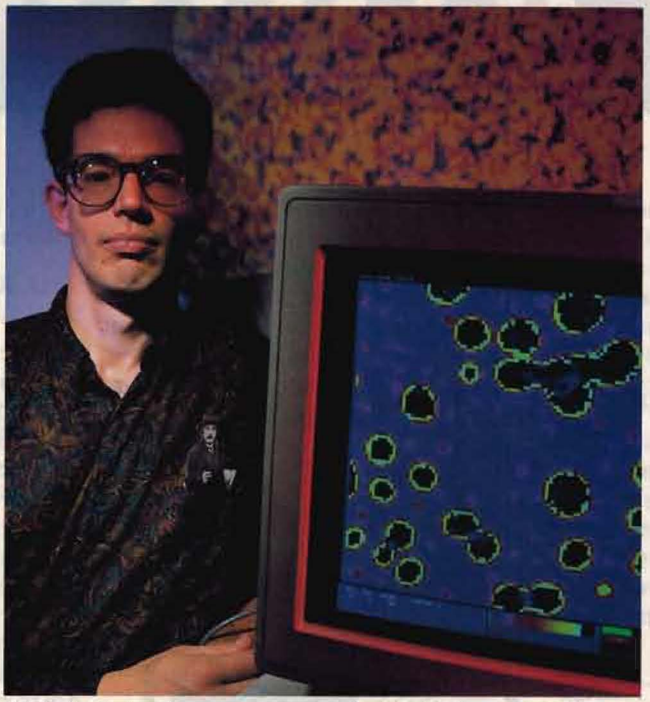
Marcia Bartusiak

The Texture of the Universe

ASTRONOMERS ARE GETting nervous. Over the past few years, as they've looked out at the most distant reaches of the cosmos, they have been finding galaxies and quasars—the energetic cores of young galaxies—popping into existence as early as 2.5 billion years after the Big Bang—far sooner than standard models suggested. Additionally, the overall structure of the universe seems to be surprisingly clumpy. Rather than being distributed across the sky in a fairly uniform spangling, galaxies appear to converge in lumps and layers, which collect into sheets, which in turn roll into hollow, bubblelike spheres up to 300 million light-years across. Finally, the bubbles nest together in a sort of cosmic foam that pervades the universe.



With the help of a computer simulation (and a pocket-size friend) Princeton physicist Neil Turok shows how misalignments in the Higgs field—known as textures—might have formed in the early years of the universe.

PHOTOGRAPH BY STEVE HILL

Observations like this have so jolted accepted cosmological theory that some stories have appeared in the media declaring—erroneously—that the Big Bang is dead. Cooler heads, however, insist that such dire conclusions are wrong. What's missing in our theories about the birth of the universe, they maintain, is not an understanding of the Big Bang itself but an understanding of what happened after that fiery cataclysm.

One of the leading researchers trying to reconstruct the universe's early years is Neil Turok, a young physicist at Princeton. Turok is now exploring an intriguing entity known as texture, a strange piece of physics that could go a long way toward explaining the cosmos we see today.

As a useful scientific concept, texture has been around for some time, though in a different guise. For solid state physicists, texture is a type of defect in crystals and other materials. Just as water freezing into ice develops thin imperfections—cracks and flaws where the water molecules are not precisely lined up—so too may the molecules in diamonds or salt or liquid crystals fail to fall into perfectly neat ranks.

In its cosmological incarnation, texture may explain how the universe could have been similarly flawed. Cosmologists generally accept the premise that when the universe was an infinitesimal fraction of a second old, its four basic forces—gravity, electromagnetism, and the strong and weak nuclear forces—were united in a single ancestral force. But after that brief instant the developing universe underwent a sort of crystallization; the symmetries broke, and a specific order was imposed on the cosmos.

In the late 1970s, when Turok was a graduate student at Imperial College in London, one of his professors, Tom Kibble, first pointed out that defects may have marred the cosmos as it cooled and expanded following the Big Bang. One such defect would be manifested as cosmic strings, slender strands of highly concentrated mass-energy—actual remnants of the Big Bang fireball—that never dissolved into the early universe's hot plasma soup. Kibble—and later Turok and others—speculated that loops of string, scattered about the universe, might have gravitationally attracted vast assemblages of matter, serving as the seeds of the first galaxies and clusters.

String theory, however, proved problematic. Computer simulations suggested that even if strings exist, they would probably be too small to be responsible for any galaxy formation. "The better the computer simulations became," Turok says, "the more the virtues of cosmic strings began to disappear."

Faced with this, Turok started looking into another key defect Kibble had mentioned: texture. Visualizing a texture is difficult, for it is defined not as a discrete object but as a misalignment in a field. Fields are ubiquitous in physics. Electromagnetic fields, for example, direct the movements of charged particles and can tell the difference between a positively charged particle and a negatively charged one; gravitational fields control the motions of matter, from rocks to planets. For texture, the relevant field is the Higgs field, which has been posited by particle physicists to perform certain tasks, such as differentiating a quark from an electron or endowing each type of particle with its characteristic mass.

Although the Higgs field would exist throughout the entire cosmos, it is possible it wasn't always uniform. Texture would form over a roughly spherical region of space where the Higgs field lines were out of kilter—that is, where the local field didn't quite mesh with the Higgs field erected throughout the rest of the universe. You might think of texture as a cloudy patch within an otherwise transparent crystal, a patch whose atoms didn't nicely align with their well-ordered neighbors. In the cosmic version this textural defect introduces a strain into the fabric of space-time.

Eventually, something has got to give. Imagine two opposing crustal plates on Earth, pushing and straining against each other. Eventually the plates will suddenly shift—will realign themselves—and release the strain in the form of a rumbling earthquake. A cosmic texture, too, must ultimately "unwind," must align its field lines with the rest of the universe so that the defect disappears. And in carrying out this reordering, the texture releases a great surge of energy, a sort of cosmic quake. That is how it becomes useful as a galaxy maker. This energy serves as a powerful trigger that can initiate galaxy formation as early as a billion years after the Big Bang, much sooner than previous theories have been able to accomplish.

The scenario goes something like this: At 10^{-35} second into the universe's birth, the grand unified symmetry is shattered and textural defects emerge in all sizes, from the microscopic to the astronomical. The smallest textures realign first, then progressively larger textures unwind. The energy that all these textures release, though, is held at bay until a moment 30,000 years after the Big Bang, when matter, rather than radiation, comes to dominate the universe's affairs. Only then are the universe's contents, a fiery hot plasma of protons, neutrons, and electrons, ready to receive the sharp kicks from all those unwinding textures. This array of waves, from small to large, starts pushing matter into galaxies, clusters, and superclusters.

The largest texture that unwinds and organizes matter at that time is 30,000 light-years wide, which is the size of the visible universe, the part we see, 30,000 years after the Big Bang. According to the calculations of the Princeton group, this 30,000-light-year-wide perturbation, once generated, will physically grow with the expansion of the cosmos. Today, 15 billion years later, after the expanding universe has swelled 10,000 times over like an inflating balloon, that texture-induced structure should now span 300 million light-years across. Intriguingly, that's just about the size of the largest bubble seen in maps of the distribution of galaxies in the universe.

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"It's possible that this is nothing more than a coincidence," says Turok, "but it's also possible that unwinding textures swept all these areas clear of matter fifteen billion years ago, and the voids have just continued to grow ever since."

Turok and his Princeton colleagues Andrew Gooding and David Spergel have also produced findings that link textures with the early appearance of some quasars—galaxies containing supermassive black holes at their centers that burst into life when they begin gobbling up galactic matter. Other models—which include cosmic strings and random fluctuations in the distribution of matter—cause galactic matter to coalesce too slowly to explain the ancient quasars recently discovered. When textures are included in computer simulations, however, the extra kick they provide causes the matter at the core of a galaxy to collapse much faster.

Turok and Spergel also believe textures should have a particular, identifiable effect on the cosmic microwave background radiation, that wash of energy that suffuses the universe and is thought to be a residue of the Big Bang. Since the Big Bang released equal amounts of energy in all directions, the microwave background should be more or less uniform anywhere in the sky. Unwinding textures, however, could have disturbed this uniformity. If so, the evidence should be detectable. Indeed, observers from MIT, Princeton, and NASA may already have seen some. Analyzing data taken in 1989, the researchers have found some regions of the sky where the background radiation looks appropriately perturbed. But much more analysis is needed to assure that textures are in fact responsible.

Preliminary results are already available concerning another form of cosmic radiation—the diffuse background of X-rays seen all over space. When the X-rays were first discovered in the 1960s, astronomers concluded that half the ubiquitous radiation was caused by quasars; the other half was of unknown origin. Jeremiah Ostriker, the head of Princeton's astronomy department, has followed Turok's work and is now incorporating textures into computer simulations of the early, developing universe. Ostriker and his associate Renyue Cen are finding out that textures in the early universe would create enormous gravity wells into which cosmic gas would "fall." As the gas was compressed it would be heated intensely, causing it to release an enormous flood of energy powerful enough to explain virtually all of the unexplained X-rays. "Almost everyone now agrees," says Ostriker, "that explaining and simulating the universe requires some kind of exotic physics like this."

Despite such votes of support, texture theory is far from gaining universal acceptance. Researchers have seen an assortment of cosmic models appear and disappear over the past decade, and at one time or another all of them seemed convincing, too. Nevertheless, in this case Turok believes cosmology may have stumbled onto a real contender.

"We have to be cautious," he says. "A texture-seeded universe involves a lot of complicated physics we're only beginning to understand. So far, however, textures are turning out to be more interesting than we ever dreamed." ❑