Meteor-Showers.

	R.A.	Decl.	
	250 ...	20 S.	
Near ζ Cygni...	318 ...	30 N.	
,, β Piscium	345 ...	0	... Very swift.

NOTES ON METEORITES.[1]

IX.

Did these Swarms or Comets always belong to the System?

MUST we assume that the members of the swarms to which we have referred and of all the other swarms similar to it have always been thus crossing the earth's orbit periodically; that the November swarm, to take an instance, has *always* been crossing it every thirty-three years? Must they of necessity have started their existence with the planets and other more stable members of the system?

This point has been well inquired into, and it is certain that it is not at all necessary that such a state of things should have existed from all time.

It is a matter of common knowledge that all stars are in motion. The so-called "fixed" stars are not really fixed: they are only relatively fixed. The sun is a star, and therefore like the other stars it is also in movement with its attendant bodies in space.

If we have a swarm of meteorites moving in space, as the sun is doing, at a very considerable distance from the sun, the directions of movement being not parallel but inclined to each other, a time will come when the two bodies, taking the swarm as representing one body, and the sun another, will begin to have an attractive influence on each other. If the attractive energy of the sun is considerable as compared with that of the swarm, the swarm will begin to change its direction obviously towards the sun. If, in changing its direction towards the sun and increasing its velocity in consequence of this increased gravitational stress, that swarm can get round the sun without any loss of momentum the two bodies will say good-bye to each other and will go different ways; but supposing there has been a loss of momentum the loss may mean that for the future the swarm of meteorites must perform its journey *round the sun*.

It does not therefore follow that when a particular group of meteorites has been watched for 900 years that these meteorites which give rise to the appearance of shooting stars always formed part of the solar system. What we do know is that *at the present moment* this particular swarm to which the November meteors are due and another swarm which is called the Biela swarm, to mention two instances, do really move round the sun in closed cometary orbits, and the chronicle of the appearances of both these swarms is so complete that very definite statements may be made about them.

With regard to the November swarm it is known that a thousand millions of miles of its orbit have been pierced by the earth in its successive passages through it since the year 902, each time the earth must have filched many millions of the small constituents of the swarm and used them up as shooting stars, and yet the swarm does not seem to be very much the worse, and enormous though the numbers are, it is known that the distances between the meteorites is so considerable that no obvious mutual gravitational effect can be noted, so that their combined or common movement is a clear indication of a common origin.

In the case of the orbit of the Biela swarm we know that more than half of it, or a length of 500 million miles, contains these meteorites; a long thin line, say a mile long and an inch in section, represents, according to Prof. Newton, the distribution of the meteorites along the orbit.

The great Laplace was the first to suggest that many comets, especially those of high inclination and great eccentricities, represented introductions of matter into the solar system from external space. But on this, as on many other points, we owe our present views chiefly to Schiaparelli, who, in 1867, attacked the problem[1] in connection with his researches on the November swarm.

[1] Continued from vol. xxxix. p. 402.

He commenced by referring to the point made by Laplace as to the phenomena presented by cometary orbits, suggesting that the planets are truly indigenous to the system; have always followed the sun in his movement through space; and had taken part in all the evolutionary changes which have finally brought the solar system to its present condition. In these characters common to planets the comets are lacking, while the eccentricities of their orbits generally is so great that the greater part of their journey is performed outside the known limits of our system. Schiaparelli considers that these facts demonstrate that the comets were not members of the solar system during its early stages, but that they are really messengers from the stellar void. Cloudlike masses wandering in parts of space where there was no star sufficient to dominate them have fallen gradually under the empire of our own by the effect of their movement relatively to our system. This movement, combined with the acceleration produced by the large mass of the sun has determined the relative orbits of these bodies in relation to the sun, which is very different from their absolute orbit in space. He next examined all the circumstances of the movement of the external mass under these conditions. First, there is no doubt that the movement of the solar system in space is comparable to that of the planets in their respective orbits, while it is possible—indeed certain—that many of the stars are in more rapid movement than our sun. Hence when it is affirmed that the relative movement of the sun and of other bodies disseminated through space is comparable in rapidity to the orbital movement of the planets, the statement is not a surprising one.

That being so, let us next suppose that one of these cloudlike masses—let us call them external swarms—wandering in space in consequence of its initial movement, penetrates eventually into a region where the attraction of the sun is much greater than that of any other star. It might be situated at a very great distance from the sun, where the annual parallax is only a small number of seconds. The relative movement will take place in a conic section. To define it, let us suppose the sun stopped, and let us give to the comet, instead of its real velocity in space, its relative velocity to the sun; and let us further imagine a perpendicular dropped from the sun in the direction of this relative velocity. It is evident that the area described by the comet round the sun in unit time will be equal to the half of the product of this perpendicular by its relative velocity.

Now as in general this velocity is of the order of planetary velocities, and since most frequently the perpendicular in question will be very much greater than the distance of the planet from the sun, we must conclude that the areas described by the comet round the sun in unit time will be incomparably greater than the corresponding areas described by the planets. But when many bodies move in conic sections round a central body, the areas described in unit time are, among themselves, as the square roots of the parameters of their respective orbits; therefore, the ratio of the parameters of cometary orbits to those of planetary orbits will be much greater than the ratio of the areas described by comets to the areas described by planets in unit time. Whence it follows that, in general, cometary orbits will have enormous dimensions in every direction, and that bodies which describe them will remain perpetually invisible to us, in consequence of their enormous distance. Nevertheless, among the infinite combinations possible in cometary orbits, there are two which may bring the cometary cloud within our ken: one, when the comet is moving directly towards the sun, describing a hyperbolic orbit very little different from a right line; and the other, when the relative movement of the comet and sun is almost zero, that is, when the two bodies are moving through the stellar space along parallel lines with nearly equal velocities.

Schiaparelli then goes on to show that when these cosmic clouds are attracted by the centre of our system, the constituent particles of the cloud must be drawn out into a parabolic current; thus, for instance, supposing a cosmic cloud equal in volume to the sun and at such a distance that its apparent diameter is 1′, the sun's attraction upon this would result in the formation of a parabolic chain or stream of such a length that it would require 636 years to pass through perihelion. When the centre was close to the sun, the beginning and the end of it would be distant from it 263 times the earth's distance from the

[1] *Les Mondes*, vol. xiii. p. 147.

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sun. There are nebulæ of which the apparent diameter is greater than that of the sun. If we assume such a nebula, with the sun's apparent diameter, 1924″, it would be transformed into a parabolic chain which would require 20,000 years to pass perihelion, its transversal dimension still being such that the earth could traverse it in one or two days at the most. In this way, then, Schiaparelli shows not only that external swarms can be attracted from external space into our system, but that when so drawn out their constituent particles must take the form which we know such swarms as that of November to possess.

More recently this subject has been treated by Prof. H. A. Newton, and some results at which he arrived have been thus stated by Prof. A. S. Herschel:—[1]

"The evidence so strongly and distinctly shown in favour of the theory of the original motion of most, if not of all, of our recorded comets in spaces far external to the solar nebula, rests upon the assumption that the comet-yielding matter of the primitive nebula, if it existed, was confined, like that which formed the planets, to the neighbourhood of the ecliptic plane. This ground for the conclusion may admit of an exception that a similar distribution of the inclinations of the orbits to that which Laplace's hypothesis requires, would have been produced were this matter otherwise spread uniformly on a very distant sphere, instead of in the distant portions of a disk or annulus. But the plane of the planetary motions in the solar system, and the analogy which they present to spiral and disk-like nebulæ in the heavens, scarcely allows us to assume with reasonable probability such a different disposition of the matter of the outer part of the nebula from what the courses of the planets show us must have been its original mode of distribution and of gradual contraction near the centre; and with no evidence before us of the past or present existence of a distant spherical envelope of nebular matter inclosing the solar system, we may certainly prefer to accept, with Prof. Newton, the much simpler conclusion to which he is finally conducted by his well-executed labours, that, with the exception of a few, perhaps, of the zodiacal comets, and comets of the shortest periods, all the comets which have been recorded are originally denizens of the interstellar spaces, pursuing unknown orbits like the stars, and separated at least and dissevered in their primitive astronomical relations from any connection with the nebular matter which, in the process of concentration supposed by the nebular hypothesis, formed the sun, the planets, and the asteroids."

Most Comets have once existed as External Nebulæ.

We now come to an important question: we have noted the extreme probability that the comets which now form part of the solar system did not always belong to it, but that they were drawn into it by the sun's attractive energy in its course through regions of space which contained the meteorites of which they are composed.

Then, instead of considering the case of a cloud of meteorites at a great distance from the sun, we have to consider one moving in an orbit round it; and we must attempt to inquire into the conditions of that cloud, both before and after it began to fall under the sun's attraction. Into what conditions must we inquire in order to compare comets with external swarms? They are mainly these—

(1) It is agreed that a comet is a swarm of meteorites, each meteorite being on an average far from its neighbours. This follows from an inquiry into the masses of comets. These are very small, for they have never been known to appreciably disturb any of the planets, or even the satellites, by their gravitational attraction.

In 1776, Jupiter and his satellites were entangled in a comet, yet the satellites pursued their courses as if the comet had no existence. The comet itself, however, was thrown entirely out of its course by the gravitational influence of the enormous mass of Jupiter, and its time of revolution changed from a long period to a short one of twenty years or so.

Biela's comet, first seen in 1826, appeared as a double comet in 1845. The extreme lightness of the two portions was shown by the fact that their mutual attraction was imperceptible, and each performed its revolution independently of the other.

The mass of a comet probably never exceeds 1/5000 of that of our globe. The meteorites composing them must therefore be very far apart, seeing that this small mass is distributed through spaces millions of miles in extent.

[1] *Monthly Notices*, vol. xxxix. p. 279.

(2) We next assume that a comet's luminosity is to a large extent produced by collisions of meteorites.

It is certain that one of the principal causes of the increase of temperature of a comet during its approach to perihelion is the increased number of collisions due to the greater tidal action which takes place. Hence the larger the swarm, the greater the difference between the attractions of the sun upon opposite sides of it, and therefore the greater the disturbance set up. Also, the shorter the perihelion distance, the greater fraction of it is the diameter of the swarm, and the greater therefore the differential attraction.

The initial movements of the individual members of the swarm, and these superadded by tidal action, may be defined as producing *internal* work.

If all the heat of a comet is produced by such internal work, it is clear that the temperature of the comet will depend (1) upon the velocity of orbital motion of the particles, (2) upon the size of the swarm of which it is composed, and (3) upon its perihelion distance. It will practically be independent of the velocity of the comet in its orbit round the sun.

If the luminosity be due entirely to internal collisions brought about by the increase of solar action, then large comets, or those best visible, should begin to be brilliant long before smaller or more distant ones. But this does not seem to be so. Mr. Hind has pointed out that proximity to the earth is not so important a condition for visibility of a comet in the daytime as close approach to the sun (NATURE, vol. x. p. 286); and M. Faye is the authority for the statement that no comet has been seen beyond the orbit of Jupiter (*ibid.* p. 228). "It is assuredly not on account of their smallness that they thus escape our notice in regions where the most distant planets, Saturn, Uranus, and Neptune, shine so clearly with the light which they borrow from the sun; this is because the rare and nebulous matter of comets reflects much less light than the solid and compact surfaces of the planets of which we speak, much less even than the smallest cloud of our atmosphere."

On the latter part of this quotation it may be remarked that it is not necessary to assume that comets at a great distance from the sun, any more than nebulæ, are visible by means of reflected light.

Another possible cause is that of collisions with bodies external to the comet. If external work is done on a comet by meteorites in space—that is to say, if there are collisions with external bodies—the velocity of the comet must be considered in the first place, and the equal or unequal distribution of the masses which it encounters can be tested by the phenomena observed.

The discussion of the recorded observations shows, indeed, that in addition to the constantly increasing action which takes place in a comet during its approach to perihelion passage, there are at times temporary increases in temperature.

We know that meteorites are scattered through space, and here and there are gathered into swarms. It is only to be expected, therefore, that at times a comet will meet with such swarms just as our own planet does, and in that case its temperature would be increased by the collisions which would occur. The increase of temperature would depend upon (1) the dimensions and density of the swarm; and (2) upon its velocity. The larger and denser the swarm the more collisions would be likely to occur, and the greater the velocity of the comet, the greater the amount of kinetic energy available for transformation into heat energy.

If we assume that the increased brightness of comets as the sun is approached depends to any extent on collisions with meteorites external to the swarm, we must conclude that such meteorites exist nearer together nearer the sun. This we should expect. A test of this view would be great and irregular variations of intensity, as we know that the meteorites which the comet is liable to meet are not equally distributed. Such a variation was noticed in Sawerthal's comet in 1888, amounting to three magnitudes (NATURE, vol. xxxviii. p. 258) in two days.

Such variations, however, would be more likely to be observed in the tails in consequence of the enormous dimensions of some of them; and indeed they have been observed from the time of Kepler.

The fact that these variations so strongly resemble at times auroral displays is an additional argument in favour of the meteoric origin of the latter.

Another result of a different order produced by a comet moving through a meteoric plenum would be the gradual shortening of a comet's periodic time, and this shortening should not be abso-

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lutely regular, as in a homogeneous gas, for the reason that the meteorites are not equally distributed.

That there is such a shortening was proved by Encke for the comet which bears his name, as the following table will show :—

Returns of Encke's Comet, showing Reduced Period of Revolution.

	Observed Period of Revolution. days. h. m.	Difference. h. m.
From 1786 to 1795 three times.........	1212 15 7	
,, 1795 ,, 1805 ,, ,, ...	1212 12 0	3 7
,, 1805 ,, 1819 four ,, ...	1212 0 29	11 31
,, 1819 ,, 1822	1211 15 50	8 39
,, 1822 ,, 1825	1211 13 12	2 38
,, 1825 ,, 1829	1211 10 34	2 38
,, 1829 ,, 1832	1211 7 41	2 53
,, 1832 ,, 1835	1211 5 17	2 24
,, 1835 ,, 1838	1211 2 38	2 39
,, 1838 ,, 1842	1210 23 31	3 7
,, 1842 ,, 1845	1210 21 7	2 24
,, 1845 ,, 1848	1210 18 29	2 38
,, 1848 ,, 1852	1210 17 2	1 27
,, 1852 ,, 1855	1210 11 17	5 45
,, 1855 ,, 1858	1209 13 41	21 36

Here, then, we have three possible sources of collisions. In any case, if any light be produced by collisions, we have the spectroscope as a sure guide to enable us to determine its chemical origin.

We have already seen that the telescopic appearance of a comet when far away from the sun and when close to it are very different. We must now introduce the verdict of the spectroscope. It was observed by Dr. Huggins in the comets of 1866 and 1867 that when they were very far away from the sun the spectrum consisted chiefly of a line seen in the spectrum of those nebulæ which he had up to that time examined. Unless, then, Dr. Huggins has withdrawn this observation, there is a *spectroscopic* connection between nebulæ and comets away from the sun.

The phenomena of comets revealed by the telescope show, as we have seen, that as a matter of fact a good many of them seem to be connected in some way or other with the production of luminous concentric or eccentric envelopes.

In the case of a comet gradually getting nearer the sun, and getting very excited as it gets there, we pass from the spectrum already described to a very different one. There is a considerable change similar to that observed in experiments with meteorites, the spectrum of carbon produced from some compound of carbon or another. In nineteen cases out of twenty when the comet gets near the sun and near enough to the earth for us to have a good look at it, the spectrum is a spectrum of carbon.

On its first appearance in a cometary spectrum, carbon is represented by the flutings which are special to low temperatures. In the most visible part of the spectrum these flutings differ very little in position from those which appear at a higher temperature, but in the blue there is a low-temperature fluting about wave-length 483, whilst the nearest high-temperature fluting is 474. If, therefore, this fluting be observed, the presence of cool carbon may be safely inferred, although it would not be quite safe to infer its presence from observations of the green flutings. This has certainly been observed in two comets—namely, Winnecke's comet (1868) on June 17 (the perihelion passage occurring on June 24), and in Brorsen's comet (1879) on March 25 (the perihelion passage occurring on March 30). The limited number of recorded appearances of cool carbon in comets is doubtless due to the same cause as in the case of the line near λ 500, which Dr. Huggins ascribed to an unknown form of nitrogen, while I ascribe it to magnesium, since we know that there is magnesium in meteorites, and we do not know that there is an unknown form of nitrogen. The reason is that the temperature being low, the light is excessively feeble and observations therefore difficult. When nearer perihelion passage, the comets get hotter, and the spectrum of cool carbon is replaced by that of hot carbon. Under these conditions of increased temperature, comets lend themselves best to spectroscopic study, and hence it happens that in the majority of cases the spectrum of a comet (if the temperature be increasing) has not been observed until it has arrived at this stage.

Manganese is the next substance which writes its record in the spectroscope. It is first represented by a fluting at 558,[1] which is the brightest fluting in its spectrum at a low temperature. This fluting is very persistent, and becomes visible even when there is only a very small percentage of manganese present in the substance examined. The fluting is always seen before the iron lines in the spectrum of ordinary iron at the temperature of the oxyhydrogen flame, and this is the case even with the purest specimens of electrolytic iron which has yet been prepared. The effect of the addition of this fluting to the spectrum of carbon is to modify the appearance of the citron band in the cometary spectrum in a very definite manner.

At a still higher temperature, the radiation of lead is added to that of manganese and carbon, which still further modifies the appearance of the citron band. The brightest lead fluting is at wave-length 546, and when this is present in the spectrum of a comet the citron band has three maxima of brightness, one at 564 (carbon), one at 558 (manganese), and one at 546 (lead).

Afterwards, the temperature having increased, the radiations of manganese and lead give way to the absorption flutings of these substances, carbon radiation from the interspaces still remaining. The result is again a very definite modification of the appearance of the citron cometary band, the general effect being an apparent shifting of the carbon fluting from wave-length 564 to a more refrangible part of the spectrum—namely, to 558, when only manganese absorption is added, and to 546 when both manganese and lead absorptions are added.

Until quite recently, the variations in the position of the citron band in different comets, or in the same comet at different periods, have been attributed to faulty observations, it being supposed that carbon pure and simple was in question. It is now certain, however, that this is not so in all cases. The variations are real, and are simply dependent upon the temperature, or indirectly upon the distance from perihelion.

In some cases iron fluting absorption has also been observed under these conditions of high temperature.

The spectral conditions brought about in the comets which in our time have got nearest to the sun were very similar to those observed in the electric arc, and the recorded observations of the spectrum show that we were dealing with a considerable number of lines of iron, manganese, and other substances.

We see in the telescope that a comet puts on the appearance of a central nucleus with surrounding envelopes or jets, so that we must understand that in the spectroscope the spectrum of the nucleus is seen distinct from the spectrum of the envelopes and jets, because the former is made to fall upon one part of the slit of the spectroscope and the latter upon another.

When a comet approaches very near to the sun we get in addition to the usual flutings of carbon, bright lines, *especially in the spectrum of the nucleus*, so that in addition to the long flutings of carbon as visible in the spectroscope we have short lines added along the nucleus in the red, yellow, green, and so on.

In those comets which have reached a very high temperature, like Comet Wells and the Great Comet of 1882, there is evidence of line absorption. At the same time there were bright lines, proceeding from the incandescent vapours driven away from the meteoritic nuclei by the solar repulsion. Without this repulsion, it is highly probable that there would be line absorption pure and simple, and this has to be taken into account in comparing the spectra of comets with the spectra of other meteor-swarms.

During the passage of a comet from perihelion to aphelion, the temperature decreasing, these changes take place in inverse order.

In spectral phenomena, then, we have another term of comparison to apply, and it may be stated that the sequence of spectral changes are now known to us in a very definite way, so that the chemical changes which take place in the composition of the vapours of comets produced by collisions at various distances from the sun have been ascertained.

Whether we take form, distance apart of component parts, or spectrum, there is now ample proof that the external bodies which supply us with these shreds and patches which we term comets are the nebulæ.

It has already been stated that if we can rely upon Dr. Huggins's observations, in some comets at aphelion and in some planetary nebulæ we get a single line at the same wave-length, so that from

[1] Students of spectrum analysis will understand that this is a "short title," and does not represent the *exact* wave-length, which with adequate instruments might require something between 10 and 100 numerals.

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this observation alone it would seem extremely probable that when a comet enters our system for the first time it simply means that a swarm of meteorites in that part of space through which the sun was passing at the time began to feel the sun's attraction, and ultimately became a member of our system, and also that when we see the appearance which we call a nebula in space, since its spectrum is the same as the spectrum of a comet, the nebula is simply a swarm of meteorites if it be true that a comet is a swarm of meteorites.

These nebulous masses, visible in all parts of the heavens, but in some parts of the heavens very much more numerously than in others, were very early observed and imagined to be very different in nature from the so-called fixed stars.

Ptolemy was the first to point out, when he was making his map of the stars that there were certain "cloudy" stars of which he gave 5 on his map, and Tycho Brahé, whose work was done before the invention of the telescope, although he did not notice any bodies which we now class as nebulæ, was firmly convinced that that nebulous luminosity, which we call the Milky Way, was something entirely different in its nature from the stars. He imagined it to be what he called an ethereal essence, a sort of fire mist, so that when in his time, in the year 1572, a new star appeared, he supposed it to be a considerable agglomeration of this ethereal fluid. Galileo was able to show that the Milky Way, the "ethereal substance" of Tycho, was only an appearance due to enormous numbers of stars lying in the same visual ray, the stars of which the Milky Way is composed can indeed be seen with very small optical power. It was not till 1612, a few years after the introduction of the telescope, that we got the first real definition of a body which we now call a nebula.

The first observation we owe to Simon Marius, who stated that some of the bodies visible exactly resembled the appearance produced by the flame of a candle seen through horn. It was not till 1656 that the nebula in Orion was discovered, although now to the trained eye it is very easily visible, so that it seems rather wonderful that it was not discovered before. In 1714, in England, attention began to by paid to these bodies, but it was not until the time of Sir Wm. Herschel that the most magnificent revelations were made. He was the first to construct very large telescopes, the function of very large telescopes being to collect light, so that objects which appear to the eye as excessively dim may be brought into full visibility.

After not only Sir Wm. Herschel but his son, Sir John Herschel, had accumulated vast stores of facts, Lord Rosse took up the story, and made a telescope very much more powerful than any which had been employed by the Herschels. His telescope has a light-grasping power compared with the eye of 130,000. One of the results of Lord Rosse's work to which we need here refer is the idea that in a great many bodies which had been classed as nebulæ this enormous increase of optical power suggested that we were only dealing with very distant clusters of stars.

Lord Rosse was able to get the suggestion of "resolvability" in so many bodies which had been classed as nebulæ by Sir Wm. Herschel and others, that gradually the idea came to be held that the most nebulous nebula, if we could get sufficient optical power to bear upon it, would be broken up into stars, just as certainly as the Milky Way had been.

This would mean that the nebulæ were simply clusters of stars so infinitely remote from our ken that even with the power of Lord Rosse's instrument they put on the appearance of an ethereal essence.

This was the general opinion in 1864, in the early days of spectrum analysis, when Dr. Huggins turned his spectroscope one night to one of the planetary nebulæ. At first he thought that something had gone wrong in the apparatus because he could only see a bright line instead of the usual sort of spectrum obtained from a star. The spectroscope, however, was doing its level best, and the cause, the anomaly, was really that the nebula gave out monochromatic light.

In some cases another line was seen, stated to be due to hydrogen. It now appears that the dispersion employed was so small that the discoverer had no right to allocate any line, so that it is fortunate that other observers have since shown that there is another hydrogen line visible.

Dr. Huggins came to the conclusion that the first line was very nearly, if not exactly, in the position of the chief line seen in the spectrum of nitrogen, and the suggestion was therefore made that these nebulæ were masses of nitrogen and hydrogen gases mixed, or, if not nitrogen, some constituent of nitrogen mixed with hydrogen. That result made the idea of Lord Rosse concerning the possibility of the resolvability of nebulæ into stars untenable. We had to consider from that time that the light of the nebulæ came from a gas, and hence it was held that the nebulæ were masses of gas.

Another explanation of the origin of the green line has already been given. If we study the spectrum of magnesium we find a very bright fluting with its less refrangible edge absolutely in the position of the green line with the dispersion generally employed; in nebulæ and in comets the same line appears, if, as I said before, Dr. Huggins's observations are to be relied upon.

We are therefore justified in holding the view that nebulæ, like the comets, consist of meteorites.

J. NORMAN LOCKYER.

(*To be continued.*)

THE ANNUAL VISITATION OF THE GREENWICH OBSERVATORY.

THE Report of the Astronomer-Royal to the Board of Visitors of the Royal Observatory, Greenwich, was received at the annual visitation on Saturday last, June 1.

As regards buildings, it is noted that the new 18-foot dome is completed, together with the photographic dark rooms, in preparation for work with the 13-inch photographic equatorial which is to be erected this year. As regards transit-circle observations, we read:—

"The regular subjects of observation with the transit-circle are the sun, moon, planets, and fundamental stars, with other stars from a working catalogue, which includes all the stars in Groombridge's Catalogue and in the Harvard Photometry not observed since 1867, and a selection from Piazzi's Catalogue. Ten close circumpolar stars taken from the *Connaissance des Temps*, or from M. Lœwy's list of stars for longitude determinations, have been observed regularly, in addition to the four standard azimuth stars. The observation of these close circumpolars has been much facilitated by the adoption (since 1889 January 1) of the method used by the officers of the French Service Géographique, which consists in making a number of bisections of the star with the R.A. micrometer during its transit, the exact time for each bisection being recorded on the chronograph. The Annual Catalogue of stars observed in 1888 contains about 1820 stars.

"Special attention has been given to the observation of the minor planet Iris and comparison stars in connection with the determination of its parallax at the late favourable opposition, eighteen observations of the planet and 113 of twenty-eight comparison stars having been made last autumn."

As regards computations, the transits have been completely reduced so as to exhibit mean Right Ascension 1889 January 1, and also the circle observations to exhibit mean North Polar distance for the same period. Two determinations of the astronomical flexure of the transit-circle telescope have been made since the last Report, the resulting values being 0″.08 and 0″.52. It has been found that the correction for discordance between reflection and direct observations of stars was erroneously applied in 1887, and hence the results for colatitude and for position of the ecliptic are also erroneous. The correct values are now given, with those recently found for 1888.

The ecliptic investigations from 1877 to 1886 have been revised to reduce the results to the same system of flexure, R—D correction, refraction and colatitude; so the computations for the ten-year Catalogue, containing 40,000 observations of 4059 stars, are now practically complete.

It has been found that the mean error of the moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is + 0·090s. in R.A., and + 1″·21 in longitude, as deduced from seventy-four meridian observations in 1888. The mean error in tabular N.P.D. is − 1″·19, indicating that the mean of the observed N.P.D.'s is too great. A number of altazimuth observations has been made and reduced to April 8, so as to exhibit errors of moon's tabular R.A., N.P.D., longitude, and E.N.P.D.

The object-glass for the new 28-inch refractor is now being worked, and, as it is to be of a special form, equally suitable for photographic and eye observations, an experimental object-glass

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