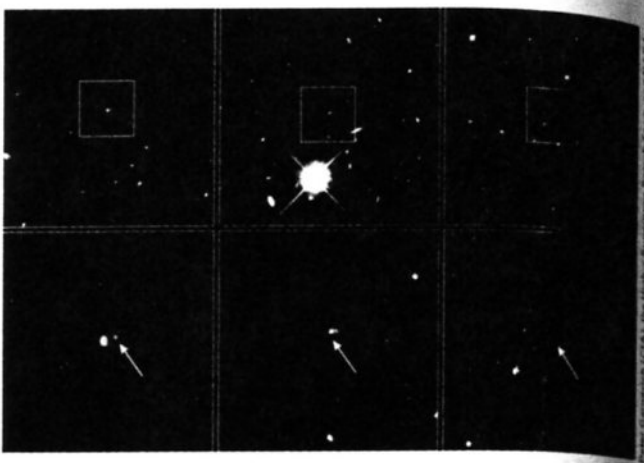

COSMOLOGY

Universe Should Expand Forever

Hubble made these portraits of some of the most distant supernovae ever seen — all lie at least five billion light-years from Earth. By analyzing the light from these cataclysmic stellar explosions, astronomers have concluded that the expansion of the universe should continue forever.

▶ Will the universe expand forever, or will it stop one day and then begin contracting? Several recent studies strongly suggest that the universe will continue expanding and may in fact pick up speed over time.

In the first two studies, astronomers used large ground-based telescopes and the Hubble Space Telescope to examine several Type Ia supernovae in the distant universe. Type Ia supernovae arise when a white dwarf star collects enough matter from a companion star to push it above 1.4 solar masses. No longer able to support itself, the white dwarf collapses and explodes.

Because all Type Ia supernovae form under similar conditions, they show remarkably similar behavior, allowing astronomers to readily compare nearby supernovae with far more distant ones. And they are so bright that they can be seen halfway across the universe.

Groups led by Saul Perlmutter of the Lawrence Berkeley National Laboratory and Peter Garnavich of the Harvard-Smithsonian Center for Astrophysics plot the apparent brightnesses of a number of these supernovae against their distances. The plots show whether or not the expansion rate has changed significantly during the history of the universe. The groups have now studied several dozen distant supernovae, and the trend is clear: "All the indications from our observations are that we live in a universe that will expand forever," says Perlmutter. Garnavich adds that his team is "95 percent confident that the density of matter is insufficient to halt the expansion."

Two other research teams have reached the same conclusion using different techniques. Neta Bahcall of Princeton University and her colleagues are looking at how many massive galaxy clusters exist in the distant

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universe. In a high-density universe — one that might one day stop expanding — most massive clusters would form in relatively recent times. In fact, the odds are about 1,000 to one against even a single massive cluster forming at a time halfway back to the Big Bang. But Bahcall has found three massive clusters, implying that the universe has only 20 percent of the matter needed to halt the expansion.

A group led by Ruth Daly, also of Princeton University, looks at radio galaxies to reach the same conclusion. The apparent size of these enormous galaxies depends on the geometry of the universe as a whole, which in turn determines the universe's ultimate fate. A relatively small size at great distance would suggest a universe that will recollapse, a larger size implies a universe that will continue expanding but at an ever-decreasing rate, and an even larger size suggests a universe that will expand forever at an accelerating rate.

Surprisingly, Daly and her colleagues find that the distant radio galaxies appear huge, supporting eternal expansion and, at this stage at least, hinting that the universe will expand faster in the future. This implies some sort of "anti-gravity" force — the famed cosmological constant introduced by Albert Einstein in his general theory of relativity. Perlmutter's group also reaches this conclusion, although the results are still preliminary. If these findings are strengthened and confirmed, it would turn what Einstein called his "greatest scientific blunder" into a remarkable prediction.