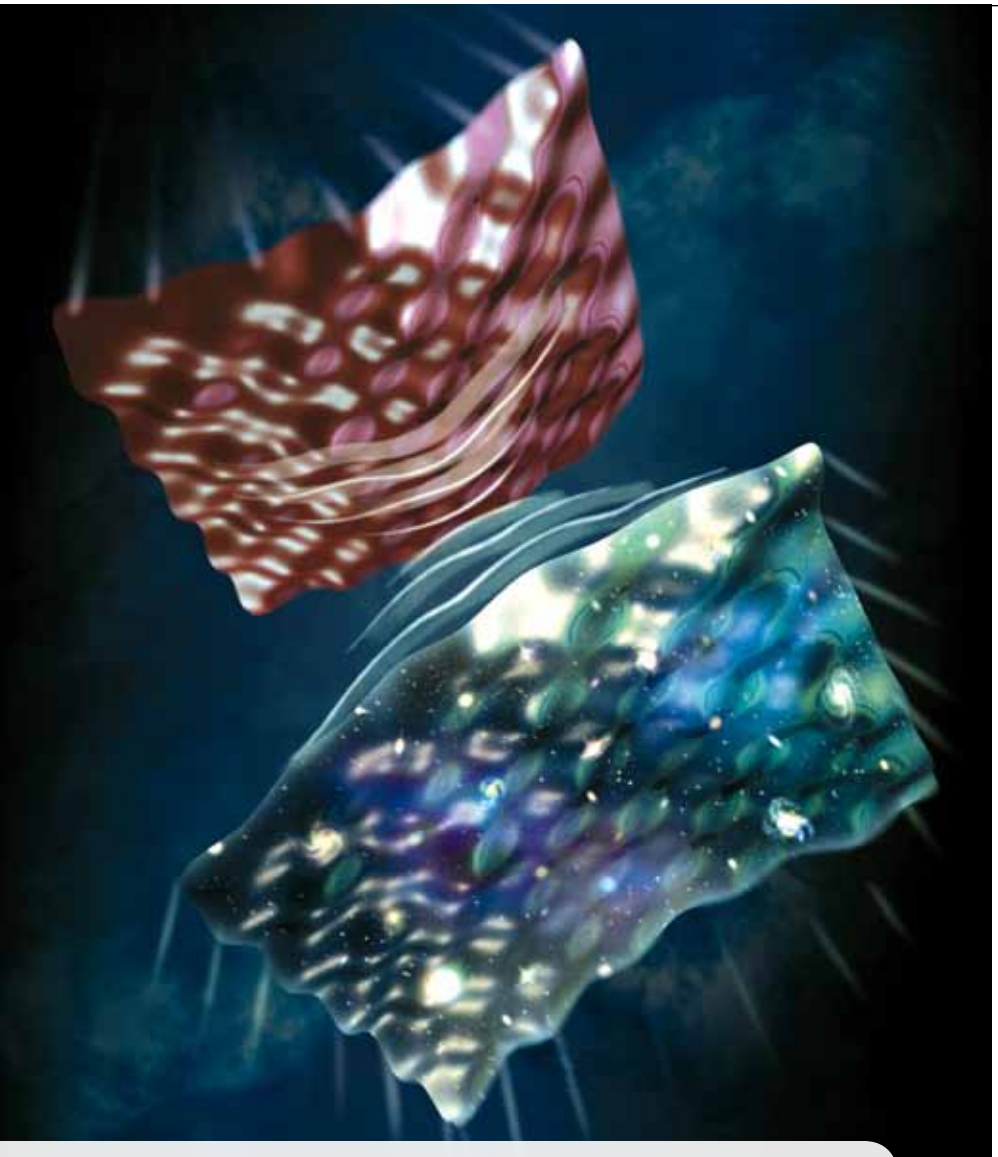


If the universe occupies a sheetlike membrane, the Big Bang may have been just one in a series of collisions, each "Big Bounce" refreshing the cosmos.

WHAT HAPPENED BEFORE THE BIG BANG?

Pre-Bang branes and bubbles

By Ron Cowen ▪ Illustration by Nicolle Rager Fuller

Cosmologists Paul Steinhardt and Neil Turok liken the early history of the universe to a play in which the protagonists — matter and radiation — move across the stage according to the laws of physics. Astronomers are actors who arrived on the scene 13.7 billion years too late to know what happened.

But that hasn't stopped Steinhardt, Turok and other researchers from pondering whether the universe was born in a giant fireball around that time or might have existed before that.

The modern-day notion of the cosmos's tumultuous beginning — known as the Big Bang — has its roots in Edwin Hubble's 1929 discovery that the universe is expanding. At the time, scientists envisioned the universe explosively flying outward from a single point in space and time.

Though this simple version of the Big Bang idea can't fully explain what people see in the cosmos today, Alan Guth of MIT added a new ingredient in 1981. Early in its history, the universe underwent a brief period of faster-than-light expansion, known as inflation, he proposed. In the years since Guth's suggestion, inflation has been wildly successful in explaining the structure of the universe and its arrangement of galaxies.

Bubbling over

Some scientists think that if inflation happened once, it could happen many more times — hinting at a cosmos alive and well eons before the Big Bang. Rapid expansion, in these interpretations, isn't confined to just one neck of the cosmic woods, like a single expanding balloon. Instead, distant patches of space keep inflating, like a child continually blowing soap bubbles, says Alex Vilenkin of Tufts University in Medford, Mass.

Every inflated patch becomes a separate universe, with its own Big Bang beginning (*SN: 6/7/08, p. 22*). In this "eternal inflation" scenario, the fireball that begot the universe seen with today's telescopes was preceded by a multitude of others just as surely as it will be followed by many more, each popping off at different times in different parts of the cosmos, Vilenkin says.

Just as the sun is merely one of billions of stars in the Milky Way galaxy, the visible universe may be one of countless in the cosmic firmament. Cosmologists call this ensemble of universes the multiverse.

Not only might there have been a plethora of universes that came before

the one people know, but each one may also have been different from the others. In combining eternal inflation with string theory, an idea that has become popular because it could help unify the four known forces in nature (see Page 26), each inflated universe would have its own set of physical properties. Although the known universe is chockablock with galaxies, for example, gravity in another, earlier universe could have been too weak to form galaxies.

Bounce not bang

String theory itself — which calls for a space with many rolled-up dimensions — may suggest a different type of pre–Big Bang picture. In a model developed by Steinhardt, now at Princeton University, and Turok, now director of the Perimeter Institute in Waterloo, Canada, the Big Bang is replaced with an endless cycle of contractions and bounces; 13.7 billion years is merely the time since the last "Big Bounce."

In this picture, the known universe resides on a three-dimensional version of a sheet, called a brane, which can travel along an extra dimension. Another brane resides a tiny distance away.

When they are separated, the two branes are perfectly wrinkle-free, representing a universe nearly devoid of matter. As the two branes pull closer, they develop tiny wrinkles. These wrinkles are the seeds of galaxies. When the branes finally collide and bounce apart, they unleash an enormous amount of energy, some of which is converted to matter and radiation. To an observer on one of the branes, this Big Bounce would look just like a Big Bang (*SN: 9/22/01, p. 184*).

While the branes are separated, they stretch and smooth out; the cosmos is expanding just as it is today. But eventually, the two branes are pulled back together for another round of collisions and bounces. Each cycle may last a trillion years or more.

In the Big Bounce model, the universe not only existed before the Big Bang, it retains the memory of what came before. All of the stars, galaxies, and large-scale structures now present owe their existence to the composition of the universe in the previous cycle. Though the details might be different, the underlying physical laws would remain the same.

Cosmic clues

Whether the Big Bounce or the multiverse captures reality — if either one does at all — remains a mystery. One observation, though, could distinguish between the Big Bounce and any inflationary scenario, Steinhardt notes. Gravitational waves, tiny ripples in the fabric of spacetime, are generated during each cycle of the Big Bounce. But in this scenario, the waves would be too weak to be detected. Inflation, in contrast, would produce a much more powerful set of the waves — strong enough to leave a noticeable imprint on the cosmic microwave background, the radiation left over from the Big Bang.

The European Space Agency's Planck spacecraft is now searching for the telltale signs that gravitational waves would leave in the cosmic microwave background (*SN: 4/11/09, p. 16*). If the imprint is found, "we're done," says Steinhardt. The Big Bounce would fall flat.

Whether or not inflation implies a multiverse is another story, but Planck may offer clues about that too.

As bubble universes expand, they can collide with each other. If another universe happened to have struck the one in which people reside, Planck might be able to detect a particular pattern of hot and cold spots in the microwave background.

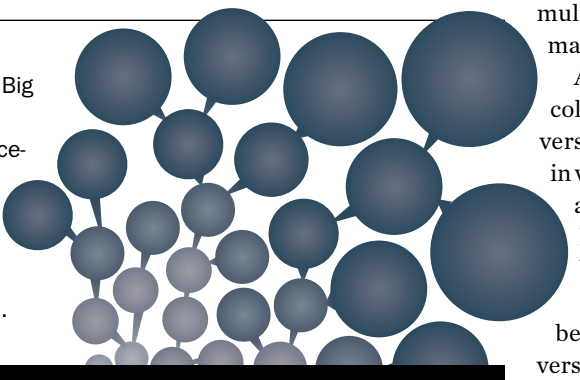
Even if no sign of a collision can be spotted, though, other bubble universes may still exist. Bumps could be so infrequent that observers might have to wait a millennium to find the pattern.

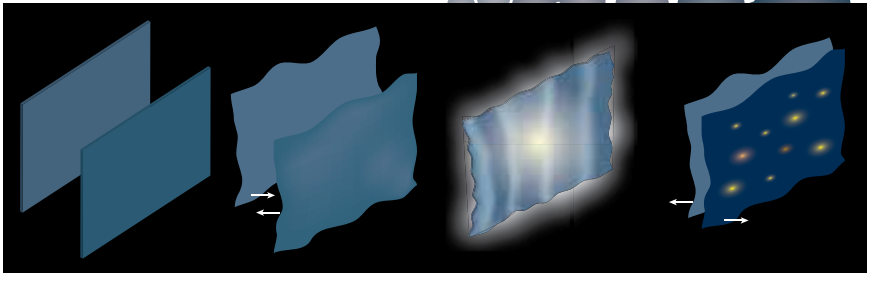
If that prolonged uncertainty about cosmic genesis sounds a bit like purgatory, consider the words of an unnamed man quoted in St. Augustine's *Confessions*. When asked what God was doing before making heaven and Earth, the man replied: "He was preparing Hell for those who pry too deep."

St. Augustine, himself, found the answer facetious: "More willingly would I have answered, 'I do not know what I do not know.'" ■

In the beginning

Not knowing what came before the Big Bang doesn't stop physicists from theorizing. In the eternal inflation scenario, the known universe bubbled out of a larger multiverse (right). Another model (below) suggests that the universe cycles through a series of contractions and bounces.





In the cyclic model, the known universe occupies a sheetlike surface, a "brane." Another brane sits a small distance away.

An interbrane force pulls the two sheets together, amplifying quantum ripples and creating wrinkles in the branes.

The branes collide and then rebound, releasing energy in what looks like a Big Bang.

Once the branes separate, galaxies and other cosmic structures form. The matter spreads out and the cycle repeats.

SOURCE: P. STEINHARDT

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