by Whitney Clavin

Radio Astronomy in the High Desert

Since 1958, astronomers have unveiled some of the deepest mysteries of the universe with the help of Caltech's Owens Valley Radio Observatory (OVRO), located in high-desert terrain east of California's Sierra Nevada mountains. The observatory, which remains at the forefront of radio astronomy, has seen many different projects come and go, including CARMA (Combined Array for Research in Millimeter-wave Astronomy), a hugely successful set of radio telescopes that ceased operations in 2015. Now, several of those dishes are being repurposed at OVRO, and two other projects, the Deep Synoptic Array and the Long Wavelength Array (LWA), are in the midst of massive expansion efforts. "OVRO is experiencing a renaissance. We are moving radio astronomy in an entirely new direction," says Gregg Hallinan, Caltech professor of astronomy and director of OVRO. "By building large numbers of small telescopes, we can scan the skies faster than ever before. These arrays will be generating more than 40 terabytes of science data per day, making them among the most data-intensive telescopes in the world."

The OVRO-LWA project was enabled by a donation from Deborah Castleman (MS '86) and Harold Rosen (MS '48, PhD '51).

The Long Wavelength Array of telescopes at Owens Valley. Inset photos: Marin Anderson (MS '14, PhD '19) and Michael Eastwood assemble antennas for the LWA.

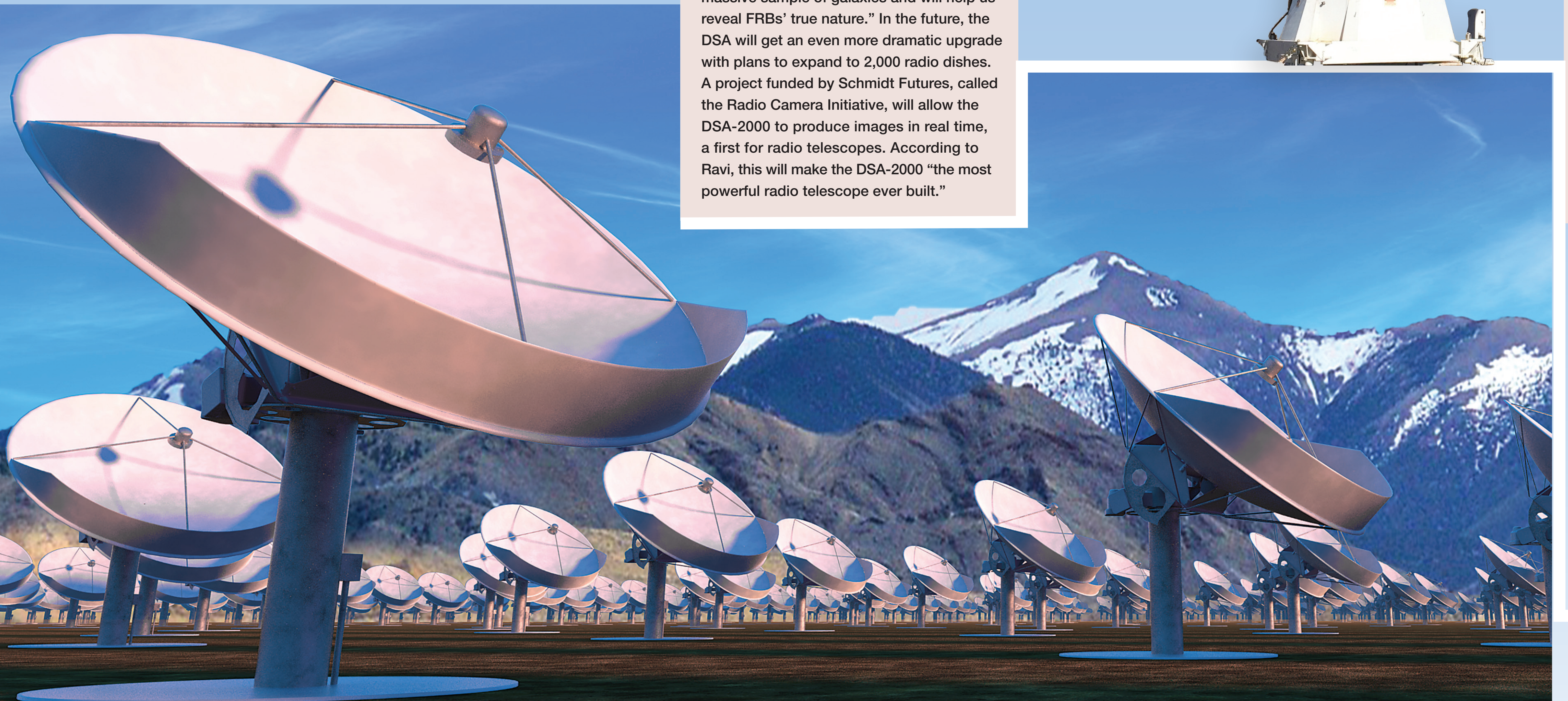
In Search of Magnetospheres

The Long Wavelength Array (LWA) consists of hundreds of pyramid-shaped radio antennas that dot a vast stretch of OVRO. Since 2015, the LWA has used 250 antennas to probe the flickering of radio signals in the night skies, studying everything from the dawn of the universe, to outbursts on our sun, to glowing exoplanets. Now, the National Science Foundation (NSF) is funding an expansion of the project, bringing the total fleet of antennas to 352. Hallinan is particularly excited for the project to search for signatures of magnetospheres around planets orbiting other stars. Magnetospheres are the regions around planets dominated by magnetic fields; Earth's magnetic field protects its atmosphere from erosion by solar wind. The presence of magnetospheres on exoplanets may be a critical ingredient for planetary habitability but have eluded detection to date. "With the LWA, we will scan the entire sky every 10 seconds to monitor thousands of exoplanets simultaneously, waiting for a planet's magnetosphere to light up in radio waves," says Hallinan.

Staring at the Whole Sky

OVRO hosts several small, focused experiments that target high-risk, high-reward science. A notable example is STARE2 (Survey for Transient Astronomical Radio Emission 2), led by Shri Kulkarni, the George Ellery Hale Professor of Astronomy and Planetary Science at Caltech. The project consists of three radio receivers located at OVRO; at NASA's Deep Space Network facility in Goldstone, California; and at Delta, Utah. The receivers scan broad swaths of the sky every night in search of the brightest fast radio bursts (FRBs). While the receivers are not as sensitive as radio dishes, what they lose in sensitivity, they gain in field of view. In April of this year, STARE2 detected what may be the first-ever FRBs seen in the Milky Way galaxy. The results are preliminary but may provide long-sought proof that FRBs are caused by erupting magnetars, a type of exotic star with powerful magnetic fields.

Below: Artist's rendering of the Deep Synoptic Array-2000. Middle right: A Leighton radio dish. Lower right: Wendy Chen, Nitika Yadlapalli, and Corey Posner assemble a DSA dish.



Many, Many Dishes

The night skies flash with intense radio pulses, called fast radio bursts (FRBs), whose causes have remained unclear. One key to unlocking the mystery of these bursts is to identify the galaxies from which they originate. In 2019, the Deep Synoptic Array-10 (DSA-10) at OVRO identified one such host galaxy of an FRB, a rare feat made even more difficult by the fact that this particular FRB did not repeat, as others have been known to do. Now, thanks to new funding from the National Science Foundation (NSF), the DSA is in the midst of a major upgrade, expanding from 10 to 110 radio dishes. The DSA-110 is expected to begin observations in October of this year. "When we begin, we will be identifying about two FRB host galaxies per week," says Vikram Ravi, assistant professor of astronomy. "That's a massive sample of galaxies and will help us reveal FRBs' true nature." In the future, the DSA will get an even more dramatic upgrade with plans to expand to 2,000 radio dishes. A project funded by Schmidt Futures, called the Radio Camera Initiative, will allow the DSA-2000 to produce images in real time, a first for radio telescopes. According to Ravi, this will make the DSA-2000 "the most powerful radio telescope ever built."

A New Purpose

CARMA, which operated from 2005 to 2015, was one of the most powerful millimeter-wave telescope arrays in the world. (Millimeter waves are considered a type of radio wave.) Located in the Inyo Mountains near Owens Valley, the array consisted of antennas brought together from telescopes across the U.S. to create a combined array of much greater sensitivity. These antennas included the Leighton dishes, named for the late Caltech professor Robert Leighton (BS '41, MS '44, PhD '47), who designed them in the 1970s to kick-start millimeter astronomy at OVRO. After the closure of CARMA, the Leighton dishes were moved back to OVRO. COMAP, which stands for CO Mapping Array Pathfinder, is one of the projects that is repurposing a Leighton dish. Begun in the summer of 2018, this project, led by OVRO associate director Kieran Cleary and professor emeritus Tony Readhead, traces the evolution of galaxies by mapping carbon monoxide (CO), a marker of faint faraway galaxies that are otherwise hard to see. A few of the Leighton dishes are also being combined to form a robotic instrument, known as SPRITE, to determine the nature of some of the most energetic explosions in the universe.

Another project for which a Leighton dish is being redeployed is the Event Horizon Telescope (EHT), which, in 2019, famously harnessed the power of several radio observatories across the globe to create the first-ever picture of a black hole. Now, with the help of new funding from the NSF, the EHT project is tapping into even more radio telescopes to better image and study black holes. "Adding a telescope dish at Owens Valley fills a critical hole in the EHT's virtual Earth-sized telescope," says Katherine L. (Katie) Bouman, an assistant professor of computing and mathematical sciences and electrical engineering who leads the Caltech portion of the international EHT team. "This brings us much closer to one day capturing a movie that allows us to track the gas falling into a black hole over the course of a single night." [C]