The Origin of Atmospherics.¹

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THAT abnormal outbursts of atmospherics—the “x storms” of the radio-telegraphist—were associated with convective weather was indicated by the work of the British Association Committee on Radio-telegraphic Investigations in 1914–15. That actual thunderstorms could be located by direction-finding on atmospherics was established early in a Meteorological Office investigation begun in 1915. But it has not yet been shown whether the fully developed thunderstorm is the only, a main, or merely a subsidiary source of atmospherics.

A critical examination of the data obtained in the Meteorological Office investigation referred to promises to throw some light on the question, and it has been thought desirable to give a preliminary indication of the evidence which is emerging.

The coastal direction-finding stations of the Admiralty co-operated in the investigation by reporting the apparent direction from which atmospherics were arriving whenever such a direction was observed, and when pressure of traffic permitted an observation.

Some twelve stations took part in this scheme, which began in March 1916. The examination of the results has been made for two years, April 1916 to May 1918. During this period there were approximately 1000 occasions on which three or more stations observed a direction of arrival of atmospherics within the same hour. On plotting these approximately simultaneous observations on a gnomonic chart, it is found that on almost exactly half of the occasions the three or more bearings gave an intersection in a point of a limited area, indicating a source of atmospherics at a point so determined. Actually the distribution of these intersections, according to the number of participating stations, is as follows:

Six stations giving bearings meeting in a point (within the limits of accuracy of observation)	2
Five stations giving bearings meeting in a point (within the limits of accuracy of observation)	15
Four stations giving bearings meeting in a point (within the limits of accuracy of observation)	68
Three stations giving bearings meeting exactly in a point	231
Three stations giving bearings meeting in a point after adjustment within the limits of accuracy, assumed ± 5 degrees	110
Three stations giving bearings failing to meet in a point but delimiting a small area as source	62
Total number of locations	488

The geographical distribution of these apparent sources of atmospherics is:

England and Wales	58	Central Europe and	
Scotland	18	Balkans	12
Ireland	45	Mediterranean and	
English Channel	59	N. Africa	44
Bay of Biscay	37	Iceland and Atlantic	9
France	144	Belgium	7
Spain	23	Holland	7
Italy	19	Switzerland	6

The comparison of these locations with meteorological data is a somewhat extensive investigation and is still in progress. In 288 cases, however, the

immediately available data seemed to provide an adequate basis for discussion. In a relatively small number of cases only were thunderstorms found to have occurred in the region located as a source of atmospherics, and near the time of observation. Since the thunderstorm is a known source of atmospherics, it is not proposed to detail here these cases, particularly as it is necessary to search more closely for records of thunderstorms, which are notoriously sporadic phenomena, liable to slip unobserved through the open mesh of the network of observing stations.

Comparison was also made with the map in the British Daily Weather Report, which shows the area over which rain has fallen during the 24 hours, 7 A.M. to 7 A.M. In 239 out of the 288 cases, the apparent source of atmospherics was definitely associated with the rainfall area for the corresponding 24 hours. In 105 cases the source was on the advancing edge of the rain area, in 75 within that area, and in 59 cases it was on the rear edge. Of the remaining 49 locations, 30 were found to fall in places where thunderstorm or squall phenomena had been reported about the same time.

Thus in only 19 of the 288 cases, i.e. in $6\frac{1}{2}$ per cent., has no meteorological relation with the source of atmospherics yet been traced, while it is also noteworthy that 10 of these 19 fell in the least trustworthy class of location, the three bearings delineating an area not negligibly small.

One is therefore faced with the alternative conclusions that—

- (1) Rainfall, without the occurrence of a fully developed thunderstorm, is an important source of atmospherics.
- (2) The climate of south-west Europe is so wet, that there is an extremely high probability of rain in a random 24 hours at a random point.

To test the validity of conclusion (2) the maps for the same two-year periods were used. Four individuals (two without knowledge of the nature of the test) were asked to carry out a blind spotting game by placing a random dot on each chart, without seeing its detail. Again, many of these dots were beyond the range of adequate data, but 335 out of 732 could be compared with data. The results show that the chances are nearly even for or against rain, the distribution of the random points being:

In rain area	73
On advancing edge	46
On rear edge	62
Total associated with rainfall	181
Total definitely not so associated	154

It appears, therefore, to be established conclusively that a very high proportion of sharply defined sources of atmospherics are to be found in areas in which rain is falling, and particularly on the advancing edge of such areas, more than 90 per cent. in the present series being in rain areas, and 36 per cent. on the forward edge of the 24 hours' rain area. It is perhaps a permissible inference that, were one able to deal with the instantaneous advancing edge instead of the edge of the area for the day, the latter figure would be increased.

The results of this investigation fall into line with modern views of the mechanism of rainfall and thunderstorm phenomena. The separation and accumulation of charges caused by ascending currents may be readily believed to be more pronounced on

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the forward edge of a rain area, and to stop short of actual thunderstorm formation, while still being sufficiently marked for the necessary readjustment of charge to originate electro-magnetic waves. The difficulty of picturing readjustments propagating radiation of such energy content as to produce audible atmospherics at distances of more than 1000 kilometres, without producing visible lightning or audible thunder at ground stations near the source, is considerable, but not so great as the difficulty

of picturing sufficient "full scale" lightning discharges, or other known phenomena, to account for the reception of atmospherics at an annual average rate of more than one per second at a station in these latitudes.

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X-Ray Electrons.

AMONG the items of the programme of section A of the British Association at Hull this year, there was one of outstanding interest consisting of the description of some very beautiful experiments which apparently constitute still another triumph for the quantum theory and the atomic theory of Bohr. Both M. le Duc de Broglie and Prof. R. Whiddington, who described the experiments, have recently been working on the same subject, namely, the properties of the electrons ejected from metallic atoms by the incidence of X-rays; and their results are in general agreement. The method of procedure has been to allow a beam of characteristic X-rays of known frequency, for example from a tungsten anticathode, to fall upon a prepared metallic surface, say of silver. The electrons which, as a consequence, emerge from the silver do not all possess, as Barkla at first supposed, equal amounts of energy. They thus have different velocities, and, by the well-known method of the application of a suitable magnetic field, the original mixed bundle of electrons can be differentially deflected, and spread out into a "magnetic spectrum." A focussing device is employed whereby the electrons of the same speed are concentrated upon the same part of the photographic plate, so that each line in the spectrum corresponds to a group of electrons having a definite velocity. There is a certain amount of general fogging of the plate, but the comparatively sharp lines superimposed are unmistakable. Several actual plates were shown both by M. de Broglie and Prof. Whiddington.

The interpretation of these spectra, which are of somewhat simple appearance, proves to be most important in relation to current theories of quanta and atomic structure. In the first place, the phenomenon obeys the general law of photo-electric effects, in that the velocity, and therefore the energy, of the electrons expelled depends only on the frequency, and not on the intensity, of the exciting X-radiation.

Of still greater importance is the bearing of the experimental results on Bohr's theory of atomic constitution. As is well known, this theory involves that the electrons, in number N , which surround the nucleus of an atom of atomic number N , are distributed in a certain number of regions, or layers, each characterised by the work which it is necessary to expend in order to remove an electron from the region under consideration, and bring it to the exterior of the atom. If we denote by the letters K , L , M , etc., the levels of these regions, we can attribute to them energies of extraction W_K , W_L , W_M , etc. The fundamental principle underlying the production of the magnetic spectra above mentioned will be made clear by quoting from M. de Broglie's remarks:

"What appears to happen is that if radiation of frequency ν strikes one of these electrons, situated, for example, in the region K , it communicates energy equal to $h\nu$ in order to extract the electron from the

atom; it is clear that the corpuscle, once removed from the atomic edifice, will possess a resultant energy equal to $h\nu - W_K$."

In this, of course, h is Planck's constant, and the resultant energy of the electron, which proves to have the value specified, is that which is measured experimentally by means of the magnetic deflection. For truly monochromatic X-radiation, the magnetic spectrum would thus consist of a few lines, corresponding to the various different regions in the atom from which electrons may be ejected, *i.e.* to the various possible values of W . Unless $h\nu$ is greater than W the radiation is incapable of extracting electrons from the atomic region in question. This proves to be true experimentally; unless an anticathode is used for which the frequency of the characteristic radiation is sufficiently large in relation to at least some of the energies of electron extraction for the irradiated metal, no magnetic spectrum appears. With a Coolidge tube as the source of X-rays it has not been possible to make $h\nu$ large enough to extract the more deep-seated electrons in metallic atoms of high atomic number; but the employment of γ -rays, with their much greater frequency, has enabled Ellis to extend the process to these regions, and to prove in this case also the validity of the general relation.

The lines in the magnetic spectra are usually composite. This arises from the fact that the X-rays used are seldom monochromatic, the characteristic radiation from the anticathode having several components. Again quoting M. de Broglie:

"Each line of the spectrum of the incident X-rays re-echoes on each level of the illuminated atom in such a way that we obtain at once an analysis both of the spectral lines of the illuminating beam and of the Bohr levels of the illuminated atom."

The method, as M. de Broglie pointed out, serves for measuring, without the intervention of a crystal, the frequency and wave-length of X-radiation. It thus furnishes a means of checking the magnitudes of the crystal spacings which form the basis of X-ray analysis.

The papers of M. de Broglie and Prof. Whiddington evoked great interest in the Section. There was some discussion, particularly with reference to the general fogging of the magnetic spectrum plates, which seemed to point to some of the ejected electrons having all sorts of emergent velocities. Prof. Lindeman suggested the possibility of having to assume that in the atom there were numerous electron levels, instead of the comparatively small number assumed by Bohr. Sir Ernest Rutherford, however, was satisfied that no such explanation was needed, for the reason that the fogging was inevitable, owing partly to the general radiation from the anticathode, and partly to the fact that some of the ejected electrons would lose random amounts of energy from various causes along their paths to the photographic plate.

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