

HOUSE OF THE SUN

How astronomers built the world's largest solar telescope on Maui even as protesters derailed a larger telescope one island away

By **Ilina Loomis**

Jeff Kuhn remembers his first trip to Haleakalā, the summit of the Hawaiian island of Maui. It was 1996, and Kuhn, a solar physicist, was being courted by the University of Hawaii's Institute for Astronomy (IfA) in Honolulu. The recruitment tour included a visit to the handful of IfA telescopes atop Haleakalā, which stands more than 3 kilometers high. Kuhn climbed through switchbacks for nearly an hour in a dreary drizzle. Then the mist suddenly parted. Kuhn looked down and realized he was above the clouds. "It's like a giant door opened up in the sky," he says. "I looked up, and saw this incredibly dark blue sky, and the sun."

Kuhn had a good feeling about this place, but he wanted to test his hunch. Getting out of the car, he held his thumb up to the sky, covering the blinding, brilliant disk of the sun. In most places, this test reveals a halo—a sign that dust particles in the atmosphere are scattering light. Dust makes it hard to see faint things next to bright things, like the corona, the wispy outer atmosphere of the sun that appears during eclipses. But on Haleakalā, Kuhn saw no halo—only a deep, dark blue. It was the perfect place, he decided, to build the largest solar telescope in the world.

Haleakalā is also a special place for Tiare Lawrence, a community organizer on Maui who has visited the summit since childhood. Native Hawaiian culture celebrates a profound spiritual connection with the land,

and few places are considered more sacred than high mountain peaks. In ancient times they were regarded as *wao akua*—"realm of the gods"—where deities and demigods walked the earth. Today, they are still treated with reverence, places many Hawaiians visit to honor ancestors and practice spiritual traditions. These days, when seeking spiritual guidance, Lawrence drives up to the summit, often visiting one of two *ahu*, or stone altars. "Haleakalā has always been that place I go to cleanse, to think, to give *pule* [prayer], to find answers," she says. But now the white dome of a towering new telescope enclosure, nearly 14 stories tall, looms over the shrine.

For Lawrence, who participated in protests against its construction, the telescope feels like a slap in the face. "It hurts," she

The Daniel K. Inouye Solar Telescope (left) stands in Science City, adjacent to Haleakalā National Park (right).

says. Other Hawaiians see an affront not just to their beliefs, but also to their sovereignty. “As a people, we don’t have control of some of our most sacred spaces,” says Kaleikoa Kaao, a Hawaiian-language educator at the University of Hawaii Maui College in Kahului, and a leader of the telescope opposition. “They say it’s Hawaiian culture versus science. I say, ‘No, it’s Hawaiian culture versus white supremacy.’”

Despite their complaints, the \$344 million Daniel K. Inouye Solar Telescope (DKIST) is nearly complete. The exterior dome was finished in August 2016. The telescope’s most important part—a 4-meter mirror—was cast in Germany, polished to a precise shape in Arizona, and shipped to Maui. This week, the road to the summit was set to be closed on the night of 1 August, so that the 3-ton mirror could be delivered at a slow crawl in a wide-load truck—with a police escort. In 2019, when the dome opens and the mirror is trained on the sun for the first time, the DKIST will be the largest and most powerful solar telescope in existence, capable of studying the sun’s surface, corona, and magnetic fields in unprecedented detail. “It’s gratifying to know that within my lifetime we actually will be using this telescope,” says Kuhn, who helped conceive the design in the 1990s and now serves as one of four lead investigators on the project.

Across the 48-kilometer Alenuihāhā Channel, the battle to build another major telescope project on a sacred peak has taken a very different turn. Two years ago, protests

led by Native Hawaiians blocked the start of construction of what was set to be one of the world’s largest optical telescopes, the Thirty Meter Telescope (TMT), atop the 4200-meter-high Mauna Kea on Hawaii Island. Court setbacks followed, although last week a former state judge recommended that the state grant a disputed permit. But the telescope faces months of further hearings, and even if it gets its permit, opponents have vowed to take the case back to court. TMT officials say that if they are not able to start construction by April 2018—and if the state is unable to manage safe construction access to the site—they will switch to an alternate site: La Palma, in Spain’s Canary Islands.

Why did these two seemingly similar projects have such different outcomes? From concept, to location, to politics, to public relations, many factors combined to smooth the DKIST’s way, whereas the TMT faced bigger challenges from the start, observers say. “There are a lot of similarities between the two projects, and also between the opponents of the projects,” says Günther Hasinger, director of IfA, which as host for both telescopes receives a portion of their viewing time. “But there was just a series of mishaps, or a confluence of more difficulties on Mauna Kea than on Haleakalā, that brought us to where we are now.”

IN THE HAWAIIAN LANGUAGE, Haleakalā means “house of the sun”—the place where the demigod Maui snared the sun to slow its passage across the sky. The traditional meanings

seemed almost too perfect to solar astronomers looking for a place to build a successor to the modest, 1.6-meter telescopes they had used for decades. Astronomers with the U.S. National Solar Observatory (NSO), headquartered in Boulder, Colorado, had whittled down a list of 50 proposed sites to six locations, where they tested the observing conditions. In 2005, NSO picked Haleakalā as the place with the lowest amount of dust and air turbulence—the atmospheric distortions that make stars twinkle—because it sits on top of a tall, cone-shaped volcanic mountain surrounded by a smooth, flat ocean.

It also had a tract of land already dedicated to astronomy. In 1961, Hawaii’s governor gave the University of Hawaii ownership of a 7-hectare parcel near the summit. Three years later, the university dedicated a first small solar telescope in what would soon become known as Science City. Today it is home to six academic telescopes (aside from the DKIST) and four space surveillance telescopes operated by the U.S. Air Force.

Still, the proposal to build a big new solar telescope went unfunded for years. It took the 2008 global economic crash to propel the DKIST forward. In 2010, the federal government’s economic stimulus package, which targeted “shovel ready” projects, delivered a large chunk of the funds needed to build the telescope. In 2013, the project, originally called the Advanced Technology Solar Telescope, was renamed for Hawaii’s longtime Senator Daniel K. Inouye.

Current solar telescopes can see things

on the surface of the sun 300 kilometers across—100 kilometers under special circumstances—but many of the details scientists want to study are smaller than that. “You need a microscope, and that’s what DKIST is,” says NSO Director Valentín Martínez Pillet. With a resolution of 25 kilometers, the DKIST ought to be able to make out a long-sought feature: magnetic flux tubes, twisted and tangled filaments that can channel energy into the corona. They may hold clues to a long-standing mystery: why the corona is a million degrees hotter than the photosphere, the visible surface.

But it’s not just the DKIST’s resolution that matters; the 4-meter mirror offers badly needed light-gathering power, too. “It surprises many nighttime astronomers that when we’re looking at the sun, we need sensitivity,” says DKIST Project Director Thomas Rimmele. Yet astronomers need to block the vast majority of the sun’s light

Hasinger says. “In relative size you could say it’s similar [to the DKIST], but in absolute size it’s much bigger.” Moreover, Mauna Kea is not only higher than Haleakalā, it’s the highest peak in the Pacific—and, consequently, it offers Native Hawaiians a higher-profile platform to air their grievances.

Mauna Kea also poses a bigger management challenge for the University of Hawaii. The science reserve on the Mauna Kea summit spans nearly 5000 hectares—an area more than 650 times larger than Maui’s compact Science City. “If someone is not happy with the management of Mauna Kea, it falls directly on the university,” Hasinger says. “On Haleakalā we only have the small area of Science City. The rest is managed by the national park.” And although the university owns Science City, its preserve on Mauna Kea is a lease, which means it is subject to state audits. In 1998 and 2005, the auditor released critical reports about IfA’s steward-

going as a guest to the TMT ceremony in October 2014. He stayed at a fancy Hawaii Island resort, surrounded by scientists and media from around the world, as big-screen TVs ran a live feed of the TMT’s construction site on Mauna Kea. But the celebratory atmosphere faded when Native Hawaiian protesters blocked a convoy of dignitaries heading up the mountain for a blessing and groundbreaking. As protesters shouted and chanted, organizers eventually turned off the live feed. “It was a disaster,” Kuhn says. “I understand why they wanted a great big party—it was a way of saying, ‘Yes, we’re moving forward, partners, come and join us, and bring your checkbooks.’ But I think it had the opposite effect, which was to put up a lightning rod that attracted lightning.” The event “marked real doubt” about the project’s future, he recalls.

TMT Executive Director Ed Stone, who is also a professor at the California Institute of Technology in Pasadena, concedes the event didn’t go as planned. “Certainly whatever groundbreaking there was could have been done better than what happened,” he says.

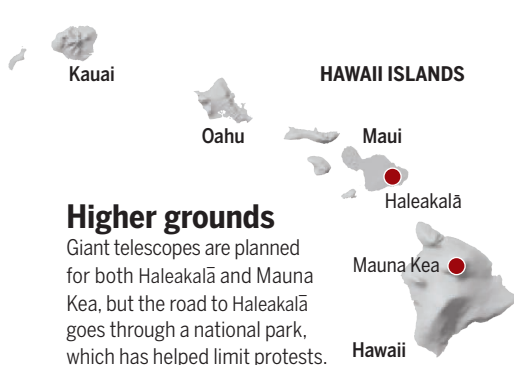
In contrast, the groundbreaking ceremony for the DKIST, in November 2012, was kept “very private,” with only a handful of people closely involved with the project, Kuhn says. “I think there was an honest sensitivity to those people who felt strongly that it shouldn’t be there,” he says.

“SECRET,” SNORTS KAE0, when asked about the private DKIST launch. Kaeo’s opposition to the telescope runs just as deep as his resentment of the TMT. But he says practical issues made it harder to disrupt construction of the solar telescope.

Mauna Kea, he notes, is wide open, sparsely populated, and minimally patrolled by authorities. “You can literally go up and touch the telescopes,” he says. Science City, on the other hand, can be reached only by traveling through a national park. The summit is swarming with tourists and park rangers, and the telescopes are in a tight cluster, safely ensconced at the end of a private road. And don’t forget the military presence. “When you go up there, you’re under surveillance,” Kaeo says. “Now you’re talking federal charges, federal crimes.”

He and Lawrence did their best to protest the DKIST anyway. By the summer of 2015, work on the telescope had been underway for more than 3 years, and opponents were largely inactive after almost a decade of court challenges that failed to stop the project. But images of Native Hawaiians being arrested on Mauna Kea inspired them to make one more stand.

In June 2015, protesters blocked the DKIST’s construction baseyard, a staging



Higher grounds

Giant telescopes are planned for both Haleakalā and Mauna Kea, but the road to Haleakalā goes through a national park, which has helped limit protests.



to see the faint corona, or to drill down into the sun’s atmosphere at specific wavelengths. “We’re struggling to get enough photons collected,” he says. The added collecting power also means that DKIST scientists don’t need long exposures: Their quick snapshots will capture the sun’s transient features, such as the reconnection of twisting magnetic fields that drives violent space weather events like solar flares and coronal mass ejections.

THE DKIST’S ABILITY TO INVESTIGATE the solar eruptions that can endanger electric grids and communications may be one reason why it received more public support than the TMT, which is solely a research tool, Hasinger says. But he believes a more important difference between the two projects is simply their scales. At 18 stories, the TMT would be not only the largest telescope on Mauna Kea, it would be the largest humanmade structure on Hawaii Island. The TMT’s footprint—2 hectares including its roads and parking lot—is 10 times the size of the plot used for the DKIST. “It’s just a huge structure,”

ship of Mauna Kea, providing ammunition to groups opposed to mountain telescopes. (A follow-up audit in 2014 reported improvements in IfA’s management of environmental and cultural resources.)

The organizations behind the two projects are very different, astronomers note. The DKIST is a national project, funded by the National Science Foundation and owned by NSO. Using federal funds meant that NSO had to follow strict accounting procedures, perform a federal environmental impact assessment, and satisfy U.S. historic preservation rules. By contrast, the TMT, a private consortium supported by institutions in five countries, received no federal funds for construction. That meant it didn’t have to deal with those same regulations. “The opponents were able to sell it as this foreign company coming in and basically using our mountain for their purpose, whereas [the DKIST] at least is a national interest,” Hasinger says.

The groundbreaking ceremonies for the two projects reflected the stark differences in their characters—and also exposed their different vulnerabilities. Kuhn remembers

area in central Maui at the foot of the mountain. They succeeded in turning back a wide-load convoy scheduled to deliver parts to the construction site late at night. A month later, the DKIST's builders tried again. On 31 July, more than 200 protesters gathered just after dusk in the road outside the baseyard. They began to shout and chant in Hawaiian, some blowing into conch shells as trumpets. They linked their arms in plastic pipes to form a human barrier across the road.

At about 10 p.m., Lawrence watched as police in riot gear began moving in to disperse the crowd. They used hacksaws to cut through the plastic pipes and started arresting protesters. At the last minute, Lawrence recalls, she rushed forward and lay down in the road. Police arrested her, along with Kaeo and 18 other people. "I was ready for it," she says. "It was exhilarating. I'd do it again if it helped our cause. Nobody wants to resort to that. Obviously it's not fun going through the court system, but at that moment, I was a proud Hawaiian."

Lawrence speaks cautiously, sensitive to portrayals of the protesters as "crazy Hawaiians." She is quick to point out that, for opponents of the telescopes, blockading the transport was a last resort, after almost a decade of going through official channels. "We did everything we could through the courts, the hearings, the public meetings—what more do we have to lose by doing direct action?"

KUHN ACKNOWLEDGES that his own understanding of Native Hawaiian objections have evolved since he first championed a solar telescope on Maui. Earlier, when surveys of the Science City site found a few sensitive archaeological sites, he bristled at the expense of hiring a cultural consultant to monitor construction and ensure work follows traditional protocol, such as not removing stones from the site. Nor did he like the idea of workers and scientists being "indoctrinated" with an educational video about the role of the mountain in Hawaiian culture and spirituality.

But over time, he says, after listening to countless hours of testimony at public hearings and meeting in private with Native Hawaiian leaders, he came to agree that it was important to respect native beliefs. The DKIST has made other concessions. Native Hawaiian leaders have given input to the project through a special working group. A dressing area was built at the summit for Hawaiian practitioners conducting ceremonies at the *ahu*—which, he notes, were constructed in the 2000s as part of IfA's cultural management plan. And the DKIST has established a \$20 million program at Maui College that combines Hawaiian culture



One of Haleakalā's *ahu*, or shrines, with Hawaii Island faintly visible in the distance (top). In 2015, protesters on Maui (bottom) disrupted the delivery of materials to Haleakalā to build the DKIST.

with science education. "There was real dialogue that took place," he says. Making a good faith effort to address Native Hawaiian concerns led to real compromise and understanding on both sides, he says.

Although the concessions mollified some opponents, they do not satisfy Kaeo, who says they fail to address the fundamental problem: Hawaiians had no say in giving away their mountain. He says he will continue to resist. As *Science* went to press, Kaeo was rallying protesters to demonstrate against the planned delivery of the mirror. "Even if we lost the battle," he says, "our goal is still to win the war, and the war is about our right to control for ourselves our future in this place."

It's another one of those deep-blue-sky days on Haleakalā, and LeEllen Phelps, the DKIST's thermal systems manager, is showing a group of visitors around. Phelps opens a door onto a catwalk that traces the outside of the telescope's white dome, and pauses for a moment to take in the view. Across the Alenuihāhā Channel, she can see the massive profile of Mauna Kea,

and, just barely, white flecks—the domes of existing telescopes. Below her stretches a forbidding volcanic landscape, dotted with silverswords—endangered plants, adapted for the harsh ultraviolet light of Haleakalā, that look like oversized sea urchins. And at her feet, almost in the telescope's shadow, is one of the two shrines.

"When I first got hired, I came up here and sat on a rock and listened," Phelps says. Haleakalā has been recognized as one of the quietest places on Earth, but between the rumble of car engines and a chorus of humming telescope chillers, she quickly noticed that wasn't the case at Science City. With the *ahu* in mind, she insisted on—and got—better soundproofing and a quieter cooling system, meeting sound engineering standards for a place of worship.

The summit may be a vantage for astronomy, but it's also holy ground. "It might not be my culture," she says, "but if you spend any time here, it's a place worthy of respect." ■

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Science **357** (6350), 444-447.
DOI: 10.1126/science.357.6350.444

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