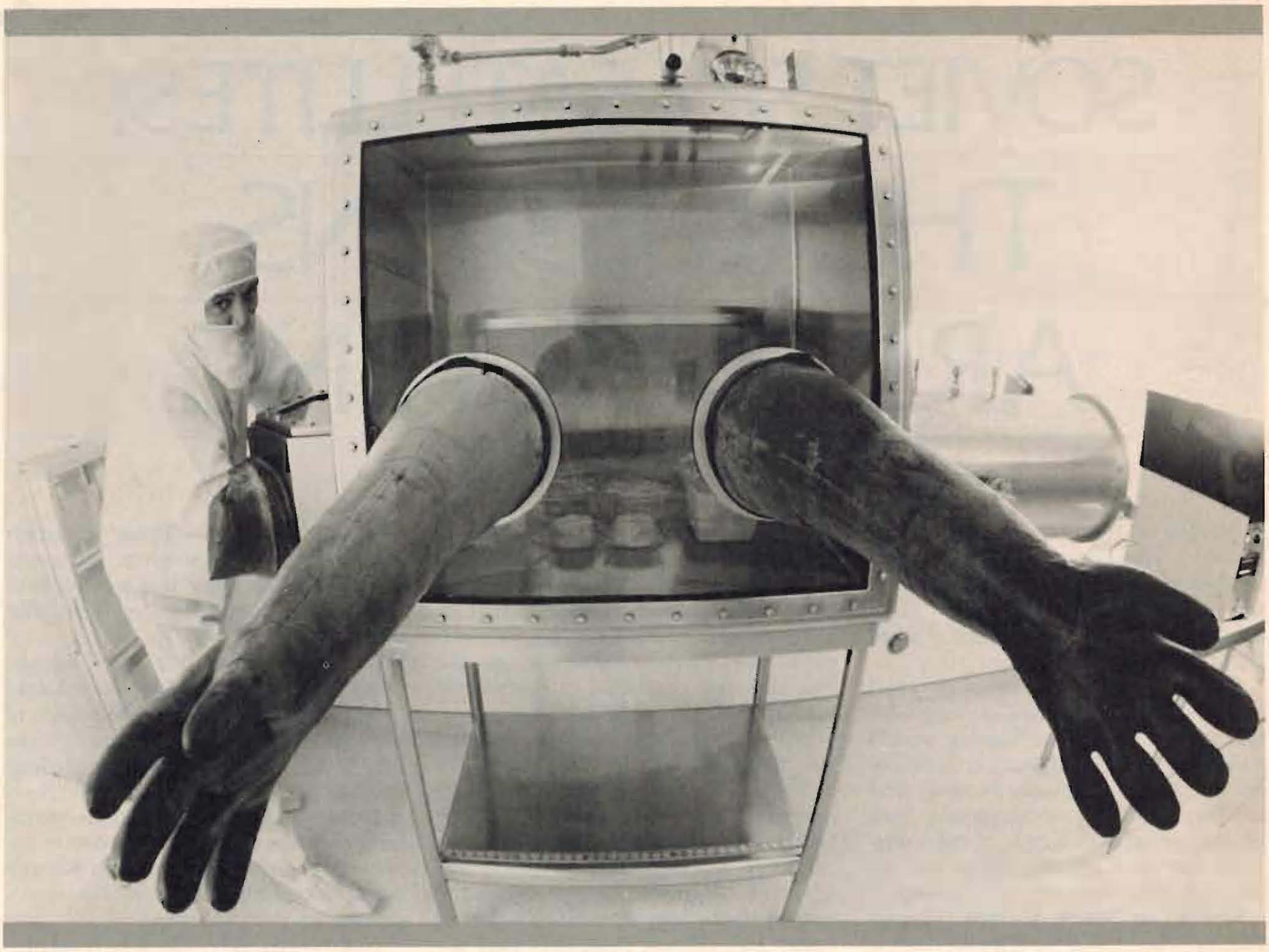


THE DUST OF CREATION

So precious is this substance, unchanged since the birth of the solar system, that one scientist spent an entire year examining just ten microscopic grains.

BY MARCIA BARTUSIAK

Right now, NASA scientists in specially equipped planes are collecting specks of unusual dust high in our atmosphere. These particles, they think, are the remnants of comets, the stuff out of which our solar system was formed 4.5 billion years ago.

In 1981, planetary scientists in the United States were devastated when NASA was forced to cancel its plans to send an unmanned probe past Halley's comet as that famous visitor sweeps past Earth in 1986. But comet hunters can now take consolation in this new effort. In fact, the Johnson Space Center in Houston may be harboring the world's largest collection of cometary matter in a tiny, ultraclean room called the cosmic dust laboratory.

Swathed in "surgical" whites from head to toe ("our bunny suits," quips James Gooding, a planetary scientist at Johnson), NASA curators spend many hours inside the pristine room painstakingly analyzing each fragile, microscopic grain; most are no bigger than a human blood cell, about one 40-thousandth of an inch across. In many ways, NASA's mission could be considered a search for man's ultimate roots—a quest to find out how his celestial home, the solar system, came to be born. For years, scientists scrutinized meteorites and lunar rocks in search of an answer; now cosmic dust offers a third window on the history of the solar system.

Out in space, these primordial specks

Minuscule bits of comet debris (below) are readied for microscope viewing and (above) stored in an ultraclean, pressurized case.

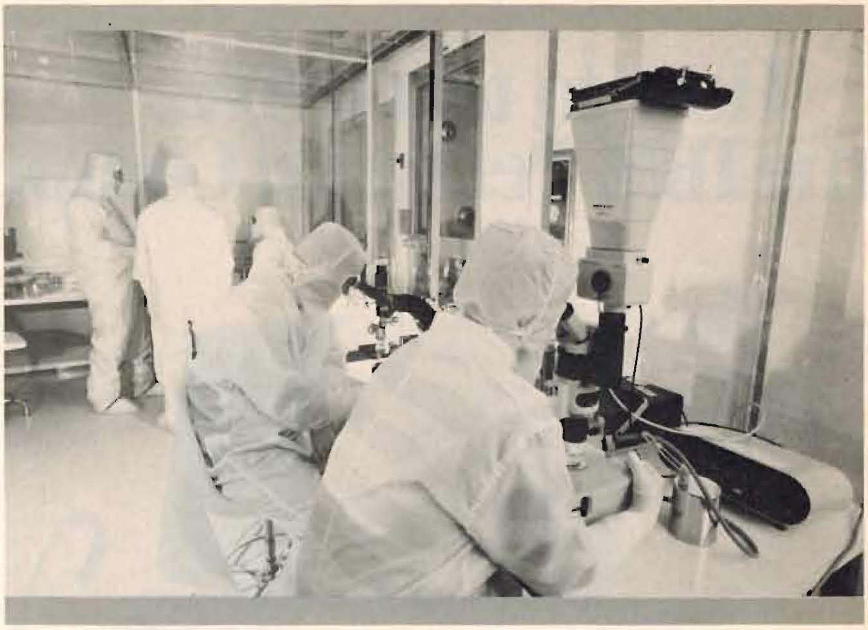
Marcia Bartusiak, who has her master's degree in physics, frequently writes about astronomy.

Photographs by Roger Ressmeyer/Starlight form a tenuous, interplanetary dust cloud around the sun that is visible as a faint glow just after sunset in the west or just before sunrise in the east. It's known as the zodiacal light. Astronomers speculate that this haze is formed out of the remnants of passing comets, an important link to the solar system's birth. Comets are believed to have condensed out of the same primordial cloud of dust and gas that formed the sun and planets eons ago.

"DIRTY SNOWBALLS"

Scientists now envision comets as "dirty snowballs," conglomerations of rocky materials and frozen compounds such as methane, ammonia, carbon dioxide and water. In 1950, Dutch astronomer Jan Oort suggested that their journey through the solar system originates in a vast reservoir of cosmic debris located several trillion miles from the sun, far past Pluto's orbit. He calculated that as many as 100 billion fragments, ranging in size from one to 30 miles in diameter, float around in this celestial deep freeze. Given the proper gravitational nudge, some of these clumps of rock and ice eventually wander in toward the sun.

As one of these clumps speeds past Mars, it begins the comet's famous trick of turning into an unworldly Roman candle. Solar energy now starts to warm the comet's head, vaporizing some of its frozen material. The stream of gases and dust that are swept off the comet's surface forms its spectacular tail and replenishes the interplanetary dust cloud. Once caught by Earth's gravitational pull, the tiny grains in this cloud can gently float through the relatively still, clean stratosphere for a few weeks before descending to terra firma, to be lost among other, Earthly dusts.



The colors of cosmic dust—clear, amber or black—are detected by NASA scientists as they peer through optical microscopes inside a special lab at Johnson Space Center.

These minuscule Rosetta stones to the solar system's past were once considered unreachable. But 10 years ago, astronomer Donald Brownlee of the University of Washington pioneered a means of snaring them during a flight in a high-flying U-2 aircraft on an atmospheric sampling mission. When the plane reached an altitude of about 60,000 feet, far above ground contaminants in the more turbulent atmosphere below, small plastic plates coated with a viscous silicone oil were exposed to the stratospheric airstream in hopes of catching extraterrestrial motes. The procedure worked.

Following Brownlee's lead, the Johnson Space Center initiated its own cosmic dust program two years ago. The center has been gathering most of its particles with eight collectors mounted under the wings of a converted WB-57F bomber that's used for Earth-resources studies.

Although tons of these extraterrestrial motes are scattered about the globe at any one time, they are so widely dispersed that it takes 40 hours to collect a sample of only 100 to 200 particles.

Once captured, the precious grains are taken to that ultraclean laboratory, situated right next door to Johnson's Antarctic meteorite and moonrock facilities. A

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A COMET UP CLOSE

For all its pyrotechnic glitz, Halley's comet is not the only celestial show in town. With the help of amateur sky watchers and sophisticated satellites, astronomers are now discovering new comets and unraveling their secrets at an almost dizzying pace.

One such lesser light was first discovered last May. Appearing as little more than a luminous smudge framed by the Big Dipper constellation, the tiny comet was spotted independently by a Japanese schoolteacher, an English astronomer and an orbiting infrared telescope known as IRAS. Accurately—if unpoetically—named Comet IRAS-Araki-Alcock, the glowing snowball whisked within 3.1 million miles of Earth, closer than any comet in 200 years.

This cosmic near-miss gave astronomers an opportunity to study comet anatomy in more detail that they ever have before. Using ultraviolet scanning equipment, radio telescopes and other elaborate systems, the scientists probed into the heart of IRAS-Araki-Alcock, hunting for its nucleus, sampling its dust and seeking its elemental makeup.

One surprise was the discovery of a unique type of dual-atom sulfur. "This is a product that we think is made in the ice after the cometary nucleus is created. Bombardment by cosmic rays would cause sulfur to break off and recombine," explains astronomer Michael A'Hearn of the University of Maryland. Learning how much double-atom sulfur appears in comets could help provide an estimate of which comets are older and which younger.

Only two weeks after its shimmery appearance, IRAS-Araki-Alcock began to recede, not to return for more than 5,000 years. But even as it was speeding away from the sun, two other comets were found in a single week, one by IRAS and one by a group of astronomers.

Even when IRAS isn't discovering comets, it is providing new profiles of those already known. Eyeing Comet Temple 2, it spotted a dust tail never before seen. The size of the long-overlooked feature? Twenty million miles. *–Jeff Kluger* cloud over there? It's going to kill you.' "

Based on initial findings of the NRC's source-term studies, Bernero does not foresee a dramatic change in planning requirements. The NRC will still require that utilities and local governments draw up contingency plans covering a radius of 10 miles. Bernero stresses that automatic evacuation of persons living within the 10-mile zone—an approach advocated by some critics of nuclear power—should *not* be required. He believes that the response should be "graded," depending on the severity of the accident and how it progresses. If an incident similar to the one that destroyed the plant at Three Mile Island were to occur, evacuation out to three miles may be necessary. If conditions worsen, the evacuation zone will be widened.

10-MILE KILLING RANGE

Though he takes exception to Levenson's attitude toward emergency planning, Bernero does believe that nuclear power has been held to a double standard. He points out that even under the worst conditions, a severe nuclear accident would be capable of killing people only within a radius of 10 miles. That's the distance covered by today's emergency plans. Nuclear power, he says, poses no greater threat than other risky industrial endeavors, such as the transportation of hazardous chemicals by rail and highway.

Bernero cites in particular an accident near Toronto, in which railroad tank cars carrying chlorine and liquid fuels derailed and burned, spewing toxic fumes into the atmosphere. A quarter of a million people were quickly evacuated—the largest peacetime effort of its kind in North American history. No one was killed and only a few people were injured.

"People want absolute assurances about safety when it comes to nuclear power," Bernero says. "But you can't be absolutely sure about anything. Frank Borman [former astronaut and now president of Eastern Airlines] can't tell you for sure that you won't die on one of his airplanes. Yet people fly Eastern every day."

MYSTERIOUS NATURE

If the concern over nuclear power overshadows that shown for other safety issues, it is probably because of its mysterious nature. The causes of tank-car explosions and airplane crashes are easily understood. The statistical probabilities of a meltdown and the intricacies of nuclear chemistry are not. And radioactivity is a silent, invisible killer that can continue taking a toll for 20 years—the latency period for some cancers.

So aside from the technical decisions that must be made, it is the perception of nuclear power that is at stake in the source-term controversy. And therein lies one of the major problems for the nuclear industry. ■

COSMIC DUST

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special filtration system ensures that the 30-by-10-foot room will contain no more than 100 bits of Earthly dust in every cubic foot, none bigger than the cosmic grains themselves. "It's the state of the art in clean-room technology," explains James Gooding. "If we tried to process our collectors in an ordinary room, we'd be hopelessly saturated with contamination from the air."

No one can enter the cosmic dust laboratory until a strict regimen has been followed. First, in an outer room, lab personnel must don special lint-free garments: a white jump suit, bootees to cover the shoes, and a special snood, or hood, that leaves only the eyes and nose exposed. Looking like space-age monks, they then step into a tiny air shower, where air jetting out of a dozen nozzles blows off any remaining dust contamination. From here, they step directly into the lab itself.

The curators begin the tedious job of cleaning, characterizing and cataloging the cosmic dust by looking at each collector plate under a microscope and plucking off the particles, one by one, with a fine-tipped glass needle. "About half of the particles we pick off turn out to be extraterrestrial," notes Gooding. The other half are either pale-yellow spheres of aluminum oxide from solid-fuel rocket exhausts or bits of volcanic ash. The tremendous El Chichón eruption in Mexico last year, in fact, is still dirtying their samples.

Once the silicone oil is washed off, each cosmic dust candidate is closely examined under intense optical magnification. Here, for the first time, the curators assess the particle's size, color, transparency and luster—"all the characteristics that are useful in understanding its essential composition," says Gooding. An electron-microscope scan gives an even closer look, revealing the myriad shapes and textures regularly found in cosmic dust. Some are smooth and crystalline; others look like bits of brown and black sand randomly glued together.

The electron microscope offers an added bonus: The electron bombardment causes the dust particle to emit a telltale

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Each dust particle has a makeup unlike any terrestrial, lunar or meteoritic rock that man has ever examined.

COSMIC DUST

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spectrum of X-rays that identifies its composition. "Very crudely," states Gooding, "the X-ray signature looks like pyroxine, a dark-brown silicate that makes up a lot of volcanic rock, mixed in with iron sulfide and nickel-iron components." But it is a mixture unlike any other terrestrial, lunar or meteoritic rock that man has ever examined.

The amount of helium found on some of the grains strongly suggests that the particles were long floating in space and are not pieces of a meteorite that broke apart recently. The solar wind deposits that light element onto the dust at a predictable rate.

COMETARY CONNECTION

Is this really man's first sample of cometary dust? Answers Gooding, "A lot of the motivation for studying cosmic dust comes from the presumption that there is a cometary connection, that the grains are spewed off as the comet approaches the inner solar system and gets heated by the sun. But, in all fairness, I must admit that it's only speculation at this point." Firm proof won't come until man can actually go out to a comet and chip off a piece for comparison.

Gooding estimates that at least 700 of the thousands of particles the laboratory now has on hand are assuredly cosmic dust, bits of debris not of this Earth. Pound for pound, they could be considered the most valuable extraterrestrial material around; those 700 grains weigh less than one-*millionth* of a gram! Now, only a decade after Brownlee's early efforts, Gooding can state proudly, "We've collected and cataloged enough samples for many different investigators to obtain particles for study."

IMMENSE REWARD

This should speed up the pioneering work in this area. So far, the researchers have hardly scratched the surface. "One of the major findings to come out of the cosmic dust program is that the particles are not identical to meteorites or lunar rocks," says Gooding. "Indeed, it does look as though a third type of material is involved." But no one knows yet what it all means.

The research is not easy (try keeping track of something the size of a blood cell) and requires the most advanced analytic techniques; one investigator spent a full year examining just 10 grains. But the scientific rewards are immense. Each of these microparticles could be the virgin stuff out of which the solar system emerged. And, if that's true, then science will be able to narrow down the number of theories about how our solar system's nine planets coalesced out of a swirling cloud of dust. ■

WEATHER TAMERS

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mass seeded at just the right point should be able to reduce significantly the power of a hurricane.

The Storm Fury tests were, predictably, inconclusive: Some storms seemed to weaken, some didn't. For those that did, meteorologists couldn't be certain that they wouldn't have waned regardless of the intervention. Other, less ambitious weather modification projects have had equally ambiguous results. In some projects, meteorologists have experimented with seeding clouds to induce them to rain out and disperse over the ocean rather than over vulnerable coastal communities. Still other studies have involved timing and triggering cloudbursts so they could be used to mitigate droughts.

Despite the tantalizing quality of such programs, parts of NOAA's Office of Weather Research and Modification were disbanded last May following a $6 million budget cut. "Weather modification is at its lowest point in twenty years," says Charles Chappell, former head of the now-dormant program. "But I think that

> Will the Administration force the Weather Service to curtail its activities and then sell off its satellites?

sometime in the future, weather modification will have its day again."

The fate of Chappell's office is emblematic of the problems besetting the Weather Service as a whole. At the same time that NOAA scientists believe that meteorology can become more sophisticated than ever before, the Administration has been pushing the agency to curtail its activities, reduce its services and even sell a number of its satellites.

All of this gets Warren Schmidt plenty steamed. "If we get a hailstorm when I'm cutting the wheat, " he says, "that's it for the year. Now, the NOAA people say that things like this gizmo on my farm will finally give me some reliable information about the weather—but now I hear the government doesn't want to spend the money to put them in use everywhere. It's too bad. All these people talking about the weather, and here somebody finally wants to do something about it." ■

In the battle to control the weather there is no bigger enemy than a hurricane. Next month, learn about the latest techniques for taming the giant as you fly with the Hurricane Hunters.

UNIFICATION

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The result of these twin changes is that the changes in observed quantities that would have been introduced by leaving everyone free to choose his own zero of voltage are exactly canceled by the changes that would be introduced by the magnetic potential. The unified theory of electromagnetism, then, has a local gauge symmetry, even though the individual phenomena of electricity and magnetism exhibit only a global symmetry.

Before leaving this topic, we should note one other feature of the theory that unified electricity and magnetism. It predicts a new sort of effect—one not contained within either electricity or magnetism taken alone. This new effect, called "displacement current," is a piece of the picture that had been missing until the unified field theory was developed. The displacement current is a physical entity by virtue of which magnetic effects can be produced by changing electrical fields. Its existence has, of course, been amply demonstrated in the laboratory.

Local gauge symmetry has deep philosophical consequences. It suggests that when we have a correct theory—when we have brought together all of the effects that are supposed to be brought together—the world will be completely independent of the arbitrary definitions made by different observers. I can go ahead and choose my own scale of voltage without having to worry about the definition someone else will choose, whether that someone is 10,000 miles or 10 inches away from me. Loosely speaking, we can say that this result suggests that the state of mind of the observer—the way that observer makes definitions—cannot affect any measurable quantity. In the case of electromagnetism, the realization that the theory had this property came long after the theory had been developed.

ELEVATED STATUS

But what was once an afterthought is now a founding principle. In searching for new theories, physicists start with the assumption that local gauge symmetry is an essential property of our world and that any correct theory *must* exhibit this property. This immediately eliminates a huge number of possible theories, making the task of finding the correct one much easier. Once a theory is found in this way, it is subjected to the same sort of experimental tests that any scientific idea would be. From being an interesting property of established ideas, then, the concept of local gauge symmetry has, in the past decade, been elevated to a major working hypothesis about the kind of world we live in. Granted, the gauge principle has wed electricity and magnetism. But is it powerful enough to perform the same sort of unification process on the four funda-