project from the Department of Energy and associated laboratories. The rest came from private industry.

Physicists and educators had different reasons for deciding that the time was ripe for Priebe's idea. While teachers such as Priebe see an immediate need in the classroom for a guide to the subatomic world, physicists such as Quinn say the chart is warranted by the current state of knowledge. "The information in this chart is pretty solid now," she says, "but it was in a state of flux just 15 years ago." Thanks to recent discoveries, Quinn says, the basic framework of the chart should endure the way the 100-year-old periodic table has.

It had better: Already more than 1500 requests have come in from schools around the country for the chart and the explanatory software, a hypercard program that allows students to wander around within the material, sampling it through graphics and sound effects.

The image that is beginning to decorate classroom walls is the picture of the structure of the atom, vintage 1991, together with the forces that hold it together—what is known as the standard model. The old solar-system electron orbits have given way to a blurry cloud, and the billiard-ball neutrons and protons of the nucleus have dissolved into fuzzy regions containing three quarks each. Flanking this thoroughly modern atom are tables of particles, with the familiar proton, neutron, and electron taking their places among more exotic and unstable particles only observed in accelerators and cosmic rays.

It all looks a little daunting for high school students, and Priebe says his classes thought so too—but only when they got their first look at the chart. "The students were negative and confused at first," he admits. "But once they got started they found it really interesting."

In fact, teachers can turn out to be a bigger obstacle than students, says Priebe. "Many teachers at the local level are rather stodgy," he says. "While we like to teach others new things, we don't like to be confronted with things we don't know ourselves."

For any teacher who disagrees with Priebe's self-characterization, a copy of the chart is available from CPEP (Mail Stop 50-308, Lawrence Berkeley Laboratory, Berkeley, CA 94720).

P.S.: Some Ph.D.s are decorating their laboratory walls with the chart as well. Barnett says as many requests have come in from physicists as from teachers.

■ FAYE FLAM

Liquid Crystals Meet the Cosmos at APS Meeting

The diversity of physics was much in evidence when 1500 physicists assembled in Washington, D.C., last week for the spring meeting of the American Physical Society (APS). But so was the emergence of unexpected cross-disciplinary links—between computer science and atomic physics, between the behavior of liquid crystals and constructs of theoretical physics such as the Higgs field. To emphasize the relevance of diverse areas to one another, the APS designated the second day of the conference Unity Day.

Atoms for Logic

Vaporized cesium atoms may not seem the obvious material for building something as precise and solid as a computer. But enclose the vapor in glass and replace the electrons that course through a conventional computer with laser light, and you could have an element in a future optical computer, says Randy Knize of the University of Southern California. He underscored the point at the APS meeting by describing how he built a logic element known as a "NOR" gate—a basic computer component—from vaporized atoms.

The NOR gate, which transmits an output signal only when it receives neither one *nor* the other of two possible inputs, enjoys a special status among logic gates: If you can build a NOR gate using a given technology, you can also make any other kind, Knize says. And, "If you can make a NOR gate you can make a computer."

Most of the other researchers competing on designs for optical computers plan to build their logic gates from more conventional, solid materials such as silicon. But a glass cube containing a thimbleful of cesium vapor could perform millions of operations simultaneously, far more than could be packed into an equivalent volume of silicon, Knize says. That's because many different beams of light could play through the cesium vapor at the same time, creating myriad separate circuits—a feature that could be a boon to designers of parallel computers. What's more, according to Knize, making cesium circuits is a breeze compared with the expensive and complex process of etching thousands of minute circuits on a chip. "It's so simple even an undergraduate could build one of these," he says.

The vapor NOR gate opens and closes as the atoms switch between absorbing a main beam of circularly polarized laser light and letting it pass through as output. The gate stays "on," transmitting the beam, as long as neither of two other input beams strikes the cesium. Switching on either one of the inputs increases the absorbing power of the vapor and shuts down the gate.

The paradox on which the gate is founded—more light in equals less light out—is a product of the way the cesium atoms respond to circularly polarized light. When a single beam polarized in one direction strikes the atoms, they absorb a certain amount of it but allow the rest to pass through. Add one or two additional beams that include some light polarized in the opposite direction, though, and some of the atoms flip into a state in which they can absorb the remainder of the original beam. The gate goes from "on" to "off."

Knize's circuit may be ethereal, but he thinks the prospect of a cesium-vapor computer is hardly a will-o'-the-wisp. "We're a long way from a real computer, but at least I think were on the right track with the concept," he says.

■ FAYE FLAM

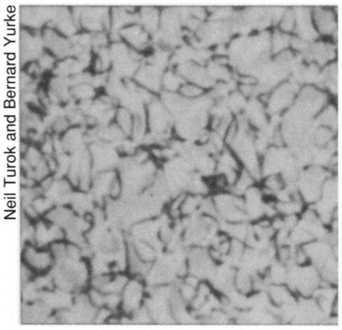
A Long Look Into a Liquid Crystal Ball

A group of scientists has looked into the shimmering fluid of a liquid crystal and has glimpsed the beginning of time. In the sudden aligning of the crystal's rodlike molecules, the researchers see the abrupt symmetry-breaking that is thought to have differentiated an expanse of indistinguishable mass-energy into distinct particles driven by separate forces during the first split-second of creation. In the flaws that mar the molecules' alignment, they see the grand defects that pulled matter toward some areas of space, allowing it to coalesce into stars, galaxies, planets, and scientists.

At the APS meeting Isaac Chuang and Bernard Yurke, solid-state physicists at AT&T Bell Laboratories, and Neil Turok, a cosmologist at Princeton University, described how they created this microcosm in a layer of the liquid crystal known commercially as 5CB. Their cosmic model—a layer of liquid crystal sandwiched between two sapphire windows—took advantage of the same rapid phase changes that let the liquid crystal readout of a digital watch keep up with the time. Monitoring the crystal with a video camera hooked up to a microscope, the researchers watched these rapid transformations as well as the ensuing slower evolution, which is also of great cosmological interest.

At high temperature and low pressure, the rods of 5CB lie scattered at random, like a disordered pile of logs. Cool and squeeze the layer of liquid crystal, and the system changes phase. It stays liquid, but the rods start to line up. Suddenly the system has a compass: one direction is different from the next. The symmetry of the system is broken, as cosmologists say.

Neil Turok and Bernard Yurke



Seeds of structure. *A fine network of defects in a liquid crystal evolves into a larger scale pattern, perhaps mimicking the early evolution of the cosmos.*

Symmetry breaking just after the beginning of time made the universe what it is today, explains Turok. Without symmetry breaking, all matter would be indistinguishable. The sudden direction-finding mimicked by the crystal, says Turok, may actually have taken place in a posited medium called the Higgs field.

"The Higgs field doesn't point in any direction in space," Turok says, "but it does come with a sort of internal direction." Back when the field was symmetrical, he explains, particles such as the electron and the neutrino were indistinguishable. Breaking the symmetry pointed the field toward the electron, endowing it with mass and charge.

Just as is thought to have happened in the early universe, the shock of symmetry breaking in the liquid crystal introduces a web of imperfections, where the perfect alignment of rodlike molecules breaks down. Yurke and his colleagues identify four kinds of defects in their crystals: monopoles, strings, walls, and textures. A monopole is a point defect surrounded by radiating rods, like a starburst or a hedgehog. A string is a line bristling with misaligned rods. A wall is a sheet-like boundary, while a texture has a more complicated form—somewhat like a knot, Yurke suggests. Symmetry breaking in the crystal even spawns such exotic creatures as monopole-antimonopole pairs, which seek out and annihilate each other.

The names of these liquid-crystal flaws will be familiar to cosmologists; as Turok explains, they are all thought to have formed in the first split second after the Big Bang. Believed to have seeded the evolution of large-scale cosmic structure, they remain with us to this day.

The cosmic flaws may have changed with time, though, as the evolution of the crystal patterns suggests. After the symmetry breaking, the network of defects gradually loosens up, spreading out into bigger defects with bigger gaps in between. The overall pattern doesn't change, Turok says, only its scale, just as if smaller and smaller pieces of the pattern were being magnified. In mathematical terms, the liquid crystal's evolution is self-similar.

Cosmologists have predicted self-similarity in the evolution of the cosmos, but they have never had a real-world model of the process—until now. Yurke and Turok say their liquid crystal representation of the cosmos is the first of its kind. In 1985, one other group of researchers did consider a similar effort, though they never carried it out. Wojciech Zurek and his colleagues at the Los Alamos National Laboratory proposed using the vortex lines that form when liquid helium is compressed to approximate the evolution of cosmic defects.

Turok rates the self-similar evolution of flaws as the most cosmologically interesting result of the new model. But he and Yurke say the liquid crystal also adds some substance to abstract thoughts about the still theoretical Higgs field. In an area of physics that's long on abstractions, their simple model is bound to come in handy, they think. "Theorists often try to make things as simple as possible, but the real thing may be much more complicated," says Yurke. "By looking at the liquid crystals you can find new possibilities you never imagined before." ■ **F.F.**

Shadows in a Sea of Hot Gas

In the months since it was launched last summer, the German-British-U.S. Roentgen satellite (ROSAT) has been imaging high-energy x-rays, mostly from sources well outside our galaxy, such as quasars. But recently the satellite's x-ray eyes have been scanning the sky in search of lower-energy, or "soft" x-rays, many of which have sources closer to home. According to a report presented at the APS meeting, ROSAT has seen evidence that the Milky Way may be awash in a sea of gas at a temperature of a million degrees.

For some astronomers, that finding comes as a vindication. For years it has been known that the earth is bathed in a glow of soft x-rays, presumably coming from a tenuous hot gas in interstellar space. But the location of the gas has been a mystery. Some observers assumed it was unique to our solar neighborhood, but others thought that the x-ray-emitting gas might pervade the entire galaxy.

The new ROSAT results suggest there may be nothing special about our part of the galaxy. The key evidence suggesting that very hot gases are distributed throughout the galaxy is a patch of shadows on a background of soft x-rays. Jürgen Schmitt of the Max Planck Institute in Garching, Germany, and Steven Snowden of the University of Wisconsin noticed that the shadows matched the position of a giant molecular cloud—a cool cloud of interstellar gas—some 1800 light-years away.

The researchers think the cloud is blocking a distant source of x-rays. "The fact that we see shadows," Schmitt argued at the APS meeting, "means the [soft x-ray] emission can't come from nearby." But the source is unlikely to be outside the galaxy: It was known from pre-ROSAT surveys that the Magellanic Clouds, satellite galaxies of the Milky Way, leave no shadows on the background. That leaves a widespread haze of hot gas within the Milky Way as the most likely source.

So far the ROSAT team has seen the x-ray shadows in only one direction—but that's as far as they've looked. According to Chris McKee of the University of California at Berkeley, who had predicted that hot x-ray-emitting gas would be widespread, he and his theorist colleagues are eager to see the result confirmed for other directions, which would pin down the galaxy-wide distribution of the gas.

Then theorists will have to face the obvious next question: Where does the hot gas come from? Supernovas are the current best guess, according to McKee. Their shock waves may heat the cooler gas known to pervade the galaxy, or they might supply the hot material directly when groups of supernovas throw off fountains of superheated ejecta. ■ **Ann Finkbeiner**

Ann Finkbeiner is a free-lance writer based in Baltimore.