COSMIC RAYS AT THE NORTH POLE

Cosmic rays have been studied at the earth's surface, at the bottoms of lakes and mines, and high in the atmosphere. Now Caltech researchers are studying them at the north geomagnetic pole.

by LYMAN FRETWELL '56

COSMIC RAYS are invisible but powerful charged particles that constantly bombard the earth's surface. They are so numerous that at sea level about 10 particles will pass through a person each second. Their energy is so great that they are found even at the bottom of the deepest mines, having penetrated hundreds of feet of rock.

The most powerful of these rays has a thousand billion times as much energy as is released from a single uranium atom in an atom bomb explosion. Our biggest accelators today produce particles of about five billion electron volts, but cosmic rays have energies as high as a billion billion electron volts. In fact, the energy reaching the earth in the form of cosmic rays is roughly equal to that reaching the earth as starlight (excluding our own sun, of course). Geological evidence indicates that cosmic rays have continued their bombardment of the earth for at least 35,000 years, and studies of meteorites indicate that they have been bombarded by cosmic rays for hundreds of millions of years.

Cosmic rays have been studied, however, only for about the last 50 years, and Millikan, Anderson, Pickering and Neher at Caltech have figured prominently in much of this work. Cosmic rays have been studied at the earth's surface, at the bottoms of lakes and mines, and high in the atmosphere by means of airplanes, balloons and rockets. In recent years Dr. H. V. Neher, Caltech professor of physics, has been studying them at the north geomagnetic pole.

The particles originally entering the earth's atmosphere from outer space are known as primary cosmic rays. But very few of these primaries ever reach the earth's surface; they interact with the atoms in the earth's atmosphere, producing other particles known as secondaries. The primaries are known to consist of about 88 percent protons (hydrogen nuclei), 10 percent alpha-particles (helium nuclei), and the remaining 2 percent heavier nuclei such as oxygen, nitrogen, carbon and on up to at least iron, following roughly the abundance of the elements in the stars as determined by astronomers. This might lead one to wonder if cosmic rays originate in the stars. Some cosmic rays are in fact known to come from rare solar flares, but the majority do not seem to originate in the sun. Just where they do come from and how nature accelerates them to such high energies remains a problem to be solved.

Studies of individual cosmic ray particles in Wilson cloud chambers have resulted in the discovery of the positron, of mesons, and of many other particles believed to relate to the nucleus and what holds it together. Studies of this type have established cosmic rays as a source of particles of extremely high energy, through the use of which fundamental nuclear processes can be examined—just as they are with a high energy particle accelerator.

No less important for our knowledge of nature is our understanding of the cosmic ray particles themselves, and their effects upon our atmosphere and upon us. Much is to be learned from studying large groups of particles rather than individual particles; this is usually done by means of ionization chambers and Geiger or scintillation counters.

One of the properties of cosmic radiation is the so-called latitude effect, which describes the variation in the energy and intensity of cosmic rays with geomagnetic latitude. The earth's magnetic field interacts with cosmic rays approaching the earth just as a magnet will act on any charged particle passing near it. This makes the particle move in a curved path, the radius of the curve being smaller as the energy is less. Thus a particle coming toward the earth will be deflected and may even be sent back into space if it does not have sufficient energy to penetrate to the earth's surface. This bending effect is least at the geomagnetic poles and greatest at the equator (in fact, at the equator a particle must have an energy of at least 10 to 12 billion electron volts in order to reach the earth's surface). Thus, studying cosmic rays in different places seems to be such a good way to locate the geomagnetic poles and equator that a plane is now being equipped to do just this.

Only at the geomagnetic poles can cosmic rays of low energy come near reaching the earth—and even there, only to the top of the earth's atmosphere. It is to study these low-energy cosmic rays at high altitudes that Dr. Neher has been making trips during the past few years to the region of the north geomagnetic pole. In the summers of 1951, 1954 and 1955 he made trips to northern Greenland, where his main base of operations was Thule, a small spot in the northwest corner of Greenland only a few hundred miles from the north geomagnetic pole. Neher made all his cosmic ray observations last summer at Thule itself, since previous observations had indicated that cosmic rays behave essentially the same there as at the pole.

Life on an icebreaker

Neher was taken to Thule on the *East Wind*, a U.S. Coast Guard icebreaker. Since Thule is well above the Arctic Circle, one must get used to a land where the sun never sets, but the ever-present light, of course, did not keep the Coast Guard from maintaining a strict schedule aboard ship; breakfast was served between 7:00 and 8:00, lunch at 12:00 or 12:30, and dinner at 5:30. Then a movie was usually shown in the "evening."

The food and living accommodations aboard ship were quite good; it was not too difficult getting used to the continuous sunlight and the roll of the ship, and a good night's sleep was just as easy to obtain aboard the *East Wind* as at home—except when the ship was plowing through ice, that is.

The charging, the grinding halt as the ship rose up on the ice, the slow return to the sea, then the backing up to start over—this was something Neher never did learn to sleep through.

Icebreakers are a sturdy lot, with rounded bottoms and carefully braced sloping hulls to withstand the terrific impacts with the ice. This special construction is necessary because of the way an icebreaker makes its attack; it backs off, gets a running start, and slides up on the ice. The weight of the ship then breaks the ice, and the ship settles back into the water. Because this method of icebreaking puts a terrific stress on the hull, the ship is divided into water-tight compartments. In fact, the ice struck back at the *East Wind* in 1954 and punched a large hole in her, so that the expedition was forced to turn back to Thule a good deal sooner than it had planned.

The perils of research

Neher was glad that the *East Wind* had a rounded hull when, during the trip north of Thule in 1954, ice began to jam together around the ship. The force of the wind-driven ice would crush the hull of a normal ship, but the icebreaker's rounded bottom merely caused it to be lifted high and dry. The *East Wind* was trapped this way for three days. All aboard calmly got off the ship and proceeded to explore the ice sheet mashed together around them; it was easily solid enough to walk on, being eight to ten feet thick. They knew that there was nothing they could do but wait for the wind to change, as it inevitably must. And surely enough, on the third morning they awoke to find no trace of the ice that had held them captive the two previous days; it had blown away and out of sight during the night.

(A rounded bottom has its evils, too; Neher vividly recalls the time the ship was rolling 30 degrees each way from the vertical. But this was nothing to the crew, who had experienced a 60-degree roll—and even less to the ship's builders, who had designed the ship to take an 87-degree roll without capsizing).

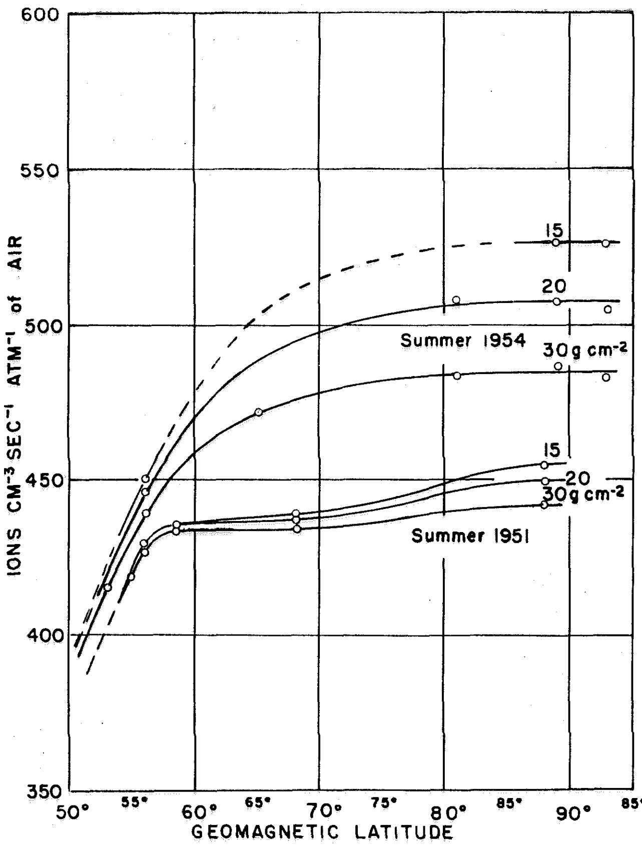
To measure the cosmic ray intensity at high altitudes Neher uses an ionization chamber. In this type of instrument the gas ions produced by the cosmic rays discharge a gold-plated quartz fiber, just as a familiar gold-leaf electroscope can be discharged by X-rays. In its discharge this fiber eventually makes contact with a second plated quartz fiber connected to the grid of a vacuum tube. This causes a radio pulse to be sent back to the recording device and at the same time deposits a new charge of electricity on the movable quartz fiber. Thus the frequency of pulses sent back is a measure of the rate of discharge of the electroscope, and therefore of cosmic ray intensity. Neher's equipment can measure the intensity to an accuracy of a few tenths of a percent. In addition to this information, other signals are sent out, giving the temperature and the atmospheric pressure around the device. The whole unit—transmitter, ionization chamber and power supply—is attached to a helium-filled balloon and is sent aloft; last summer one of the balloons reached a height of almost 24 miles before bursting.

In 1954 Dr. Edward Stern, then a graduate student, went along with Dr. Neher to Greenland. At the same time that Neher was making his flights, two other graduate students, Alan Johnston and Robert Morris, sent up similar flights at Bismarck, North Dakota, for purposes of comparison.

Some of the results of Dr. Neher's trips are shown in the accompanying diagrams. The one at the right shows that there was not much difference in the cosmic rays at Bismarck (55°N.) between 1951 and 1954, but there was quite a difference near Thule (88°N.). Since the weaker cosmic rays could not reach the earth at Bismarck because of the earth's magnetic field, but could reach the earth near Thule, this curve seems to indicate that much more low energy cosmic radiation was present in 1954 than in 1951.

Weaker cosmic rays would also be more strongly absorbed in the upper atmosphere than their more powerful relatives. The diagram below shows that the ionization (and hence the number of cosmic rays) was greater in 1954, and the upward swing of the 1954 curve toward the left indicates the presence of relatively more low energy rays in 1954 than in 1951. Hence it appears that low energy radiation reached the earth in considerably greater quantities in 1954 than in 1951.

Why should this be so? According to Neher, the explanation that seems most plausible at the moment is one that has been blamed for everything from the weather to politics—the sunspot cycle. In 1951 there was a fair amount of sunspot activity; 1954, on the other hand, was the quietest year for sunspots in 24 years. It is known that when sunspots occur, large amounts of matter may be shot out from the sun. These clouds of ionized gas could possess fairly strong electric and magnetic fields, and thus prevent some of the weaker cosmic rays passing near them from reaching the earth.



Recordings at Bismarck (55° N.) and Thule (88° N.) show more low energy cosmic radiation in '54 than in '51.

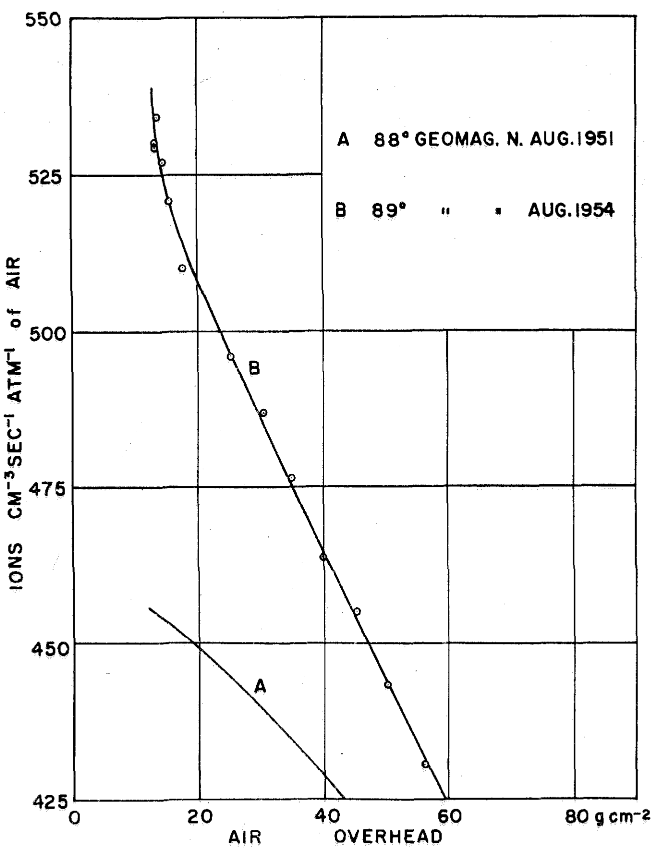


Diagram shows that the ionization (and hence the number of cosmic rays) was greater in 1954 than in 1951.

If this is the correct explanation, we might have expected to find more variation in the day-by-day cosmic ray intensity in 1951 than in 1954, due to the random nature of the sunspots and the matter they emit. Just such a difference in the variation was actually observed to exist.

It is still too early to evaluate the results of last summer's work, other than to say that it seems to agree with the solar-cycle hypothesis in a general way. It must still be shown conclusively that the cosmic ray curves tie in with sunspot intensity, and it must also be ascertained that there are not other factors contributing to this change in low energy cosmic radiation (for instance, contrary to supposition, cosmic radiation from outer space may not be constant). But it does seem that low energy cosmic rays may provide a valuable tool for studying the regions of space in the planetary system, and they may provide some clue as to the origin of cosmic rays. Only time can tell just how important they may be to interplanetary studies. And even when this last summer's work has been fully analyzed and interpreted, the final chapter to this story will not have been written, for Dr. Neher is planning to go back to Greenland again next summer and to the Antarctic the following winter.