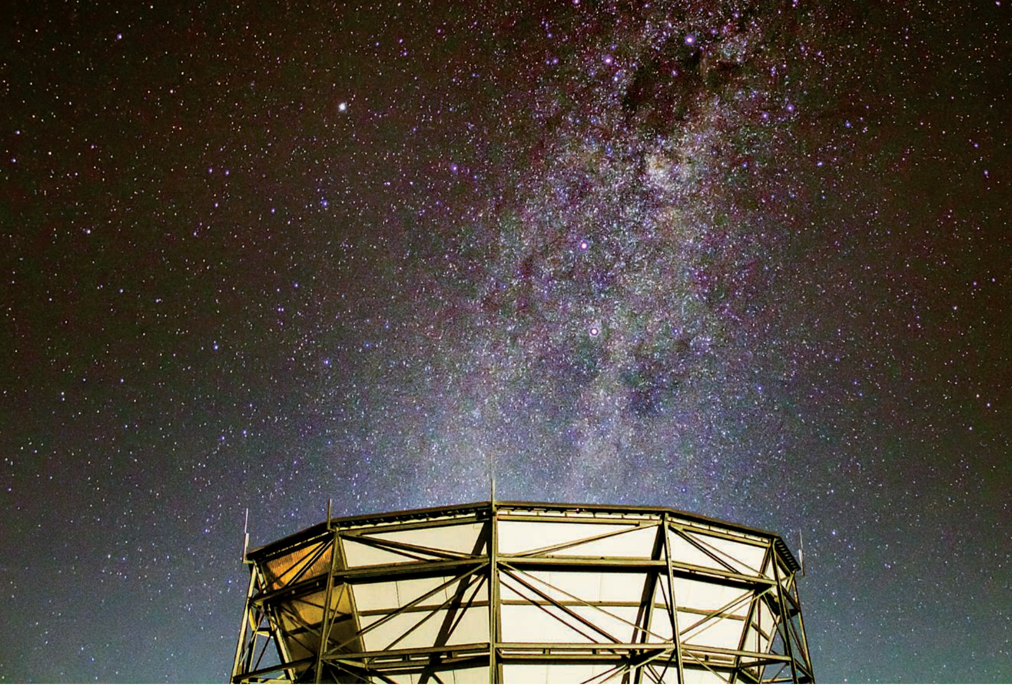

The Atacama Cosmology Telescope in Chile is searching for patterns in polarized microwaves.

COSMOLOGY

Microwave background teams mull a grand unification

United effort would aid search for signs of cosmic inflation

By **Adrian Cho**

The half-dozen groups and hundreds of scientists studying the afterglow of the big bang—the cosmic microwave background (CMB)—are planning to join forces. By consolidating their efforts in a single experiment that would be running by the middle of the next decade, they hope to reach an elusive goal: detecting direct evidence that in the moment after the big bang, the universe expanded exponentially in a mind-bending growth spurt called cosmic inflation.

"This is the industrialization of the CMB," says Jamie Bock, a cosmologist at the California Institute of Technology in Pasadena, and co-spokesperson for the Keck Array, a battery of CMB telescopes at the South Pole.

Next month, a concept definition team, convened by the National Science Foundation (NSF) and the Department of Energy (DOE), will lay out the science goals and technological requirements for the project, called CMB stage 4 (S4). The team will also sketch out a "strawman" design for the hardware. Researchers envision a variety of small and large telescopes at the South Pole, in Chile's Atacama Desert, and possibly elsewhere, says Charles Lawrence, a cosmologist at NASA's Jet Propulsion Laboratory in Pasadena and chairperson of the team.

Discovered in 1965, the CMB is light from the big bang stretched or "red shifted" to microwave wavelengths by the expansion of the universe. It is rich with clues to the birth and makeup of the cosmos. By studying tiny variations in the CMB's temperature across the sky, cosmologists have deduced that only 5% of the universe consists of ordinary matter, with two unseen ingredients, dark matter and dark energy, constituting the rest (*Science*, 29 March 2013, p. 1513).

For more than a decade, scientists have searched for another gem: a clear signature of inflation, a scenario that is widely accepted but far from proven. The flash of exponential growth should have produced ripples in space itself called gravitational waves, which would have left tell-tale spiral patterns in the polarization of CMB microwaves called primordial B modes.

In 2014, the team working with the Background Imaging of Cosmic Extragalactic Polarization telescope (BICEP2), a 26-centimeter telescope at the South Pole, claimed to have discovered such spirals in a small patch of sky (*Science*, 21 March 2014, p. 1296). However, microwave radiation from dust within our galaxy can generate its own B mode swirls. Within months, researchers had shown that some, or possibly all, of the BICEP2 signal came from dust (*Science*, 26 September 2014, p. 1547).

Several groups are still racing to detect B modes with telescopes now deployed or in the works. But observations increasingly suggest that the B mode signal may be faint and tough to tease out, and scientists think that they need many more microwave detectors to see it. Current "stage 3" telescopes typically use a few thousand pixellike detectors on their focal planes. S4 telescopes would deploy 10 to 20 times more detectors than those on all of the stage 3 telescopes, perhaps 250,000 in total.

They would be spread out among a suite of telescopes of different sizes. Primordial B modes show up most prominently at angular scales larger than about a degree—more than twice the moon's diameter—and to target such broad features researchers typically employ smaller telescopes with larger fields of view. To discriminate primordial B modes from the effects of galactic dust they also employ multiple scopes working at different frequencies. But scientists will likely also have to weed out another confounding B mode signal induced by the gravity of dark matter lying in front of the CMB. And that work will require larger telescopes with finer angular resolution, says Cora Dvorkin, a theoretical cosmologist at Harvard University.

Unification would radically alter the build-it-yourself culture of CMB experiments. "If you look at the progress, it's been stunningly good with different groups trying different things," says Charles Bennett, a cosmologist at Johns Hopkins University in Baltimore, Maryland, and co-spokesperson for the Cosmology Large Angular Scale Surveyor, an array of four 60-centimeter telescopes under construction in the Atacama. Still, Dvorkin says, "I don't know anyone who is saying explicitly, 'I'm not going to be a part of this.'"

NSF and DOE are discussing how to collaborate on the project. The idea gained steam in 2014, when U.S. particle physicists endorsed it in their latest long-range plan for DOE. "They keep calling up and saying, 'Fund S4!'" says Kathy Turner, project manager for the cosmic frontier in DOE's office of high energy physics in Washington, D.C. But first, S4 will have to receive the blessing of U.S. astronomers in their next decadal survey, which will set priorities for the 2020s, says Richard Barvainis, program director in NSF's division of astronomical sciences in Alexandria, Virginia.

DOE and NSF officials say it's too soon to discuss S4's cost, although the particle physicists' long-range plan listed it among mid-sized projects costing between \$50 million and \$200 million. "It better not be a billion," says Jim Siegrist, DOE's associate director for high energy physics in Washington, D.C., "or we won't be talking very long." ■

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