# The universe may be far thinner than thought

The density of matter in the universe is an extremely important cosmological datum. If the universe is dense enough, the mutual gravitational attraction of its parts will eventually slow down and reverse the expansion, and the universe will begin to collapse. Many cosmologists would like to have this kind of closed universe with a limited maximum size because the other alternative, limitless, infinite expansion, is difficult to contemplate.

Unfortunately, results just obtained by John B. Rogerson and Donald G. York of Princeton University tend to indicate a density too low for closure and contraction. The density is calculated from the abundance of the deuterium found in interstellar space.

The Princeton astrophysicists obtained their value for the deuterium abundance, which Rogerson says is the first measurement of deuterium abundance outside the solar system, with the Princeton telescope on the Copernicus satellite. They observed the absorption of the ultraviolet light of the star beta Centauri by deuterium between it and the earth, and were thereby able to calculate the abundance of deuterium in that space. It comes to one deuterium atom in every 100,000 atoms.

According to current theory the only place in nature where deuterium could have been made is in the big bang at the beginning of the universe. Thus any deuterium we see now is a relic of the big bang, and its abundance can indicate what fraction of the primordial hydrogen was fused into deuterium near the time of the origin. Knowing this fraction, one can calculate how much original hydrogen there was, and that enables computation of the present density of the universe. Rogerson and York figure it out to one hydrogen atom in every 10 cubic meters. (In the universe as a whole elements other than hydrogen and deuterium are too rare to affect the density very much.)

This figure, says Rogerson, is a factor of 25 or 30 too small to cause closure and contraction of the universe. Thus there doesn't seem to be the large amount of unseen matter that some cosmologists had hoped there was.

It should be noted that the present results are based on observation of only the one star, beta Centauri. The work continues with efforts to observe other stars in different directions. It remains to be seen whether future data will support the present calculations. Nevertheless, Rogerson says, the result from the one star alone seemed important enough to justify immediate publication. A report is being submitted to the ASTROPHYSICAL JOURNAL. □

## Just how far can the universe collapse?

According to the big-bang theory of cosmology the universe started in a small, perhaps infinitesimally small, hot fireball that exploded and began to expand. Cosmologists try to deduce what conditions may have been like in that fireball. Even though the evidence reported above seems to tell against the idea, they also worry what might happen if the universal expansion stops and the universe begins to collapse under the influence of its own gravitation. Could the universe collapse to a point and vanish like the Cheshire cat? Or perhaps the events of collapse might resemble stages gone through in the reverse direction during expansion.

In the Aug. 6 NATURE PHYSICAL SCIENCE, C. J. Isham of Imperial College, London, Abdus Salam of Imperial College and the International Center for Theoretical Physics in Trieste and J. Strathdee of the International Center for Theoretical Physics bring to bear on the question a reworking of gravitational theory that they have been engaged in for some time. Their work is a reformulation of Einstein's theory that takes into account the difference between two main classes of subatomic particles, the hadrons and the leptons. Their reformulation proposes that gravity affects the two classes differently (SN: 4/10/71, p. 249).

When gravity thus takes account of the differences between the two kinds of particles, Isham, Salam and Strathdee find that there is indeed a limit to the possible collapse of the universe: a radius of 100 million kilometers —somewhat less than the radius of the earth's orbit. They also find a limit to the density: 100 quadrillion ($10^{17}$) grams per cubic centimeter.

The limits are for a universe composed of $10^{80}$ neutrons with their spins all aligned in the same direction. (Neutrons are specified because after collapse has reached the point of crushing atoms, the electrons will be driven into the nuclei, where they will turn the protons into neutrons; in effect, nothing remains but neutrons.)

There are some difficulties with this picture, however. There must be some mechanism for aligning the spins; none is specified in the calculation. There may be trouble from the so-called exclusion principle, according to which two neutrons with the same energy may not be in the same place at the same time. Finally the size of the collapsed universe remains so large that other effects of the mechanics of the microcosm have not been taken into account. □

## Quasars' great distance: A voice from radio

Astrophysicists have long been arguing over whether the quasars are as far away as the redshifts in their light make them appear to be. Or, putting the question in slightly different terms, are the redshifts due entirely to the quasars' velocities of recession or does part of the redshifts come from some other cause?

Two astronomers of the National Radio Astronomy Observatory, Robert L. Brown and Morton S. Roberts, now have evidence from the radio spectrum of quasar 3C 286 in favor of the all-redshift-due-to-velocity point of view. Their findings, issued last week by NRAO, support the hypothesis that quasars are at or near the edge of the observable universe.