SCIENCE NEWS of the week

The Cosmos' Fate: World Without End

Will the universe expand forever, or will it eventually contract into a Big Crunch? Observing the fireworks from distant, exploding stars, two independent research groups have found evidence suggesting that the cosmos will balloon indefinitely.

The density of matter may simply be too low for gravity to halt the expansion that began with the birth of the universe—the Big Bang—some 15 billion years ago. Although other studies over the past several years have hinted at the same conclusion, the technique employed in the two new reports is a particularly promising method of determining the fate of the cosmos, researchers say.

If further observations support the notion of perpetual expansion, cosmologists may have to rethink their options. The widely accepted theory known as inflation explains why the structure of the universe looks the same in all directions, but it also predicts that the cosmos has exactly the right density to bring expansion to an eventual halt (SN: 6/7/97, p. 354). Reconciling this theory with endless expansion may require cosmologists to resurrect the so-called cosmological constant—an antigravity term in the equations of general relativity.

The new results are based on measurements of the brightness and recession velocity of a special class of supernovas, or exploded stars. Known as type 1a, these supernovas are the brightest in the cosmos and can be seen from great distances. Moreover, they all have about the same intrinsic brightness.

The most distant 1a supernova observed with the Hubble Space Telescope provides a glimpse of the cosmos when it was half its current age. The rate at which the universe was expanding in the past determines how far away a supernova with a given recession velocity lies. By comparing observations of faraway supernovas to those of nearby ones, astronomers can infer the rate at which cosmic expansion may be slowing down.

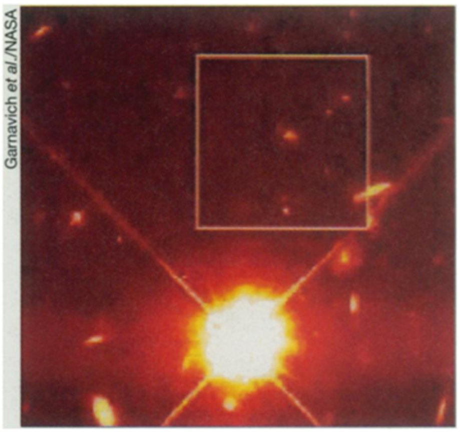
Saul Perlmutter of the Lawrence Berkeley (Calif.) National Laboratory and his colleagues find little or no sign of deceleration, they report in the Jan. 1 NATURE.

Their analysis of five nearby supernovas and a newly discovered distant one suggests that the universe will expand indefinitely. A preliminary analysis of about 35 additional supernovas, both nearby and distant, to be presented next week at a meeting of the American Astronomical Society in Washington, D.C., supports that finding, Perlmutter says.

Observations of three other distant supernovas, to be described by Peter M. Garnavich and Robert P. Kirshner of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., and their colleagues in an upcoming ASTROPHYSICAL JOURNAL LETTERS, yield a similar conclusion.

"We cannot make much of a conclusion from a single farthest supernova . . . but when we average it with several others, we find, to a 95 percent level of confidence, that the density of matter is insufficient to halt the expansion of the universe," Garnavich says. In a year or two, adds Kirshner, when both teams will have completed studies of several dozen supernovas, the fun will begin.

"This is a hard subject, and the data do not [yet] constrain the imagination very much," says Kirshner. "What's new here is that we're beginning to show that we have the potential to [distinguish among models of the cosmos] and that it isn't just going to be a matter of what you like, what you think is beautiful. It's going to be a matter of looking into the real answer book of nature and finding out what it says."



Garnavich et al./NASA

Central boxed object is a distant type 1a supernova. Bright body is a nearby star.

"It's very exciting—not from the results, but from the promise of what's in the future," says Michael S. Turner of the University of Chicago and the Fermi National Accelerator Laboratory in Batavia, Ill. —*R. Cowen*

Zeroing in on an infinite number of primes

Prime numbers have long fascinated and perplexed mathematicians. Evenly divisible only by themselves and 1, these whole numbers occupy a central place in number theory.

More than 2,000 years ago, Euclid of Alexandria proved that there is an infinite number of primes among whole numbers. Now, two mathematicians have shown that the supply of primes is also unlimited in a particular subset of the whole numbers. Along the way, they developed new, potentially powerful mathematical techniques for probing some of the mysteries of primes, including their rather haphazard distribution.

John Friedlander of the University of Toronto in Scarborough, Ontario and Henryk Iwaniec of Rutgers University in New Brunswick, N.J., report their findings in a pair of papers scheduled for publication in the ANNALS OF MATHEMATICS.

"It's a tremendous achievement," says Peter C. Sarnak of Princeton University.

Andrew J. Granville of the University of Georgia in Athens adds, "They've succeeded in solving a problem that we've been stuck on for about 100 years."

The sequence of primes goes 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, and so on. Broadly speaking, primes become more scarce as numbers get larger. Nonetheless, the sequence of primes never ends, even though the gaps between successive primes, on average, get longer.

In probing the distribution of primes, mathematicians have investigated whether the number of primes among certain subsets of the whole numbers is also infinite. For example, about a century ago, they proved that there are infinitely many primes among numbers of the form $a^2 + kb^2$, where a and b are integers and k is a certain constant.

It's also easy to come up with simple examples of subsets in which the number of primes is finite. For instance, among even numbers, only 2 is prime.

"The general belief is that, whenever you write down some definition of a sequence, you will have infinitely many primes unless there's some obvious reason why you don't," Sarnak says. "But there are very few cases in which [the infinitude of primes] can be proved."

Friedlander and Iwaniec tackled the question of whether there are infinitely many primes among numbers of the form $a^2 + b^4$. These numbers are relatively scarce among whole numbers in general. Mathematicians describe such a sequence as sparse.

Thus, among whole numbers up to 100, there are 18 numbers of the required form: 2, 5, 10, 17, 20, 25, 26, 32, 37, 41, 50, 52, 65, 80, 82, 85, 90, and 97, of which only six—2, 5, 17, 37, 41, and 97—are primes. Among whole numbers up to 1 trillion, there are fewer than 1 billion numbers of the form $a^2 + b^4$.