they are seen in almost all directions, and, as stated, they are all moving outwards from us, and thus the whole universe seems to be expanding.

These results are giving the astronomer great concern, and Einstein's theory of relativity, the fifth dimension, curved space, and other bewildering hypotheses have been invoked to explain the puzzle, but the solution is not yet in sight.

THE SUN AS A STAR*

By C. A. CHANT

ASTRONOMY is the oldest of the sciences. After thousands of years of careful observation and discussion we have reached conclusions which are now universally accepted, namely, that the sun is an immense body and around it revolve a number of smaller bodies called planets, of which the earth is one: also, that beyond the sun and the planets, at distances so great as to make our system appear as a drop in the ocean of space, are millions of other suns, which are the fixed stars,—seen as points of light on the sky.

Our sun is of superlative importance for two reasons, (1) because it is the central body and ruler of our system; and (2) because it is one of the stars, being the only one which is near enough for detailed study; and what we learn about it will help us to solve the problem of the universe around us.

One of the first things we should wish to know about the sun is, how far it is away. Now a surveyor, by measuring a base line and two angles, can calculate the distance of an object on the other side of a river; and in a similar way the astronomer determines the distance of the sun from the earth. It is approximately 93 millions of miles—a great distance indeed. An express train travelling a mile a minute without a stop would require 175 years to cover it.

Knowing the distance of the sun it is easy to deduce its actual size from the space it covers in the sky. The diameter is 864,000

*Broadcast from Station CFRB on January 18, 1932 in the University of Toronto series of broadcasts.

miles, which is 109 times that of the earth, and consequently the volume of the sun is 1,300,000 times that of the earth.

There is good reason to believe that at one time the earth and the other planets formed a part of the sun; but it was only a small part as the sun contains enough material for 332,000 earths or 750 sets of planets like those of our system. Perhaps the following illustration will make some of these distances and dimensions clearer. If we represent the sun by a ball one foot in diameter, then the earth will be a small pea at a distance of 107 feet, while the nearest of the fixed stars will be a ball 12½ inches in diameter and 5500 miles away—in Cairo or in Tokio!

It is recognized by everyone that the illumination from the sun is incomparably greater than that from artificial sources. With a bright sun, or even when it is behind a cloud, the illumination of our streets and houses would not be appreciably increased by switching on all the public and private lighting systems. There is nothing like sunlight. It is customary to state the illuminating power of a source of light, such as an electric lamp, as equal to a certain number of candles. You may be surprised to learn that if the sun were replaced by candles—at the same distance, of course—the number would be 1.575×10^{27} or 1575 millions of millions of millions, which is entirely beyond our comprehension.

Next, let us consider briefly the heat received from the sun. This is a very important matter and the Astrophysical Observatory at Washington has established stations in different parts of the earth in order to secure a continuous record of the sun's radiation. The rate at which it comes to the earth is usually expressed in calories but as at present "calories" are *out* and "vitamins" are *in* I shall use more familiar terms. Let the sunlight fall perpendicularly upon a sheet of ice one inch thick; then if none of it was absorbed by the earth's atmosphere the ice would be melted in 1¾ hours. As a matter of fact about 40 per cent of the sun's radiation coming to the earth is absorbed in the atmosphere. The heat energy which falls upon the deck of a steamer in tropical waters, if it could be used without loss, would drive the ship at a speed of about 10 knots. But the entire earth receives only the tiniest fraction of the sun's radiation, and we see that the sum total energy sent out is stupendous. Further, this enormous outflow has been

going on for millions of years. What maintains it? Not combustion. A lump of pure coal of the mass of the sun if burned in oxygen would keep up the supply for only about a thousand years. Physicists have been almost driven to the belief that this energy which is distributed with such profusion actually comes from the atoms of matter themselves—that atoms are annihilated and energy is produced. According to the theory of relativity the sun's mass is diminishing at the rate of 1.7×10^{14} or 17,000 millions of millions of tons per year, but the radiation could continue at this rate for 1.5×10^{13} or 15 millions of millions of years, so we need have no fear on that score.

Perhaps you would like to know the temperature of the sun. Indeed it may seem strange that we can find the temperature of a body 93 million miles away. But an instrument known as a pyrometer has been devised which will indicate the temperature of a furnace simply if held in front of it, and a suitable instrument directed towards the sun will give its temperature. Indeed there are several methods of arriving at its temperature. It turns out to be about 6000°C. or 11,000°F., which is sufficient to vaporize tungsten, the most refractory of the chemical elements. It must be noted, however, that this is the sun's surface temperature: at the sun's centre the temperature is probably above 10,000,000 degrees.

In our investigations we wish sometimes to use the very lowest temperatures, sometimes the very highest, You all know how a lens will converge the sun's rays to a point and produce a temperature high enough to scorch paper or ignite gunpowder. At the present time there is being constructed at the Mount Wilson Observatory in California an instrument containing 19 lenses, each 24 inches in diameter and other smaller lenses and mirrors which will concentrate sunlight upon substances within a vacuum chamber where it is hoped to obtain a temperature approaching that of the sun. The substances will be vaporized and then studied with the spectroscope.

Ever since the invention of the telescope some 300 years ago it has been used to study the surface of the sun. Soon there were discovered strange dark blotches which moved across the sun's face, from the east to the west edge. This motion was due to the

sun's rotation which was thus found to have a period of about 25 days. Continued study has shown that for weeks at a time there may be no spots. Then they increase in size and numbers and in two or three years the surface is never free from them. A few years later they will all be gone again. Actually the spots occur in cycles, the time from one maximum of spots to the next being on the average 11.1 years, though the period may be two or three years shorter or longer. The last maximum occurred in May, 1928, and we are now well on to a minimum.

Now a cycle of similar length has been discovered in the thicknes of he growth-rings of trees, and the latter we naturally associate with the quantity of precipitation; but direct attempts to show a relation between sun spots and rainfall have not been very successful. The relation seems to hold for some places, but not at others. But it should be remarked that the increase of precipitation claimed at the time of a sun spot maximum is very slight, not enough to change a dry season into a wet one. Our knowledge of the sun's radiation and of sun spots is not sufficient to enable us to predict a rainy or a dry season for any part of the country.

There are some terrestrial phenomena, however, whose relation to sun spots is undisputed. When we have many sun spots there are numerous auroral displays, or Northern lights; also, there are many disturbances of the magnetic needle.

Another interesting study has been made during the last few years, namely, the relation of sun spots to radio reception. Sufficient time has not elapsed for arriving at absolutely certain conclusions, but observations seem to show pretty clearly that the fewer the sun spots, the better the reception. If such is the case, reception will improve for several years, then it will grow poorer until about 1940, after which it will inprove again.

There are many other things which I have not time even to mention. I confidently believe that in the years to come the relations between solar and terrestrial phenomena will be determined with such certainty that the astronomer will be able to assist materially the workers on the land and in other fields as well.