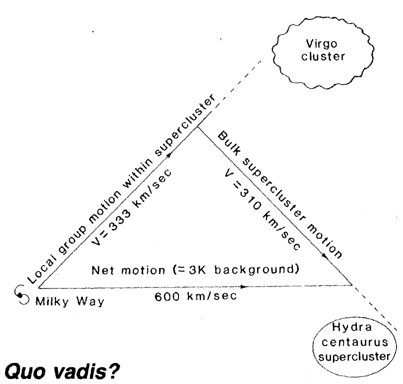
Going with the Flow

The textbook image of cosmic expansion is that the galaxies just drift along, receding from each other in a smooth, serene "Hubble flow." * Unfortunately, the real universe is much more complicated than that, with random velocities and gravitational interactions between the galaxies producing large deviations from the overall flow. This fact has always been a headache for astronomers, since it introduces major uncertainties into their measurements of the Hubble parameter—the ratio of the expansion rate of the universe to its size—and therefore into their understanding of the age of the universe.

Obviously, a critical element of this puzzle is the non-Hubble motion of our own galaxy, the Milky Way. The galaxy is known to have a velocity of some 600 kilometers per second relative to the 3 K microwave background radiation, which is a relic of the Big Bang and therefore defines a kind of cosmic reference frame. (Observationally, the radiation is found to be a fraction of a degree warmer in the direction of motion.) But not only is this velocity surprisingly large, it is directed, apparently at random, toward a more or less empty section of the sky in the constellation of Leo.

At the recent national meeting of the American Astronomical Society,† however, Marc Aaronson of the University of Arizona in Tucson told of new observations that allow the motion to be understood in a vivid and physically plausible way: locally, he said, the Milky Way is falling toward the massive cluster of galaxies in Virgo, which lies 30 million light-years away at the center of our local supercluster; globally, the local supercluster as a whole seems to be falling toward Hydra-Centaurus, the next supercluster over.

Since 1977, explained Aaronson, he, Jeremy Mould of the California Institute of Technology, and a number of other colleagues have been surveying galaxies and clusters of galaxies using the so-called "infrared Tully-Fisher technique," which is probably the best indicator of true galactic distances now available. As the name suggests, the method was first developed in the 1970's by R. Brent Tully of the University of Hawaii and James R. Fisher of the National Radio Astronomy Observatory. These researchers showed that there exists a correlation between the absolute luminosity of a galaxy in visible light and the orbital velocities of its interstellar hydrogen; since these velocity dispersions can be measured spectroscopically at radio wavelengths, independent of the galaxy's distance or redshift, the absolute luminosity can thus be found and compared to the observed luminosity to determine the galaxy's true distance.



Quo vadis?

The Milky Way's overall velocity relative to the microwave background is a product of us falling toward the Virgo cluster and the local supercluster falling toward Hydra-Centaurus.

Aaronson and Mould later refined this technique by looking not at the galaxies' visible luminosities but at their infrared luminosities, for which the correlation is much stronger; this was one of several achievements cited this year when they were jointly awarded the astronomical society's 1984 Newton Lacy Pierce Prize for outstanding observational research by a young investigator.

One of the first phases of the survey was published in 1982,‡ Aaronson told the meeting in his prize address. Redshifts from some 300 galaxies within the local supercluster revealed first, the expected Hubble expansion; second, a certain random scatter; and third, a systematic deviation from random that could best be explained if the Milky Way were moving toward the Virgo cluster at some 333 kilometers per second.

Most recently, said Aaronson, he and his colleagues have completed a survey of ten clusters of galaxies located well outside the local supercluster. The same kind of analysis indicates that, relative to these objects, the Milky Way is moving at some 600 kilometers per second toward the constellation of Leo.

Gratifyingly, he said, this is almost exactly equal to the galaxy's previously measured velocity relative to the 3 K background. Moreover, once our galaxy's motion toward Virgo is taken out, this velocity is equivalent to a bulk motion of the local supercluster of some 310 kilometers per second toward the nearest neighbor supercluster, Hydra-Centaurus.

One additional datum from this work, said Aaronson, is a new value for the Hubble parameter: 90 kilometers per second per megaparsec. The Hubble parameter is still the subject of considerable controversy, he added, with some astronomers favoring a value of 50, which would mean that the universe is roughly 20 billion years old, and other astronomers favoring a value closer to 100, corresponding to a universe only 10 billion years old.

The new value of 90 obviously favors a younger universe, said Aaronson. This may be a bit embarrassing considering that some globular clusters are roughly 16 billion years old. However, he also pointed out that nobody's Hubble values can be taken very seriously until galactic distances are calibrated correctly. And that will be a job—appropriately enough—for the Hubble Space Telescope.

A Dash of Aluminum-26

A long-standing goal of gamma ray astronomy has been the detection of radioactive isotopes injected into the interstellar medium by violent events in stars. But it was only at the Tucson meeting that William A. Mahoney of the Jet Propulsion Laboratory in Pasadena, California, could at last report success: the detection of interstellar aluminum-26 by the third High Energy Astrophysical Observatory, HEAO 3.

Gamma ray astronomy is a notoriously time-consuming business; it is only a slight exaggeration to say that the field has more astronomers than photons. Mahoney and his colleagues

*The expansion of the universe was discovered in the 1920's by the astronomer Edwin Hubble.
†The 165th Meeting of the American Astronomical Society, Tucson, Arizona, 13 to 16 January 1985.

‡*Astrophysical Journal* **256**, 64 (1982).

have been analyzing and reanalyzing the HEAO 3 data since 1979. "We had a very, very weak signal [the 1809 KeV emission line from the decay of aluminum-26] in the presence of a strong background from the Earth's radiation belts," he said. However, now that the analysis is complete, they are extremely confident of their result—especially since the aluminum-26 line has recently been verified by the gamma ray detector on the Solar Maximum Mission satellite.

The aluminum-26 discovery is particularly striking because of its impact on theories of the formation of the solar system. During the last decade or so, much has been made of the excess quantities of magnesium-26 found in certain very primitive meteorites. Magnesium-26 is the decay product of aluminum-26, and indeed the anomalies occur only in aluminum-rich grains within the meteorites; the inference is that aluminum-26 was markedly more abundant in the original grain material than it was in the solar system as a whole. The question is where it came from. Aluminum-26 has a mean lifetime of only a million years, which implies that the source was fairly close by, and active just as the solar system began to form.

This is such an unlikely coincidence that people have been tempted to postulate cause and effect—the most popular idea being that a supernova went off in the vicinity of the presolar nebula; presumably, the resulting interstellar shock wave would have triggered the nebula to begin its gravitational collapse to form the sun and planets, and at the same time would have salted the nebula with aluminum-26 freshly made by explosive nucleosynthesis.

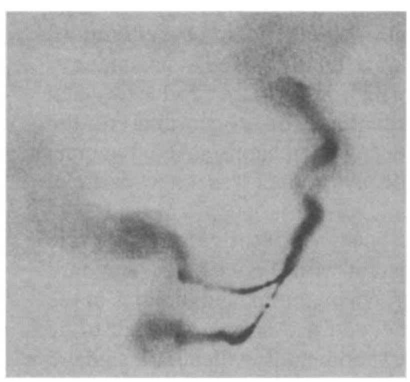
However, this argument is not totally compelling, said Mahoney. The million-year lifetime of aluminum-26 may be short on a cosmic time scale, but it is long compared to the time between production events. Possible sources include supernovas, of course, but also ordinary novas, hot young stars, and red giant stars—the latter three being much more abundant. The isotope could thus be widely distributed around the galaxy. And this is exactly what was found by HEAO 3: roughly three solar masses of aluminum-26 in the galactic disk as a whole, with the higher concentrations lying in the general direction of the galactic center. This works out to roughly one atom of aluminum-26 on the average for every 100,000 atoms of the stable isotope aluminum-27.

"We expect there to be variations of at least a factor of 10, depending on the details of mixing," said Mahoney. Thus, the meteorite anomalies, in which the ratios are up to five times as large, need not be the result of a nearby supernova. They could be part of a general galactic background.

"We can't say that we don't *need* a supernova to trigger the solar system," says Mahoney. "But our observations do say that having a supernova is not so critical."

Mating Dance of the Two-Tailed Radio Source

There is nothing particularly new anymore about finding galaxies with compact, hyperactive nuclei, nor is there anything unusual about those nuclei beaming back-to-back jets of relativistic matter into intergalactic space. Insofar as anyone understands what is going on, the things seem to be miniature quasars, deriving their energy from the disruption and compression of stars and gas falling unto ultramassive black holes.



National Radio Astronomy Observatory

Cosmic dance

Two active galactic nuclei (small black dots), each emitting twin beams of relativistic particles, orbit within the radio galaxy 3C 75.

What is unique, however, is what has now been found in the radio source 3C 75: *two* such active nuclei, with two jets apiece, performing a kind of cosmic dance only 20,000 light-years apart within a single galaxy.

"The bottom line," the National Radio Astronomy Observatory's Frazer Owen told the astronomical society meeting, "is that this is a very mysterious object."

The galaxy in question is an extended halo of stars at the center of Abell 400, a cluster of galaxies located in the constellation of Cetus, the whale. Its bizarre double nucleus was discovered during a survey of radio sources at the Very Large Array of radio telescopes near Socorro, New Mexico. The observers were Owen, his NRAO colleague Christopher P. O'Dea, and Makoto Inoue of Japan's Nobeyama Radio Observatory.

The obvious interpretation is that Abell 400 originally contained two active galaxies that have now collided and merged. But Owen, for one, is not so sure. "The absorption and coalescing of galaxies tends to go very fast," he said. "So the fact that we see two nuclei means either that we're seeing the system at a special time, or that it is relatively long-lived.

"We expect, perhaps naïvely, that the nuclei are orbiting each other," he added. Supporting that interpretation are periodic wiggles seen in the outer parts of the jets, like the stream from a hose when someone is moving the nozzle in a circle.

An additional puzzle is that the two jets in the upper right seem to be twining around each other. This may just be a projection effect, says Owen, but some members of his group think it is real—perhaps caused by forces between electrical currents in the jets.

Finally, as in many other cases where jets are found in rich clusters, the jets of 3C 75 are bent and swept back, almost as if they were streams of smoke in a high wind. In fact, said Owen, x-ray observations have shown that rich clusters of galaxies contain extended halos of very hot gas, so it is easy to imagine that the jets are being buffeted by turbulence in the gas. Moreover, Jean Eilek of the New Mexico Institute of Mining and Technology in Socorro has recently shown that it is possible for a relativistic jet of particles to extract energy from such turbulent motions; if this is indeed what is happening, says Owen, it would be much easier to understand where the energy comes from to power such huge, turbulent jet structures—which in this case are a million light-years across, and are emitting energy at 100 million times the rate of the sun.

—M. MITCHELL WALDROP