Ron Cowen reports from Atlanta at a meeting of the American Astronomical Society

Hubble: A universe without end . . .

Measuring with unprecedented accuracy the abundance of deuterium in space, the Hubble Space Telescope has found evidence suggesting that the universe will expand forever.

Most cosmologists believe that the Big Bang — the explosive event thought to have sparked the expansion of the cosmos — produced helium, hydrogen, deuterium (a hydrogen isotope) and traces of a few heavier elements.

Later, during nuclear reactions that led to starbirth, hydrogen, deuterium and helium atoms served as building blocks for making other elements, astrophysicists theorize. Thus, the present ratio of deuterium to hydrogen should enable researchers to calculate the maximum amount of ordinary matter in the universe.

If the universe contains too little mass, the expansion that began with the Big Bang would continue indefinitely. But a sufficiently large amount of matter could provide the gravitational tug required to eventually stop expansion and cause the cosmos to collapse back upon itself — perhaps to reexpand during some future Big Bang. For years, cosmologists have debated whether the amount of mass in the universe — still an unknown quantity — is more likely to favor the first scenario or the second.

In the latest attempt to measure the ratio of deuterium to hydrogen in the cosmos, Jeffrey Linsky of the University of Colorado at Boulder and his colleagues used light from the Milky Way star Capella as a cosmic probe. As light from Capella — the sixth brightest star in the universe — passes through interstellar gas on the way to Earth, specific chemical elements absorb specific wavelengths. For example, the ultraviolet wavelengths absorbed by interstellar hydrogen differ slightly from those absorbed by deuterium. And the amount of light absorbed by each isotope indicates the relative concentrations of the two chemicals.

Using Hubble's Goddard High-Resolution Spectrograph to precisely measure the ultraviolet absorption lines, Linsky and his co-workers calculated the deuterium-hydrogen ratio at about 15 parts per million, with an uncertainty of less than 10 percent. Other satellites, such as the International Ultraviolet Explorer, have yielded similar ratios but with far greater uncertainty, Linsky notes.

The primordial ratio may have been somewhat larger, since some deuterium from the early universe may have been destroyed during starbirth or other processes. Nonetheless, says Linsky, Hubble's measurement suggests that the universe contains only about one-tenth the mass required to keep it from expanding forever.

Alternatively, he says, the universe may contain large amounts of dark matter — still-undetected material that would exert the additional gravitational force needed to keep the cosmos from expanding indefinitely. But so far, ground-based and satellite studies have failed to locate sufficient amounts of this "missing matter."

. . . and a search for dark matter

In one such study, an ongoing set of Hubble observations, astronomers have now examined images of some 300 distant quasars. By analyzing the images for telltale distortions, they have inferred the presence of dark matter along the line of sight between Earth and any of these quasars.

The distortions, an effect known as gravitational lensing, occur when any massive foreground object — whether or not it is visible to an observer — bends light rays coming from a more distant source. In fact, if an unseen foreground object has enough mass, it can make its presence known by bending the light from a background galaxy or quasar into several distinct images. This phenomenon provides researchers with a powerful probe for dark matter.

Ground-based telescopes have inferred the presence of about 12 gravitational lenses during the past 13 years. Among the several hundred quasars surveyed by Hubble since 1990, only one appears to have its light bent by a gravitational lens, reports a research team led by John N. Bahcall of the Institute for Advanced Study in Princeton, N.J.

This quasar, known as 1208 + 101, lies about 12 billion light-years from Earth. As viewed by Hubble, it appears as two images, one a much fainter version of the other. If further studies verify that this effect results from gravitational lensing, 1208 + 101 will represent the most distant object known to have undergone such distortion.

Bahcall cautions, however, that it will take another set of Hubble observations, scheduled for late January, to rule out the possibility that the second image merely represents light emitted by a star or galaxy that happens to lie along the same line of sight as the quasar.

Boring into an ancient star

Using Hubble's Goddard High-Resolution Spectrograph, astronomers have detected boron in an elderly star for the first time. This discovery, coupled with earlier, ground-based observations that the same star contains far more beryllium than predicted by the standard Big Bang model, may call into question some key assumptions about the chemical environment in the very early universe (SN: 9/7/91, p.151).

Although the new findings don't contradict the premise that the universe began with a giant explosion, they do cast doubt on the notion that the universe began as a perfectly smooth mixture.

Douglas Duncan of the Space Telescope Science Institute in Baltimore, along with Michael Lemke and David L. Lambert of the University of Texas at Austin, relied on the Hubble spectrograph to detect boron emissions — ultraviolet light that can't penetrate Earth's atmosphere — from the Milky Way star HD 140283. The star lies about 100 light-years from Earth, and researchers regard it as one of the most ancient objects in the universe, about 15 billion years old.

Because it was one of the first stars to form in the Milky Way, HD 140283 should contain elements that formed long ago. Like a well-preserved fossil, an ancient star whose surface remains unchanged should reflect the chemical composition characteristic of the universe soon after the Big Bang.

Ground-based observations showed that the star primarily contains elements predicted to have been synthesized during the Big Bang — hydrogen, helium and a trace of lithium. The discovery of boron came as a surprise and suggests that the Big Bang may have produced some elements heavier than lithium, Duncan says. If so, the initial distribution of material in the universe — often assumed to have been a perfectly smooth, hot broth — may have contained more structure, or "lumps," than researchers believed.

Duncan's team has not ruled out an alternative explanation for the abundance of boron and beryllium in the Milky Way star. Cosmic rays striking the star sometime after the Big Bang would have split heavier atoms, creating extra boron and beryllium. To test the cosmic ray scenario, the researchers plan to analyze boron emissions from an even older star in the Milky Way.

If cosmic ray bombardment generated the bulk of the boron, then the older star should contain less of the element because its emissions date closer to the birth of the Milky Way. On the other hand, a finding that the older star contains the *same* amount of boron would support the theory that the Big Bang itself created boron.