SCIENCE NEWS OF THE WEEK

Cosmic Blackbody: Confirmation and Questions

When the cosmic background (radio) radiation was discovered about 15 years ago, its intensity at the first wavelengths measured seemed to fit the spectrum of a blackbody at about 3°K. As more and more frequencies were measured, their intensities also tended to fall on the 3° blackbody curve, even, or especially, in stretches where that curve deviates significantly from other possibilities such as a Rayleigh-Jeans spectrum.

The discovery made a revolution in cosmology. It lifted the big bang theory of the origin of the universe out of a rather obscure place in cosmologists' regard and made it the dominant cosmological model of our time. Since then the question has been how close to the simon-pure theoretical blackbody curve the actual cosmic background radiation comes and what can be learned from deviations, if any, about the physical details of the history of the universe.

How close? In the April 2 Physical Review Letters D.P. Woody and P.L. Richards of the Lawrence Berkeley Laboratory present the results of a measurement over a fairly wide frequency range (2.5 to 24 waves per centimeter) that yields an accuracy of better than 10 percent of the peak flux of a 3° blackbody. As Woody and Richards point out, some of the earlier measurements on which belief in the blackbody is based were incapable of detecting deviations from a blackbody as big as 20 percent. The new measurement was done with a specially made spectrophotometer, in which for high accuracy the actual measuring implements are kept at liquid helium temperature. It was flown on a balloon from Palestine, Tex., to minimize atmospheric absorption.

In the view of a colleague, George F. Smoot of LBL, who is studying another delicate aspect of the cosmic background, its polarization, the experiment of Woody and Richards is "a remarkable achievement. It really is the first good experiment to show [the spectrum is] thermal." Arno Penzias of Bell Labs in Holmdel, N.J., who won the Nobel prize last year for his part in the original discovery of the cosmic background, calls the observation "a superb piece of experimental work, a tribute to their experimental skill." It is, he says, "the first very profound improvement in our knowledge of the spectrum." He points out that they were able to determine not only the intensity of the radiation, which is a first-order effect, and the shape of the spectrum, which is second-order, but also the third-order deviations. "Such things are extremely difficult to measure."

Deviations? Let us go back to the beginning of Woody's and Richards's paper, where they state the thesis of their investigation. "In its most elementary version this theory [the big bang] predicts a blackbody spectrum for the CBR." The textbook picture of a blackbody is of a heated box with a lot of radiation inside. This radiation has been in there long enough to reach a kind of equilibrium with itself. The box is black on the outside, because all the radiation is on the inside. For the benefit of the outside observer, who always lives in textbooks, a pinhole is made in the box. This lets out some of the radiation so that the observer can determine that there is a blackbody there.

In the case of the universe we don't need the pinhole because we are inside the box. But the observing job is complicated. We have to see that the brightness is the same in all directions and that the spectrum in all directions is thermal (that is, there is no nonthermal source of radiation in the box). Does the spectrum that Woody and Richards find correspond to the Planck curve (perfect thermal spectrum) for 2.96°K?

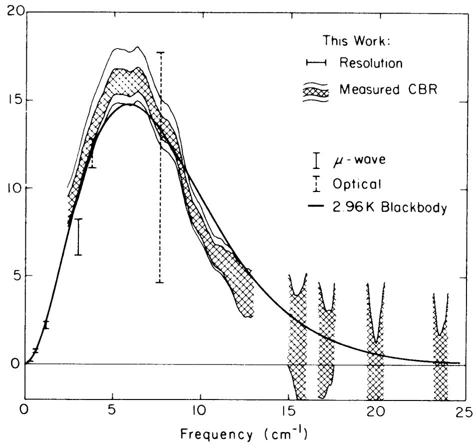
It doesn't. There is a small, but apparently real, deviation. It is expressed by Woody and Richards as a curve with the shape of a 2.79° blackbody and an emissivity of 1.27. That is a statement likely to stop a physicist cold. By definition the emissivity of a blackbody is 1. Anything else, being less than a perfect radiator, has an emissivity less than 1. Enhancement of a perfect radiator seems impossible.

That isn't implied, says Woody. The 1.27 is "just a mathematical parameter" put in to characterize the shape of the data curve. Its physical interpretation, if any, is not specified. Yet it does indicate that the deviation goes the wrong way.

On the basis of emendations to the simplest forms of the big bang theory, alterations to the blackbody can be calculated. There are physical processes that theorists think may have gone on in the early universe (some seem to be necessary to provide for such things as the formation of galaxies) that would have fogged up the inside of the box a little and degraded the blackbody slightly from perfection. This should lead to an emissivity less than 1. As Woody puts it, "Standard calculations show an effect opposite of ours."

There are some nonstandard calculations that might explain it. Woody cites particularly the "chronometric cosmology" of I.E. Segal, a mathematician at Massachusetts Institute of Technology. But the attitude of experimentalists seems to be to hold their intellectual breath and wait.

Penzias is not disturbed by deviations. To him the overriding thing is the blackbody character of the radiation. Deviations may not mean much. Smoot would like to see the experiment repeated to confirm the deviation. "It's hard to see where they made a mistake," he says. But the deviation does go in the wrong direction.



Phys. Rev. Let.

Measured radiation conforms closely to blackbody but falls off the curve in places.

A repeat is not likely soon. The experiment is difficult, delicate and expensive. Woody has now moved from LBL to Caltech's Owens Valley Radio Observatory, and both he and Richards have gone on to other work. A similar experiment is not likely until the COBE satellite does it five years from now. Meanwhile people will have time to speculate. ☐

Saturn: A ring within the rings?

Although the classically recognized rings of Saturn are generally described as a threesome, various observers have from time to time reported signs of what may be two additional rings, inside and outside the accepted trio. The existence of the extra rings has been less than certain — they are much less dense than the others if present at all and thus much more difficult to detect — and there are at least two reasons researchers wish they knew more about them: The recent discoveries of very different types of rings around Uranus and Jupiter have shown that wide, bright, "Saturn-style" rings are not the only possibility, and improved knowledge of any of them could help with the study of the rest. The other reason, which makes the first more critical, is that three spacecraft are now on their way to Saturn, and all three will pass at some point through the plane of the rings. Will they survive the crossing?

All three will go outside the main three-ring system, but for different reasons. The path of Voyager 1, which will pierce the ring plane on Nov. 12, 1980, was determined by the need to get a close look at Saturn's moon Titan. Voyager 2, due on Aug. 27, 1981, is aimed for a point at which Saturn's gravity will swing the probe toward a 1986 encounter with Uranus. Preceding both probes is Pioneer 11, whose flyby this Sept. 1 will take it the same distance outside the main rings as will Voyager 2's, making Pioneer 11 a guinea pig to test the safety of the ring-plane crossing for the latter mission.

Yet in choosing Pioneer 11's course, the National Aeronautics and Space Administration overrode the majority of the project's scientists, who had voted to send the craft between the inner part of the main ring system and the planet itself. While the Saturn trajectory was being chosen in 1977, some of the scientists said that in order to get some data close to Saturn, they'd rather go "inside" even if the spacecraft might be destroyed by ring particles after what amounted to "half a mission" (SN: 10/15/77, p. 249).

According to a just-published study of evidence for the extra, inner ring, called the "D ring," that's just what might have happened.

"There *is* a D ring," says astronomer Stephen M. Larson of the University of Arizona in Tucson. His evidence is a pair of observations of Saturn made in 1977 with a charge-coupled device (CCD) detector on the 154-centimeter Catalina telescope in Arizona. The CCD, Larson says, is about five times as sensitive in measuring dim light as conventional photographic methods, giving it a better chance of distinguishing a faint inner ring from the reflected glare of Saturn. Also, the observations were made at an 8,900-angstrom wavelength at which the methane in Saturn's atmosphere absorbs rather than reflects sunlight, making the planet much dimmer relative to the rings.

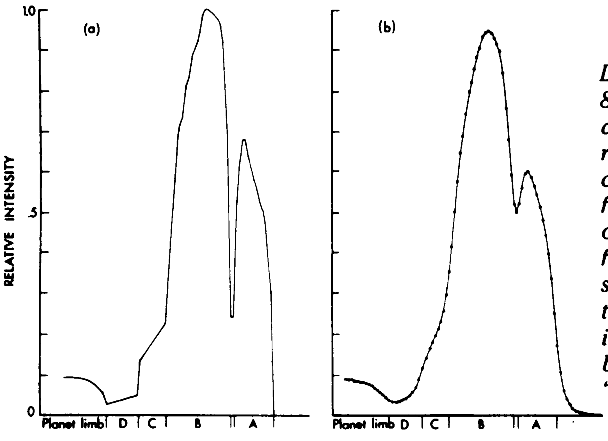
Using previous observations of the rings, Larson first constructed a "model" of how the brightness of the rings ought to vary radially, from Saturn all the way out across the ring system. Then he calculated a "smearing function" to mathematically represent the distortions caused by earth's atmosphere on the night the CCD observations were made, also including related effects due to the telescope's optical system. The model of what the rings should actually look like, corrected for the distortions of the atmosphere and telescope, would presumably match the brightness profile recorded by the CCD.

The result, reported in ICARUS (37:399) is an almost perfect match — and the D ring does seem to be present.

It is dim, to be sure, ranging from five percent to as little as three percent of the brightness of the ring system's brightest part. Even the gap known as the Cassini Division in the main ring structure, a region largely cleared of particles by satellite gravitational effects, is brighter by comparison. But to a passing spacecraft, Larson's data suggest, the D ring would not be a negligible barrier. Crossing the D ring at the 16.5° angle that was being considered for the "inside option," he says, Pioneer 11 would have encountered as many as 10,000 one-centimeter particles (or an equivalent cross-sectional area in different sizes), and at speeds of tens of thousands of kilometers per hour.

So Pioneer 11 will go outside, penetrating the ring plane about 34,000 km beyond the outer edge of the main rings. But there's also evidence (a bright line visible in some observations when the ring plane was viewed edge-on) for material out there as well. W.A. Feibelman of Allegheny Observatory in Pennsylvania reported the line to extend as much as twice the known ring diameter (and thus to about four times the distance of Pioneer 11's crossing from the main ring system's outer edge), and a later observation increased Feibelman's number by about 50 percent. Using Feibelman's data, University of Arizona astronomer Bradford Smith has calculated the possible outward ring extension to be about 100,000 times less dense than the D ring, Larson says, so the hazard should be greatly reduced—but it's still greater than zero. The spacecraft will be penetrating the ring plane at a much shallower angle (between 5° and 6°), which will roughly triple the area of the ring to which it will be exposed, and it will pierce the plane twice (swooping down and up again).

If Pioneer 11 is actually damaged or destroyed during the crossing, one consequence could be a decision to re-aim Voyager 2 farther out from the main rings, sacrificing the visit to Uranus. Whatever happens, however, scientists stand to learn — albeit perhaps the hard way — from the attempt. ☐



Larson's model for the 8,900-angstrom brightness distribution of Saturn's rings (a) becomes a smooth curve (b) when corrected for atmospheric distortion on the observing night and for telescope effects. Dots show how CCD observations fit the predicted curve, including measurable brightness where a possible "D ring" may lie.

Diabetic rats cured by islet transplant

The immune system is a mighty barrier to successful transplant of body tissue. Insulin-producing islet cells, for example, survive only a few days when moved from a rat of one strain into a rat of a distantly related strain. Now a two-pronged approach to evading a rat's defense system has allowed rat islets transplanted by Washington University scientists to function successfully in the recipient for more than 100 days. That success may lead to the eventual use of islet transplantation to treat some forms of human diabetes.

The experimental diabetics in the study reported in the April 20 SCIENCE were rats treated with a drug that specifically destroys their insulin-producing cells. Like human diabetics, the treated rats could not control blood sugar levels, and they excreted sugar in their urine. Paul E. Lacy, Joseph M. Davie and Edward H. Finke performed an islet transplant by injecting about 1,000 clusters of pancreatic cells into a vein that empties into the liver. The islets lodged in the liver sinuses, Davie said in a telephone interview. In the most successful experiments, the islets functioned normally in the liver for an indefinite period. The recipient rats could again regulate their blood glucose level, eliminate sugar from their urine and gain weight at the same rate as normal rats.

The successful protocol combined two procedures. Islets were incubated for a week in the laboratory before being injected into the recipient, and the recipient received an injection of antibodies that attack white blood cells. The approach was based on the hypothesis that "passenger" white blood cells in the transplant are partially, or entirely, responsible for the recipient's immune response.

Lacy and collaborators were surprised to find that the insulin-producing cells of an islet remained healthy after a seven-day incubation in tissue culture medium at room temperature. But during that time, the passenger white blood cells lost some of their immunity-triggering power. When transplanted into a distantly related strain of rat, the laboratory cultured islets survived longer than freshly dissected cells.

An additional boost to the islets' successful transplantation came from an injection into the recipient rat of rabbit antibodies (ALS) raised to attack rat white blood cells. How the antibodies work is a matter of some question, Davie explains. One possibility is that they depress the recipient's immune system during a crucial period in which the islets establish themselves. The other explanation, the one Davie finds more interesting, is that the antibodies attack any remaining white blood cells of the transplant. "ALS would remove the last few immune stimulatory cells," he says.