Solar Eclipse

NATURE'S SUPER SPECTACULAR

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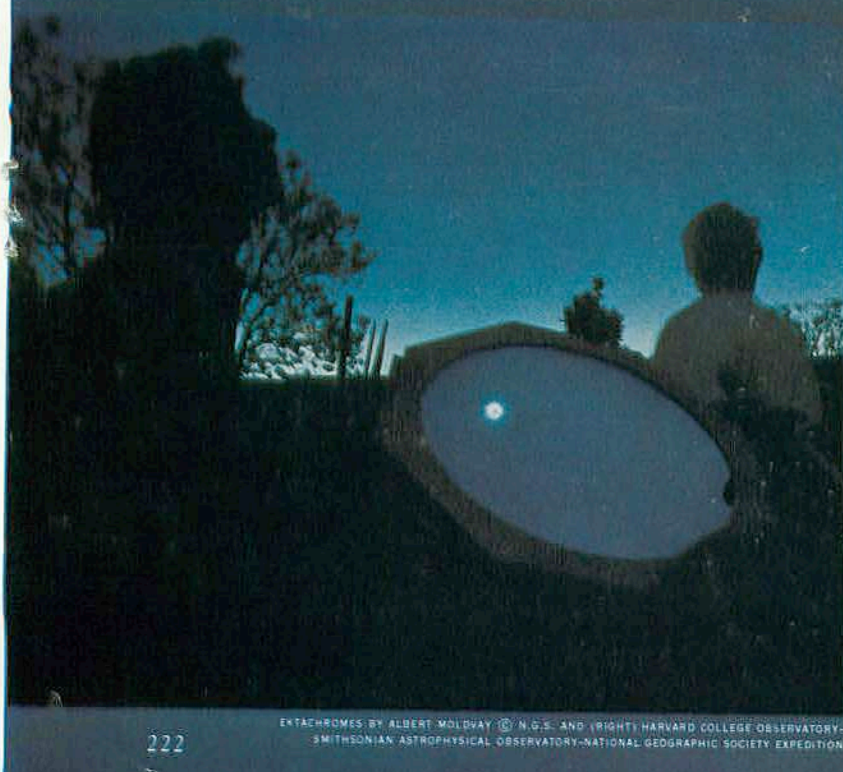


ABOUT EVERY 18 months, some part of our world experiences an event that awes astronomer and layman alike. In a remarkable coincidence of size and distance, the 2,160-mile diameter of the moon—1/400 the size of the sun but also only 1/400 as far from the earth—blots out the face of the sun, that huge ball of glowing gas. The result: a rather eerie false night for anyone in the lunar shadow.

As a dedicated observer of total solar eclipses, I have been privileged to witness 13, perhaps as many as anyone in the

world. My first occurred over the Colorado Rockies in 1918. Jay, my colleague on the latest expedition, viewed his first of three total eclipses in 1959, when he joined other members of my freshman seminar at Harvard on an eclipse pursuit by airplane over Boston.

Corona Holds the Key

Like most eclipse chasers, we seize any opportunity to stand within the lunar shadow for a brief, invaluable glimpse into the secrets of the sun. Our key to those secrets is the incredibly hot corona, the halo of pearly light surrounding the eclipsed sun (above).

Most scientists believe the corona's ionized gases stretch all the way to the earth, enveloping our planet as well as the sun. Thus, understanding the corona is relevant to understanding our own environment.

Though eclipses occur reasonably often, opportunities to examine the corona arise rarely. The central dark shadow, or umbra, has a most perverse habit of crossing our globe in inaccessible regions. The umbra touched down on the broad Pacific Ocean, for example, in the

Celestial gem: Sunlight bursting through a lunar valley produces the "diamond-ring effect," signaling the end of the total eclipse of March 7, 1970.

With support from the National Geographic Society, the authors led a 17-man expedition to the village of Miahuatlán in southern Mexico to record the dramatic alignment. Near the end of totality (left), astronomers Menzel, right, and Pasachoff gaze at the phenomenon, visible in their coelostat—a motor-driven mirror that reflects the eclipse into a spectrograph (next page).

eclipse of May 30, 1965, hitting only remote islands. On July 10, 1972, the shadow will cut through inhospitable areas of Russia, Alaska, and Canada, before leaving land at Nova Scotia. The following major eclipse, on June 30, 1973, will occur over the Sahara.

Washington, Oregon, Idaho, and Montana will lie within the umbral shadow on February 26, 1979. The U. S. East Coast must wait until August 21, 2017, for its next total eclipse.

Fortunately for professional and amateur astronomers, the eclipse of March 7, 1970, represented a welcome exception to the rule of inaccessibility. The last total solar eclipse to occur over the eastern United States in this century cast its shadow across the homes of more than a million and a half people from Mexico to Newfoundland.

Shadow Grazes Edge of North America

Starting over the Pacific, the umbra first touched land in southern Mexico (diagram, page 232). The wave of midday darkness crossed the Isthmus of Tehuantepec and traversed the Gulf of Mexico before striking land again in northern Florida. The shadow streaked up the coast of Georgia, South and North Carolina, and Virginia, then quickly swept across Atlantic waters to blanket Nantucket Island and touch Nova Scotia. The three-hour journey ended at sea beyond Newfoundland, 8,500 miles from touchdown point.

Undoubtedly more people traveled to see this eclipse than any other in history. Some fifty million people lived within a day's drive of the umbra's path, from 80 to 100 miles wide. Countless thousands lined highways and beaches during the eclipse, awaiting the two to three minutes of totality to watch a vision of rare beauty, the sun's corona. Totally or partially, the eclipse could be seen over nearly every section of North America.

Many interested scientists, however, established observation posts not in the populated centers of the East but in the mountains and valleys of southern Mexico. There we were promised the clearest weather and longest duration of totality, about $3\frac{1}{2}$ minutes.

Our 17-member expedition, sponsored by the Harvard College Observatory, the Smithsonian Astrophysical Observatory, and the National Geographic Society, chose as its base of operations the Indian community of Miahuatlán.* Some 300 miles southwest of Mexico City, the town lies in the midst of magnificent archeological remains from the Zapotec civilization. The state government at Oaxaca, 50 miles north of Miahuatlán, arranged for a suitable observation site and headquarters.

Our advance party arrived in Mexico on February 7, allowing only a month to set up our complex equipment. The temporary quarters delighted us. We had two rooms and the courtyard of an old music school, the Escuela Filarmonica Municipal, atop the tallest hill in town. The school's high adobe walls blocked the sweeping winds and dust, and offered protection from friendly but curious Miahuatlecans who might have unwittingly interfered with our work.

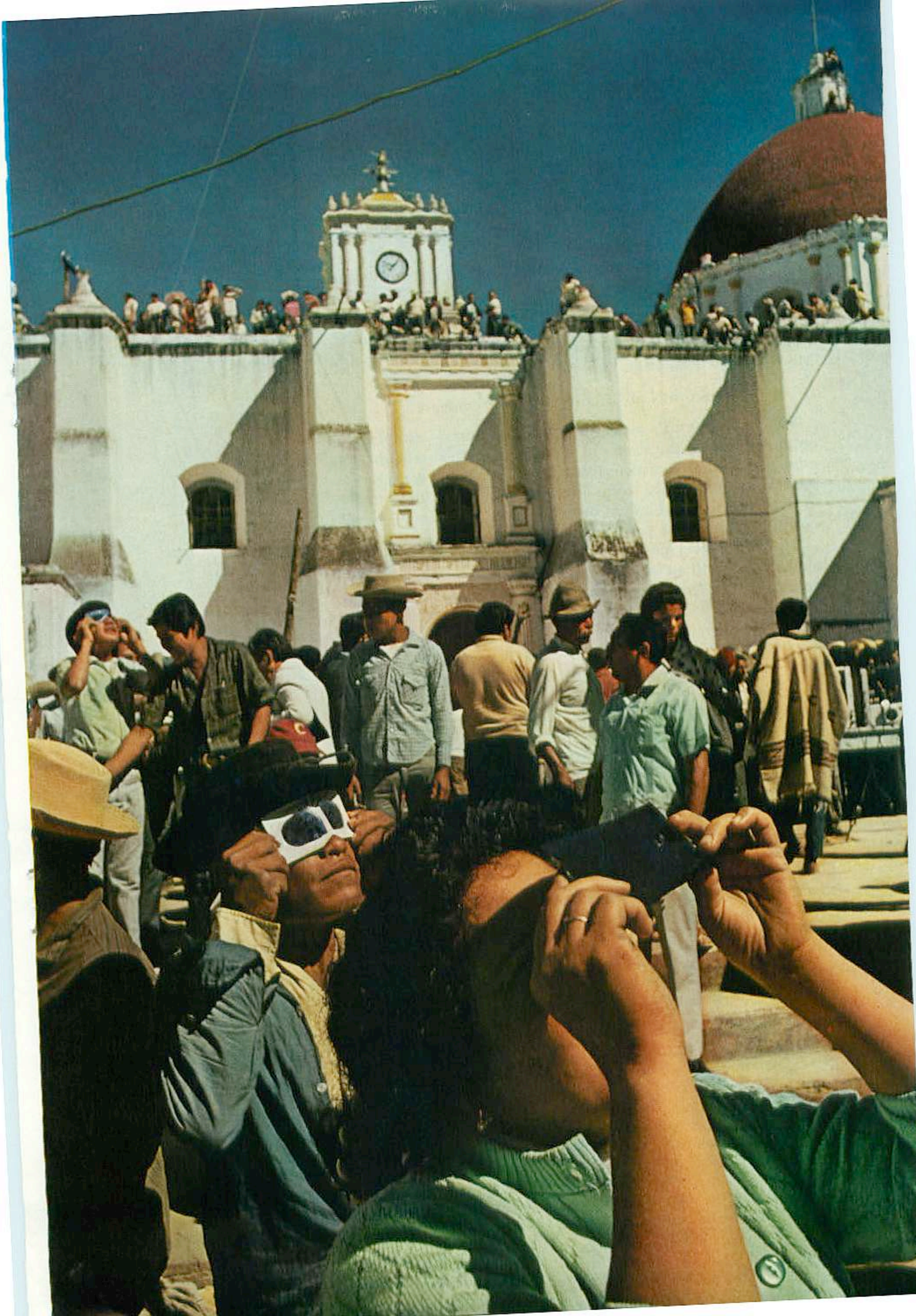
Electric lines, toilets, and running water—

*Additional support came from the Air Force Cambridge Research Laboratories; National Science Foundation; Austin Stanton Foundation; Duncan H. Read of Middleburg, Virginia; John J. Terlep of Pueblo, Colorado; and Videonics, Inc., of Cambridge, Massachusetts.

KODACHROMES BY ALBERT MOLDVAY (ABOVE) AND GUILLERMO ALDANA ESPINOSA © N.G.S.

Awesome rendezvous of sun and moon draws villagers to Miahuatlán's main square and cathedral roof. Some watch the progress of the eclipse through smoked glass or goggles of dense film. Eclipse day nearly doubled the population of this Indian town of 16,500; the area offered astronomers from more than a dozen nations clear skies and a long period of totality—3 minutes, 23 seconds.

Awaiting darkness at noon (left), Doctors Menzel, right, and Pasachoff check the solar image on the spectrograph that separates it into component colors for analysis. A ghost image of the partial eclipse, reflected in the camera lens, appears beside them.



even a hot shower—had been installed. We had our own telephone, a rarity thereabouts. Our number was easy to remember: Miahuatlán 7.

Bob Hamilton, our architect, directed local craftsmen who constructed a wood-and-aluminum structure for our delicate spectrograph. An adjoining patio provided an observation site for five Peruvian astronomers, who joined us later. They were led by Fernando de Romaña, an old friend who, during the eclipse of 1937, was the first person to photograph the corona with Polaroid filters.

One room within the school building served as our laboratory, darkroom, and storage space. The other, fitted with a stove and electric refrigerator, became our kitchen, dining room, and dormitory. We also moved cots and a bed into the nearby, as yet unoccupied, new store of the village mayor, Moisés López Ramírez.

Cooks in Nuns' Habits Help Astronomers

We ate most meals at an improvised restaurant established on our behalf by the sisters of the local parochial school. The nuns provided an indispensable—albeit somewhat confused—service. Unaccustomed to fussing over hungry guests, as many as five "chefs" in habit bent over the stove simultaneously, all carefully tending the same solitary omelet.

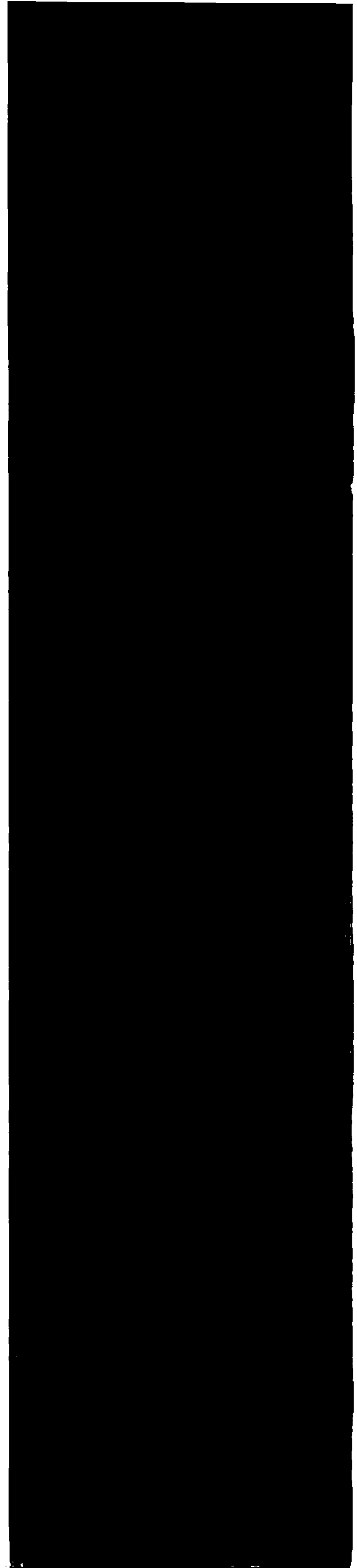
Observers from around the world converted the usually quiet region into an international community of several hundred scientists from more than a dozen countries. Compared with some others, our accommodations were plush.

The Russians, who had a large party of 32 astronomers, roughed it more than most on an open plain four miles away. Wind and dust swirled often around their tents, but did not inhibit their scientific or social activities (pages 228-9).

The three-week period of aligning and testing equipment to prepare for the big event passed quickly, but with occasional problems, which were not unexpected. An electric motor—which turned the guiding mirror to follow the sun—burned out. This caused some anxious moments. Fortunately, not an hour later a telephone call from Boston radio station WHDH asked how we were faring.

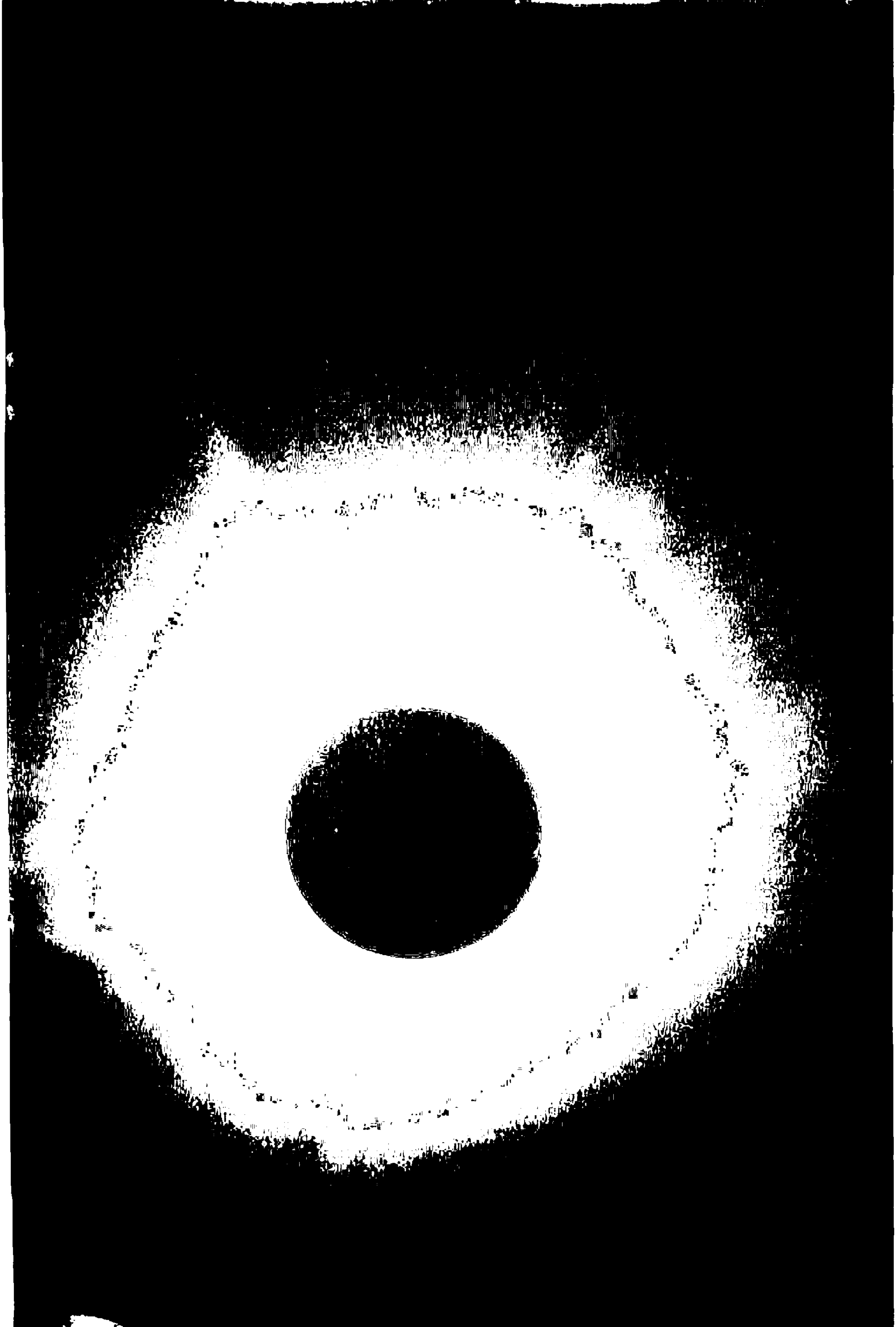
We explained about the motor and how to obtain a replacement in Cambridge. Within 24 hours we received assurance that a replacement was on its way, as indeed it was.

A week before the eclipse, all Miahuatlán assumed a carnival atmosphere. Perhaps the townspeople found the scientific value of the eclipse a bit vague, but they recognized a festive occasion. Nightly fiestas enlivened the *zócalo*, the village square, and everyone danced to music and Indian chants.



"Most exciting thing we have seen . . . streamers extending as far from the sun as have ever been photographed," said Dr. Menzel, veteran of 13 total eclipses. Films revealed the corona—the white-hot halo of luminous gas that is most visible when the moon blocks the sun's dazzling face—thrusting spikes more than five million miles into space. Tracing the energy from the pearly ring helps explain the makeup of the sun as well as the bombardments of radiation that may distort radio communications and endanger space travelers.

KODACHROME BY HARVARD COLLEGE OBSERVATORY-SMITHSONIAN ASTROPHYSICAL OBSERVATORY-NATIONAL GEOGRAPHIC SOCIETY EXPEDITION. EXPOSURE TIME 2 SECONDS AT F 8



Church bells clanged frequently and interminably, and nerve-shattering fireworks displays added a new dimension to the clamor. The supply of fireworks seemed inexhaustible. Within five blocks of our quarters, no fewer than seven factories turned out elaborate displays.

Though we tried not to think about it, one recurring situation bothered us. Each morning the sun shone brilliantly, but high cirrus clouds often drifted over before noon. Sister Maria Gutiérez Muñoz told us not to worry; this was a crazy month. *"Febrero es loco,"* she said, assuring us that March—and the day of the eclipse—would be better. She was right. Of the nine days immediately preceding the eclipse, seven were excellent.

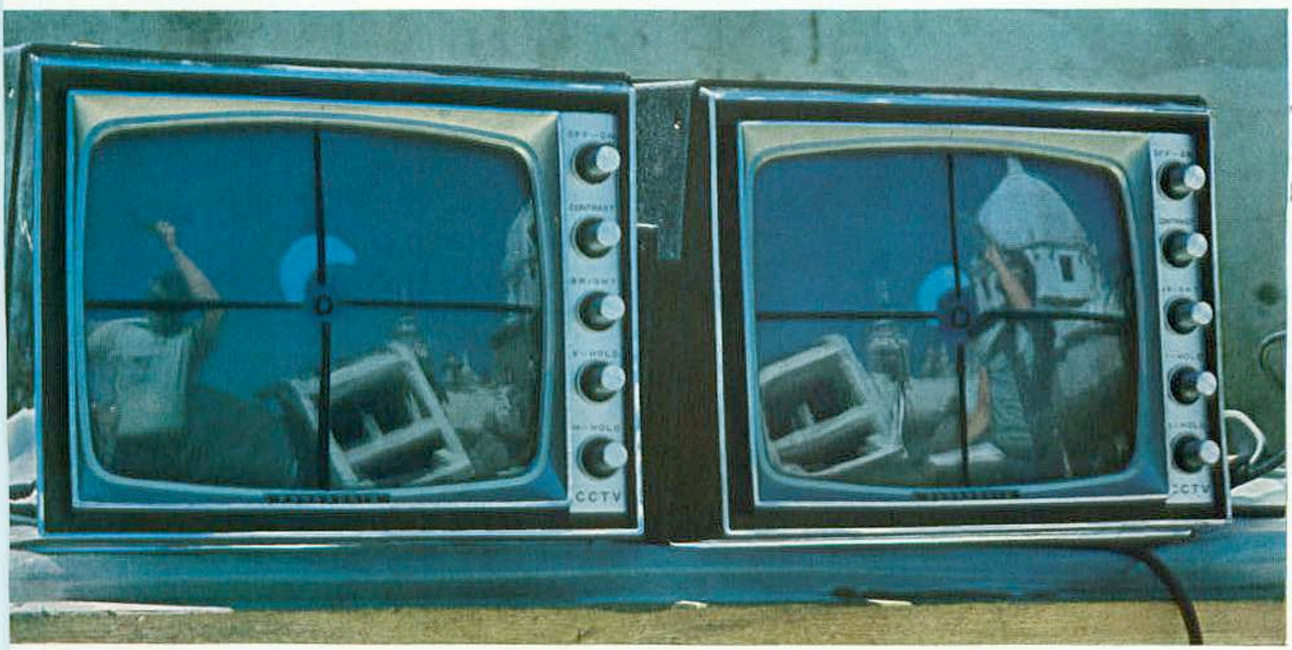
Sky Clears for Eclipse Day

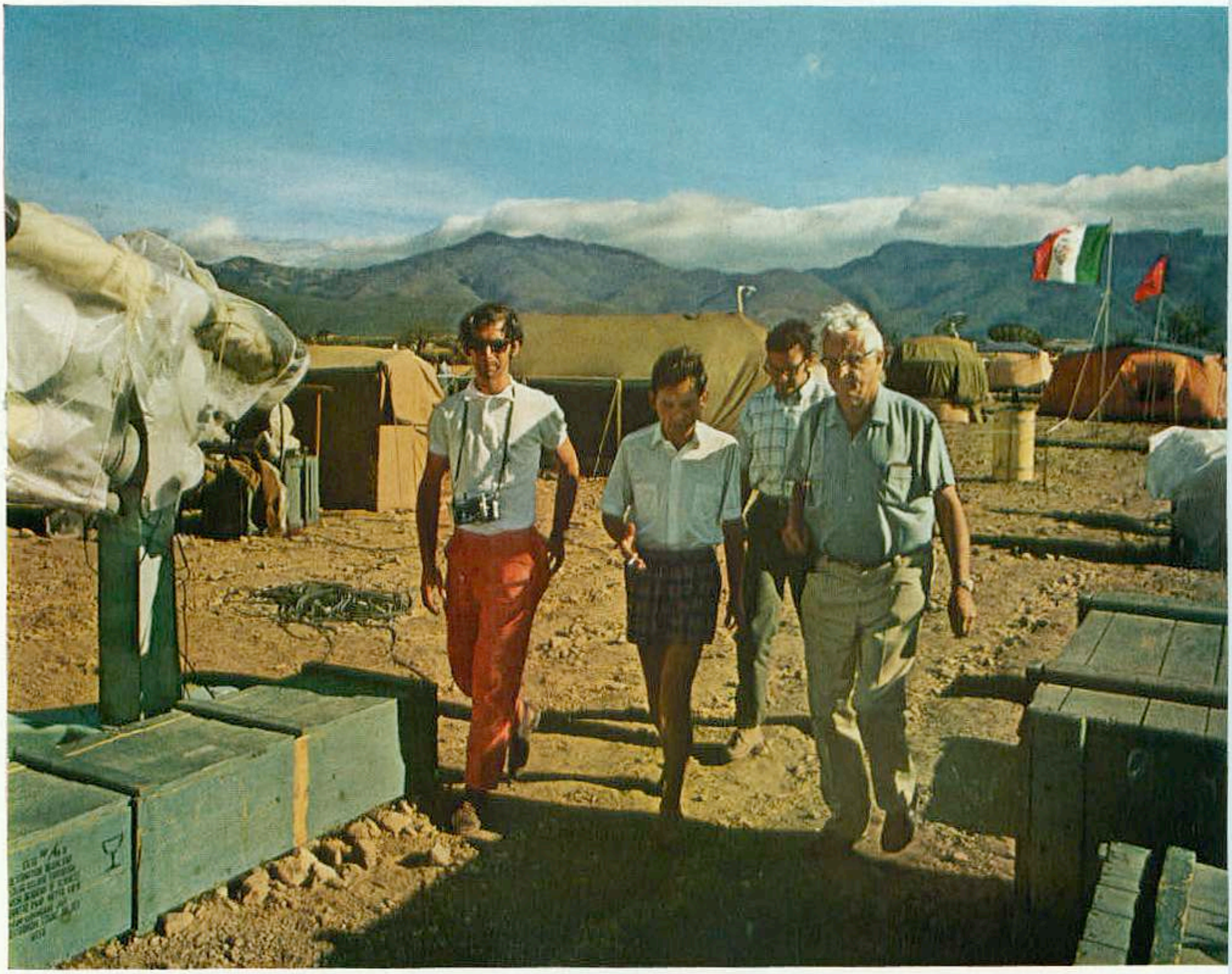
Rising at dawn on March 7, we saw no clouds anywhere. I am a specialist in beautiful skies, and I've never seen one more magnificent. The color was a deep blue, seldom seen except at much higher altitudes than mile-high Miahuatlán. Not the slightest trace of dust, fog, or cloud marred the view. It was the most perfect sky I had ever seen.

As the first contact of moon and sun occurred on schedule at 10:07 a.m., the sky remained unbelievably blue. The moon bit into the sun's disk about an hour and a half before totality, and we completed our final tests. The sun became a narrow crescent and, just before totality, the shadow bands—ripples of light and dark caused by irregularities in the earth's upper atmosphere—rushed over the ground.

My voice, counting off the seconds to totality, boomed from a tape recorder. We had made the recording a few days earlier so that we could devote all our attention to the spectrograph.

Our largest single piece of equipment, the spectrograph was designed by Dr. James G. Baker of Harvard, a leading specialist in optical systems. The instrument, which analyzes light by breaking it down into its component colors, is so massive that



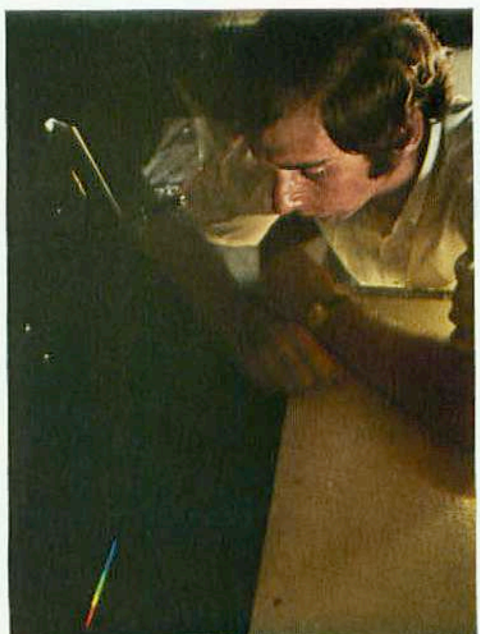


The universal urge to study the sun

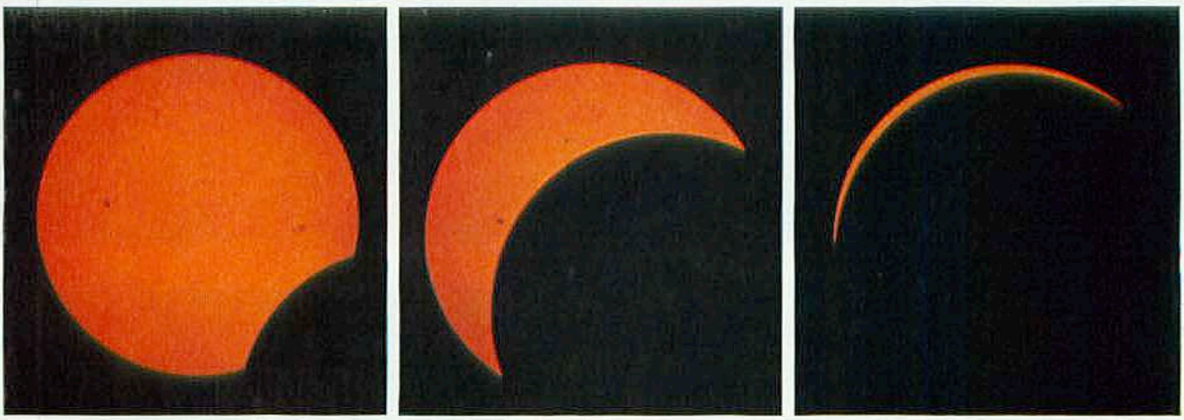
SOVIET GROUP LEADER Dr. N. V. Steshenko, center, escorts the authors and Mexican student Caesar Sepulveda, rear, on a tour of the 32-man Russian camp, one of the largest of more than 40 teams at Miahuatlán. Mexican and Soviet flags fly at right. Plastic cover protects a battery of telescopes, left, from dust. Clouds over the mountains never advanced to the plain; thin clouds overhead threatened for two days, but did not appear on March 7.

In the Harvard camp before "E-Day," Dr. Pasachoff opens the spectrograph (right), revealing the band of solar color. A dust-free hut housed the 1,500-pound instrument; only its first lens protruded.

During the eclipse, solar crescents appear in monitors (left) for TV cameras, used for the first time to measure polarization of coronal light. Video tape records the images for later study. Screens reflect two of the expedition's 17 members, Darrell Fernald, left, and Jeffrey Pitts, manning cameras beside a church.



KODACHROMES BY DAVID L. MOORE © N.G.S.



Tongues of luminous gas arch more than 25,000 miles above the sun's vanishing rim in the upper photograph, taken through a six-inch telescope in Kinston, North Carolina. Sunlight shines through the moon's irregular terrain in final gleams known as Baily's beads.

As the moon draws its slow curtain across the sun's face, the lower sequence—taken at Assateague Island, Virginia, with a 3½-inch telescope—reveals sunspots as dark specks, some larger than the earth.

Crescents quilt a wall in Annandale, Virginia (right), as light leaks through foliage and projects inverted images of the eclipse. Stephen Mazzatenta, four, watches near totality.

On a special Eastern Airlines flight (left), racing the moon's shadow over Nantucket Island, Massachusetts, Dr. Leonard Carmichael, Chairman of the Society's Committee for Research and Exploration, peers through dense film. Flares from the camera lens seem to float across the picture.

EKTACHROME BY GILBERT M. GROSVENOR © N.G.S.

KODACHROME BY JAMES J. KREBS AND RICHARD K. JECK © N.G.S.

KODACHROME BY O. LOUIS MAZZATENTA © N.G.S.

it cannot readily be pointed at the sky and turned to follow the sun. Instead, we built brick piers to support it horizontally, and a rotating mirror, called a coelostat, reflected the sun's image into the lens (page 224).

Our two and a half tons of equipment also included four television cameras (page 228) for recording the corona on video tape at different wavelengths through turning Polaroid filters. Measuring the polarization tells us how much of the light we see as the corona comes from the sun's upper atmosphere, and how much is sunlight scattered by dust particles between the earth and the sun.

We also used a special eclipse camera-telescope to photograph the sun through a polarizing filter oriented at different angles, and we used seven additional still cameras and two movie cameras to record the corona with various lenses.

For a change, we had enough people to handle all this equipment. My wife Florence, who had often assisted me at eclipses in the past, could relax and enjoy this one.

Wave of Night Sweeps Over the Camp

As we tended to our different assignments, the camp grew darker. Birds flew aimlessly above us. A distant rooster crowed. Then silence. The sky, by now reflecting a pink tint from the horizon, dimmed as if a storm were approaching. It grew noticeably colder. The solar crescent vanished behind the dark moon, and slivers of light—Baily's beads—sparkled momentarily through the valleys and crags of the lunar edge. The beads slipped away, leaving a quick flash, the "diamond-ring effect" (page 223), as the corona burst into view.

"Totality!" I shouted. Our programs of picture-taking already were in motion.

Jay, using a sheet of black foam rubber, acted as a human shutter for the lens of the spectrograph, avoiding the possibility of mechanical failure. I checked the guiding of the solar image in the coelostat. Others managed the cameras and telescopic gear.

Time stood still, but eventually Baily's beads peeked from the other edge of the moon. With sighs of relief and joy, we threw our arms around one another.

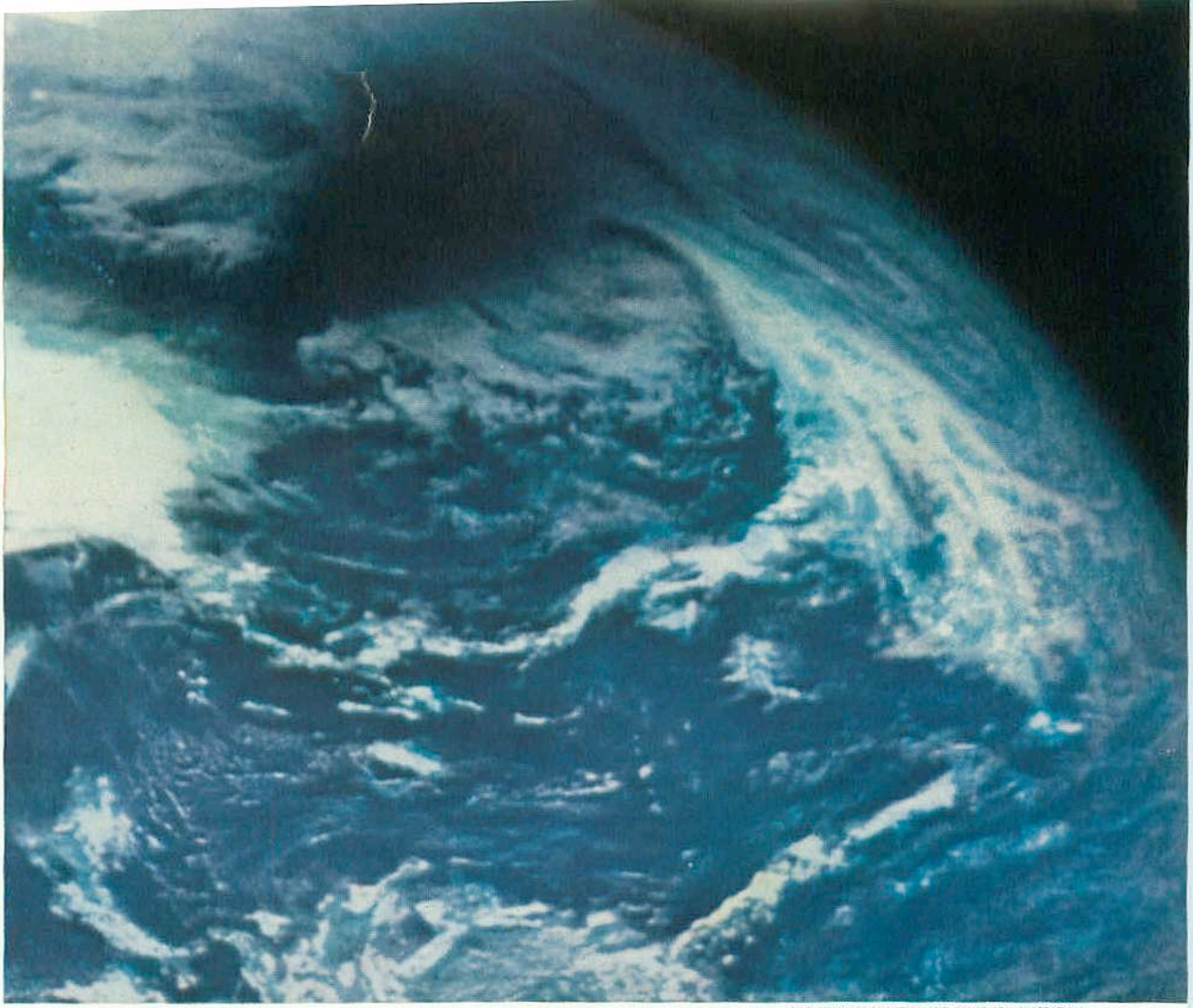
Some of our most intense work still lies ahead. Much of the data collected will be fed into machines and computers during the coming months. Even at this preliminary stage, however, we have reason to be excited. Amazingly, our auxiliary cameras gave us a thrilling prize: perhaps the longest solar

"I will darken the earth in the clear day" AMOS 8:9

VIEW FROM A NASA SATELLITE, poised in synchronous earth orbit 22,300 miles over Quito, Ecuador, offers the first look from space at an entire eclipse shadow, the dark umbra surrounded by the fuzzy, lighter penumbra. Like an ink stain on the earth's bright face, the moonshade shrouds Newfoundland just before slipping off into space. The United States and Mexico, with Baja California clearly visible at left center, lie partly covered by clouds.

Whimsical sketch (right) by Dr. Menzel, well-known among academic colleagues for his scientific doodles, depicts the path of totality. Drawn with a toothy grin, Comet Bennett, visible during March, watches the scene. Point of the conical umbra touches earth about every 18 months on the average and most often on oceans or inaccessible land. Streaking 8,500 miles in three hours, this shadow skimmed the populous Eastern Seaboard. It was the last total eclipse the eastern United States will see in this century.

SOLAR ECLIPSE OF MARCH 7, 1970
AS SKETCHED BY DR. MENZEL



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streamers ever photographed (pages 226-7).

The sky's extreme clarity enabled us to see those spikes jutting out at least five diameters from the sun. Streamers I had seen in the past extended barely two diameters.

These rays tell us much about the nature of the corona. The streamers' great length convinces me that interplanetary dust contributes little to the brightness of the outer corona, and that the role of dust has been greatly overestimated. This evidence has enormous significance in our quest to learn how much of the light we see comes directly from the sun's outer atmosphere and how much results from reflection by particles in space.

The answer to this question, and others, would have immediate application. For example, we must learn what we can about the solar wind, the outer corona blowing by the earth. Further, if a major blast of protons from a solar flare were to strike an astronaut, the effect would be much the same as would be caused by radiation from an atomic blast. Most important, eclipse studies also help us to understand the sun itself.

The final fiesta at Miahuatlán, overflowing with joy and gratitude for completely successful expeditions, lingers in our thoughts as we ponder the test results at our observatory. Even the people of the village—some of whom had expressed misgivings about the entire affair—seemed reassured now that the crisis had passed. Though missionaries had tried for weeks to calm the Indians, many clung to the belief that the sun and moon would "bump" and be lost forever.

At least one senior citizen actually relished the experience, however. A Mexican colonel assigned to Miahuatlán explained later, "This wise old man of the village said that he enjoyed the festivities and excitement, and wondered if you couldn't make the eclipse an annual affair."

We wish we could.