The denser heart of the nuclear matter

By colliding heavy ions at high energies, scientists have artificially created for the first time an unusually compressed state of nuclear matter, perhaps as dense as that found in the cores of neutron stars and supernovae. The discovery, the researchers say, is an important step towards understanding how nuclear matter behaves in response to varying conditions of pressure, density and temperature — and especially those conditions that might have existed when the universe was formed.

As reported in the April 30 PHYSICAL REVIEW LETTERS, the new dense state was produced at the Bevalac accelerator at the Lawrence Berkeley Laboratory (LBL) in California by bombarding a niobium target with niobium nuclei accelerated to energies of 40 billion electron volts. The researchers, led by Arthur Poskanzer at LBL and Hans Gutbrod and Hans-Georg Ritter of GSI Laboratory in West Germany, had found in previous experiments with less massive nuclei that the protons, neutrons and subatomic particles created by such collisions normally bounce off the target in many random directions.

In the niobium experiments, however, says Poskanzer, "We observed matter squirting out of the high pressure region produced at the point of collision." This sideways emission of globs of nucleons, called "collective flow," is predicted by hydrodynamic models to occur when the compressed material re-expands.

"This is the first direct evidence we have of increased density," says Poskanzer. It has only been possible, he adds, since the Bevalac was upgraded to accelerate ions as heavy as uranium nuclei at high energies (SN: 10/9/82, p. 228). Another unique feature of the experiment was the so-called Plastic Ball detector; this was the first use in nuclear physics of an instrument that can simultaneously identify and measure almost all electrically charged products of heavy ion collisions occurring at high energies.

The researchers have repeated these experiments, replacing the niobium with gold. While the data are still being analyzed, Poskanzer believes that the larger size and mass of the gold nuclei will create a greater pressure buildup and an even more pronounced collective flow effect. The next step, he says, is to make quantitative measurements of this effect in order to formulate and refine theories describing the state of nuclear matter.

—S. Weisburd

Atomic nuclei: Quarks in leaky bags

The theory that describes neutrons and protons (and related subatomic particles) as made up of more elementary objects called quarks has usually regarded the quarks as forever confined within the particles they build. One way of depicting this is to regard the particles as "bags" in which the quarks may move around a bit, but which they cannot leave. It shouldn't matter very much to the quarks whether the bags are flying around free or bound together in an atomic nucleus. However, recent experiments show that it does. One of the latest, done at the Stanford Linear Accelerator Center (SLAC) and reported at last week's meeting in Washington, D.C., of the American Physical Society by Raymond G. Arnold, indicates that quarks are sensitive to the size and density of the nuclei in which they live.

The first evidence for the existence of quarks came about 15 years ago in experiments that probed nuclei with energetic electrons. They revealed pointlike objects (then called partons or quark-partons) inside the neutrons and protons of the nuclei. The behavior of quarks inside a nucleus was expected to be slightly affected by inclusion therein: The neutrons and protons tend to bump into and overlap each other, and this should affect quark motion a little. About two years ago a group known as the European Muon Collaboration (EMC) did an experiment at the CERN laboratory in Geneva to test this prediction and found an effect exactly opposite to the prediction, an effect that seemed to vary according to what element the nucleus was (SN: 12/11/82, p. 375).

Arnold, of American University in Washington, D.C., was on leave at SLAC when an experiment to test the EMC result was run with helium, beryllium, aluminum, carbon, calcium, silicon and gold. He calls these targets "the ones you can get in the drugstore for a reasonable price and which don't melt when you put them into the beam." The result is a complete conformation of the EMC result, he says. The anomalous behavior of the quarks can be analyzed in two ways: It can be seen as dependent on the size of the nucleus, that is, the atomic weight, or it can be related to the variations in the density of neutrons and protons from element to element.

After some dismay nuclear physicists realized that they now have a powerful new investigative tool that will allow them to probe problems of structure and behavior from the tiniest nuclei to neutron stars that they couldn't solve before, Arnold says. Particle physicists can now study somewhat deconfined quarks, loose from their bags. Basic quark characteristics that were supposed to stay confined inside neutrons or protons can now be studied in whole nuclei — there is talk of them moving in waves through the nuclei the way acoustic vibrations move through crystals.

— D. E. Thomsen

Air pollution and tree rings

The presence of particular trace elements in tree rings may be a useful indicator for past and present air pollution episodes, say researchers at the Oak Ridge National Laboratory in Tennessee. By measuring the levels of elements like iron and titanium in ring tissue, the researchers hope to be able to correlate tree growth rates with changes in these element levels.

In the May 4 SCIENCE, Charles F. Baes III and Samuel B. McLaughlin report, "Our study suggests that multielement analysis of tree rings would be useful in determining when changes in air pollution and acid rain began to occur and in geographically mapping their extent, thereby providing key evidence of the source or sources."

Their study of annual growth rings from short-leaf pine trees in eastern Tennessee shows increasing metal concentrations since the 1950s and a possibly related decrease in growth during the 1970s. For samples taken from older trees in the Great Smoky Mountains National Park, Baes and McLaughlin were also able to see evidence for the effects of a copper smelter that operated between 1863 and 1912. The smelter at Copperhill, Tenn., about 88 kilometers upwind from the sampling site, released large amounts of sulfur dioxide, and the tree rings show suppressed growth and increased levels of iron and other metals during that period.

Baes says that there are important differences between the Copperhill episode and changes that have taken place during the last few decades. Additional metals like aluminum, cadmium and copper show up in samples from more recent rings. In addition, the recent changes occur at all the sites, indicating a regional effect, rather than in just a few locations as in the case of trees affected by the smelter.

Several puzzles remain to be worked out. Baes says there are no data available on what the normal levels of these elements should be in trees. In many cases, the levels found in tree tissues are much higher than those considered toxic in agricultural plants. At the same time, "we don't know where the elements come from," says Baes. Iron may be taken in from the soil, but the source of titanium, for example, is a mystery. It also isn't clear why aluminum, often associated with acid rain, doesn't show up in the older samples.

The researchers are beginning to look at tree ring samples from sites in Vermont and other places. Baes says early indications are that the concentrations of heavy metals found in trees in the Northeast are even higher than those found in Tennessee. However, the extent of the contamination and its direct relationship to tree growth remain uncertain (SN: 4/7/84, p. 215).

—I. Peterson

News of the week continued on p. 286