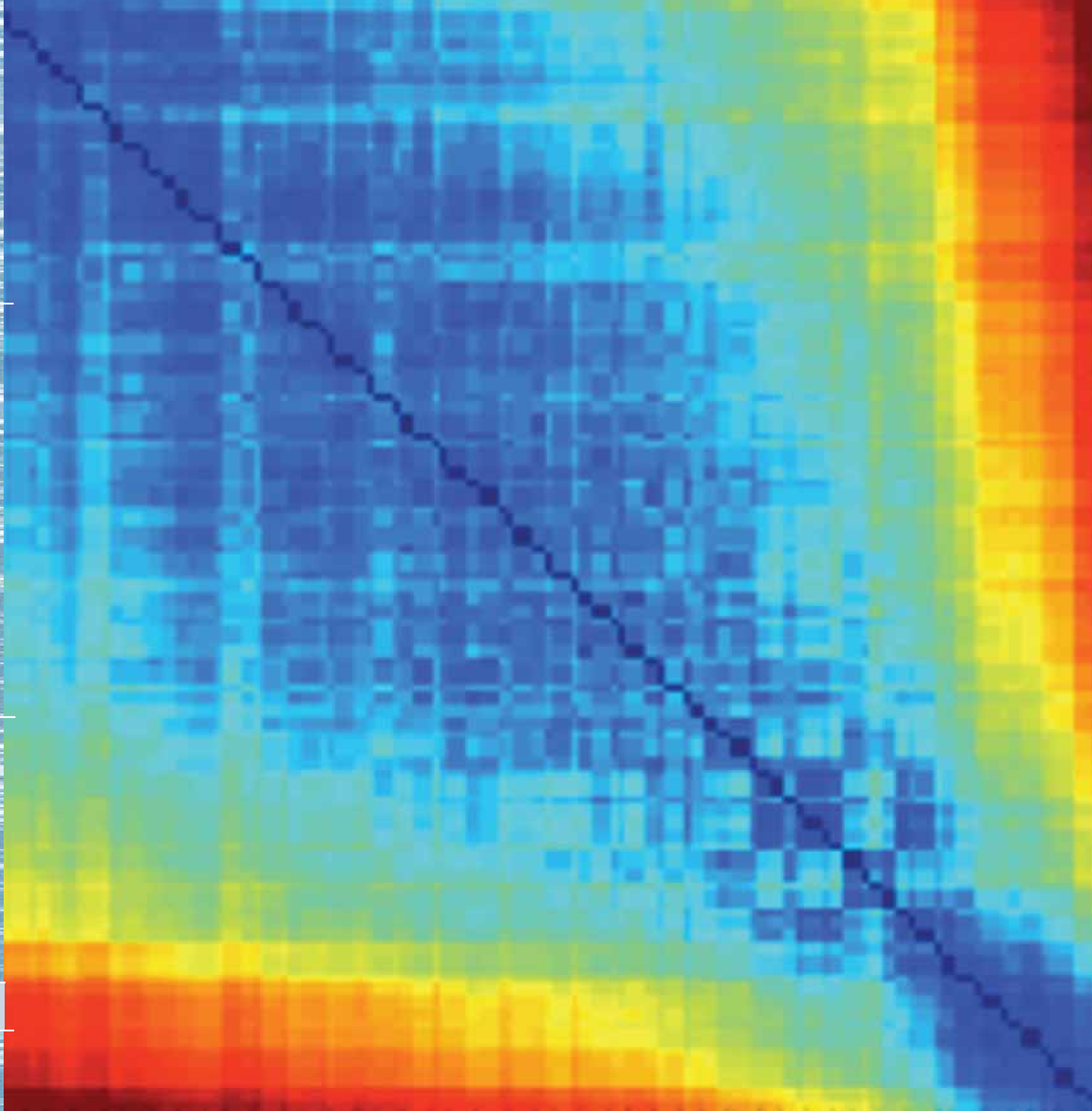
72

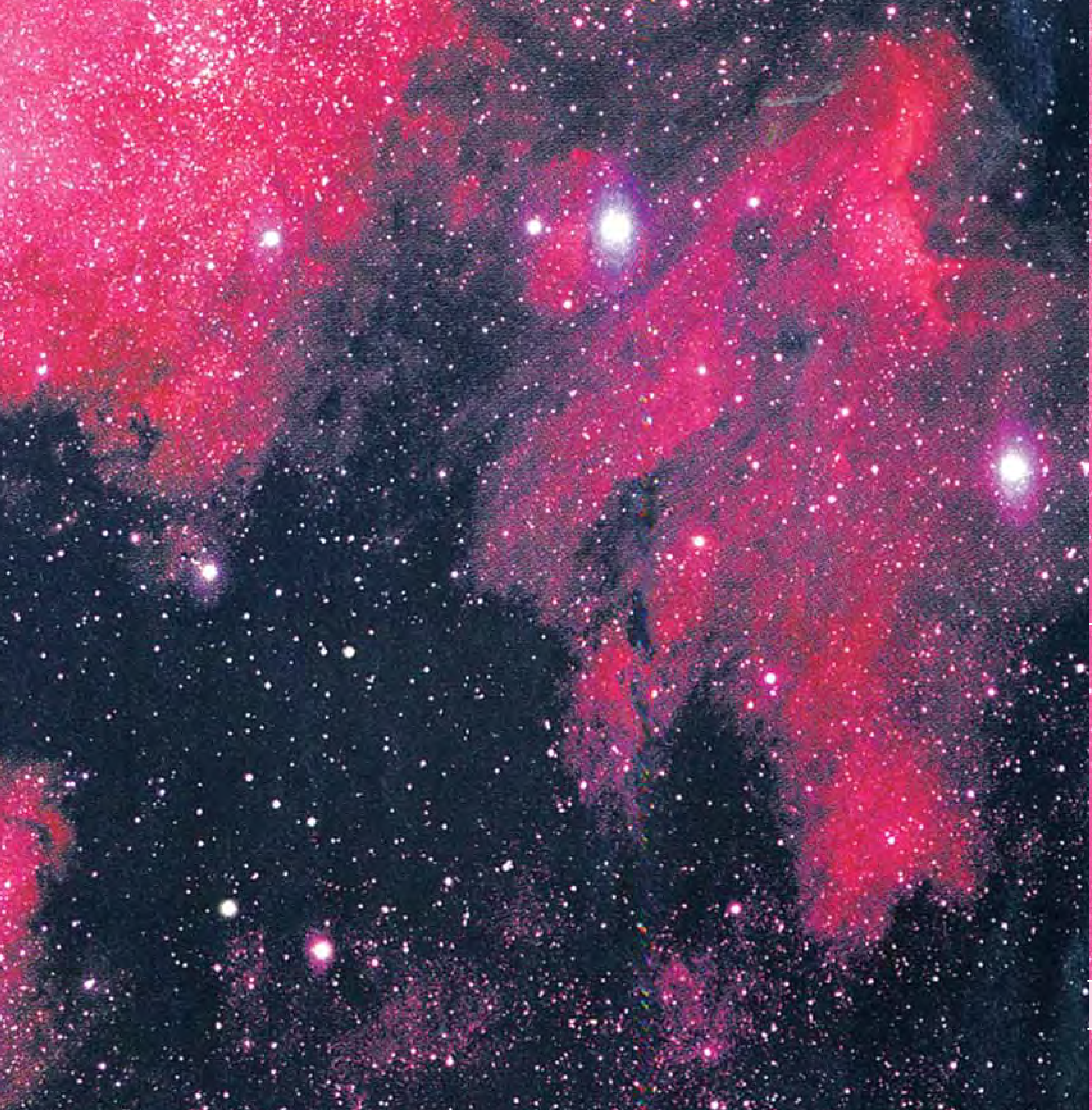
2000 The Information Age

Institute scientists developed an innovative system for processing information that enables genetic "data mining." With the advent of gene-chip technology, scientists are able to observe the expression of thousands of genes in multiple tissue samples at once. This means that researchers can obtain a hundred thousand, or even a million pieces of data from an experiment. To efficiently analyze such a mountain of information, new tools had to be invented for processing it. Institute scientists developed such a tool, based on an algorithm that enables the computer to sort objects into groups according to either similarity or connectivity, even if it has not been programmed beforehand to recognize the specific properties of those objects.

The algorithm they developed "pools" a relatively small group of genes with something in common and, through them, identifies tissue samples that have a biological similarity. For example, it might sort them into two groups: one in which certain cancerous processes are taking place and another of healthy tissues. In one study, for example, the algorithm was used to identify a molecular mechanism that controls the appearance of malignant cancer growth. The scientists hope that the system will aid, in the future, in the early prediction and even prevention of various diseases.

The algorithm may also be used to analyze other types of data and problems, such as MRI data for brain research, for sorting documents in large collections and more.





73

The Origins of Radiation 2000

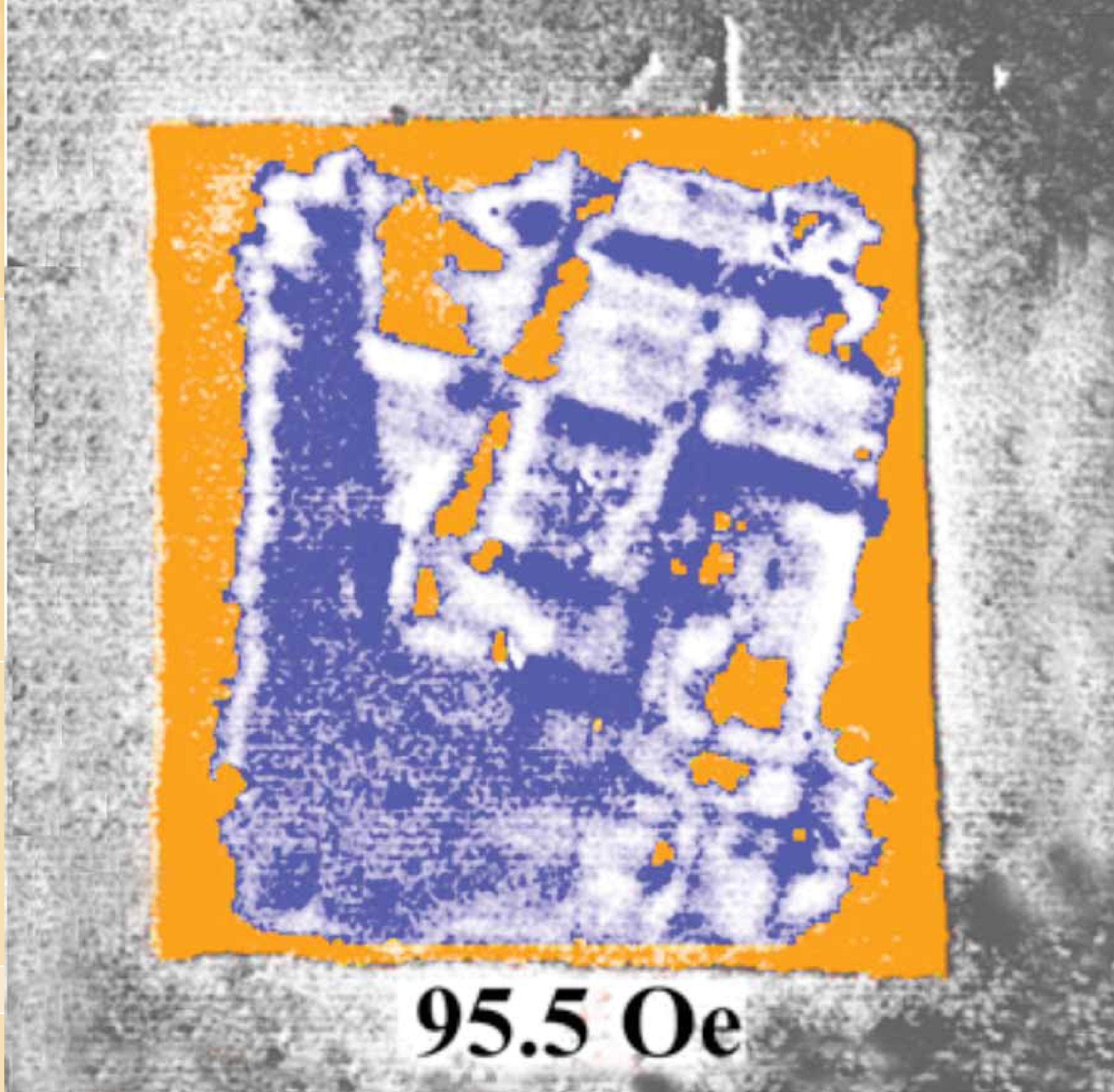
Institute scientists, together with colleagues in the US, showed that most of the isotropic (non-directional) component of energetic gamma radiation hitting Earth may actually be leftover energy from massive shock waves induced by gravitational forces. When gravity acted on intergalactic clouds of gas, the force caused them to collapse into themselves, creating giant galactic clusters. This process produced electrons moving at nearly the speed of light – roughly 300,000 km or 185,000 miles per second. The electrons then collided with low-energy photons of the cosmic microwave background radiation, which is believed to be an echo of the Big Bang. The collision scattered the photons, increasing the energy of a fraction of them to that of gamma rays and thus producing the gamma-ray background radiation seen in today's Universe. This model, which fits in with theories of the distribution and development of particles following the Big Bang, may aid in solving the "mystery of the missing material" in the Universe. The model's predictions will soon be checked by new space telescopes that work in the gamma- and X-ray range.

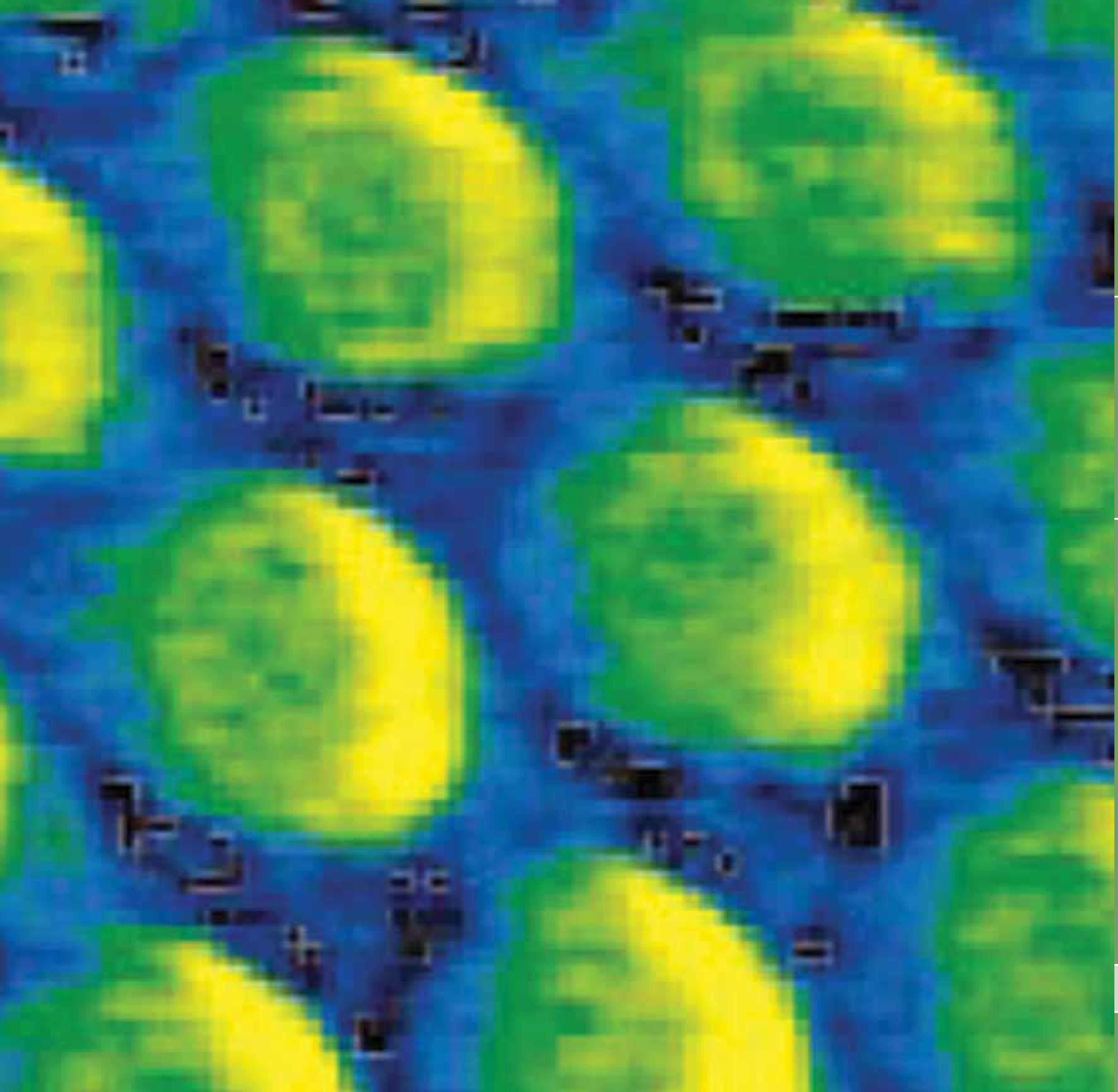
74

2000 Magnetic Fields Forever

Weizmann Institute scientists explained how superconductors penetrated by magnetic fields “remember” the physical properties of electrical currents. Magnetic fields infiltrate some superconductors in the form of tiny whirlpools, each containing a weak magnetic flux at its core. Under optimal conditions, these whirlpools settle at equal distances from one another, in a fashion similar to the arrangement of molecules within a solid crystal. The scientists showed, however, that under certain conditions this “crystal” may undergo a meltdown, so that the whirlpools are transformed into a disorganized state resembling the material’s liquid structure.

In later research, the scientists explained how these whirlpools enable the superconductor to remember the properties of currents that passed through it (for example: their strength, direction and course). They then built a unique measuring system that allowed them to view a sort of “movie” showing the series of events in which a change of temperature causes changes in the magnetic field in the superconductor, and how different impurities in the superconducting crystal affect this process. The researchers succeeded in tracing the transition of a magnetic whirlpool from a “solid” to a liquid state and back again as a result of temperature changes in the system.



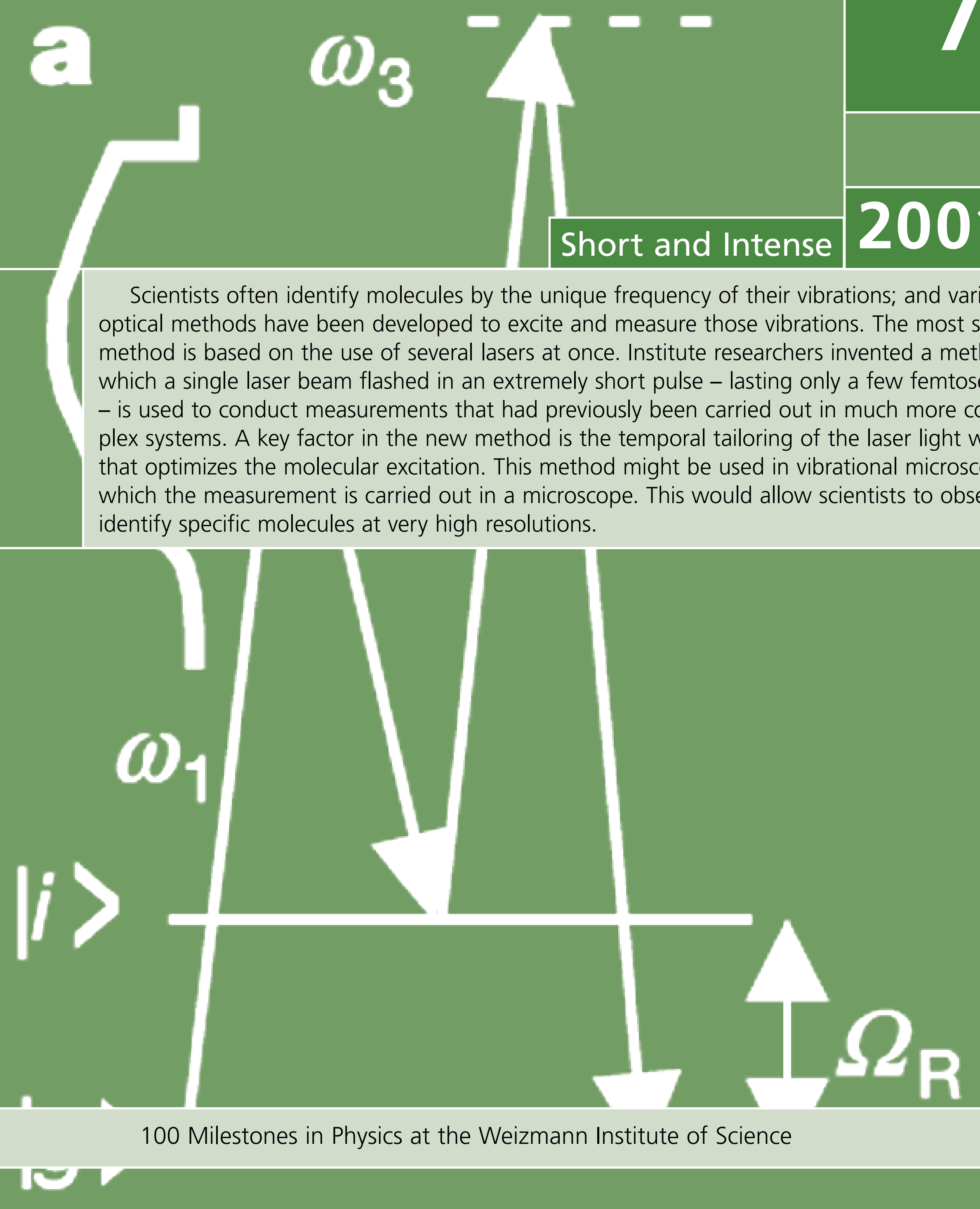


75

2001

Short and Intense

Scientists often identify molecules by the unique frequency of their vibrations; and various optical methods have been developed to excite and measure those vibrations. The most sensitive method is based on the use of several lasers at once. Institute researchers invented a method in which a single laser beam flashed in an extremely short pulse – lasting only a few femtoseconds – is used to conduct measurements that had previously been carried out in much more complex systems. A key factor in the new method is the temporal tailoring of the laser light wave that optimizes the molecular excitation. This method might be used in vibrational microscopy, in which the measurement is carried out in a microscope. This would allow scientists to observe or identify specific molecules at very high resolutions.



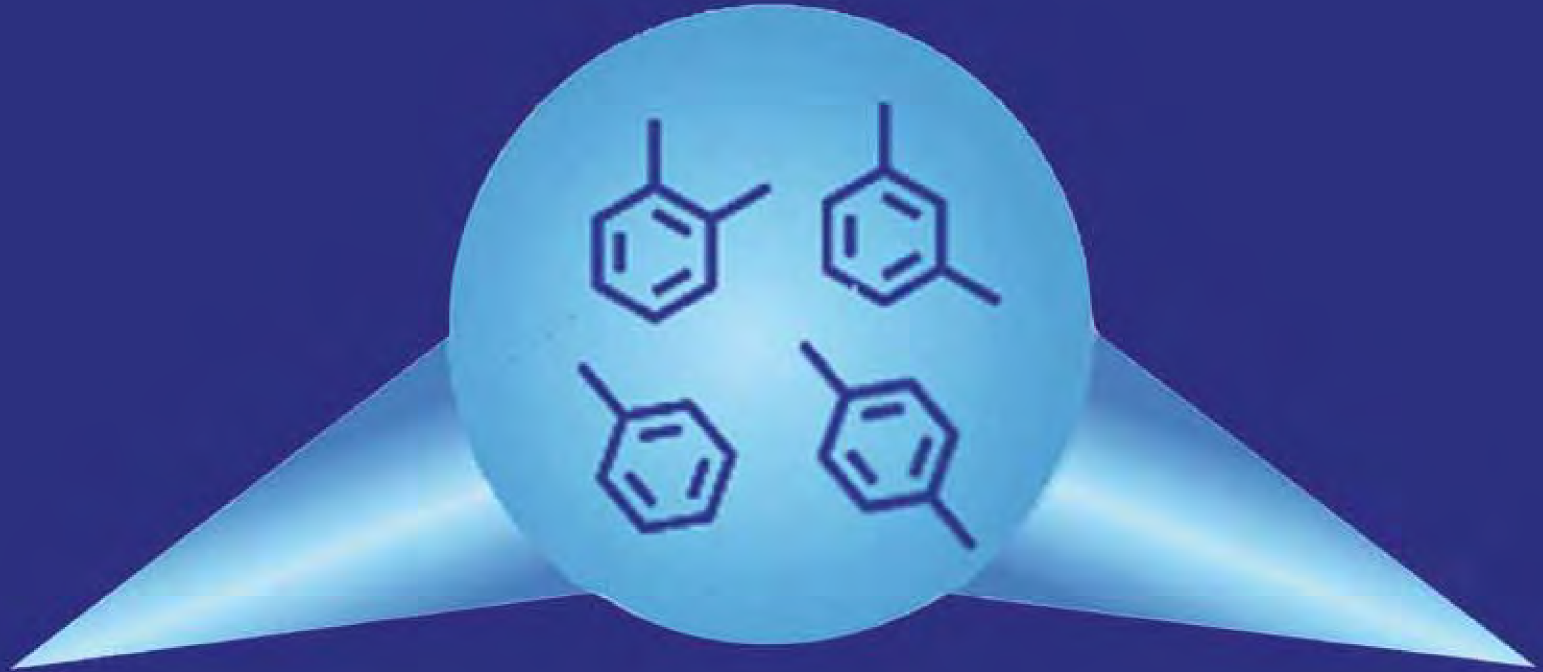
76

2001 Moving up to Movies

Scientists use nuclear magnetic resonance (NMR) to research the structure and characteristics of various molecules by measuring the magnetic properties of the atoms in them. By analyzing this atomic-level information, scientists can extract dynamic and geometric information on proteins, DNA or RNA, and elucidate the chemistry of organic and polymer molecules. These principles also serve as the basis of magnetic resonance imaging (MRI) in pre-clinical and clinical settings.

Scientists at the Institute developed an improved version of these technologies, dubbed "ultrafast multidimensional NMR." Their approach "slices up" the sample, doing away with the need to perform multiple scans. From a single scan produced in a fraction of a second, scientists can obtain an array of data on the three-dimensional structure of matter, its dynamics or metabolic information.

Because it is so fast, the new method can move some research fields from the era of "still photos" to "movies." It enables researchers, for example, to follow such real-time processes as biomolecular folding or the functioning of organs. In addition, it can significantly speed up traditional NMR investigations of molecular structure. Along with uses in spectroscopy and imaging, these techniques are important for the development of new materials for industry, for the design and development of new drugs, and for monitoring metabolic processes in real time.



77

The Physics of Falling Leaves 2001

Institute scientists grappled with a challenge that has engaged scientists for 150 years: How do non-spherical objects fall in liquid or gas? James Maxwell and Lord Kelvin attempted in vain to offer equations that would accurately predict the path of such falling objects.

To address this age-old riddle, the scientists built a narrow glass tank, filled it with liquid and then dropped into it a series of thin metal strips. Their precise observations of this two-dimensional system led the scientists to formulate a theoretical model that could predict the path of a falling metal strip fairly accurately. This two-dimensional model can be expanded somewhat, so that it describes the path of falling leaves or other similar bodies in a three-dimensional system.

The scientists found two general types of motion: "flutter," in which the falling strips move back and forth from side to side; and "tumble," in which the strips rotate end over end. Their calculations suggested that the type of motion is determined by a numerical constant known as the Froude number. The Froude number includes the relationship between the size of an object and its weight: A long strip will flutter while a shorter strip tumbles. In the process of developing their model, the scientists borrowed tools from the mathematics of chaos theory (which is based on the progression of tiny differences in initial conditions). Their model was used to aid Israeli naval investigators in understanding what took place when the submarine *Dakar* sank.

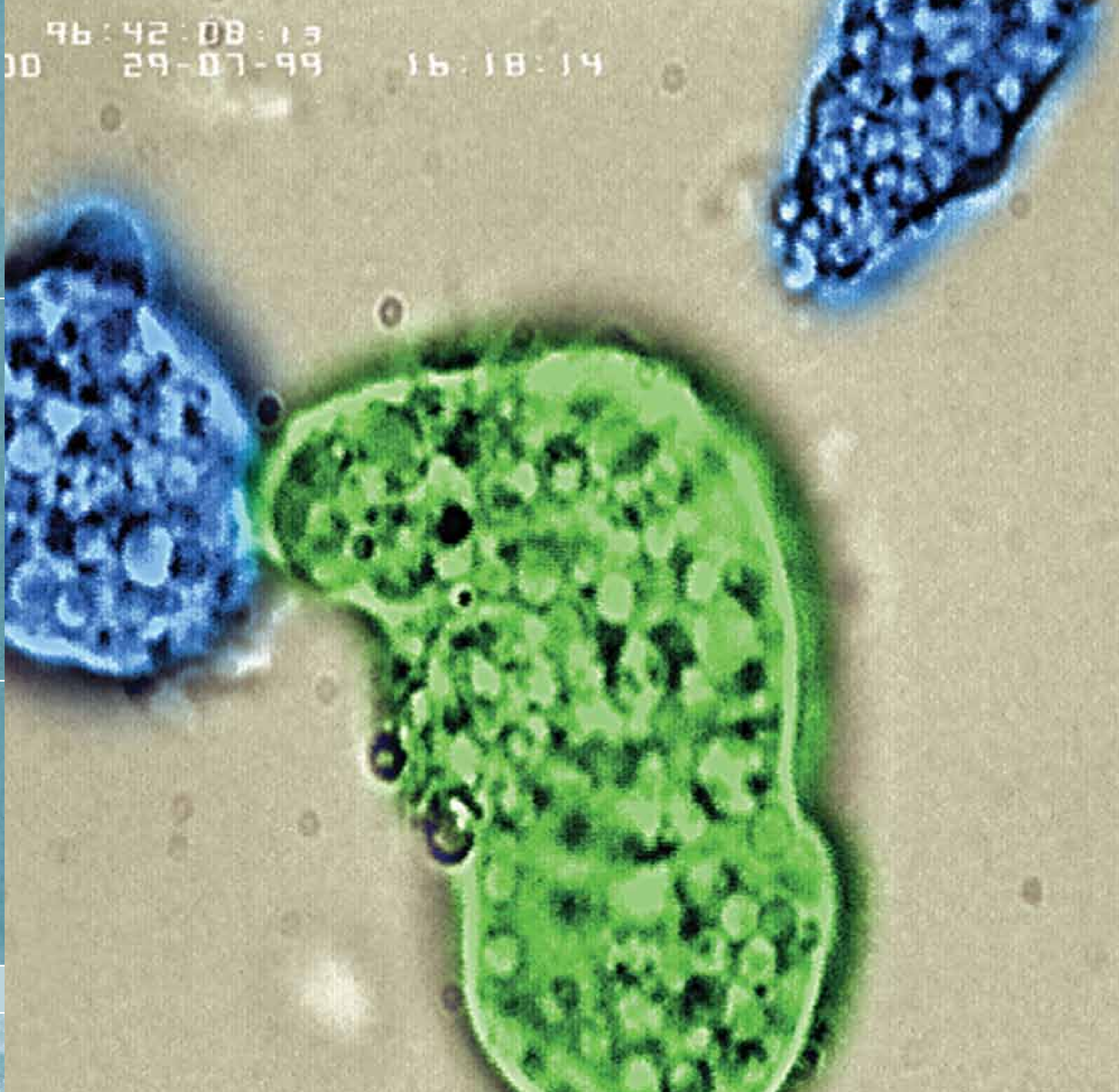
78

2001 Amoeba Midwives

Amoebae reproduce asexually, but as Weizmann Institute scientists discovered, they sometimes need the services of "amoeba midwives." When the time to divide nears, an amoeba doubles its genetic material, forms two nuclei and starts to swell at the ends as the middle contracts to form a narrow "waist." This continues until there are two nearly separate cells joined by a thin tether. At this fateful stage, one of several scenarios might play out: The mother and daughter cell pull on the tether hard enough that they manage to separate into two individual cells; or they pull but don't manage to separate, eventually tiring and remaining a single cell with two nuclei. But Institute scientists identified a third scenario, in which an "amoeba midwife" helps out.

The study was conducted as part of a large-scale effort to unravel the mechanical-physical aspects of the process of cell separation. The researchers discovered that, in not a few cases, when the amoeba "mother cell" is having difficulty separating from its daughter, a third amoeba comes to the rescue, squeezing between the two and pushing against them until the "umbilical cord" is severed and each is free to go its own way.

The researchers observed that the reproducing amoebae call for assistance through chemical signals that attract these midwives right to the spot where their help is required.



79

Gene Loops 2001

The bonds connecting the nitrogen-containing bases of DNA come apart in certain conditions (when the temperature rises above 70° Celsius, for example), so that the two strands separate. In this process, “loops” are created in the genetic material.

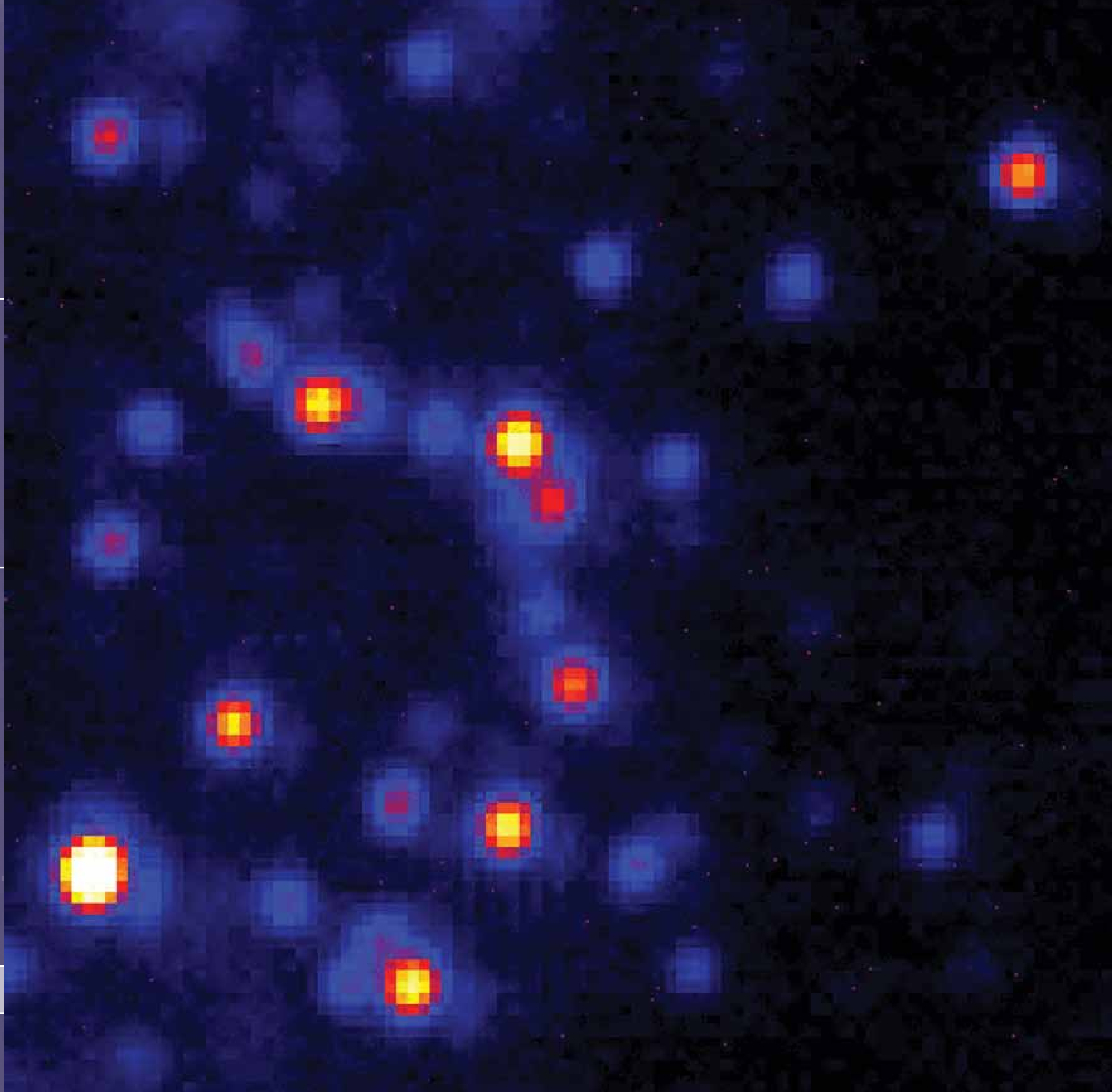
Various theoretical models used to analyze this phenomenon allowed for situations in which adjacent loops of DNA overlapped. But such overlapping never occurs in nature, because the strands of genetic material repel one another electrically. Institute scientists who noticed this discrepancy began to check the possible shapes that a DNA loop can take on while refraining from overlapping either themselves, the neighboring loops or any other molecular strand.

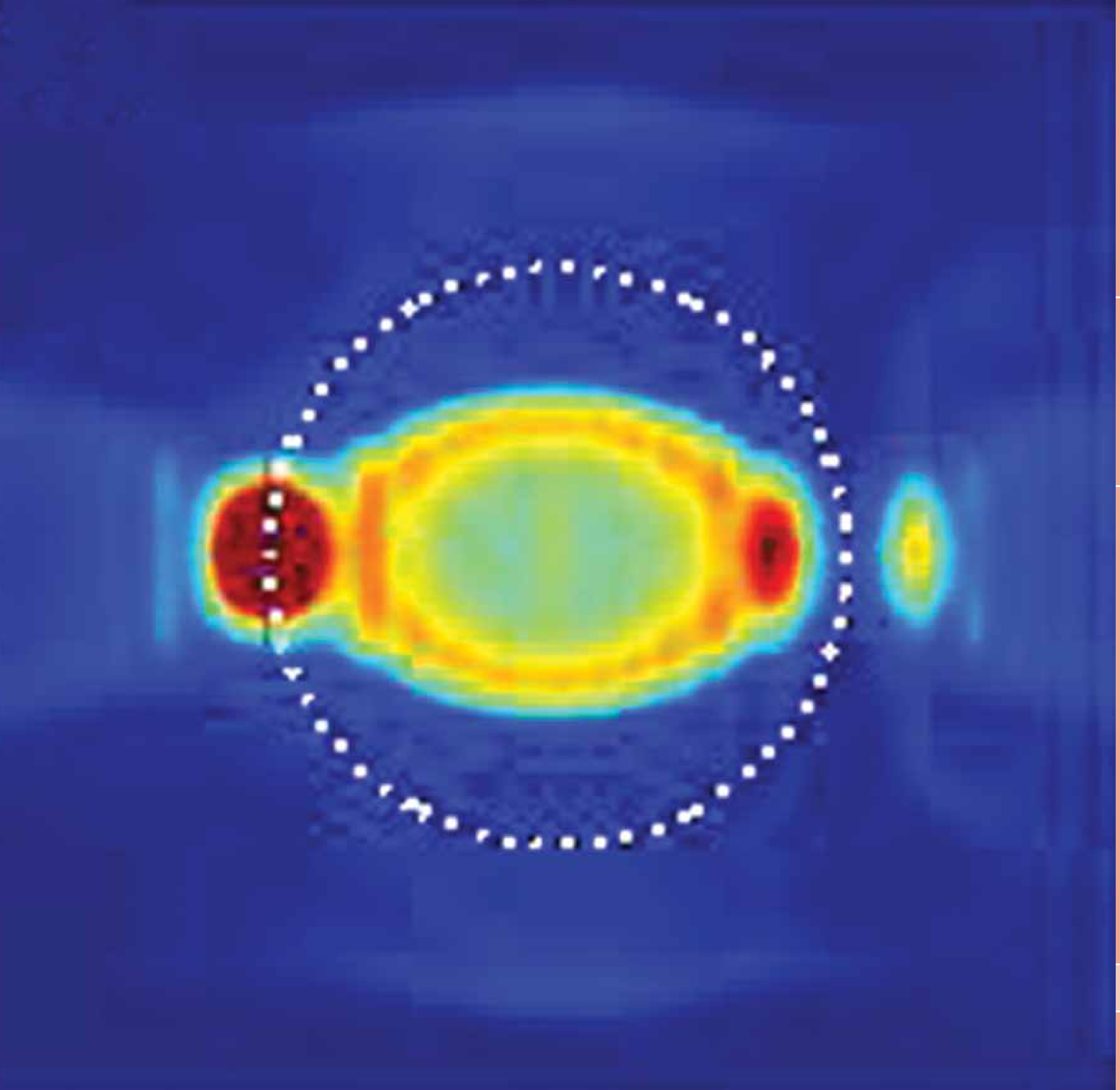
To calculate the complex array of possible relationships between different loops, the researchers used mathematical formulae that came out of studies of the behavior of random networks of polymers. These complex but precise calculations revealed a sudden transition between the normal configuration of bound strands and one in which the strands are separated, just the way it happens in real life.

80

2002 A Good Place in the Middle of the Galaxy

Together with astronomers from Germany, Weizmann Institute scientists who followed the path of a star orbiting an “empty point” in space found evidence to support the hypothesis that the center of our galaxy – the Milky Way – is occupied by a supermassive black hole, a body around four million times as massive as our sun. This giant body, called Sagittarius A*, initially appeared to observers as an empty spot in space. But a year later, it was discovered that this empty spot emits radiation of a type thought to be typical of gas sucked into a massive black hole. In their research, the scientists traced the path of the star orbiting Sagittarius A*. Whizzing around at a speed of 5,000 km a second, the star flew extremely close to the black hole: just 17 light hours from its event horizon. If the star had been just a tad closer to the black hole, it would have been torn apart and sucked inside. The research was carried out with the ESO Very Large Telescope in Chile.





81

The Lowest Temperature

2002

Bose-Einstein condensate is a phenomenon first predicted by Bose and Einstein in 1925. To create it, one must cool material to very low temperatures until it enters a new state of matter, called a condensate, in which the energy state of the system is the lowest possible. Only in 1995 did scientists succeed in observing this phenomenon, when they used lasers to cool a low-density cloud of gas atoms to about a millionth of a degree above absolute zero.

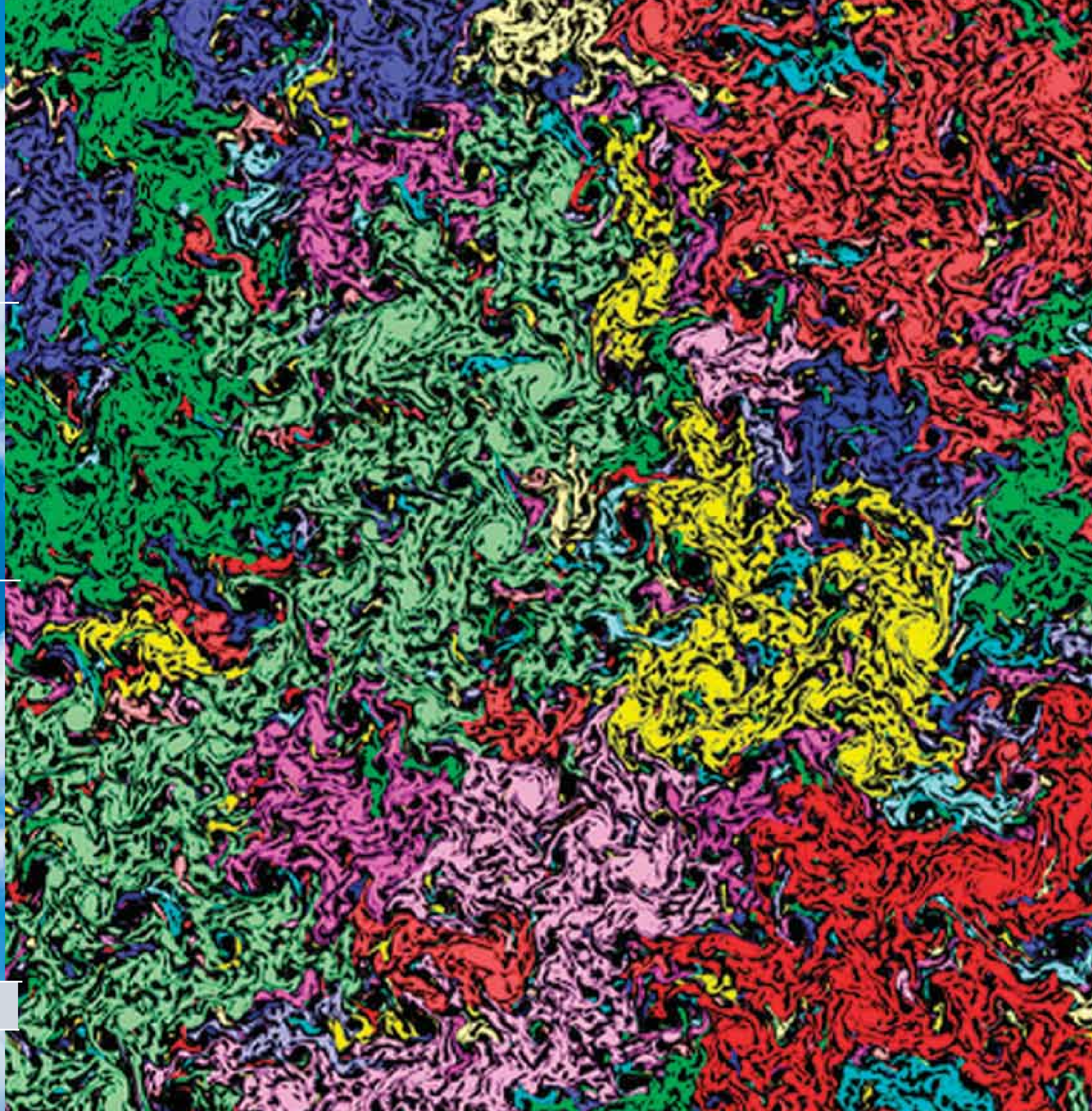
Institute scientists were the first to measure the energy of excited states in a Bose-Einstein condensate. Later, they also succeeded in characterizing the dynamics of these excitations.

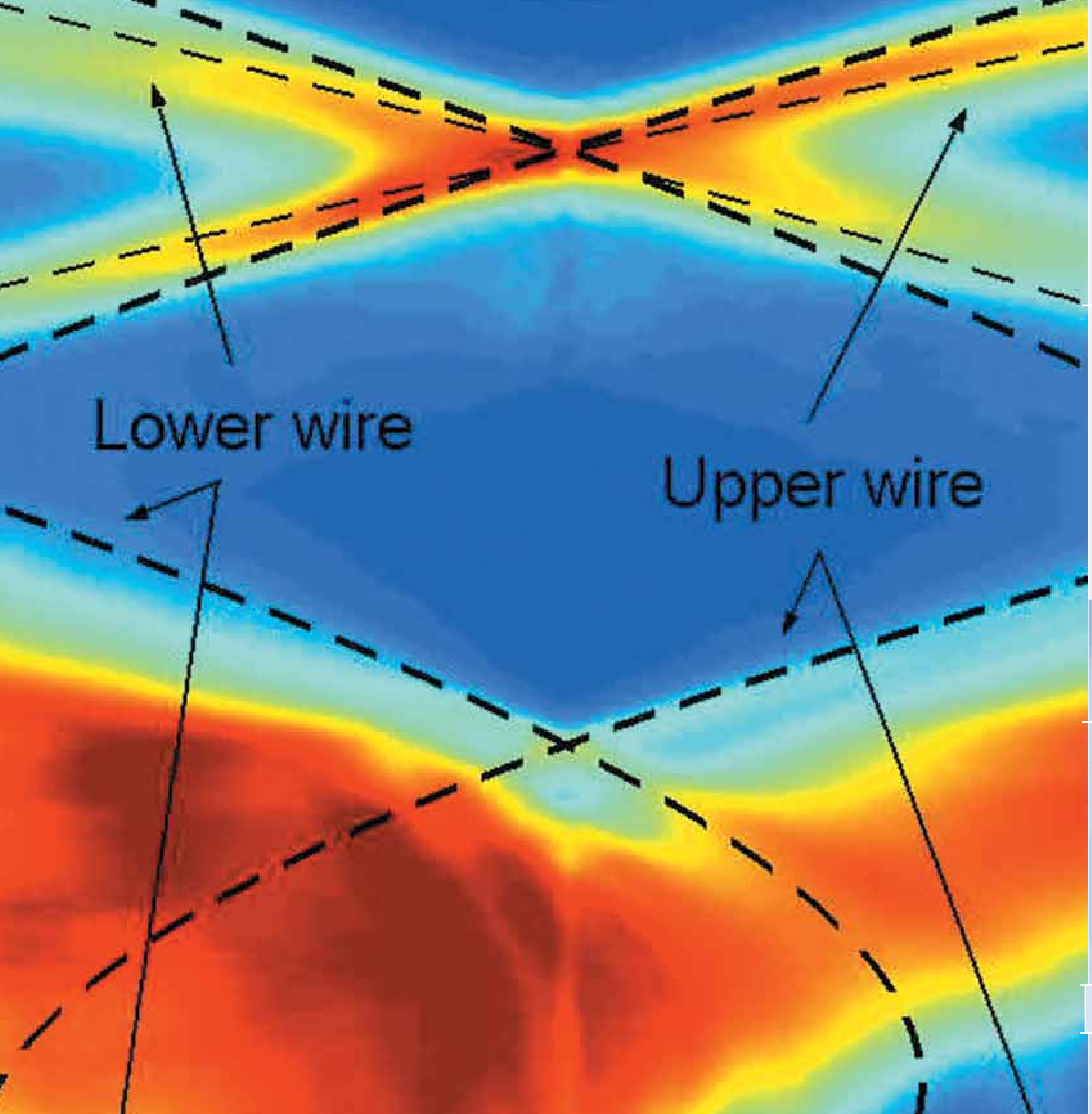
82

2002 Adding Up the Drops

Turbulent whirlpools in clouds can bring on rain. This conclusion came out of the research of Institute scientists, who developed an equation enabling them to calculate how much time is needed for a microscopic water drop in a cloud to grow and gain enough weight to fall to the ground as a raindrop. Their findings may help improve weather prediction as well as improving the efficiency of automobile fuel use and air pollution monitoring.

The scientists discovered a mechanism that ties turbulent air flow to rainfall. They called this the "sling effect," because air whirlpools in clouds behave like small centrifuges or slingshots. As they spin, they throw the heavier drops farther out from the center, so that these congregate near the whirlpool's edges. This concentration of somewhat heavy drops in a relatively small area increases the chance that drops will collide and join together to form drops of about a millimeter in size – big enough to fall as rain.





83

Islands of Stability, Lines of Flow 2002

For a long time, physicists had assumed that electrical conduction at low temperatures can take place only in a three-dimensional system. Deciding to test this belief, Institute scientists came up with a way to measure how electrons are arrayed in a two-dimensional layer. They developed a microscopic method that can sense even a small fraction of a single electron's charge, enabling them to map the placement of electrons in an ultra-thin layer of material, as well as the area occupied by each. The scientists discovered that at low density, the electrons in this material are found in sorts of "islands of stability"; thus, when electrons are added into the system, they tend to gather in one of these islands rather than passing through the material. Electric current can traverse the whole system, but only if it percolates through these islands.

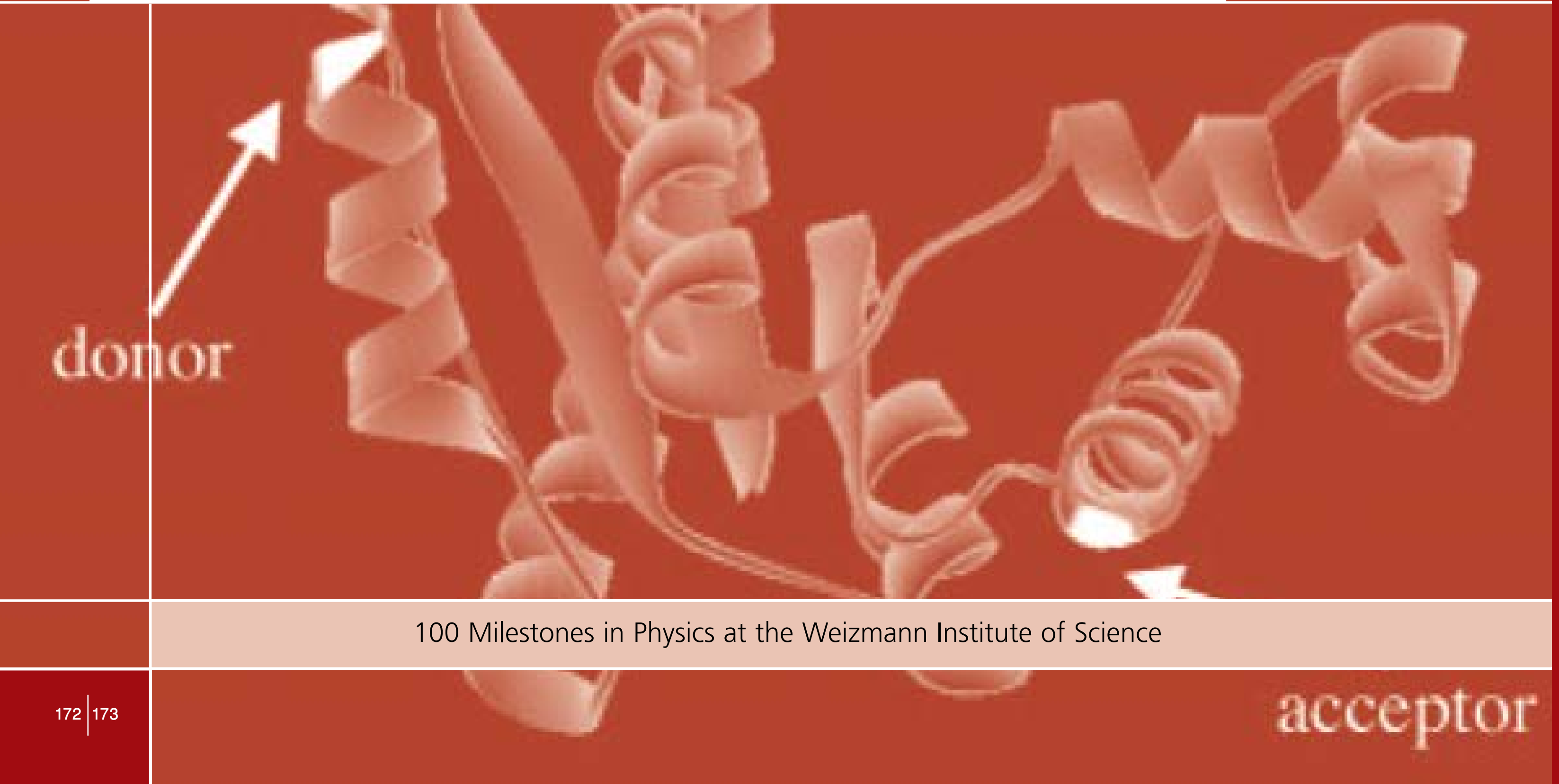
In another study, they tested a phenomenon in a one-dimensional system in which mutual electrical repulsion causes electrons to act like little hard balls lined up in single file, one after another, with no possibility of moving left or right, up or down. When an electron is added to the system, it joins at the end of the line; but its momentum moves up from electron to electron until it reaches the front of the line, where it passes out of the system. The rate at which this momentum passes between electrons is determined by the strength of the electrical repulsion between them. The greater the repulsion, the faster the momentum moves up the line.

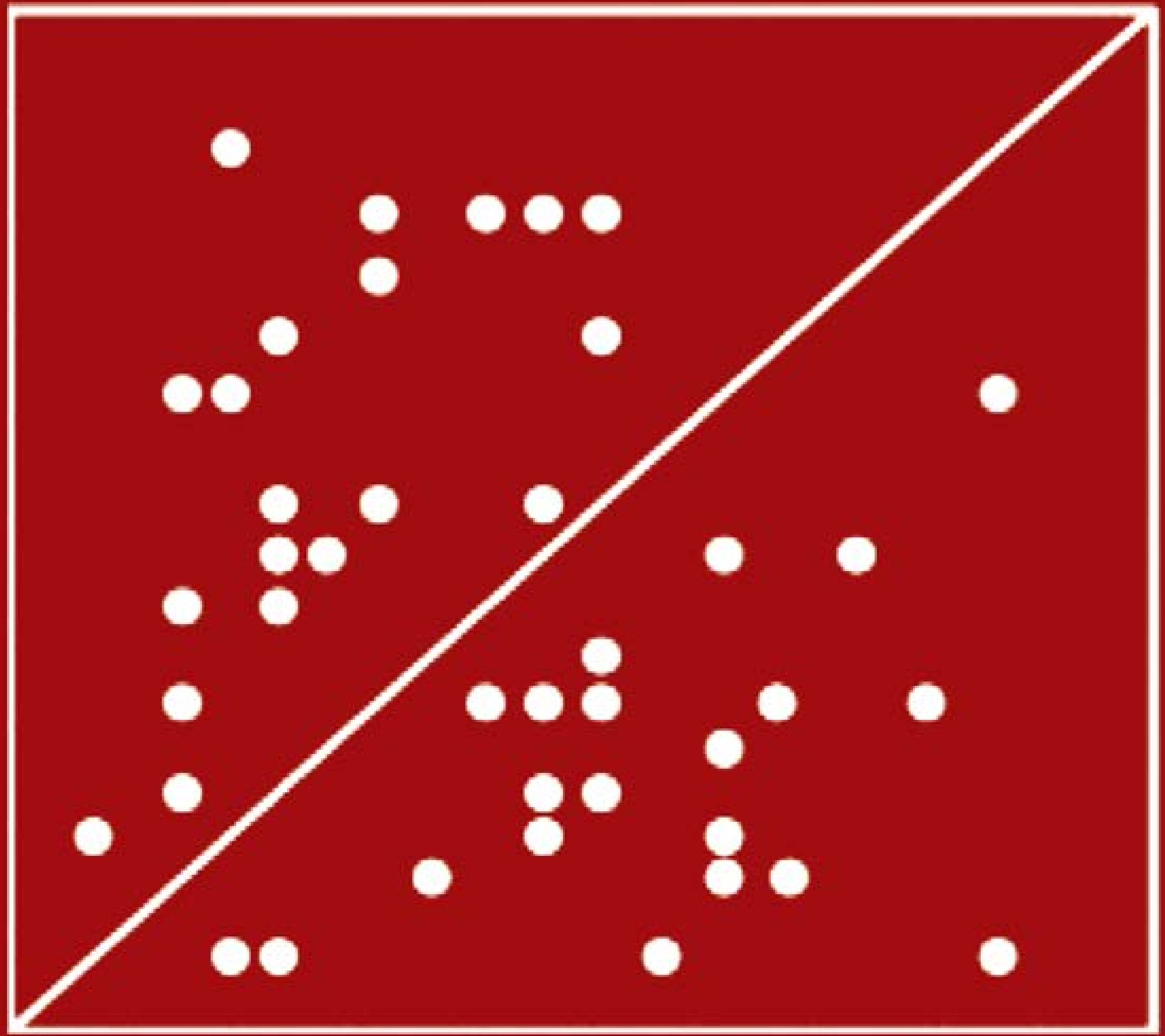
84

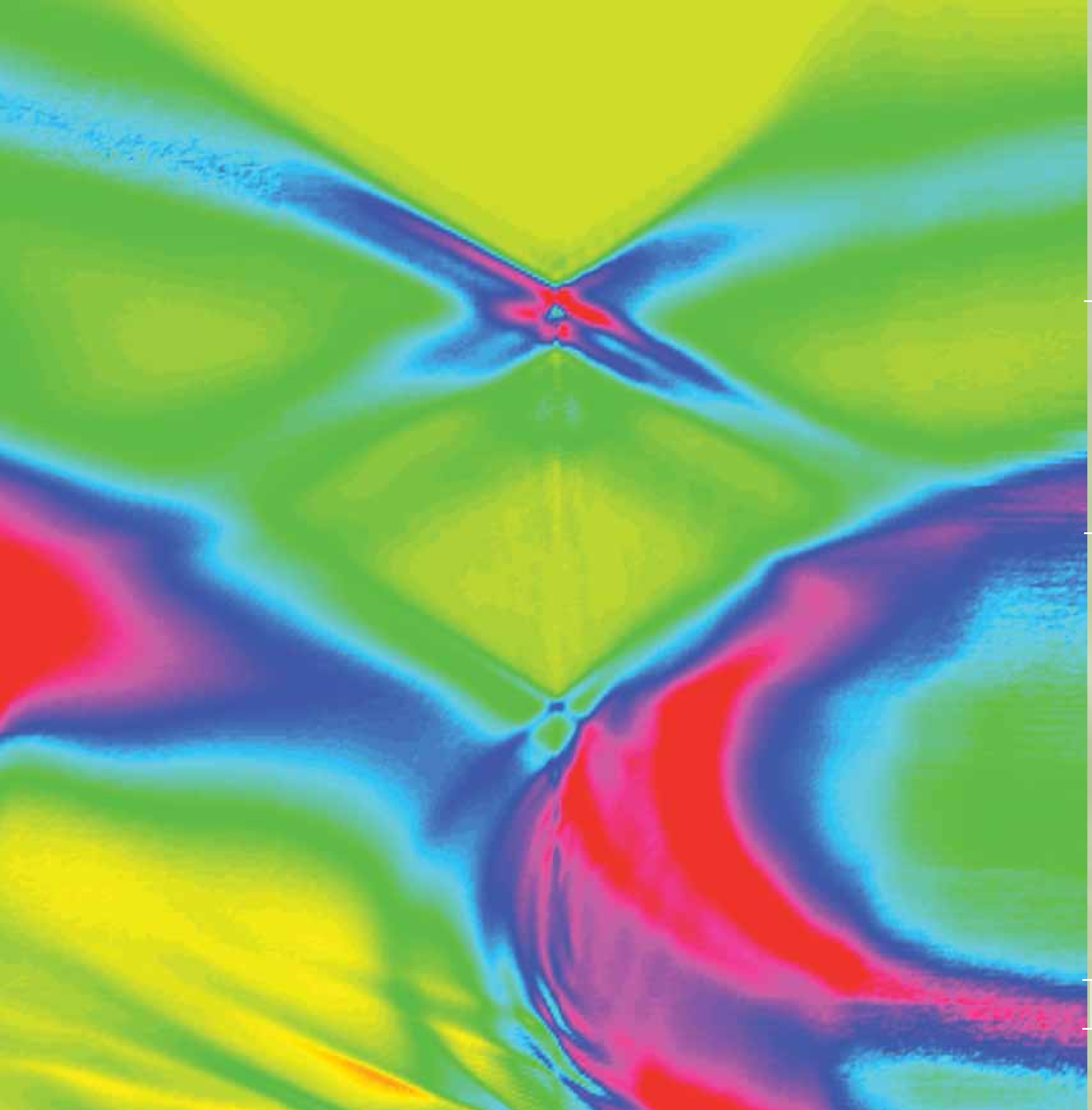
2003 Folding in Its Own Way

Institute scientists were the first to catch a glimpse of single molecules in the act of folding. This is how they discovered that different molecules that end up with exactly the same shape can get there in completely different ways, going through a large assortment of unique and varied intermediate steps on the way.

Proteins are the basic components of living cells, and correct folding is necessary for them to function properly. To observe folding on the scale of a single molecule, the scientists developed new technology based on trapping proteins in vesicles in which they could move freely. These vesicles were made of lipids (the fatty molecules that make up the cellular and nuclear membranes). The protein-containing vesicles were attached to a glass substrate, giving the scientists an unobstructed view of the activity inside.







85

Separating Spins 2003

Physicists at the Institute discovered that when electrons are forced to march in single file along the length of a one-dimensional conductor, it is possible to separate their two main properties – electric charge and electron spin. In a series of experiments, the scientists succeeded in showing how this separation takes place in theory and in practice.

The possibility of changing an electron's spin without affecting its charge is the first step in developing a new kind of electronics, called spintronics. While today's electronics are based on charge, spintronics – involving changes in spin – could make new applications possible, including new types of data storage, and magnets and devices that will be able to perform tasks not possible with today's electronics.

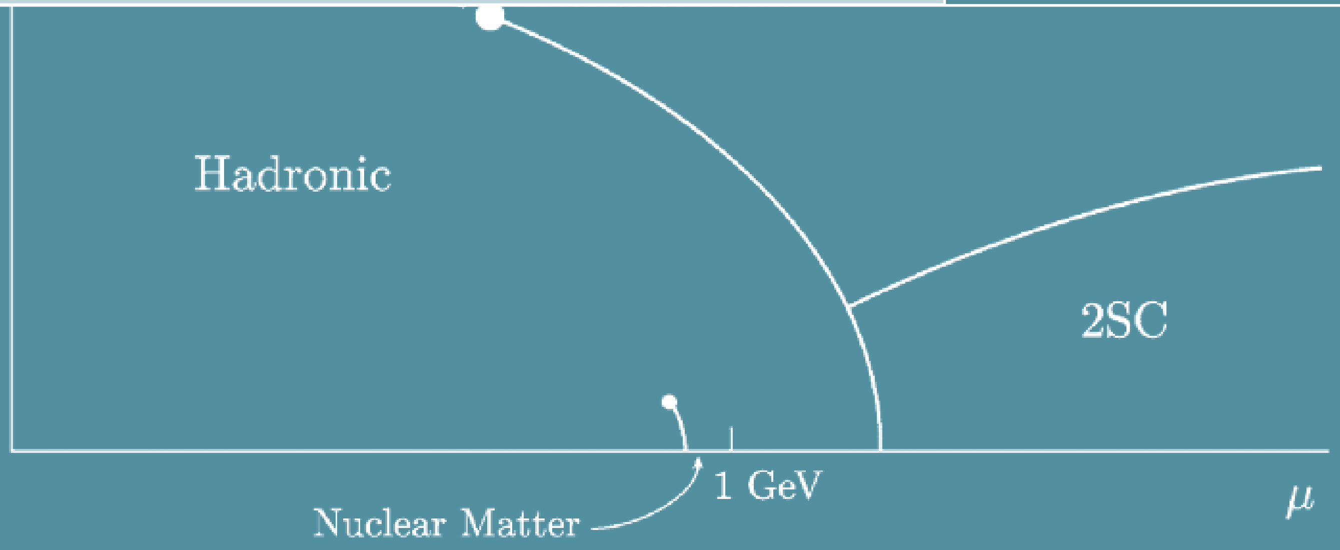
86

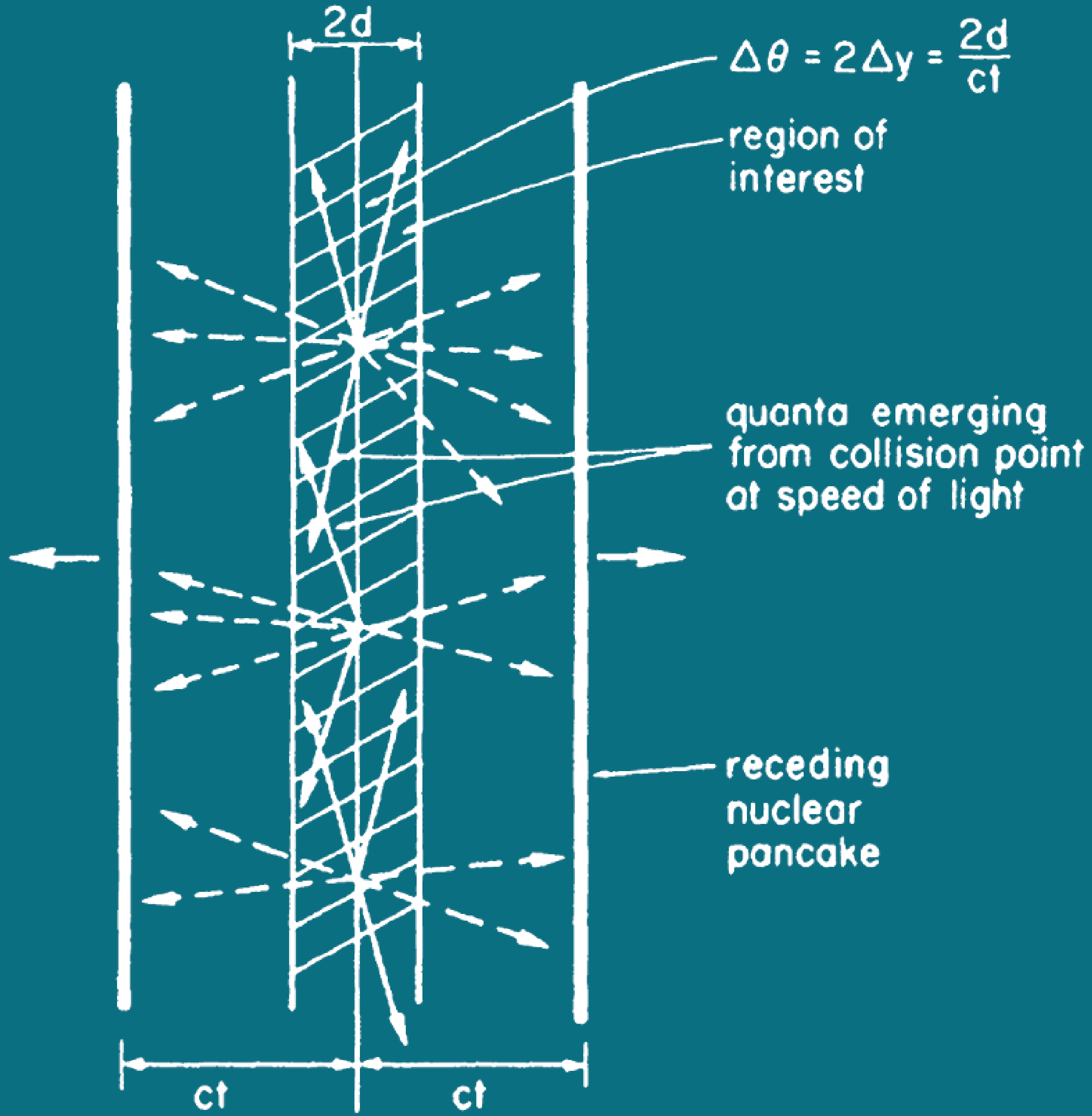
2003 First Matter

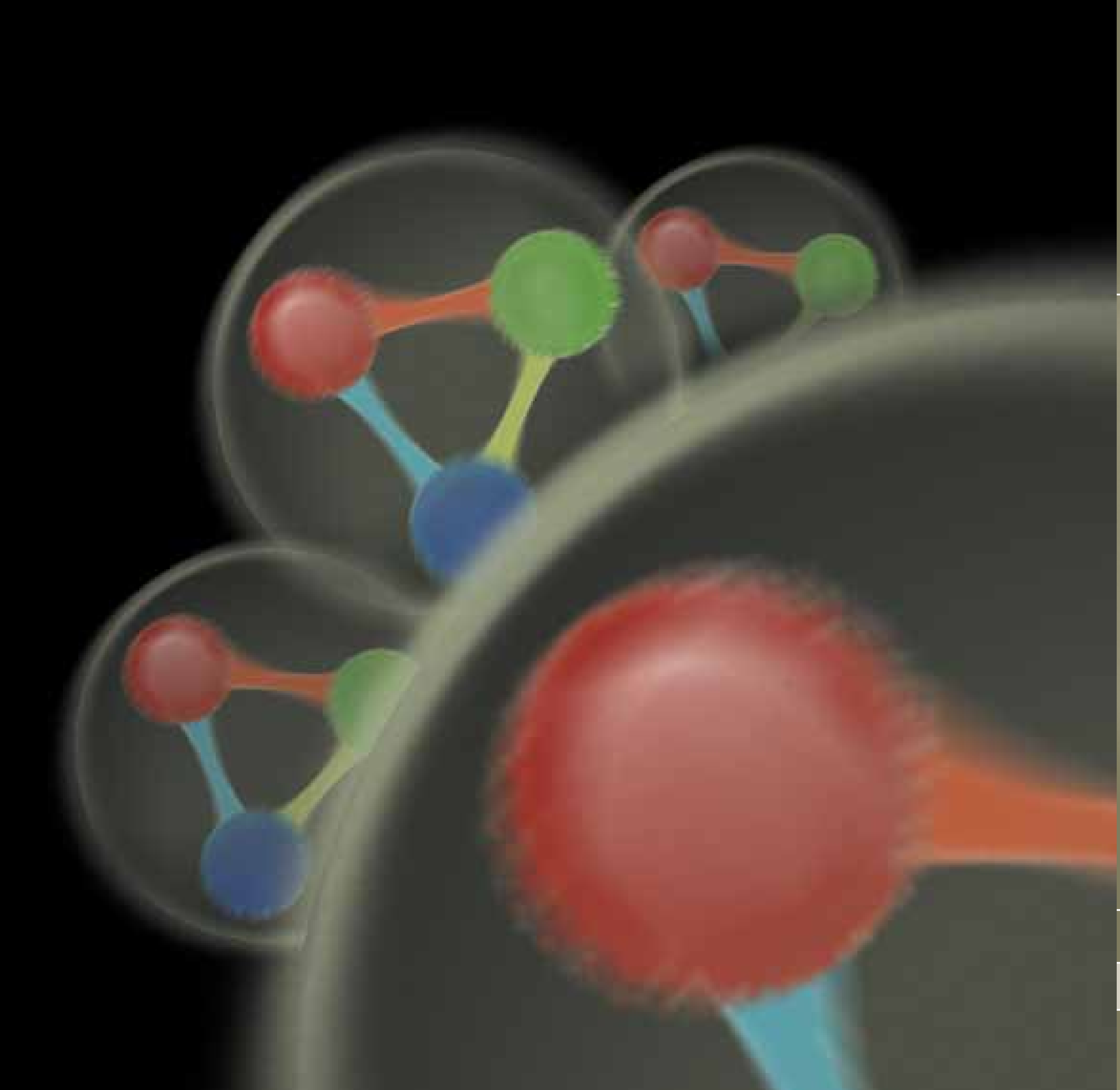
$$m_{u,d} = 0; \quad m_s = \infty$$

Institute scientists played a central role in an experiment that aimed to recreate the primordial matter – that which preceded the formation of protons and neutrons – in the Universe. This matter is known as quark-gluon plasma. The Institute scientists planned and built special particle detectors that were installed at the Brookhaven National Laboratory in New York. Some 460 physicists from 57 research institutes and universities took part in the PHENIX experiment.

In this experiment, the scientists attempted to identify signs of the quark-gluon plasma by tracing the behavior of jets of material penetrating it. When a single quark propagates through regular matter (containing protons and neutrons), it emits radiation that slows down its progress somewhat. In contrast, when it enters a very dense medium such as the quark-gluon plasma, it will slow down quite a bit. That's precisely the phenomenon that was observed and analyzed in the PHENIX experiment. According to the physicists taking part in the experiment, these findings could indicate that they have succeeded in recreating the first matter in the Universe.







87

Colors 2003

No one has yet seen an isolated quark or gluon, mainly due to fact that these particles are confined in more complex structures, such as protons and neutrons. What keeps them tightly bound in these formations is the strong nuclear force. One way to free them, so they could be observed, would be to heat matter to temperatures exceeding a million million degrees. Today, we are not able to attain such temperatures, but they existed in the primordial Universe, a short instant after the Big Bang. As the Universe expanded and cooled, matter entered a new state – that which exists until today – in which quarks and gluons are tightly confined in protons and neutrons.

As yet, scientists are not sure how to prove the phenomenon of confinement or to investigate how the transition to the present form of matter occurred, because calculations involving the theory of the strong nuclear force are extremely difficult. To try to overcome this hurdle, Institute scientists used one of the most powerful scientific tools available: the human imagination. They tested an imaginary situation in which the Universe is not large and possibly infinite, but rather a tiny sphere. Here, they found, the strong nuclear force is weakened and it can then be included in calculations without too much difficulty. In order to obtain a transition to the state of matter present in this imaginary Universe, they had to increase the number of "colors" in it. (Color refers to a specific charge carried by quarks and gluons.) In our Universe, there are three colors, but the theoretical Universe the scientists worked with required the existence of many more.

They showed that in spite of the enormous differences between the known Universe and the imaginary one, matter in the imaginary Universe also undergoes cooling and transition to another state, as in our Universe. That is, at low temperatures the quarks and gluons become confined, and at high temperatures they are freed. Thus the scientists showed how a phenomenon that can't be investigated in our own Universe can still be approached through a theoretical, imaginary Universe. Nonetheless, it is still not clear to what extent this model makes possible an understanding of the way these particles get confined in our own Universe.

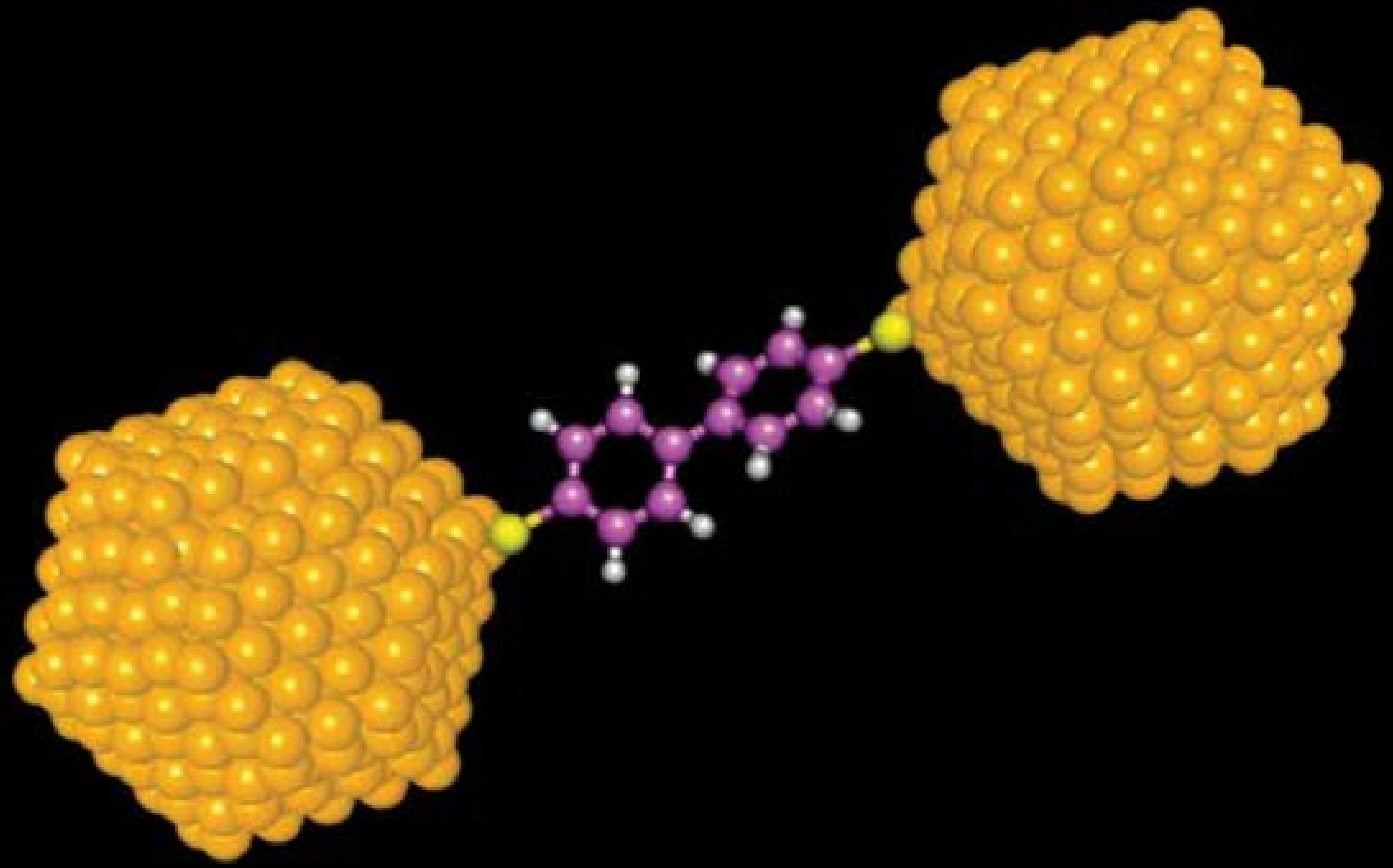
88

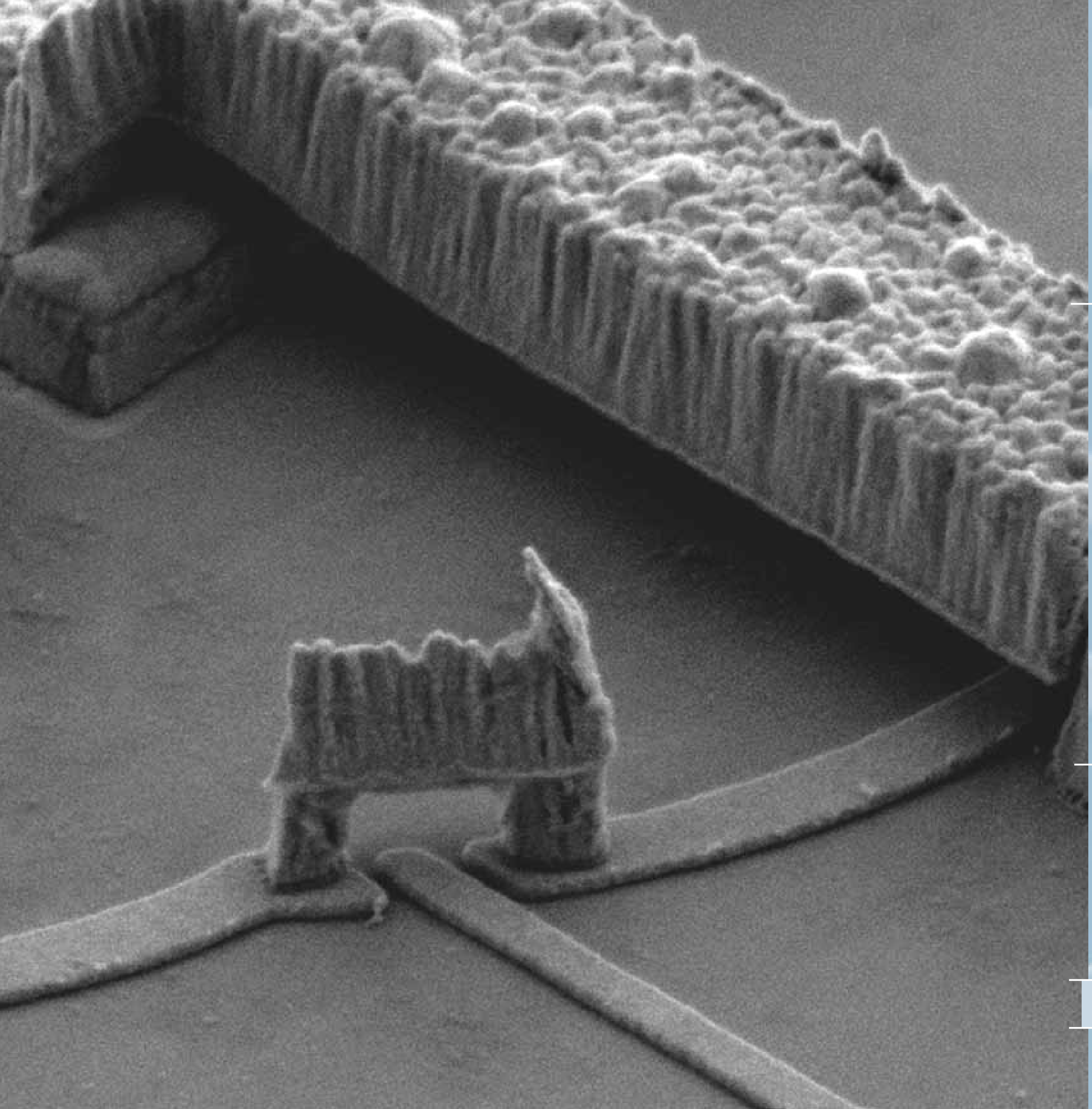
2005 Molecule on a Wire

Size matters, at least in electronic devices. The smaller the device – the further it is miniaturized – the more it can be fast, efficient and accurate. But to what extent can electronics be shrunk? Would it be possible, for instance, to connect a wire to single molecules and to measure their electrical conductivity? Institute scientists found a way to do just this and, in the process, they reset the lower limit for miniaturization.

The scientists stuck two gold nanoparticles, one at either end of a tiny organic molecule called biphenyldithiol. This molecule is just one nanometer long (too small to manipulate). But with the nanoparticles on its ends, the biphenyldithiol molecule forms a structure that can be worked on. The scientists placed the biphenyldithiol structure between two contacts on a tiny device, and the molecule behaved like a wire, passing electric current between the contacts.

This apparatus is used by the scientists to develop ways to control the conductivity of molecular wires. Such control should enable the creation of advanced nanotransistors for future electronics.





89

The Quantum Observer

2006

An observer, according to one of the better-known laws of quantum mechanics, changes things just by the act of observing. Scientists at the Weizmann Institute demonstrated this principle using electrons. They had previously built a micron-sized experimental device (a thousandth of a millimeter across), containing a barrier with two openings through which electron beams passed to a plate on the other side. According to quantum theory, subatomic particles have a dual existence: They can behave as matter and at the same time as waves. As waves, they can pass through both openings at once, leaving interference patterns on the far plate. This interference can be constructive – in which case the electron continues past the point where the interference takes place – or it can be destructive – so that the waves cancel each other and the electron never arrives.

The scientists built a new experimental device, in which single electrons passing through the openings in the barrier are also under the "eye" of a "quantum observer." This "observer" was actually a potential observer: An electron wave passing by it affected the potential in the observer, which in return acted on the wave behavior of the interfering electrons – thus destroying the interference. When this observer was turned on, there was no interference; when it was off, interference resumed. When the sensitivity of the observer was adjusted, affecting its capacity to accurately sense the electrons as they passed through the barrier, the instruments recorded a progression of behavior from wave-like to particle-like. In other words, the presence of an "observer" was shown to change the experimental results.

1μm

90

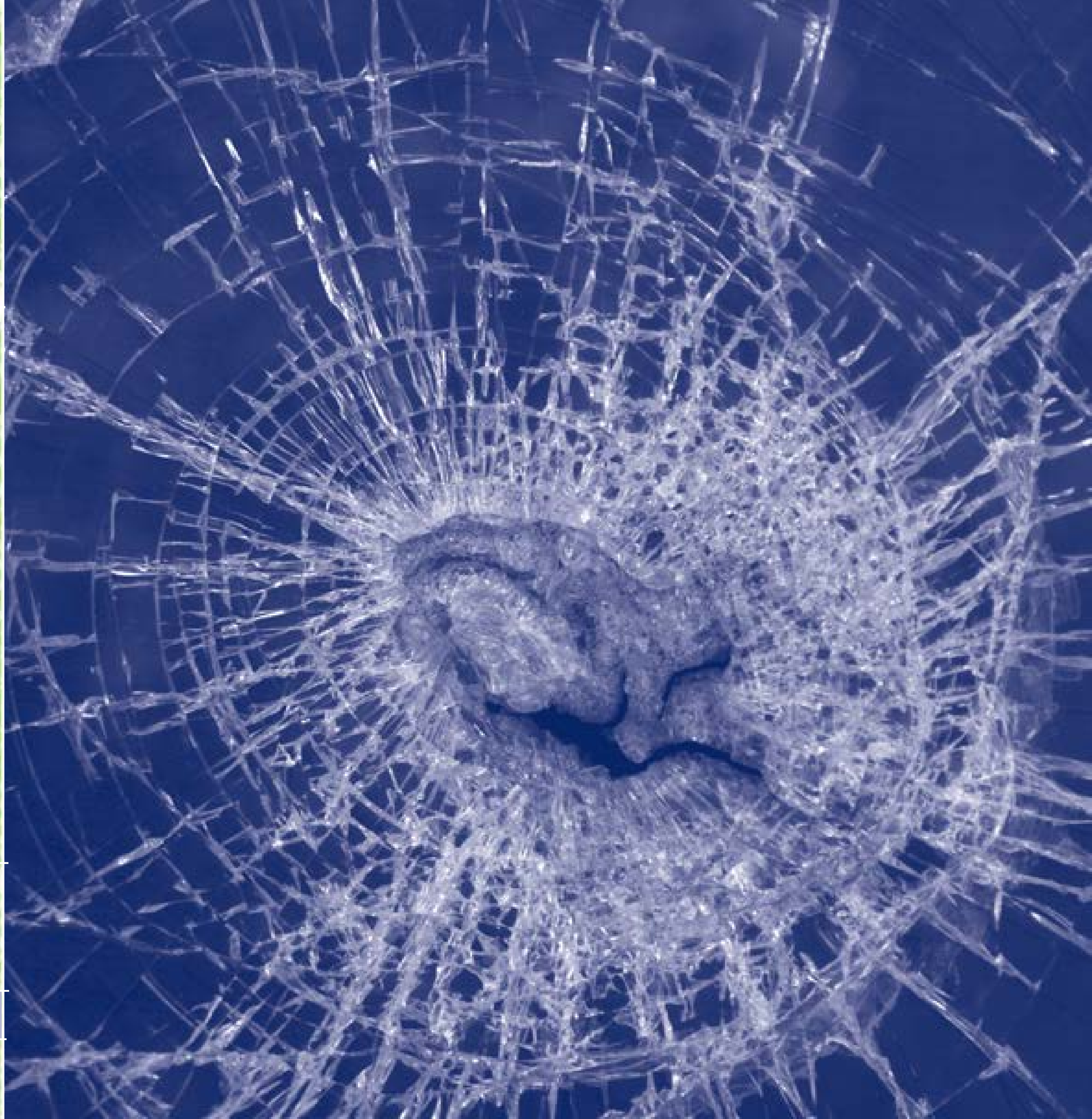
2006 Signs of Cracking

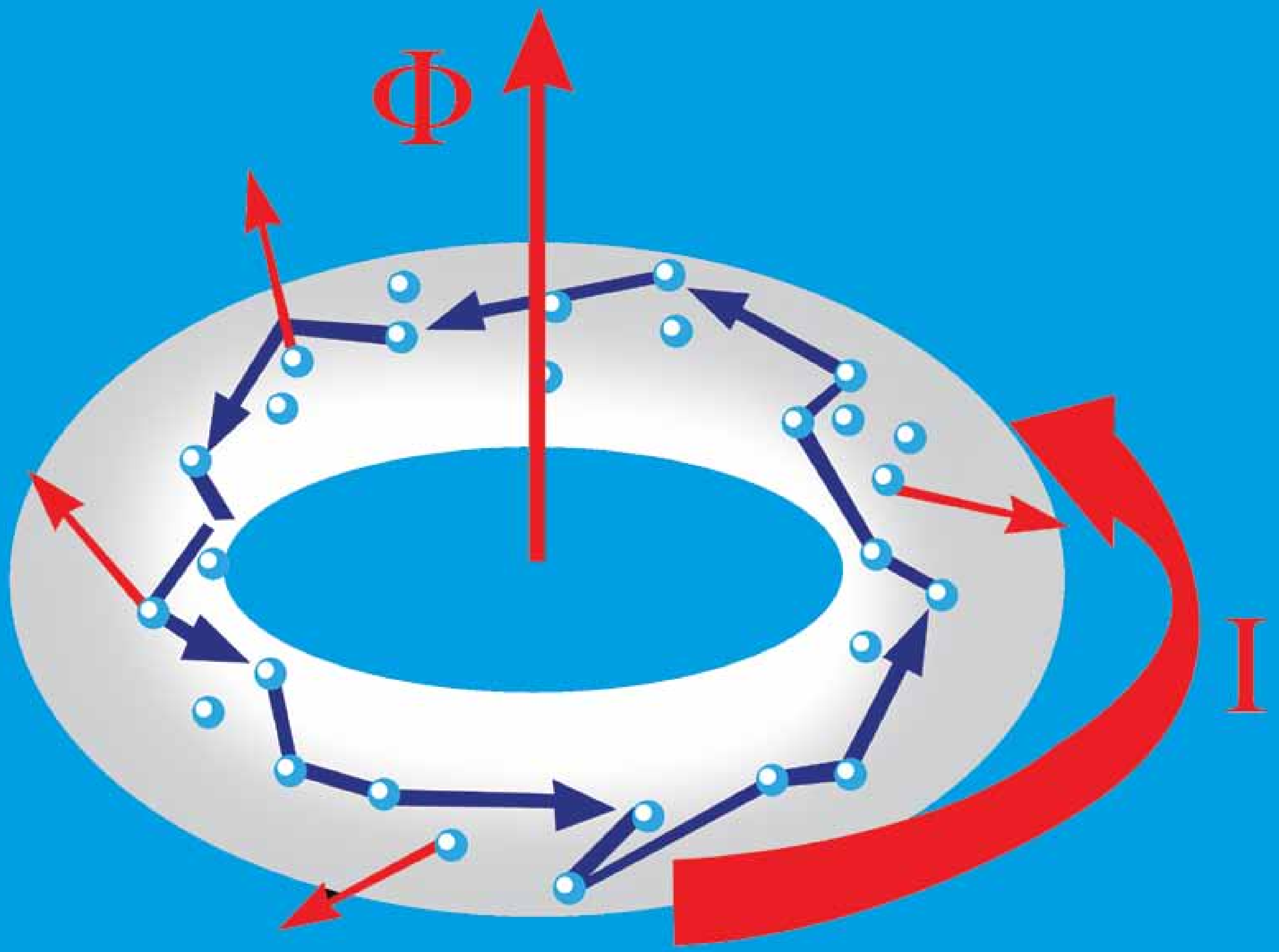
Institute scientists formulated a new theory to predict the different stages of cracking in solid crystalline materials.

When force is applied to a material (for example, when a rock is thrown at a piece of glass), a crack starts to form in the internal layers of the material. The crack travels through the material, accelerating as it advances, until it reaches a stage at which the structure of the glass pane falls apart. The force applied and the structure of the material both affect the direction of cracking, as well as the formation of branches – side cracks that often resemble herringbones. Under a microscope, the cracked surface shows a characteristic bumpy pattern. Physicists who had attempted to predict the shape and dynamics of a crack encountered difficulty: Because the process of cracking is directional, the same crack will look different when observed from different angles.

To deal with this problem, the scientists divided the bumpy cracked surface into segments with unique traits, so that in each one they could measure the forming crack and assign it directionality as well as other properties. Complex calculations enabled them to understand the dynamics of the crack independently of the direction in which the measurement was conducted. In the future, the formula may be extended to successfully predict the direction in which a developing crack will move, as well as the influence of the material in which the crack takes place.

Comprehensive studies based on the new theory will enable scientists and engineers to learn about the real traits of different materials and about the ways in which a crack can develop in these materials. Such research may make it possible to predict how assorted structures (for example a dam or an airplane wing) will stand up to various pressures and forces – especially after a period of time, when small, unseen cracks may have accumulated inside the material.





91

Eternal Flow

2008

Electric current can flow forever in tiny circuits in the presence of a magnetic field, even if the circuits are not superconductors. In microscopic circuits, this quantum mechanical phenomenon can, in principle, take place even when temperatures approach room temperature. Institute scientists encountered many raised eyebrows when they first presented this finding, which arose from a theoretical study; until then, the general assumption had been that eternal electrical currents could take place only in superconductors. But superconductors' need for extremely low temperatures and other difficulties make their use fairly impractical. The Institute scientists and their colleagues succeeded in demonstrating such a current in a mesoscopic ring (an intermediate size between the macroscopic, everyday world and the microscopic one in which the laws of quantum physics apply). This was an important impetus to the burgeoning field of mesoscopic physics, which was initiated by Institute scientists.

To the surprise of many, the theory was proven in experiments; but the electric current that "flowed forever" was five to ten times larger than predicted by the theory. This fact put the theory in doubt. But the Institute physicists managed recently to find a theoretical explanation that fits the facts, one that rests on new insights into the forces acting between the electrons that carry the electric current, and that garnered much interest worldwide. Eternal flow phenomena could pave the way toward the development of advanced technology applications in research and, hopefully, even in medicine.

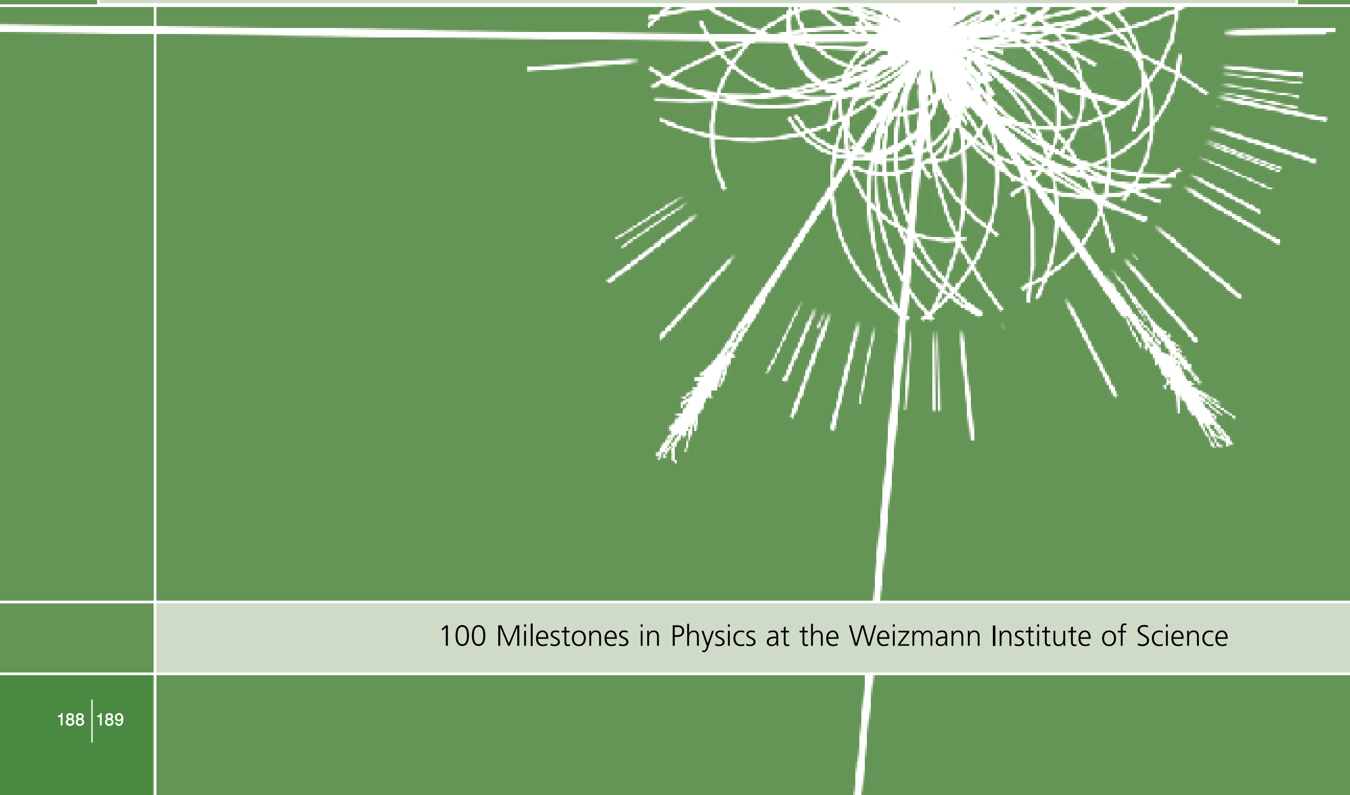
92

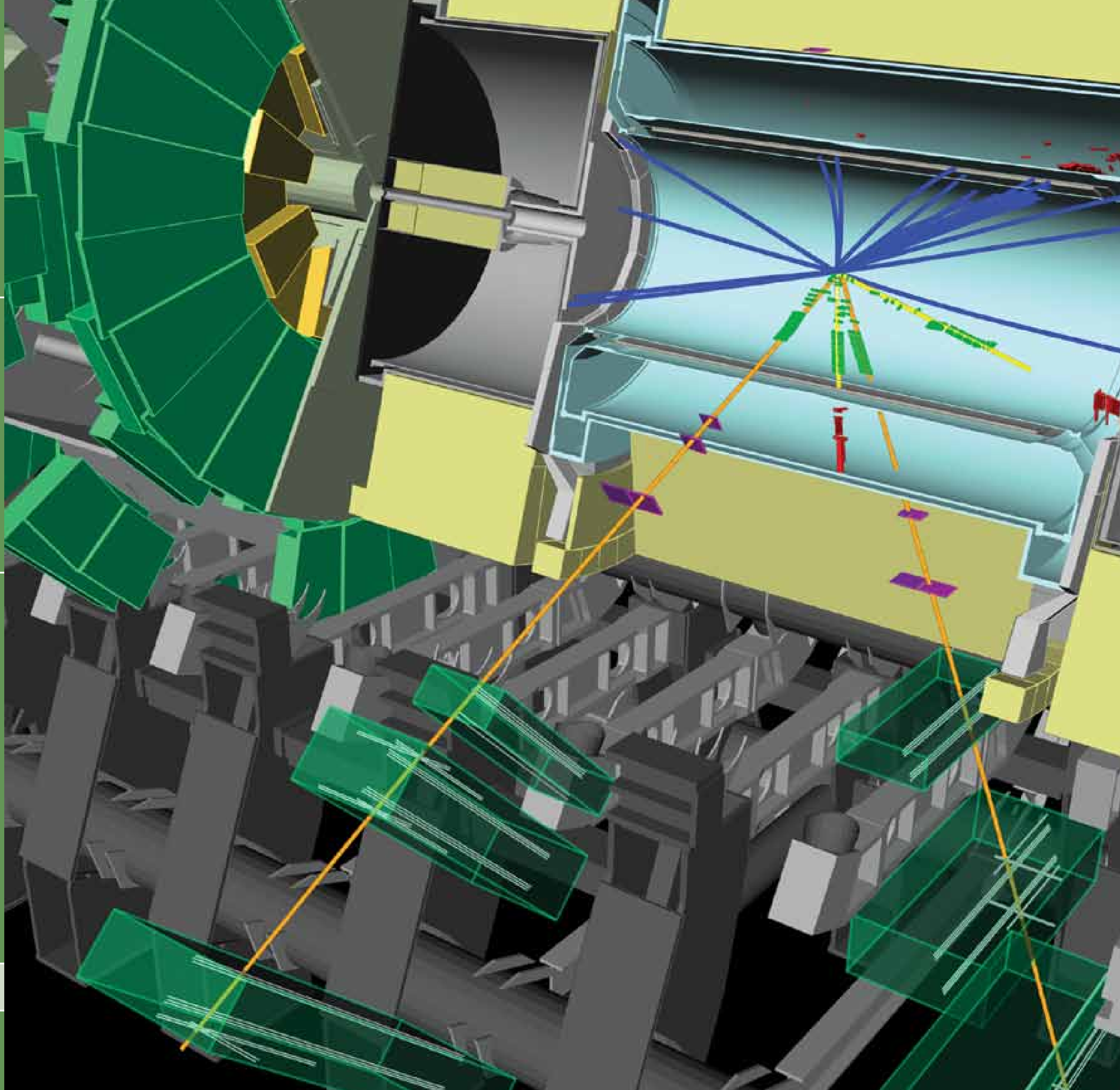
2008

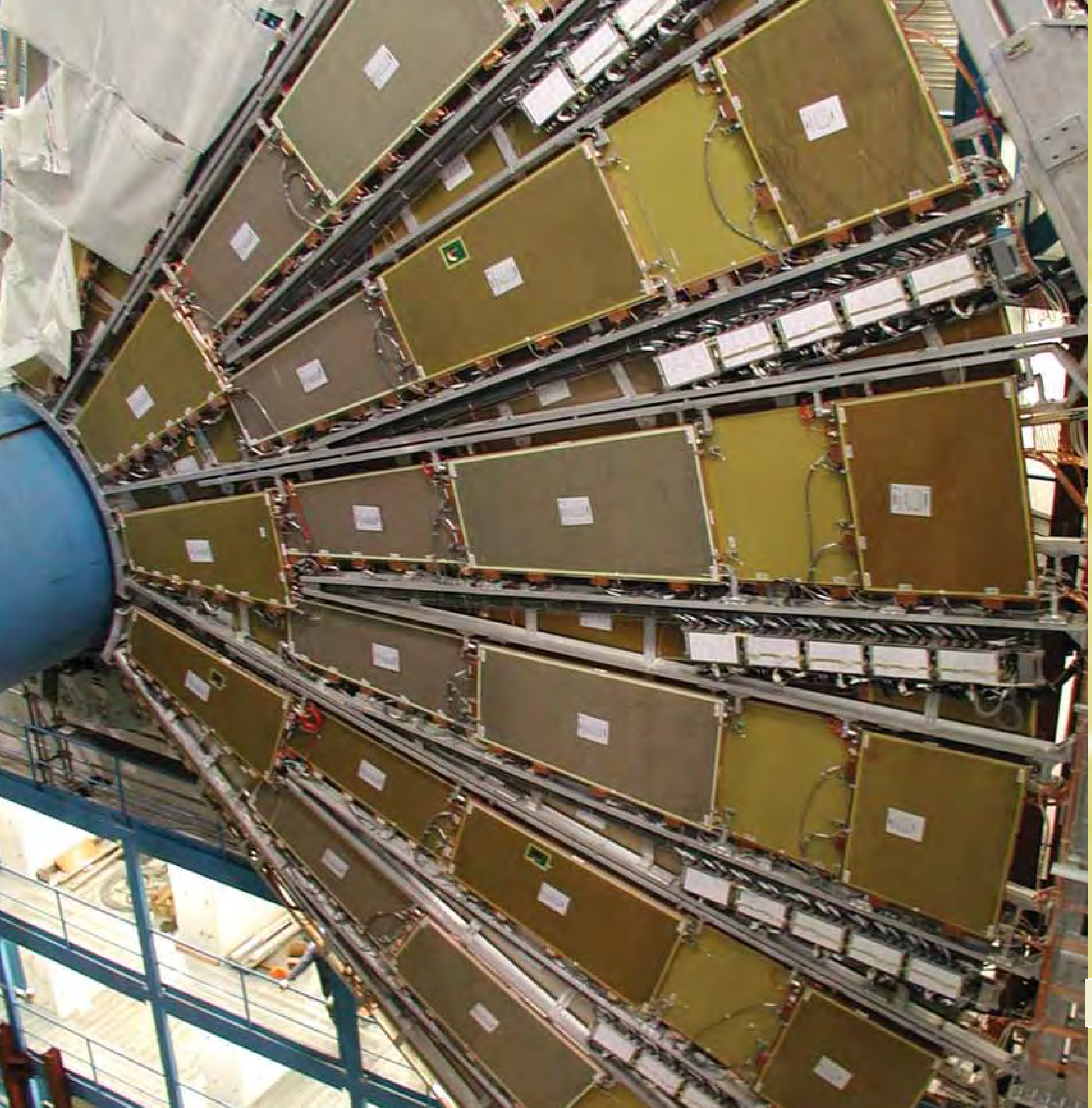
The Source of Mass

Institute scientists play key roles in a research project being conducted by thousands of physicists from 65 countries, who are attempting to prove the existence of the "God particle" – the Higgs boson – which, according to accepted theory, is one of the particles carrying the electroweak force (a marriage of the electromagnetic and weak forces).

The research is taking place in the Large Hadron Collider (LHC) – the largest machine ever built – of the European Organization for Nuclear Research (CERN), near Geneva. Institute scientists are responsible, among other things, for the statistical methods used to analyze the data amassed in the ATLAS experiment in which physicists hope to discover the God particle. This task is enormous: A billion collisions occur every second, yielding a thousand billion bits of data per second. The chances of discovering the Higgs boson in all of this are about the same as finding a single plant cell on the entire face of planet Earth.







93

The Largest Machine on Earth

2008

For over a decade, an Institute scientist headed the Muon Spectrometer Group (consisting of about 400 scientists) of the ATLAS experiment at the Large Hadron Collider of the European Nuclear Research Organization, CERN. One of the goals of this experiment is to prove the existence of the “God particle” (see p. 188).

This particle accelerator is based on electromagnetic superconductors that work at extremely low temperatures (-271° Celsius); at the height of its activity it will produce about a billion particle collisions per second. This is the most expensive science experiment ever undertaken: Eight billion dollars were invested in the construction of the LHC, and some 8,000 scientists from 500 research institutes and universities from 65 countries are taking part.

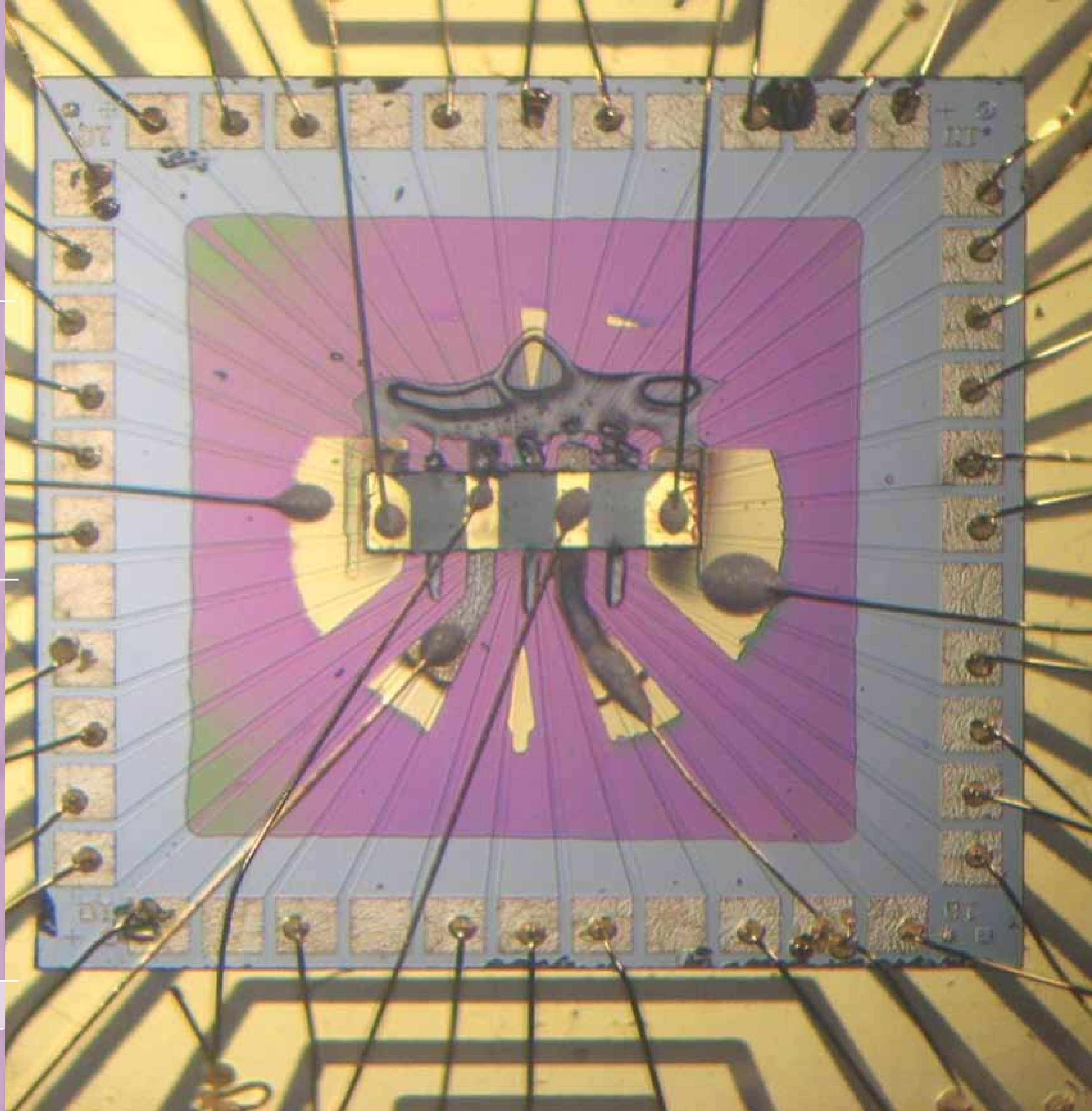
The LHC is situated in a circular tunnel 100 meters underground (the height of Big Ben in London). The length of the tunnel is 27 km – 20 times longer than the Golden Gate Bridge in San Francisco – and it crosses the border between France and Switzerland. The area inside the accelerator’s circumference is 58 sq km – about the size of Manhattan. Protons whiz through the tunnel at speeds near the speed of light. They go around the accelerator’s path 11,245 times a second – or a billion kilometers an hour. An object travelling at that speed could get from Earth to Neptune in only five hours.

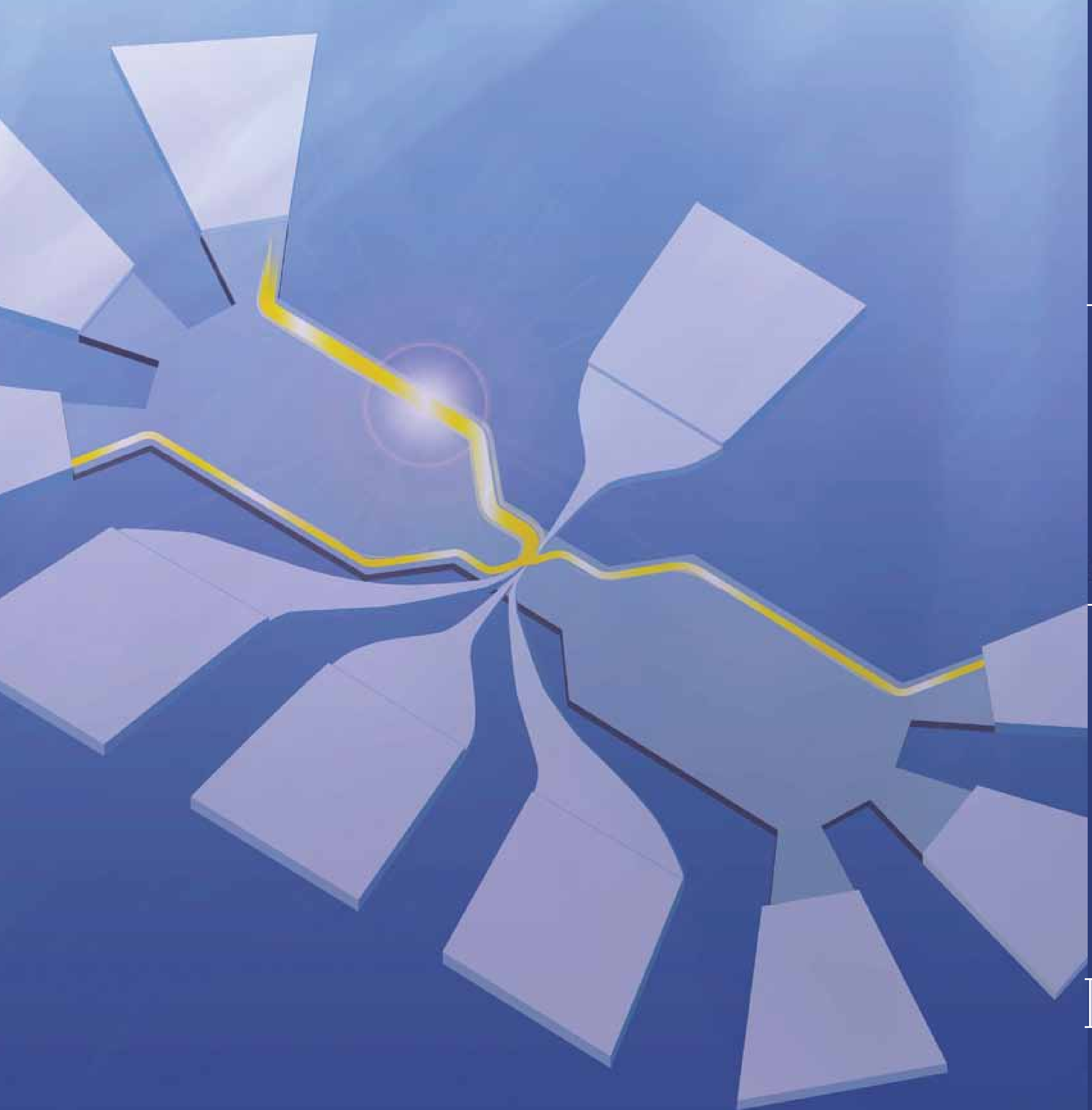
94

2008 Magnetic Measurement

Institute scientists developed ultra-sensitive arrays of Hall sensors. The active element in these sensors is a two-dimensional layer of electron gas created at the interface of unique structures, and it is produced by a molecular beam on crystal surfaces. The Hall phenomenon takes place when electrons flow through a system that is exposed to a magnetic field. Each electron “wants” to keep traveling straight ahead, but the magnetic field pulls it off its path. The magnetic field, therefore, causes a buildup of electrons on one side of the system.

The scientists placed superconductor samples on the surface of the Hall sensors, obtaining extremely accurate measurements of the magnetic fields in the sample – and outside of it. These arrays of sensitive sensors enable scientists to trace changes taking place in magnetic eddies in superconductors, a capability that could aid in the development of various types of future advanced technology.



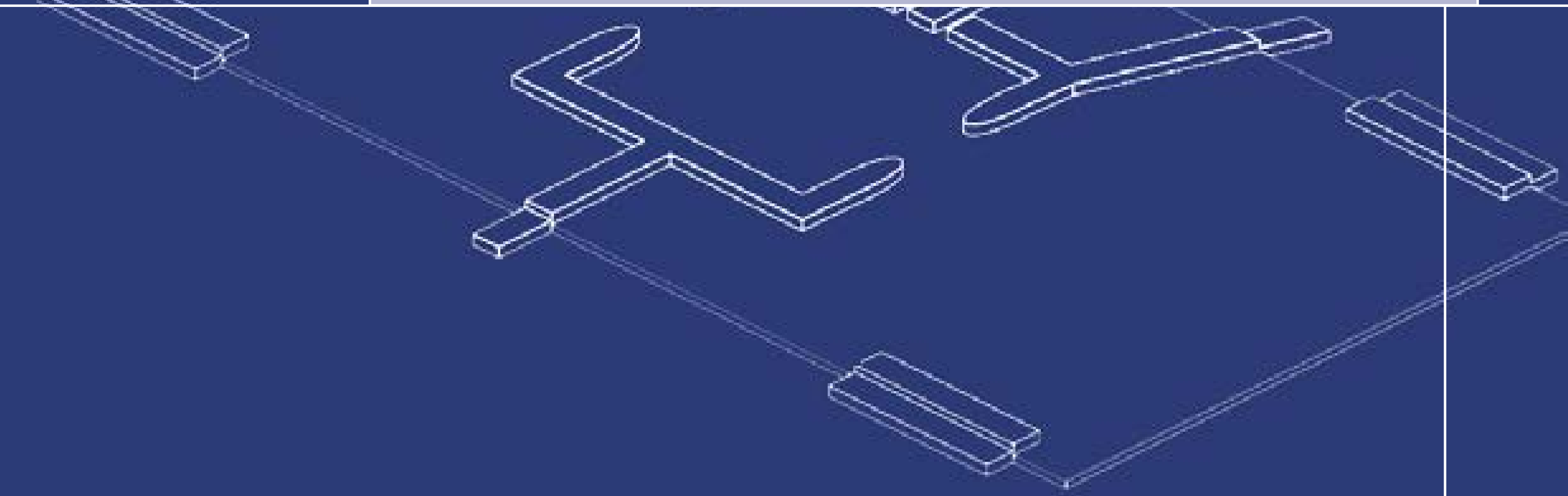


95

A Quarter of the Charge

2008

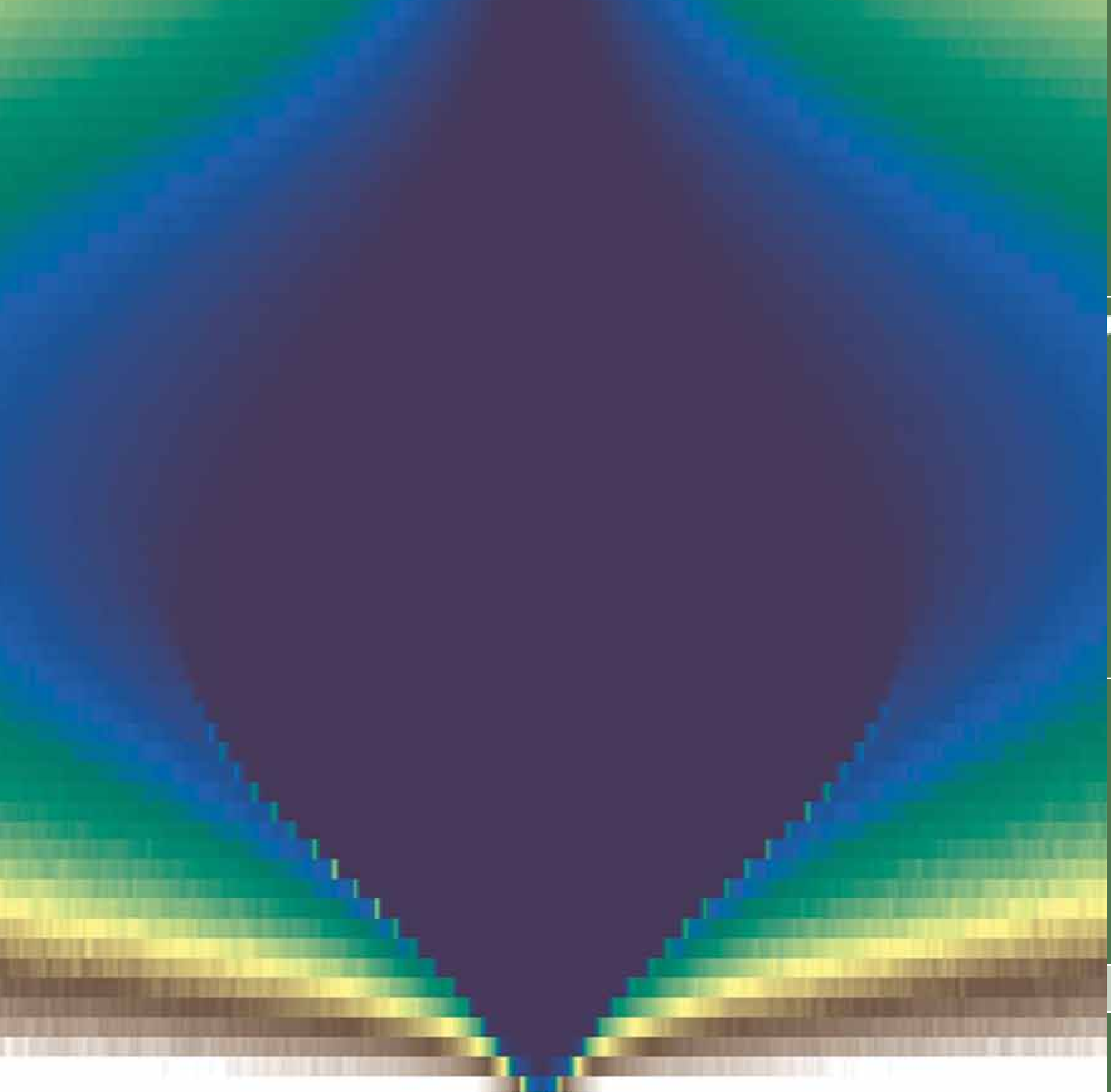
Physicists at the Institute discovered that imaginary particles with an electric charge of one-quarter the charge of an electron can be created in a novel system in which a non-Abelian quantum Hall process takes place. Such a system and the imaginary particles it contains could be used as a quantum bit – a possible basis for a quantum computer. In order for this possibility to be realized, the system must have several identical ground states. (A ground state is one in which the system energy is the lowest possible.) Another requirement for a programmable quantum computer is a system that can move from one ground state to another through a process in which several imaginary particles exchange places. The progression of the system through different ground states is determined by the topology of the path along which the imaginary particles travel, and therefore computation methods based on the movements of such particles are called “topological quantum computing.” If all of the above conditions exist, the system is relatively resistant to minor disturbance and impervious to its surroundings.



96

2008 Nella and Leon Benoziyo Physics Building

The Nella and Leon Benoziyo Physics Building was created when a second floor, designed by the architects Avi Livay and Yoel Dvoriansky, was added in 2008 to the one-story wing that connected the physics building with the particle accelerator laboratories. The original one-story wing, designed by the architects Moshe Harel and Nahum Zalkind in 1963, was constructed of concrete, with a gray plaster facing covering the walls and shading ribs that protrude about one meter beyond the narrow, recessed windows. Due to the topography, the original structure is at a lower level than the rest of the physics faculty buildings and includes the entrance to the Nella and Leon Benoziyo Physics Library. The decision to build the new wing as a light, airy structure stemmed mainly from engineering but also from design considerations. The different style and materials make it clear that this floor was added long after construction of the original one-story building.



97

2008

Super Insulation

Weizmann Institute scientists discovered that in certain conditions, a phenomenon called "superinsulation" can occur. The scientists were investigating superconductivity. This takes place when a material that conducts electricity (metal or ceramic) is cooled to a very low temperature, at which point all resistance to the flow of electricity drops to zero.

When superconductors are created from conducting material that is fairly disordered, and one then causes it to lose its superconductivity (through heating, for example), the material, rather than returning to its previous conducting state, becomes an insulator. The scientists chose to "spoil" superconducting properties in a different way – by activating a strong magnetic field. They gradually changed the intensity of the magnetic field along with the temperature, and discovered that at a certain stage, the material loses every bit of its capacity to conduct electric current. In other words, they had discovered a superinsulator.

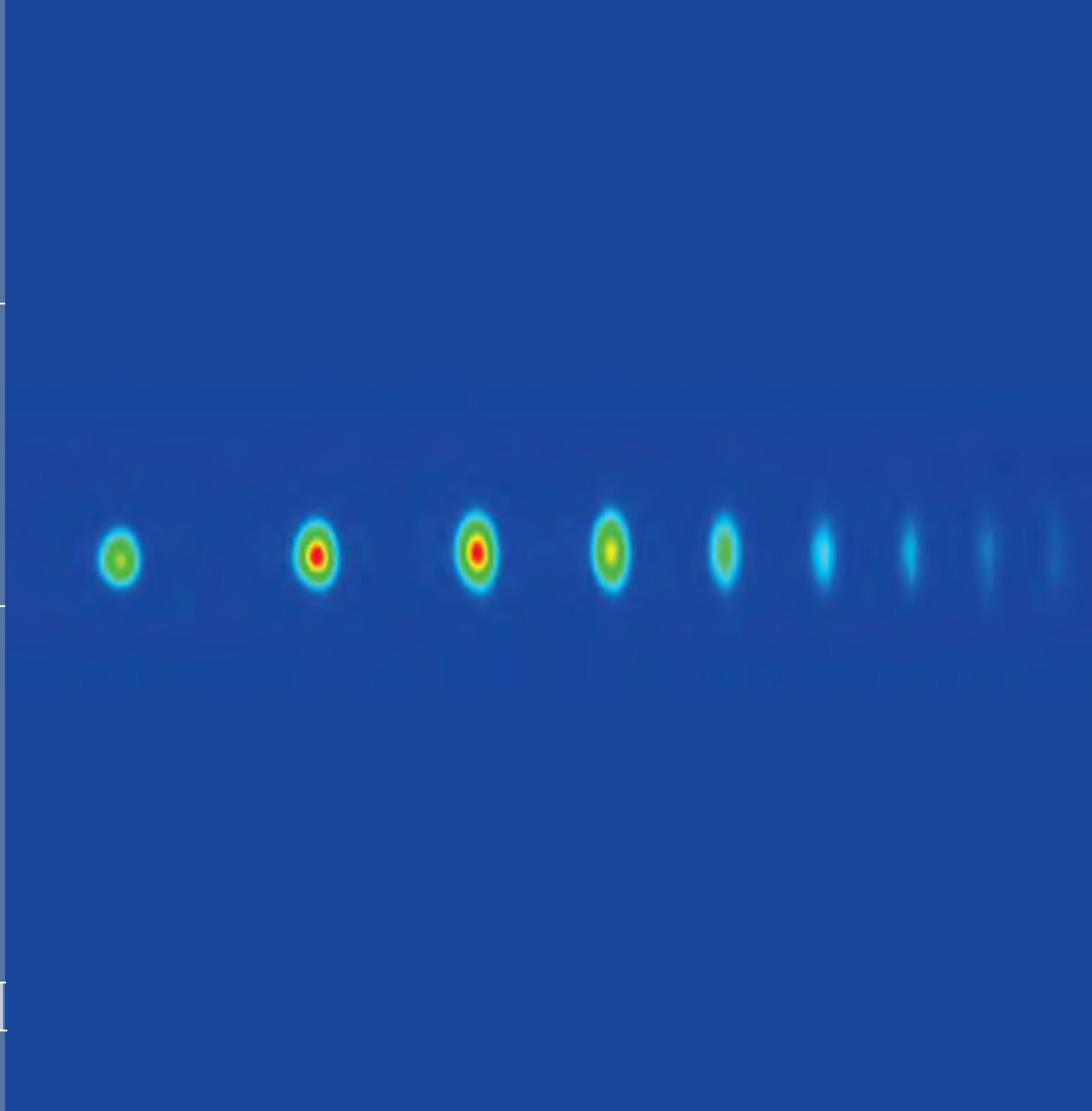
Superinsulation takes place today at temperatures of 40 thousandths of a degree above zero Kelvin (almost absolute zero). But superinsulators that operate at room temperature – if science can produce them – could present a solution to the problem of heating in electronic components and make possible the production of transistors that do not leak electricity, as well as batteries that last many times longer than those of today.

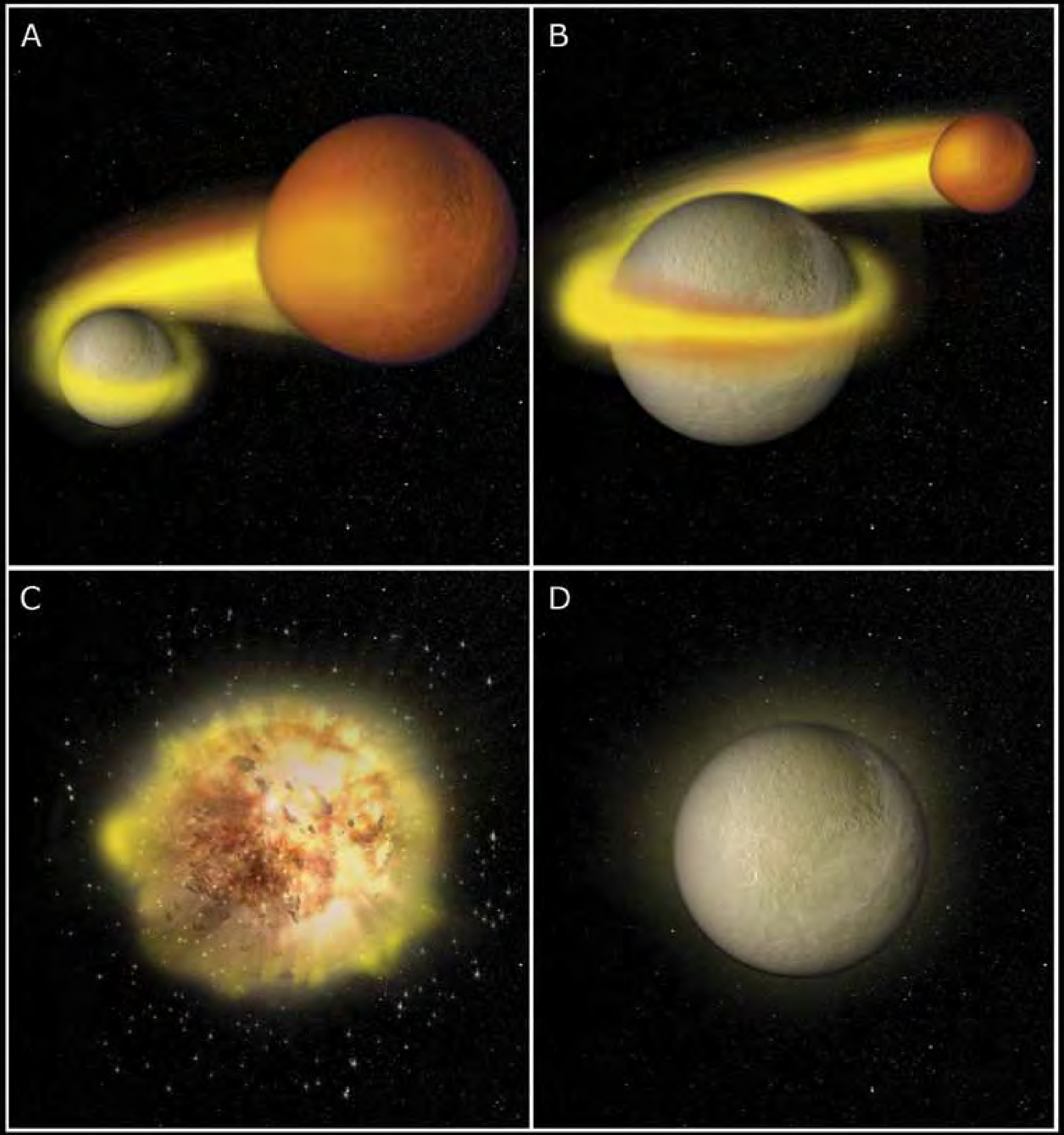
98

2009 The Fastest Laser

Up to what point is it possible to document and understand ultra-fast processes? For example, when an electron is "torn" from a molecule, the remaining electrons quickly reorganize so as to preserve the balance of electric charges in the molecule. How does this reorganization take place, and how long does it take to complete? To follow rapid processes in molecules and atoms, Institute scientists used the fastest laser pulses in the world as a sort of stop-action camera that captures them in "freeze frames." These lasers "shoot" tens of attosecond flashes of light (an attosecond is a billionth of a billionth of a second).

The scientists used these laser systems to investigate the emission of light from the molecules or atoms on which the lasers themselves are based. In other words, they turned the camera back on itself, and in this way, succeeded in characterizing the distribution of electrons in an atom. In the future, they hope to use the system to investigate ultra-fast processes that have never before been seen in more complex systems.





99

2008

White Dwarves, Heavy Elements

Institute physicists found that an unusual exploding star (supernova) fits a model in which a compact star known as a white dwarf “steals” a thick layer of helium from a neighboring star. According to this model, the star undergoes a unique type of thermonuclear explosion that destroys the helium, but not the rest of the white dwarf. In contrast, in the more common Type 1a supernovae, which also involve white dwarves (made up mainly of carbon and oxygen), the stars explode to smithereens after they steal a neighbor’s matter.

Exploding stars of the new type are relatively dim, making them more difficult to observe; but the scientists think they may be fairly common. If so, these stars may have made a significant contribution to the creation of such important elements as calcium in the Universe.

100

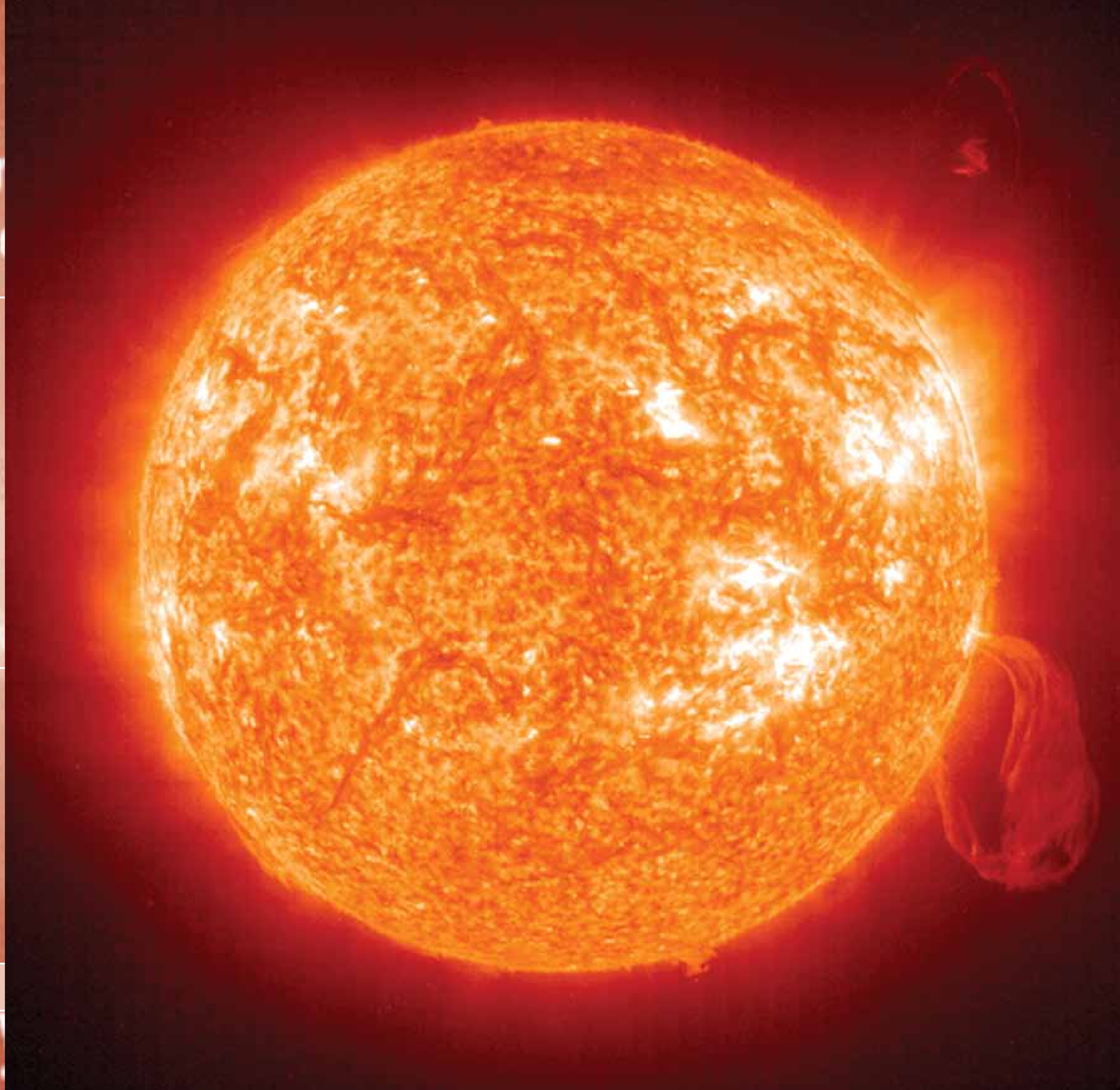
2010

A Sun in the Lab

Nuclear reactions taking place in the center of the sun were recreated in a Weizmann Institute lab. The two reactions the scientists measured were, first, the fusion of a proton and the nucleus of a beryllium 7 atom, in which a beryllium 8 nucleus was created; and, second, the fusion of helium 3 and helium 4 nuclei to form a nucleus of beryllium 7. Getting an accurate estimate of the probability of these occuring is critical for understanding the reaction chain that produces the sun's energy – a process that makes life on Earth possible.

The results of the measurements conducted at the Institute also serve as a crucial ingredient for the insight that neutrinos, generally thought to come in three types, can change from one type to another, providing evidence that neutrinos have mass (though very small). This insight lends support to the idea that there is a supreme theory of particles and forces that transcends the Standard Model. These experiments also have implications for understanding the process by which the light elements were created in the Universe, some three minutes after the Big Bang.

The series of experiments took place in the Van de Graaff accelerator at the Institute. The beryllium 7, a radioactive isotope with a half-life of two months, was produced in the radioactive isotope ion accelerator, ISOLDE, at the European Organization for Nuclear Research (CERN).



מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

The Weizmann Institute of Science is one of the world's leading multidisciplinary basic research institutions in the natural and exact sciences. The Institute's five faculties – Mathematics and Computer Science, Physics, Chemistry, Biochemistry and Biology – are home to 2,700 scientists, graduate students, researchers and administrative staff.

The Institute's roots go back to the Daniel Sieff Research Institute, built in 1934 with the support of Israel and Rebecca Sieff of London in memory of their son Daniel. It was established upon the initiative of Dr. Chaim Weizmann, the driving force behind its scientific activity and its first President. A world-renowned chemist, he headed the Zionist movement for many years and later became the first President of the State of Israel. In November 1944, with the agreement of the Sieff family, it was decided that the Sieff Institute would become the nucleus of a large-scale research institution named after Dr. Chaim Weizmann. On November 2, 1949, marking Dr. Weizmann's 75th birthday, the Weizmann Institute was formally dedicated.

The Weizmann Institute of Science played a key role in the development of the State of Israel. Its scientists pioneered cancer research in Israel, and they designed and built the first electronic computer in the country – one of the first in the world. They were the first in Israel to establish a nuclear physics department, which led to the construction of a particle accelerator; and they were the first to create an academically linked office for technology transfer and to initiate the creation of a science-based industrial park, built near the Institute. The Institute also played a pioneering role in the development of brain research, nanotechnology and solar energy research.

Institute scientists' research has led to the development and production of Israel's first ethical (original) drug; and to the development of additional drugs to treat a number of diseases, including cancer. They created new computer languages; the solving of three-dimensional structures of a number of biological molecules – including one that plays a key role in Alzheimer's disease. Their inventions in the field of optics have become the basis of such advanced devices as virtual head displays for pilots and surgeons. A method for separating isotopes developed at the Institute is used around the world.

Additional research led to the development of advanced methods for transplanting embryonic tissue, for finding and identifying genes that are involved in disease, and the development of a nano-biological computer that may one day be able to operate in the body's cells, identifying disease processes and blocking them before they cause damage.

Today, the Institute is a leading force in alternative energy research, as well as in the worldwide trend of breaking through the boundaries of traditional scientific fields and advancing research in such multidisciplinary fields as biomatics. The Institute is highly involved in efforts to improve science education, with the aim of enabling people from all levels of society to understand the current scientific revolution, and to successfully integrate into the new techno-scientific world. The Davidson Institute of Science Education, which operates the educational programs on the Weizmann campus, offers dozens of programs that target everyone from exceptional and science-oriented students to high school dropouts, elementary through high school teachers, and students of every age. These special programs enable the public to share in the excitement that accompanies scientific discovery, as well as giving them a taste of the new directions in which science is advancing.