PHOTO: JUSTIN BOLLE

ECLIPSE CHASER

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University of Hawai'i astronomer *Shadia Habbal* treks through deserts, crosses oceans and braves polar bears in pursuit of a fleeting glimpse of a total solar eclipse.

By **ILIMA LOOMIS**

Snow drifts along the road leading to the old auroral observatory about three miles from the town of Longyearbyen, in Norway. At right: Peter Aniol, left, and Pavel Starha, right, check the alignment of the imaging instrument mount.

It didn't bode well that the flight to *Svalbard*, a remote archipelago in the Arctic Ocean, about halfway between Norway and the North Pole, had been delayed by rain, snow and 50-mile-per-hour winds.

It was March 2015, and University of Hawai'i astronomer Shadia Habbal had led some 20 scientists, engineers and technicians halfway across the planet in the hopes of capturing new images and scientific observations of a total solar eclipse, gathering data that could help unlock some of the biggest mysteries of the sun. But, even though she had been planning the expedition for more than four years, she knew there was one thing critical to her work over which she had absolutely no control: clear skies.

Cooling his heels in the Oslo Airport, Judd Johnson, a Colorado-based engineer and one of Habbal's longtime collaborators, wasn't feeling optimistic. Planning for an eclipse on an island in the Arctic Circle—in March, no less—was risky at best. Plus, he'd traveled to Svalbard a year earlier on a scouting trip with Habbal, and the weather was anything but good. "I think we saw the sun for four hours over a week's time," he recalls. "It wasn't very encouraging."

In her two decades of traveling the world as an eclipse chaser, Habbal has had her share of disappointment. It's a delicate science. After shepherding her team and instruments into what's often a remote and inaccessible part of the world, she'll get only one chance to observe the eclipse during a window of totality that's usually no longer than two or three minutes. A sudden shower, a foggy day, a dust storm that passes through at just the wrong moment is all it takes to render an expedition that may have taken years of planning a complete loss.

Even within the scientific community, the enormous logistical challenges and the unmitigatable risk of total failure have led some to question the value of eclipse research. But the fact remains that science currently has no better way of observing the solar corona—the mysterious atmosphere that surrounds the sun and plays a key role in the solar wind and magnetic forces that affect our planet—than during a total solar eclipse.

Earthbound telescopes can be outfitted with a tool called a coronagraph, blocking the glare of the solar disk to create a kind of artificial eclipse. But the corona is still so faint that it all but disappears against the blue sky, making it difficult to observe in normal daylight. Space-based telescopes can get a clearer view, but they're limited by sensors and technology that are now out of date.

"The standard criticism is, 'You're at the mercy of the weather, is it worth all this effort and expense?" she says. "I say, 'Yes.'"

Not that Habbal won't hedge her bets.

For an eclipse in such a remote and challenging environment as the Arctic, she's taken an unusual number of precautions to ensure her team doesn't walk away empty handed. On Svalbard, she's secured the use of an old observatory to set up her instruments. Part of her team will work there during the eclipse, while another group will be making observations from an empty hangar at the Svalbard airport, 10 miles away. At the same time, she's dispatched a smaller crew to the Faroe Islands, off Denmark. A fourth team will record observations from a special plane and follow the path of totality at 49,000 feet—not an ideal viewing environment, due to the movement of the platform and the thick Plexiglas windows, but well above any bad weather. Finally, a colleague has secured the use of a second plane out of Ireland, so Habbal will send instruments on that flight as well, at a lower altitude of 10,000 feet.

But, if Habbal felt any anxiety about the upcoming trip as she went through her final preparations in February, it was less about weather than wildlife.

"My biggest fear is polar bears," she confided, surrounded by papers, books and instruments in her office at the Institute for Astronomy in Mānoa. "Because they're lethal, and they're huge."

> "My biggest fear is polar bears."
> —SHADIA HABBAL

MYSTERIES OF THE SUN

The interior of the sun is an inferno, reaching temperatures of around 15 million degrees. The sun's surface is significantly cooler, a mere 6,000 degrees. But travel outward through the

PHOTOS: COURTESY OF GARRY NITTA, UNIVERSITY OF HAWAI'I INSTITUTE FOR ASTRONOMY

solar corona, and the heat rises again, to between 1 million and 2 million degrees. It's this mysterious temperature change that scientists are struggling to explain.

The corona is a scientific enigma. As the outer atmosphere of the sun, it's the origin point of the solar storms and flares that can knock out satellites, disrupt the electrical grid and illuminate Earth's sky with the Northern Lights. But the force that governs those powerful phenomena—the sun's magnetic fields—is completely invisible.

That's one reason Habbal has focused on studying iron, one of the most abundant elements found in the corona. Heated to extreme temperatures, iron, like other elements, becomes ionized, which means its atoms lose electrons. By placing special filters over her camera lenses during an eclipse, Habbal is able to capture images of the light reflected by two kinds of these altered iron particles, effectively creating a temperature map of the solar corona.

She leans over her desk to indicate a photograph of an eclipse on her wall, tracing the overlapping halos and plumes with her finger. Red lines indicate iron at 2 million degrees, green at 1 million degrees. But it's not just the temperature that's interesting. "When you see this, then you realize, well, there's a lot of structure in the corona," she says.

Because the particles tend to ionize at the lines of the sun's magnetic fields, observing where they gather and disperse can also help scientists start to understand these invisible boundaries—much like watching driftwood move through an ocean current.

Shadia Habbal (left in red hat) being interviewed after the eclipse by a Norwegian TV crew.

THE MAKING OF A SCIENTIST

Habbal grew up in Syria, in a family of teachers who emphasized the importance of education for all their children. She was enrolled in a private school where she learned French, English and Arabic. In ninth grade, a dynamic teacher inspired her dream of becoming a scientist, with experiments that tested electricity and magnetism.

"There was something fascinating to me about physics," she says. "I still feel that it's the foundation of all sciences."

Around the same time, she read the life story of Marie Curie, and the female physicist who pioneered the study of radiation became Habbal's idol. Syria was a progressive place at the time, before the rise of religious extremism and violence that affects the region today, and Habbal saw no reason she might not follow in Curie's footsteps.

PHOTOS: COURTESY OF GARRY NITTA, UNIVERSITY OF HAWAI'I INSTITUTE FOR ASTRONOMY

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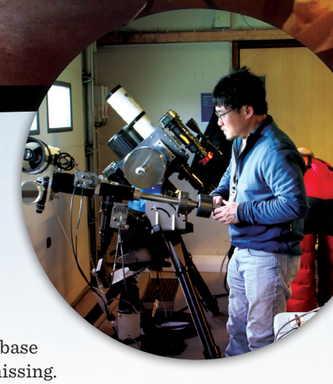

Setting up the observing site in a hangar at the airport in Longyearbyen, Svalbard. In the photo are Haosheng Lin (left) and Pavel Starha (right). Inset: Lin checking his telescope.

"Nobody ever told me, 'You can't do this because you're a woman.' Never," she says. "Ironically, I never felt discriminated against, except when I first came to the United States."

She graduated from the University of Damascus, went on to study physics at the American University of Beirut, then moved to the United States to get her doctorate from the University of Cincinnati in the 1970s. It was there that she noticed her gender sometimes left her the odd woman out—she sometimes felt excluded at social gatherings, and made a mental note of the lower salaries paid to women. Even so, Habbal never felt that her gender stood in her way.

"I mean, I never think of myself as a 'woman scientist,'" she says. "I didn't feel any inhibition, so I was able to compete and be as accomplished as—or even exceed the accomplishments of—my male colleagues."

It was Habbal's interest in magnetism that drew her to study the sun. Then, in 1995, almost out of curiosity, she planned a trip to observe a solar eclipse in India. She traveled with a small group, and brought only enough equipment to capture a few images—she was still using photographic film at the time—but the experience is fixed indelibly in her memory.

"It was early in the morning in India, around 8 o'clock. The sun was at the minimum of its activity. And you could see the streamers almost shooting to infinity," she recalls. "I've never seen a corona like it since—I could almost feel it." Totality lasted only 42 seconds. She was hooked.

"A SNOWBALL'S CHANCE IN HELL"

Arriving in Svalbard a day behind schedule, the storm had passed, but it was still chilly and overcast, and the team quickly set about retrieving and organizing their equipment. Not willing to risk a delicate lens or priceless scientific instrument being lost or broken in shipping, Habbal and her team had long ago adopted the habit of carrying all their gear to the site by hand, packing sturdier items in their luggage, and carrying fragile instruments in carry-on bags, a practice that has earned them the self-imposed nickname "solar wind Sherpas."

This time, though, two bulky instrument mounts, too heavy to travel as baggage, had been shipped ahead. When Johnson went to pick them up, his heart sank to see that a large supporting base plate was missing. "Things were no longer strapped down," he says. "Apparently they had taken them off the pallets, and lost one piece, which was kind of critical."

On the island of 2,600 people, the team found a mechanic with a heavy-equipment repair shop, who promised to rummage in his pile of scrap and see what he could do. With just two days to prepare before the eclipse, Johnson turned his attention to the remaining equipment and hoped for the best.

Then, "much to our surprise, at 11 o'clock at night, we got a text message saying, 'I've finished the base, it's outside in the snow.'"

The new piece was massive, but it would work. It took two men to heave it onto the back of a snowmobile and lug it out to the main observatory, staggering under its weight through the heavy snow. In the final hours before the eclipse, the team rushed to make its final preparations.

In the last few days before the eclipse, Habbal and the team watched the weather carefully. A day earlier, the

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>
> —HABBAL

The total eclipse of the sun cast the researchers into temporary darkness.

clouds had looked like they might be breaking up. Then, the morning of the eclipse, the sun rose into a sky that was perfectly clear. "We were very fortunate," Johnson says. "I wouldn't have given it a snowball's chance in hell."

They rose early and hurried to their stations. At the observatory, Habbal and her team opened the doors and windows, giving the room time to cool off and equalize to the temperature outside.

Although the scientists stayed bundled in their down parkas, hats and gloves, at 20 degrees below freezing, the computers that controlled their cameras were being pushed to the limit. Then, as the eclipse began to approach totality, the computers crashed. With just a few minutes to go, the team quickly rebooted.

As the computers began a two-minute countdown to totality, the team members set their equipment to record. Then came the hard part—they had to leave. Habbal feared that even their footsteps on the old observatory's creaky wooden floors would cause enough motion to blur their images. "We all stepped outside and left the cameras running. I was in such a daze. I couldn't do anything except look at the sun."

It was a rare moment. Although she's now been to 13 eclipses around the world, Habbal usually finds herself glued to her computers and instruments, sparing no more than a few seconds to admire the view. Now, standing close enough to the observatory door so she could hear the reassuring click of her cameras, for the next two minutes and 20 seconds, she took it all in.

Even after 20 years, she says, the sight is awe inspiring.

"It's absolutely gorgeous," she says. "You're witnessing the mechanics of the universe—the motion of the moon, and the sun, and the Earth."

As the eclipse passed out of totality, she hurried back inside to check her equipment. The cameras had worked perfectly, capturing stunning images of the corona in its full glory. It would be months before she'd be able to pore through her results and properly analyze the data, but she'd gotten what she came for. This time, at least, she wouldn't be going home empty-handed.

Minutes later, the computers crashed again. PAU

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