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U.R.S.I. and the Early History of the Ionosphere

W. J. G. Beynon

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U.R.S.I. and the early history of the ionosphere

By W. J. G. Beynon, F.R.S.
President of U.R.S.I.

1. Introduction

Although the origins of the International Union of Radio Science can be traced back to October 1912, the formation of the Union itself as an international organization for the cooperative scientific study of problems in wireless telegraphy, dates from 1919.

In the wireless communication field the years immediately following World War I were a period of transition, in which the advantages of short waves over long waves for World-wide communication were being rapidly appreciated. It was a period too in which large numbers of enthusiastic wireless operators were demobilized from the armed services and started the great boom in amateur wireless communication which continues to this day. In fact it was not without significance that the original title of U.R.S.I. was the 'International Union for Scientific Wireless Telegraphy' (later changed to 'International Union for Scientific Radio') – the inclusion of the word 'Scientific' was, from the start, a matter of deliberate policy. However, as we shall see, the founding fathers of U.R.S.I., while inserting 'Scientific' into the title of the new organization, were careful not to isolate it completely from the great world community of amateur wireless enthusiasts.

The activities of U.R.S.I. have always centred largely on its General Assemblies and in the early days, when science advanced at a more leisurely pace, papers describing new work sometimes presented at these Assemblies before they had appeared in the usual scientific journals. However, because of the large intervals between General Assemblies, this did not happen very often and perhaps the most interesting and unique contributions to a history of the ionosphere, which can be found in U.R.S.I. annals, are the detailed reports of discussions which took place at these Assemblies on problems current at the time. These often provide a direct glimpse into the thinking of leading workers of the day and reveal views and opinions which are altogether missing, or difficult to pinpoint in formal published papers.

Appleton first participated in U.R.S.I. in 1927 at its Second General Assembly and was soon a leading figure in all its affairs, so much so, that the history of U.R.S.I.'s concern with the ionosphere is inextricably linked with that of Appleton himself.

2. The period 1922–38

The first General Assembly was held in Brussels in July 1922 and at this meeting U.R.S.I. established its first four Commissions: (i) on measurement and standards; (ii) on propagation; (iii) on atmospherics; (iv) on cooperation with amateurs, practitioners and operators. The establishment of Commission (iv) was a clear recognition of the contribution which amateurs were making, and were expected to continue making, to the study of wireless wave propagation. It was felt that U.R.S.I. might be able to coordinate such work and even provide selected skilled operators with some equipment to enable them to make precise quantitative measurements

(From the U.R.S.I. records it is not clear why a distinction was made between 'practitioners' and the other two categories – 'amateurs' and 'operators'). An example of a very effective use of amateur collaboration in observing atmospherics was reported in one of the early U.R.S.I. Assemblies. As part of a large-scale study of the incidence of atmospherics, amateurs in Europe and N. Africa were asked 'to mark on a typescript circulated in advance, the syllables of a broadcast talk on which were heard superposed atmospherics' and, referring to the results of the project, it was stated that the quantitative accuracy of the results obtained was far in excess of expectations and the combination with these data, of directional observations on the same atmospherics, provided conclusive evidence on the reception of atmospherics at great distances from their sources'. From time to time, in subsequent Assemblies, U.R.S.I. placed on record its appreciation of assistance received from amateurs in other areas, e.g. wave-interaction phenomena, sporadic E observations and propagation in the troposphere. Appleton himself was always a strong supporter, both within and outside U.R.S.I. of amateur radio enthusiasts and this Commission for cooperation with amateurs existed until 1946.

Following the 1922 Assembly, U.R.S.I. did not meet again until 1927, this time in Washington, and in the five years which had elapsed much had happened in the ionospheric field. Four papers relating to the ionosphere presented at this 1927 Assembly merit special note. The first, by Appleton, on 'The existence of more than one ionized layer in the upper atmosphere' was an expanded version of a letter to *Nature* and is notable as probably being the first occasion on which the designation of the layers by the letters 'D', 'E' and 'F' appeared in print. Incidentally in this 1927 paper Appleton actually suggested that the D-layer might be identified with the ozone layer but unfortunately his grounds for saying so are not recorded – possibly they were no more than that the two layers were then thought to be at roughly the same height.

The second important paper submitted by Appleton to the 1927 Assembly, was perhaps destined to be of more importance than any other. This was entitled 'The influence of the Earth's magnetic field on wireless transmissions'. Unfortunately only a summary of this paper was reprinted in the published proceedings of the meeting. In this, Appleton couples the names of the U.S. workers Nichols and Schelling with his own as having extended the early theory of Lorentz on longitudinal and transverse propagation to the general case of propagation in any direction with respect to the magnetic field. Using the same nomenclature as Lorentz, he gave the usual formula for refractive index when absorption is neglected, deduced the conditions for reflexion of the ordinary and extraordinary rays and called attention to the differential absorption to be expected for the two components. It is interesting to note that no less than five years were to elapse before Appleton published his full paper on the magnetoionic theory.

At this 1927 Assembly L. W. Austin and I. J. Wymore read a paper on 'The influence of solar activity on radio transmission'. In this, curves were given showing good positive correlation between the field strength of transatlantic long wave (13000 m) signals from the German station Nauen and sunspot numbers, over a solar cycle between 1915 and 1926, and also over 27-day periods. Although not by any means the first to observe a link between the field-strength of transatlantic signals and magnetic activity – credit for this probably belongs to R. A. Fessenden in 1906, this paper by Austin & Wymore was the first to give results for a whole sunspot cycle. It is interesting to note that a year or two later, Appleton showed that the results of Austin & Wymore indicated that the conductivity of the E-layer was 1.6 times as great at sunspot maximum as at sunspot minimum.

The 1927 Assembly was also notable for a paper by E. O. Hulbert of the Naval Research

Laboratory, Washington, on 'Ionization in the upper atmosphere'. Hulbert began by listing all the more important agencies which could conceivably produce substantial ionization in the upper atmosphere and after briefly reviewing such experimental data as existed, he chose 'the ultraviolet light of the Sun as being the ionizing agency deserving first consideration'. He then states that after taking account of many relevant factors such as the temperature, pressure and chemical composition of the upper atmosphere, processes of recombination and attachment in the diffusion of electrons and ions 'it is concluded that solar ultraviolet light is a necessary and sufficient cause of the Kennelly–Heaviside layer and that hypotheses of other agencies of ionization such as charged particles from the Sun, penetrating radiation, etc., are uncalled for except in unusual cases'. Hulbert proceeded to calculate theoretically the maximum electron densities to be expected for a temperate latitude station and gave estimates of 3×10^5 e cm^{-3} in summer noon decreasing at winter noon to 1.4×10^5 e cm^{-3} with a day to night variation by a factor of 6. Hulbert claimed that 'this ionization is shown to explain quantitatively many facts of wireless telegraphy, i.e. the skip distance, overhead absorption coefficients, limiting waves, ranges and the apparent heights reached by the waves'. Considering the very limited knowledge available in 1927 on the upper atmosphere, on solar u.v. radiation, etc., this paper by Hulbert is a remarkable pioneer effort in the theory of the formation of the ionosphere.

The next Assembly was held less than one year after the Washington meeting, and here Appleton presented a paper on 'Wireless methods of investigating the electrical structure of the upper atmosphere' – a paper which later appeared in the *Proceedings of the Physical Society*. In this he discussed the general equivalence of parameters measured by the three methods then in use for measuring the height of reflexion and also made suggestions for determining the height gradient of ionization.

At this 1928 Assembly a major paper, critically reviewing seven years work on 'Radio direction finding' (and which included more than one hundred references) was contributed by Smith-Rose. One short paragraph from it may be quoted here since it will serve to remind us that fifty years ago, near the time Appleton and Barnett carried out their key experiment, Smith-Rose and Barfield successfully used direction-finding equipment to show the existence of a downcoming signal. In this U.R.S.I. paper Smith-Rose wrote: 'It has now been satisfactorily established that these variations in apparent bearing are due to the arrival at the receiver of waves from the upper atmosphere polarized with their electric force in a horizontal plane. This explanation was first put forward by T. L. Eckersley in 1921 and supported by experimental results. In recent years considerable direct confirmation of the theory has been provided and the study of the propagation of electromagnetic waves through the ionized regions of the atmosphere now forms the subject of large numbers of papers published in all parts of the World.'

Other papers presented at this 1928 Assembly dealt with studies of the relation between radio propagation and magnetic disturbances and with the possible influence on radio-wave propagation of irregularities in the reflecting layer. Irregularities of quite another kind were suggested in a paper by Taylor and Young of the Naval Research Laboratory, Washington, who, when looking for round-the-world echo signals on 20 MHz, noticed signals which appeared to have reached their receiver by some path shorter than the great circle distance. They suggested 'either a reflexion from a heavily ionized region near the magnetic pole or reflexions scattered back from mountainous regions in zones of reception beyond the skip distance'. This, I believe, must be one of the earliest suggestions of back-scattering of radio waves at the ground. Another paper at the 1928 Assembly dealt with some aspects of long distance short-wave communication and included an interesting table of figures on commercial traffic which underlined the steady decrease in long-wave traffic between 1923 and 1928 and the corresponding rapid increase, year by year, in the volume of traffic carried by short waves. For the particular circuit considered by these authors, traffic on short waves started to exceed that on long waves sometime around 1926. (Nearly fifty years later we are probably seeing the volume of short-wave traffic in its turn being overtaken by that carried by satellite communication systems.)

At this time much of the information on the reflecting layers still came from field-strength studies on short-wave communication circuits and discussions at the 1928 Assembly show that the skipped distance phenomenon was certainly not widely understood – indeed it was not accepted at all by some, since there were reports of its apparent complete absence at equatorial latitudes. Appleton was appointed Chairman of a Working Group to look into this matter and, apart from showing that he clearly understood the theory of a skipped distance, he urged upon his colleagues the advantages to be gained from radio-wave investigation of the reflecting layers using as short a base-line as possible. These remarks of Appleton, made in 1928, show that he was one of the first to recognize that the mystery of the reflecting layers were going to be solved by radio sounding at vertical, rather than at oblique incidence. Indeed even two years before this he had made the same point at a discussion meeting in the Royal Society.

The fourth General Assembly of U.R.S.I. was held at Copenhagen in 1931 and at this meeting plans were adopted for coordinated radio sounding measurements at different locations. By modern standards the proposed programme was extremely modest – just weekly measurements of equivalent height on 2 and 4 MHz at some eight sites throughout the world – at midnight on Wednesday and at noon on Thursdays. Modest though the proposal was, it is worth noting since it marked the beginning of what was to become a world network of ionospheric sounding stations.

This was the year too in which U.R.S.I. joined with other Scientific Unions in an international coordinated programme in geophysics. In 1882–3 a series of international cooperative studies had been carried out at northern latitudes in the fields of meteorology, geomagnetism and aurora – this was the First International Polar Year. Radio, of course, played no part in that programme of 1882–3. Fifty years later, in 1932–3, plans were drawn up for the 'Second International Polar Year' and at the 1931 Assembly U.R.S.I. set up a Polar Year Subcommission with the task of 'considering the advisability of making wireless observations during the Polar Year, and if agreeing that such measurements were desirable, of formulating definite proposals concerning the nature of the work'. Appleton was appointed Chairman of this Subcommission which included in its proposals for Polar Year radio observations a limited programme for noon critical frequency measurements on a total of 31 days. It is interesting to record that 25 years later Appleton was again Chairman of an U.R.S.I. Committee which drafted plans (on a somewhat larger scale) for radio observations during the I.G.Y. In the I.G.Y., in place of the eight or so sites of the Second Polar Year, there were some 170 vertical incidence sounding stations and the recommendations of the U.R.S.I. Committee were not for 31 critical frequency measurements in a year but for $\frac{1}{4}$-hourly observations over the whole frequency range every day for 18 months, with still more frequent soundings on special days.

The 1931 Assembly appears to have been the first occasion on which U.R.S.I. adopted the procedure of formulating official Resolutions. These Resolutions would first be drafted and voted upon by the official national representatives in the separate Commissions and then put to a vote in the final Plenary Session of the Assembly. They thus carried the authority of U.R.S.I and, over the years, it is clear that they exerted a significant influence on the course of radio history expecially in matters requiring international cooperation. I know that Appleton himself placed great weight on the formulation and adoption of Resolutions by U.R.S.I. and was personally responsible for initiating many of them. It is probably no accident that four of the total of five Resolutions adopted by the Radio Propagation Commission in 1931 specifically mentioned Appleton by name – it certainly pointed to the leading role which he was about to play in U.R.S.I. and which was to last for the next thirty years.

The 1934 Assembly was held here in London, at the Royal Society rooms in Burlington House. In the absence of the President, A. E. Kennelly, the Chair was taken by W. H. Eccles, who was at this time one of the U.R.S.I. Vice-Presidents. One of the matters discussed at this Assembly was nomenclature and Appleton opened the discussion by saying that 'some agreement is desirable as to the acceptability of the term "ionosphere" which is already in fairly common use'. In view of the fact that this term had, in fact, been suggested by Watson-Watt eight years earlier, and indeed had been fairly widely used from about 1930, it is a little surprising to find it being reconsidered at this 1934 Assembly. Anyway the term was now given the seal of international acceptance by U.R.S.I. at this Assembly. Some speakers thought that a formal definition of the meaning of 'ionosphere' was also required and Appleton himself proposed 'the ionosphere is the sphere of air whose predominating physical characteristic is ionization'. However this was not accepted, and after much discussion the agreed definition (proposed by Dr R. A. Heising, U.S.A.) was 'the ionosphere is that part of the upper atmosphere which is ionized sufficiently to affect the propagation of radio waves'. A number of other definitions, terms and symbols were also agreed at this Assembly such as the use of the term 'region' rather than 'layer' and of 'virtual' or 'equivalent' height rather than effective height, the letters P, P′ for optical and equivalent path respectively, and of *f*E, *f*F1, *f*F2, etc., for critical frequencies. This discussion on nomenclature for critical frequencies was a reflexion of the fact that around this time (1933–4) sounding stations were being equipped with newly developed automatic sweep-frequency equipment and photographic recording was coming into routine use. The following is the text of the letter written by Watson-Watt in 1926 in which adoption of the term 'ionosphere' is first suggested.

Radio Research Station,
Ditton Park, Slough.
4386. *8th November* 1926.

Dear Sir,

With reference to recent discussions on the nomenclature of the 'upper conduction layer' of the atmosphere, may I suggest that it is not yet too late to obtain general agreement on a systematic name for the 'layer', avoiding the controversy arising from personal names.

We have in quite recent years seen the universal adoption of the term 'stratosphere' in lieu of a previously well established misnomer 'isothermal layer', and the adoption of the companion term 'troposphere' for the 'convective layer'.

The term 'ionosphere', for the region in which the main characteristic is large scale ionization with considerable mean free paths, appears appropriate as an addition to this series. The objection that ionization occurs throughout the atmosphere is no more adequate against the proposed term than is the fact that stratification occurs locally in the troposphere, the systematic name should be characteristic of the main 'grand scale' phenomena without reference to minor and local phenomena.

I am writing in these terms to the Secretary of the National Committee for Radio-Telegraphy.

Yours sincerely,
R. A. Watson-Watt

The Secretary,
Radio Research Board,
16, *Old Queen Street,*
Westminster, S.W. 1.

A whole day of the 1934 London meeting was devoted to a discussion of work carried out under the auspices of the Union by workers in nine countries during the International Polar Year of 1932. Appleton quoted some of the main results obtained by the British expedition to Tromsø including the first recorded report of a polar 'radio black-out'. Dr Jensen reported on noon measurements of critical frequencies made daily over a whole year at Deal, U.S.A., and noted the different seasonal variations in regions E and F2. He claimed that the critical frequency of the F1 layer exhibited a direct correlation with earth potential and also showed curves comparing the variations of fE with the parameter $(\cos \chi)^{\frac{1}{4}}$ where χ is the solar zenith angle. This must have been one of the earliest comparisons between experimental measures of critical frequency with a prediction of the Chapman theory of layer formation. In commenting upon Jensen's result Appleton pointed out that the seasonal variation in fF1 was less than that in fE and that it was absent altogether or even completely reversed in fF2, and added 'this points to an influence increasing with height and suggests a seasonal variation of temperature, which increases with height'.

In 1938 the sixth General Assembly met in Venice. At this meeting some 135 papers were presented of which nearly one-half dealt in one way or another with the ionosphere. Appleton was now President of the Union and was also Chairman of two of its five Commissions. In his Presidential address he called attention to the growth in the systematic investigation of the ionosphere which had taken place in the previous four years, stating that twenty-four stations were now making radio soundings by manual or automatic means over a wide range of latitudes. He expressed the view that enough data had now been collected to make it clear that regions E and F1 could be explained by a simple theory involving photoionization by solar radiation and recombination. However, for region F2, measurements made at Washington and Watheroo, stations at approximately the same latitudes north and south of the equator, had shown that there were at least two outstanding problems associated with this region. In Appleton's words 'One is to explain the anomalous seasonal effect first recognized in the northern hemisphere (i.e. that the electron density is larger in winter than in summer) – the other is a non-seasonal anomaly which appears to affect both hemispheres similarly and which is related in some way to solar activity'. Here in 1938, was an early hint of what was later to become known as the 'F2 equatorial anomaly', the detailed study of which Appleton resumed years later immediately at the end of the War.

One interesting event at the 1938 Assembly was the establishment of a new Subcommission charged with studying 'the propagation of waves in the lower atmosphere' (note 'atmosphere' not 'ionosphere'). It may be recalled that in 1936 Colwell & Friend in the U.S.A. had claimed to have observed echo signals from heights of a few kilometres – so-called 'C' region reflexions – and in 1937, Watson-Watt and some of his colleagues had also claimed to have obtained tropospheric reflexions on 6 MHz with very high reflexion coefficients. U.R.S.I.'s response to these reports of observations of echo signals from the lower atmosphere was to appoint this new Subcommission – Watson-Watt was elected Chairman and Friend was one of its members. Of course World War II presently interrupted the affairs of U.R.S.I. and there is no record that this Subcommission ever met or reported its findings.

3. The post-War period

Soon after the end of World War II, U.R.S.I. resumed its General Assemblies, first meeting biennially, and then from 1954 onwards, meeting triennially. In 1948 the Union reorganized its structure with the new Commission III given responsibility for the ionosphere and wave propagation. Appleton was again President of the Union and he was also President of Commission III. In this period, through its Commission III, U.R.S.I. was again very active in a wide range of ionospheric matters – but in addition in the years 1948–57, through Appleton and others, U.R.S.I. was also closely associated with the activities of two other international organizations – the 'Mixed Commission on the Ionosphere' and the 'Special Committee for the International Geophysical Year (C.S.A.G.I.). The Mixed Commission on the Ionosphere was established by I.C.S.U. in 1948 and consisted of representatives of those Scientific Unions having a common interest in the ionosphere, i.e. the Unions of Astronomy, Geodesy and Geophysics, Pure and Applied Physics and Radio Science. U.R.S.I. was the so-called mother union and Appleton was Chairman of the Commission. This Commission remained in being for nine years during which time it formulated no less than seventy six resolutions which were transmitted to the Scientific Unions of I.C.S.U. (including U.R.S.I.) and to interested bodies such as national organizations concerned with ionospheric studies. The work of the Commission was clearly reflected in these resolutions and there can be little doubt that over a period of many years these exerted a considerable influence on the general course of World-wide ionospheric investigations. Reference may be made to one very important action of the M.C.I. taken at its meeting in 1960. Two of its members at this time were Dr Lloyd Berkner and Professor Sydney Chapman and they presented to the Commission their suggestion for organizing a Third International Polar Year in 1957–8. On the basis of its discussions the Commission prepared a lengthy memorandum and all the main proposals in this document were subsequently adopted by the Unions concerned, and by I.C.S.U. At the General Assembly of I.C.S.U. at Amsterdam in October 1952, the Executive Board reported that 'On the suggestion of the Mixed Commission on the Ionosphere and with the subsequent support of the International Unions of Geodesy and Geophysics, of Astronomy and of Radio Science, the Executive Board has decided to set up a committee for a Third International Polar Year for the year 1957–8.' At the same meeting it was noted that 'the title International Geophysical Year had been suggested and had met with general approval'.

Appleton was himself not directly involved with the activities of C.S.A.G.I. itself but he was Chairman of the U.R.S.I.–I.G.Y. Committee which U.R.S.I. itself appointed in 1952 to deal with all aspects of ionospheric measurements during the I.G.Y. The deliberations of the Committee and of its various sub-committees over a period of six years also resulted in many formal resolutions and one, which is now of historic interest, merits special mention. This reads

'Study of solar radiation in the upper atmosphere' – U.R.S.I. recognizes the extreme importance of continuous observations, from above the E-region of extraterrestrial radiations, especially during the forthcoming I.G.Y. U.R.S.I. therefore draws attention to the fact that an extension of present isolated rocket observations by means of instrumented earth-satellite vehicles would allow the continuous monitoring of solar ultraviolet and X-radiation intensity and its effects on the ionosphere, particularly during solar flares, thereby greatly enhancing our scientific knowledge of the outer atmosphere'.

This resolution, adopted by U.R.S.I. more than three years before the first successful satellite launching, is possibly the earliest reference by an international scientific body to the special value of Earth satellite projects.

The very first Bulletin, published in May 1914 by the Commission Internationale Télégraphie Sans Fil Scientifique (T.S.F.S.) – the Commission out of which U.R.S.I. grew – starts with these words: 'Les recherches sur les lois de la propagation des ondes électromagnétiques nécessitent la collaboration d'un grand nombre d'observateurs placés en des points souvent très éloignés.'

The authors of that historic, if somewhat trite, opening phrase can hardly have foreseen the enormous role which studies of the ionosphere were to play in unravelling the problems of wireless propagation, nor indeed could they have foreseen the extent to which the organization they were founding would be the focal point for ionospheric radio workers the world over. U.R.S.I. is justly proud of the role it has played for more than half a century in the history of the ionosphere – in this short article I have been able to relate only a very small part of the full story.

Appendix

Early history of ionospheric investigations

By M. V. Wilkes, F.R.S.

I arrived on the scene just ten years after the events that we are celebrating today. Appleton had left Cambridge immediately after his pioneering work with Barnett, and the task of building up a research group in Cambridge had fallen to Mr Ratcliffe, then a young member of the Cavendish staff. When I joined Mr Ratcliffe's group in October 1934, there were four people working with him on ionospheric research, J. E. Best, F. T. Farmer, and S. Falloon, who were all doing experimental work, and H. G. Booker, who was a theoretician. Mr Ratcliffe's early students, F. W. G. White, E. C. L. White, and J. L. Pawsey, had all left the group and were only names to me at that time. W. B. Lewis, a University Demonstrator in the Cavendish Laboratory, although primarily an atomic physicist, took a great interest in ionosphere work and would always attend the evening literature discussions held once a week in Mr Ratcliffe's rooms in Sidney Sussex College.

Long waves had become very unfashionable, but Mr Ratcliffe realized that a study of them might contribute greatly to our knowledge of the lower ionosphere. He had, accordingly, restarted work on long waves and Best was already working on the subject when I joined the group. The source of signals for study was the British Post Office station at Rugby, operating on a frequency of 16 kHz. The experiment in which I first became involved was the mapping of the pattern formed on the surface of the Earth by interference between the ground wave and the down-coming wave. For this purpose we used measuring equipment mounted in a caravan that could be towed behind a car and we pursued our researches eastwards from Cambridge towards the coast. We were once stopped near Newmarket by a stranded member of the racing confraternity who mistook our caravan for a horse-box. There was very little money to spend on equipment in those days and I was proud when Mr Ratcliffe told me that if I needed some small component costing about five shillings I could obtain it from a shop where the Laboratory had an account provided that I did not do so too often.

It was in connexion with long-wave research that I first studied Chapman's theory of absorption of solar radiation by a spherical atmosphere. I found that if the phase of the downcoming wave was plotted against a function given by Chapman then a straight line was obtained; from the slope of this line a value for the scale height and hence for the temperature of the lower ionosphere could be obtained.

I was beginning my third year of research when Appleton was elected Jacksonian Professor. A new field laboratory near the observatory was built for him and our little group went on much as before working in its old huts just off Grange Road. The main difference was that there were more people to talk to. The literature discussions now took place in Appleton's rooms in St John's College instead of in Sidney Sussex College. K. G. Budden joined the group about this time and took part in the long-wave research. J. W. Findlay came a year later. K. Weekes, a contemporary of Budden's, worked with Appleton and their joint work on the lunar tide in the E-region was instrumental in turning my own attention in the direction of atmospheric oscillations.

Appleton had been only three years in Cambridge when he left to take up his post as the Secretary of the D.S.I.R. at the beginning of October 1939. By then war had intervened and brought ionosphere research temporarily to an end. When the war was over, Mr Ratcliffe restarted the research and initiated a number of new lines, in particular the study of whistlers and work on the correlation of signals received on spaced aerials. M. Ryle joined him as a research student and together they started the work on radio-astronomy. More money was available and there was more interest in scientific research. Soon the activities were of a scale that made those of the interwar period seem very small.

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