Cosmological inflation: A budding universe

"You, too, can create a universe — right in your own backyard! Just gather together 10 kilograms of false vacuum, then let physics do the rest."

That sounds like the kind of ad that might appear at the back of a disreputable tabloid newspaper. But calculations by two groups of theorists seem to indicate that a bubble of false vacuum — a peculiar state of matter with an extremely high energy density — could develop into a new universe, quickly splitting off from ours to become an isolated, closed entity. Such a process might serve as a model for the way in which our own universe came into being.

"My real goal was to understand whether or not it's possible for a universe to materialize as a quantum fluctuation in empty space, and then, if so, to find out what consequences that might have for a universe formed in that way," says MIT's Alan H. Guth. "Because it's conceivable that our universe was created in that way, I think it's worth pursuing."

The inflationary model of the universe, first formulated by Guth a decade ago, suggests that the cosmos underwent a brief but tremendous growth spurt during its first microsecond. According to this scenario, a fraction of a second of extraordinarily rapid expansion saw the creation of all the matter and energy in the universe from virtually nothing. By postulating that the entire universe grew from a tiny seed, the model seeks to account for the observed universe's large-scale uniformity.

But the inflationary model remains speculative — more an outline than a complete theory (SN: 2/12/83, p.108). Theorists are still exploring the model's implications and tinkering with its details, striving to fill in gaps and to patch up apparent flaws (SN: 3/24/90, p.184). One puzzle concerns how a false vacuum functions to drive inflation and allow the entire observed universe to evolve from a very small initial mass.

Guth and others argue that at temperatures greater than 10^{27} kelvins, all forces between particles merge into a single interaction. In such a state, there's no way of distinguishing between electrons, neutrinos and quarks. Below that temperature, the interactions and particles take on separate identities.

However, just as water may remain in its liquid state even when cooled to a temperature below its normal freezing point, supercooled cosmic material could stay in its merged form at temperatures below 10^{27} kelvins. As it gets colder, this material would approach what is known as a false vacuum state, in which essentially all the energy present is stored in so-called Higgs fields rather than in the form of particles.

When put into Einstein's equations of general relativity, this peculiar property of the false vacuum leads to the notion of gravity as a repulsive rather than an attractive force. "It's the gravitational repulsion of the false vacuum that drives the expansion," Guth says.

Moreover, as the universe expands, more false vacuum would create itself to fill the space so that the energy density of the false vacuum remains constant, Guth maintains. Eventually, the false vacuum would decay, releasing its energy. This enormous energy release would generate the vast number of particles now present in the universe. Thus, the inflationary model suggests that virtually all the matter and energy in the universe were created during inflation rather than having to be present at the start.

"It becomes reasonable to ask whether or not, in principle, it's possible to replicate those conditions to produce a new universe," Guth says. "We're looking at the possibility that a universe that has already come into being somehow might produce a new universe."

Two sets of calculations, done independently using totally different methods, now indicate that it may indeed be possible to create a universe out of a ball of false vacuum. Willy Fischler, Daniel Morgan and Joseph Polchinski of the University of Texas in Austin report their results in the April 15 PHYSICAL REVIEW D. Guth and his colleagues describe their calculations in a paper scheduled for publication in a forthcoming NUCLEAR PHYSICS B.

In their calculations, both groups concentrate on the question of what would happen if a ball of false vacuum already existed. Actually assembling such a ball would require packing 10 kilograms of material into a space only 10^{-24} centimeters across (a proton's diameter is roughly 10^{-13} cm).

"That's not within the range of any foreseeable technology, but one could still imagine sometime in the distant future there might be some civilization that could manufacture a sphere of this form," Guth says.

The calculations also hint at the intriguing possibility that even without a sphere of false vacuum present, there is still a finite probability that a piece of empty space could contort itself into a universe. "This is something we want to work on more," Guth says.

"It seems to be a common feature of inflationary models in that whenever you produce one universe, you end up producing an infinite number of universes," he adds. "It creates a mind-boggling picture." *— I. Peterson*

Whistlers may sing Neptune's lightning call

Both Voyager spacecraft photographed bright "superbolts" of lightning in Jupiter's atmosphere in 1979 and recorded radio emissions called "whistlers" — because of their declining frequencies — which lightning often triggers on Earth. At Saturn, the Voyagers neither saw lightning nor heard whistlers, but they did record a kind of high-frequency static associated with terrestrial lightning and audible on AM radios. And one group of scientists has proposed that Voyager 2 detected such static at Uranus.

Now Neptune gets nominated to the lightning club.

Voyager 2 neither saw lightning bolts nor encountered the high-frequency static as it flew past Neptune last August, but one of the spacecraft's instruments apparently detected whistlers. The instrument's chief scientist, Donald A. Gurnett of the University of Iowa in Iowa City, was reluctant at the time to call the signals that, even though he says "they behaved exactly like whistlers."

Now, he says, "I am confident that these are whistlers produced by lightning in the Neptune atmosphere."

Gurnett's initial uncertainty stemmed from measurements by another Voyager instrument, which he felt raised the possibility that the planet's ionosphere contained far too few electrons to carry whistlers to the spacecraft from the lightning bolts that would have spawned them.

The apparent Neptune whistlers took far longer to sweep down through their range of frequencies than those at Jupiter. According to Ralph L. McNutt Jr. of the Massachusetts Institute of Technology in Cambridge, that would happen if the whistlers followed either a long path with few electrons — a low-density ionosphere — or a short path through a dense ionosphere. Yet Voyager 2 was barely 5,000 kilometers from Neptune when it detected the whistler-like signals, too close for a long path to explain their sound — which implies a concentration of electrons, called a plasma, much more dense than the plasma measured by the spacecraft.

After studying the problem, however, Gurnett reported last week at the American Geophysical Union meeting in Baltimore that the presence of a dense but relatively cold plasma at a temperature of only about 950 kelvins could resolve the discrepancy. This would be too cold for Voyager 2's plasma instrument to detect, but would contain far more electrons than the hotter plasma (at about 55,000 K) that the craft did measure. Confirming the answer will require more study, says McNutt, but he acknowledges that hot and cold plasmas could coexist at Neptune. *— J. Eberhart*