Astrophysics Goes South

Antarctica's location and meteorology make it a prime spot for observing the infancy of stars, galaxies, and the universe

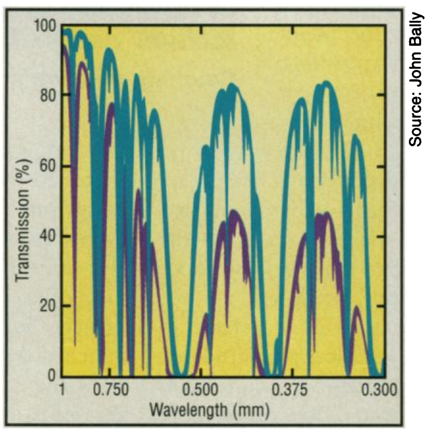
John Lynch

The pole at the pole. *The dry air scatters little light from the sun, hidden by the post.*

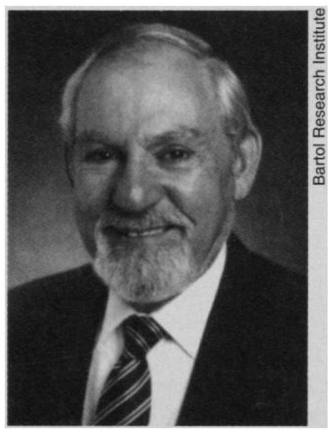
"IT TAKES A WHILE BEFORE PEOPLE UNDERstand that something unusual has some particular benefits," says Martin Pomerantz, a physicist at the Bartol Research Institute of the University of Delaware. For nearly 30 years, Pomerantz has been touting the benefits of a most unusual place: the South Pole. "It is a hard place to do science, unless you compare it to space," Pomerantz concedes. But that is precisely what he and a growing number of converts are now doing. Weighing the inhuman cold and the logistical challenges of Antarctica against the limited observing opportunities and expense of space, they are concluding that their observing programs might stand a better chance of flourishing at the South Pole.

With its high altitudes and extremely dry atmosphere, Antarctica may be the best place on Earth to observe at the long wavelengths, in the infrared to millimeter range, that are probes of infant stars, newborn galaxies, and the early universe. What's more, Antarctica is proving to be a friendly environment for high-altitude balloon flights, which can provide a cheaper alternative to spacecraft for x-ray and gamma-ray observations.

Years of proselytizing by Pomerantz and other Antarctic pioneers are now getting a major response. Earlier this year, the National Science Foundation (NSF) set up a new Science and Technology Center, the Center for Astrophysical Research in Antarctica (CARA), headquartered at Yerkes Observatory and budgeted at $13.6 million for the next 5 years. A consortium of colleges, universities, and industrial research labs headed by Al Harper, a former Yerkes director, CARA is coordinating projects to build a series of long-wavelength telescopes at the pole, perhaps culminating in instruments that might play a role in searching for planets around distant stars.



Good seeing. *Submillimeter transparency predicted at Mauna Kea* (purple) *and the South Pole* (blue).



Bartol Research Institute

Forward looking. *Martin Pomerantz, prophet of the South Pole.*

None of this means that observatories at the South Pole will replace the great telescopes at lower latitudes. Aside from the mind-numbing engineering problems of constructing observatories in Antarctica—plastic insulation cracks, lubricants act like molasses in the cold, water vapor condenses in electric circuits, and everything must be flown in during the southern summer—the viewing conditions can be far from ideal. The high clouds of the Antarctic winter—the same polar stratospheric clouds that midwife ozone destruction—get in the way of nighttime optical astronomy, according to John Lynch, a program manager at the NSF's Division of Polar Programs. Nor will telescopes high on the polar ice displace spacecraft as the best platforms for observing at wavelengths obscured by the earth's atmosphere.

Despite these drawbacks, Antarctica has been luring astrophysicists and space scientists for years, though not for the kinds of observations that are spawning the current interest. "All the fields that are now taking [people to] Antarctica were nonexistent at the time I first thought of this as a place to do astronomy," Pomerantz says. What he sought there 30 years ago were cosmic rays, specifically the low-energy cosmic rays that are screened out at lower latitudes by the earth's magnetic field. Near the poles, though, the cosmic rays can slip in through the cusps of the magnetic field. In 1960 Pomerantz set up cosmic-ray monitors at McMurdo Station, on the coast, and later at Amundsen-Scott station at the pole—the beginnings of an Antarctic cosmic-ray program that continues to flourish.

The surface of the Antarctic ice sheet, undisturbed by human activity, later became a prime hunting ground for researchers seeking more tangible missives from space—meteorites. An American collecting program, the Antarctic Search for Meteorites, headed by William Cassidy of the University of Pittsburgh, has sent out search parties nearly every year since 1976. So fruitful have these collection efforts and those of the Japanese been that efforts elsewhere have dropped off sharply.

The first major step to mainstream astronomy came in 1978, and Pomerantz was the driving force. "We started by bootlegging some solar observations onto the cosmic-ray program," he says. Pomerantz and his colleagues were interested in studying oscillations of the sun, which bear clues about its deep interior, and the advantages of the pole were tempting. During the summer, the sun stays above the horizon continuously for 6 months, eliminating the nighttime interruptions that can complicate the data analysis. These pioneering efforts led to a burgeoning solar-oscillation program.

But the latest boom in Antarctic astrophysics owes more to meteorology than to geography. Like mountaintop observatories at lower latitudes, the South Pole is perched above much of the earth's atmosphere. Amundsen-Scott station is set atop nearly 3 kilometers of ice, with low winter temperatures reducing air pressure enough to add an extra half-kilometer to the effective altitude. And what little atmosphere remains is practically devoid of water vapor, which obscures infrared and other slightly longer radiation. If all the water vapor in the atmosphere over the pole were condensed out, it would form a layer of less than .4 mm in summer, and as little as .05 mm in winter—less than a tenth of the amount over Mauna Kea, one of the driest low-latitude sites. According to Lynch, one reason for the bone-dry air in winter is a persistent weather system called the polar vortex—a continent-wide cyclone that excludes the moister air of lower latitudes.

When the vortex breaks up in mid-December, it is replaced by a much weaker flow in the opposite direction. That pole-circling flow lasts all summer and is one reason researchers are eying Antarctica as a site for astrophysical balloon flights, which can carry instruments to the very edge of space.

Robert Lin, an astronomer at the University of California at Berkeley, points out that an unmanned balloon can ride the circulation around the continent and back to its starting point, which simplifies payload recovery—a task that is made easier still by the almost featureless landscape. And because a balloon in Antarctica flies in continuous sunshine, it does not experience the temperature variations that cause balloons elsewhere to flex and lose helium, so it can stay aloft—and at a nearly constant height—for longer.

Lin tested these advantages last December by launching an instrument-carrying balloon on a flight that, he says, may have been the longest balloon flight ever at extreme high altitudes—nearly 10 days at a height of nearly 40 kilometers. During the balloon's 5000-kilometer circuit, which took it around the continent and back to within 200 kilometers of its launch site at McMurdo station, gamma- and x-ray detectors in the payload observed sources such as supernova 1987A and solar flares with satellite-rivaling clarity, 24 hours a day. Lin is already thinking about a sequel to this near-space mission. "A 20-day flight, 24-hour observations, and a payload capacity of 1700 kilograms will make such unmanned Antarctic balloon flights almost competitive with Shuttle flights for observing hard x-rays and gamma-rays," he says.

But the biggest advantages of Antarctica's peculiar meteorology are found at the other end of the spectrum. It is there, in the infrared and submillimeter wavebands, that water vapor in the atmosphere makes the most mischief for astronomers. At midlatitudes, water vapor completely rules out observations in part of that wavelength band—between .04 mm and .3 mm—and screens out many neighboring wavelengths as well.

Yet these obscured wavelengths are tracers of processes astrophysicists are struggling to understand, among them the birth of stars. The central regions of the dense clouds of gas and dust that spawn stars, for example, can be mapped by radio astronomers, but the outer layers can only be traced by observing submillimeter radiation from atomic carbon, according to John Bally, an astrophysicist at AT&T Bell Laboratories. "Carbon provides a way to study how newborn stars literally destroy their placental cloud environment by radiation and winds," he says.

The trouble is that for most ground-based observers water vapor comes close to blocking a key carbon line, forcing astronomers studying starbirth to compete for scarce observing time on NASA's Kuiper Airborne Observatory, a converted jet transport that flies above most of the atmospheric water vapor. That may change with the completion of a project funded 2 years ago and now part of CARA: the 1.7-meter Antarctic Submillimeter Telescope and Remote Observatory (ASTRO), to be installed at the South Pole in late 1992. The dry air of the pole, it is hoped, should give ASTRO observers a clear line to the stellar nurseries.

Long-wavelength clues to another kind of infancy will be the target of a CARA project called SPIREX, the South Pole Infrared Explorer. Light from the youngest galaxies is strongly red-shifted because of their great distances, which pushes it into the infrared region of the spectrum. CARA plans to build a 60-centimeter near-infrared telescope at the South Pole. One goal of the project is to test the South Pole as a site for infrared observing—if it lives up to its promise, CARA organizers plan to replace the small telescope with a 2.5-meter one. Another goal, though, is to begin surveying the southern sky for young galaxies.

While an infrared search for young galaxies hasn't started yet, longer-wavelength investigations of an even earlier epoch—the aftermath of the Big Bang—have been under way at the South Pole for several years. Again it was Pomerantz who saw the observational virtues of the South Pole, promoting it in the mid-1980s to a Bell Labs group including Robert Wilson, who with his Bell Labs colleague Arno Penzias reported the discovery of the cosmic background radiation in 1965.

Kinsey Anderson and Robert Lin

Friendly skies. *An unmanned balloon is readied for 10 days of astrophysical studies in the upper atmosphere.*

The dry air of Antarctica aids the search for the slight unevenesses in the background radiation that might offer clues to how the first galaxies and other large structures in the universe took shape. Three groups, from Bell Labs, Princeton University, and the University of California at Santa Barbara, have been searching for anisotropy—very slight variations in the intensity of the background in different patches of sky. And the anisotropy studies will accelerate under a CARA program called COBRA (Cosmic Background Radiation Anisotropy), which is planning a 3-meter telescope at the South Pole.

These Antarctic ventures in long-wavelength astrophysics will complement rather than supplant observations made from astronomical satellites, such as the current Cosmic Background Explorer satellite and the Space Infrared Telescope Facility, scheduled for launch in 1999. But Antarctic proponents point to the possibility of bigger projects that at present could be done only on terra firma: a planned 10-meter submillimeter telescope, for example, which might be linked with one or several other telescopes to form an interferometer. The combined resolution might be fine enough to detect planets circling nearby stars.

John Bally is dreaming of something even bigger: a 30-meter telescope to record signals in the submillimeter waveband. That, he calculates, would be big enough to probe the "dark ages" of the universe—the period before known galaxies took shape. Any protogalaxies lurking in that dim epoch would likely be veiled in dust from supernova explosions, which would absorb starlight and reradiate it at longer wavelengths that would reach Earth as submillimeter waves. A 30-meter telescope, Bally thinks, would have enough resolution to distinguish any protogalaxies from more normal, closer galaxies.

As if the rigors of working at the South Pole were not enough, Lynch of the NSF has suggested an international site for astrophysics in an even more inhospitable spot: 1000 kilometers away from the Pole at the highest—hence driest—point on the Antarctic plateau, where the wintertime pressure is equivalent to that at an altitude of 5 kilometers. Sooner or later, telescopes at such sites may be operated by remote control, from comfortable offices half a world away. But for now, astrophysicists wanting to observe in Antarctica have to make the trip.

"You wouldn't go to Antarctica unless you had a good reason," says Pomerantz. For growing numbers of astronomers, the reason is simple: There may be no better place. ■ PER H. ANDERSEN

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