Stargazing From the End of the Earth

Astronomers say they have proved that the South Pole is a worthy—and viable—site to build an international collection of telescopes early in the next century

SOUTH POLE—The dry, bitterly cold snow squeals underfoot like Styrofoam as Tony Stark trudges toward the Dark Sector, an astrophysics zone situated a kilometer beyond the shelter of Amundsen-Scott dome. At 30 degrees below zero on a sunny summer's day, with a steady breeze from the north—the only direction it can come from—Stark's breath glazes his dark-brown beard, aging him 20 years. The image is fitting because Stark, an astronomer with the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, is himself gazing into the future: He's starry-eyed over plans to build a major astronomical facility here early next century to explore, among other things, the nebulae that spawn stars and the ripples in the cosmic microwave background that hint at how the earliest galaxies formed.

A decade ago, astronomers could only dream of a major observatory at the South Pole, where the thin, still, bone-dry air and constant winter darkness offer observing conditions better than practically anywhere else short of outer space. However, says Stark, "we didn't know if it would be possible to operate a telescope over the winter here." That was before the National Science Foundation (NSF) began funding the Center for Astrophysics in Antarctica (CARA), a $28 million test-bed for astronomers to build and operate instruments in the unforgiving antarctic environment. Stark and many of his colleagues contend that, since it was founded in 1991, CARA has succeeded in demonstrating that this is a viable place to do cutting-edge astronomy, especially in the long-wavelength, infrared, and submillimeter regions of the spectrum. "We're convinced that the preliminaries are over," he says. "We're now at a critical break point."

At an American Astronomical Society meeting in San Diego in June, CARA staff members will make a pitch to the broader community to support an International Antarctic Observatory (IAO) here. The organization would be established soon after 2000, during construction of a new $150 million U.S. South Pole station—about the time that CARA, which has an 11-year lifetime, closes up shop.

But unless IAO boosters overcome several hurdles, the grand plans for an observatory could fade like fata morgana ice cliffs, the stunning mirage that sometimes rises on the horizon here during temperature inversions. The biggest hurdle is funding. Realizing that NSF alone won't foot a bill totaling at least $100 million for all the telescopes they want, proponents will try to put together international coalitions under IAO's umbrella to pay for individual instruments. The project would have to compete for logistical support—cargo space on planes and construction time—with the new station. And CARA's own image as a clubby organization that doesn't welcome outside ideas, together with the problems it has experienced with some of its telescopes, could also hamper the bid for a new observatory. For Antarctica's astronomers, the time of reckoning has arrived. "We know how to make things happen at the pole," says the center's assistant director, Jim Jackson, an astrophysicist at Boston University. "It would be silly to toss that away."

The projects described in this Special News Report provide a snapshot of science in Antarctica in a period of transition. Researchers are lobbying for two big new programs to follow existing efforts in astronomy and ice coring, while the National Science Foundation (NSF)—which sponsors U.S. research in Antarctica—has started construction of a new U.S. station at the South Pole. And these changes are taking place in a new political environment: The Antarctic Environmental Protocol, which bans mining and mineral exploitation on the continent for at least 50 years, took force on 14 January. The treaty should protect Antarctica for science. Reporting for these articles was conducted during a visit to the continent supported in part by NSF—a trip that featured the first visit to Russia's Vostok station by a U.S. journalist.

Polar visionaries

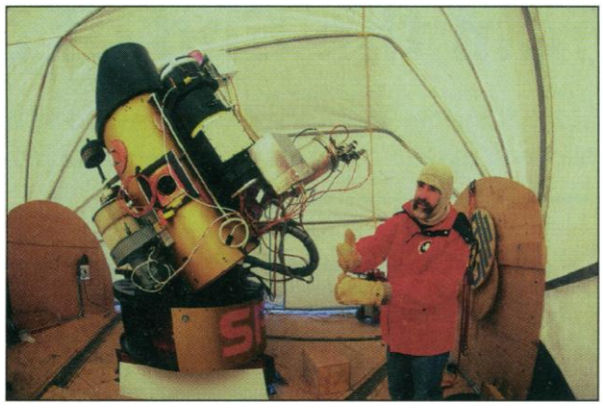
Much of the credit for turning the South Pole into an astrophysics hotbed belongs to Martin Pomerantz. For 3 decades, Pomerantz, a director emeritus at the University of Delaware's Bartol Research Institute, has been touting the advantages of the pole's freeze-dried atmosphere—especially for long-wavelength observations, which are hindered by atmospheric water vapor. One convert was Al Harper, an astrophysicist at the Yerkes Observatory at the University of Chicago, who deftly forged collaborations and cut deals with other institutions to assemble a convincing proposal for an antarctic center. Harper is a "visionary ... who got CARA rolling," says Jackson.

Harper guided the center in its early years, after the University of Chicago won an NSF science and technology center grant to launch CARA in 1991. Two telescopes soon began churning out valuable data: the 0.8-meter Python and the 1.7-meter Antarctic Submillimeter Telescope and Remote Observatory (AST/RO). Python measured variations in the cosmic microwave background, the afterglow of the big bang, complementing observations by the Cosmic Background Explorer satellite. AST/RO set about mapping the neutral carbon that traces star-forming nebulae. "We have gone from working in tents and only during the short summer season to a year-round operation in laboratory facilities that rival anything you'll find [elsewhere]," says Harper.

But another project—the South Pole Infrared Explorer (SPIREX)—was not so successful. Astronomers had predicted that SPIREX, a 0.6-meter telescope located far from any warm objects radiating heat in the infrared, would be 200 times better at resolving infrared signals from distant galaxies than are its temperate-latitude counterparts. But the first set of experiments faltered, partly because some instruments worked poorly and partly because minor atmospheric turbulence distorted images more than had been predicted. In the summer of 1996, when a team of outside researchers reviewed CARA to recommend whether to renew the center's funding for another 5 years, SPIREX "was in big trouble, not producing," says one center scientist. The timing was inauspicious: Harper was then asking NSF to double CARA's budget to fund an ambitious new set of projects.

SPIREX wasn't the only problem the review team—led by astrophysicist Charles Lawrence of NASA's Jet Propulsion Laboratory in Pasadena, California—was eyeing. For

instance, CARA had a reputation as a closed shop that shunned new ideas from noncenter researchers, according to astrophysicists affiliated with the center and outsiders. The panel concluded that "the South Pole is a valuable observing site that justified larger and permanent facilities," Lawrence says, but he adds that his team wasn't convinced that CARA was doing an adequate job in laying the groundwork for future big telescopes. The panel recommended to NSF that CARA be given a year to address such concerns—or be shuttered.



ERIC BAKER

Corrected vision. Rejuvenated SPIREX is now mapping infrared signals from the Large Magellanic Cloud.

David Oxtoby, dean of physical sciences at the University of Chicago, asked Harper to step down as CARA director last April but stay on to help rescue SPIREX. Specialists from the National Optical Astronomy Observatories in Arizona and the University of New South Wales in Australia, among others, were brought in to help shift the telescope's focus from the original 2.4 micrometers to the 3.4- to 4.1-micrometer range—a change that has dramatically boosted the telescope's sensitivity. "The longer wavelengths seem to be the sweet spot," Lawrence says. SPIREX, adds new CARA director Stephan Meyer of the University of Chicago, "is completely rejuvenated." Last month, it launched an infrared survey of faint stars in the Large Magellanic Cloud. Impressed by the management changes, a revamped SPIREX, and efforts to reach out to the broader community, Lawrence's panel recommended last summer that CARA be renewed for another 4 years.

But, like crevasses hidden beneath the snow, other pitfalls could jeopardize CARA's transformation into an international observatory. One concern is delayed start-up of Viper, a 2-meter follow-up to Python that was scheduled in a few months to begin producing a finer map of temperature deviations in the cosmic microwave background. Last October, bad weather delayed South Pole station's summer reopening by 2 weeks, which led to a backlog of flights that in turn delayed shipment of components for Viper and other projects. As a result, Viper won't be ready to start observing in earnest when the long polar night begins next month. "It will take another year before we begin to get the data we really want," says project leader Jeff Peterson of Carnegie Mellon University in Pittsburgh.

Scientists on the submillimeter telescope, AST/RO, will have a different kind of worry when the sun sets at the pole next month. Last austral winter, project scientists at Harvard had a contretemps with the lone AST/RO staffer to winter at South Pole station. (He was one of 28 people who wintered there.) Stark says repeated attempts by AST/RO scientists to persuade the staffer by e-mail to collect data according to a "carefully constructed" observing plan failed. "We got a lot of different data than what we wanted" last season, he says. "It's a matter of psychology whether the winter over will succeed," adds Jackson. "A person's down there in the dark, at a hundred below zero, and here are some bozos from the north giving orders." This is a potential problem for any instrument run by a skeleton crew in the winter, warns Stark.

Future gazing

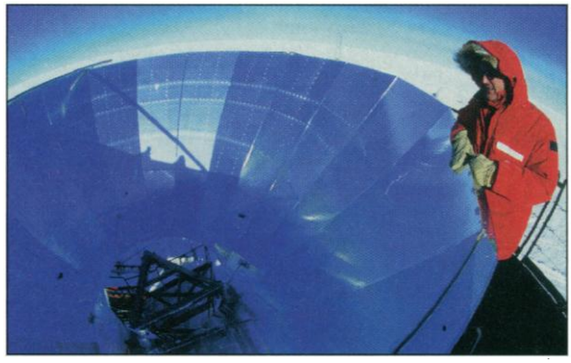
Despite these setbacks, the polar astronomers are campaigning for new instruments—and a new organization to coordinate them. As an NSF center, CARA is mandated to begin winding down during its 10th year, in 2000. It can then reapply for another long-term grant, but few CARA scientists want to see the center perpetuated in its current form. The level of support—about $4 million a year—would not even begin to replace CARA's demonstration scopes with major instruments.

Stark, for one, is thinking big: His group has drafted a proposal for a 10-meter submillimeter telescope, a successor to AST/RO with 75 times its collecting area that would, among other things, study dusty protogalaxies whose energy is redshifted into submillimeter wavelengths that are inaccessible to the Hubble Space Telescope. The dryness of the polar atmosphere, says Stark, would allow a 10-meter telescope at the pole to make observations in just 1 day that would require 100 days on a comparable telescope atop Mauna Kea, Hawaii. Aiming such a scope at a class of protogalaxies invisible to optical telescopes, he says, "we would be able to observe routinely an entirely new class of objects." The prospect is drawing interest from the Max Planck Institute of Radioastronomy in Germany; other potential international partners, including Italy and the Netherlands, might also sign onto the $23 million telescope. "The 10-meter is likely the next thing that will happen at the pole," says Jackson, perhaps as early as 2003.

Next in line could be the South Pole Infrared Imaging Telescope (SPIRIT), a 2-meter follow-on to SPIREX proposed by CARA and the Joint Australian Centre for Astrophysical Research in Antarctica. SPIRIT would also join the search for protogalaxies in the early universe, and it would peer into stellar cradles in the Milky Way and the Magellanic Clouds. Further down the road might be a polar stratospheric infrared telescope held aloft by a tethered balloon, a 4-meter infrared telescope, and a 30-meter submillimeter telescope.

To oversee these projects, CARA is pushing for the establishment of the IAO, which would provide logistical support and manage a public database for disseminating results. A good model, Meyer says, would be the board that coordinates the independently run telescopes at Mauna Kea. Meyer's group has begun informal talks with a variety of organizations that might take part in IAO, including prospective partners on the new telescopes and scientists who run the Antarctic Muon and Neutrino Detector Array (AMANDA), a series of photomultiplier tubes buried in the ice to detect faint flashes set off by elusive high-energy neutrinos from the distant universe.

In fall 1996, AMANDA—a project independent of CARA—recorded as many as 10 events highly suggestive of its quarry; project scientists are hoping in the coming years to spend up to $30 million to sink enough detectors to monitor a cubic kilometer of ice, more than 10 times the current array's size, to spot neutrinos routinely. To do so, says AMANDA director Robert Morse of the University of Wisconsin, "we're going to be asking our European collaborators for sizable amounts of money." Assigning oversight of South Pole astrophysics to IAO or



ERIC BAKER

Inauspicious start. Bad weather has delayed Viper's detailed survey of the microwave background radiation.

some other body with an international board "would make the funding situation a little bit easier," Morse says.

Some scientists picture an even bigger role for an international coordinating body: overseeing the entire South Pole science operations by serving as an NSF contractor. The International South Pole Science Consortium, as its backers are calling it, could also serve as a powerful voice for science early next decade when construction on the new station is expected to be going full swing. Such a voice may be sorely needed. "It looks like we don't have enough airlift capability to modernize the station and do all the science we can do," says NSF Antarctica Representative Dwight Fisher.

If an international board does assume control of antarctic astrophysics, the South Pole may face some competition as a telescope site. Some scientists argue that Dome Concordia (Dome C), a site about 2000 kilometers from the pole, may offer the best viewing on the continent. France and Italy are building an international base at Dome C—Concordia station, which will open for limited operations in 2001—and may seek to have at least one major telescope under IAO located there. "It's a very, very interesting site," says Meyer. In addition to having a thinner atmosphere, Dome C is less windy and sits at a higher elevation than the pole and is visible to geostationary satellites, giving it 24-hour communications. (South Pole station has satellite contact only 6 hours a day.)

For now, however, "spending any time at Dome C is hero's work," says Meyer. "There's a heck of a lot of infrastructure at the South Pole not reproduced there." And there may soon be more: If Congress appropriates funding to continue the upgrades to South Pole station, three new lab and living modules could replace the 23-year-old geodesic dome by 2005.

Still, cozy quarters isn't the main force dragging astrophysicists far from home—it's the sky. "As far as getting more scientists," says Jackson, "we don't have to go out and pimp for the South Pole." CARA's success over the next couple of seasons at doing astronomy—and lobbying for its successor—could ensure that the polar sky draws admirers for years to come.

–Richard Stone

MARINE BIOLOGY

First Glimpse at Hidden Life of Seals

MCMURDO SOUND—From an observation tube suspended in the frigid waters here, the sea ice's fleecy underside looks like the tormented skies of an El Greco painting: a stormy expanse of umber clouds tinged with green. All is eerily still—except for the jellyfish, ghostly white, that drift with the current—until an oblong shape thrusts up from the murky depths, toward a hole in the algae-discolored ice. The faint light near the surface transforms the blob into a female seal, which disappears up into the hole.

R. STONE

Star of the show. New seal cam is revealing secrets of seal behavior.

Researchers have been waiting for days for this particular Weddell seal to haul herself onto the ice so they can retrieve a tiny $50,000 camera mounted on her head. As the seal bobs in the breathing hole, the device glints tantalizingly in the brilliant sunlight. But after a few minutes, she sinks back into the El Greco–like world below. "She's bored," says physiologist Terrie Williams of the University of California, Santa Cruz. The delay is only a minor irritation in a gratifying field season: Williams and her colleagues have, for the first time, filmed Weddells plying the pitch-black waters of McMurdo Sound—images that are offering new insights into how the seals dive and forage.

To marine biologists, the astounding athleticism of Weddells made them stars long before these flicks. Some can hold their breath for 80 minutes while swimming—a feat that "is the equivalent of a lion pursuing its prey while holding its breath," says team leader Randy Davis of Texas A&M University in Galveston. Navigating with few visual cues, Weddells can range up to 5 kilometers from a lone breathing hole and still find their way back. And they efficiently locate fish—they consume about 200 or so a day—in the inky waters.

But researchers know little about how seals manage these feats or what else they do down deep. "These behaviors are more or less invisible to us," says Davis. To study the secret lives of diving animals, his team for a decade has been developing progressively smaller and more sophisticated cameras. So far, they have chronicled the comings and goings of sea turtles, dolphins, and elephant seals, and now they are breaking new ground with Weddells. "The camera will help us understand just what kind of hunter these critters are," says Williams.

In a talk that wowed fellow scientists last November at McMurdo Station, the main U.S. base in Antarctica, Davis and Williams detailed their findings from the first field season of their 3-year project. One video showed a seal blowing air bubbles into the underside of the sea ice. Suddenly, a fish darted out from a cranny in the ice, the seal lunging after it. "Our hypothesis is that the animal is using great backlighting to look at a silhouette of a fish" before exhaling to flush it out of its nook, explains Davis—a foraging behavior never seen before, he says.

They also learned more about how the seals dive. "We wanted to know if we would see a real exercise bout or just lazing around," says Williams. Turning the "head cam" into a "butt cam," she says, the researchers saw that the seals sank like rocks while hardly twitching a flipper. Williams speculates that the seals somehow alter their buoyancy to take advantage of pressure changes.

To do their snooping, the scientists employed the "isolated hole paradigm" pioneered by penguin specialist Gerald Kooyman of the Scripps Institution of Oceanography in La Jolla, California. Davis's team found a spot on McMurdo Sound surrounded by at least 5 kilometers of unbroken ice. They drilled a hole big enough for seals to get out and breathe. Next, they captured a seal, brought it to the site, slapped on a neoprene rubber patch, and attached the camera setup. Because the seal had to return to the breathing hole, the researchers could always recover their camera.

Filming in near-infrared light—invisible to the seal's eye and to its prey, which suggests it won't alter either one's behavior—emitted from the camera like a flashlight, the researchers taped 23 dives by four animals. The results leave Davis feeling vindicated. "For quite a few years, people have been telling us this is not possible," he says. Indeed, the seal grant proposal was rejected five times, Davis says, before reviewers for the National Science Foundation deemed the technology workable.

Next, Davis's team plans to turn a mass of data on the precise locations of seals during a dive—information gleaned from a seal's recorded depth, speed, and bearing—into three-dimensional graphs that reveal the intricacies of the dives. This is a step, Davis says, toward scientists tagging along in a virtual environment with an animal as a satellite tracks its movement, feeding data to a computer in real time. Davis envisions ever tinier instruments that will someday turn marine creatures into autonomous vehicles for remote-sensing the oceans. When that day comes, he says, "it will open up a whole new world to us."

–Richard Stone