In the Beginning, Let There Be Beryllium

Hints of a richer-than-expected legacy of primordial elements suggest the Big Bang may have to take its lumps

BETWEEN THE FIRST MINUTE AND THE FIRST billion years after the Big Bang, the universe consisted of nothing but hydrogen, helium, and a dash of lithium, the three lightest elements in the periodic table. All the heavier elements that add variety and color to today's world had to wait for the first stars to build them up. That's the standard view of the birth of the universe. But now cosmologists are facing the possibility that the Big Bang was more inventive than they have long surmised.

Observations of some of the oldest stars are suggesting that the initial explosion may have spiced the early universe with heavier elements. "There appears to be a lot more beryllium in the early universe than we expected based on predictions of the standard model of the Big Bang," says astronomer Sean Ryan of the University of Texas at Austin, who with a competing group led by Gerard Gilmour of Cambridge University has been searching the stars for that element, the next up from lithium in the periodic table. A third group, led by Doug Duncan of the Space Telescope Science Institute in Baltimore and Robert Lambert and Michael Lemke of the University of Texas, has found hints of primordial boron as well, and some astronomers think that may be just the beginning. "Nuclear processes [during the first seconds] after the Big Bang might have made everything in the periodic table," says Richard Boyd of Ohio State University, one of the astronomers who first speculated about primordial heavy elements.

"The Big Bang might have made everything in the periodic table."
—Richard Boyd

If those searches continue to strengthen the case for a more inventive Big Bang, the standard picture of the universe in its first hundred-thousandth of a second may have to give way to an alternative. Instead of the uniform sea of particles usually pictured, the newborn universe may have been riddled with zones of higher and lower density, where nuclear processes could have formed heavier elements. And because calculations based on this revised Big Bang imply that the universe contains more matter than the standard Big Bang allows, this idea could go a long way toward solving one of the most vexed problems in cosmology: the shortage of matter calculated with the standard model. Most cosmologists think the universe must contain much more in order to keep it from expanding to infinite size.

Searching for elements made in the Big Bang is an exercise in stellar archeology, Boyd explains. As the universe aged, the material that formed successive generations of stars became more and more enriched with heavier elements. These elements, from beryllium on up, were formed either by nuclear processes within stars or—like beryllium and boron—by cosmic rays, acting on star-forged elements in the interstellar medium. As a result, tracking down any heavy elements dating from the Big Bang means looking at the oldest stars, made from the most primitive, pristine material. "It's like looking at a fossil," says Boyd. The standard picture of the Big Bang implies that the very first stars to form should be entirely free of beryllium and boron. But if the Big Bang itself made some proportion of those elements, their abundance in even the oldest stars would level off to that primordial fraction.

In search of that effect, Ryan trained the Anglo-Australian Telescope at a series of relatively old stars, looking for the spectral signature of beryllium. The result, which he and his colleagues will publish in the March issue of the *Astrophysical Journal*: "We may be coming to a leveling—a plateau—and if we do then we know we are seeing primordial beryllium."

The oldest, purest star in the group, which was also studied by Gilmour's group, is a case in point. That particular star, HD140283, rotates in a sort of senior citizens' halo of stars outside the plane of the Milky Way—an assemblage that astronomers say predates the galaxy's other stars. It's so old that it has less than 1% of the oxygen and other heavier elements in our sun. Yet the observations show 1000 times more beryllium than would be expected from cosmic rays alone.

Those observations haven't been enough to convince most astronomers that the beryllium was made in the Big Bang. Even Ryan admits that the extra beryllium could be there because cosmic rays produce more than astronomers thought. For more convincing evidence, astronomers are turning to boron, the next element up in the periodic table. If cosmic rays make all boron and beryllium, as standard theory suggests, the elements should show up in a ratio of 12 to 1; a different ratio would open the possibility of additional production in the Big Bang itself.

To pin down the ratio in the same ancient star that showed so much beryllium, Duncan and Lambert had to resort to the Hubble Space Telescope, because the spectral lines of boron fall in the ultraviolet range, which is blocked by Earth's atmosphere. Again the result is tantalizingly at odds with a homogeneous Big Bang, says Duncan, who is describing the work at next week's meeting of the American Astronomical Society in Atlanta. When he and his colleagues compared their boron measurement with Gilmour and Ryan's beryllium count for the same star, they found a ratio of 6 to 1—half the expected ratio, and perhaps a hint of a Big Bang contribution to the abundances of these elements. Still, says Duncan, "no one would be willing to go out on a limb over this." It will take more measurements, done on other stars, to get a definite answer.

"The data so far do not force one away from the standard picture," agrees cosmologist David Schramm of the University of Chicago. "However, the potential is there, if the present trends continue." And if that happens, it could mean a new lease on life for the idea of a lumpy Big Bang, a notion that originated in the mid-1980s.

The lumpy Big Bang model was inspired by dissatisfactions with the orthodox model, chief among which was the fact that the traditional Big Bang theory seemed to produce too little matter. The theory allows cosmologists to calculate the density of ordinary matter knowing the relative amounts of hydrogen, helium, and lithium in the interstellar medium. When astronomers first did the calculations in the 1960s, they came up with only about 5% of the amount of mass they had expected, based on the assumption that the universe contains enough mass to "close" it—to keep it balanced between collapse and expansion to infinite size.

Many cosmologists, who have strong theoretical and philosophical reasons for expecting a closed universe, were in a quandary. Some proceeded to fill in the missing mass with all sorts of exotic "dark matter," most of which consisted of as-yet-undetected particles. But others, less fond of speculative particles, thought it made more sense to reexamine the model and adjust it until it predicted the amount of matter needed. The result was the notion of a lumpy Big Bang, which would have spawned heavy elements in its neutron-rich clumps of particles. These lumps would have vanished after the first 100 seconds of the universe, so they wouldn't affect today's clustering of stars and galaxies. Nor would they have left a trace in the universe's pervasive background of radiation, which appears perfectly smooth in current observations.

Soon after the revised Big Bang was proposed, its original impetus evaporated: Calculations showed that the new model didn't predict the hoped-for closure density either, says Robert Malaney, a theorist at the Canadian Institute for Theoretical Astrophysics. But with the emergence of tentative evidence supporting the model's predictions of primordial beryllium and boron, its prospects may brighten again. "The original motivation is going away at the same time observations are sort of indicating that it happened," says Malaney.

And even if a lumpy Big Bang can't close the universe, it might provide enough mass to solve a smaller missing mass problem, posed by observations showing that more matter than the standard picture allows is exerting its gravitational pull on galaxies and clusters of galaxies. All of which is enough to keep astronomers searching the universe's stock of boron and beryllium for clues to the shape of the Big Bang.

Even if they eventually conclude that all boron and beryllium were generated through ordinary channels, not in an unorthodox Big Bang, Duncan expects that they will learn something valuable from their trouble. "At the very least you are probing [cosmic ray processes] in the early galaxy," he says. But the hope, says Boyd, is that "these measurements will tell us something about what happened a hundred-thousandth of a second after the Big Bang. I find that pretty mind boggling." ■ FAYE FLAM

Fowl feast. *The Arawete prefer to eat toucan and other large game birds but dislike deer.*

Rain Forest Diet: You Are What You Eat

How does an anthropologist identify Indians from different tribes in the Amazon rain forest? One way is to check their menu. If they're eating tapir—and liking it—they're probably from the Mayoruna or Parakana tribes. But if they're eating monkey, you can bet that they're from the Arara tribe.

Such differences in the diet of the tribes that live deep in the lowland rain forests of the Amazon have long stumped anthropologists. The prevailing view has been that the various tribes eat different foods because they live in different parts of the rain forest, and supplies of game and conditions for growing crops vary among those regions. But that's not the whole story, says Katharine Milton of the University of California, Berkeley, an anthropologist and ecologist who has lived with five different tribes over the past 10 years. The areas where she stayed show little variation in the foods available. The tribes' diets differ, Milton says, because the Indians choose to restrict what they eat to only certain of the numerous plants and animals available as a way of isolating themselves from their neighbors. "Diet is a cultural boundary, much like their use of body decoration and (facial) perforation," she explains. "Consumption of certain classes of animals is taken as a badge of a particular group." For example, it is distasteful for a Mayoruna or Parakana to eat certain monkey meat, and these tribes look down on their "not-so-human" neighbors who do so.

Milton, who published her findings in the November issue of the *Transactions of the Royal Society*, found that the tribes' lifestyles are similar: They are hunter-gatherers who also engage in slash-and-burn agriculture. Although they have had some contact with the outside world, they still hunt almost exclusively with traditional weapons and obtain their food by their own means. A survey of their diets found that they eat a wide range of food, including forest animals, such as birds, insects, porcupines and monkeys; wild plants; and cultivated crops, such as corn, manioc, sweet potatoes, and bananas.

Nonetheless, each tribe has distinctly different food preferences. Some of those differences could reflect historical variations in food supply, since none of the tribes lives in precisely the same areas today that they did 100 to 200 years ago. But Milton thinks it more likely that the dietary preferences arose centuries ago as a way for tribes to set themselves apart. Back then there were far larger populations of Indians packed together in the rain forest, giving rise to tribal hostilities as the groups fought one another for territory and food. And the hostilities continued into modern times. Tribal fighting occurred as recently as 1983, and the Mayoruna tried to keep out outsiders, raiding settlers' camps and river boats along the Javari River until the mid-1970s. "These different groups are very jealous of their territory," says Milton, who has observed friction even between two different groups of the same tribe.

Lest we think that such food customs are the remnants of more simple cultures, Milton has a response. At Thanksgiving, her students recorded what their families ate. One student noted that recent Mexican immigrants choked back the bland turkey with hot peppers, while another student's Philippine family served turkey, pumpkin pie—and Philippine dishes. Observes Milton: "Even in a melting pot culture like our own, very often these differences persist. It's a way each group has of reaffirming its identity." ■ ANN GIBBONS