MEETING BRIEFS

Dwarfs and Dim Galaxies Mark Limits of Knowledge

When 250 astronomers met in Cardiff early this month at the U.K. National Astronomy Meeting, sponsored by the Royal Astronomical Society and the Particle Physics and Astronomy Research Council, they grappled with some big problems, among them the age of the universe and its mass. They also took on an even bigger metaproblem: How confident can they be in their knowledge about cosmic origins?

At Home in the Early Universe

To an outsider, cosmology can seem mired in uncertainty. The origins of the universe, after all, lie billions of years back in time and billions of light-years away in space, out of reach of experiment and most observations. But there are patches of solid ground, and they turn up in some surprising places, said Martin Rees of the University of Cambridge, Britain's Astronomer Royal, in a lecture called "How Much Cosmology Should You Believe?"

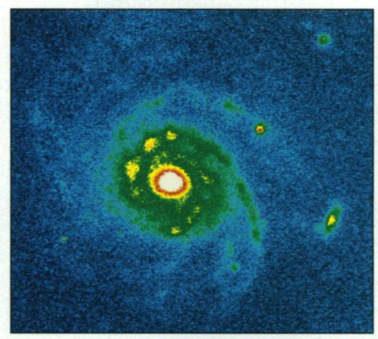
Contrary to what you might think, he said, cosmologists' understanding doesn't necessarily grow more tenuous as they go back in time. Between a millisecond and a million years after the big bang, said Rees, the universe was in many ways simpler and easier to comprehend than it is now: "It's an era where cautious empiricists like myself feel at home." True, the universe was utterly unlike our current surroundings—a nearly uniform gas cooling from a temperature of many millions of degrees. But that's familiar ground for physicists, who can re-create such conditions in laboratories and accelerators. "The relevant physics is firmly based on laboratory tests," said Rees.

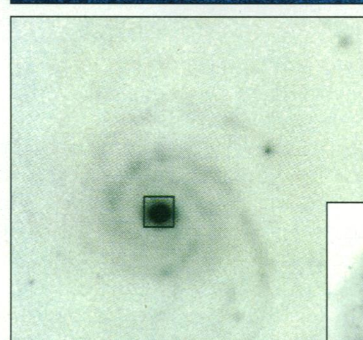
What's more, observations can provide direct clues to conditions in this era. "The theory is corroborated by good quantitative evidence," said Rees. One clue is the cosmic background radiation, which dates from the point at which the universe had cooled enough to become transparent. Another is the cosmic abundance of helium, which traces element-forming processes in the hot gas.

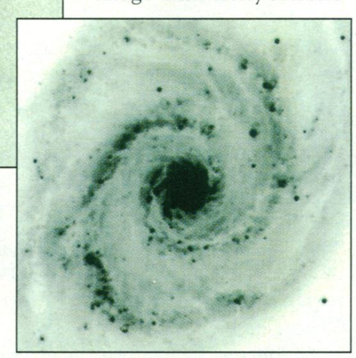
Such confidence fades when it comes to the universe's first millisecond, however. "Everything connected with the very early universe is uncertain; it is uncertain because the basic physics can't be independently checked," said Rees. "For the first 10^{-14} seconds, the energy of every particle would surpass what even CERN's new accelerator will reach." This period, when the universe may have undergone a drastic growth spurt, or inflation, "is the intellectual habitat of the high-energy theorist and the 'inflationary' or quantum cosmologist."

Cosmology becomes uncertain again after the first million years, Rees argued, but for a different reason. Once the undifferentiated matter of the early universe begins clumping into stars and galaxies, "we witness complex manifestations of well-known basic laws. ... It is difficult [to understand] for the same reason that all environmental sciences—from meteorology to ecology—are difficult." No surprise, then, that cosmologists are deeply divided about how the galaxies and clusters of galaxies seen today took shape.

But Rees, like most other astronomers, believes that under all these uncertainties lies a firm foundation: the big-bang theory. "I don't think there is anything in the last 10 years, besides publicity, that has rocked the foundations," agrees Richard Ellis of Cambridge University. But he notes that "there are some very interesting puzzles, which suggest that in the next 5 years we might well have quite a few shocks."







PHOTOS BY CHRIS IMPEY

Dim giant. The diffuse galaxy LSB 1226+0105, shown in false color at top, is typical of the missing galaxies. The familiar galaxy M51 *(right)* would fit in the outlined area at the center of this giant galaxy.

Awash in Dim Galaxies

One of those cosmic puzzles is astronomers' inability to find all the matter they believe the universe must contain. Just explaining how individual galaxies move within galaxy clusters, for example, requires the gravitational pull of at least 10 times more matter than can be seen in stars and galaxies. But one finding presented at the meeting could help a bit.

Astronomers may have overlooked as many as half of the galaxies in the universe, reported Christopher Impey of the University of Arizona and his colleagues David Sprayberry of the Kapteyn Laboratorium in Groningen, the Netherlands, Michael Irwin of the Royal Greenwich Observatory, and Gregory Bothun of the University of Oregon. The missing galaxies have escaped notice because they are exceptionally dim, but they are everywhere, says Impey: "The universe is awash in dim galaxies."

The first clues to these galaxies came from a sky survey done at the U.K. Schmidt Telescope at Siding Spring, Australia. The Automated Plate Measuring Machine at Cambridge University analyzed the plates to reveal hundreds of objects that had never been cataloged before. "Astronomers count the galaxies that are most easy to see—it's as simple as that," explains Impey.

To learn more about these uncataloged galaxies, Impey and his colleagues photographed and measured the spectra of more than 600 of them using a battery of instruments, including the Multiple Mirror Telescope on Mount Hopkins, Arizona, and the 305-meter radio dish at Arecibo, Puerto Rico.

The galaxies turned out to lie relatively nearby, some 200 million to 400 million light-years away, but "their density of stars is hundreds of times lower than the Milky Way's," says Impey.

Extrapolating from his sample of 600, Impey believes that the universe contains 30% to 100% more galaxies than have been catalogued in the past. This windfall of dim galaxies may not be enough to get cosmologists out of their missing-matter bind, says Cambridge University astronomer Richard Ellis: "It would be an enormous leap of faith to bring this up by the factor of 2 or 3 that would be needed to solve some of the problems that we now face." But, being a cosmologist, Ellis can't afford to rule anything out. "Maybe it is possible," he says.

Telltale Dwarfs

The age of the universe puts cosmologists in another bind: It is looking younger than its oldest stars. As Gerard Gilmore of the University of Cambridge told *Science*, that puzzle is, if anything, growing more acute. When he and his colleagues tested the usual method for estimating stars' ages, they came up with evidence that the technique may actually be understating stellar ages.

Gilmore and his colleagues Ted von Hippel of the National Optical Astronomy Observatories in Tucson, Arizona, and Derek Jones of the University of Cambridge derive their evidence from a star cluster—a clutch of stars that all formed at about the same time. By measuring the temperature of the cluster's white dwarf stars, they found evidence that these stellar cinders have been cooling for longer than the accepted age of the cluster. The disparity suggests, says Gilmore, that "the standard model of the way stars evolve is seriously in error."

Astronomers ordinarily estimate the age of a star cluster by checking the brightness and colors of its stars against stellar evolution models, which predict how those characteristics should change over time. A more direct strategy, though, is to examine a cluster's dimmest white dwarfs. Because white dwarfs no longer produce energy, they cool at a steady rate. And because the oldest dwarfs in a cluster are the cinders of stars that burned only briefly after it formed, their age is a good proxy for the age of the cluster.

But cool white dwarfs are by nature hard to see, so it took the repaired Hubble Space Telescope to pursue this dating strategy, explains Gilmore. From the observed temperatures of faint white dwarf stars in the open cluster NGC 2477, he and his colleagues derived an age of 1.25 billion years. That's more than twice the age astronomers had calculated based on stellar evolution models. Stellar evolution researcher James Kaler of the University of Illinois isn't discouraged, saying, "I think that getting as close as they do between the various ways of measuring ages of stars is quite remarkable. ... Little by little it will all fall together."

But Gilmore and his colleagues think the finding could exacerbate an existing problem: The same stellar evolution models that seem to underestimate the age of NGC 2477 also assign other clusters an age of 12 billion years or so, greater than some recent estimates of the age of the universe as a whole. Based on measurements of how fast the universe is expanding, those estimates have been coming in as low as 8 billion years (*Science*, 28 October 1994, p. 539).

To test the stellar evolution models more directly, Gilmore and his colleagues are now planning to look for white dwarfs in much older clusters. If the white dwarfs push up the age of star clusters even further, a cosmic conflict may turn into a crisis.

–Alexander Hellemans

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IMMUNOLOGY

Researchers Find Molecules That Muzzle Killer Cells

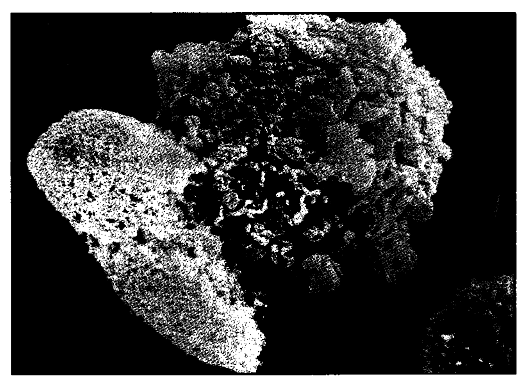
Natural killer (NK) cells are the pit bulls of the immune system. Lab studies have shown that once excited, they can kill all kinds of cells. But in the body, they are more discriminating—they kill tumor cells or virally infected cells, but not normal cells. Now immunologists are getting a clearer—and somewhat surprising—picture of just how the immune system muzzles NK cells to keep them from killing indiscriminately.

Two research groups, one led by Marco Colonna of the Basel Institute for Immunology in Switzerland and the other by Eric Long of the National Institute of Allergy and Infectious Diseases and Alessandro Moretta of the University of Genoa in Italy, have cloned human genes that encode proteins located on NK cells that apparently act as receptors for signals that tell the cell "don't kill." The Basel team reports their results on page 405, and the Long and Moretta results will be published in the May issue of *Immunity*.

What the two groups found has come as a big jolt to the field: The human NK cell receptor proteins are completely unrelated to those previously identified in mice. That implies one of two things: Either mice and humans use totally different genes to perform the same function—which is highly unlikely—or NK cells have two different systems of inhibitory receptors working simultaneously. "Until now we have known almost nothing about NK cells," says University of California (UC), Berkeley, immunologist David Raulet. "Now they seem more complicated than we had thought."

And the surprises don't end there. On page 403, Lewis Lanier of DNAX Research Institute in Palo Alto, California, and his co-workers report that they have found members of the same family of human receptor proteins on the surface of another killing cell, the cytotoxic T cell, and that the receptors seem to inhibit the T cells' drive to kill. This finding adds a new and unexpected level of control to these cells, which, like NK cells, play important roles in defending the body against viral infections and cancer. The discovery, says Harvard University immunologist Jack Strominger, suggests that there may be "a modulation, a fine-tuning going on," in T cells that could rein them in from killing normal cells. Failure of the fine-tuning could perhaps contribute to autoimmunity.

This similarity between NK cells and cytotoxic T cells is all the more surprising considering where the search for the NK receptor began: a discovery made 9 years ago by Klas Kärre of the Karolinska Institute in Stockholm, Sweden, that highlighted the fundamental differences between the two cell types. For T cells, a group of cell surface proteins known as the major histocompatibility complex (MHC) class I proteins is key to immune recognition. Present on virtually all cells, the class I proteins have the job of "presenting" fragments of foreign proteins to cytotoxic T cells, thereby triggering them to kill virus-infected or cancer cells. But Kärre found that NK cells selectively kill tumor cells that are missing class I molecules. That meant NK cells might fill an important niche: Some tumor cells and virus-infected cells shut down their production of class I protein and so might slip through T cell surveillance. "The NK cells would act as a backup," says Lanier, "because they would then be able to detect" those cells.



Delicate balance. Inhibitory, as well as stimulatory, receptors regulate killer T cells, like this one attacking a cancer cell.

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Several labs subsequently showed that MHC class I proteins disarm NK cells by binding to specific protein receptors on the NK cells' surfaces. In 1992, Wayne Yokoyama, then at UC San Francisco, and his colleagues got the first lead on what those inhibitory receptors might be. Their work with mouse NK cells suggested that the inhibitory receptors belong to a family of proteins called Ly-49, which binds to class I molecules on potential target cells. The Ly-49 proteins are lectins, proteins that bind to the sugar molecules found on many proteins, including the class I molecules. Following the Ly-49 discovery, immunologists expected that the inhibitory receptors on the surface of human NK cells would turn out to be members of the lectin family as