NATURE'S MOST DRAMATIC SPECTACLE

By S. A. Mitchell

Scientific Leader, National Geographic Society-U. S. Navy Eclipse Expedition, 1937 *

With Illustrations from Photographs by Richard H. Stewart

LIKE a hungry small boy sitting down to Thanksgiving dinner, an astronomer at a total eclipse of the sun is there to get all he can while he has the chance. The boy is determined to stuff himself with as much turkey as possible while it lasts, and the astronomer is eager to gather in all the knowledge of the sun that he can during the brief few minutes of favorable conditions created by a total eclipse.

A real "eclipse feast" on June 8, 1937, was the happy lot of the National Geographic Society-United States Navy Expedition to Canton Island, far out in the mid-Pacific (maps, pages 364, 380).

To digest this "Thanksgiving dinner of knowledge" and prepare its complete results will take many months, but I can give National Geographic Society members at least a preliminary report of what we learned and why we were anxious to travel to a place 6,500 miles from home to see the sun eclipsed for only 213 seconds.

A LITERAL "CHANCE OF A LIFETIME"

A total eclipse of the sun takes place about once every three years in some part of the earth accessible enough for astronomers to view it, and even then clouds or rain may blot out the sight and render a long journey and large expense futile.

Why not study the sun at home, where it may be seen any day? Because some of the most important features of the sun can be observed only during an eclipse, when the moon shuts off the glare of the sun's light, or can be seen best at that time.

Scientists starting out for an eclipse are truly "grasping the chance of a lifetime," because the average eclipse lasts only about three minutes. Therefore an astronomer, with the best possible luck, cannot expect more than one hour's total time for observing eclipses in his entire life!

No wonder then that astronomers are willing to gamble on the chance of bad weather and travel half around the world, risking disappointment, as has often happened, or like Father Stephen Perry, leader of a British expedition to Cayenne, French Guiana, in 1889, to carry on even when taken suddenly ill, and knowing death is near.

With observations successfully completed the stricken scientist called for three cheers, saying, "I can't cheer myself, but I'll wave my helmet!"

Our own expedition, fortunately, was marred by neither illness nor accident, but we did defy the gods of bad luck enough to arrive at our island on May 13, and set up camp on shore with 13 scientists and officers and 13 sailor assistants!

But thirteen must have been our lucky number. The skies over the island were clear and free of haze throughout the total phase of the eclipse, and our observations were made under conditions practically ideal, which rarely have been excelled in eclipse history.

Astronomers do not travel to a desert island, as we did, or to some other remote part of the world, merely to be spectators at the gorgeous spectacle of an eclipse of the sun. More than one scientist has traversed vast distances to observe an eclipse, knowing all the time that he would not see it himself, because while it goes on he must remain shut up in a dark room to operate his apparatus.

The scientists of our own expedition, busily working their instruments most of the time, had a chance to look at the eclipse only for a few seconds of the total duration of three and one-half minutes.

Why make photographs and other observations of the eclipsed sun?

One striking answer is the fact that, as a direct result of observing eclipses, we

* Herein the National Geographic Society presents to members a preliminary report of the highly successful eclipse expedition jointly sponsored by their Society and the U. S. Navy. Dr. S. A. Mitchell, the scientific leader, is Director of the Leander McCormick Observatory, University of Virginia, and President of the Commission on Eclipses of the International Astronomical Union. Captain J. F. Hellweg, U. S. N., commanding the Navy detachment (page 377), is Superintendent of the U. S. Naval Observatory, Washington, D. C. "A brilliant success, far beyond our most extravagant expectations, has attended our venture," was Dr. Mitchell's preliminary bulletin to The Society's headquarters. It will require many months for complete study of all the expedition's findings.

TO THE "CANTONESE" CRUSOES THE U. S. S. "AVOCET" WAS A SILENT SYMBOL OF GETTING BACK HOME

The Navy seaplane tender, which brought the Expedition from Honolulu to this desert isle, found a good anchorage off the mouth of the lagoon. The tidal current had piled up two humps of coral sand on the ocean bottom, which enabled the skipper to locate shallow water (page 381). Some of the crew stayed aboard the ship; others were assigned to help the scientists.

actually know more about the distribution of gases in the atmosphere of the sun, 93,000,000 miles away, than we know of the earth's atmosphere only 20 miles above our heads.

ECLIPSES HELP SET WORLD'S WATCHES

A second answer perhaps comes closer home.

The alarm clocks that awaken us in the morning are set by radio time signals from the U. S. Naval Observatory, and owe at least part of their accuracy to observations during eclipses of the sun.

Only during an eclipse can scientists make certain checkups on the movements of the sun, moon, and earth, in relation to one another and the stars, which relation forms the basis of our whole time system.

Our expedition "checked up on the solar system" again during this eclipse.

This is done by noting the exact times of the four "contacts," that is, first, when the edges of the sun and moon appear to touch, and the moon begins to move across in front of the sun; second, when the sun disappears behind the moon (beginning of totality); third, when the sun begins to emerge (end of totality); and fourth, when the sun emerges completely (page 363).

The contacts were timed visually by Captain J. F. Hellweg, Superintendent of the Naval Observatory, who was in charge of the Navy's participation in the expedition. Mr. John E. Willis, also of the Naval Observatory, timed them photographically.

These data will be extremely useful to

the Naval Observatory in its time calculations, as well as in predicting future eclipses.

SUN AIDS RADIO RECEPTION AND BALLOON FLIGHTS INTO STRATOSPHERE

The sun not only helps tell time, but even makes possible the transmission over long distances of the radio signals that bring the time to us. Scientists now believe that ultraviolet light from the sun produces the ionosphere, or radio-reflecting layer high in the air, which keeps radio signals from being lost in space, and enables them to travel around the earth.

Experiments were made to determine whether the transmission of radio signals would be affected by the eclipse, which data would give us additional knowledge about the different parts of the radio-reflecting layer. Results of these experiments are now being studied.

During an eclipse of 1868, astronomers found on the sun traces of a new chemical element, previously unknown. What good is it, one may ask, to discover something on the sun, 93,000,000 miles away?

This new element was helium, and 27 years later, in 1895, it was recognized on earth. Today it carries our dirigibles and balloons * safely through the skies and is used in treating divers to prevent the dread "bends."

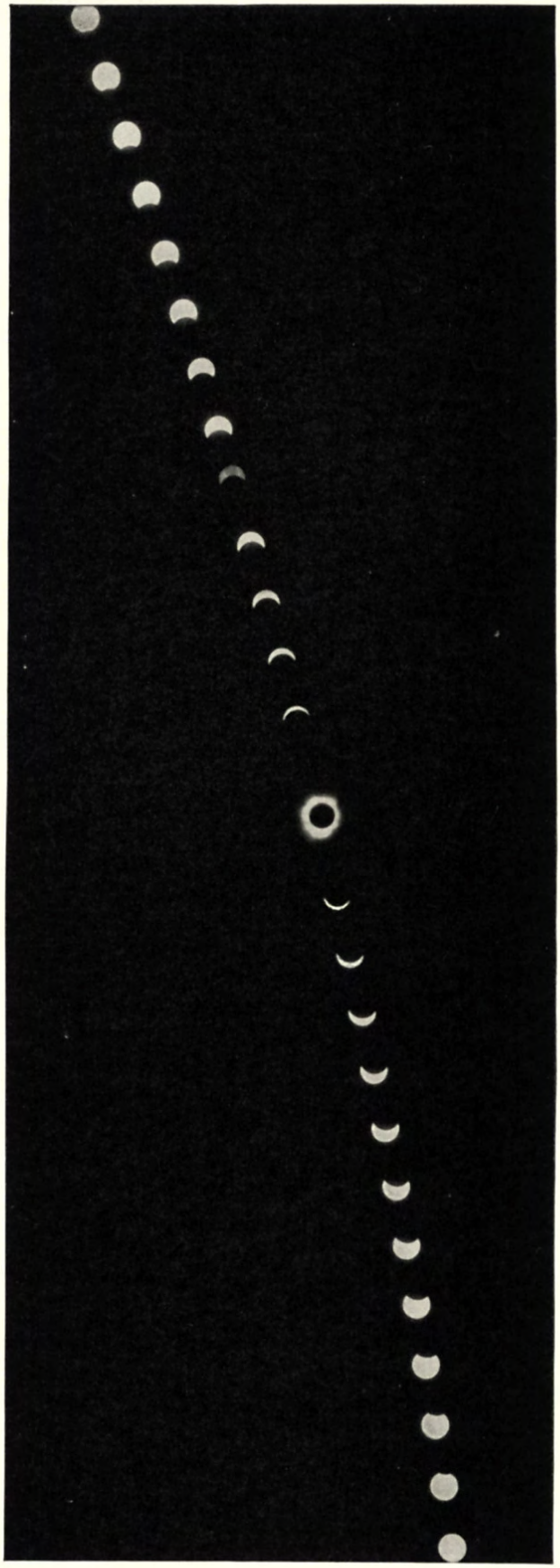
Possibilities from the study of the sun are almost limitless, even though it is really an old and not very important sample of the vast family of stars. For the sun actually is a star, and a very ancient star at that, one of the class of stars called by astronomers "yellow dwarfs."

It enjoyed its flaming youth eons ago, passed its prime billions of years back, and is now slowly cooling, heading toward inevitable death, though that time, luckily for us, is still uncounted millions of years away.

"MOTHER SUN" AND "BABY EARTH"

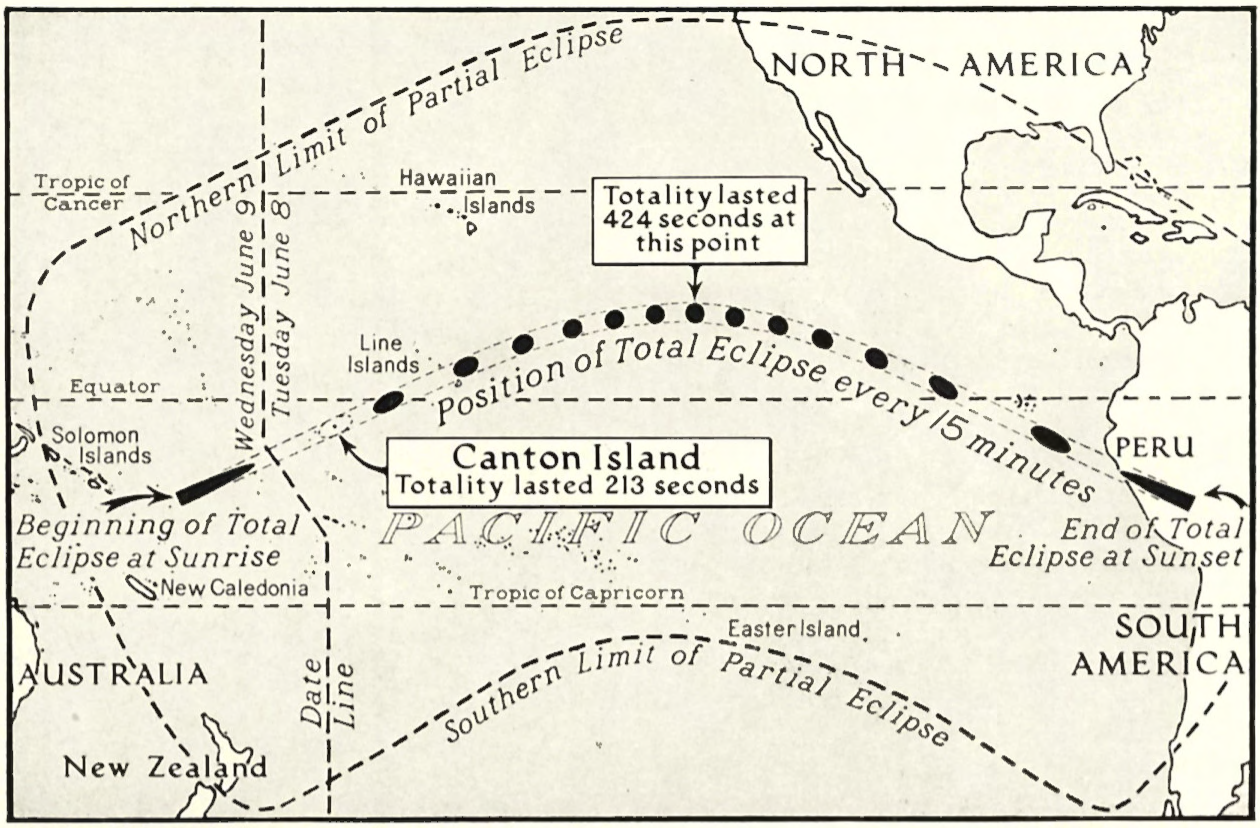
We speak of "Mother Earth," but more properly we should speak of "Mother Sun." For from her body our own earth was born, according to one widely accepted theory, long ago when the gravitational attraction

* Helium, a noninflammable gas, made it possible to carry out in complete safety the National Geographic Society-U. S. Army Air Corps stratosphere flight of November 11, 1935, which attained a new altitude record of 72,395 feet and accomplished important scientific observations.



ECLIPSE PRINTS IN THE SKIES OF TIME

Exposures made every five minutes for more than two hours show how the eclipse progressed (from bottom to top). The moon gradually moved across the sun, then covered it completely, with the corona flashing into view (center), then slowly uncovered the sun again.



Drawn by Newman Bumstead

THE ECLIPSE OF 1937 WAS THE LONGEST SINCE 699 A. D. AT THE CENTER OF ITS 8,800-MILE PATH

The duration, boon to astronomers, was because the sun and moon were far apart and the moon relatively close to the earth, and also because the path lay near the Equator. Unfortunately, the maximum duration, 7 minutes, 4 seconds, was 1,200 miles from land. On Canton Island it lasted 3 minutes, 33 seconds, the precious working time which culminated months of laborious preparation. Black spots along the eclipse path show how the shape of the shadow varied as it traveled for 3 hours and 21 minutes from a point about 1,500 miles northeast of Australia to Peru. Within the large area enclosed by the heavy dotted line a partial eclipse was visible, with the moon moving part way over the sun and then retreating. The next eclipse of comparable duration will be June 20, 1955.

of another star, passing close, pulled a long streamer of matter out from the sun until it was detached, cooled, and broke up to form the planets.

Like a true mother still, the sun makes possible all life that exists on earth. It gives us light, the heat that sustains us, the wind that cools us, and long ago manufactured even the coal that today warms us in winter and runs our factories.

Without the sun there would be no flowers, no grass, no crops to feed us, no animal life, not even man himself. If the sun were blotted out for a single month we should all be frozen to death. Even the air would freeze and fall in a final mighty blizzard.

Moreover, without that invisible "apron string" of gravitation, 93,000,000 miles long, which ties us safely to Mother Sun, we would long ago have gone hurtling off into the depths of space, doomed to an end that no man knows.

Because it is the only star near enough to give us a chance to study it "close up," the sun can teach us much about the countless other stars which probably we will never see except as pin points of light.

There is every reason, then, to learn all we can about the sun. We can scarcely agree with the schoolboy's naïve statement that the moon is a more important body than the sun because it gives us light at night when it is dark and we need its light, whereas the sun shines in the daytime when it is light and we could possibly get along very well without it!

CHASING AN 8,800-MILE SHADOW

Every so often, as the moon moves around the earth, it comes directly between the earth and the sun. Then its round shadow falls upon the earth, and those within the area covered by the shadow see the sun in total eclipse.

This year, on June 8, the moon came into

THREADING A NEEDLE IS EASY COMPARED TO THE INFINITE CARE IT TAKES TO PLACE ECLIPSE INSTRUMENTS

Sighting through a surveyor's transit, to insure that his apparatus is pointed with hairbreadth precision, is Dr. S. A. Mitchell, scientific leader of the expedition. Days of exacting work were required to make perfect adjustments of his three spectrographs, mute detectives of solar atoms (369).

such a position that its shadow, about 150 miles wide, swept 8,800 miles across the Pacific Ocean, from a point northeast of Australia to the mainland of Peru (p. 364).

Because of the time of the year, relative distance of the sun and moon from the earth, and nearness of the eclipse path to the Equator, the duration of darkness at the middle of the path of this eclipse was the longest in any eclipse in 1,238 years.

SUN'S LIGHT CUT OFF MORE THAN 7 MINUTES IN MID-PACIFIC

At the middle point, about 1,800 miles southwest of Los Angeles, in the Pacific, the moon blotted out the sun's light for 7 minutes and 4 seconds, longer than it had been shut off by any eclipse since 699 A. D., the year after Carthage was utterly destroyed.

Of course all the astronomers in the world would have liked to go to that point to observe the eclipse, during the long dimming of the sun.

But unfortunately there is no land there; no land, in fact, within 1,200 miles of the place in any direction. Modern instruments with which an eclipse is observed must be mounted on solid concrete on solid ground.

Moreover, as though Nature were playing a gigantic joke to tease the astronomers, it developed that there was almost no land at all throughout the entire 8,800 miles of the eclipse shadow's path across the Pacific.

Far toward the western end of the path were Canton and Enderbury Islands, part of the Phoenix Group,* and far to the east the shadow just before sunset would touch the mainland of Peru.

At these points the duration of the eclipse would be much shorter than at the middle of the path, but still long enough to make it well worth observing.

We chose the islands, remote and little-known as they were, because there the sun would be fairly high in the sky during the eclipse, 22 degrees, while in Peru it would be almost set at eclipse time.

The Chief of Naval Operations, Admiral William D. Leahy, arranged for us to be taken to the islands by the Navy seaplane tender, *Avocet* (page 362).

* Other islands in the Phoenix Group were in the path, but too far from its center for satisfactory observations.

LIKE A BATTERY OF WEIRD ARTILLERY, ECLIPSE INSTRUMENTS ARE AIMED AT THE SUN

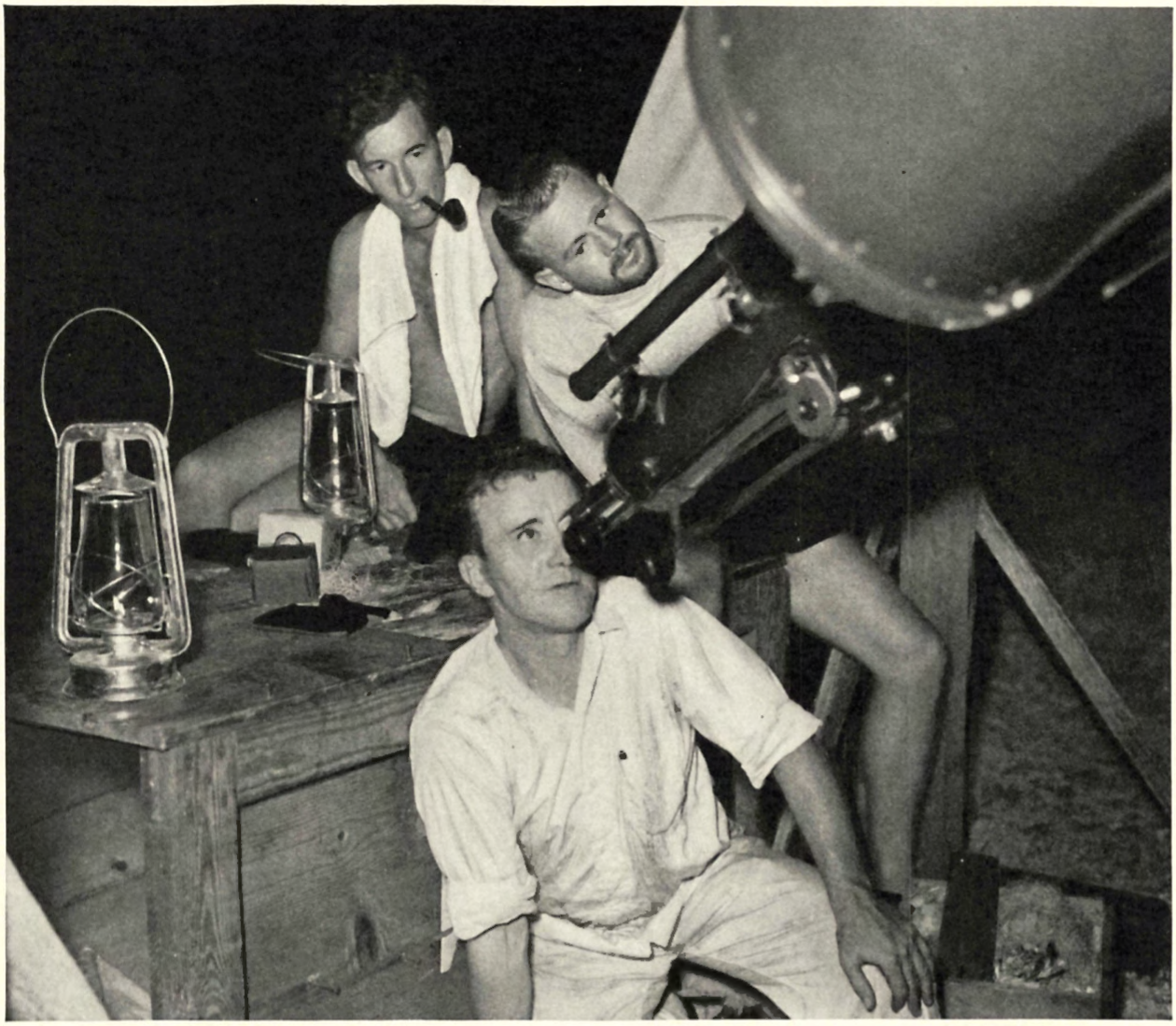
Under the canopy, left foreground, the long box with the four black squares on its end is the first "polaroid camera" used successfully at a solar eclipse (pages 370, 371, 372). It was operated by Dr. F. K. Richtmyer, of Cornell University (right, under tower). On top of the tower is his "driving clock," which kept his instruments constantly pointed at the sun as the earth whirled on its way during the eclipse. The clock was run by a weight, shown hanging under the tower, improvised by Dr. Richtmyer out of old iron from a wrecked ship on the island. In left background is the cannonlike camera of Dr. Irvine C. Gardner of the National Bureau of Standards (page 375).

A PERT FRIGATE BIRD SNATCHES A TWIG FROM DR. MITCHELL

This is good practice for its future occupation, stealing fish or squid from boobies and terns. Big as it is, the youngster is not old enough to fly from the nest. These feathered pirates, common on Canton Island, are known also as man-o'-war birds (page 390).

CHARLIE AND JACOB SHOW A FLARE FOR FISHING

Their kerosene torch lures prey toward them in a shallow part of the lagoon. Once, while angling with a spear, Charlie barely escaped from a big blanket fish, dread denizen of these waters (page 387). The two Hawaiian boys were taken aboard the *Avocet* in Honolulu.



YOU SQUINT AT A STAR TO "GET THE RANGE" ON AN ECLIPSE

To avoid wasting precious seconds in adjusting their cameras after contact begins, astronomers focus on the stars night after night ahead of time. Here the Reverend Paul A. McNally, S.J., is looking through an eyepiece at a more distant star to train his cameras on our closest star, the sun. During the eclipse he spent his time exposing photographic plates. Everybody on Canton Island saw more of the eclipse than the astronomers; the latter were busy with their recording apparatus. Two members of the *Avocet's* crew are watching how it is done.

Her commander, Lieut. T. B. Williamson, and his officers and men were most valuable members of the expedition, and the cooperation of the Navy was in every way efficient and helpful.

After finding that Enderbury Island lacked a safe anchorage, we proceeded to Canton Island, 43 miles away, which proved to be ideal for our purpose, although the eclipse there was 30 seconds shorter than on Enderbury.

THE MASSIVE SUN COULD HOLD A MILLION EARTHS

Our program for observing the eclipse was very extensive; in fact, one of the most complete ever undertaken by any one expedition.

Along the shore of the quiet lagoon we set up our delicately poised instruments, puny tools indeed for probing into the secrets of the sun's tremendous inferno (page 385).

The sun is a huge ball of superheated gases, large enough to contain a million planets the size of the earth. Its surface is hotter than the fiercest blast furnace, thousands of degrees Fahrenheit, and its interior temperature probably rises to millions of degrees. It has an atmosphere surrounding it, somewhat as the air or atmosphere surrounds our earth, but of course very different from our own atmosphere.

This atmosphere of the sun is known as the chromosphere, because of its reddish color. It is cooler than the sun, but only

as hot water is cooler than boiling water.

In it are believed to be all or most of the materials of which the sun is composed, seething in the form of superheated vapor, and changed into that form by the terrific heat of the sun proper.

All elements known to exist on the sun also exist on earth.

High above the general level of the chromosphere, which is thousands of miles thick, enormous flamelike clouds of hot, rosy-red hydrogen gas, called prominences, shoot up, some moving as much as 100 miles a second.

Some of them have been seen to extend out from the sun as much as 200,000 miles, nearly as far as from the earth to the moon. Even the smaller ones could easily engulf the entire earth were they near enough.

We could see with the naked eye two enormous red prominences during this eclipse, one near the lower edge of the sun and one near its top (page 373). Many more not readily visible to the eye were recorded on our photographs. They are now being measured and studied.

Still farther out around the sun is the mysterious corona, a glorious halo of pearly white light extending millions of miles out into space, forming the most spectacular feature of a total eclipse of the sun. It surrounds the sun at all times, yet can be seen only during a total eclipse because at other times the sun's bright light blots it out.

FLAUNTING A STREAMER FIVE MILLION MILES LONG

In the first few hundred thousand miles outward in any direction from the sun the corona is of roughly equal depth, but from it, in all directions, long pointed streamers like the spines of a sea urchin extend much farther out.

The corona is like the halo that you see around a street lamp on a foggy night. The fog halo is the lamp light scattered by fog particles. The corona's light is believed to be sunlight scattered by vast numbers of inconceivably small particles floating in space around the sun.

This year we saw the corona almost circular in outline out to a distance of nearly a million miles from the sun.* Farther out beyond the sun this year's corona had many long streamers, those extending east and west being longer than those north and south. The longest streamer recorded on our photographs so far developed was 5,000,000 miles in length.

The chromosphere, the prominences, the corona—all of them vast and awe-inspiring—are the things we study chiefly during an eclipse of the sun. But, strangely enough, it is not their vastness that interests us most, but the structure and behavior of the tiny atoms of which they are composed.

Locked up in the sun's atoms are the secrets of the sun, and though atoms are so small that several hundred million of them could be laid side by side in one inch of space, we can learn a great deal about them even from 93,000,000 miles away.

"FINGERPRINTS" OF DISTANT ATOMS

The wonderful instrument that makes this possible is the spectrograph, which searches out the secrets of atoms across vast distances, and writes them down for all to read.

Point a spectrograph at the sun. The sun's light enters, is broken up into its spectrum of different colors or wave lengths like a rainbow, and is focused on a photographic plate.

In each of the colors of the rainbow thousands of lines appear, like a ladder with rungs close together. This long ladder of light is photographed, and the lines or rungs are as good as a written message for those who can read them (pp. 365, 375).

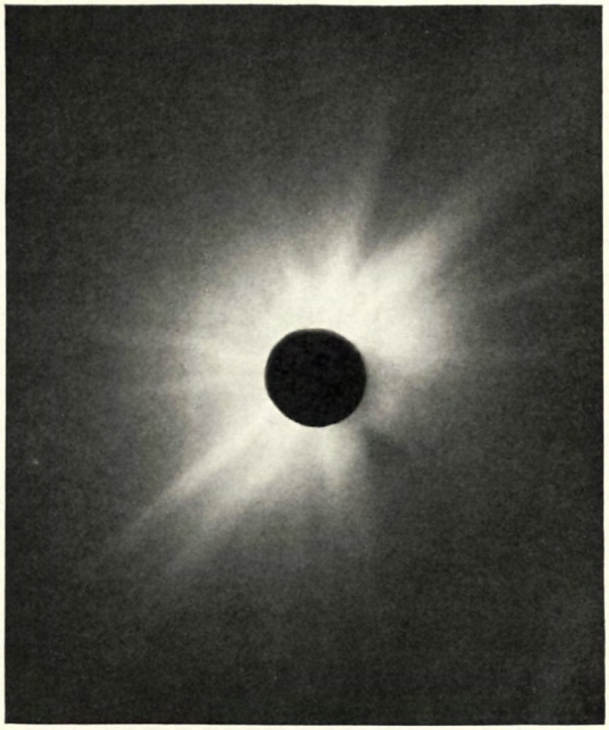
They tell what kinds of materials exist on the sun, in what quantities, how hot they are, to what pressure they are subjected, and whether they are solids or gases.

Each chemical element has an unchangeable identifying set of "finger-prints"—its spectrum lines—that can be seen with the spectrograph.

When a substance in the sun is heated to greater temperature, placed under greater or less pressure, or undergoes some other change, the tiny electrons inside its atoms are excited and rush about. This activity changes the wave length of the vibrations of light that are constantly coming from the atoms of the substance.

Then these changed wave lengths appear in the spectrograph as new lines, or old lines shifted in position or changed in other ways. They tell the astronomer exactly what has been going on.

* The diameter of the sun is about 865,000 miles.



Photographs by F. K. Richtmyer

THESE PICTURES WILL HELP REVEAL THE NATURE OF THE SUN'S CORONA

They were taken through screens of "polaroid," the new material that cuts down the glare of automobile headlights. In the upper picture there is a minimum of light along a line from upper left to lower right; and below, a minimum in the horizontal direction. This results from absorption, by the polaroid screens, of the light that is polarized, or vibrating in these directions. From these photographs the percentage of polarized coronal light at various distances out from the sun can be measured; thus may be disclosed the nature of corona material. The longest streamers of the corona in the lower picture extend out 5,000,000 miles.

With the spectrograph he does not take photographs of the eclipse as a whole. Instead he allows the light from the chromosphere, the prominences, or the corona, to enter and be split up into its thousands of lines.

Then he photographs these lines, and so gains enough material to keep him busy for months, or even years afterward, decoding the messages the lines contain.

A FAR-DISTANT LABORATORY

Thanks to the spectrograph, the scientist can use the sun's vast laboratory for studying atoms almost as easily as his own workshop, and from this study has come vastly improved understanding of the structure and behavior of atoms.

But he can get much of his evidence only at eclipses, years apart, and then he can hunt only for a very short time.

He is something like a boy trying to follow a ball game by quick looks through a hole in the fence at the rare intervals when the policeman's back is turned.

Why study atoms? Because everything is made of atoms, from the human body to the most distant stars. By artificially changing atoms, one element actually can be transmuted into another (though so far on a very small scale), a partial realization of the old alchemists' dream of transmuting base metals into gold.

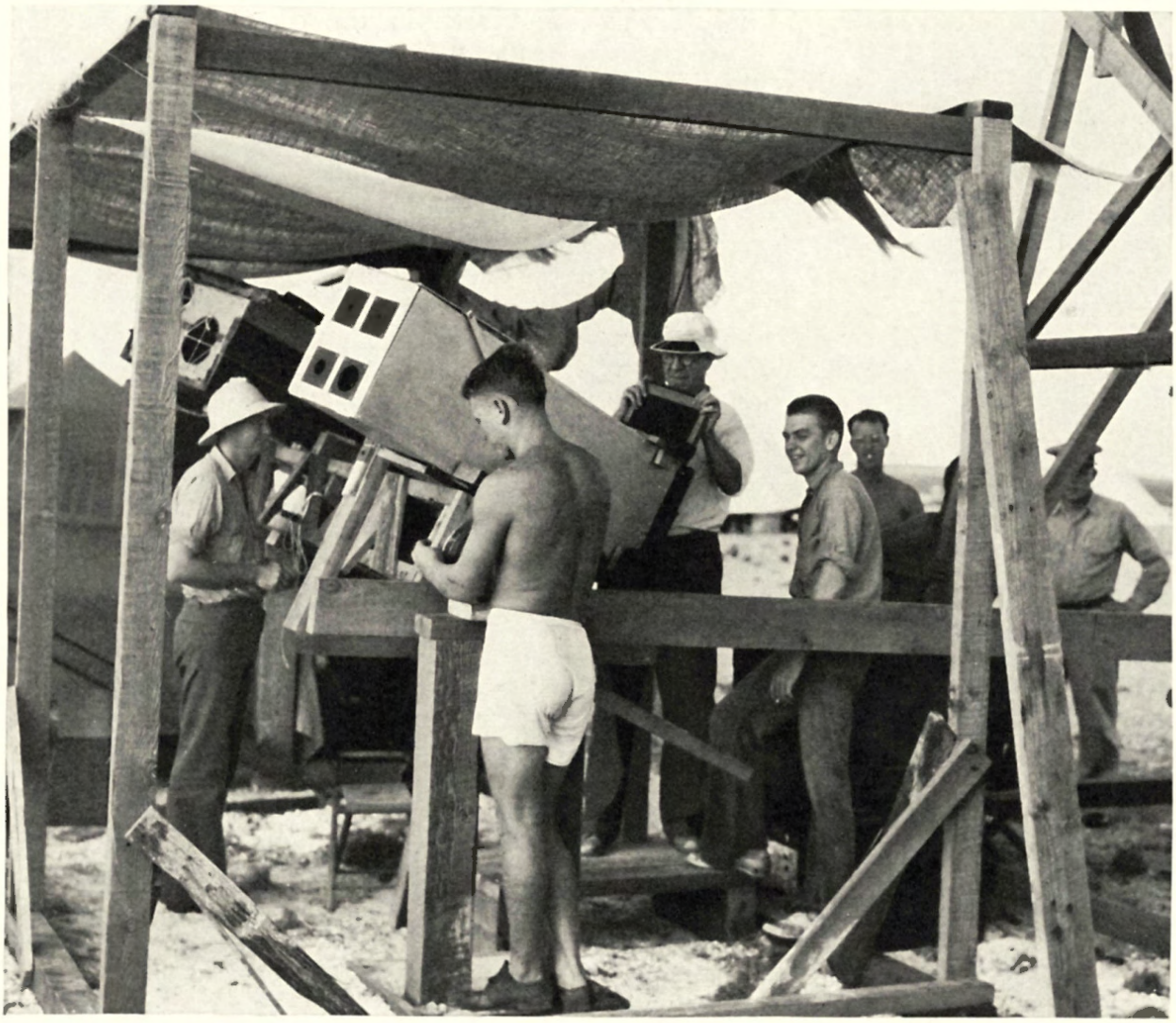
A very quick glance of only a few seconds is all the chance that astronomers have for one of their most important tasks during an eclipse—photographing the spectrum lines of the chromosphere, or sun's atmosphere. These lines tell what materials exist there, and their temperature, pressure, and general behavior, all-important for the understanding of solar secrets.

At the time of an eclipse astronomers have an opportunity to learn what is going on in the chromosphere because then they can photograph its spectrum lines without undue complications from the light of the sun itself.

THE CHROMOSPHERE'S "BIG MOMENT"

Ordinarily, when the sun is not eclipsed, its light shines through the chromosphere, and some of it is absorbed by the chromosphere.

But during an eclipse, for a few brief seconds, the chromosphere gets a chance to shine forth with its own glory alone. Then the lines of its spectrum can truly reveal



AN ECLIPSE "GUN CREW" TRAINS FOR THE BIG BARRAGE

"Drill, drill, drill," was the day and night routine to prevent lost time and motion for the 213 seconds of the eclipse. Since an astronomer can hope for only an hour's observation time in his whole life, he can't afford to make mistakes (page 361). Dr. Richtmyer (center with hat) here rehearses putting a plate in his "polaroid camera" (page 370), while sailor assistants from the *Avocet* stand by. This camera took four pictures simultaneously through the four square black openings on its front. The awning kept off the tropical sun.

what is happening to the gases within it.

The chromosphere's "big moment" comes just after the main disk of the sun is covered by the advancing moon. For some three or four seconds then, the moon shuts off the light of the sun proper, and the light of the chromosphere shines alone as a thin, bright, red crescent along the edge of the moon.

Then the moon advances, and the chromosphere, too, is covered. It is a case of "now you see it, now you don't."

The astronomer must be ready at just the right instant to open his shutter and quickly photograph the lines of the chromosphere's spectrum. Again, at the end of the eclipse, the chromosphere shines briefly in the same way.

The lines registered by the chromosphere's light are known as the flash spectrum (page 375). This is because, ordinarily, the spectrum of light from the sun has dark lines on a bright background, known as the Fraunhofer lines, for their discoverer, but at the moment when the advancing moon covers the sun during an eclipse the spectrum suddenly changes to bright lines on a dark background.

Photographing the flash spectrum is generally considered the most difficult feat, not only in observing eclipses, but in photographing all light spectra.

These lines show the kinds of materials existing in the chromosphere, but, more important still, they reveal also the heights to which these elements, all in vaporized form, are shot up above the sun's hot sur-

face, and this can be learned only during an eclipse.

These heights indicate how the different elements are affected by the great heat and pressure conditions on the sun, and this also has added to scientists' understanding of the behavior of atoms.

Our expedition had five spectrographs carefully focused to catch the fleeting flash spectrum.

The apparatus of Dr. Theodore Dunham, Jr., of Mount Wilson Observatory, specially built for this occasion, was the most elaborate ever tried at an eclipse. Assisting him was Mr. Charles G. Thompson, President of the Foundation for Astrophysical Research (page 374).

The Reverend Paul A. McNally, S.J., Director of Georgetown College Observatory, used a spectrograph that previously had been carried on the National Geographic Society-Army Air Corps stratosphere flight in 1935.

I had three spectrographs, belonging to the Mount Wilson Observatory, the U. S. Naval Observatory, and the Allegheny Observatory. During the eclipse I was assisted in operating them by Lieutenant Williamson, the commander of the *Avocet*, and Chief Quartermaster Hancock.

We were successful in catching the chromosphere's quick flash, and the code messages contained in its spectrum lines are now being studied (page 375).

The sun's corona, so thin and tenuous that the stars easily can be seen through it, and comets can pass through it undamaged, also is a target for the spectrograph.

After shooting the flash spectrum, our five spectrographs were trained on the corona during the three and one-half minutes that it was visible during the eclipse, to catch the messages of its spectrum lines.

NEW LINES DISCOVERED IN CORONA'S SPECTRUM

Dr. Dunham already has reported that he has found some new lines of unknown origin in the blue region of the corona's spectrum. Whether they come from a new element or a known element in an unfamiliar state, we do not yet know.

Also we again found the lines of our old and mysterious friend coronium still present in the corona.

Coronium probably is a familiar element so changed by heat or other conditions on the sun that it is unrecognizable. It was first seen in the corona in 1869. The "code messages" from the corona, like those from the chromosphere, will need many more months of study.

When someone invented a new material called "polaroid," which reduces the glare of automobile headlights, he probably never expected that it would help tell us what the sun's corona is made of. Yet such is the case.

The corona's light is thought to be scattered sunlight, and all scattered light is partially polarized. Ordinary light waves vibrate in all directions as does a taut piece of string when it is plucked, but "polarized" light waves vibrate in only one direction, as would the string if it were lying in a narrow groove and therefore could move only up and down.

If you can measure the percentage of light that is polarized—the percentage that vibrates in only one direction—it will help you to understand the nature of the particles that scatter the light.

Some astronomers believe that the long, spikelike streamers of the corona may have something to do with sunspots. The streamers are most numerous when there are the most spots.

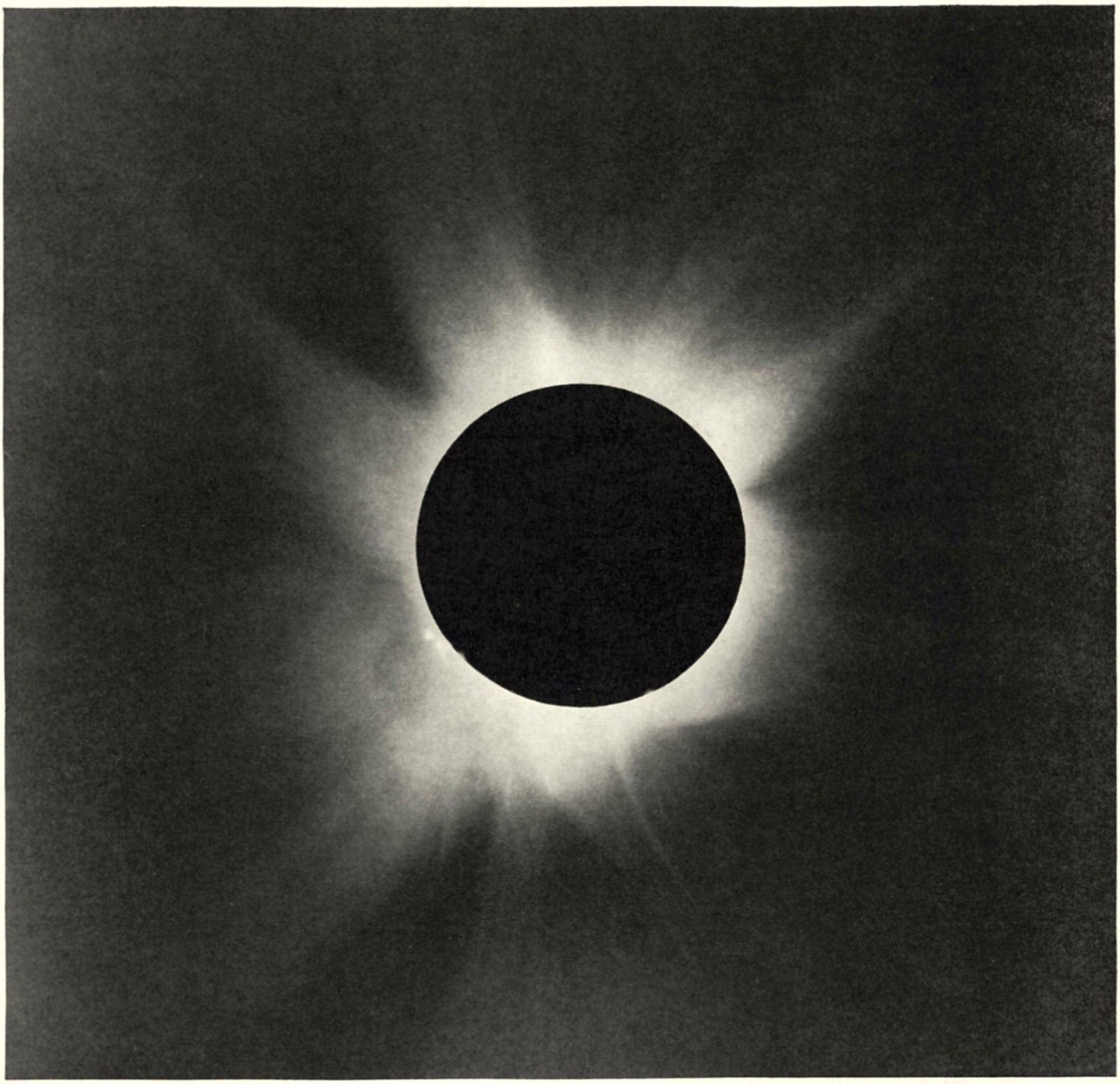
THE FIRST "POLAROID CAMERA"

Measuring the polarization of the streamers helps tell us in what direction the streamers are pointing. If we can learn their direction, we can then try to determine whether sunspots existed on the sun under the bases of the streamers at the time of the eclipse. If so, it might mean that the spots supplied the forces that extended the streamers so far outward.

The polarization measurements were made by Dr. F. K. Richtmyer, of Cornell University, with the first "polaroid camera" ever successfully used at an eclipse of the sun. He photographed the corona through disks of "polaroid," which registered the percentage of polarization of the corona's light on his plates (pages 366, 370, 371).

His photographs show for the first time that the percentage of polarization of the light of the corona and of its streamers increases outward from the sun, which is a new and important aid to better understanding of the nature of the corona.

The variation of the brightness of the corona outward from the sun is a clue to its density or thickness, and the corona's total



Photograph by Irvine C. Gardner

"MOTHER SUN" ARRAYS HERSELF IN MILLION-MILE STREAMERS, AND CHANGES THEIR STYLE EVERY YEAR

Only during a total eclipse can this pearly-white corona around the sun be seen; at other times the sun's light blots it out. On the lower left edge of the moon's black disk is a prominence, a flame-like cloud of hot hydrogen gas, rosy-red, which extends 50,000 miles or more above the surface of the sun. Here the corona appears flat; actually its streamers extend out in all directions. This year the expedition found in it traces of what may be a new chemical element, or a known element in an unfamiliar state (see page 372). This photograph was taken with ten seconds exposure. Longer exposures show the corona extending out some 5,000,000 miles (page 370).

light or candle power is a key to the amount of matter that exists in it. Dr. Richtmyer measured these with delicate, light-sensitive "targets."

First readings of his records indicate that the total light of the corona in this eclipse, as in most previous eclipses, was about equal to one-half that of the full moon or about one millionth the light of the noon-day sun.

Styles in coronas, like styles in ladies' dresses, change from year to year.

One year it may be long streamers extending out on both sides of the sun's equator, with short, stubby ones at the poles. Other years the corona may be roughly star-shaped, or almost round.

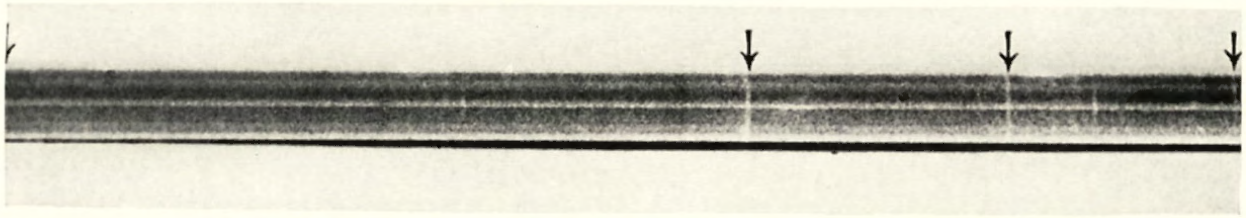
But, unlike ladies' fashions, styles in coronas repeat themselves about every 11 years, and we have reason to believe that this is because the "style arbiter" of the corona is the same mysterious power that causes the numbers of sunspots to increase and decrease over the same period.

NO MOVIE STARS EVER REHEARSED MORE HOURS FOR THEIR 3½ BIG MINUTES!

Helping Dr. Gardner insert photographic plates in the 14-foot aluminum camera is Richard H. Stewart, National Geographic Society staff photographer (left). The camera is set up on its globe-trotting packing case, where warnings in English, German, and Russian recall its part in the National Geographic Society-National Bureau of Standards Eclipse Expedition of 1936, led by Dr. Gardner.

BURNING MIDNIGHT LANTERN OIL TO STUDY THE MORNING SUN

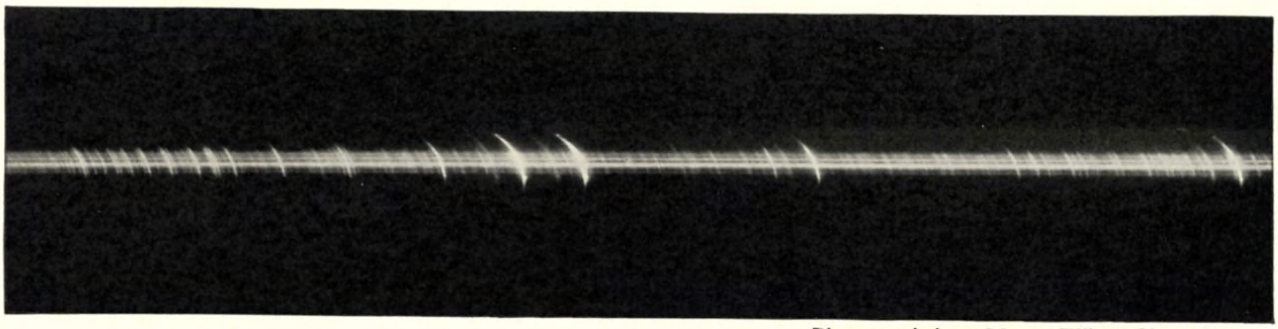
Dr. Theodore Dunham, Jr. (left), and Charles G. Thompson, who assisted him during the eclipse, take nocturnal notes while checking their two coelostats. These machines have mirrors turned by a mechanical device so that they point continuously at the sun and focus an image of it into the spectrograph. Thus they need not keep the big spectrograph itself pointed at the sun.



Photograph by Theodore Dunham, Jr.

"SOMETHING NEW ON THE SUN" IS THE BULLETIN OF THESE MARKINGS

The faint white lines marked by the arrows were registered by light from the sun's corona during the eclipse in the spectrograph of Dr. Theodore Dunham, Jr. (page 374). Their origin is yet an unsolved mystery, but they represent the "signature" either of a new chemical element previously unknown or of a known element in a state unfamiliar to scientists (page 369). The new lines are in the blue region of the corona's spectrum.



Photograph from Mount Wilson Observatory

WHAT'S DOING ON THE SUN? THIS "CODE MESSAGE" TELLS YOU

The elusive flash spectrum of the sun lasts only a few seconds during an eclipse (page 371). The tiny arcs are registered on the photographic plate by light from the chromosphere, or atmosphere of the sun, just after the advancing moon has covered the main body. The arcs of light tell astronomers how high above the sun the vapors of various chemical elements are rising, some of them shooting up 8,000 miles or more. Thus the solar detectives deduce how various substances are affected by great heat and other conditions which cannot be duplicated on earth.

For this and other reasons it is important to make as many photographs as possible of the corona and also of those hot hydrogen clouds, the prominences, during an eclipse.

Our expedition made many pictures of both, in black and white and in color, with long and short exposures.

NATURAL COLOR PHOTOGRAPHS TAKEN

Mr. Willis took twelve fine pictures of the corona. Dr. McNally made six photographs to record the extent of the corona, and the variation of the intensity of its light outward from the sun. He also made natural color photographs, using three different processes, and took a series of six pictures with six different color filters and emulsions sensitive to various colors, from which he hopes to reconstruct the appearance of the corona in colors.

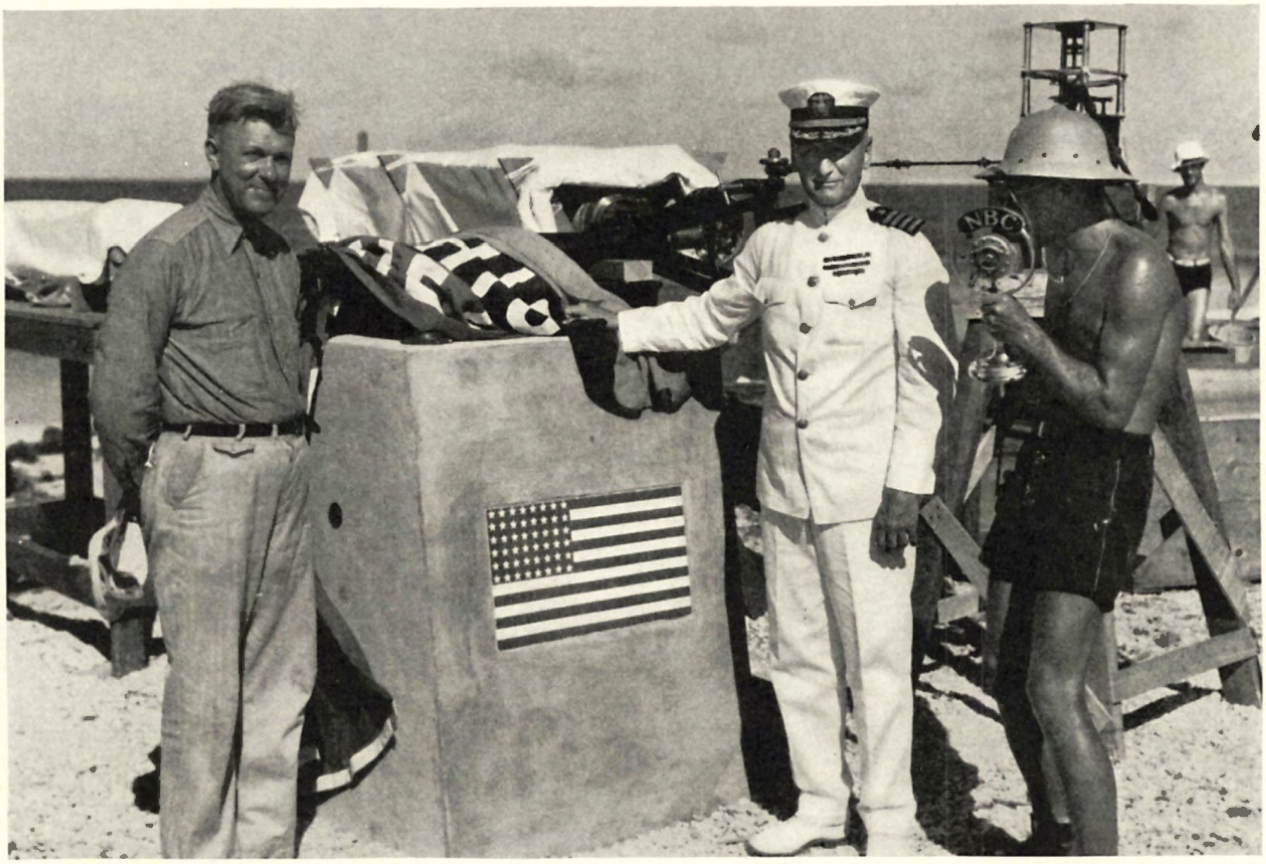
When photographing the sun's corona in the past, it has been next to impossible to make an exposure long enough to register the faint light of the thin outer ends of the streamers without overexposing the brighter parts of the corona nearer the sun, and the prominences, and thus losing important details.

So this year Dr. Irvine C. Gardner, of the National Bureau of Standards, tried something new in eclipse photography, a process which was designed to equalize the amount of light reaching his plates from different parts of the corona, thus making it possible to photograph both the long, faint outer streamers and the prominences near the sun with good definition.

He also photographed the eclipse on "color separation plates," which record the red, yellow, and blue ranges of color separately. These plates carried their own filters, greatly improving their definition. Later he will try to combine the different plates to give an accurate color picture of the eclipse. He also made natural color photographs by two different processes.

AN OIL PAINTING AT ONE "SITTING"

To make an oil painting of an eclipse, with the subject giving only one "sitting," and that but three and one-half minutes long, might seem like an impossible undertaking, but it was accomplished by Mr.



"OLD GLORY," IN NEW STAINLESS STEEL, ADORNS THE MONUMENT UNVEILED MEMORIAL DAY

George Hicks broadcasts a description of the ceremony as Captain Hellweg lifts a cloth American Flag from the marker which commemorates the Expedition's stay on Canton Island. The small disk in the monument, near Dr. Mitchell (left), is the seal of the National Geographic Society. Behind Captain Hellweg is the Naval Observatory's 15-foot camera.

Charles Bittinger, of Washington, D. C., our artist.

Motion pictures of the entire eclipse, from the time when the moon first began to cover the sun, throughout totality and until the sun was again uncovered, were made by Mr. Richard H. Stewart, staff photographer of The National Geographic Society.

No report of our expedition would be complete without mention of the three representatives of the National Broadcasting Company.

Mr. M. S. Adams and Mr. Walter Brown, radio engineers, made possible what was probably the first series of radio broadcasts from a desert island in history, and, better still, enabled us to hear on our lonely island the voices of the "folks at home" (pages 392, 393).

Mr. George Hicks, our announcer, did a splendid job of describing the eclipse to the American radio audience (page 394).

Dr. Herman A. Gross, our Navy surgeon, had few patients, but made himself useful in many other ways. Chief Boatswain H. S. Bogan, of the *Avocet*, in charge of loading and unloading our instruments, performed extremely valuable service.

We greatly regretted that Dr. Heber D. Curtis, of the University of Michigan Observatory, who was originally scheduled to be a member of the expedition, was prevented by illness from being with us.

To the following may I express the appreciation of the expedition for instruments and materials loaned, manufactured or supplied, for services rendered, and for other valuable aid:

Mount Wilson Observatory; Allegheny Observatory; the U. S. Navy and the Naval Observatory; Eastman Kodak Company; Dr. C. W. Gartlein, of Cornell University; Mr. William P. Roth, President, Matson Navigation Company; the Weston Electrical Instrument Corporation; National Bureau of Standards; Folmer Graflex Corporation; the Bausch and Lomb Optical Company; the Carrier Corporation, and the Servel Company.