

By **Katrina Miller**

Photographs by Marcos Zegers

Katrina Miller and Marcos Zegers visited the Vera C. Rubin Observatory atop Cerro Pachón in Chile in May.

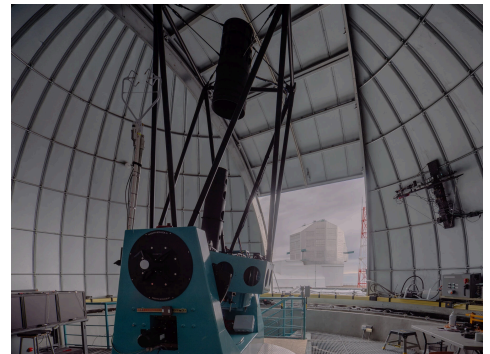
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To reach the top of Cerro Pachón, a mountain at the edge of the Atacama Desert in Chile, astronomers take a drive of two hours up a winding, bumpy road. The lush greenery at the mountain's base slowly gives way to the browns and yellows of the desert. Eventually, telescopes rise in the distance, the sun glinting off their metal domes.

The newest eye on the cosmos is the Vera C. Rubin Observatory, which houses the [largest digital camera ever built](#). For the next 10 years, the telescope will take advantage of its station under Chilean skies, some of the darkest on Earth, to conduct an astronomical survey more ambitious than any scientific instrument that came before it.

From that survey, astronomers hope to learn about the birth of our Milky Way galaxy, the mysterious matter comprising much of the cosmos, and how the universe evolved into its current arrangement. Perhaps they will even uncover clues about its fate.

They will also use the telescope to home in on millions of transient objects, “faint things that go bang, explode or move in the night,” said Tony Tyson, an astrophysicist at the University of California, Davis. That includes gorging black holes and collisions of dense, dead stars.



The Rubin Observatory; a camera integration area; the view through the Rubin Auxiliary Telescope of the Vera C. Rubin Observatory.

But the most valuable discoveries, astronomers say, lie beyond the reaches of their imagination.

“The universe always throws us surprises,” said Michael Strauss, an astrophysicist at Princeton University. With Rubin, he said, “we don’t yet know what those surprises will be.”

For all that humanity has learned about the universe, the vast majority of this cosmic plane in which we exist remains in the dark. The best theory yet describes a universe in which the galaxies, the stars, the planets and all of us make up only 5 percent of all the matter and energy there is. The other 95 percent is dark matter, an invisible substance that glues everything together, and dark energy, an unknown force ripping the universe apart.

[Vera C. Rubin](#), the astronomer whom the Rubin Observatory is named after, uncovered evidence of dark matter in the 1970s. By studying the swirling motion of galaxies, driven by the gravity of the mass within them, she deduced the existence of a type of matter that could not be directly observed by telescopes, because it did not emit, reflect or absorb any light.

In the decades since, theoretical physicists have come up with countless ideas about the composition of this so-called dark matter. Experimental physicists have built [ever larger detectors](#) in an attempt to observe it directly, [so far to no avail](#). All the while, astronomers have helped narrow the possibilities of its nature by relying on increasingly powerful telescopes that measure how dark matter influences the structure and motion of the universe that can be seen.



The astronomer Vera Rubin at the Lowell Observatory in Flagstaff, Ariz., in 1965. via Carnegie Institution of Washington

[Dark energy](#) was a newer discovery. In the 1990s, two independent groups of astronomers attempted to measure the rate at which the universe was expanding outward. Both groups found, however, that instead of slowing down as expected, the universe's expansion was speeding up.

The term dark energy was coined to describe the underlying force driving this accelerating expansion. But what it actually is, and the physics behind how it works, remain a mystery.

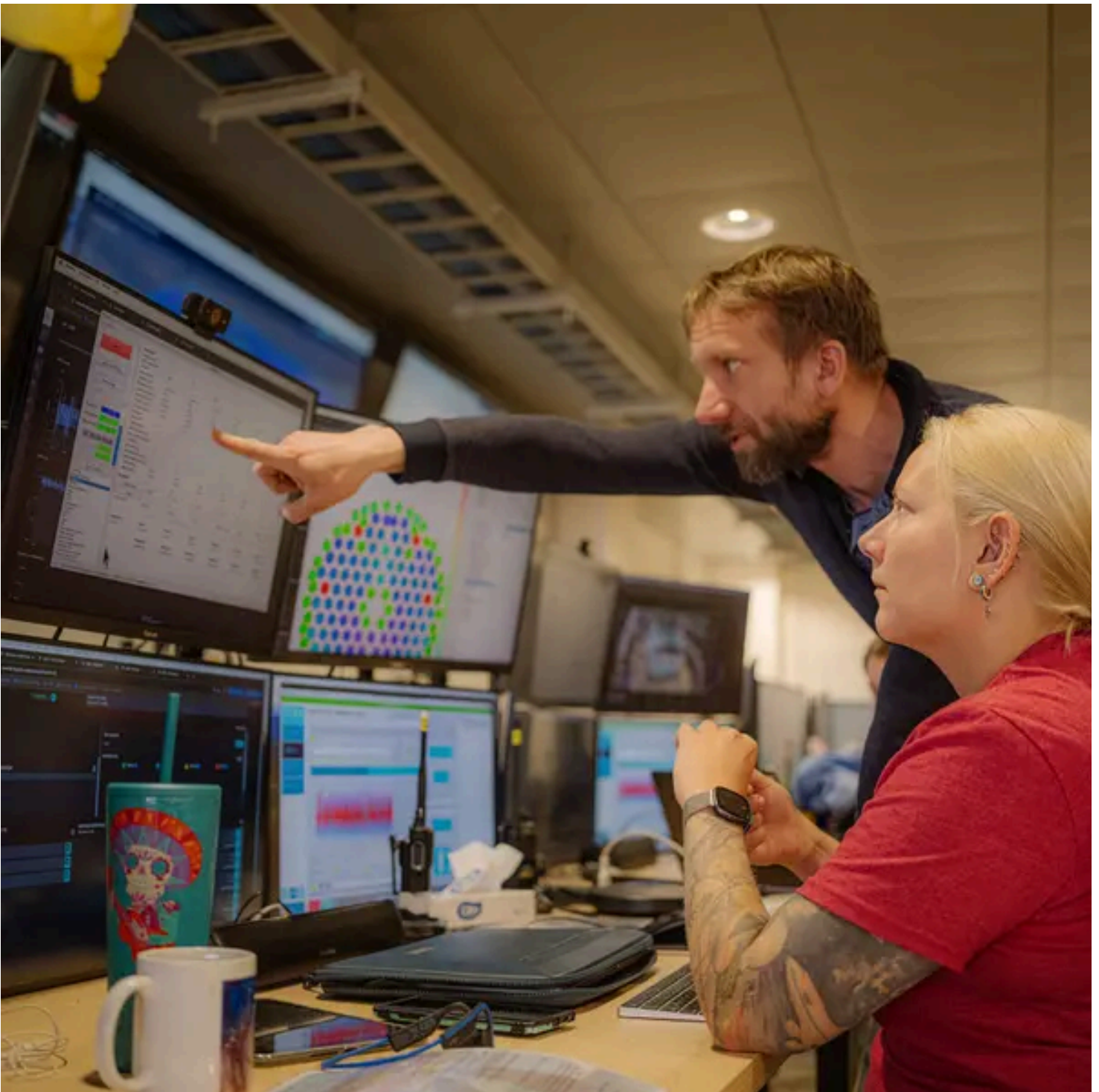
For decades, astronomers have scanned the night sky to measure the effects of dark matter and dark energy on what they observe in the cosmos.

It was during one such night of observing in 1996 when the idea for the Rubin Observatory was born.

Dr. Tyson was helping astronomers visiting the Blanco 4-meter Telescope in Chile to record the brightness of supernovas exploding at different distances from Earth. These measurements helped compute the expansion rate of the universe, which led to a [Nobel Prize for the discovery of dark energy in 2011](#).

At the time of the observations, Dr. Tyson recalled thinking, “We can do a whole lot better than this.” He had a bigger telescope, more sky coverage and a larger camera in mind.

“It all seemed possible,” he said.



Alysha Shugart, nighttime operations manager at the observatory, with Petr Kubanek, an engineer at the observatory, reviewing a checklist of evening duties.

Astronomers seized upon this idea, and in 2009, they published [a nearly 600-page document](#) describing all of the science that could be accomplished with what was then referred to as the Large Synoptic Survey Telescope. Proposals ranged from studying the tiniest galaxies to tracing the largest structures of the cosmos.

Construction of the observatory began six years later. U.S. government agencies announced that the instrument [would be renamed for Dr. Rubin](#) in 2020.

Astronomers generally have a choice when they build a big telescope. They can seek views that are wide, capturing broad swaths of the night sky, like the Apache Point Observatory in New Mexico and its Sloan Digital Sky Survey. Or they can go deep, allowing for observations of the faintest, most distant objects in the universe, like NASA's James Webb Space Telescope in orbit.

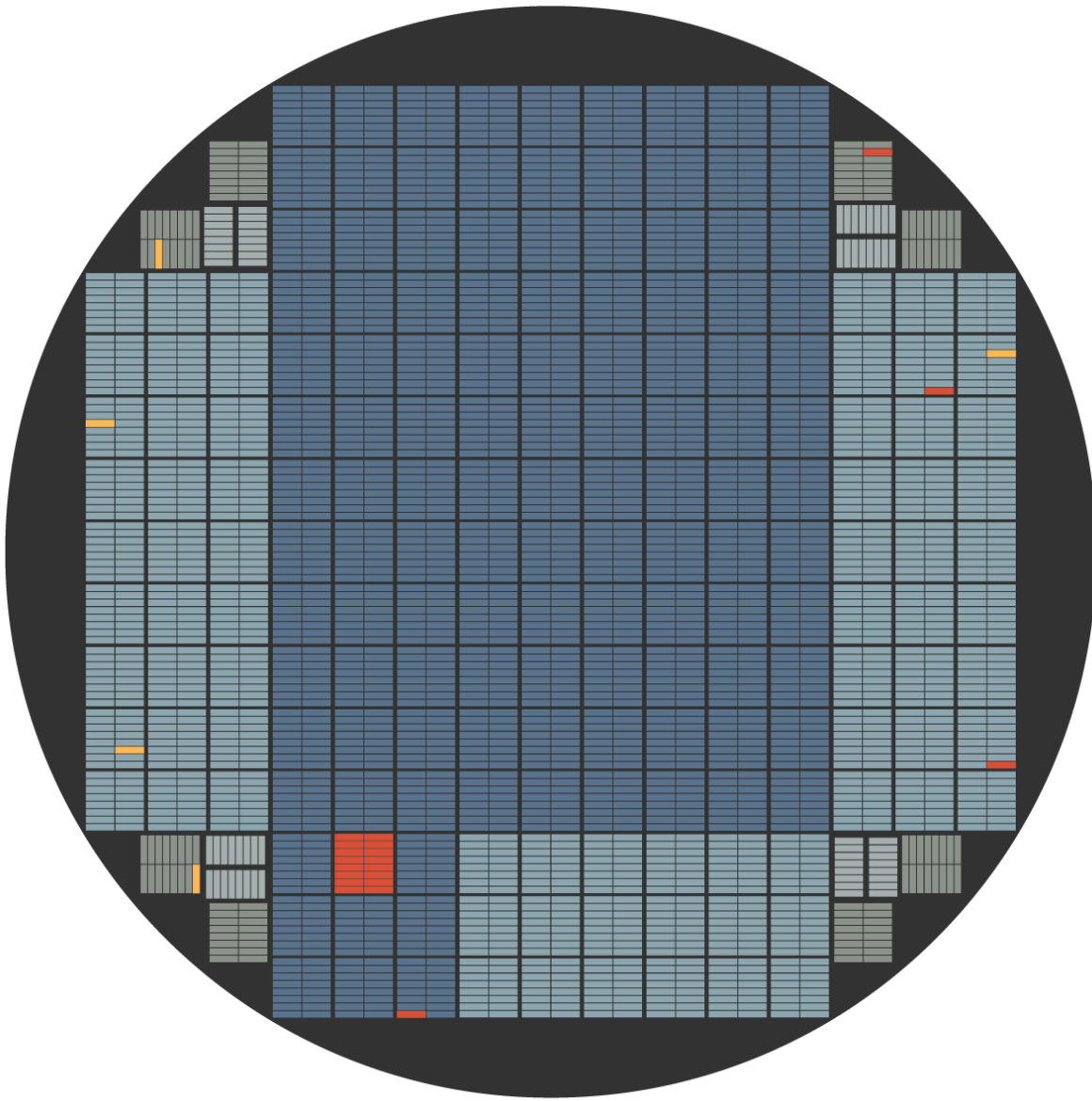
But no telescope so far had accomplished both, and that means phenomena that might have been observed are missed by existing telescopes. "We wanted to do it all," Dr. Tyson said.

Rubin will chart the depths of the entire southern sky every three nights for the next 10 years, resulting in a crisp motion picture of the ever-changing cosmos above.

"There have been a whole lot of surveys, but they don't go wide, fast and deep all at the same time," Dr. Tyson said. Rubin is the start of a new astronomical era, he added, "something that's never been done before."

Rubin's 3.2 Gigapixel Camera

At the heart of the Rubin observatory is the largest digital camera in the world, a supercooled grid with hundreds of high-resolution sensors. [See how the camera works.](#)



By The New York Times

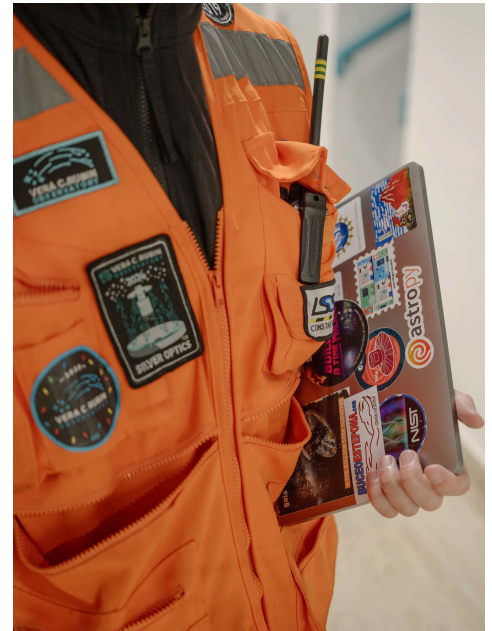
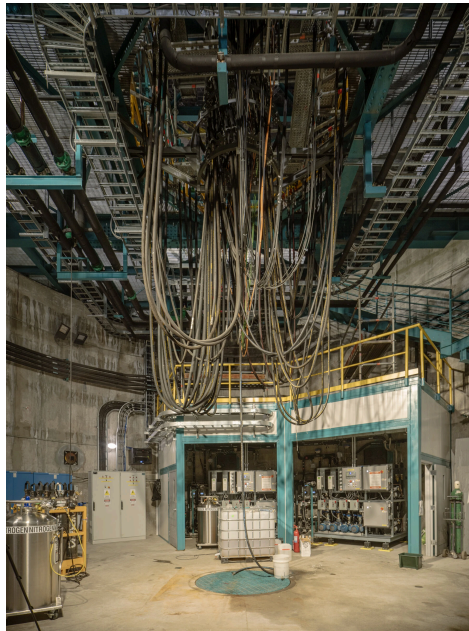
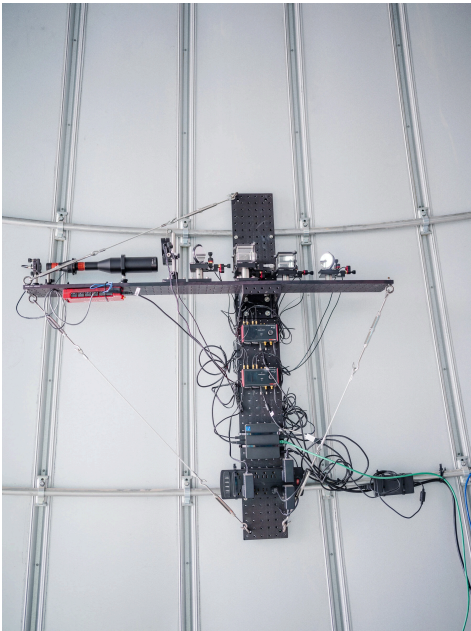
The Rubin Observatory, now fully constructed and in working condition, sits at the cusp of its astronomical potential. It captured its first photon in April, and sparkling images showcasing its perspective of the universe are anticipated on Monday. Though the commissioning team is still addressing operational hiccups, the telescope is expected to begin its scientific survey later this year.

Every 30 seconds, the observatory will point to a different part of the sky, capturing an area greater than 40 full moons. The end result will be a catalog of 20 billion galaxies and 20 billion stars in six different colors, stretched across not only the wide expanse of space, but also of time.

The directions astronomers can go with its survey are endless.

Some are eager to study bright transient objects, like supernova explosions and gamma-ray bursts, which signify the births of black holes. Others are curious about new types of transients that Rubin is expected to uncover while peering into the faintest corners of the universe, some of which have never been seen before.

“I guarantee you, we’ll find something there,” Dr. Tyson said.



Weather equipment in the auxiliary dome; cables on Level 5; a bedazzled laptop.

Rubin will also help astronomers identify long streams of stars, pulled from smaller galaxies that once merged with our Milky Way. These relics from ancient collisions reveal the history of how our home galaxy formed. Gaps and kinks in these stellar streams, resulting from gravitational interactions with dark matter, may also elucidate how the invisible substance behaves on smaller scales.

Rubin will shed light on the evolution of other galaxies, too, as well as their uneven distribution across the universe. Galaxies organize along filaments in a structure known as the cosmic web, believed to be shaped by an invisible scaffolding of dark matter.

Astronomers also will observe many more examples of an effect known as gravitational lensing, by which dark matter warps the light emitted from galaxies behind it. Such observations will hone their understanding of how dark matter

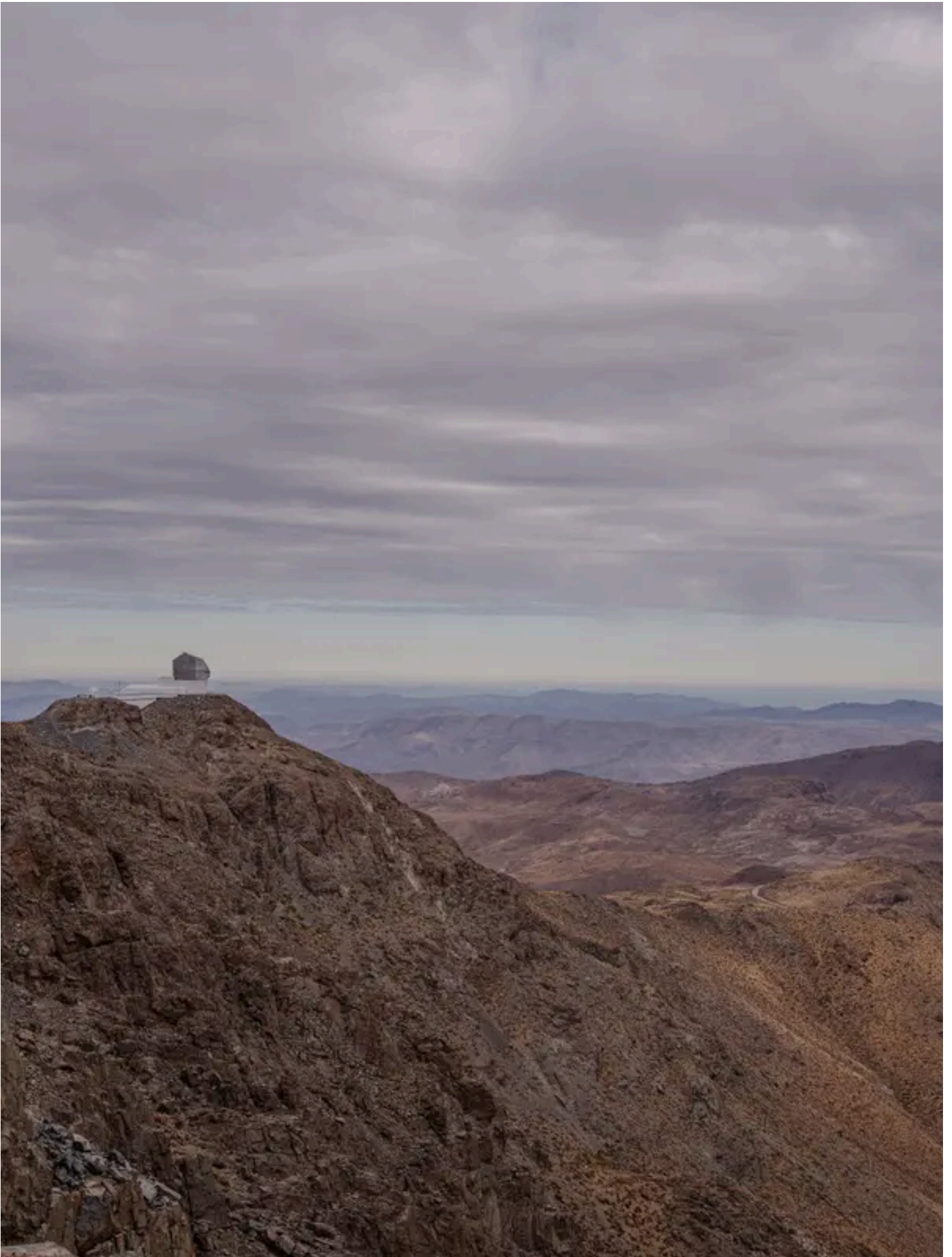
may influence the ordinary matter it surrounds, and how its presence has evolved across cosmic time. Those findings can, in turn, be used to measure the expansion of the universe and probe the behavior of dark energy.

“We are eager to see what Rubin will uncover,” said Michael Levi, the director of the collaboration running the [Dark Energy Spectroscopic Instrument](#).

The treasure trove of data compiled by Rubin will complement an [ongoing survey of the dark universe by Europe’s Euclid space telescope](#), as well as NASA’s Nancy Grace Roman Space Telescope, scheduled to launch in 2027.

And though Rubin is an American-funded initiative, astronomers say that people around the world will benefit from what the observatory will find.

“We are doing this for all of humanity,” said Hiranya Peiris, an astrophysicist at the University of Cambridge. “It is how we understand our place in the universe.”



Katrina Miller is a science reporter for The Times based in Chicago. She earned a Ph.D. in physics from the University of Chicago.