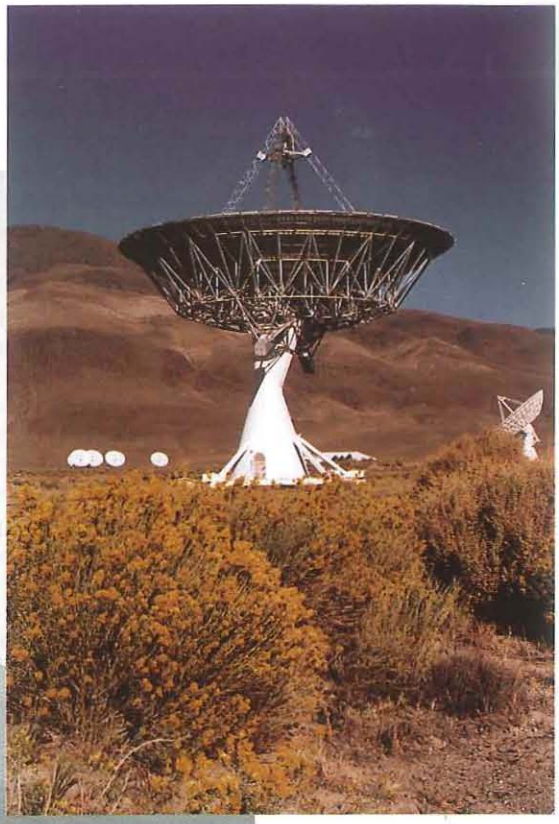
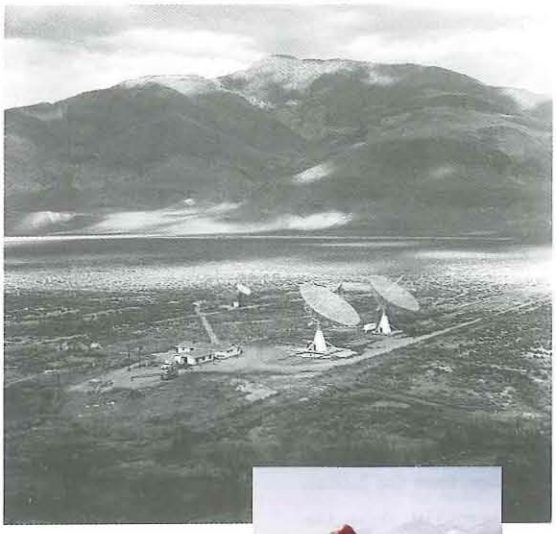


Left: One of the 90-foot dishes (foreground) is lined with reflecting steel mesh before being hoisted onto its pedestal in 1958. Above: In 1998 the same antenna has been joined by the 130-foot (right) and the millimeter-wave array (left).

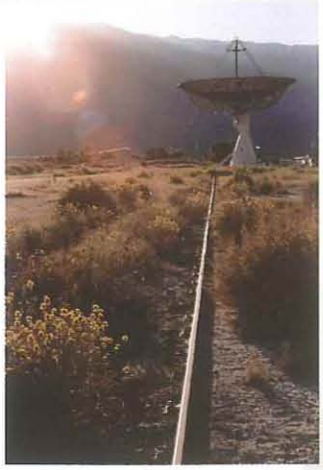
. . . and OVRO at 40

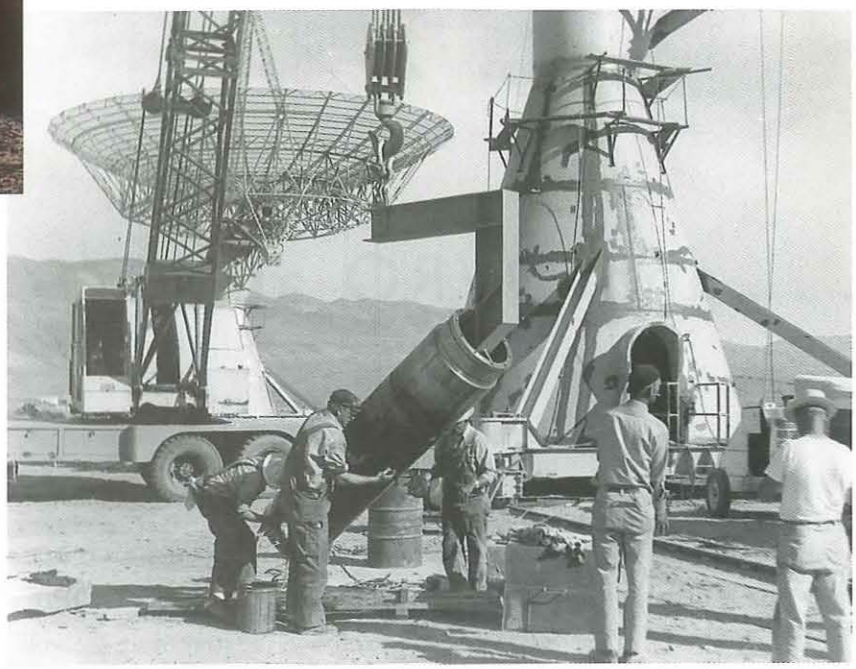


Right (top): Surveying the empty Owens Valley site; the cattle were gone but the telescopes had not yet appeared. Center: Both 90-foot dishes and the living quarters and shop (with the White Mountains in the background) can be seen here in 1959—after the dedication but before the north arm of the L-shaped track was begun. Bottom: OVRO's first director, Gordon Stanley, and current director, Professor of Astronomy Anneila Sargent, enjoy the desert air during a coffee break at the 40th birthday celebration.

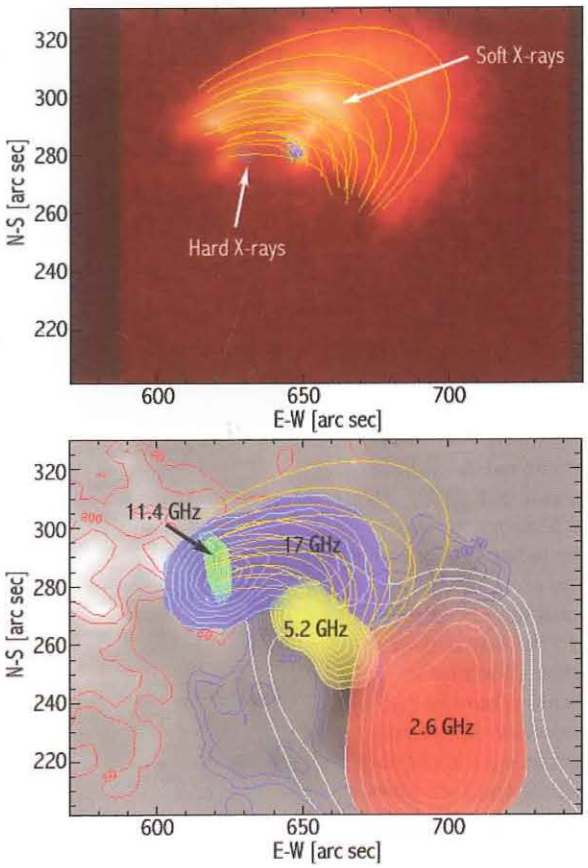
Farther down the spectrum, and a few hundred miles north of Palomar, the Owens Valley Radio Observatory marked its 40th anniversary with a day-long celebration October 3. There are actually three generations of telescopes at OVRO. The two 90-foot (27-meter) antennas were dedicated in 1958; the 130-foot (40-meter) dish was finished in 1968; and the array of six millimeter-wave antennas, each 34 feet (10.4 meters) in diameter, on a T-shaped track, was begun in 1977 and completed in 1995.

A couple of hundred guests gathered in a wind-whipped tent (no capacious dome here) to hear several sessions of talks on OVRO's history and current work. After greetings from President David Baltimore, relayed by Provost Steve Koonin, Gordon Stanley, who was the observatory's director from 1965 to 1975, spoke about the past. He described driving up past the (electronically noisy) Mojave desert, through Red Rock Canyon and into the Owens Valley in an almost unbearable combination of heat and dust, discovering the remote, and relatively noiseless, site in 1955: "By the time we arrived at Lone Pine, I was becoming excited. Here the magnificence of the Sierra Nevada reveals itself for the first time; the outside temperature was now a seemingly tolerable 115 degrees, and the lack of stations was noticeable on the car radio." Driving down a dirt road running east out of Big Pine, nestled up against the White Mountains, the Sierra Nevada rising up on the other side of the valley, he ended up in a remote piece of desert where the 130-foot antenna now stands. Providentially, the land belonged to the Los Angeles Department of Water and Power (but that's another story), and Stanley recalled how he stopped at their Independence office on his way back to Pasadena to start negotiating for a square mile of land. Stanley spoke about the early days at OVRO and about John Bolton, its founding director. He credited Bolton's vision for the





The 90-foot antennas were originally constructed to study the structure of radio galaxies in the distant reaches of the universe. Now they are being used to trace the sun's magnetic fields.

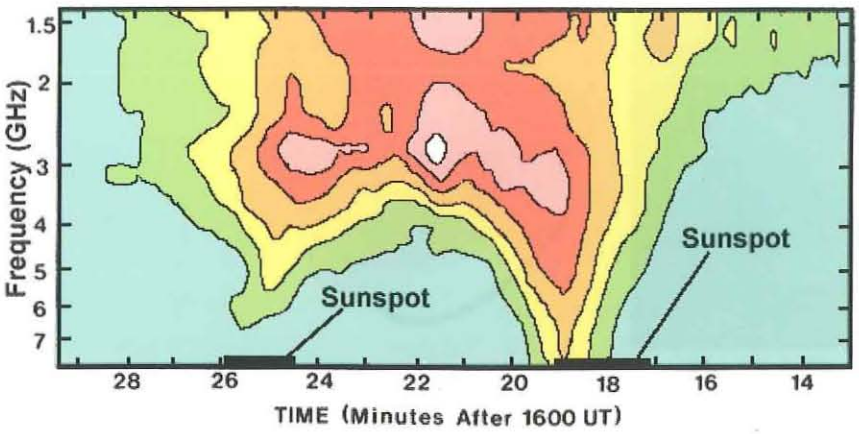


Solar flares, which erupt out of tangled magnetic fields, emit x-rays and radio waves from a layer of the sun's atmosphere called the corona. The top image, from the Yohkoh spacecraft, shows the flare's x-ray emissions, while the bottom panel plots OVRO observations at various radio frequencies, overlaid on magnetic field data for the sun's photosphere, or visible surface, a few thousand kilometers below.

observatory's later accomplishments, even though Bolton had returned to his native Australia in 1960, where he died in 1993. (His widow, Letty, traveled back for the anniversary celebration.) In conclusion, Stanley, who also calls Australia his home, quoted an Australian "bush" poet, A. B. Patterson:

> "And the bush had friends to meet him and
> their kindly voices greet him
> In the murmur of the breezes and the river
> on its bars,
> And he saw the vision splendid of the
> sunlight plains extended
> And at night the wondrous glory of the
> everlasting stars."

Anneila Sargent, OVRO's current director, thanked him and said she had been waiting for 30 years to hear that line quoted at a conference. Most of the observatory's other previous directors were also in attendance, including Robbie Vogt (acting director 1980–81), Tony Readhead (1981–1986), and Nick Scoville (1986-96). Many of the original graduate students who worked at OVRO (as well as later ones) also returned for the occasion, and several gave talks on the early work on the two 90-foot dishes, which, linked together as an interferometer, formed for a time the largest and most sensitive instrument of its kind in the world (*E&S*, Spring 1994). Its sensitivity enabled the extremely accurate measurement of the position of radio sources, making possible their identification with optical counterparts. Among the



Dale Gary, visiting associate in astrophysics, has been using the 90-foot antennas to study sunspots, which are also associated with strong electromagnetic activity. This is a cross-sectional view of a magnetic loop derived from OVRO solar data, showing how its radio emissions stretch from one sunspot to the other. Although the vertical dimension here is frequency, it can be thought of as height, lower frequencies correlating with higher heights.

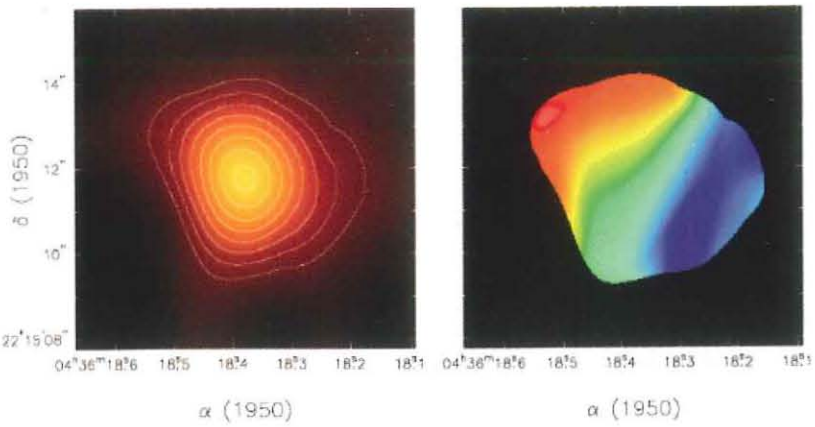
former grad students who spoke was Bob Wilson, PhD '62, known in his OVRO days as the Galaxy Man. Later, while at Bell Labs, Wilson co-discovered the cosmic background radiation, for which he shared the Nobel Prize in 1978.

In later years, the two oldest antennas might have gone begging for something to do, according to Sargent, but with new receivers and signal processing equipment, Professor of Astrophysics, Emeritus, Hal Zirin cleverly adapted them to solar astronomy. In their current incarnation as part of a five-element array, they use the microwave spectrum to study the structure and activity of the solar atmosphere, in particular the corona's magnetic fields.

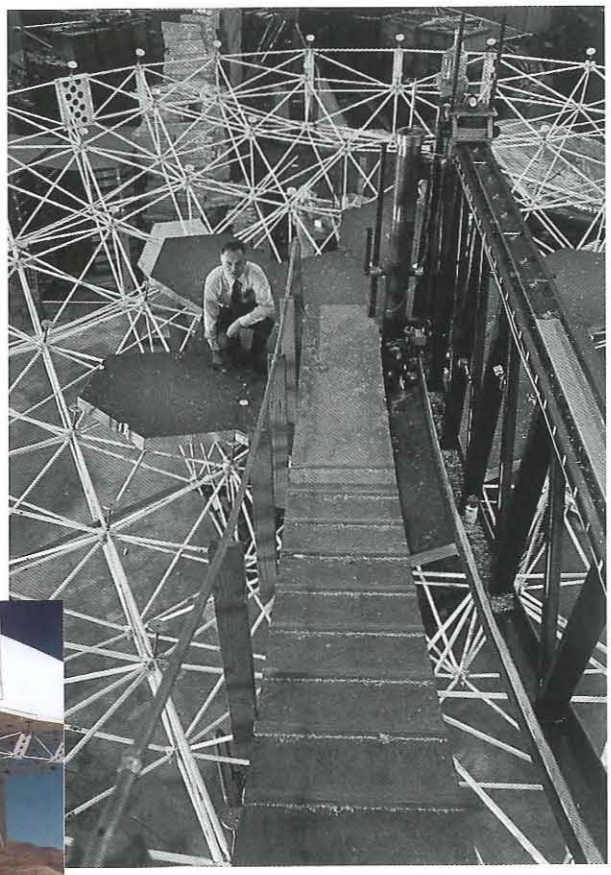
Besides the anniversary of the two original dishes, 1998 was also the 30th birthday of the 130-ft. antenna, an occasion that was pointed out by Marshall Cohen, professor of astronomy, emeritus, who had come up with the idea of the anniversary celebration. This huge antenna was built as a prototype for what was to be an array of eight large dishes, which never came to pass, having been beaten out by the Very Large Array in New Mexico. (The VLA starred with Jodie Foster in the 1997 film *Contact;* OVRO's 130-ft. dish had its own 15 minutes of fame in *The Arrival* in 1996.) The 130-ft. has served as one station in Very Long Baseline Interferometry (VLBI), an array of antennas worldwide. It was always one of the most important, said Cohen; since it was large and on the West Coast, it was used in the longest baselines, which have the weakest signals. Astronomers use VLBI to study the structure of distant quasars and radio galaxies.

Starting in 1978, the 130-ft. antenna also carried out observations of the microwave background radiation, which has led to what Professor of Astronomy Tony Readhead described as a child of OVRO. That's the Cosmic Background Imager (see *E&S,* No. 4, 1996). On a mountaintop in Chile, far from its parent, the CBI will look for

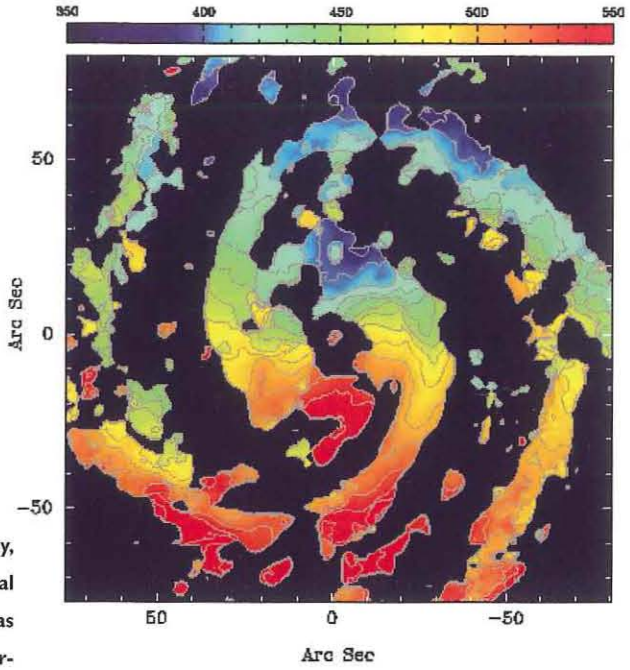
Caltech President Lee DuBridge dedicates the 130-foot antenna in October 1968 (above), and visitors get a rare opportunity to clamber around it in 1998 (left).



Professor of Astronomy Anneila Sargent and her group have been employing the millimeter array to search for other solar systems—observing stars that resemble the young sun (T Tauri stars) with surrounding disks of dust and gas out of which planetesimals, and eventually planets, might form. The image above is of a star named LkCa 15, about 500 light years away, which has a very promising protoplanetary disk. The image on the left shows contours of intensity, and the center picture represents motion—blue gas is approaching us and red gas is moving away. Comparison with computer simulations shows that LkCa 15 is surrounded by a disk about seven times the size of our solar system that contains enough material to make all the planets, and is rotating like the planets rotate around the sun.



Above: Bob Leighton works on the first dish of the millimeter array in 1974 at Caltech. His ingenious "Tinkertoy" design made it possible to take the telescope apart and reassemble it at Owens Valley. Left: In 1998 guests at the anniversary celebration tour one of Leighton's 10-meter dishes, which now number six (far left). The sixth dish, built with a gift from the Kenneth T. and Eileen L. Norris Foundation, was added in 1995.



The Whirlpool Galaxy, M51, a large nearby spiral galaxy, is shown at right as seen by the millimeter-wave interferometer's observations of the carbon monoxide (CO) molecule, which is used to trace the location of the dense molecular gas clouds that are the birthplaces of stars in galaxies and to study the association of these locations with the spiral structure. This image shows the gas's velocity (red for receding and blue for approaching), as derived from the doppler shift of the CO emission line. The overall rotation of M51's galactic disk can be seen, as well as the streaming motions associated with the spiral arms. The images on this page are the work of a team led by Nick Scoville, the Francis Moseley Professor of Astronomy.

fluctuations in the very early universe that might explain the lumpy structure that we see today, with clumps of galaxies spread unevenly about the cosmos.

The newcomers to Owens Valley are Bob Leighton's 10.4-meter millimeter-wave antennas, a marvel of creative engineering. Leighton, the Valentine Professor of Physics, emeritus, who died in 1997 (his widow, Marge, attended the anniversary party), built the dishes out of panels machined to a particular figure and held up by a system of 1,400 struts tapped together with dowel pins—"the world's best Tinkertoy set," according to David Woody, OVRO's assistant director for site development. First constructed at Caltech (they were designed for potential assembly by astronauts in space), they were then reassembled at OVRO. The six dishes may be moved again, this time to Harkless Flats—at 9,000 feet in the Inyo Mountains, 5,000 feet above Owens Valley—for better imaging of the microwave radiation.

The millimeter-wave array is so sensitive that it can pick up signals 10 billion light years away. Among the closer subjects it is observing are the spiral structure of nearby galaxies, galactic nuclei, colliding galaxies, the interstellar clouds that supply the fuel for star formation, and the circumstellar disks around nearby stars that may be incubating planetary systems like our own.

In closing the talk sessions, Sargent announced that two graduate fellowships in radio astronomy, named for John Bolton and Bob Leighton, had been established, thanks to a gift from Gordon Moore, chair of Caltech's Board of Trustees.

The telescopes were open for tours, or just scrambling around on your own, following the talks, and the anniversary celebration concluded with OVRO's annual party, featuring live music and dancing and an almost-full moon. □

Carbon monoxide imaging of the extremely luminous galaxy Arp 220 was carried out in the new ultra-high resolution configuration of the OVRO millimeter array. These new observations uncovered the presence of two counter-rotating disks of gas, believed to be the remnants of two merging galaxies in Arp 220's nucleus. The upper plots show a color-coded intensity map and the gas motions. The bottom diagram illustrates a theoretical model based on the observations.