thing first." But two daunting problems are forcing him to start small. A WIMP would move through the material of any detector like a bullet in a difficult shooting gallery, rarely touching a target. Unaffected by the forces that act on ordinary matter, the WIMP would register in the detector only when it ricocheted directly off a nucleus or an electron. That means that any WIMP detector will have to search for a faint signal. And—problem number two—the search will have to take place against a dense background of misleading events, created by cosmic rays and natural radioactivity. No one design is certain to work, so Smith is working on designs for a half-dozen different detectors. Among the furthest along, he says, is a cylinder-shaped crystal of sodium iodide that would record a flash of light—called a scintillation—if hit right in a nucleus or electron by a WIMP. If all goes well, he says, that detector might capture about one WIMP count per day.

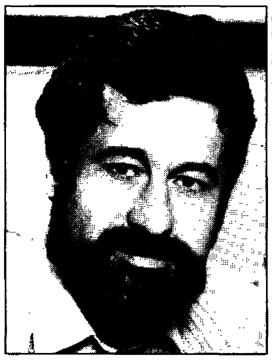
Sorting WIMPs from chaff

To avoid swamping the detectors with cosmic rays, Smith plans to stage his WIMP watch 1100 meters underground at the bottom of a salt and potash mine on the northeast coast of England. And to protect them from natural radioactivity in the rocks, he will shield them with hundreds of tons of pure water. But even the materials in the detectors will generate confounding signals. "Most materials are 10,000 times as radioactive as you can tolerate," he says.

Because these problems are so frustrating, Smith says he will launch his dark matter search in two stages. In the first stage, he explains, "We can make a start and learn something about the background, about the materials, about working in the mine." For the second stage he will use detectors with the ability to sort out more of the background junk from his real signal. His competitors in Berkeley and Gran Sasso, however, are plunging ahead to this second stage, hoping to snare conclusive results.

The Berkeley group was encouraged to take this bold approach by their discovery last spring that they can filter out most of the background events by searching simultaneously for two different WIMP signals in crystals of germanium. One test involves the detection of vibrations, or phonons, triggered by passing WIMPs. To pick up these faint signals, the Berkeley group cools the crystals to 20 millikelvin—just above absolute zero. The cold makes the detectors sensitive to the minute vibrations that should result if a WIMP blunders into a nucleus or electron. The second test looks for a small pulse of ionization that should also traverse a crystal when a passing WIMP nudges an electron or a nucleus.

In combination, says Berkeley team member Tom Shutt, these signals can distinguish real dark matter sightings from most of the unwanted background events. The key, explains team member Betty Young, is the proportion of phonons to ionization. That value changes depending on whether the intruding particle has ricocheted off a nucleus or an electron in the crystal. WIMPs should create a high nucleus-hit value, and background radiation, a high electron-hit value.



UC BERKELEY

RUTHERFORD-APPLETON LABORATORY

WIMP hunters. Bernard Sadoulet of Berkeley *(left)* and Peter Smith of England's Rutherford-Appleton Laboratory.

The Berkeley scientists recently demonstrated this discriminating ability by comparing their detector's response to a beam of neutrons (surrogates for WIMPs) and natural radioactivity. The test showed that the sensor was able to tell the difference between the two. With that breakthrough, Young says, she and her colleagues are within months of setting up the equipment. At least at first, they won't be going as deep underground as Smith; their early runs will take place in a 20-meter-deep hole at Stanford. With the detectors' powers of discrimination, Young says, that should be deep enough "to get a really meaningful experiment."

Other groups around the world are edging up to the starting line. Another entrant in the race is a group of Stanford scientists who will be sharing an underground facility with the Berkeley group, says Young. The Stanford team, led by physicist Blas Cabrera, has devised yet another kind of detector, based on silicon crystals coated with fine lines of superconducting material that should lose their superconducting ability, or "go normal," with the slightest nudge in temperature—even just the whisper of a WIMP. Yet another entrant is a group from the University of Milan, led by Ettore Fiorini. Its detector, already set up at Gran Sasso, is designed mainly to detect a rare radioactive process known as double beta decay, but Fiorini says that the device might also be sensitive to WIMPs.

Once the detectors are in place in their mines and tunnels, the waiting game will begin. "It could take 10 years," says Smith. But one brush with a WIMP, he says, would make it all worthwhile. To get a sense of why, says MIT's Bertschinger, "remember all the elation surrounding the results from the Cosmic Background Explorer," the satellite that recently found unevenness in the pervasive background of microwaves believed to come from the Big Bang. "This will be four times as big," he says. "It will reveal to us the dominant component of matter in the universe."

"It would change physics," adds Fiorini. "I don't even dare to have such a hope." Like the others, Smith says he tries not to think too hard about the rewards. He recalls a story about a famous tennis player who played in the Wimbledon match and lost because he started thinking about his victory speech while still in the game. Smith says he wants to avoid that folly. "You don't think about winning until you've actually won."

–Faye Flam

INTERNATIONAL COOPERATION

A Match Made in Laser Heaven

As the world watched the dramatic political changes unfolding in the former Soviet Union over the past year, the last thing on the minds of most onlookers was how the upheaval might affect laser technology. But for physicists John Madey at Duke University and Vladimir Litvinenko, formerly of the Budker Institute of Nuclear Physics in Novosibirsk, Russia, the fall of communism may lead to a scientific dream come true—the opportunity to speed up development of what they hope will be the world's first tunable laser capable of operating in the very high ultraviolet (UV) and possibly even the x-ray range.

Today, after months of negotiations, Duke officials announced an agreement to bring a so-called free electron laser developed by Litvinenko and his colleagues in Novosibirsk to Duke, where it will be joined to an accelerator, developed by Madey and his colleagues, that would boost the laser's operating range into the far ultraviolet. If funding can be found to finance the move, the partnership should shave 2 years off the time it would have taken the Duke team to produce a tunable UV laser on its own, says Madey. He predicts that the machine will be up and running before the end of 1994, although that may not be soon enough to beat out some stiff competition from the big national labs at Los Alamos and Brookhaven, which also have tunable UV lasers under construction. Madey says those machines will have different technical capabilities and objectives, however.

But wherever a tunable UV laser comes from, it would be widely welcomed by both chemists and medical researchers. Although some conventional lasers operate in the high UV and x-ray ranges, no single conventional laser can operate over the entire range, which leaves large gaps in the available spectrum. So a tunable machine would offer unprecedented possibilities for spectroscopic analysis of chemical structures and reactions in the high ultraviolet range. Indeed, says Ilan Ben-Zvi of Brookhaven National Laboratory, "interest is on the rise everywhere in the scientific community. People see that [tunable] UV and x-ray [lasers] are around the corner and are thinking of new uses for them." In addition to their applications in basic chemistry research, the lasers might be valuable for laser surgery, making holographic images of subcellular structures, and etching extremely fine circuits on miniature computer chips.

Free-electron lasers (FELs) are so versatile because they lack the lasing material of conventional lasers, Madey says. In conventional lasers, energy is pumped into a chemical compound, like carbon dioxide, in such a way that its electrons absorb the energy and subsequently emit it in the form of light. The wavelength of the light emitted depends on the atomic structure of the material used. As a result, a conventional laser is generally limited to emitting just one wavelength of light.

But free the electrons from their atomic structures and it is theoretically possible for them to absorb and emit at almost any wavelength, from the lower infrared to the upper reaches of the UV range. That's the theory behind the FEL, which incorporates a cathode tube to generate a beam of pure electrons. Even so, far ultraviolet lasers have been hard to achieve, because so much energy must be pumped into the electrons to get them to emit such short wavelengths, says James R. Allen, who works with the FEL at the University of California, Santa Barbara. And that's where Madey's accelerator, which he built especially for use with an FEL, comes in.

The Russians had been operating their FEL with a storage ring built in the 1960s, which was not powerful enough to push the FEL beyond the low-to-middle ultraviolet. And in the current economic climate in Russia, says Litvinenko, it is unlikely that the Novosibirsk team would get the funds to develop their own storage ring. Hence the decision to move it to Duke. "Initially, when I came here," says Litvinenko, who has been at Duke since January 1991, "I had in mind that I could bring this [FEL] system [to Duke], but until the recent changes in Russia following the coup attempt, it wasn't possible."

But funding may also be a problem for the Duke group, which has yet to come up with the financing to move the Russian FEL and to support the subsequent research and development of their tunable laser. And on this score Madey is philosophical, saying that whether or not their efforts result in a new laser, the new openness between the Americans and the Russians is certain to provide valuable "intellectual cross-fertilization."

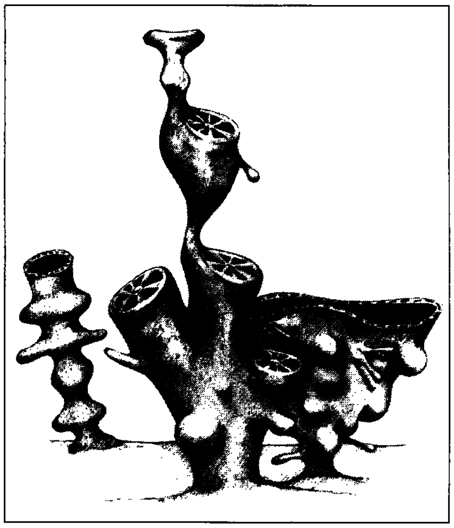
–Michelle Hoffman

PALEONTOLOGY

The Earliest Mass Extinction?

Surprises still turn up in the Cambrian explosion, the wild proliferation of marine life forms during the Cambrian Period beginning roughly 570 million years ago. It was a time when soft-bodied animals as well as those that had just learned how to form shells and exoskeletons seemed to go into an evolutionary frenzy, appearing in shapes both familiar and bizarre. By about 520 million years ago, life in the sea seemed to be on a roll. Then calamity struck, as University of California, Davis, paleobiologist Philip Signor recently reported to colleagues at the North American Paleontological Convention in Chicago. By Signor's reckoning, up to 80% of the existing genera of marine animals disappeared.

That would rank this early Cambrian extinction event, which Signor is the first to propose, with the five generally recognized mass extinctions of the past 600 million years—select company indeed. Each mass extinction marked a watershed in the evolution of life, in which whole groups of flora and fauna fell by the wayside, giving the survivors a chance to reign supreme for 100 million years or more.



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Lost in the Cambrian. During a major extinction 520 million years ago, sponge-like archaeocyathans (5 centimeters tall) were major victims.

Signor had not expected to find one of life's turning points as he compiled Cambrian fossil records scattered through the literature; instead he was trying to sort out which life forms coexisted in the early Cambrian. That meant deciding which of four subdivisions of the early Cambrian, called stages, each of 886 genera of marine animals fell into. When he finished, though, he saw a surprising pattern. Although 40% or more of the genera in the first and second stages failed to make it to the next stage—times were hard in the early Cambrian—the losses between the third and fourth stages soared to 80%. That was as sharp an increase over the background rate of extinction as took place in the ocean during the mass extinction 65 million years ago, when the dinosaurs disappeared.

In other respects, too, the early Cambrian crisis was "a fairly typical mass extinction," said Signor. Like many others, it coincided with a drop in sea level. And, as in other cases, creatures that built reefs on the continental shelf—in this case an entire phylum of odd sponge-like organisms called archaeocyathans—lost big. The archaeocyathans never recovered and disappeared before the end of the Cambrian. The drop in sea level may have left the archaeocyathans' habitat high and dry, but Signor isn't speculating what might have wiped out the numerous other groups that vanished at the same time.

Signor's proposed mass extinction has gotten a mixed reception. John Sepkoski of the University of Chicago, who specializes in compiling marine fossil records, agrees that "there's something there," but he worries that Signor may have overstated the magnitude of the extinction event. It may have been sizable but not large enough to fall in the top class of extinctions, he says. Allison "Pete" Palmer of the Cambrian Research Institute in Boulder won't even go that far. "I would view it with skepticism," says Palmer, who works primarily on Cambrian rocks in North America. "I don't think the record is adequate to justify calling it a mass extinction. It's an artifact of how little we know about the [early] Cambrian."

If there was a mass extinction in the early Cambrian, or even a major one, it may well have had an effect on the evolution of life much like that of the mass extinction 65 million years ago. That one cleared the way for mammals to rise to the top of the heap after millions of years as mouse-sized underlings of the dinosaurs. The early Cambrian extinction may have done the same for the primitive arthropods called trilobites, which passed through the extinction event unscathed and went on to dominate the seas for the next 100 million years.

And this particular pruning of the tree of life could have been all the more important, notes Signor, falling as it did so close to its root. It may take one step further the argument made by Stephen Jay Gould of Harvard—that life was reshaped for all time by the loss of the wonderful diversity of beasts evident in the Burgess Shale fossils, dating from later in the Cambrian. If Signor is right, the mayhem began far earlier.

–Richard A. Kerr