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MISSING MATTER: KEY TO THE COSMOS'S FATE.

one-fourth of the universe's mass comes in the form of helium can be explained only by using the Big Bang model.

The original Big Bang was simple—too simple to be right. In fact, the scenario described above didn't include the crucial idea of inflation until Alan Guth of MIT (one of *Science Digest*'s Top 100 Young Scientists) came upon it in 1980. Originally, it was just an unexpected consequence of some calculations Guth was doing on the particle physics of the Big Bang. But it explains features of the observable universe that are other-

Continued on page 101

HOW WILL IT END?

By Marcia Bartusiak

More than half a century ago, Edwin Hubble pried open a cosmic can of worms. Using the 100-inch telescope atop Mount Wilson in southern California, the young legal-scholar-turned-astronomer made the startling discovery that we live in an expanding universe, where billions of galaxies rush away from one another at tremendous speeds.

The expansion must have started somewhere; that's where the concept of the Big Bang comes from. But will this celestial marathon ever end? Will their mutual gravitational attraction lasso the speeding galaxies, slowing them down in the far, far future, then drawing them inward until space-time curls back up in a cosmos-canceling Big Crunch? Or are they going too fast for anything to stop them, implying a universe that will expand forever.

It all depends on how much stuff there is. If the density of matter is high enough, the final crunch is inevitable. If not, it's impossible.

Ten years ago, scientists were sure they had the answer. They knew roughly how many galaxies were out there, how massive they were, how fast they were moving and how far apart they were.

It just didn't add up. The best estimates indicated that the matter we can see is only about one percent of what would be needed to collapse the universe. Particle physicists nodded in agreement. "After applying known laws of nuclear physics to the presumed conditions of the early universe, it was concluded that the Big Bang couldn't have produced enough ordinary matter to close the universe back up," says Princeton astrophysicist J. Richard Gott, who coauthored a classic paper on the topic.

Now, though, they're not so sure. At the microscopic level, new theories

Continued on page 101

Galaxies tend to cluster, as the computer map (above) shows. The distribution reflects the structure of the original Big Bang.

Messier 31, the Andromeda galaxy, is closer to us than any other. Like most galaxies, it is surrounded by a halo of invisible matter.

this apparent microscopic violation of time's reversibility. No one knows whether to interpret the violation as merely an annoying aberration or as a big red flag signaling that our understanding of time's irreversibility is seriously flawed.

Another unanswered question is how the different arrows of time—the different kinds of irreversibility—are related. Is there an underlying principle that accounts for the five arrows of time: the psychological perception that time flows, the expanding water waves caused by a dropped pebble, the expanding light waves emanating from a bulb, the universal recession of galaxies and the rare decay of the rare kaon? Can one of these arrows be reversed without affecting the others? Until physicists come up with hard answers, science-fiction writers will continue to explore the possibilities. ■

PROBLEMS

Continued from page 57

on the other hand, in which the idea is to figure out whether the highway inspector can go on a round-trip journey that will take him on every road once, can be solved by a fast algorithm regardless of the complexity of the network. The fast algorithm is based on the simple, proven fact that a round-trip journey is possible if an even number of roads comes out of each city. For the traveling-salesman problem there's no comparable fact that makes it easy to solve.

Faster! Faster!

The traveling-salesman problem belongs to a large class of problems—called NP-complete—for which all the known algorithms are as inefficient as an exhaustive search. For NP-complete problems, the existence of faster algorithms has not been ruled out, as it has in the case of the chess problem. Whether or not faster algorithms exist is the most important unanswered question in theoretical computer science.

If faster algorithms do exist, then the traveling-salesman problem is no different in kind than the highway-inspection problem—and has an easy solution, too. "Most mathematicians, I think, would say that these problems are different. I certainly would," says AT&T's David Johnson, an expert on NP-completeness, "but no one really knows." ■

EVOLUTION

Continued from page 51

are subjected to differential selection."

Scrutiny of genetic variation has revealed that evolution follows a different set of rules on a small scale. "Molecular biologists are finding that the gene is not monolithic," Eldredge explains. "Crazy things are going on in the chromosomes. We think we're seeing chemical mechanisms that bias the retention or elimination of genetic information but don't impinge on reproductive success."

The Cooperative Gene

To a Darwinist like Richard Dawkins, lecturer in animal behavior at Oxford and author of *The Selfish Gene*, the gene *is* the unit of selection. "You can think of a large organism like us as a machine built by a cooperative of lots and lots of genes," he says. "Each gene is selected for its capacity to work well with other genes it's likely to meet in the gene pool. The criterion for selection is the effect it has upon the world. The shape of a leg, the color of an eye or the form of a behavior pattern is causally linked to a particular gene difference. What we see in the world are the phenotypic products of those genes that have been successful in the past."

But evolution is not just something that happened in the past; it is going on all around us. For man, at least, it is no longer a question of survival of the fittest. The achievements of civilization have conceivably put the control of evolution in his hands. ■

UNIVERSE

Continued from page 61

wise mysterious.

One is the universe's extreme homogeneity: No matter what direction we look in, we see the same density of galaxies and the same intensity of microwave radiation. Ordinary cosmology can't explain why the uniformity of the original blast would have persisted until the present; inflation says that uniformity was preserved by the prodigious expansion rate of the first second.

Another prediction of inflation is that there should be very few of a peculiar class of particles called magnetic monopoles in the universe—in fact, there *are* very few. And therein lies perhaps the oddest aspect of our universe's birth.

The grand unified theories (GUTs—see page 37), which describe relationships between fundamental particles and forces, suggest that pieces of the early universe should have survived to the present. One such piece—though most have now disappeared—is the magnetic monopole, an isolated bit of positive or negative magnetic charge (in normal matter, magnetic charges always come in pairs).

Another is the cosmic string. These strings, which may *not* have disappeared, have a density of trillions of grams per centimeter of length; they should be traveling at nearly the speed of light; and, say some, they may be the massive seeds around which ordinary matter condensed to become the first galaxies when the whole thing started. ■

BIG CRUNCH?

Continued from page 61

of physics have predicted—and experiments have, in some cases, found—a host of unsuspected, exotic particles.

Meanwhile, astronomers have learned, through precise observations, that stars within galaxies and galaxies within clusters aren't moving the way they should. Something, some massive, invisible substance, is tugging on them gravitationally. It may be made of these new, exotic particles or just ordinary matter in the form of stars and planetoids too faint to see—or a combination of the two. Whatever it is, it's 10 times as massive as the stuff we can observe.

That's not all. Several years ago, physicist Alan Guth, of MIT and the Harvard-Smithsonian Center for Astrophysics, revised the model of our cosmic birth. His inflationary universe model, which explains many of the cosmos's observed characteristics, predicts that the universe should be just on the dividing line between open and closed. This suggests there is not 10 but 100 times more dark matter than luminous stars and galaxies.

"So where is it all hiding?" asks astrophysicist Michael Turner.

The extent to which scientists are baffled is evident in the number of candidates for what makes up *this* dark matter. Perhaps the universe is littered with quark nuggets, boulder-size, planet-mass lumps of the particles that make up protons and neutrons. Maybe there are miniature black holes sprinkled around. Or the missing material might exist in the form of cosmic strings—kinks in the fabric of space-time. Some adventurous souls even talk of "shadow matter," a substance that we could never see or touch but which would exert gravitational pull.

Right on the Edge

Determining the nature and abundance of dark matter—perhaps in a particle accelerator—may ultimately tell us if the universe is on the brink of closure. Or the answer may come from another line of attack. Precise measurements of the speed of expansion earlier in the universe's lifetime could be contrasted with measurements from later on; that would let us know whether the galaxies are slowing as time goes on. That information will probably have to wait for the launching of the Hubble Space Telescope in 1986—which will look back in time to the very edges of the universe.

Unfortunately, says Guth, "inflation predicts that the universe is so close to the borderline between open and closed that we wouldn't be able to measure, in our lifetimes, on which side we fall." If he's right, the most significant question of all—that of the fate of the entire cosmos—must remain unanswered. ■