Positions of the Comet Barnard (for Berlin Midnight)

May		R.A.		Decl.		Log. Δ		Brightness
		h. m. s.		° ′				
16	...	2 20 49	...	28 0 N.	...	9·682	...	284
18	...	2 35 41	...	23 17	...	9·637	...	318
20	...	2 53 8	...	17 23	...	9·596	...	349

GEOGRAPHICAL NOTES

AMONGST the members of the mission proceeding from India to Tibet, under the charge of Mr. Colman Macaulay, are Col. Tanner, surveyor, Dr. Oldham, geologist, and Dr. Cunningham, naturalist. The expedition will leave Darjeeling about the end of the present month, and, marching through independent Sikkim, will cross the Jalepla Pass into Tibet. Its destination is Lhassa, the capital. Once only has this city been visited by an Englishman, Thomas Manning, and practically the whole route lies through a *terra incognita*. As Mr. Macaulay bears letters from the Chinese authorities, for which he made a special journey to Pekin last year, it is not anticipated that he will meet with any obstacles on his way to, or during his stay on, "the roof of the world." The three scientific members of his mission will find abundance of work to do, and the news of the progress of the expedition may be looked for with interest.

THE new number of the *Journal* of the Royal Asiatic Society (vol. xviii., part 2) contains an interesting article by Mr. Morison, of Tiflis, on the geographical distribution of Turki languages. The following is a summary. Dividing Turki into five sub-branches—Turki proper, Nogai, Uigur, Khirghiz, and Yakut—he states that the various subdivisions of, first, Turki proper, are spoken by the ruling class of the Ottoman Empire and the inhabitants of Asia Minor, in the Governments of Nijni Novgorod, Kasan, Simbirsk, Viatka, and Orenburg, in Trans-Caucasia, and North-Western Persia; the Nogai in Bessarabia, the Crimea, Cis-Caucasia, the Volga Delta, North-Eastern Daghestan, Terek Valley, the north-western shore of the Caspian, the Governments of Kasan and Simbirsk, Astrakan, Orenburg, and Ufa; the Uigur in Yarkhand and Chinese Tartary, the country of the Tekke, Zarafshan Valley, and generally in Central Turkestan, in the Khanate and Desert of Khiva and south of the Aral Sea, and in Kuldja; the Kirghiz from the Volga to the confines of Manchuria, but most compact in South-Western Siberia; and the Yakut in North-Eastern Siberia and on the northern slopes of Mount Sayan. Broadly speaking, says Mr. Morison, the Ugro-Altaic languages, of which Turki is one, are spoken over a region extending through more than 100° of longitude, from the shores of the Adriatic to the Great Wall of China and the plateau of Tibet, and through 35° of latitude, from the frozen steppes of Samoyede and Yakut to the plains of Northern Persia and the head-waters of the Indus. The Turki alone, according to the figures given, is spoken, in one or other of its various forms, by more than 20,000,000 of people.

THE *Proceedings* of the Royal Geographical Society for May contains a paper by Mr. Carles on his recent journeys in Corea, accompanied by a very useful map of the peninsula. Some account of these journeys has already appeared in Parliamentary Blue-Books, but much is added in the present paper. The writer refers to the many different types found amongst the Coreans of the present day; the facial characteristics of the people greatly resemble those of the Manchus, but Jews, Japanese, and Caucasians appear to be universally represented. There is also a curious reference to evidence of some forms of religion other than those imported from China in the *miriok*, or half-length human figures carved in stone. Mr. Needham also contributes an account of an excursion to the Abor Hills from Sadiya in Upper Assam.

BARON MIKLUHO-MACLAY has just returned to Odessa from his journey to New Guinea, which has lasted two years. He has brought a large collection of rare fishes, lizards, snakes, insects, and so on, packed in twenty-two boxes.

ANOTHER Russian traveller, M. Goudatti, the Secretary of the Moscow Society of Friends of Natural Science, who has also just returned from his journey to the north of Siberia, gives a curious account of his failure to accomplish his purpose. The Ostiaks and Samoyedes took him for a Government official on a recruiting mission, especially when he attempted to measure their heads, and took notes in his note-book. Finally the book was stolen, and all the results of his efforts lost.

HERR RADDE, who had started in January last with a scientific expedition from Tiflis to the Transcaspian region, writes from Askabad lately that this spring was very unfavourable for his researches, being three to four months later than usual. Therefore up to the middle of April he had not succeeded in collecting more than 35 species of plants and about 150 birds. Amongst these latter there is an interesting novelty, the *Picus sindiacus*, a pretty bird living in the high shrubs of *Tamarix*. The explorer intends to proceed during the present month to the mountain region between the Murghab and Tejen, and to return to Askabad through Sarakhs.

THE May number of the *Scottish Geographical Magazine* has an interesting article by Mr. Tripp on the physical configuration and rainfall of South Africa, with notes on its geology, diamond and coal-fields, and forests. The paper is accompanied by two maps showing contours and mean annual rainfall. A note by M. Dingelstedt on geographical education in the schools of the Caucasus shows that in Russia primary instruction in geography is as defective as in England. It is not made attractive, the writer complains; it only taxes the memory; the text-books are written to match, and few teachers are equal to the task of interesting their pupils in the subject. There are some interesting notes on the place-names of Kinross-shire by Mr. Liddall, and on the seaboard of Aberdeenshire, by Mr. Ferguson. The geographical notes are particularly copious and comprehensive.

THE current number (Bd. xiii. No. 4) of the *Verhandlungen* of the Berlin Geographical Society contains only one paper—a lecture by Dr. Naumann on the Japanese Islands and their inhabitants. The *Zeitschrift* of the same Society (Bd. xxi. Heft 2) is mainly occupied by a paper of Dr. Schweinfurth's on a journey which he made in the "region of depression" around Fayoum at the commencement of the present year. It is accompanied by a map, and fills 53 of the 66 pages forming the number. There is a short paper of great interest on the Maori population of New Zealand, based on the last census of that colony. The writer (who does not give his name) discusses the causes of the dying out of the race, and also the attitude of the Colonial Government towards the Maories. There is a note from Prof. Kunze on the climatology of South America, and, lastly, a long list of barometrical observations by Lieut. Francois in the Kassai region.

THE SUN AND STARS[1]

VI.

Summary of Results

IN what has gone before we have found that the prominences, and the spots, have special spectra unlike the ordinary spectrum of the sun, and unlike the spectra of the chemical elements.

Further, we know that when we proceed outwards to the spectra of the inner and outer corona we find ourselves very little better off, for, with the exception of hydrogen, there is no substance which is perfectly familiar to us; and finally, when we come to study the association of phenomena on the sun, we find that, exactly while the spots and prominences give us the greatest divergences from terrestrial conditions, solar facts indicate that these phenomena are allied in the most close and obviously important manner. We must henceforth consider that the spots and the metallic prominences and the faculæ represent different indications of the same solar action.

Now, to continue this part of the inquiry is fundamental for us. It is almost impossible to see a large spot at the edge of the sun, which is the place for observing it best, without finding this downrush towards the photosphere answered, so to speak, by an uprush from below the photosphere—without finding this downrush of cool, absorbing, dark-and-widened-line-producing material, re-echoed by an uprush of bright-lined substance.

There is one word which expresses, as well as anything I can think of, the impression which is made on one by the phenomena. There is a *splash*. Imagine an enormous cauldron of liquid iron, as hot as you like. Play some water into it from a hose; there will be a splash. The water, of course,

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[1] A Course of Lectures to Working Men delivered by J. Norman Lockyer, F.R.S., at the Museum of Practical Geology. Revised from shorthand notes. Continued from vol. xxxiii. p. 543.

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would be very violently heated; we probably might get some explosions, and as the result of these explosions some liquid iron might be carried with the liquid water which has entered into the liquid iron here and there. The metallic prominences always are close to spots. They almost always follow them like the faculæ. I might have told you, in fact, while talking of this, that of 1100 cases in which spots and faculæ have been observed together, in 581 the faculæ were to the left of, or behind, the spots. Only in 45 were they on the right or in front. We shall see the importance of this by and by.

If we can invariably, as we do, associate the descent of material which, though we do not see it falling, we know is there, and that it is relatively cool—*if we can associate these descending absorption-phenomena with a subsequent upward splash*, we must look upon the most intensely active prominences as being return upward currents, though in some cases it may be that what we see as the spectrum of a prominence at the limb is, in part, that of the vapour descending to form a spot.

The Sunspot Period

The next thing we have to do is to discuss the periodicity of the various solar phenomena, to which attention has already been directed. It is worth while again to refer to the two very interesting and important curves in which Prof. Spörer has recorded the results of his own observations.

When the spots are at their fewest the small number we do see begin in a high latitude N. or S., from 30° to 35°; as the spots increase in number and activity we get, at the maximum sunspot period, the chief appearances observed in middle latitudes—about lat. 18°; and then the mean latitude of the spot zone still gets lower and lower, until at the next sunspot minimum we get two systems of spots—one of them, lowest in latitude (about 8° N. and S.), ending the first cycle, and another in latitude 30° beginning the next. These are the salient features of the periodicity to which we have now to confine our attention.

It has been previously pointed out that there are other periodicities with a much shorter period than eleven years; certain changes are seen to occur among the quiet prominences. Still this is the main periodicity with which we are familiar on the sun; and what we have now to do is to endeavour to see whether we can follow all the phenomena in their changes.

The two last maxima occurred in the year 1871 and eleven years afterwards in 1882 and some time after that year. At those times we got the greatest amount of spotted area and the most intense solar action. Similarly the two last periods of minimum activity were in 1867 and eleven years afterwards in 1878.

Now, in order to investigate this question in the most satisfactory manner, I think, and I doubt not you will agree with me, that we should begin with the simplest case.

The Minimum

The simplest case is evidently that in which the sun is quietest. At first sight it may appear a little hazardous to talk about the sun being at its quietest; but we know, as a matter of fact, that there is a tremendous difference at different times in the solar activity along the lines to which reference has been made.

But in the light of what has already been stated let us suppose the sun at its quietest, what phenomena shall we see?

There will be very few of the ordinary tree-like prominences anywhere on the sun, and especially will there be a dearth of them near the poles and near the equator.

There will be faculæ, but the faculæ will be dim; they will not present the bright appearance they generally do, and what there are will be mostly confined to the regions of latitude comprised between 20° N. and 20° S.

If by means of a spectroscope we attempt to determine the chemical materials in the chromosphere, we shall find just those five lines only to which we have referred in the spectrum as ordinarily visible—that is, four lines of hydrogen, and one line named D_3.

Practically speaking, there will be no spots visible upon the disk; the disk will appear to be perfectly pure, almost equally illuminated throughout, barring always the darkening towards the limb.

As there are no spots, or only very small ones in high latitudes, there will be, we can easily understand from what has gone before, no metallic prominences whatever. The spectroscope searching right round the limb of the sun will gather no indications of violent action—no region giving us many lines—nothing but that simple spectrum of hydrogen to which I have already referred.

What, then, is the appearance put on by the corona if we can manage to get an idea of a corona at the minimum sunspot period? We see, the moment that question is suggested, how excessively important it is that all eclipses should be observed, whether they occur at the maximum or the minimum of the solar activity. Fortunately, since the year 1860 these wonderful phenomena have been observed with more or less diligence; and since the year 1871—that is fifteen years ago now—with few exceptions, not only have those eclipses been observed by the eye with great care, but photographs of the extremest value have been obtained.

Unfortunately, that first minimum to which I have referred—the minimum in 1867—took place practically before the general introduction of this perfect photographic record of eclipses; and there is no good photograph extant of that eclipse; but fortunately, good photographs were secured of the eclipse of 1878. You can imagine our American cousins did not let an opportunity like that of advancing knowledge slip; and the result was that the whole land along the line of totality bristled with telescopes and cameras, which did their work in an admirable way. So that in the eclipse of 1878 we did get a photographic record, that is to say, an absolutely trustworthy record, of the appearance presented by the sun's corona at the minimum sunspot period. If it were not so, I should have hesitated to show you the drawing made in 1867; but I think you will say, when I show you these records together, that the drawing in 1867 is so like the photograph taken in 1878 that on that ground alone it is worthy of extreme confidence; and if we can accord such confidence to it, we arrive at the very important conclusion that at two different sunspot minima the appearances presented by the corona were very much alike indeed.

At the minimum period the chief feature is a tremendous extension of the corona in the direction of the solar equator. At both the poles, north and south, there is a wonderful curving right and left; this outcurving having been one of the most exquisite things which it is possible to imagine.

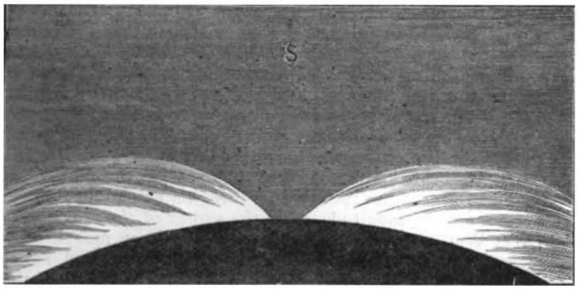

FIG. 19.—Outcurvings at the solar poles (1878).

There is further evidence indicating that the equatorial extension on the photograph may only after all have been a part of a much more extended phenomenon, one going to almost incredible distances—considering it as a solar atmosphere—from the sun itself.

It has already been stated that at that eclipse one observer took extreme precautions to guard his eyes from being fatigued by the light of the inner corona, which sometimes is so bright that observers have mistaken it for the limb of the sun itself. What this gentleman, Prof. Newcomb did, was to erect a screen which covered the moon and a space 12′ high round it. The result was, that as soon as he took his station at the commencement of totality, he saw a tremendous extension of the sun's equator on both sides the dark moon, the extension being greater than that recorded in the photograph. It does not follow that the photograph gives us the totality of the extension; it may be that the extended portions may have been so delicately illuminated, that they would not impress their image on the photographic plate in the time during which that plate was exposed, or that the light itself is poor in blue rays. So considerable was this extension, amounting to six or seven diameters of the dark moon, which practically may be taken to be the same as that of the sun behind it, that Prof. Newcomb had at once suggested to him the zodiacal light. It happened that while this eclipse was

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being observed by Prof. Newcomb and myself—we were practically close together at a height of 7000 feet—other observers were viewing the eclipse from Pike's Peak, some few hundred miles away, at a height of 13,000 feet. You can imagine the purity of the air at that height; there was not too much of it—so little in fact that some observers had to go down. These saw the corona very well indeed; and one or two observers, without taking the precaution of putting up a screen, saw an extension almost comparable with that recorded by Prof. Newcomb.

That, then, we must take to be the undoubted result arrived at during the eclipse of 1878, which happened at the last sun-spot minimum. We have a tremendous equatorial extension; that is the great feature, and it is proved by photographs.

The drawing made in 1867 gives us the same result. We again get the equatorial extension east and west, and the wonderful outcurving right and left from the sun's poles.

Hence, then, we must associate a corona of that kind, *i.e.* having a considerable equatorial extension, with that quiet condition of things at the sun, during which metallic prominences, ordinary prominences, faculæ, and spots show a minimum of activity.

You will remember that we saw from the sunspot curve that from minimum to maximum it mounts rapidly, reminding one of a steep cliff. We have in fact only three years from minimum to maximum, while we have eight years from maximum to minimum.

The Approach to Maximum

We have then next to consider the solar condition between minimum and maximum. We must suppose ourselves to be half-way up the steep part of the curve that connects the maximum with the minimum. In this case we find a greater activity in all directions. The hydrogen—or the quiet—prominences are more numerous. The faculæ are brighter. If we now examine the chromosphere we find hydrogen and D^3 are not the only constituents—we get those other short lines added of which Prof. Tacchini has given us such a valuable list, among them chiefly being those three lines of magnesium which are designated b^1, b^2, b^4. That is the chemical difference between the chromosphere of the sun at this time, and the first period at which we considered it. The spots also are more numerous, and what spots there are we have in a lower latitude; instead of making their appearance in latitude 35°, they will be nearer latitude 25°—they will have come down 10° from the solar poles towards the equator. These more numerous spots will also be constantly accompanied by metallic prominences, and the number of lines visible as bright lines in these prominences we shall find increasing as the observations are made month after month.

How about the outer atmosphere of the sun? Well, remarkable changes begin to take place in it too. In considering the minimum corona I said nothing about its spectrum, for the reason that I wished that wonderful bilateral and symmetrical and simple form to rivet the attention. But now it is right that I should say that one of the chief changes between this corona as the maximum is approached and the minimum one is not only the change of form to which I shall have to draw attention, but a change in the spectrum. At the minimum sunspot period the corona gives exactly, or very nearly exactly, the same spectrum as the lime-light or a jet of gas—we get very nearly a continuous spectrum. The chief difference between the spectrum of the corona, then, and the spectrum of the gas jet, is that in this continuous corona spectrum certain dark lines will be seen, but no very obvious bright lines are there. We therefore have to come to the conclusion that at the minimum the corona is not chiefly gaseous in its spectrum, but that it consists of solid particles to a very large extent; and that these solid particles are not only competent to reflect light, but that they actually do reflect light coming from the lower portions of the sun; and in that way we account for the presence of the Fraunhofer lines.

But when we come to the second period we are now discussing, these change to a very large extent; the spectrum is no longer continuous; bright lines begin to make their appearance, and with this coming-in of bright lines comes in a greater brilliancy.

And then as to the form. The diagram is copied from a drawing taken in the year 1858, at exactly the right period to illustrate any change which may have taken place on the approach to maximum. Unfortunately it is not a photograph. Those who lecture in this theatre twenty or a hundred years after me will be under many better conditions than we are, because they will have a more complete series of photographs to refer to; but in the absence of photographs we must do the best we can. Strange though the drawing is, it brings together so many features seen in other eclipses, that there is very little doubt that it is near the truth. However that may be, it must be acknowledged that between the last drawing you saw and this there is a most enormous difference. The remarkable point about it is that we have no special feature in the equatorial zone: we get a streamer here with very strange outlines, and we get another there, but the point of this drawing is that we get in middle latitudes, north and south, four wonderful luminous cones, and the amount of light and structure in the corona has increased to such an extent, that that exquisite, that beautiful tracery and double curves—curves east and curves west—we saw at both poles at the minimum, are now hidden in a strong radiance. So much then for the second act, so to speak, in this solar drama.

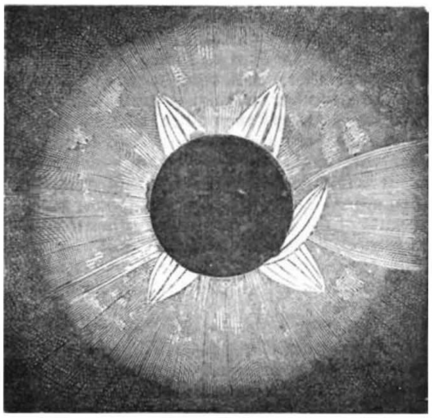

FIG. 20.—Corona of 1878.

The Maximum

We next deal with the maximum period when all the solar forces are working full time, and when we get both in prominences and in spots, and indeed in every outcome of action that we can refer to, indications of the most gigantic energies at work, and the most wonderful changes produced; energies and changes displayed from one pole of the sun to the other. When we come to this period of enormous action, we shall find that, although it becomes more general in one sense, it is really more limited in another.

The ordinary prominences, instead of clinging to the equator as they have done previously, are now found to be most frequent at the solar poles; the faculæ are brighter and more spread over the solar surface than they have ever been before. The chromosphere is richer in lines.

The spots occupy broad zones, the mean latitude being in about 18° N. and S. No spots near the poles, no spots near the equator, but spots indicating enormous activity and of enormous area, surrounded by gigantic faculæ, will be seen following each other in these zones. We shall find every one of these indicators of solar activity accompanied by enormous prominences. It is at this time we get the greatest velocities of upthrow in the prominences, and the greatest indications of tremendous downward velocity in the vapours which form the spots. It is at this time we get the spots riddled by bridges of intense brilliancy, full of veiled tints, red, yellow, blue, and violet, and all those other more delicate and beautiful phenomena described by M. Trouvelot and others, to which I have drawn attention.

How about the outer atmosphere of the sun? What has happened to that? Here, fortunately, we have the photographic records of two years—of two maximum years—to study. In these records there is no doubt that we have a thing which is absolutely and truly solar, for the reason that the photograph has undoubtedly, I think, sifted out what may be considered as due to non-solar causes. I say this distinctly, because I was fortunate enough to see both of these eclipses, one in India, and one in Egypt, and certainly there were things which I saw with the

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naked eye which one does not see in the photographs. We will consider the eclipse of 1871 first.

We see in a moment that we have something here at the maximum sunspot period different from what we have had before. To compare it with the record of the preceding minima in 1867 and 1878. Instead of having streamers limited to the equator, they exist in high latitudes, and instead of having them limited to four chief maxima, as we had in the year after the minimum in 1868, the energy is now so great that they practically extend to every part of the sun.

The directions of the lines of force, as they may be called, are very various: there are straight rifts; there are curved boundaries; here another streamer is curved bodily, and so we go on. We must always remember that in this photograph what we see is, after all, a projection. We have the spherical moon in front of the spherical sun, from which these streamers project in all longitudes—some straight towards the earth, the tips of which are seen over or under the moon, some more sideways from parts of the sun nearer to or further from the eye than the central section, so that the unravelling of the appearances is very difficult, especially if the eclipse happens when either the sun's north or south pole is tipped towards us or away from us to the greatest extent.

So much for 1871: in another eleven years we have another maximum—that of 1882—an eclipse seen in Egypt. In this case we find the activity more general than in the former one. The top and the bottom of the diagram represent the north and the south poles of the sun as before; but we see now that the streamers are more broken up, and furthermore that the rifts visible round the north and south pole at the previous maximum are entirely covered up—not that the rifts were not there, but that one could not see them in consequence of the extreme brilliancy of the streamers that were thrown towards the eye from the sun between us and the plane passing through the solar poles.

Independently of that, it is easy to recognise that there is a tremendous family likeness between the photographs taken at both maxima, whereas there is the greatest possible difference between either of them and the drawings or photographs taken at the minimum sunspot period. If we accept that, that is a very great step gained.

After Maximum

We need not, after what has gone before, take up any more time, which is short, by discussing the gradual descent to minimum. I say the *gradual* descent because we know there are more years consumed in going from maximum to minimum than from minimum to maximum.

Of course all the various energies slacken down, the mean latitude of the spots and metallic prominences still getting lower till they reach lat. 8° N. and S.; then another series of spots breaks out in lat. 35° N. and S., and the whole story begins anew.

Summary

Now let us deal with the results we have arrived at. At the maximum period the continuous spectrum of the corona gives way almost entirely to a spectrum of bright lines. When I say gives way almost entirely, I mean so far as this: the striking thing when you observe the spectrum of the corona at the maximum period is a series of brilliant lines, or of brilliant circles, according as we use a slit, or simply look through a prism, and the brilliancy of the spectrum seen between these lines or rings is small compared with the brilliancy of the lines or rings. That indicates that the temperature of the gases in the corona is greater than the temperature of the other substances, and of course is very much higher than it is during the time of the minimum, when the gases do not make themselves visible, and, as I said before, the chief spectroscopic effect obtained is the continuous spectrum with dark lines here and there, showing that some part of the light is derived from cooled solid particles which can and do reflect light from the subjacent photosphere.

To deal with results, and to bring them together as sharply as may be, we find, first, that the dimness of the light and absence of bright lines at the minimum shows that the outer atmosphere of the sun is cooler at the minimum sunspot period. When I was in America in 1878, at the period of minimum to which we have referred, I saw at once that the corona was not anything like so brilliant as I had seen it previously in 1871 in India. Eventually, when the observations came to be discussed, the conclusion arrived at was that the brilliancy was not one-seventh of what it was at the previous maximum. There is a very considerable difference which no one can mistake who observes one eclipse after another.

Secondly, when the corona is thus cooler, and therefore dimmer, an extension in the plane of the sun's equator is seen. A question arises here whether this extension is not seen at the maximum because the eye is so much affected by the very brilliant corona? That is a subject which will require to be investigated in subsequent eclipses.

Thirdly, there are plenty of minor prominences at the minimum sunspot period; there are no spots, or very few.

Fourthly, the lower temperature, and therefore relative quiescence, of the solar atmosphere seems to depend on the absence of spots. That is an important matter; and the point I wish to make is this: the quietude cannot depend on the absence of prominences, because they are there—not so many of them, but still some prominences.

Fifthly, when the spots begin in these higher latitudes, 30° or 35°, as we have seen, we get the first brightening of the corona.

Sixthly, the coronal streamers follow the spots—by which I mean that the cones and coronal streamers put on their greatest intensity according as the spots have moved nearer to the equator. When we have the minimum sunspot period, you can hardly call that equatorial extension a streamer at all, because it is so very dim; and further, I take it, it is really of a different nature and origin.

The Circulation in the Sun's Atmosphere

If we make an attempt to discuss the circulation of the atmosphere, a question which we acknowledge to be an extremely difficult one, we must bear in mind the enormous difference between solar and terrestrial conditions. When a portion of the earth's surface is heated in a whole zone—as the equator is in the tropics—by the sun, you see the heat is outside, an ascending current is formed, and winds from north to south set in. For instance, if we consider the equator, and suppose the sun to be over it, we get the earth's atmosphere over that region more highly heated than those parts of the atmosphere near either pole; and the result is, we get an indraught current in that way, both from the northern and southern hemispheres. In consequence of these two currents meeting and beginning their ascent at some distance from the equator, we get a belt of calms, of reduced pressure, and we get almost perpetual rains.

Now, you see, that is all very well as a piece of terrestrial meteorology, but it is of no value to us from the solar point of view, unless it sets us thinking how very different the conditions are.

The sun cannot be heated from the outside. We have seen, in fact, that one chief point about the sun is that it is cooled on the outside; that masses of gas going up to tremendous altitudes eventually arrive where the atmosphere is cold and quiet, and where they again take on the solid or liquid forms, when they begin to go down again. Now the sun, if it is heated at all, must be heated from the inside. What do I mean by the inside? I mean—seeing that the phenomena we have been discussing in these lectures take place outside the photosphere—that the inside must be something below the level of the photosphere. Now what form must that heat take? It will take, as undoubtedly we see in the metallic prominences it does take, the form of the ejection of the tremendously brilliant and incandescent vapours. How are these produced? Something must produce them; they do not ascend of their own sweet will, or they would not come up so locally as we see them.

We get this fact most indisputably, which I hope I have been able to make quite clear, that these ascents of vapours from below the spot region always accompany the spots, and they always follow the spots in time. Then is it not reasonable to suppose they are produced by the spots? You remember I objected to the word "eruption" in connection with these prominences. I do not so much object to the word "explosion," for I cannot understand how if you get twenty million tons of meteorites falling down in a particular latitude of the sun, and plunging into the photosphere—I do not understand how there must not follow after that the most gigantic and terrific explosion, driving heated gases many hundreds and thousands of miles into the upper air along the line of least resistance, and disturbing the photosphere for months afterwards. Now that really does seem to be the plain English of what happens.

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I have told you that in the origin of the spots the first disturbance is the formation of a few little openings probably by the advanced guard of the falling solid material. In a few days, by the continuous downpours, these develop into a spot. This spot is followed by a metallic prominence sending up the masses of gas at the rate, may be, of 250 miles a second—a rate Prof. Young has observed; and after that the faculæ appear. I throw that idea out because the greatest prominences are associated with the greatest spots; the spots begin the disturbance, and the energies radiate from the point where we first see the disturbance, which, I repeat, the spot begins.

We see, then, that on the sun the action will be almost just the opposite of what it is on the earth. We get first of all the descent of cooled matter on to the part of the sun where the disturbance begins.

Here we get ascent in consequence of greater heat outside. At the sun the greater heat inside the sun is liberated by the splash and explosion of spot-producing material.

Now, when the material falls in the way we have indicated, we shall get, if the idea is true, a considerable temperature in the region above the fall accompanying the return current in the shape of prominences. We may probably also get a current in the lower atmosphere set up towards the north and towards the south, and another thing we shall certainly get will be a tremendous brightening of this part of the solar atmosphere.

One of the great differences between one part of the solar atmosphere and another depends upon its temperature; so that you must imagine that the moment we get any great change in the temperature of any part of the atmosphere we must get a great change in its brilliancy, even in the higher regions: this may explain the streamers.

If there are these lower currents towards the poles there will probably be upper currents away from them which may in some way locate spot-forming material over the spot zones. On this subject, however, which, though one of the most important in solar physics, is one in which we see our way least clearly, I have not time to enter. J. NORMAN LOCKYER

(*To be continued.*)

THE INSTITUTION OF MECHANICAL ENGINEERS

THE Institution of Mechanical Engineers held their annual meeting, under the presidency of Mr. Jeremiah Head, at the Theatre of the Institution of Civil Engineers, on the 6th and 7th inst.

Mr. T. B. Lightfoot read a paper on refrigerating and ice-making machinery and appliances. He commenced by describing a complete refrigerating machine as an apparatus by which heat is abstracted, in combination either with some system for renewing the heat-absorbing agent, or, as is more usually the case, with a contrivance by which the abstracted heat is rejected and the agent is restored to a condition in which it can again be employed for cooling-purposes.

The first method by which heat is abstracted by the rapid fusion of a solid is probably the oldest. It depends upon the very strong tendency of mixtures of certain salts with water or acids, and of some salts with ice—which form liquids whose freezing-points are below the original temperatures of the mixtures—to pass into the liquid form; heat is absorbed more quickly than it can be supplied from without, and the temperature consequently falls. This method has been mainly employed for domestic and laboratory purposes.

When heat is abstracted by the second method, that is, by the evaporation of a more or less volatile liquid, other things being equal, the liquid with the highest latent heat will be the best refrigerant, because for a given abstraction of heat, the least weight of liquid will be required, and therefore the power expended in working the machine will be the least. There are four different kinds of processes employed.

The first, in which the refrigerating agent is rejected with the heat it has acquired, is generally known as the vacuum process. Water, the only agent cheap enough to be employed, must be reduced to a pressure below 0·089 lb. per square inch, which is the pressure of water-vapour at the temperature of melting ice. A vacuum-pump is employed, combined with a vessel containing strong sulphuric acid, for absorbing the vapour from the air drawn over, and so assisting the pump. Lately an improvement has been effected in this process by the employment of a pump with two cylinders and intermediate condenser, the water being admitted to the ice-forming vessels in fine streams, so as to offer a large surface for evaporation. The second, or compression-process, is used with liquids whose vapours condense under pressure at ordinary temperatures. The first apparatus employed, though in some respects crude, is yet the parent of all compression-machines used at the present time, the improvements being generally in matters of constructive detail. The water to be frozen was placed in a jacketed copper pan, the jacket being partially filled with the volatile liquid, and carefully protected on the outside with a covering of non-conducting material. A pump drew off the vapour from the jacket, and delivered it compressed into a worm, around which cooling water was circulated, the pressure being such as to cause liquefaction. The liquid collected at the bottom of the worm, and returned to the jacket through a pipe, to be again evaporated. Most modern machines comprise a refrigerator, a water-jacketed pump, a condenser, and ice-making tanks containing moulds or cells, around which brine cooled to a low temperature in the refrigerator is circulated by means of a pump. The working pressure in the refrigerator depends upon the reduction in temperature desired, the higher the pressure the greater being the work that can be got out of any given capacity of pump. The liquefying pressure in the condenser depends on the temperature of the cooling water, and on the quantity that is passed through in relation to the quantity of heat carried away; this pressure determines the mechanical work to be expended. To produce transparent ice, the water has to be agitated during freezing, so as to allow the air to escape. Various refrigerating media have been used, such as ether, sulphur dioxide, and anhydrous ammonia. The third is known as the absorption process: the principle employed is chemical or physical rather than mechanical, and depends on the fact that many vapours of low boiling-point are readily absorbed by water, but can be separated again by the application of heat to the mixed liquid. Taking advantage of the fact that two vapours, when mixed, can be separated by means of fractional condensation, an absorption machine has been brought out in which the distillate was very nearly anhydrous. Ordinary liquid ammonia of commerce was heated, and a mixed vapour of ammonia and water was driven off. By means of vessels termed the analyser and the rectifier, the bulk of the water was condensed at a comparatively high temperature and run back to the generator, while the ammonia passed into a condenser, and there assumed a liquid form. The nearly anhydrous liquid was then evaporated in the refrigerator in the ordinary way; but, instead of the vapour being drawn off by a pump, it was absorbed by cold water or weak liquor in a vessel called an absorber, which was in communication with the refrigerator, and the strong liquor thus formed was pumped back to the generator and used over again. In the fourth, which is known as the binary absorption system, liquefaction of the refrigerating agent is brought about partly by mechanical compression and partly by absorption; or else the refrigerating agent itself is a compound of two liquids, one of which liquefies at a comparatively low pressure, and then takes the other into solution by absorption. An interesting application of this system has been recently made by Raoul Pictet, who found that, by combining carbon dioxide and sulphur dioxide, he could obtain a liquid whose vapour-tensions were not only very much less that those of carbon dioxide, but were actually below those of pure sulphur dioxide at temperatures above 78° Fahr. This very remarkable and unlooked-for result may open up the way for greater economy in ice-production.

The third method is that in which machinery is used by which gas is compressed, partially cooled while under compression, and further cooled by subsequent expansion in the performance of work, the cooled gas being afterwards used for abstracting heat. This method has been much employed of late years, under the title of "Cold-air machines" for the preservation of meat and other perishable food. The author has designed machinery of this class, in which a weight of 1000 lbs. of air per hour can be reduced from 60° above to 80° below zero Fahrenheit, with cooling water at 60° F., with the expenditure of about 18 indicated horse-power. The air after being compressed in the compresser passes to the coolers, which consist of a couple of vessels containing tubes, through which water is circulated by a pump. The compressed air passes through one cooler and returns through the second, being cooled to within 5° or 6° of the initial temperature of the cooling water, which circulates in a direction opposite to that of the air. From the coolers the air passes to

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