford of the California Institute of Technology, who developed some of the mathematics underlying the mapping technique.

Krolik and his colleagues call the strategy reverberation mapping, because it relies on the timing of light "echoing" from the clouds as the central engine surges and subsides over periods of days. The central radiation source—probably the inner edge of the gas disk—generates a "continuum spectrum" of radiation that includes ultraviolet light and x-rays. That energy in turn ionizes the clouds, which glow at specific wavelengths like the gas in a fluorescent tube. When the central power source flickers, this "line emission" from the clouds should flicker in response—after a delay that reflects how much farther light has to travel when it reaches Earth via a gas cloud than when it comes straight from the source. By analyzing the pattern of time delays, researchers should be able to map the clouds.

The basic idea dates from 1969, but it took extensive observations from space to make it work, says Krolik. Earth's atmosphere blocks most ultraviolet light—where both the continuum and many of the strongest emission lines are found—and detecting the light echoes requires months of regular observations, with no time out for cloudy nights. In 1991, Krolik and other mappers finally had the data they needed: 8 months of observations of NGC 5548, a nearby Seyfert galaxy (a species of active galaxy), compiled by more than 100 astronomers from data gathered by the International Ultraviolet Explorer satellite and ground-based telescopes. As Blandford observes, "You only got scientifically useful results because you marshaled a lot of observers to cooperate in an unprecedented manner."

"You only got useful results because you marshaled a lot of observers to cooperate."
–Roger Blandford

This mother lode of data revealed enough flickers to give Krolik and his colleagues the first anatomy of the nucleus of an active galaxy. They found a roughly spherical distribution of clouds around the central engine, concentrated 4 to 14 light-days out, with additional material beyond 20 light-days. "That's closer, overall, than we used to think," notes Blandford. And the pattern of delays also suggested that different emissions came from different distances, perhaps because of variations in gas pressure and density. It's not enough detail to tell astronomers how active galaxies are fed, but the researchers are now planning another mapping foray into the heart of NGC 5548 using the Hubble Space Telescope.

With better data, they may be able to build a detailed map of cloud velocities, densities, and pressures. And if that picture tells them anything about how this particular Seyfert galaxy is fueled, some of the mystery of the much more powerful and distant quasars may be dispelled. As Krolik puts it, "At least in [some] properties, quasars look like Seyfert galaxies with the volume knob turned up."

–Tim Appenzeller

APS MEETING

Up Close and Personal With DNA

The research community has always fantasized about being able to manipulate individual molecules—both to see how they behave and to construct new materials from them. In the 1980s, when the scanning tunneling microscope and its instrumental kin took the research community by storm, that fantasy began crossing the line into reality. Now, with the ascent of another tool, optical tweezers, single-molecule science in the real world is picking up momentum.

Last week, at a meeting of the American Physical Society in Washington, D.C., Oxford University graduate student Stephen Quake reported using focused laser light like minuscule Star Trek tractor beams to pull on individual DNA molecules glued between tiny plastic beads. "We use light to stretch out the molecule, then we let go and watch it crumple," said Quake, who began this work as an undergraduate at Stanford University in physicist Steven Chu's lab, where he will visit again this summer to continue the project with Chu and his team.

Using optical tweezers on individual molecules takes finesse. The tweezer's twin laser beams cannot simply grab onto either end of a slinky DNA molecule. So the Stanford tweezer operators must first glue each DNA molecule, via a trio of off-the-shelf intermediary biochemicals, to a pair of polystyrene beads, each about 0.5 micron in diameter. A focused beam of laser light then immobilizes each bead, much as a stream of air levitates a ping pong ball in one spot. By steering the beams apart, the researchers can stretch the 15 micron, 18,500 base pair, segment of viral DNA they used in their study to its full extension.

The Stanford crew has used the optical tweezer technique, first suggested in the 1970s by Arthur Ashkin of AT&T Bell Laboratories, to measure fundamental polymer properties—in this case the "persistence length" of individual DNA molecules. "This is a measure of the wiggliness" of a polymer molecule, says Steven Block, an optical tweezers aficionado at the Rowland Institute for Science in Cambridge, Massachusetts. In turn, DNA's persistence length can serve as an indicator of the shapes it can wiggle into. Quake reported that his team had arrived at a value near 500 angstroms for the double helix's persistence length. Chu notes that similar values previously determined by other experimentalists using measurements on huge populations of DNA molecules vouch for the validity of the new single molecule method.

"This technique has obvious extensions to other molecules," including other biopolymers, notes Block, who previously used optical tweezers to study individual kinesin molecules, a mechanoenzyme involved in the transport of cellular paraphernalia along microtubules. With optical tweezers, it appears, you can get up close and personal with a variety of molecular individuals.

–*Ivan Amato*