RASH OF BURGLARIES not a trend, say Menlo Park police. Page 22

The Almanac

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NEW AT SLAC

Dark matter in the universe; new theorems by Archimedes: scientists at the Stanford Linear Accelerator Center push the boundaries of knowledge

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NEW AT SLAC -

X-rays at SLAC expose theorems of Archimedes under medieval prayers

By Marion Softky
Almanac Staff Writer

A modern marriage of ancient wisdom with space-age technology at the Stanford Linear Accelerator Center (SLAC) is producing new insights into the mind and work of one of the greatest mathematical thinkers of antiquity.

Just this year, scientists have aimed powerful X-ray beams at faded pages of a scruffy medieval prayer book and come up with long-buried writings of Archimedes that shed new light on his discoveries about floating objects, mechanical theorems, and even a mathematical game.

Greek copies of Archimedes' original works were recycled by a medieval monk in Constantinople, who wrote a prayer book on top of the parchment after scraping and washing it to erase the old writing.

"The Archimedes Palimpsest" (a palimpsest is a document that has been erased and written over) is now on loan to the Walters Art Museum of Baltimore. It is being studied by scientists and scholars from all over the country to tease out the messages under the Latin prayers and later forged pictures of gilded saints.

Just this summer, the news media watched as a beam of high-powered X-rays from the Stanford Synchrotron Radiation Laboratory (SSRL) at SLAC zapped the most difficult pages that had resisted gentler techniques. The hair-sized beam — brighter than a million suns — penetrated dirt, mold, gilt paint, and medieval ink to reveal Greek writing and diagrams from Archimedes' treatise, "The Method of Mechanical Theorems."

"We're getting a vastly better understanding of one of the greatest minds of all time," says Uwe Bergman of Menlo Park, the SLAC physicist who first realized that X-rays from the SSRL could excite the iron in the original ink and make it glow. "We're also showing it is possible to read completely hidden texts in ancient documents without harming them."

Twisty tale

Dr. Bergmann, an enthusiastic scientist from the Black Forest in Germany, relishes the twisty tale of how Archimedes' work filtered from Syracuse in Sicily, where Archimedes was born in 287 B.C., to SLAC in California in 2006.

Archimedes, of course, may be most famous from the legend that gave us the expression "eureka." As he was sitting in his bath, the story goes, he figured out how to measure the volume of a solid — and then ran naked through the streets of Syracuse shouting "Eureka" ("I have found it!").

Archimedes' works covered an extraordinary range, from calculating pi and discovering the laws governing levers, to inventing pulleys, catapults and devices that crashed or clawed Roman ships. He invented a pump that worked like a screw and is still used today.

"He was a genius," says Dr. Bergmann. "He was dealing with infinity and calculus almost 2,000 years before Newton and Leibniz."

Archimedes was a towering figure in his time. His works were transcribed onto papyrus. As the papyrus failed, his works were copied onto parchment made from animal skins. The copy that became the palimpsest was made in the ninth century. "It may have been a copy of a copy of a copy. No one knows," Dr. Bergmann says.

In 1229, a monk needed some parchment for a prayer book, so he raided the library and collected several old documents. It was probably too expensive for the monastery to make its own parchment, Dr. Bergmann notes. "It takes a flock of sheep to make a prayer book. This was medieval recycling."

In making the prayer book, the monk first scraped the pages and washed the Archimedes script with a mild acid like lemon juice. Then he cut the

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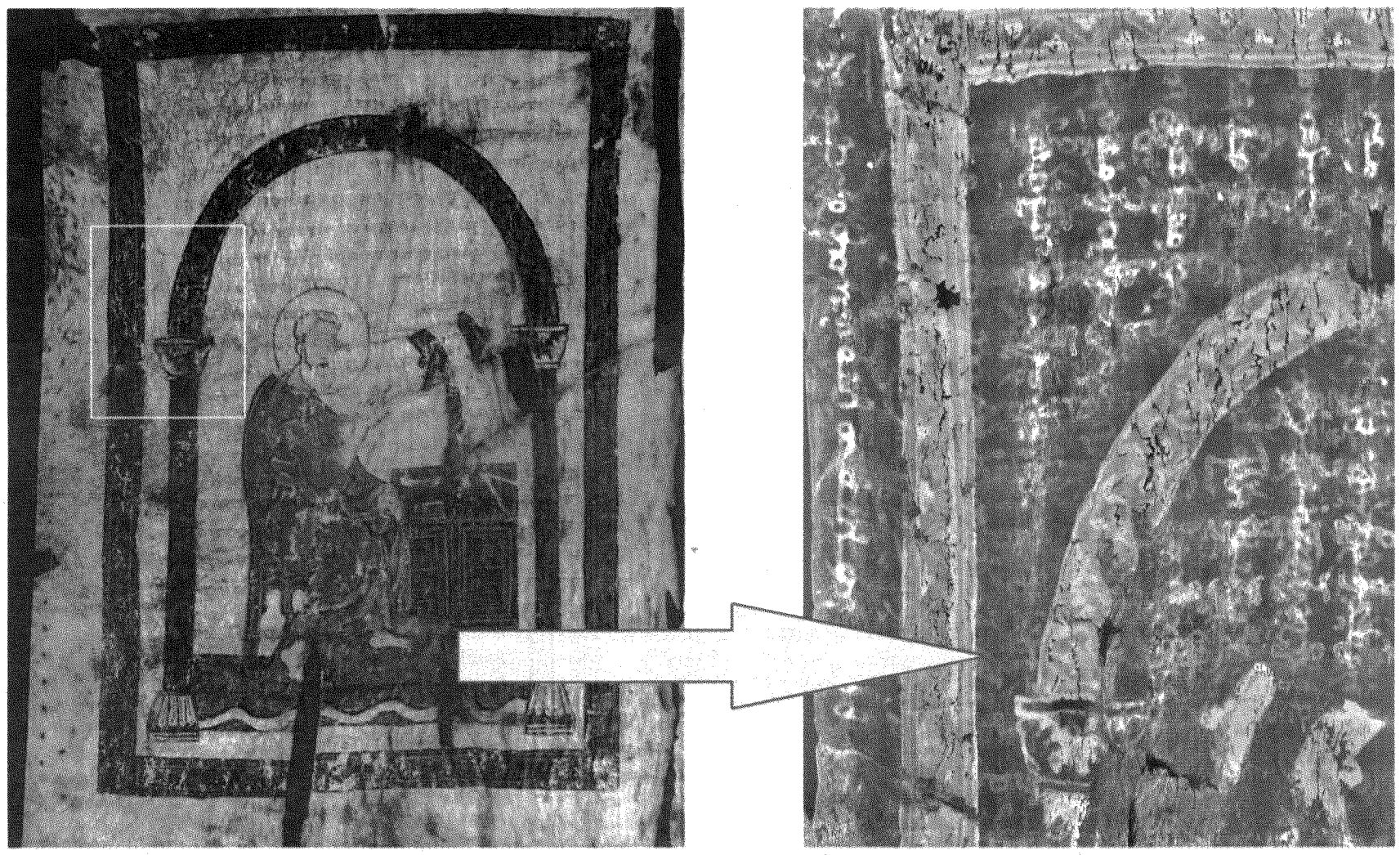
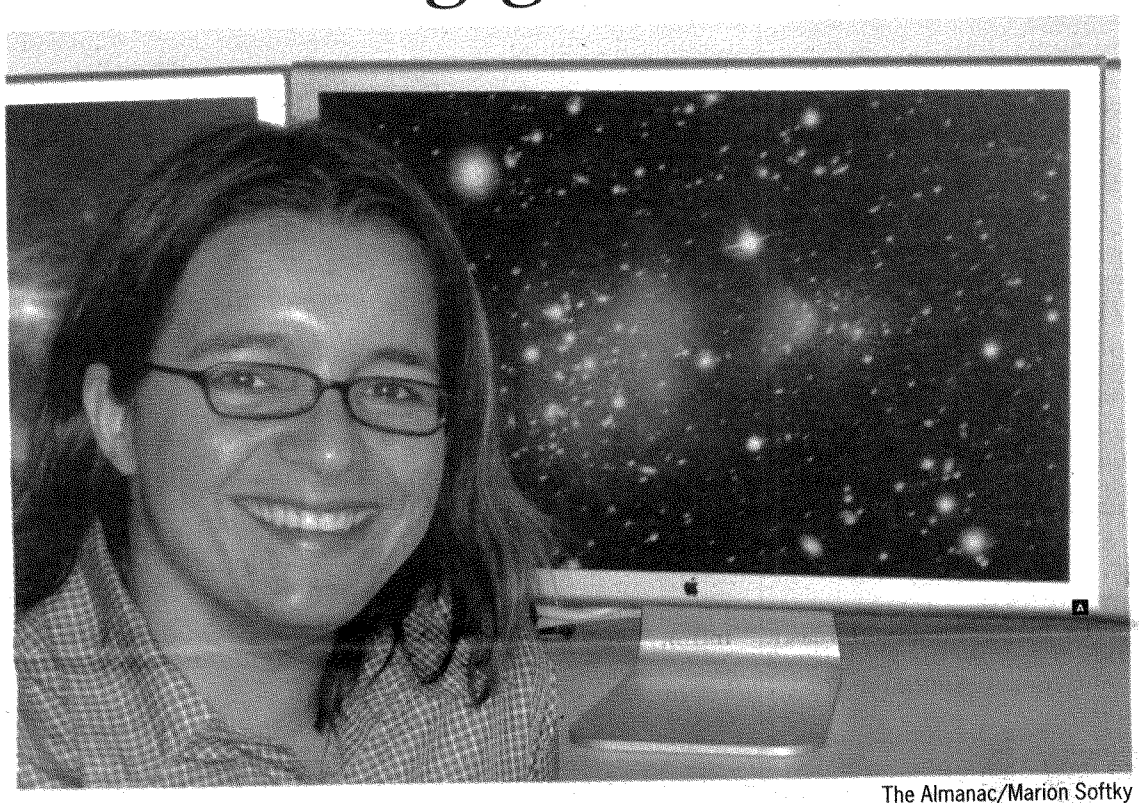


Images produced by Rochester Institute of Technology/John Hopkins University, and the Stanford Linear Accelerator Center (SLAC) © Owner of the Archimedes Palimpsest

Powerful X-rays at SLAC penetrated the forged gilt picture of St. Matthew in the Archimedes Palimpsest to reveal medieval prayers, horizontal, and Greek text, vertical, from Archimedes' treatise, "The Method of Mechanical Theorems."

Science center confirms dark matter that makes up most of the universe, and new theorems by master-mathematician Archimedes

Dark matter confirmed in colliding galaxies



The Almanac/Marion Softky

Marusa Bradac, of Menlo Park and Slovenia, performed the simulation that confirms the existence of the invisible dark matter that makes up much of the universe.

By Marion Softky
Almanac Staff Writer

Since the 1930s, astronomers have recognized that the universe contains far more matter than can be explained by all the stars and planets and galaxies that can be observed.

Now, scientists at SLAC, studying a collision of galaxy clusters three billion light years away, have confirmed the existence of the invisible dark matter that gives the universe its gravitational heft.

"We had predicted the existence of dark matter for decades, but now we've seen it in action. It's groundbreaking," says astrophysicist Marusa Bradac, of Menlo Park and Slovenia.

Dr. Bradac, who is a postdoctoral fellow at the Kavli Institute for Astrophysics and Cosmology (KIPAC) at SLAC, did a computer simulation of the collision of two clusters of galaxies in what is called the "Bullet Cluster," possibly the largest explosion since the Big Bang launched the universe we know.

"The simulation shows how the collision happened and what happened afterwards," Dr. Bradac says during an interview at the Kavli Institute, which just opened last spring. "All the gas (and stars) stayed in one place, and the dark matter kept going."

Weird stuff

Dark matter has proved extraordinarily difficult to pin down, because the evidence of its existence is indirect, Dr. Bradac explains. We know it's there because clusters of galaxies are far more massive than their visible parts. Yet it doesn't shine or give off light or heat or any signal we can detect; it interacts with other matter only through gravity.

To confirm the existence of dark matter, scientists used the technique of gravitational lenses. These are based on an effect, first discovered by Einstein, that a massive object can bend the light from galaxies behind it. "With gravitational lenses, we can measure the mass that bends the light," says Dr. Bradac. "We still can't 'see' it because it doesn't shine. But we can see its effects."

The latest discovery comes from a huge collaboration of scientists, using four major telescopes, including the Hubble Space Telescope and the orbiting Chandra X-ray Observatory. They mapped the distortions caused by the bullet cluster in the positions of galaxies in the background.

The result showed four separate clumps of matter: two large clumps of dark matter speeding away from the collision, and two smaller clumps of luminous matter trailing in their wake. "I actually measured the gravitational lens effect and discovered where the dark matter is positioned," says Dr. Bradac.

"These measurements are compelling," adds KIPAC Director Roger Blandford of Menlo Park. "The direct demonstration that dark matter has the properties inferred on the basis

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SLAC pushes frontiers of science

Located on 430 acres of Stanford land in the foothills south of Sand Hill Road, the Stanford Linear Accelerator Center (SLAC) has been exploring the makeup of matter since 1962.

The heart of SLAC is the linear accelerator, which speeds electrons through a two-mile tube at nearly the speed of light. As they crash into other particles at a target, scientists can study the basic structure and behavior of matter.

Five scientists have been awarded Nobel Prizes for research done at SLAC.

SLAC is almost entirely funded by the Department of Energy, and operated by Stanford under contract.

Over the years, SLAC has expanded its staff and its research. It now employs 1,500 people; some 3,000 scientists from around the world conduct research at SLAC every year.

Research at SLAC falls into three major areas that range from studying the smallest of particles to the whole universe:

■ **Photon science:** The Stanford Synchrotron Radiation Laboratory (SSRL) uses high-energy X-rays emitted by electrons rotating inside a ring to study different materials. Practical experiments have included studies leading to designer drugs, pollution-control equipment, treatment for osteoporosis, and — this year — new pages from Archimedes.

■ **Particle physics:** BaBar is the world's largest experiment examining the difference between matter and anti-matter, according to public information officer Neil Calder. Six hundred physicists from 11 countries study the results of collisions between B-mesons and anti-B mesons spinning in opposite directions around an underground ring.

■ **The universe:** The new Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) is expanding SLAC's research on particles to the scale of the universe, with research on the dark matter and dark energy that make up most of the universe.

SLAC is also engaged in a major new project. Bulldozers are preparing for the official groundbreaking in late October of a breakthrough X-ray source.

The Linac Coherent Light Source (LCLS) will the world's first free electron X-ray laser. This will produce high-energy X-rays that are coherent and with identical wavelength, leading to the ability to do research at even smaller distances and shorter times. It will open in 2009.

Scientists at SLAC are also collaborating with an international group to plan the next-generation linear accelerator. To be called the International Linear Collider, it will also be an electron accelerator, but 40 miles long. "It won't be here," said Mr. Calder

— Marion Softky

■ INFORMATION

■ Tours of the Stanford Linear Accelerator Center (SLAC) can be arranged by calling Maura Chatwell at 926-4931. Lots of information on SLAC and its projects are available on the Web. For starters, try: slac.stanford.edu; www.archimedespalimpsest.org; and exploratorium.edu for a Webcast on the Archimedes palimpsest.

■ The History Channel will include a section on the Archimedes Palimpsest in its program Wednesday, Oct. 4, at 10 p.m. The program, "Modern Marvels," focuses on the history of ink, starting 3,000 years ago in China.

X-rays at SLAC expose theorems of Archimedes under medieval prayers

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pages in half, and rotated them 90 degrees, so that his writing was horizontal while the old writing was vertical. "That's nice," Dr. Bergmann says. "We can see both inks and separate the texts."

The palimpsest surfaced publicly on July 7, 1907. The front page of the New York Times proclaimed: "Big Literary Find in Constantinople." A Danish scholar had recognized it and bought it. Later he translated it to the best of his ability.

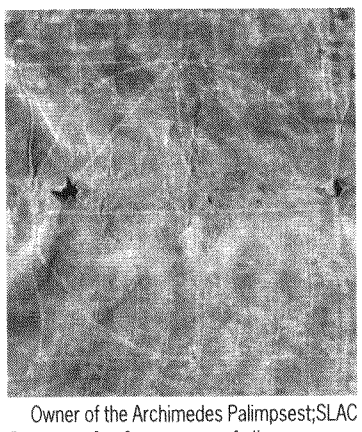
A forger got hold of the palimpsest after 1939, and painted over four pages with gilt pictures of the four evangelists.

The palimpsest surfaced again in 1998, when an anonymous American bought it for $2 million at Christie's. He loaned it to the Walters Art Museum in Baltimore, and supported extensive research to find and interpret the Archimedes text.

Actually, the 174-page palimpsest is not made up just of Archimedes documents, it contains four other ancient books, Dr. Bergmann notes.

Eureka

Dr. Bergmann never heard of the palimpsest until 2003. He had earned a Ph.D. from the State University of New York at Stoneybrook, writing his thesis at Brookhaven National laboratory using X-rays "I develop novel X-ray techniques to study all sorts of problems," he says.



Owner of the Archimedes Palimpsest;SLAC

A yet-to-be interpreted diagram from Archimedes' "Method of Mechanical Theorems" was discovered under medieval writing at SLAC by shining powerful X-rays tuned to detect calcium and make it fluoresce.

By 2003, he was working at the SSRL and living in Menlo Park with his wife, Elisabetta, and their daughter Sofia, a third-grader at Oak Knoll School.

Dr. Bergmann credits his discovery of the palimpsest to his mother. He was visiting his family in the Black Forest while attending a conference on photosynthesis. At the time he was studying spinach, using X-rays to excite manganese and iron.

His eureka moment came one evening when he was reading a pile of clippings put out for him by his mother. An article on the palimpsest mentioned that the ink contained a lot of iron.

Wow! "I thought, if we can study iron in spinach, we should be able to detect it in ink," he recalls. "I was 100 percent convinced. That was my eureka moment."

Dr. Bergmann contacted the Walters Art Museum, attended a workshop, and did tests to prove the X-rays would not harm the fragile manuscript. In May 2005, the first pages came to SLAC; they included one of the forged pages with the gold paint, which are the hardest to read. "We didn't image anything important, but we showed we could do it," he says.

To scan one page takes 12 hours. The X-ray beam, the size of a human hair, pulses back and forth across the page; it shuts off at the end of each line to protect the paper. The beam is tuned to a frequency that makes iron, or sometimes other elements, fluoresce. For one page, it makes 15 million measurements.

Discoveries

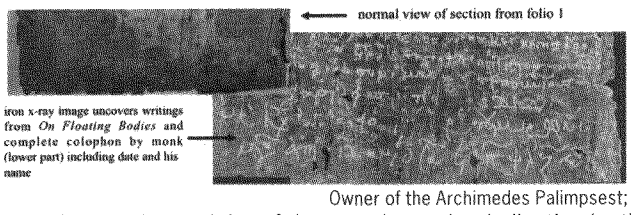
Results started to pour out when several pages including those covered with evangelists Mark and Luke came back to SLAC in March 2006.

The beam focused on the first page of a book called Folio 1. Dr. Bergmann exults, "Not only could we read the whole Archimedes text, we could read the name of the culprit." Johannes Myronas dedicated his prayer book with a flourish on April 13, 1229.

The scientists and scholars who interpret what they find, were excited to be able to read major sections of Archimedes' famous treatise "On Floating Bodies." "One page was never read before," says Dr. Bergmann.

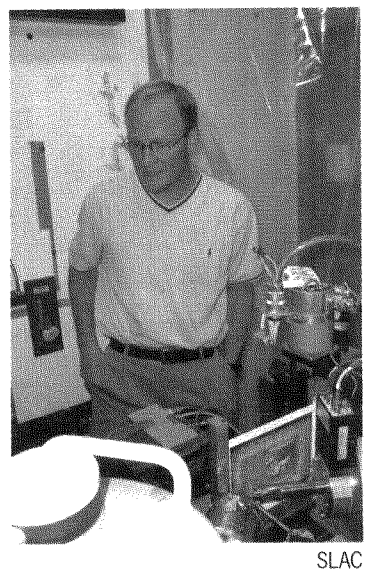
These pages, which had been copied in Greek, differed in some respects from Latin translations that have been available to scholars, Dr. Bergmann notes. "We were the first in modern times to read the treatise in its original Greek," he says. "There are differences."

In August, the SLAC team scanned more pages, including those under evangelists Matthew and John. These contained Archimedes' most important work, "The Method of Mechanical Theorems." This appears nowhere else, and includes diagrams, says Dr. Bergmann.



Owner of the Archimedes Palimpsest; SLAC

The X-ray image, lower right, of the text shows the dedication by the Byzantine monk who penned the palimpsest in 1229, Johannes Myronas, along with new theorems from "On Floating Bodies."



SLAC

Uwe Bergmann of Menlo Park at the Stanford Synchrotoron Radiation Laboratory, where high-powered X-rays reveal the Greek script by Archimedes.

The Web site, www.archimedespalimpsest.org, notes that two treatises: The Method of Mechanical Theorems" and the "Stomachion," are found only in the palimpsest.

Dr. Bergmann hesitates to interpret much of the material the team has unearthed, because it needs extensive further analysis. "The scholars have a lot of work over the next two years," he says.

So far SLAC has scanned 14 of the 174 pages of the palimpsest, including images overlapping on both sides of each page. Dr. Bergmann and the palimpsest team are busy planning for a return visit for more pages early next year.

Dr. Bergmann hopes they will pursue the Stomachion. This is a game like Tangrams, only it has 20 shapes that can be assembled into a rectangle in 14,000 ways. "Archimedes wrote a treatise about that." ▲

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of indirect arguments shows that we are on the right track in our quest to understand the universe."

Dark matter and beyond

Dark matter is only part of the mysteries of the universe that scientists are probing; past observations have shown that only a very small percentage of the mass in the universe — maybe 5 percent — can be explained by regular matter.

"A universe that's dominated by dark stuff seems preposterous, so we wanted to test whether there were any basic flaws in our thinking," says Doug Clowe of the University of Arizona, one of the leaders in the study. "We believe these results prove that dark matter exists."

From there, it gets even more confusing. Dr. Bradac estimates that about 25 percent of the universe is dark matter, 5 percent is luminous matter, and 70 percent is dark energy.

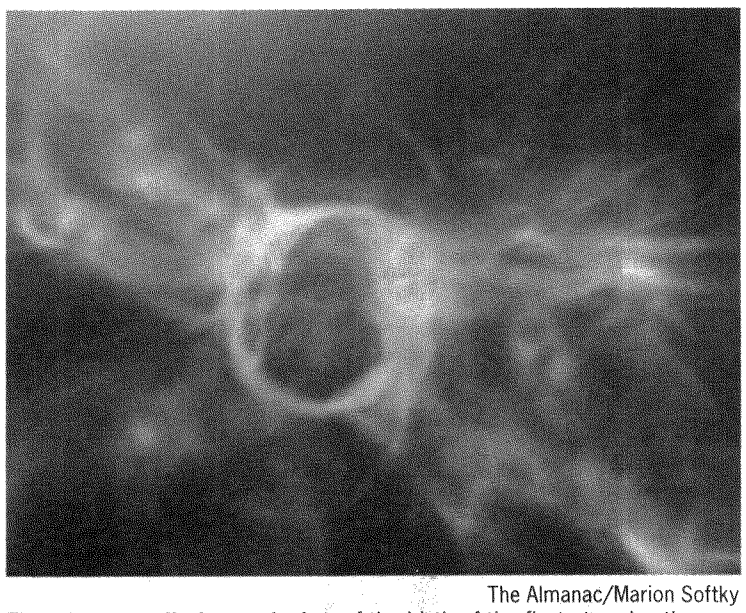
"Dark energy is even more mysterious," Dr. Bradac says. She refers to theories suggesting that dark energy is a form of material that exerts negative pressure that causes the universe to expand faster and faster, rather than collapsing.

This kind of mind-stretching thinking makes Dr. Bradac love her time at SLAC. She comes from Slovenia, part of the old Yugoslavia, and earned her Ph.D. in astrophysics from the University of Bonn in Germany. She is here on a three-year fellowship.

"It's so exciting here," she says, especially the interface with scientists studying such varied subjects. She hopes the particle physicists, working with SLAC's accelerators, will be able to detect some effects of dark matter.

"Dark matter particles barely see each other; they interact only gravitationally," Dr. Bradac says. "We tell particle physicists about properties they are trying to detect. The accelerator people will be trying to detect dark matter particles.

"Bridging the gap between particle physicists and astrophysicists — that's great." ▲



The Almanac/Marion Softky

This **photo-realistic rendering** of the birth of the first star shortly after the Big Bang was created by John Wise.