Smashing debut for a subatomic fireball

A millionth of a second after its creation in the Big Bang, the universe was so hot that neutrons and protons had not yet condensed out of a sea of quarks and gluons. Now researchers have obtained experimental evidence supporting this scenario. They found the evidence for a new state of matter — a quark-gluon plasma — in the spray of subatomic particles released by a fireball created in a violent head-on collision between two atomic nuclei.

Protons and neutrons, the two constituents of atomic nuclei, are each thought to consist of three quarks, bound together by force-carrying particles known as gluons. Theoretical calculations predict that at sufficiently high temperatures, protons and neutrons overlap and lose their identities. Collections of these particles would "melt" into a loose agglomeration of quarks and gluons. Although still confined, the loosely bound quarks would be free to roam over distances much larger than the size of a neutron or proton. Then, as the material cooled, quarks would begin to recombine, producing particles such as pions, which consist of pairs of quarks.

To generate the high energies needed to create a quark-gluon plasma, physicists at CERN, the European Laboratory for Particle Physics near Geneva, Switzerland, use an accelerator to hurl the nuclei of oxygen atoms, each a bundle of eight protons and eight neutrons, at a gold target. Like a high-speed bullet hitting a tin can, an oxygen nucleus traveling at nearly the speed of light punches a neat hole in a gold nucleus, excising about 50 of the gold's 197 neutrons and protons. The oxygen, carrying an energy of 3.2 trillion electron-volts, deposits a significant proportion of this energy into the excised material, creating the atomic equivalent of a fireball.

"You're creating a mini-Big Bang," says Thomas J. Humanic of the University of Pittsburgh. "You're simulating the early universe, a microsecond after creation." Humanic was a member of the large CERN team that performed the experiment and analyzed the results.

The researchers determine the fireball's nature and geometry by studying how quickly it emits pairs of negative pions as it cools. "It survives an unusually long time, longer than one would expect," says theorist George F. Bertsch of Michigan State University in East Lansing. "It takes a long time for the plasma to decay back to ordinary matter."

The fireball is also much larger in size than it would be if it consisted only of protons and neutrons knocking about. Both the bigger size and the longer lifetime indicate that during a collision, at least some of the fireball's protons and neutrons undergo a phase transition, or melt, to form a droplet of quark-gluon plasma.

"Unambiguous signatures for this predicted change of state have been hard to find," Bertsch says. "This is the first physical indication of the new state of matter that people have been looking for." The discovery was announced last week in Lenox, Mass., at the Quark Matter '88 meeting.

"It's a preliminary result, but it's very tantalizing," says Humanic. "And it seems to agree very well with theoretical ideas." The CERN researchers have so far observed 105 suitable oxygen-gold collisions. They want to increase the number of observations and to test other nuclei. Alternative strategies include firing sulfur nuclei at a sulfur target and lead nuclei against a lead target to study whether the type of nucleus involved in a collision has an effect on plasma formation.

If the quark-gluon plasma state is confirmed, the finding will encourage further theoretical work, Bertsch says. It would be interesting to determine the details of how a plasma droplet gets rid of its energy and how the system achieves equilibrium. In addition, the surface of a quark-gluon plasma droplet may have unusual features. — *I. Peterson*

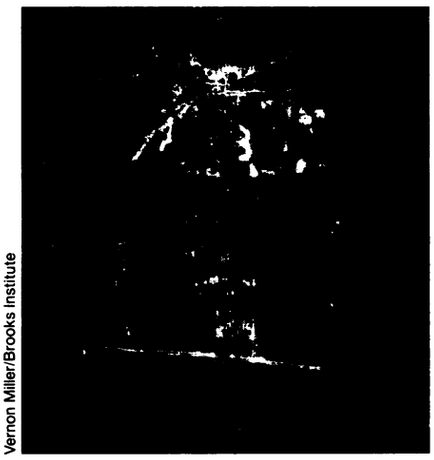
Shroud of Turin is fake, official confirms

A centuries-old body of controversy wrapped up in the Shroud of Turin seems at last laid to rest. Luigi Gonella, scientific adviser to the Archbishop of Turin, has confirmed that radiocarbon dating showed that the shroud — a linen relic believed by many to be the burial shroud of Jesus Christ — was woven in the 14th century.

Although the three scientific teams conducting the first-ever carbon dating of the shroud swore to keep the results secret until the Church announced their findings, repeated rumors surfaced that those scientists had dated the shroud to a time far later than the 1st century AD. At press time the Church had yet to announce the official findings, but Gonella's comments to the media last week were widely interpreted as an official verification of those rumors.

Carbon dating of the shroud ends an era of dogged detective work by historians and intense scrutiny by scientists looking for clues to the yellowed cloth's true origin. Doubts about the shroud's origin were expressed only a few years after the cloth containing the image of a crucified man first surfaced at the opening of a new church in Lirey, France, in about 1357. Scientific investigations began in earnest in the early 1970s, when Church officials allowed scientists to stick tape on the shroud and analyze the few particles pulled away as the tape was peeled off. A more complete investigation came with a widely publicized 1978 effort by an international team of scientists, almost all of whom found no evidence of forgery.

The 1978 tests failed to include perhaps the most definitive test, carbon-14 dating, because it would have required the destruction of a piece of cloth about the size of a pocket handkerchief. After some controversy, the Church agreed to carbon-14 dating by teams at the University of Arizona in Tucson, the Federal Technical Institute in Zurich, Switzerland, and the University of Oxford in England. They subjected the samples to mass spectrometry using a newly refined method that requires only milligrams of material (SN: 4/16/88, p.245).



Vernon Miller/Brooks Institute

A negative image dramatically shows the face of the figure in the Shroud of Turin, the relic now confirmed as a forgery.

Carbon-14 dating is based on the principle that the atmosphere has a small, fixed ratio of the radioactive isotope carbon-14 to the much more common isotope carbon-12. The constant circulation of carbon atoms keeps this ratio static in all living plants and animals, but after death the carbon atoms become locked in place and carbon-14 decay begins to change that ratio. Knowing how many centuries the flax in the linen shroud has been dead is simply a matter of measuring its ratio of carbon-14 to carbon-12.

The carbon-14 results are something of a vindication for one member of the 1978 team who dissented from the others by deciding the shroud was a forgery dating from 1356. After subjecting residue peeled off the shroud with sticky tape to analysis under a light microscope, Walter C. McCrone of the McCrone Research Institute in Chicago concluded the shroud was a very thin watercolor painting done in a style common to the 14th century. — *C. Vaughan*