exhibition, to be held in connection with the meeting, should write to the "Ausstellungs Comité der Naturforscher-versammlung, Wien., Universitat."

PROPOSED ASTRONOMICAL CONGRESS IN 1896.—At the end of a paper read at the last meeting of the Royal Astronomical Society, Dr. Gill propounded the following questions, which we reprint from the *Observatory*. (1) Whether, in the opinion of astronomers generally, steps should be taken for a more complete and harmonious organisation and partition of the astronomical world from the year 1900? (2) Are astronomers prepared to enter upon a preliminary study, discussion, and experiment on the practical methods by which the art of observation may be raised to a higher level of accuracy, and its results be derived and published in a more systematic and homogeneous system? (3) If these questions are answered in the affirmative, would it be desirable to hold an international astronomical congress, say in 1896, to discuss and make the necessary preliminary arrangements, and then let the definitive programme and partition of work be made at another general congress to be held in the year 1899?

THE LAW AND GREENWICH TIME.—Is there any legal authority for the use of Greenwich Time throughout Great Britain? The editors of the *Observatory* point out that in the Statutes (Definition of Time) Act 1880, 43 and 44 Vic. cap. 9, it is enacted that whenever any expression of time occurs in any Act of Parliament, deed, or any other legal instrument, the time referred to shall, unless it is otherwise specifically stated, be held in the case of Great Britain to be Greenwich Time, and in the case of Ireland, Dublin Time. It is remarked, however, that Sir James Stephen says, in the Larceny Act, "Criminal Law Digest," p. 247, sec. 3, in referring to the expression "of the clock":—"It may be worth while to observe that the expression 'nine of the clock,' 'six of the clock, indicates *mean* as opposed to *solar* time; but a question might arise as to whether they mean local mean time or the mean time commonly observed at any given place. London time, or, as it is called, railway time, is now very generally observed, and there is a difference of more than twenty minutes between London and Cornwall. Local mean time is the natural meaning." In the case which led our contemporary to look up the matter, a defendant arrived at a court at the local (Carlisle) time appointed by the court to sit, but found that the court had met by Greenwich Time, and had decided against him. The difference of interpretation of the time appointed led to the granting of a new trial.

THE WORK OF HERTZ.[1]

THE untimely end of a young and brilliant career cannot fail to strike a note of sadness and awaken a chord of sympathy in the hearts of his friends and fellow-workers. Of men thus cut down in the early prime of their powers there will occur to us here the names of Fresnel, of Carnot, of Clifford, and now of Hertz. His was a strenuous and favoured youth; he was surrounded from his birth with all the influences that go to make an accomplished man of science—accomplished both on the experimental and on the mathematical side. The front rank of scientific workers is weaker by his death, which occurred on January 1 of the present year, the thirty-sixth of his life. Yet did he not go till he had effected an achievement which will hand his name down to posterity as the founder of an epoch in experimental physics.

In mathematical and speculative physics others had sown the seed. It was sown by Faraday, it was sown by Thomson and by Stokes, by Weber also doubtless, and by Helmholtz, but in this particular department it was sowed by none more fruitfully and plentifully than by Clerk Maxwell. Of the seed thus sown Hertz reaped the fruits. Through his experimental discovery, Germany awoke to the truth of Clerk Maxwell's theory of light, of light and electricity combined, and the able army of workers in that country (not forgetting some in Switzerland and France and Ireland) have done most of the gleaning after Hertz.

This is the work of Hertz which is best known; the work which brought him immediate fame. It is not always that public notice is so well justified. The popular instinct is generous and trustful, and it is apt to be misled. The scientific eminence accorded to a few energetic persons by the popular estimate is more or less amusing to those working in the same lines. In the case of Hertz no such mistake has been made. His name is not over well known, and his work is immensely greater in every way than that of several who have made more noise.

His best known discovery is by no means his only one. I have here a list of eighteen papers[1] contributed to German periodicals by him, in addition to the papers incorporated in his now well-known book on electric waves. I would like to suggest that it would be an act of tribute, useful to students in this country, if the Physical Society of London saw their way to translate and publish a collection of, at any rate, some of these papers.

Portrait Slide.

The portrait which I show is not a specially pleasing one. It is from a photograph taken by Mr. Yule, one of the band of foreign students who flocked to Hertz's laboratory at Bonn. It is excellent as a photograph, though it fails to represent Hertz at his best; perhaps because it was not taken till after the pharyngeal trouble had set in, which ultimately carried him off.

In closing these introductory and personal remarks, I should like to say that the enthusiastic admiration for Hertz's spirit and character, felt and expressed by students and workers who came into contact with him, is not easily to be exaggerated. Never was a man more painfully anxious to avoid wounding the susceptibilities of others; and he was accustomed to deprecate the prominence given to him by speakers and writers in this country, lest it might seem to exalt him unduly above other and elder workers among his own sensitive countrymen.

Speaking of the other great workers in physics in Germany, it is not out of place to record the sorrow with which we have heard of the recent death of Dr. August Kundt, Professor in the University of Berlin, successor of von Helmholtz in that capacity.

When I consented to discourse on the work of Hertz, my intention was to repeat some of his actual experiments, and especially to demonstrate his less known discoveries and observations. But the fascination exerted upon me by electric oscillation experiments, when I, too, was independently working at them in the spring of 1888,[2] resumed its hold; and my lecture will accordingly consist of experimental demonstrations of the outcome of Hertz's work rather than any precise repetition of portions of that work itself.

In case a minority of my audience are in the predicament of not knowing anything about the subject, a five minutes' explanatory prelude may be permitted, though time at present is very far from being "infinitely long."

[1] A Lecture delivered at the Royal Institution on Friday, June 1, by Prof. Oliver Lodge, F.R.S.

[1] *Hertz's Papers.*

1878-79. *Wied. Ann.*, 1880, vol. 10, p. 414. Experiments to establish an Upper Limit for the Kinetic Energy of Electric Flow.

1880. Inaugural Dissertation (Doctor Thesis) on Induction in Rotating Spheres.

1881. Vol. 13, *Wied. Ann.*, p. 266. On the Distribution of Electricity on the Surface of Moving Conductors.

1883, March. *Schlömilch Zeitschrift*, p. 125. On the Distribution of Pressures in an Elastic Circular Cylinder.

1881 (?) Crelle. vol. 92, p. 156. On the Contact of Solid Elastic Bodies.

1882. *Verhandlungen des Vereins des Gewerbfleisses* (Sonderabdruck). On the Contact of Solid Elastic Bodies and on Hardness

1881. Vol. 14, *Wied. Ann.*, p. 581. Upper Limits for the Kinetic Energy of Moving Electricity.

1882. *Wied. Ann.*, vol. 17, p. 177. On the Evaporation of Liquids, especially of Quicksilver, in Air-Free Space, and on the Pressure of Mercury Vapour.

1883. *Wied. Ann.*, vol. 20, p. 279. On the Property of Benzine as an Insulator and as showing Elastic Reaction (Rückstandsbildner).

1882. *Verhandln. d. phys. Gesellschaft in Berlin*, p. 18. On a New Hygrometer.

1883. *Wied. Ann.*, vol. 19, p. 78. On an Appearance accompanying Electric Discharge.

1883. *Ib.*, vol. 19, p. 782. Experiments on Glow Discharge.

1883. *Zeitschrift für Instrumentenkunde.* Dynamometric Contrivance of Small Resistance and Infinitesimal Self-Induction.

1884. *Met. Zeitschrift*, November, December. Graphic Methods for the Determination of the Adiabatic Changes of Condition of Moist Air.

1884. *Wied. Ann.*, vol. 22, p. 449. On the Equilibrium of Floating Elastic Plates.

1884. *Ib.*, vol. 23. On the Connection between Maxwell's Electrodynamic Fundamental Equations and those of opposition Electrodynamics.

1885. *Ib.*, vol. 24, p. 114. On the Dimension of a Magnetic Pole in different Systems of Units.

1887–1889. Papers incorporated in his book, "Ausbreitung der Elektrischen Kraft," translated under the title of "Electric Waves."

1892. *Wied Ann.*, vol. 45, p. 28. On the Passage of Cathode Rays through thin Metal Sheets.

[2] *Phil. Mag.*, xxvi. pp. 229, 230, August 1888: or "Lightning Conductors and Lightning Guards" (Whittaker), pp. 104, 105; also *Proc. Roy. Soc.* vol. l. p. 27.

The simplest way will be for me hastily to summarise our knowledge of the subject before the era of Hertz.

Just as a pebble thrown into a pond excites surface ripples, which can heave up and down floating straws under which they pass, so a struck bell or tuning-fork emits energy into the air in the form of what are called sound waves; and this radiant energy is able to set up vibrations in other suitable elastic bodies.

If the body receiving them has its natural or free vibrations violently damped, so that when left to itself it speedily returns to rest, then it can respond feebly to notes of almost any pitch. This is the case with your ears and the tones of my voice. Tones must be exceedingly shrill before they cease to excite the ear at all.

If, on the other hand, the receiving body has a persistent period of vibration, continuing in motion long after it is left to itself, like another tuning-fork or bell for instance, then far more facility of response exists, but great accuracy of tuning is necessary if it is to be fully called out; for if the receiver is not thus accurately syntonised with the source, it fails more or less completely to resound.

Conversely, if the *source* is a persistent vibrator, correct tuning is essential, or it will destroy at one moment motion which it originated the previous moment. Whereas if it is a dead beat or strongly-damped excitor, almost anything will respond equally well or equally ill to it.

What I have said of sounding bodies is true of all vibrators in a medium competent to transmit waves. Now a sending telephone or a microphone, when spoken to, emits waves into the ether, and this radiant energy is likewise able to set up vibration in suitable bodies. But we have no delicate means of directly detecting these electrical or etherial waves, and if they are to produce a perceptible effect at a distance they must be confined, as by a speaking tube, prevented from spreading, and concentrated on the distant receiver.

This is the function of the telegraph wire; it is to the ether what a speaking-tube is to air. A metal wire in air (*in function*, not in details of analogy) is like a long hollow cavity surrounded by nearly rigid but slightly elastic walls.

Sphere charged from Electrophorus.

Furthermore, any conductor electrically charged or discharged with sufficient suddenness must emit electrical waves into the ether, because the charge given to it will not settle down instantly, but will surge to and fro several times first; and these surgings or electric oscillations must, according to Maxwell, start waves in the ether, because at the end of each half swing they cause electrostatic, and at the middle of each half wings they cause electromagnetic effects, and the rapid alternation from one of these modes of energy to the other constitutes etherial waves.[1] If a wire is handy they will run along it, and may be felt a long way off. If no wire exists they will spread out like sound from a bell, or light from a spark, and their intensity will decrease according to the inverse square of the distance.

Maxwell and his followers well knew that there would be such waves; they knew the rate at which they would go, they knew that they would go slower in glass and water than in air, they knew that they would curl round sharp edges, that they would be partly absorbed but mainly reflected by conductors, that if turned back upon themselves they would produce the phenomena of stationary waves, or interference, or nodes and loops; it was known how to calculate the length of such waves, and even how to produce them of any required or predetermined wave-length from 1000 miles to a foot. Other things were known about them which would take too long to enumerate: any homogeneous insulator would transmit them, would refract or concentrate them if it were of suitable shape, would reflect none of a particular mode of vibration at a certain angle, and so on, and so on.

All this was "known," I say, known with varying degrees of confidence, but by some known with as great confidence as, perhaps even more confidence than, is legitimate before the actuality of experimental verification.

Hertz supplied the verification. He inserted suitable conductors in the path of such waves, conductors adapted for the occurrence in them of induced electric oscillations, and to the surprise of everyone, himself doubtless included, he found that the secondary electric surgings thus excited were strong enough to display themselves by minute electric sparks.

Syntonic Leyden Jars.

I shall show this in a form which requires great precision of tuning or syntony, both emitter and receiver being persistently vibrating things giving some thirty or forty swings before damping has a serious effect. I take two Leyden jars with circuits about a yard in diameter, and situated about two yards apart. I charge and discharge one jar, and observe that the surgings set up in the other can cause it to overflow if it is syntonised with the first.[1]

A closed circuit such as this is a feeble radiator and a feeble absorber, so it is not adapted for action at a distance. In fact, I doubt whether it will visibly act at a range beyond the $\frac{1}{4}\lambda$ at which true radiation of broken off energy occurs. If the coatings of the jar are separated to a greater distance, so that the dielectric is more exposed, it radiates better; because in true radiation the electrostatic and the magnetic energies are equal, whereas in a ring circuit the magnetic energy greatly predominates. By separating the coats of the jar as far as possible we get a typical Hertz oscillator, whose dielectric extends out into the room, and this radiates very powerfully.

Ordinary size Hertz Vibrator.

In consequence of its radiation of energy its vibrations are rapidly damped, and it only gives some three or four good strong swings. Hence it follows that it has a wide range of excitation, *i.e.* it can excite sparks in conductors barely at all in tune with it.

The two conditions, conspicuous energy of radiation and persistent vibration electrically produced, are at present incompatible. Whenever these two conditions coexist, considerable power or activity will of course be necessary in the source of energy. At present they only coexist in the sun and other stars, in the electric arc, and in furnaces.

Two Circular Vibrators sparking in sympathy.

The receiver Hertz used was chiefly a circular resonator, not a good absorber but a persistent vibrator, well adapted for picking up disturbances of precise and measurable wave-length. I find that the circular resonators can act as senders too; here is one exciting quite long sparks in a second one.

Electric Syntony—that was his discovery, but he did not stop there. He at once proceeded to apply his discovery to the verification of what had already been predicted about the waves, and by laborious and difficult interference experiments he ascertained that the previously calculated length of the waves was thoroughly borne out by fact. These interference experiments in free space are his greatest achievement.

He worked out every detail of the theory splendidly, separately analysing the electric and the magnetic oscillation—using language not always such as we should use now, but himself growing in theoretic insight through the medium of what would have been to most physicists a confusing maze of troublesome facts, and disentangling all their main relations most harmoniously.

Holtz Machine, A and B Sparks; Glass and Quartz Panes in Screen.

While Hertz was observing sparks such as these, the primary or exciting spark and the secondary or excited one, he observed as a bye-issue that the secondary spark occurred more easily if the light from the primary fell upon its knobs. He examined this new influence of light in many ways, and showed that although spark light and electric brush light were peculiarly effective, any source of light that gave very ultra-violet rays produced the same result.[2]

Wiedemann and Ebert, and a number of experimenters, have repeated and extended this discovery, proving that it is the cathode knob on which illumination takes effect; and Hall-

[1] Strictly speaking, in the waves themselves there is no lag or difference of phase between the electric and the magnetic vibrations; the difference exists in emitter or absorber, but not in the transmitting medium. True radiation of energy does not begin till about a quarter wave-length from the source, and within that distance the initial quarter-period difference of phase is obliterated.

[1] See NATURE, vol. 41, p. 368; or J. J. Thomson, "Recent Researches," p. 395.

[2] The experiment shown in the lecture was on the lines of those described in my book, "Lightning Conductors," pp. 314 and 340; the connections being much as on p. 285, or as depicted in *Proc. Roy. Soc.*, vol. 50, p. 4.

wachs made the important observation, which Righi, Stoletow, Branly, and others have extended, that a freshly-polished zinc or other oxidisable surface, if charged negatively, is gradually discharged by ultra-violet light.

It is easy to fail in reproducing this experimental result if the right conditions are not satisfied; but if they are, it is absurdly easy, and the thing might have been observed nearly a century ago.

Zinc discharging Negative Electricity in Light; Gold Leaf Electroscope; Glass and Quartz Panes; Quartz Prism.

Take a piece of zinc, clean it with emery paper, connect it to a gold leaf electroscope, and expose it to an arc lamp. If charged positively nothing appears to happen, the action is very slow, but a negative charge leaks away in a few seconds if the light is bright. Any source of light rich in ultra-violet rays will do; the light from a spark is perhaps most powerful of all. A pane of glass cuts off all the action; so does atmospheric air in sufficient thickness (at any rate, town air), hence sunlight is not powerful. A pane of quartz transmits the action almost undiminished, but fluor-spar may be more transparent still. Condensing the arc rays with a quartz lens and analysing them with a quartz prism or reflexion grating, we find that the most effective part of the light is high up in the ultra-violet, surprisingly far beyond the limits of the visible spectrum.[1]

This is rather a digression, but I have taken some pains to show it properly because of the interest betrayed by Lord Kelvin in this matter, and the caution which he felt about accepting the results of the Continental experimenters too hastily.

It is clearly a chemical phenomenon, and I am disposed to express it as a modification of the Volta contact effect [2] with illumination.

Return now to the Hertz vibrator, or Leyden jar with its coatings well separated so that we can get into its electric as well as its magnetic field. Here is a great one, giving waves 30 metres long, radiating while it lasts with an activity of a hundred horse-power, and making ten million complete electric vibrations per second.

Large Hertz Vibrator in action; Abel's Fuse; Vacuum Tube; Strike an Arc.

Its great radiating power damps it down very rapidly, so that it does not make above two or three swings; but, nevertheless, each time it is excited, sparks can be drawn from most of the reasonably elongated conductors in this theatre.

A suitably situated gas-leak can be ignited by these induced sparks. An Abel's fuse connecting the water-pipes with the gas-pipes will blow off; vacuum tubes connected to nothing will glow (this fact has been familiar to all who have worked with Hertz waves since 1889); electric leads, if anywhere near each other, as they are in some incandescent lamp-holders, may spark across to each other, thus striking an arc and blowing their fuses.

This blowing of fuses by electric radiation frequently happened at Liverpool till the suspensions of the theatre lamps were altered.

The striking of an arc by the little reverberating sparks between two carbon points connected with the 100 volt mains I incidentally now demonstrate.

There are some who think that lightning flashes can do none of these secondary things. They are mistaken.

Specimens and Diagrams.

On the table are specimens of various emitters and receivers such as have been used by different people. The orthodox Hertz radiator of the dumb-bell type, and the orthodox Hertz receivers—a circular ring for interference experiments, because it is but little damped; and a straight wire for receiving at a distance, because it is a much better absorber. Beside these are the spheres and ellipsoids (or elliptical plates) which I have mainly used, because they are powerful radiators and absorbers, and because their theory has been worked out by Horace Lamb and J. J. Thomson. Also dumb-bells without air-gap, and many other shapes, the most recent of mine being the inside of a hollow cylinder with sparks at ends of a diameter; this last being a feeble radiator but a very persistent vibrator,[1] and therefore well adapted for interference and diffraction experiments. But indeed spheres can be made to vibrate longer than usual by putting them into copper hats or enclosures, in which an aperture of varying size can be made to let the waves out.

Many of these senders will do for receivers too, giving off sparks to other insulated bodies or to earth; but besides the Hertz type of receiver, many other detectors of radiation have been employed. Vacuum tubes can be used, either directly, or on the trigger principle, as by Zehnder,[2] the resonator spark precipitating a discharge from some other auxiliary battery or source of energy, and so making a feeble disturbance very visible. Explosives may be used for the same purpose, either in the form of mixed water-gases or in the form of an Abel's fuse. Fitzgerald found that a tremendously sensitive galvanometer could indicate that a feeble spark had passed, by reason of the consequent disturbance of electrical equilibrium which settled down again through the galvanometer.[3] This was the method he used in this theatre two years ago. Blyth used a one-sided electrometer, and young Bjerkness has greatly developed this method, abolishing the need for a spark, and making the electrometer metrical, integrating, and satisfactory.[4] With this detector many measurements have been made at Bonn, by Bjerkness, Yule, Barton, and others, on waves concentrated and kept from space-dissipation by guiding wires.

Mr. Boys has experimented on the mechanical force exerted by electrical surgings, and Hertz also made observations of the same kind.

Going back to older methods of detecting electrical radiation, we have, most important of all, a discovery made long before man existed, by a creature that developed a sensitive cavity on its skin; a creature which never so much as had a name to be remembered by (though perhaps we now call it trilobite). Then, in recent times, we recall the photographic plate and the thermopile, with its modification the radio-micrometer; also the so-called bolometer, or otherwise known Siemens' pyrometer, applied to astronomy by Langley; applied to the detection of electric waves in wires by Rubens and Ritter and Paalzow and Arons. The thermal junction was applied to the same purpose by D. E. Jones and others.

And, before all these, the late Mr. Gregory, of Cooper's Hill, made his singularly sensitive expansion meter, whereby waves in free space could be detected by the minute rise of temperature they caused in a platinum wire: a kind of early and sensitive form of Cardew voltmeter.

Going back to the physiological method of detecting surgings, Hertz tried the frog's-leg nerve and muscle preparation, which to the steadier types of electrical stimulus is so surpassingly sensitive, and to which we owe the discovery of current electricity. But he failed to get any result. Ritter has succeeded; but, in my experience, failure is the normal and proper result. Working with my colleague Prof. Gotch, at Liverpool, I too have tried the nerve muscle preparation of the frog, and we find that an excessively violent stimulus of a rapidly alternating character, if pure and unaccompanied by secondary actions,

[1] While preparing for the lecture it occurred to me to try, if possible, during the lecture itself, some new experiments on the effect of light on negatively charged bits of rock and ice, because if the effect is not limited to metals it must be important in connection with atmospheric electricity. When Mr. Branly coated an aluminium plate with an insulating varnish, he found that its charge was able to soak in and out of the varnish during illumination (*Comptes Rendus*, vol. 110, p. 898, 1890). Now, the mountain tops of a negatively charged earth are exposed to very ultra-violet rays, and the air is a dielectric in which quiet up-carrying and sudden downpour of electricity could go on in a manner not very unlike the well-known behaviour of water vapour; and this perhaps may be the reason, or one of the reasons, why it is not unusual to experience a thunderstorm after a few fine days. I have now tried these experiments on such geological fragments as were handy, and find that many of them discharge negative electricity under the action of a naked arc, especially from the side of the specimens which was somewhat dusty, but that when wet they discharge much less rapidly, and when positively charged hardly at all. Ice and garden soil discharge negative electrification too, under ultra-violet illumination, but not so quickly as limestone, mica schist, ferruginous quartz, clay, and some other specimens. Granite barely acts; it seems to insulate too well. The ice and soil were tried in their usual moist condition, but, even when thoroughly dry, soil discharges quite rapidly.

No rock tested was found to discharge as quickly as does a surface of perfectly bright metal such as iron, but many discharged much more quickly than ordinary dull iron, and rather more quickly than when the bright iron surface was thinly oiled or wetted with water.

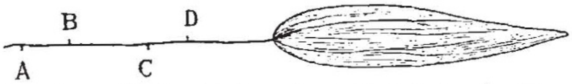
To-day (June 5) I find that the leaves of a geranium discharge positive electrification five times as quickly as negative, under the action of an arc-light, and that glass cuts the effect off while quartz transmits it.

[2] See Brit. Assoc. Report, 1884, pp. 502, 519; or *Phil. Mag.* vol. 19, pp. 267, 352.

[1] J. J. Thomson, "Recent Researches," p. 344.
[2] *Wied. Ann.* 47, p. 77.
[3] Fitzgerald, NATURE, vol. 41, p. 295, and vol. 42, p. 172.
[4] *Wied. Ann.* 44, p. 74.

produces no effect,—no stimulating effect, that is, even though the voltage is so high that sparks are ready to jump between the needles in direct contact with the nerve.

All that such oscillations do, if continued, is to produce a temporary paralysis or fatigue of the nerve, so that it is unable to transmit the nerve impulses evoked by other stimuli, from which paralysis it recovers readily enough in course of time.



Experiment of Gotch and Lodge on the physiological effect of rapid pure electric alternations. Nerve and muscle preparation, with four needles or else non-polarisable electrodes applied to the nerve. C and D are the terminals of a rapidly alternating electric current from a conductor at zero potential, while A and B are the terminals of an ordinary very weak galvanic or induction coil stimulus only just sufficient to make the muscle twitch.

This has been expected from experiments on human beings; such experiments as Tesla's and those of d'Arsonval. But an entire animal is not at all a satisfactory instrument wherewith to attack the question; its nerves are so embedded in conducting tissues that it may easily be doubted whether the alternating type of stimulus ever reaches them at all. By dissecting out a nerve and muscle from a deceased frog, after the historic manner of physiologists, and applying the stimulus direct to the nerve, at the same time as some other well-known 1/100th of a volt stimulus is applied to another part of the same nerve further from the muscle, it can be shown that rapid electric alternations, if entirely unaccompanied by static charge or by resultant algebraic electric transmission, evoke no excitatory response until they are so violent as to give rise to secondary effects such as heat or mechanical shock. Yet, notwithstanding this inaction, they gradually and slowly exert a paralysing or obstructive action on the portion of the nerve to which they are applied, so that the nerve impulse excited by the feeble just perceptible 1/100th volt stimulus above is gradually throttled on its way down to the muscle, and remains so throttled for a time varying from a few minutes to an hour after the cessation of the violence.

I had intended to exhibit this effect, which is very marked and definite, but it is impossible to show everything in the time at my disposal.

Air Gap and Electroscope, charged by Glass Rod and discharged by moderately distant Sphere excited by Coil.

Among trigger methods of detecting electric radiation, I have spoken of the Zehnder vacuum tubes; another method is one used by Boltzmann.[1] A pile of several hundred volts is on the verge of charging an electroscope through an air-gap just too wide to break down. Very slight electric surgings precipitate the discharge across the gap, and the leaves diverge. I show this in a modified and very simple form. On the cap of an electroscope is placed a highly-polished knob or rounded end, connected to the sole, and just not touching the cap. Such an electroscope overflows suddenly and completely with any gentle rise of potential. Bring excited glass near it, the leaves diverge gradually and then suddenly collapse, because the air space snaps; remove the glass, and they rediverge with negative electricity; the knob above the cap being then charged positively, and to the verge of sparking. In this condition any electrical waves, collected if weak by a foot or so of wire projecting from the cap, will discharge the electroscope by exciting surgings in the wire, and so breaking down the air-gap. The chief interest about this experiment seems to me the extremely definite dielectric strength of so infinitesimal an air space. Moreover, it is a detector for Hertz waves that might have been used last century; it might have been used by Benjamin Franklin.

For to excite them, no coil or anything complicated is necessary; it is sufficient to flick a metal sphere or cylinder with a silk handkerchief, and then discharge it with a well-polished knob. If it is not well-polished the discharge is comparatively gradual, and the vibrations are weak; the more polished are the sides of an air-gap the more sudden is the collapse, and the more vigorous the consequent radiation, especially the radiation of high frequency, the higher harmonics of the disturbance.

For delicate experiments it is sometimes well to repolish the knobs every hour or so. For metrical experiments it is often better to let the knobs get into a less efficient but more permanent state. This is true of all senders or radiators. For the generation of the, so to speak, "infra-red" Hertz waves any knobs will do, but to generate the "ultra-violet" high polish is essential.

Microphonic Detectors.

Receivers or detectors which for the present I temporarily call microphonic are liable to respond best to the more rapid vibrations. Their sensitiveness is to me surprising, though of course it does not approach the sensitiveness of the eye; at the same time, I am by no means sure that the eye differs from them in kind. It is these detectors that I wish specially to bring to your notice.

Prof. Minchin, whose long and patient work in connection with photoelectricity is now becoming known, and who has devised an instrument more sensitive to radiation than even Boys' radio-micrometer, in that it responds to the radiation of a star while the radio-micrometer does not, found some years ago that some of his light-excitable cells lost their sensitiveness capriciously on tapping; and later he found that they frequently regained it again while Mr. Gregory's Hertz-wave experiments were going on in the same room.

These "impulsion-cells," as he terms them, are troublesome things for ordinary persons to make and work with—at least I have never presumed to try—but in Mr. Minchin's hands they are surprisingly sensitive to electric waves.[1]

The sensitiveness of selenium to light is known to everyone, and Mr. Shelford Bidwell has made experiments on the variations of conductivity exhibited by a mixture of sulphur and carbon.

Nearly four years ago, M. Edouard-Branly found that a burnished coat of porphyrised copper spread on glass diminished its resistance enormously, from some millions to some hundreds of ohms, when it was exposed to the neighbourhood, even the distant neighbourhood, of Leyden jar or coil sparks. He likewise found that a tube of metallic filings behaved similarly, but that this recovered its original resistance on shaking. Mr. Croft exhibited this fact recently at the Physical Society. Branly also made pastes and solid rods of filings in Canada balsam and in sulphur, and found them likewise sensitive.[2]

With me the matter arose somewhat differently, as an outcome of the air-gap detector employed with an electroscope by Boltzmann. For I had observed in 1889 that two knobs sufficiently close together, far too close to stand any voltage such as an electroscope can show, could, when a spark passed between them, actually cohere; conducting an ordinary bell-ringing current if a single voltaic cell was in circuit; and, if there was no such cell, exhibiting an electromotive force of their own sufficient to disturb a low resistance galvanometer vigorously, and sometimes requiring a faintly perceptible amount of force to detach them. The experiment was described to the Institution of Electrical Engineers,[3] and Prof. Hughes said he had observed the same thing.

Coherer in open, responding to Feeble Stimuli; Small Sphere, Gas-lighter, Distant Sphere, Electrophorus.

Well this arrangement, which I call a coherer, is the most astonishingly sensitive detector of Hertz waves. It differs from the actual air-gap in that the insulating film is not really insulating; the film breaks down not only much more easily, but also in a less discontinuous and more permanent manner than an air-gap. A tube of filings, being a series of bad contacts, clearly works on the same plan; and though a tube of filings is by no means so sensitive, yet it is in many respects easier to work with, and, except for very feeble stimuli, is more metrical. If the filings used are coarse, say turnings or borings, the tube approximates to a single coherer; if they are fine, it has a larger range of sensibility. In every case what these receivers feel are sudden jerks of current; smooth sinuous vibrations are ineffective. They seem to me to respond best to waves a few inches long, but doubtless that is determined chiefly by the dimensions of some conductor with which they happen to be associated.

Filings in open, responding to Sphere, to Electrophorus, to spark from Gold-leaf Electroscope.

I picture to myself the action as follows. Suppose two fairly clean pieces of metal in light contact—say two pieces of

1 *Wied. Ann.* 40, p. 399.

1 *Phil. Mag.* vol. 31, p. 223.
2 E. Branly, *Comptes Rendus*, vol. 111, p. 785: and vol. 112, p. 90.
3 *Journal Inst. E. E.*, 1890, vol. 19, pp. 352-4; or "Lightning Conductors and Lightning Guards" (Whittaker), pp. 382-4.

iron—connected to a single voltaic cell; a film of what may be called oxide intervenes between the surfaces, so that only an insignificant current is allowed to pass, because a volt or two is insufficient to break down the insulating film except perhaps at one or two atoms. If the film is not permitted to conduct at all, it is not very sensitive; the most sensitive condition is attained when an infinitesimal current passes, strong enough just to show on a moderate galvanometer.

Now let the slightest surging occur, say by reason of a sphere being charged and discharged at a distance of forty yards, the film at once breaks down—perhaps not completely, that is a question of intensity—but permanently. As I imagine, more molecules get within each other's range, incipient cohesion sets in, and the momentary electric quiver acts as it were as a flux. It is a singular variety of electric welding. A stronger stimulus enables more molecules to hold on, the process is surprisingly metrical; and as far as I roughly know at present, the change of resistance is proportional to the energy of the electric radiation from a source of given frequency.

It is to be specially noted that the battery current is not needed to effect the cohesion, only to demonstrate it. The battery can be applied after the spark has occurred, and the resistance will be found changed as much as if the battery had been on all the time.

The incipient cohesion electrically caused can be mechanically destroyed. Sound vibrations, or any other feeble mechanical disturbances, such as scratches or taps, are well adapted to restore the contact to its original high-resistance sensitive condition. The more feeble the electrical disturbance the slighter is the corresponding mechanical stimulus needed for restoration. When working with the radiating sphere at a distance of forty yards out of window, I could not for this reason shout to my assistant, in order to cause him to press the key of the coil and make a spark, but I showed him a duster instead, this being a silent signal which had no disturbing effect on the coherer or tube of filings. I mention forty yards, because that was one of the first outdoor experiments; but I should think that something more like half a mile was nearer the limit of sensitiveness. However, this is a rash statement not at present verified. At forty yards the exciting spark could be distinctly heard, and it was interesting to watch the spot of light begin its long excursion and actually travel a distance of two or three inches before the sound arrived. This experiment proved definitely enough that the efficient cause travelled quicker than sound, and disposed completely of any sceptical doubts as to the sound-waves being perhaps the real cause of the phenomenon.

Invariably, when the receiver is in good condition, sound or other mechanical disturbance acts one way, viz. in the direction of increasing resistance, while electrical radiation or jerks act the other way, decreasing it. While getting the receiver into condition, or when it is getting out of order, vibrations and sometimes electric discharges act irregularly, and an occasional good shaking does the filings good.

I have taken rough measurements of the resistance, by the simple process of restoring the original galvanometer deflection by adding or removing resistance coils. A half-inch tube, eight inches long, of selected iron turnings, had a resistance of 2500 ohms in the sensitive state. A feeble stimulus, caused by a distant electrophorous spark, brought it down 400 ohms. A rather stronger one reduced it by 500 and 600, while a trace of spark given to a point of the circuit itself, ran it down 1400 ohms.

This is only to give an idea of the quantities. I have not yet done any seriously metrical experiments.

From the wall diagram which summarises the various detectors, and which was prepared a month or so ago, I see I have omitted selenium, a substance which in certain states is well known to behave to visible light as these other microphonic detectors behave to Hertz waves.

And I want to suggest that quite possibly the sensitiveness of the eye is of the same kind. As I am not a physiologist I cannot be seriously blamed for making wild and hazardous speculations in that region. I therefore wish to guess that some part of the retina is an electrical organ, say like that of some fishes, maintaining an electromotive force which is prevented from stimulating the nerves solely by an intervening layer of badly conducting material, or of conducting material with gaps in it; but that when light falls upon the retina these gaps become more or less conducting, and the nerves are stimulated.

I do not feel clear which part is taken by the rods and cones, and which part by the pigment cells; I must not try to make the hypothesis too definite at present.

If I had to make a demonstration model of the eye on these lines, I should arrange a little battery to excite a frog's nerve and muscle preparation through a circuit completed all except a layer of filings or a single bad contact. Such an arrangement would respond to Hertz waves. Or if I wanted actual light to act instead of grosser waves, I would use a layer of selenium.

But the bad contact and the Hertz waves are the most instructive, because we do not at present really know what the selenium is doing, any more than what the retina is doing.

And observe that (to my surprise I confess) the rough outline of a theory of vision thus suggested is in accordance with some of the principal views of the physiologist Hering. The sensation of light is due to the electrical stimulus; the sensation of black is due to the mechanical or tapping-back stimulus. Darkness is physiologically not the mere cessation of light. Both are positive sensations, and both stimuli are necessary; for until the filings are tapped back vision is persistent. In the eye model the period of mechanical tremor should be say $\frac{1}{10}$th second, so as to give the right amount of persistence of impression.

Eye Model with Electric Bell on Board.

No doubt in the eye the tapping back is done automatically by the tissues, so that it is always ready for a new impression, until fatigued. And by mounting an electric bell or other vibrator on the same board as a tube of filings, it is possible to arrange so that a feeble electric stimulus shall produce a feeble steady effect, a stronger stimulus a stronger effect, and so on, the tremor asserting its predominance and bringing the spot back whenever the electric stimulus ceases.

An electric bell thus close to the tube is, perhaps, not the best vibrator; clockwork might do better, because the bell contains in itself a jerky current, which produces one effect, and a mechanical vibration, which produces an opposite effect; hence the spot of light can hardly keep still. By lessening the vibration—say by detaching the bell from actual contact with the board, the electric jerks of the intermittent current drive the spot violently up the scale; mechanical tremor brings it down again.

You observe that the eye on this hypothesis is, in electrometer language, heterostatic. The energy of vision is supplied by the organism, the light only pulls a trigger. Whereas the organ of hearing is idiostatic. I might draw further analogies, about the effect of blows or disorder causing irregular conduction and stimulation, of the galvanometer in the one instrument, of the brain cells in the other.

A handy portable exciter of electric waves is one of the ordinary hand electric gas-lighters, containing a small revolving doubler—*i.e.*, an inductive or replenishing machine. A coherer can feel a gas-lighter across a lecture theatre. Minchin often used them for stimulating his impulsion cells. I find that, when held near, they act a little before the spark occurs, plainly because of the little incipient sparks at the brushes or tinfoil contacts inside. A Voss machine acts similarly, giving a small deflection while working up before it sparks.

And notice here that our model eye has a well-defined range of vision. It cannot see waves too long for it.

Holtz Sparks not exciting Tube: except by help of a polished knob.

The powerful disturbance caused by the violent flashes of a Wimshurst or Voss machine it is blind to. If the knobs of the machine are well polished, it will respond to some high harmonics, due to the vibrations in the terminal rods; and these are the vibrations to which it responds when excited by a coil. The coil should have knobs instead of points. Sparks from points or dirty knobs hardly excite the coherer at all. But hold a well-polished sphere or third knob between even the dirty knobs of a Voss machine, and the coherer responds at once to the surgings got up in it.

Electrophorous Lid and insulated Sphere.

Feeble short sparks again are often more powerful exciters than are strong long ones. I suppose because they are more sudden.

This is instructively shown with an electrophorous lid. Spark it to a knuckle, and it does very little. Spark it to a knob, and it works well. But now spark it to an insulated sphere, there is some effect. Discharge the sphere, and take a second spark.

without recharging the lid. Do this several times; and at last, when the spark is inaudible, invisible, and otherwise imperceptible, the coherer some yards away responds more violently than ever, and the spot of light rushes from the scale.

If a coherer be attached by a side wire to the gas-pipes, and an electrophorous spark be given to either the gas-pipes or the water-pipes, or even to the hot-water system, in another room of the building, the coherer responds.

In fact when thus connected to gas-pipes, one day when I tried it, the spot of light could hardly keep five seconds still. Whether there was a distant thunderstorm, or whether it was only picking up telegraphic jerks, I do not know. The jerk of turning on or off an extra Swan lamp can affect it when sensitive. I hope to try for long-wave radiation from the sun, filtering out the ordinary well-known waves by a black-board or other sufficiently opaque substance.

We can easily see the detector respond to a distant source of radiation now, viz. to a 6-inch sphere placed in the library between coil knobs.

Portable Detector.

Also I exhibit a small complete detector made by my assistant Mr. Davies, which is quite portable and easily set up. The essentials are all in a copper cylinder three inches by two. A bit of wire a few inches long, pegged into it, helps it to collect waves. It is just conceivable that at some distant date, say by dint of inserting gold wires or powder in the retina, we may be enabled to see waves which at present we are blind to.

Observe how simple the production and detection of Hertz waves are now. An electrophorous or a frictional machine serves to excite them; a voltaic cell, a rough galvanometer, and a bad contact, serve to detect them. Indeed they might have been observed at the beginning of the century, before galvanometers were known. A frog's leg or an iodide of starch paper would do almost as well.

A bad contact was at one time regarded as a simple nuisance, because of the singularly uncertain and capricious character of the current transmitted by it. Hughes observed its sensitiveness to sound-waves, and it became the microphone. Now it turns out to be sensitive to electric waves, if it be made of any oxidisable metal (not of carbon), and we have an instrument which might be called a micro-something, but which, as it appears to act by cohesion, I call at present a coherer. Perhaps some of the capriciousness of an anathematised bad contact was sometimes due to the fact that it was responding to stray electric radiation.

The breaking down of cohesion by mechanical tremor is an ancient process, observed on a large scale by engineers in railway axles and girders; indeed, the cutting of small girders by persistent blows of hammer and chisel reminded me the other day of the tapping back of our cohering surfaces after they have been exposed to the welding effect of the electric jerk.

Put Copper Hat over Tube. Shut up everything in Box completely.

If a coherer is shut up in a complete metal enclosure, waves cannot get at it, but if wires are led from it to an outside ordinary galvanometer, it remains nearly as sensitive as it was before (nearly, not quite), for the circuit picks up the waves, and they run along the insulated wires into the closed box. To screen it effectively it is necessary to enclose battery and galvanometer and every bit of wire connection; the only thing that may be left outside is the needle of the galvanometer. Accordingly here we have a compact arrangement of battery and coil and coherer, all shut up in a copper box. The coil is fixed against the side of the box at such height that it can act conveniently on an outside suspended compass needle. The slow action of the coil has no difficulty in getting through copper, as everyone knows; only a perfect conductor could screen off that, but the Hertz waves are effectively kept out by sheet copper.

Chink; Round Hole; Protruding Wire.

It must be said, however, that the box must be exceedingly well closed for the screening to be perfect. The very narrowest chink permits their entrance, and at one time I thought I should have to solder a lid on before they could be kept entirely out. Clamping a copper lid on to a flange in six places was not enough. But by the use of pads of tinfoil, chinks can be avoided, and the inside of the box becomes then electrically dark.

If even an inch of the circuit protrudes, it at once becomes slightly sensitive again; and if a single branch wire protrudes through the box, provided it is insulated where it passes through, the waves will utilise it as a speaking tube, and run blithely in. And this whether the wire be connected to anything inside or not, though it acts more strongly when connected.

Receiver Hat and Metal Tube for Connecting Wires.

If wires are to be taken out of the box to a coherer in some other enclosure, they must be enclosed in a metal tube, and this tube must be well connected with the metal of both enclosures, if nothing is to get in but what is wanted.

Similarly, when definite radiation is desired, it is well to put the radiator in a copper hat, open in only one direction. And in order to guard against reflected and collateral surgings running along the wires which pass outside to the coil and battery, as they are liable to do, I am accustomed to put all these things in a packing case lined with tinfoil, to the outside of which the sending hat is fixed, and to pull the key of the primary exciting circuit by a string from outside.

Sender in Hat and Box, with Lid (adjustable) clamped on.

Even then, with the lid of the hat well clamped on, something gets out, but it is not enough to cause serious disturbance of qualitative results. The sender must evidently be thought of as emitting a momentary blaze of light which escapes through every chink. Or, indeed, since the waves are some inches long, the difficulty of keeping them out of an enclosure may be likened to the difficulty of excluding sound; though the difficulty is not quite so great as that, since a reasonable thickness of metal is really opaque. I fancied once or twice I detected a trace of transparency in such metal sheets as ordinary tinplate, but unnoticed chinks elsewhere may have deceived me. It is a thing easy to make sure of as soon as I have more time.

One thing in this connection is noticeable, and that is how little radiation gets either in or out of a small round hole. A narrow long chink in the receiver box lets in a lot; a round hole the size of a shilling lets in hardly any, unless indeed a bit of insulated wire protrudes through it like a collecting ear-trumpet.

Gas-lighter with Tinfoil.

It may be asked how the waves get out of the metal tube of an electric gas-lighter. But they do not; they get out through the handle, which being of ebonite is transparent. Wrap up the handle tightly in tinfoil, and a gas-lighter is powerless.

Optical Experiments.

And now in conclusion I will show some of the ordinary optical experiments with Hertz waves, using as source either one of two devices: either a 6-inch sphere with sparks to ends of a diameter, an arrangement which emits 9-inch waves, but of so dead-beat a character that it is wise to enclose it in a copper hat to prolong them, and send them out in the desired direction; or else a 2-inch hollow cylinder with spark knobs at ends of an internal diameter. This last emits 3-inch waves of a very fairly persistent character, but with nothing like the intensity of one of the outside radiators.

As receiver there is no need to use anything sensitive, so I employ a glass tube full of coarse iron filings, put at the back of a copper hat with its mouth turned well askew to the source, which is put outside the door at a distance of some yards, so that only a little direct radiation can reach the tube. Sometimes the tube is put lengthways in the hat instead of crossways, which makes it less sensitive, and has also the advantage of doing away with the polarising or rather analysing power of a crossway tube.

Various Apertures in Lid.

The radiation from the sphere is still too strong, but it can be stopped down by a diaphragm plate with holes in it of varying size clamped on the sending hat.

Reflecting Plate, Wet Cloth, Glass Plate.

Having thus reduced the excursion of the spot of light to a foot or so, a metal plate is held as reflector, and at once the spot travels a couple of yards. A wet cloth reflects something, but a thin glass plate, if dry, reflects next to nothing, being, as is well known, too thin to give anything but "the black spot." I have fancied that it reflects something of the 3-inch waves.

Refracting Prism and Lens.

A block of paraffin about a cubic foot in volume is cast into the shape of a prism with angles 75°, 60°, and 45°. Using the large angle, the rays are refracted into the receiving hat, and produce an effect much larger than when the prism is removed.

An ordinary 9-inch glass lens is next placed near the source, and by means of the light of a taper it is focussed between source and receiver. The lens is seen to increase the effect.

Arago Disk, Grating and Zone-plate.

The lens helps us to set correctly an 18-inch circular copper disk in position for showing the bright diffraction spot. Removing the disk, the effect is much the same as when it was present. Add the lens, and the effect is greater. With a diffraction grating of copper strips two inches broad and two inches apart, I have not yet succeeded in getting good results. It is difficult to get sharp nodes and interference effects with these sensitive detectors in a room. I expect to do better when I can try out-of-doors, away from so many reflecting surfaces; indoors it is like trying delicate optical experiments in a small whitewashed chamber well supplied with looking-glasses; nor have I ever succeeded in getting clear concentration with this zone-plate having Newton rings fixed to it in tinfoil. But really there is nothing of much interest now in diffraction effects except the demonstration of the waves and the measure of their length. There was immense interest in Hertz's time, because then the wave character of the radiation had to be proved; but every possible kind of wave must give interference and diffraction effects, and their theory is, so to say, worked out. More interest attaches to polarisation, double refraction, and dispersion experiments.

Polarising and Analysing Grids.

Polarisation experiments are easy enough. Radiation from a sphere is already strongly polarised, and the tube acts as a partial analyser, responding much more vigorously when its length is parallel to the line of sparks than when they are crossed; but a convenient extra polariser is a grid of wires something like what was used by Hertz, only on a much smaller scale; say an 18-inch octagonal frame of copper strip with a harp of parallel copper wires. The spark-line of the radiator being set at 45°, a vertical grid placed over receiver reduces the deflection to about one-half, and a crossed grid over the source reduces it to nearly nothing.

Rotating either grid a little rapidly increases the effect, which becomes a maximum when they are parallel. The interposition of a third grid, with its wires at 45° between two crossed grids, restores some of the obliterated effect.

Radiation reflected from a grid is strongly polarised, in a plane normal of course to that of the radiation which gets through it. They are thus analogous in their effect to Nicols, or to a pile of plates.

The electric vibrations which get through these grids are at right angles to the wires. Vibrations parallel to the wires are reflected or absorbed.

Reflecting Prism.

To demonstrate that the so-called plane of polarisation of the transmitted radiation is at right angle to the electric vibration,[1] *i.e.* that the wires of the grid are parallel to it, I use the same paraffin prism as before, but this time I use its largest face as a reflector, and set it at something near the polarising angle. When the line of wires is parallel to the plane of incidence, in which case the electric vibrations are perpendicular to the plane of incidence, plenty of radiation is reflected by the paraffin face. Turning the grid so that the electric vibrations are in the plane of incidence, we find that the paraffin surface set at the proper angle is able to reflect hardly anything. In other words, the vibrations contemplated by Fresnel are the electric vibrations; those dealt with by McCullagh are the magnetic ones.

Thus are some of the surmises of genius verified and made obvious to the wayfaring man.

[1] *c.f.* Trouton, in NATURE, vol. 39, p. 393; and many other optical experiments by Mr. Trouton, vol. 40, p. 398.

THE REPORT OF THE ASTRONOMER ROYAL.

AT the annual visitation of the Royal Observatory, Greenwich, on Saturday last, the Astronomer Royal presented his report of the progress made from May 11, 1893, to May 10 of this year. We take from it the following information:—

It appears that the average number of transits observed was no less than 31 each day, or if Sundays are excluded, 36. As an instance of the number of observations which were made under very favourable conditions, it may be mentioned that on three consecutive days in February no fewer than 458 transits and 460 zenith distances were observed.

A new universal transit-circle or altazimuth is being constructed by Messrs. Troughton and Simms, and satisfactory progress has been made towards completion. All the heavy portions of the instrument, including the rotating and reversing gear, are made, and have been put together, the object glasses for the instrument and collimators are practically finished, as well as the eye end with its micrometers, and the circles, microscopes, &c., are in hand.

As previously noted in our astronomical column, a valuable gift has been made to the Observatory by Sir Henry Thompson, who has generously offered a sum of £5000 to provide a large photographic telescope with accessories, which would serve as the complement of the 28-inch visual telescope just completed. This munificent offer was readily accepted by the Admiralty, and after careful consideration and discussion, a photographic telescope of 26 inches aperture and 22 feet 6 inches focal length, equatorially mounted, was ordered of Sir H. Grubb on May 5, the instrument to be completed in eighteen months. This telescope will be of exactly double the dimensions (aperture and focal length) of the astrographic equatorial which has proved so successful, and it will be mounted on a very firm stand which will allow of complete circumpolar motion without the necessity for reversal on the meridian, which has been felt as a drawback in the astrographic equatorial. It will be erected on the central tower of the new Physical Observatory, under the 30 feet dome which is shortly to be placed there, and will carry the 12¾-inch Merz refractor as a guiding telescope and the Thompson 9-inch photoheliograph. It will thus be mounted under very favourable conditions for work, and will be in every respect a most effective instrument.

The new 28-inch refracto has been brought into working order after much time spent in the erection of the instrument, in the adjustment of the object glass, and in the provision of various fittings at the eye end. The adjustments were finished by October 1, when, under good atmospheric conditions, the definition was found to be very fine. Since then the object glass has been tested on various objects with very satisfactory results. A sketch of Jupiter and some measures of double stars have been made, and the colour correction of the object glass has been determined on stars by readings for focus at different parts of the spectrum.

The object glass has also been tried in the photographic position, with the crown lens reversed and the lenses separated on the plan proposed by Sir G. G. Stokes. The determination of the best distance between the lenses and the exact adjustment of the crown lens for tilt and centering relatively to the flint has necessarily taken a long time, as small modifications were required in the cells and special contrivances had to be devised for the delicate adjustment of the heavy crown cell and lens. A large number of photographs have been taken at different distances inside and outside of the focus corresponding to different positions of the crown lens, and affording interesting information which will be useful in connection with the Thompson 26-inch photographic telescope.

With the astrographic equatorial, 923 plates, with a total of 2143 exposures, were taken on 183 nights in the year ending May 10. Of these 181 were rejected, owing to photographic defects, mechanical injury, mistakes in setting, the plate being wrongly placed in the carrier, failure in clock driving, and interference by cloud. The following statement shows the progress made with the photographic mapping of the heavens in the year covered by the report:—

	No. of Photos taken.	Successful Plates
Astrographic chart (exposure 40m.) ...	280	220
Plates for catalogue (exposures 6m., 3m. and 20s.)	508	387
Number of fields photographed for the chart		200
Number of fields photographed for the catalogue		367
Total number of fields photographed since the commencement of the work for the chart		333
Total number of fields photographed since the commencement of the work for the catalogue		610