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

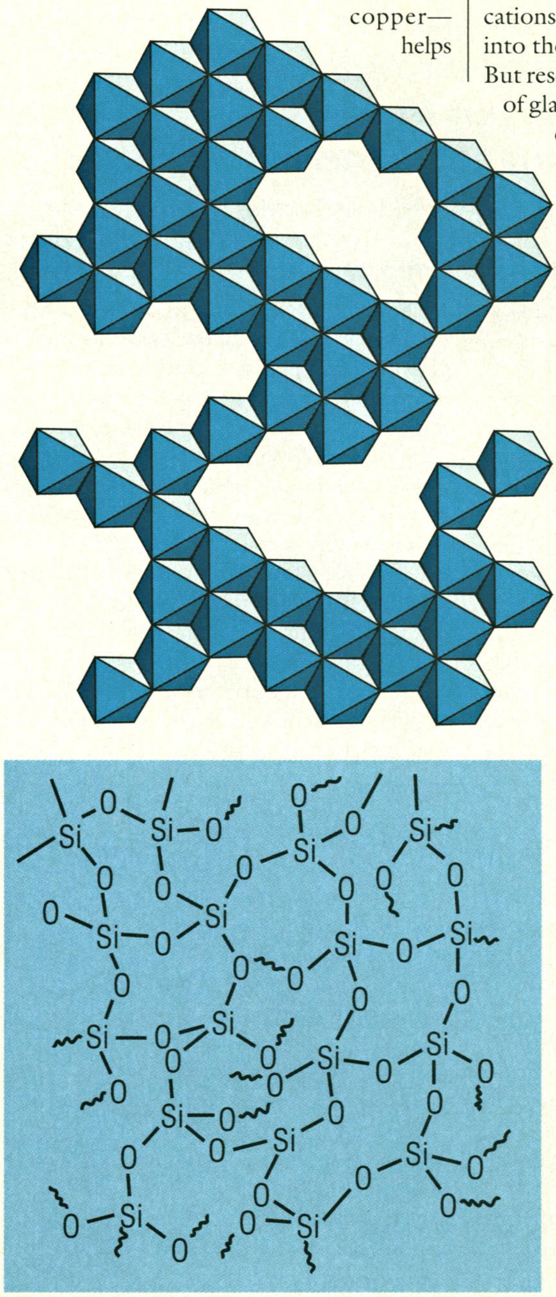
A beam of neutrons has helped blur some traditional distinctions between glass and crystal

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.

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



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).

power over it, Jeanloz thinks the new, more detailed microstructural blueprints could point the way to new uses for glass. If glasses do turn out to have a more predictable and controllable microstructure than was thought, new ways might open up to tailor them for such uses as entombing nuclear waste until kingdom come, filtering and steering light in optical systems, and carrying currents in batteries—not to mention keeping cattle well nourished.

To be sure, materials scientists have already empirically discovered ways of precisely controlling many properties of glass, says senior research associate Nicholas F. Borrelli of Corning Inc. "Glass is being continuously engineered," he says. But that engineering power can only increase with more precise understanding of glasses' microstructure. So why is previously unrecognized molecular order in glass only now coming to light?

> ***"Normally glass is considered a random network, but that really is a misnomer."***
>
> —Nicholas Borrelli, Corning Inc.

Quentin Williams, a mineral physicist at the University of California in Santa Cruz, thinks scientists have been blinded by the obvious differences between glasses and crystals. X-ray crystallography, the standard technique for studying crystal structure, highlights the disorder of glasses. When x-rays are bounced off a crystal's extensive atomic or molecular planes, they emblazon orderly patterns onto film, which researchers can interpret as a detailed crystal structure. Similar treatment of glasses yields diffuse patterns, indicating that glasses lack the long-range order of a crystal—the endless repetitions of a regular atomic or molecular geometry. Smaller patches of order lie beyond the reach of x-ray crystallography to resolve, but researchers have generally assumed that the disorder of glasses is pervasive, extending virtually down to the smallest scales. "When you don't know anything, you assume the least," says Gaskell.

Gaskell and his colleagues got a finer-scale look at glass structure by turning to neutrons. Neutrons produced in a reactor in Grenoble were beamed at samples of silicate glass little different from the material that rattles in six-packs and sheathes skyscrapers. This common glass consists mostly of tiny silicate tetrahedra—one silicon atom surrounded by four atoms of oxygen(SiO_4)—interspersed with additives such as soda (sodium oxide) and lime (calcium oxide) that make the glass more workable and durable. For the purpose of neutron analysis, Gaskell and his colleagues laced each of their samples with one of two different isotopes of calcium (in the form of calcium oxide) or an equal dose of both. Neutrons scatter differently depending on a material's isotopic composition, but by comparing the scattering profiles of the three sample types, the researchers were able to infer how neighboring calcium atoms were arranged over intervals as large as 8 angstroms, or several atomic spacings.

That purview, though diminutive, was enough to let the researchers see that the molecular architecture of glass at these scales is far from random. "Now we have seen evidence of ordering at these intermediate ranges," says Gaskell. "It is more extensive than we had imagined." Indeed, they say, it's almost crystalline.

The neutron scattering studies of the calcium silicate glass show that the separation between nearest-neighbor calcium ions in the glass samples (.38 nm) is close to the calcium-to-calcium distance in $CaSiO_3$ crystals (.36 nm), which have nearly the same chemical composition. A longer distance (.64 nm) that showed up in the neutron scattering data most likely corresponds to the separation between every second calcium.

After considering the structures that might host such inter-calcium distances, the researchers concluded that each calcium ion lies at the center of an octahedron with oxygen atoms at its six vertexes. The finding that the calcium ions maintain a consistent spacing over distances of several atomic neighbors suggested that the octahedra, in turn, form orderly arrays. Gaskell and his colleagues think that, as in crystalline $CaSiO_3$, the octahedra link together by sharing edges. Instead of assembling in the endless three-dimensional array of a crystal, though, they make up sheet-like oases of order scattered through a silicate ocean.

Having identified these patches of order, Gaskell notes, "We can now start to determine the possible structures that the glass could have." As a working hypothesis, Gaskell and his co-workers propose that their silicate glass samples consist of "essentially parallel" sheets of octahedra interleaved with extensive silicate networks. Tears and buckles in the sheets and differing degrees of connectivity between them keep the intermediate-scale order of the material from summing to long-range order; on scales larger than a few molecular neighbors, disorder still reigns.

So far, the most detailed picture of intermediate-scale order comes from silicate glass, but Gaskell's team has also done neutron scattering from other glassy materials and come up with similar results. Intermediate-scale order in glasses may be a rule and not an exception, Gaskell suggests.

Jeanloz has caught glimpses of that kind of order himself. Last year, he and a graduate student reported an observation they made while transforming a single crystal of a material into a glass by squeezing it in a high-pressure cell. When they eased the pressure, the "amorphized" sample reverted to exactly the same single-crystal form it had started with, as though it had retained a "memory" of its previous structure. Such a precise structural round-trip could only happen, Jeanloz contends, if the amorphous (glassy) and crystal forms of the material were "very closely related."

For Borrelli of Corning the report of memory glass and the neutron scattering data come less as a surprise than as confirmation of a long-held suspicion. "Normally glass is considered a random network, but that really is a misnomer," he says. In crystals, the angles between the bonds linking atomic or molecular building blocks are identical throughout the material; in glasses they vary, and that's the key difference, Borrelli says. So he thinks it's natural to view glass not as an entirely different structure from the corresponding crystal but simply as a deviation from it. Even so, it's one thing to assume that a semblance of crystalline order exists in a glass and it's another to show it experimentally, notes Jeanloz.

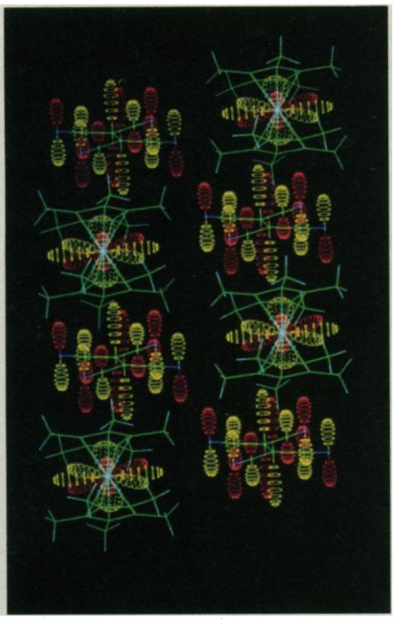
The work by Gaskell and his colleagues challenges not only glass theory but also some of the received wisdom of the glass-making business. "Cations [such as calcium and sodium] had been viewed as network disrupters," Williams says. The calcium ions in ordinary glass had been seen as saying no to crystal formation—which would make the resulting material hard to shape—by interfering with bonding between silicate tetrahedra and occupying vacancies in the resulting network.

But the discovery of intermediate-range structural order in those very same ions throws doubt on this "structural vandal" interpretation of calcium and kindred ions. Rather than playing second fiddle to the silicate network, they might be actively involved in forming orderly structures within the glass, dictating the locations of nearby atoms. "It now looks as though they may have a very definite structure directing role," Gaskell notes. That kind of observation, he and his colleagues hope, may be a first step toward orderly glasses made-to-order. ■ IVAN AMATO

Some Molecular Magnets Like It Hot

When Joel S. Miller and Arthur J. Epstein first measured the properties of a new material they had synthesized, they thought their instruments weren't working properly. They appeared to have created an organic-based magnet that stays magnetic at room temperatures and above—hundreds of degrees higher than the temperature record for previous so-called molecular magnets. As they report on page 1415 of this issue, they soon became convinced that their measurements were correct and that they had indeed produced an extraordinary material.

Epstein, a physicist at Ohio State University in Columbus, and Miller, a chemist at DuPont's Central Research and Development facility in Wilmington, Delaware, think their finding may point the way to new magnetic materials for applications such as lightweight motors and data storage devices. But whether this particular material turns out to be a technological boon or a dud, its discovery presents researchers with both a hefty scientific mystery and a host of new research opportunities. "This is the type of breakthrough that changes the way people do their work," predicts Epstein, who measured the new material's magnetic properties after Miller and his DuPont colleagues synthesized it.


Miller *et al.*

Favorable alignments. *A computer image shows the aligned orbitals that are the basis of magnetism in a TCNE-based molecular magnet related to the new material.*

Epstein's comment may seem a little immodest, but the high-temperature magnetic material the team has described could be a prize quarry. Compared to traditional magnets, magnets based on molecules might offer far more options for improving specific properties such as mechanical strength and ease of processing—especially if they could be made from organic polymers having the versatility of plastics. Ordinary iron and alloy magnets are made of atomic constituents, which are hard to modify, but molecules can be tailored more freely. That design advantage has spurred an international quest for molecular magnets that has lasted nearly a decade.

Some molecular magnets have already been devised, but their magnetism survives only at temperatures within a few degrees of absolute zero. Warmer temperatures tend to break up the cooperative alignment of electron spins that is the basis of the materials' magnetism. But the DuPont workers have made a material that retains its magnetism even at the temperature of a sauna. The new concoction is still magnetic at 350 K, the temperature at which it starts to break down chemically. Besides suggesting that these materials could survive in the real world, inside tape decks and on optical disks, that dramatically higher temperature may betray previously unknown physical mechanisms underlying the magnetism, notes Miller.

"If this is indeed a molecular magnet, it would be an enormous leap," adds Brian Hoffman, who works on related molecular magnets at Northwestern University. "No one has even come close [to 350 K]."

Miller's team of chemists expected something more pedestrian when they combined tetracyanoethylene (TCNE), a favorite electron-accepting compound among molecular magnet makers, with an electron-donating vanadium ingredient [bis(benzene)vanadium] that resembles a manganese compound used in some of the best molecular magnets to date. In the ensuing reaction, each molecule of the vanadium compound transferred an electron to a TCNE molecule and shed its benzene components, leaving isolated vanadium atoms. Each vanadium joined with a pair of TCNEs (and a number of solvent molecules) to form a black, noncrystalline solid. When the researchers saw that, at room temperature, the product was sticking to the magnetic stirring bar in the reaction vessel, they knew immediately that they had made an uncommon material. Their surprise only grew when they learned just how high its magnetic transition temperature was.

> ***"If this is indeed a molecular magnet, it would be an enormous leap."***
>
> —Brian Hoffman,
> Northwestern University

At the moment, the researchers can merely shrug their shoulders when it comes to explaining the tantalizing magnetic behavior of their product. But they speculate that the electrons cooperate to produce a brand of magnetism known as ferrimagnetism—the same kind as in magnetite (Fe_3O_4)—which results from two unequal sets of electrons with opposite spins. But the material's disorderly molecular structure has so far prevented Miller and Epstein from rigorously testing that hypothesis by using x-ray crystallography to examine the magnet's microscopic architecture.

Hoffman doesn't doubt that the team has come up with a remarkable new magnetic material. "But their approach still may not be a route to good molecular magnets," he cautions. For technological applications, the material would have to be cheap to make, chemically and physically stable, easy to process, or superior in some other way to existing materials that hold their magnetism at ambient or higher temperatures.

Miller concedes that "this may never reach the guy in the street." The material has several drawbacks that will relegate it to the research arena, at least for a while. For example, exposure to anything but an inert atmosphere like argon makes the material "go poof," immediately annihilating its magnetism.

But one thing at a time, Epstein says. If the team has indeed made a room-temperature molecular magnet, lack of a technological punch line would not necessarily mean the end of the story. What is more important, the researchers may have found a chemical pathway to other molecule-based magnets that might fit the high-tech bill. ■ IVAN AMATO