Of Brilliant Galaxies and Gamma-ray Flashes

Seattle was the setting last week for a meeting of the American Astronomical Society (AAS), where 1000 astronomers assembled to hear early results from one space mission, the Gamma Ray Observatory (GRO), late results from another, Astro-1, and ongoing findings by the Hubble Space Telescope and earth-bound observatories. Active galaxies and gamma-ray-bursters—among the universe's most energetic inhabitants—provided highlights.

Grand Unified Galaxies?

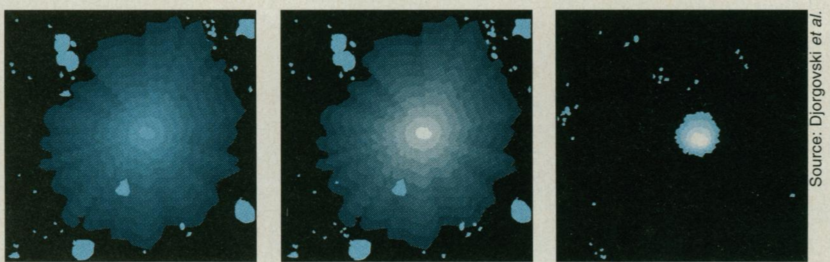
In his book *Infinite In All Directions,* physicist Freeman Dyson divides scientists into two types, diversifiers and unifiers. Most scientists are diversifiers, making discoveries that add one more species, particle, or heavenly body to the banks of knowledge. But a few invent the rules that pull diverse things together.

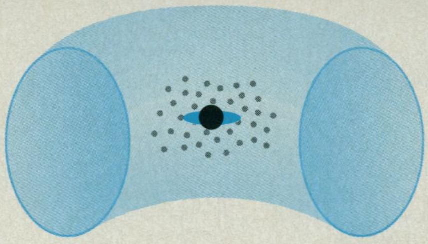
In astronomy, diversifiers have catalogued a zoo of unusual and energetic "active" galaxies—quasars, powerful radio sources known as radio galaxies, and several kinds of Seyfert galaxies, distinguished by bright centers and strong emission lines. But at the AAS meeting, two groups of astronomers presented evidence favoring a "grand unified theory of quasars"—so-called as a play on physicists' effort to create a single theory uniting all fundamental particles and forces.

According to the proposal, all of the various radio and Seyfert galaxies may actually be quasars in disguise. Known quasars, which include the most distant and energetic objects in the universe, are thought to be galaxies whose light is dwarfed by the brilliance of a central region no bigger than our solar system. Most scientists think the energy comes from matter being devoured by a massive black hole.

In recent years, astrophysical unifiers had speculated that radio and Seyfert galaxies may have that same kind of "central engine." But they had little hard evidence for the notion. Now, groups led by S. George Djorgovski of the California Institute of Technology and Andrew Wilson of the University of Maryland have independently presented evidence that the same focused, brilliant source that is the hallmark of quasars does lurk in several radio galaxies—albeit shrouded by a thick cloud of dust.

To peer into the dusty centers of their target galaxies, both groups examined them at infrared wavelengths. The Wilson group, using the United Kingdom Infrared Telescope on Mauna Kea, concentrated on a radio galaxy called Cygnus A. Working with the 200-inch telescope at Mount Palomar, Djorgovski and his colleagues trained an infrared detector on Cygnus A and seven





A quasar revealed? *The longer the infrared wavelength, the clearer the point source inside Cygnus A becomes* (top). *A doughnut of dust may be shrouding the quasar* (above).

other radio galaxies. Says Wilson: "The infrared light [allowed] us to see right into the middle," revealing small, energetic cores in Cygnus A and in four other galaxies examined by the Djorgovski group.

But the infrared pictures alone don't say whether these central sources emit enough energy to qualify as quasars. To find out, both groups extrapolated from the infrared observations. By comparing the brightness of the galaxy cores at two infrared wavelengths that are differently affected by dust, the researchers could estimate how much of the visible light was being blocked by dust. For the objects they studied, both groups calculated that the dust was dimming the light by a factor of 10^{21}. Correcting for the dust, Djorgovski says, suggested sources bright enough to be quasars.

Why are some quasars visible while others are hidden by dust? According to Wilson and other unifiers, the central engine in all types of active galaxies might be surrounded by a dust cloud that is flattened by rotation and hollowed out at the center by the power source. The result is a vast dusty doughnut encircling the black hole and the bright, turbulent material near it. What astronomers see, says Wilson, depends on the orientation of a galaxy—whether it allows them to look directly down the hole or forces them to peer through the side of the doughnut.

Looking down the hole to the central engine, they see bright light in all wavelengths. They may also record broad spectral lines, characteristic of the fast-moving material whipping around the black hole. The galaxy would then qualify as a quasar or one of the closely related subtypes: a "broad-line radio galaxy" or type 1 Seyfert galaxy. In a side view—as with Cygnus A and its kin—the dust screens out all but the longest wavelengths of light and blocks the view of the turbulent broad-line region. The object then appears as a narrow-line radio galaxy or Seyfert type 2.

Not all astronomers are ready to accept that picture, or the evidence the Djorgovski and Wilson groups presented in support of it. But if the unifiers are right, the burgeoning astrophysical zoo would, for once, have gotten a little more manageable.

GRO's Verdict: Gamma-ray Bursts Lie Close to Home

If you had a seat above Earth's atmosphere and an eye for gamma rays, you would be dazzled every day or so by an immensely powerful burst of energy, flaring briefly from an unpredictable direction in space. Some of these gamma-ray bursts flicker on for just a fraction of a second. Others shine for a few minutes. "There is nothing else out there like them," says Gerald Fishman, an astrophysicist at NASA's Marshall Space Flight Center in Huntsville, Alabama. "During their brief appearances, they outshine all other gamma-ray sources in the sky."

From its vantage in space, NASA's Gamma-ray Observatory (GRO) satellite has spent the past few weeks cataloguing gamma-ray bursts. Now, at least one of their many mysteries seems to be yielding. Though astronomers first discovered gamma-ray bursts 30 years ago, no one could tell whether they came from within our own galaxy or millions of light-years away from some distant galaxy or galactic cluster. But Fishman announced at the AAS meeting that detectors aboard GRO are locating the bursts within our own galaxy.

The GRO observations—among the first to be made by the satellite, which was launched just 2 months ago—confirm French-Soviet results announced in the 23 May *Nature*. That report, an analysis of observations from the Soviet spacecraft Phobos and Venera 13 and 14, showed that the bursts tend to be aligned with the plane of the galaxy—a strong sign that they probably lie within the Milky Way.

The new evidence bolstering that conclusion comes from one of GRO's four experiments, the Burst and Transient Source Experiment (BATSE). Fishman, the chief investigator, and his colleagues designed BATSE's array of eight detectors specifically to pick up gamma-ray bursts from all directions. "We are detecting gamma-ray bursts with greater sensitivity and accuracy than ever before," he says.

GRO hasn't yet confirmed that the bursts fall within the plane of the galaxy. The new evidence suggesting that the bursts are indeed coming from close by has to do with their brightness rather than their positions.

Fishman explains that if the bursts were spread evenly through space at all distances, the sensitive BATSE should pick up many faint ones—corresponding to more distant bursts—as well as stronger, nearer ones. "We would have seen about 50 little ones per day," he says. Instead, BATSE picks up only really big bursts. The number of detected bursts falls off quickly at lower intensities, he says, suggesting that the sources all lie within a certain distance from Earth. What is penning in the bursts, he says, is probably the edge of our galaxy or the halo of material around it.

Learning where gamma-ray bursts come from is only the first step for astronomers. They also want to know what causes them. Some speculate that the bursts come from huge thermonuclear explosions of unknown origin. Others say that comets or asteroids plunging into neutron stars could trigger bursts. Still other theorists favor neutron stars but propose a different mechanism: cataclysmic neutron "starquakes" that release a blast of gamma rays as the dense, solid neutron material cracks and shifts. One astronomer at the conference remarked that a new theory springs up for every burst that goes off. Only more data will help astronomers sort out the speculative tangle.

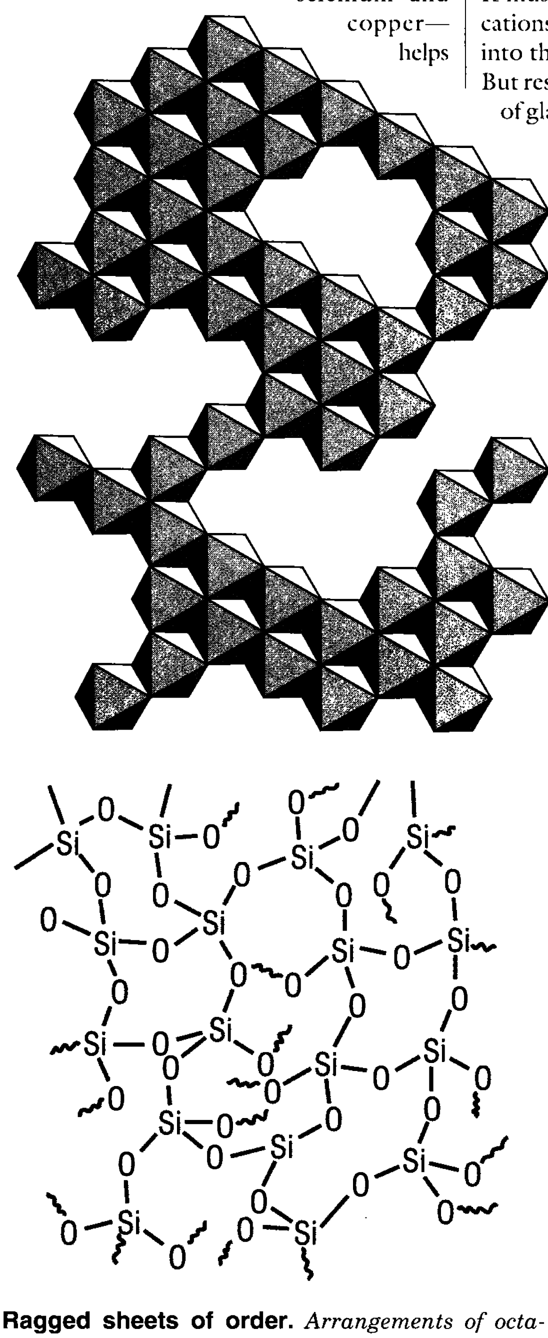
GRO promises to provide that data in short order. Fishman says his experiment is already distinguishing different types of events. Some give off a single flash, while others flicker. At this rate, many astronomers believe GRO will help them solve the gamma-ray burst mystery within a year.

■ FAYE FLAM

A New Order in Glass

A beam of neutrons has helped blur some traditional distinctions between glass and crystal

BRITISH CATTLE FARMERS SOMETIMES GIVE their animals a strange addition to their winter feed: glass. With grazing scaled back or on hold during the cold months, the livestock need some extra trace nutrients, and the glass—specially formulated thumb-sized pellets laced with elements such as selenium and copper—helps provide them. Lodged in the animals' stomachs, the pellets release their cargo of dietary trace minerals as they slowly dissolve all winter long.



Ragged sheets of order. *Arrangements of octahedral clusters* (top), *each made up of a calcium atom and six oxygens, may add order to the otherwise unkempt structure of silicate glass*(above).

Though the practice seems to work, exactly what sets the pace of this controlled dissolution remains somewhat mysterious. It must have something to do with the way cations (positively charged ions) are locked into the molecular architecture of the glass. But researchers have had only a blurry image of glass microstructure, which governs this chemical choreography together with many other glass properties. Traditionally, glasses have been viewed as amorphous solids—substances whose molecular architectures lack the rigid geometric symmetries of crystals but instead are made up of a riot of disorderly molecular liaisons, rather like a liquid in arrested motion. Given that picture, a search for more discernible structure in glass seemed doomed to fail.

But now University of Cambridge physicist Philip Gaskell, working with Pilkington plc, the British-based glass company that makes the glass cattle pellets as a minor specialty product, has spotted some islands of order in the widespread disarray of glass. That's just the kind of observation that could help materials scientists at Pilkington and elsewhere design advanced glass products with far more finesse. In the 25 April *Nature*, Gaskell and his colleagues at the Institut Laue-Langevin in Grenoble and the University of Bristol report that the order prevails on intermediate scales—over distances of several atomic or molecular units. So striking is it, the researchers say, that they now think some of the same rules underlying crystal structure apply to glass as well.

The finding does more than just upset the traditional view of glass as a veritable molecular cacophony, says geophysicist and glass researcher Raymond Jeanloz, who has seen his own hints of order in glass. Because knowing the microstructure of a material is a route to