The Sturtevant Memorial Spa was formally dedicated in a short ceremony on May 2. The spa was built in memory of the late Bradford Sturtevant (MS '56, PhD '60), the Hans Liepmann Professor of Aeronautics, who died in October 2000. A legendary swimmer, Sturtevant was long active on the faculty athletic committee and was a key figure in the planning and construction of the Braun Athletic Center. His widow, Carol, thanked all who had contributed to the unique memorial, which will "enhance the Caltech experience for students and the Caltech family." "It will offer respite from the academic pressures of Caltech," said athletic director Tim Downes. "Brad Sturtevant will always have a spot on this pool deck."

As the guests of honor at Dodger Stadium on Saturday, June 1, some 1,600 members of the Caltech/JPL community watched the Battlin' Beavers' battery of pitcher Isaac Gremmer (freshman) and catcher Eric Peters (sophomore, chemistry) handle the ceremonial first pitch. From left: Gremmer; Peters; and honorary coaches David Baltimore, president of Caltech; and Charles Elachi (MS '69, PhD '71), director of JPL. The Dodgers beat the Arizona Diamondbacks, 2–0.

What Bleach Can Teach About Ozone Leach

Results from a JPL/Caltech collaboration have unraveled a mystery that may permit better global measurements of some ozone-depleting gases. Scientists have long known that the HO_x radicals—hydroxyl (OH) and hydroperoxyl (HO_2)—destroy ozone in Earth's stratosphere, allowing more ultraviolet radiation to reach Earth's surface. The HO_x radicals can't be measured easily, but the hydrogen peroxide (H_2O_2) produced when they react with each other can be.

So atmospheric scientists would like to use peroxide as a proxy to map HO_x distributions, but there has always been a large, nagging discrepancy between the actual peroxide measurements and the levels predicted by global computer models of the atmosphere, suggesting that the chemistry has not been completely understood. The new study has resolved much of the disparity.

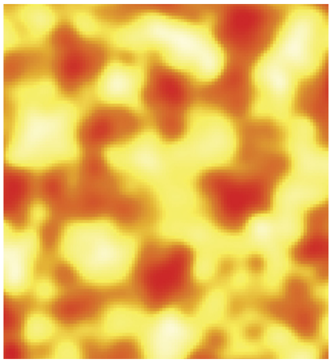
In the May 7 issue of *Geophysical Research Letters*, the scientists report discovering an error in the calculations for the rate at which two hydroperoxyl radicals form hydrogen peroxide, which were thought to be well known. Lance Christensen, a Caltech grad student in chemistry working at JPL and the paper's lead author, showed that at the low temperatures relevant to the stratosphere, the rate is slower than had been previously measured. In lab studies, hydroperoxyl radicals are typically formed from methanol, but Christensen discovered that the trace amounts of methanol present accelerated the rate of hydrogen peroxide formation.

"The importance is not so much the hydrogen peroxide itself, but that it opens the possibility for remotely measuring hydrogen peroxide to infer the HO_x radicals" from space or the ground, says Mitchio Okumura, an associate professor of chemistry and a coauthor of the study. "The HO_x radicals are central to the chemistry of the stratosphere and upper troposphere in understanding ozone depletion."

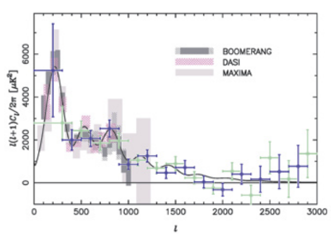
"We're trying to improve our understanding of the atmosphere well enough to be able to model ozone depletion and climate change in general," says JPL's Stan Sander (MS '75, PhD '80), another coauthor. "This work provides an important tool."

In addition to Okumura, Sander, and Christensen, the other authors are Ross Salawitch, Geoffrey Toon, Bhaswar Sen, and Jean-Francois Blavier, all of JPL; and K.W. Jucks of the Harvard-Smithsonian Center for Astrophysics. The study was funded by NASA. □—*RT*

An Ultrasound of the Infant Universe



In this view from the Cosmic Background Imager, the hotter, denser regions are the "seeds" from which galaxy clusters will eventually grow. The image covers a 2° by 2° field—an area about 16 times that of the full moon—and shows details about 1 percent the size of the moon.



The fluctuations in the microwave background can be sorted by area the way the graphic equalizer on your stereo sorts sound waves by frequency. Seen this way, the CBI data (green and blue crosses) extend to much higher "frequencies" than the other experiments. The solid line shows the predicted size distribution; the CBI has verified "overtones" beyond the other instruments' hearing.

Caltech's Cosmic Background Imager (CBI), a radio telescope set high in the Chilean Andes, has uncovered the finest detail seen so far in the cosmic microwave background radiation, which originates from the era just 300,000 years after the Big Bang. The new images are essentially photographs of the infant universe from before stars and galaxies existed, and reveal, for the first time, the seeds from which clusters of galaxies grew.

The cosmic microwave background radiation was emitted some 14 billion years ago, when matter first got cool enough for electrons and protons to combine and form atoms. Minuscule fluctuations in the universe's density at that point imprinted themselves on the radiation as subtle temperature differences—about one part in 100,000. The CBI makes fine-detailed, high-precision pictures of these temperature differences in order to measure the geometry of space-time and other fundamental cosmological quantities (*E&S*, 1996, No. 4). Tony Readhead, the Rawn Professor of Astronomy, is the project's principal investigator.

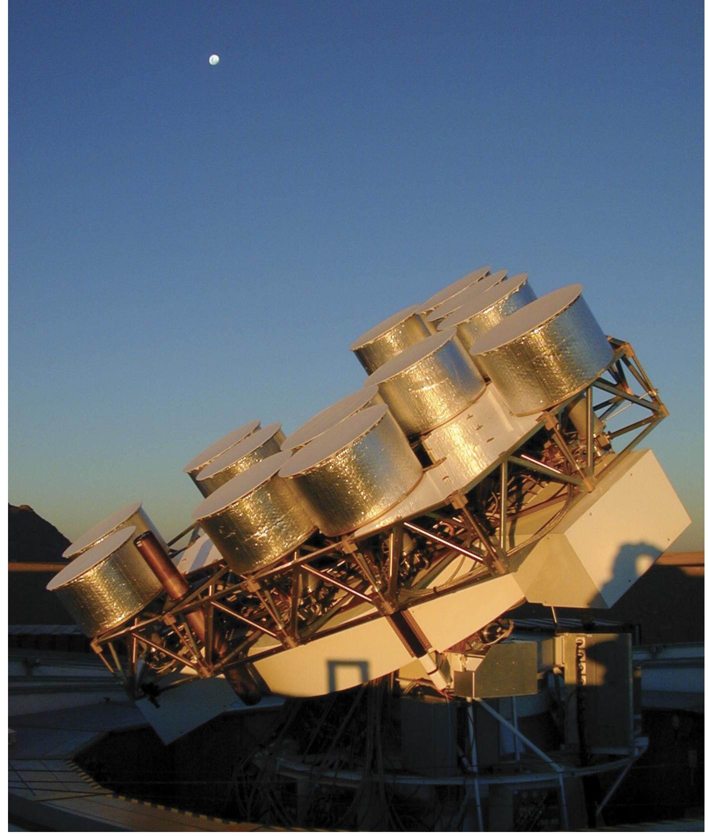
Because it sees finer details, the CBI goes beyond the recent successes of the BOOMERANG and MAXIMA balloon-borne experiments and the DASI interferometer experiment at the South Pole. The BOOMERANG experiment, led by Andrew Lange, the Goldberger Professor of Physics, demonstrated two years ago that the universe is "flat" (*E&S*, 2000, No. 3). The CBI results verify this, and confirm that most of the matter in the universe is exotic "dark matter" and that "dark energy" plays an important role in the evolution of the universe. The flat universe and the existence of dark energy lend additional empirical credence to the so-called inflation theory, which states that the universe grew from a tiny subatomic region during a period of violent expansion a split second after the Big Bang.

The CBI and BOOMERANG observations, combined with the MAXIMA and DASI data, cover a range of angular scales from about one-tenth of a moon diameter to about one hundred moon diameters. Each instrument uses different methods and different frequencies and looks at a different part of the sky, yet all agree, giving great confidence in the combined results.

The CBI is an array of 13 separate antennas, operated in concert so that the entire machine acts as an interferometer. Sited on the Llano de Chajnantor, a 16,700-foot plateau, it is by far the most sophisticated scientific instrument ever used at such an altitude. The telescope is so high, in fact, that team members must carry bottled oxygen. The CBI hardware was designed primarily by Stephen Padin, the chief scientist, assisted by senior mechanical engineer Walter Schaal (BS '58) and research engineer John Yamasaki. The software was designed and implemented by senior research associate Timothy Pearson and staff scientist Martin Shepherd. Postdoc Brian Mason and grad students John Cartwright, Jonathan Sievers, and Patricia Udomprasert also played critical roles. The telescope was built on campus and hauled from Pasadena to the Andes in August, 1999.

In five separate papers submitted to the *Astrophysical Journal*, Readhead and his Caltech colleagues, together with collaborators from the Canadian Institute for Theoretical Astrophysics, the National Radio Astronomy Observatory, the University of Chicago, the Universidad de Chile, the University of Alberta, the University of California at Berkeley, and the Marshall Space Flight Center, report on observations collected since the CBI began operation in January 2000. The images cover three patches of sky, each about 70 times the size of the moon.

The CBI team will next look for polarization in the cosmic microwave background's photons as part of a two-pronged attack with DASI. An upgrade to the CBI required for the polarization measurements was generously underwritten by the Kavli Institute. □—*RT*



The CBI at twilight. Each metal canister contains a 90-centimeter dish antenna. The array maps a patch of sky slightly larger than the moon every night.

SORTING SIGNALS FOR STORAGE

Quick! Memorize this sentence: The temporo-ammonic (TA) pathway is a entorhinal cortex (EC) input that consists of axons from layer III EC neurons that make synaptic contacts on the distal dendrites of CA1 neurons. If by chance you can't, say grad student Miguel Remondes and Erin Schuman, associate professor of biology, it may be due to this very TA pathway.

In another clue toward understanding how memories form, Remondes and Schuman (who is also an assistant investigator of the Howard Hughes Medical Institute), have found that this pathway may be part of the brain's decision-making process about whether to save a particular input. The research was reported in the April 18 issue of *Nature*.

Input from the senses—an odor, say—follows a well-known path. The signals are first received by the brain's cortex. From there, they are sent to the dentate gyrus, and then to the hippocampus, both of which are known to be involved in saving and retrieving long-term memories. Scientists divide the seahorse-shaped hippocampus into four regions, named CA1 to CA4. The signals are processed first in CA3 and then in CA1 before the hippocampus sends its output back to the cortex, probably for long-term storage. This pathway is called the trisynaptic circuit.

Scientists had also mapped the TA pathway, but did not know its function. Remondes and Schuman report that it may serve as a gatekeeper that enhances or diminishes the signals of each specific set of neurons that attempts to form a memory. Further, this pathway may also provide the hippocampus with the information it needs to form so-called place-selective cells; that is, cells that help animals to know where they are in their environments.

The TA pathway's input comes from a different part of the cortex, and goes directly to CA1. Remondes and Schuman found that the TA pathway's effect depends on the time lag between when the hippocampus receives the inputs and when it sends its own signals back to the cortex. If the timing is close, within 40 milliseconds, the TA pathway acts as a signal (and memory) enhancer; that is, it stimulates stronger signals from the hippocampus. If the delay is more than 400 milliseconds, it inhibits the signals.

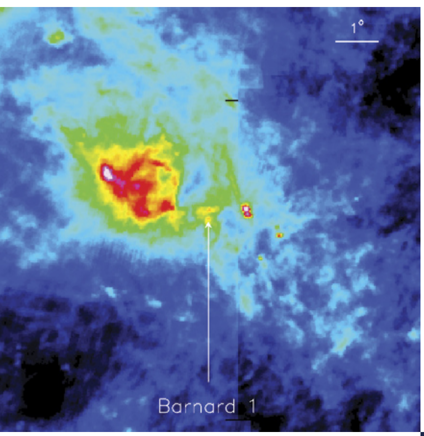
"So the brain sends the information to the hippocampus," says Remondes, "and instead of just collecting the results, the hippocampus may very well perform 'quality control' on the potential memory. And it may be doing this by using the direct cortical input from the TA pathway."

Although the scientists have not done any specific spatial-memory experiments, the work may also shed light on how the brain forms place-selective cells. Since other studies have established that the trisynaptic circuit is not needed for spatial memory, some of the information entering the hippocampus may actually be provided by the TA pathway.

"The TA pathway has been briefly described in the past, but not really acknowledged as a 'player' in the memory debate," says Remondes. "Hopefully, these findings will bring new insight into how we form, or don't form, memories." □—*MW*

CSO Wins the Lottery

This IRAS image (below) shows the galactic neighborhood of Barnard 1, the region of the Milky Way where the Caltech Submillimeter Observatory (below, right) discovered triply deuterated ammonia.



A rare type of ammonia containing three atoms of deuterium has been found in a molecular cloud about 1,000 light-years away, in the direction of the constellation Perseus. The comparative ease with which the molecules were detected means that there are more of them than previously thought. The observations were done by an international team of astronomers using the Caltech Submillimeter Observatory atop Mauna Kea in Hawaii, and were reported in the May 20 issue of the *Astrophysical Journal Letters*.

Deuterium, or "heavy hydrogen," has a neutron in its nucleus in addition to the single proton that ordinary hydrogen has. Ammonia contains one nitrogen and three hydrogen atoms per molecule.

Triply deuterated ammonia was thought to be so rare in deep space as to be undetectable from Earth, says Professor of Physics Tom Phillips, director of the Caltech Submillimeter Observatory and leader of the Caltech team. No other molecules containing three deuterium atoms have ever been found in interstellar space. "From simple statistics alone, the chances for all three hydrogen atoms in an ammonia molecule to be replaced by the very rare deuterium atoms are one in a million billion," Phillips explains. "This is like buying a $1 state lottery ticket two weeks in a row and winning a $30 million jackpot both weeks. Astronomical odds indeed!"

Both hydrogen and deuterium are present in the interstellar medium, says Dariusz Lis, a senior research associate in physics and lead author of the paper, and at higher temperatures they freely trade places with their counterparts in the ammonia molecules. But at the frosty 10 to 20 degrees above absolute zero that prevails in the clouds, the deuterium atoms prefer to settle into the ammonia molecules and stay there.

The study furthers our understanding of the chemistry of the cold, dense interstellar medium and the way that molecules transfer from dust grains to the gas phase, Phillips explains. The researchers think the triply deuterated ammonia was returned to the gas state, and thus rendered observable, when it was kicked off dust grains by energy from a young star forming nearby.

The Caltech Submillimeter Observatory, funded by the National Science Foundation, has the world's most sensitive submillimeter detectors, making it ideal for seeking out the diffused gases and molecules crucial to understanding star formation. The observing team also included members from France's Observatoire de Paris and the Max-Planck-Institut für Radio-astronomie in Germany. □—*RT*