

tron waves from any possible penetration into the magnet. One beam of electrons went through the hole in the ring; the other went outside the ring. After passing by the field, the electron beams were made to interfere with each other, producing a hologram that revealed the relation between their phases.

Tonomura and co-workers concede that experimentally it is impossible ever to get exactly zero magnetic field, and they hope the critics will agree that what occurs at a negligible amount of field is effectively the same as what happens at zero field, and not demand the ideal. Otherwise "only a futile agnosticism results," they point out.

In addition to action at a distance, the Aharonov-Bohm effect has another interpretation, related to a mathematical quantity known as the electromagnetic vector potential. Many decades ago, physicists working on a unified mathematical description of electricity and magnetism found this vector potential, from which descriptions of both electric and magnetic phenomena could be derived. However, this mathematical uni-

fier seemed to have no physical existence in itself. No phenomena could be directly attributed to it.

In 1916 Albert Einstein published his general relativity theory, which attributes gravitational forces to changes in the curvature of space from point to point. Following Einstein's example, Hermann Weyl tried to relate electromagnetic forces to geometry. He used the vector potential, and because of the way it acts mathematically, he tried to relate it to changes of scale or "gauge" that he imagined between different points in space. This somewhat weird idea is akin to meter sticks or other measuring standards having different sizes at different points in space. The attempt failed as physicists found that subatomic particles have an intrinsic scale or gauge that cannot change from place to place.

As quantum mechanics developed, however, Weyl found a quantity that does change in the proper way and to which he could relate the vector potential: the phases of the waves associated with material objects. Confusingly the term "gauge" is still used although it refers no longer to changes in standards of length but to changes in the phases of matter waves and of the internal properties of subatomic particles (the properties that determine their identities, really) that are related to the phases. In this sense the gauge principle has become very important in theories of particle physics, which are concerned with how the identities of the particles come to be. The Aharonov-Bohm effect can be interpreted to mean that the magnetic field acts on the phases of the electron waves through the vector potential. It is thus evidence of the physical reality of the vector potential and of the "gauge" nature of electromagnetism.

— D.E. Thomsen

### SPOT satellite launched

The French SPOT earth-observation satellite, designed to photograph surface details as small as 10 meters across, is now being checked out in orbit following a successful Feb. 21 launch by a European Ariane rocket. The photos, obtainable at a variety of spectral wavelengths, are to be about three times as sharp as those available to civilian-sector users of images from the U.S. Landsats.

The launching, formerly scheduled for last Oct. 15, had been delayed following a malfunction of the previous Ariane rocket, which had to be destroyed in midair from the ground following the failure of its third stage to ignite. Additional delay resulted from the discovery of cracks in the next Ariane's second-stage fuel tank.

Initial images from SPOT, which are available both in visible light and in a group of three bands that extend through the near-infrared, have already been received on earth. Once the satellite has completed its planned 60-day checkout, its data will be made available for sale to both private and government users, who can obtain them as either photos or computer-compatible digital tapes. Users will be able to request that images be made of specific locations, or they can select pictures if available from the data base of SPOT Image Corp., in Reston, Va., which is marketing the data from the French space agency (CNES) satellite.

Along with SPOT, the same Ariane booster also successfully lofted Viking, a Swedish scientific satellite. □

### Soviet modular space station

A new Soviet space station, described as the primary building block of a permanently manned orbital complex, was launched into orbit on Feb. 20 from the Baikonur space center in Kazakhstan. Called "Mir," the Russian word for peace, the new facility includes six docking ports to accommodate a variety of expansion modules, cargo transports and visiting manned spacecraft.

The station was sent aloft without a crew, but cosmonauts will be sent up "after it is run in outer space," according to Alexei Leonov, former cosmonaut and now chief of the Soviet cosmonaut training center. The initial crew will return to earth after a brief period of checking out the station's systems, to be followed by a period of unmanned operation and later a succession of crews working perhaps

### Monopole, maybe

On Feb. 14, 1982, a magnetometer operated by Blas Cabrera at Stanford University recorded the passage of what seemed to be a magnetic monopole. In the years since, no purported second sighting has occurred that stirred any acceptance or enthusiasm. Now there is a possible second event, this time at Imperial College of the University of London, England, reported in the January/February CERN COURIER.

Magnetic monopoles would be single north or south poles flying free. Theories that posit an exact and complete symmetry between electricity and magnetism predict their existence; electric monopoles are very common. Magnetic monopoles are also very important in recent theories of particle physics and cosmology.

The second possible sighting — called the "South Kensington event" after the section of London where Imperial College is located — occurred Aug. 11, 1985. Since then the experimenters have considered and rejected several explanations for it, but they are still not completely ready to call it a monopole. Searches in South Kensington, Stanford and other places continue. □

on a rotating basis.

Creature comforts are said to be improved over past Soviet stations, such as the Salyut 7 facility still in orbit (it was launched in 1982). Individual cabins, though small, are each equipped with a desk, an armchair and a sleeping bag. The main staff compartment, according to the government newspaper *Izvestia*, offers a built-in dining buffet, a food-warming device and exercise equipment, as well as windows on all sides including the "floor," through which the crew can observe the earth more easily.

Mir is also said to offer greatly increased use of automation, including completely automated operation, a capability lacking on Salyut 7. A variety of modules are to be sent up later for a variety of purposes, such as astrophysics, biology and medicine, and materials processing.

Mir, according to the Soviet news agency Tass, is "a base module for assembling a multipurpose, permanently operating complex." Says Leonov, "Practical cosmonautics has now entered a new stage: the beginning of a transition from research and experiments to large-scale production activities in outer space."

Meanwhile, U.S. space station plans, though still being strongly pushed by the administration, are in the same state of flux that has affected the entire U.S. manned space program — and even some of the unmanned part — following the explosion of the shuttlecraft Challenger.

— J. Eberhart