white sunlight, which, although admitted in small quantity, increased the percentage of white enough to reach the limit for x. With $a = 8.4\ \mu$ a white rainbow was yet obtained, the white band, however, had already decreased in width.

RADIATION IN THE SOLAR SYSTEM.

By Prof. J. H. POYNTING, F. R. S.

[Afternoon address delivered at the Cambridge meeting of the British Association for the Advancement of Sciences, August 23, 1904. Reprinted from Nature, September 22, 1904, vol. 70, p. 512.][1]

I propose to discuss this afternoon certain effects of the energy which is continuously pouring out from the sun on all sides with the speed of light—the energy which we call sunlight when we enjoy the brilliance of a cloudless sky, which we call heat when we bask in its warmth, the stream of radiation which supports all life on our globe and is the source of all our energy.

As we all know, this ceaseless stream of energy is a form of wave motion. If we pass a beam of sunlight, or its equivalent, the beam from an electric arc, through a prism, the disturbance is analyzed into a spectrum of colors, each color of a different wave length, the length of wave changing as we go down the spectrum from, say, 1/30,000 of an inch in the red to 1/80,000 of an inch in the blue or violet.

But this visible spectrum is merely the part of the stream of radiation which affects the eye. Beyond the violet are the still shorter waves, which affect a photographic plate or a fluorescent screen, and will pass through certain substances opaque to ordinary light. Here, for instance, is a filter, devised by Professor Wood, which stops visible rays, but allows the shorter invisible waves to pass and excite the fluorescence of a platinocyanide screen.

Again, beyond the red end are still longer waves, which are present in very considerable amount, and can be rendered evident by their heating effect. We can easily filter out the visible rays and still leave these long waves in the beam by passing it through a thin sheet of vulcanite. A piece of phosphorus placed at the focus of these invisible rays is at once fired, or a thermometer quickly rises in temperature. The waves which have been observed and studied up to the present time range over some nine octaves, from the long waves described to the section yesterday by Professor Rubens, waves of which there are only 400 in an inch, down to the short waves found by Schumann in the radiation given off by hydrogen under the influence of the electric discharge, waves of which there are a quarter of a million in an inch. No doubt the range will be extended.

Radiant energy consists of a mixture of any or all of these wave lengths, but the eye is only sensitive at the most to a little more than one octave in the nine or more.

This radiation is emitted not only by incandescent bodies such as the sun, the electric arc, or flames. All bodies are pouring out radiant energy, however hot or cold they may be. In this room we see things by the radiation which they reflect from the daylight. But besides this borrowed radiation, every surface in the room is sending out radiation of its own. Energy is pouring forth from walls, ceiling, floor, rushing about with the speed of light, striking against the opposite surfaces, and being reflected, scattered, and absorbed. And though this radiation does not affect our eyes, it is of the utmost importance in keeping us warm. Could it be stopped, we should soon be driven out by the intense cold, or remain to be frozen to death.

As the temperature of a body is raised, the stream of radiation it pours out increases in quantity. But it also changes in quality. Probably the surface always sends out waves of all lengths from the longest to the shortest, but at first when it is cold the long waves alone are appreciable. As it gets hotter, though all the waves become more intense, the shorter ones increase most in intensity, and ultimately they become so prominent that they affect our sense of sight, and then we say that the body is red or white hot.

The quality of the stream depends on the nature of the surface, some surfaces sending out more than others at the same temperature. But the stream is the greatest from a surface which is, when cold, quite black. Its blackness means that it entirely absorbs whatever radiation falls upon it, and such a surface, when heated, sends out radiation of every kind, and for a given temperature each kind of radiation is present to the full extent; that is, no surface sends out more of a given wave length than a black surface at a given temperature.

A very simple experiment shows that a black surface is a better radiator, or pours out more energy when hot, than a surface which does not absorb fully, but reflects much of the radiation which falls upon it. If a platinum foil with some black marks on it be heated to redness, the marks, black when cold, are much brighter than the surrounding metal when hot; they are, in fact, pouring out much more visible radiation than the metal.

It is with these black surfaces that I am concerned to-day. But, inasmuch as it seems absurd to call them black when they are white hot, I prefer to call them full radiators, since they radiate more fully than any others.

For a long time past experiments have been made to seek a law connecting the radiation or energy flow from a black or fully radiating surface with its temperature. But it was only 25 years ago that a law was suggested by Stefan which agrees at all satisfactorily with experiment. This law is that the stream of energy is proportional to the fourth power of the temperature, reckoned from the absolute zero, 273° below freezing point on the centigrade scale. This suggestion of Stefan served as the starting point of new and most fertile researches, both theoretical and practical, and we are glad to welcome to this meeting Professors Wien, Lummer, and Rubens, who have all done most brilliant work on the subject.

Among the researches on radiation recently carried out is one by Kurlbaum, in which he determined the actual amount of energy issuing from the black or fully radiating surface per second at 100° C., and, therefore, at any temperature.[2]

Here is a table which gives the amount at various temperatures, as determined by Kurlbaum:

Rate of flow of energy from one square centimeter of fully radiating or "black" surface.

Absolute temperature.	Calories (grams of water heated 1°) per second.
0°	0.0
100°. Air boils	0.000127
300°. Earth's surface	0.0103
1,000°. Red heat	1.27
3,000°. Arc carbon	103
6,000°	1,650
6,250°	1,930

As an illustration of the "fourth power law," let us see what value it will give us for the temperature of the sun, assuming that he is a full radiator, or that his surface, if cooled down, would be quite black.

We can measure approximately the stream of energy which the sun is pouring out by intercepting the beam falling on a

[1] The foot notes to this article, where not otherwise credited, are adapted from a technical paper by Professor Poynting: "Radiation in the solar system: its effect on temperature and its pressure on small bodies." Philosophical Transactions of the Royal Society, Series A, 1903, vol 202, p. 525.—*F. O. S.*

[2] [The constant factor, the product of which by the fourth power of the absolute temperature gives the amount of radiant energy per square centimeter per second, is called the constant of radiation. According to Kurlbaum, this constant, expressed in units of mechanical energy, is 5.32×10^{-5} ergs. By dividing this by the mechanical equivalent of heat, it becomes 1.27×10^{-12} calories or thermal units.]

surface exposed to full sunlight, measuring the heat given to that surface per second, and then calculating what fraction the beam is of the whole stream issuing from the sun.

This was first done by Pouillet, and his method will serve to illustrate the principal of all other methods.

In his apparatus the sunlight fell full on a box containing water, and the rate at which the water rose in temperature gave the energy in the stream of solar radiation falling on the box.

Simple as the experiment appears, the determination is beset with difficulties, the chief being the estimation of the fraction of the energy intercepted by the atmosphere, and we are still unable to give a very definite value. Indeed, we can not yet say whether the outflow of energy is constant or whether it varies. In all probability, however, it does vary, and Professor Langley, who has devoted years of work to the subject, has recently obtained evidence indicating quite considerable variation.

We may, however, assume that we are not very far from the true value if we say that the stream of radiation from the sun falling perpendicularly on one square centimeter outside the earth's atmosphere will heat one gram of water 1/24° C. every second, or will give 1/24 calory per second.[3]

Now the area of a sphere round the sun at the distance of the earth is 46,000 times the area of the sun's surface. The energy from 1 square centimeter of the sun thus passes through 46,000 square centimeters at the surface of the earth. It is, therefore, 46,000 × 1/24 calories, or 1920 cal./sec.[4] But from the table already given, a black surface at 6250° absolute, say, 6000° C., gives 1930 calories per second, or the temperature of the sun's radiating surface is 6000° if he is a full radiator, and there is good reason to suppose that no great error is made in taking him to be one.[5]

Let us now take another illustration of the fourth power law.

[3] [Ångström estimated this value as 1/15 calory. Langley assumed that the atmosphere transmits about 59 per cent of the energy from a zenith sun, and from his measurement of the heat reaching the earth's surface he estimated the value of the constant at 1/20 calory per second. Rosetti assumed a transmission of 78 per cent from the zenith sun, but Wilson and Gray consider that 71 per cent represents Rosetti's numbers better than 78 per cent. If in Langley's value we replace 59 per cent by 71 per cent, we get 1/24 calory.] (Abbot, from observations at the Astrophysical Observatory of the Smithsonian Institution, obtains a value of about 1/27 calory per second.—*F. O. S.*)

[4] Or, more strictly, if A is half the area of the sun's surface, expressed in centimeters, then $1/24\ A$ calories per square centimeter is the amount received at the earth from each square centimeter of the sun's surface, and $\frac{46000\ A}{24A}$, or 1920 calories, is the total radiation from each square centimeter of the sun.—*F. O. S.*

[5] [Accepting Ångström's value of the solar constant, we should find 7000° absolute as the sun's temperature, while taking Langley's value it would be 6500°. Wilson (Proceedings of the Royal Society, vol. 69, 1901-2, p. 312) made a direct comparison of the radiation from the sun with that from a full radiator at known temperature. Assuming that the atmosphere transmits 71 per cent of the radiant energy received from the sun when the sun is in the zenith, he obtained 5773° absolute as the solar temperature. If we denote the solar constant by S, and put

$$46000\ S = 1.27 \times 10^{-12} \times 5773^4$$

we get S equal to about 1/33 calory per second. This is no doubt too low a value. Either, then, Wilson's zenith transmission was less than 71 per cent, or Kurlbaum's constant is too small.

The low value is probably to be accounted for chiefly by the first supposition. Wilson points out that if x is the true value of the transmission, his value of the temperature is to be multiplied by $(71/x)^{1/4}$. If we take 6200° as the true value of the sun's temperature, then x will be found from the equation

$$x = \left(\frac{5773}{6200}\right)^4 \times 71 = 53.$$

This low value is not necessarily inconsistent with the much higher value, 71 per cent, used in finding Rosetti's solar constant, for no doubt the transmission varies widely with time and place, and we have no reason to assume that 1.77 calories per minute, obtained by Langley, would have been received from the zenith at the time and in the place where Wilson was making his determination.]

Imagine a little black body which is a good conductor of heat placed in full sunlight at the distance of the earth. Let it be 1 square centimeter in cross section, so that it is receiving 1/24 calory per second.

It will soon warm up to such a temperature that it gives out just as much as it receives, and, since it is so small, heat will rapidly flow through it from side to side, so that it will all be very nearly at the same temperature. A sphere 1 square centimeter in cross section has area 4 square centimeters, so that it must be giving out from each square centimeter of its surface 1/96 = 0.0104 calory each second. From the table above it will be seen that this corresponds very nearly indeed to a temperature of 300° absolute or 27° C., say 70° F.

It is to be noted that this only applies to a little round body. A flat plate facing the sun would be about 60° C. hotter, while if it were edgewise to the sun it might be very much colder.

Let us now see what would be the temperature of the small black sphere at other distances from the sun. It is easily seen that, inasmuch as the heat received, and therefore that given out, varies inversely as the square of the distance, the temperature, by the fourth power law, will vary inversely as the square root of the distance.[6]

Here is a table of temperatures of small black spheres due to solar radiation.

Distance from sun's center.	Temperature centigrade.
3¾ million miles	1,500° ..... cast iron melts.
23 million miles	327° ..... lead nearly melts.
At Mercury's distance	210° ..... tin nearly melts.
At Venus's distance	85° ..... alcohol boils freely.
At Earth's distance	27° ..... warm summer day.
At Mars's distance	— 30° ..... arctic cold.
At Neptune's distance	—219° ..... nitrogen frozen.

We see from this table that the temperature at the earth's distance is remarkably near the average temperature of the earth's surface, which is usually estimated as about 16° C., or

[6] [In determining the steady temperature of any body as conditioned by the radiation received from the sun, we have to consider whether it is necessary to take into account the radiation from the rest of the sky. If it receives S from the sun, ρ from the rest of the sky, and if its own radiation is R, then, in the steady state, that is, when the radiation that it gives out is equal to that received from all sources, $R = S + \rho$.

It behaves, therefore, as if it were receiving S from the sun, but as if it were placed in a fully radiating inclosure of such temperature that the radiation is ρ. This temperature is the "effective temperature of space."

The temperature may perhaps be more definitely described as that of a small full absorber placed at a distance from any planet and screened from the sun. Various well known attempts have been made to estimate this temperature, but the data are very uncertain. The fourth power law, however, shows that it is not very much above the absolute zero, if we can assume that the quality of starlight is not very different from that of sunlight.

According to l'Hermite (L'Astronomie, vol. 5, p. 406) starlight is one-tenth full moonlight. Full moonlight is variously estimated in terms of full sunlight. Langley (First memoir on the temperature of the surface of the moon, National Academy of Sciences, vol. 3) takes it as $\frac{1}{400000}$. These two values combined give sunlight as 4×10^6 starlight, but since starlight comes from the whole hemisphere, we must, for the purpose of comparing temperatures, consider the illumination that would be received if the whole hemisphere were paved with suns. This would be $46{,}000 \times 4 \times 10^6 = 1.84 \times 10^{11}$ times that from the stellar sky. If we assume that the ratio of the energy of the visible rays to the total energy is the same in both cases, then, according to the fourth power law, the effective temperature of space is equal to the temperature of the sun divided by

$$(1.84 \times 10^{11})^{\frac{1}{4}} = \frac{\text{temperature of sun}}{655}.$$

Since the temperature of the sun probably lies between 6000° and 7000° on the absolute scale, this gives the effective temperature of space as about 10° above the absolute zero.

If, then, a body is raised by the sun to even such a small multiple of 10° as, say, 60°, the fourth power law of radiation implies that it is giving out, and therefore receiving from the sun, more than a thousand times as much energy as it is receiving from the sky. The sky radiation may, therefore, be left out of account when we are dealing with approximate estimates and not with exact results.]

60° F. This can hardly be regarded as a mere coincidence. The surface of the earth receives, we know, an amount of heat from the inside almost infinitesimal compared with that which it receives from the sun, and on the sun, therefore, we depend for our temperature. The earth acquires such a temperature, in fact, that it radiates out what it receives from the sun. The earth is far too great for the distribution of heat by conduction to play any serious part in equalizing the temperature of different regions. But the rotation about its axis secures nearly uniform temperature in a given latitude, and the movements of the atmosphere tend to equalize temperatures in different latitudes. Hence, we should expect the earth to have, on the average, nearly the temperature of the small black body at the same distance, slightly less because it reflects some of the solar radiation, and we find that it is, in fact, some 10° less.[7]

Professor Wien was the first to point out that the temperature of the earth has nearly the value which we should expect from the fourth power law.

Here is a table showing the average temperatures of the surfaces of the first four planets on the supposition that they are earth-like in all their conditions.

Table of temperatures of earth-like planets.

	°C.
Mercury	106
Venus	79
Earth	17
Mars	—38

The most interesting case is that of Mars. He has, we know, a day nearly the same in length as ours; his axis is inclined to the ecliptic only a little more than ours, and he has some kind of atmosphere. It is exceedingly difficult to suppose, then, that his average temperature can differ much from —38° C. His atmosphere may be less protective, so that his day temperature may be higher; but then, to compensate, his night temperature will be lower. Even his highest equatorial temperature can not be much higher than the average. On certain suppositions I find that it is still 20° below the freezing point, and until some new conditions can be pointed out which enable him to establish far higher temperatures than the earth would have at the same distance it is hard to believe that he can have polar caps of frozen water melting to liquid in his summer and filling rivers or canals. Unless he is very different from the earth, his whole surface is below the freezing point.

Let us now turn from these temperature effects of radiation to another class of effects, those due to pressure.

More than 30 years ago Clerk Maxwell showed that on his electromagnetic theory of light, light and all radiation like light should press against any surface on which it falls. There should also be a pressure back against any surface from which radiation is reflected or from which it is issuing as a source, the value in every case being equal to the energy in a cubic centimeter of the stream. The existence of this pressure was fully demonstrated independently by Lebedew and by Nichols and Hull some years ago in brilliant experiments in which they allowed a beam of light to fall on a suspended disk in a vacuum. The disk was repelled, and they measured the repulsion and found it to be about that required by Maxwell's theory. Nichols and Hull have since repeated the experiment with greater exactness, and there is now no doubt that the pressure exists and that it has Maxwell's value.

The radiation, then, poured out by the sun is not only a stream of energy. It is also, as it were, a stream of pressure pressing out the heavenly bodies on which it falls. Since the stream thins out as it diverges, according to the inverse square of the distance, the pressure on a given surface falls off according to the same law. We know the energy in a cubic centimeter of sunlight at the distance of the earth, since, moving with the velocity of light, it will supply 1/24 calory per second. It is easy to calculate that it will press with a force of 6×10^{-5} dynes on a square centimeter, an amount so small that on the whole earth it is but 70,000 tons, a mere trifle compared with the three million billion tons with which the sun pulls the earth by his gravitation.

But now notice the remarkable effect of size on the relation between the radiation pressure and the gravitative pull. One is on the surface and proportional to the surface, while the other penetrates the surface and pulls every grain of matter throughout the whole volume.

Suppose we could divide the earth up in eight equal globes. Each would have half the diameter of the earth and a quarter the surface. The eight would expose twice the surface which the earth exposes, and the total radiation pressure would be doubled, while the total gravitative pull would be the same as before. Now divide up each of the eight into eight more equal globes. Again the radiation pressure would be doubled, while gravitation would be the same.

Continue the process, and it is evident that by successive division we should at last arrive at globes so small and with total surfaces so great that the pressure of the radiation would balance the pull of gravitation. Mere arithmetic shows that this balance would occur when the earth was divided up into little spheres 1/40,000 cm. in diameter.

In other words, a little speck 1/40,000 cm., say, 1/100,000 of an inch in diameter, and of density equal to that of the earth, would be neither attracted nor repelled by the sun.

This balance would hold at all distances, since both would vary in the same way with the distance. Our arithmetic comes to this: that if the earth were spread out in a thin spherical shell with radius about four times the distance of Neptune, the repulsion of sunlight falling on it would balance the inward pull by the sun, and it would have no tendency to contract.

With further division repulsion would exceed attraction, and the particles would be driven away. But I must here say that the law of repulsion does not hold down to such fine division. The repulsion is somewhat less than we have calculated owing to the diffraction of the light.

Some very suggestive speculations with regard to comets' tails have arisen from these considerations, and to these Professor Boys directed the attention of Section A last year. We may imagine that the nucleus of a comet consists of small meteorites. When these come near the sun they are heated and explosions occur, and fine dust is produced not previously present. If the dust is sufficiently fine, radiation may overpower gravitation and drive it away from the sun, and we may have a manifestation of this expelled dust in the tail of the comet.

I do not, however, want to dwell on this to-day, but to look at the subject in another way.

Let us again introduce our small black sphere, and let us make it 1 sq. cm. in cross section, 1.13 cm. in diameter, and of

[7] Mr. C. G. Abbot, of the Astrophysical Observatory, in a paper entitled "Radiation and terrestrial temperature," read before the Washington Philosophical Society on November 12, 1904, discussed the substantial equilibrium of temperature of the earth, and consequent equality of solar radiation absorbed in and about the earth to that emitted from and about the earth to space. After speaking of the great complexity of the earth and atmosphere as an absorber and radiator, certain maximum and minimum values of the solar constant and of the possible terrestrial temperature were obtained by considering the substitution of a black body or perfect radiator for the earth. In this way it was shown that the solar constant can not exceed 3.88 calories per minute, and may be indefinitely below this according as the earth reflects less than 44 per cent of solar radiation, or radiates to space less perfectly than a black body. Taking 1.9 calories as the minimum allowable assumption of the solar constant, it was shown that the mean temperature of the earth would remain above —33° C. if the earth were a perfect radiator and the reflection of solar rays did not exceed 44 per cent. Accordingly we owe not exceeding 58° C. rise of temperature to the imperfect radiation of the earth. (Science, December 9, 1904, vol. 20, p. 802.)

the density of the earth. The gravitation pull on it is 42,000 times the radiation pressure.

Now, let us see the effect of size on the radiating body. Let us halve the diameter of the sun. He would then have one-eighth the mass and one-quarter the surface. Or, while his pull was reduced to one-eighth, his radiation push would only be reduced to one-quarter. The pull would now be only 21,000 times the push. Halve the diameter again, and the pull would be only 10,500 times the push. Reduce the diameter to 1/42,000 of its original value, that is, to about 20 miles, and the pull would equal the push.

In other words, a sun as hot as ours and 20 miles in diameter would repel bodies less than 1 cm. in diameter, and could only hold in those which were larger.

But it is, of course, absurd to think of such a small sun as this having so high a temperature as 6000°. Let us then reduce the temperature to 1/20, say 300° absolute, or the temperature of the earth. Then the radiation would be reduced to the fourth power of 1/20, or 1/160,000, and the diameter would have to be reduced to 1/160,000 of 20 miles, or about 20 cm., say, 8 inches, when again radiation would balance gravitation.

It is not very difficult to show that if we had two equal spheres each of the density and temperature of the earth they would neither attract nor repel each other—their radiation pressure would balance the gravitation pull—when their diameters were about 6.8 cm., when in fact these were about the size of cricket balls.

It must be remembered that this is only true for spheres out in space receiving no appreciable radiation from the surrounding region.

It would appear that we have arrived at a result of some importance in considering the aggregation of small meteorites. Imagine a thinly scattered stream of small meteorites at the distance of the earth from the sun. Then, even if they be as large as cricket balls, they may have no tendency to move together. If they are smaller they may even tend to move apart and scatter.

In conclusion, let me mention one more effect of this radiation pressure. You will remember that radiation presses back against any surface from which it issues. If, then, a sphere at rest in space is radiating equally on all sides it is pressed equally on all sides, and the net result is a balance between the pressures. But suppose that it is moving. It is following up the energy which it pours forth in front, crowding it into a smaller space than if it were at rest, making it more dense. Hence, the pressure is slightly greater, and it can be shown that it is greater the greater the velocity and the higher the temperature. On the other hand, it is drawing away from the energy which it pours out behind, thinning it out, as it were, and the pressure at the back is slightly less than if the sphere were at rest.

The net result is a force opposing the motion, a force like viscous friction, always tending to reduce the speed.

Thus calculation shows that there is a retarding force on the earth as it moves along its orbit amounting in all to about 20 kgm., say, 50 lbs. Not very serious, for in billions of years it will only reduce the velocity by one in a million, and it will only have serious effects if the life of the earth is prolonged at its present temperature to hundreds of billions of years.

But here again size is everything. Reduce the diameter of the moving body, and the retarding effect increases in proportion to the reduction. If the earth were reduced to the size of a marble, the effect would be appreciable in a hundred thousand years. If it were reduced to a speck of dust a thousandth of a centimeter in diameter, the effect would be appreciable in a hundred years.

Note what the effect would be. Imagine a dust particle shot out from the earth and left behind to circulate on its own account round the sun. It would be heated by the sun and would be radiating out on all sides. As it journeyed forward there would be a resisting force tending to stop it. But instead of acting in this way the resistance would enable the sun to pull the particle inward, and the fall inward would actually increase the velocity. This increase in velocity would increase the resistance, and at the same time the approach to the sun would raise its temperature, increase the radiation, and so increase the resistance still further. The particle would therefore move in a more and more rapid spiral orbit, and ultimately it would fall into the sun. Small marble-sized meteorites would fall in from the distance of the earth probably in a few million years. Small particles of dust would be swept in in a few thousand years.

Thus, the sun is ever at work keeping the space round him free from dust. If the particles are very minute he drives them forth into outer space. If they are larger he draws them in. It is just possible that we have evidence of this drawing in in the zodiacal light, that vast dust-like ring which stretches from the sun outward far beyond the orbit of the earth, and is at once the largest and the most mysterious member of the solar system.

A SIMPLE, EFFECTIVE, AND INEXPENSIVE LIGHTNING RECORDER.

By HENRY F. ALCIATORE, Observer. Dated November 22, 1904.

In the latter part of August, 1902, the writer, at his own expense, constructed and erected in the local office of the United States Weather Bureau in New Orleans, La., a lightning recorder which has proved fairly satisfactory. Our object was to obtain automatic records of the hundreds of electric discharges, visible and invisible, that usually precede and accompany thunderstorms, and to study the same with a view to increasing the accuracy and value of local weather forecasts.

The action of the instrument is based upon the effect that high-tension electric waves in free air, such as lightning, have upon metal filings suitably arranged in a glass or other insulating tube between two metal electrodes, one of which is connected to a collector above the ground and the other to the earth. In their normal state the filings rest loosely at the bottom of the tube between two electrodes about 1/16 inch apart, and their electrical resistance is comparatively high. Now, when lightning occurs in the vicinity of the filings some of the electric waves traveling through the air pass through the filings from one electrode to the other; this causes the filings to stick together and their electrical resistance is greatly reduced, thereby rendering it possible for the current from a local battery to operate a relay in circuit with the filings, which in turn operates a device that separates the filings and restores them to their original condition, and at the same time records the passage of the electric waves.

Two years' experience with the lightning recorder described below has demonstrated that lightning records can be used to some advantage in making local forecasts. If, for instance, the recorder ticks frequently on a clear summer morning when there are no visible signs of an impending thunderstorm (each tick represents an electric discharge somewhere near the station, may be only a mile distant and may be 50 miles away) we conclude that the condition of the atmosphere is unstable, and that some time during the day there will be a thunderstorm. On July 3, 1903, for example, the first signal occurred at 5:21 a. m., and the first audible thunder at 12:40 p. m., or seven hours and nineteen minutes later. The last thunder occurred at 3:00 p. m., and the last signal at 3:53 p. m. About 180 signals were recorded by the instrument before the first audible thunder. In its present crude condition our recorder can not tell us from what direction the storm is approaching the station, nor with what speed and intensity, but by improving it such information may some day be obtained.