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MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday, 1955 October 14 at $16^h\ 30^m$

Professor Sir HAROLD JEFFREYS, *President*, in the Chair

Secretaries: C. W. ALLEN
A. HUNTER

The minutes of the previous meeting were read, confirmed and signed.

The President. We have two papers by Mr. J. E. Baldwin on "A survey of the integrated radio emission at a wave-length of 3·7m", and on "The distribution of the galactic radio emission".

Mr. Baldwin. A survey of the background radio-frequency radiation from the Galaxy has been made using an aerial of comparatively high resolving power at a low frequency (81·5 Mc/s) where accurate measurements of the sky brightness in regions away from the galactic plane can be made. The aerial used was one section of the Cambridge radio telescope, having beam widths to half power of 2° in right ascension and 15° in declination. The aerial could be moved in the declination plane in steps of 5°, and 23 settings of the aerial were used between declinations + 82° and − 28°. At declinations lower than − 28°, corresponding to elevations of the aerial beam of less than 10° above the horizon, the effects of ground reflections became important and these determined the southern limit of the survey. At each setting of the aerial a 24-hour record of the power received was obtained. Daily calibrations were provided by replacing the aerial by a standard source of noise power comprised of a resistance in series with a temperature limited diode. The derived values of the brightness temperature of the sky at different aerial settings were combined to form a contour map of the distribution of radio emission across the sky. A consideration of the errors arising in the determination of these contours shows that the absolute accuracy of the quoted temperatures is ± 10 per cent except in those areas of sky close to the galactic plane where the resolving power of the aerial is insufficient to show some of the fine detail of the galactic structure. The accuracy of the relative temperatures in different parts of the sky is probably about ± 5 per cent.

An earlier analysis of the distribution of the background radiation by Westerhout and Oort in 1951 suggested that the observed emission could conveniently be divided into two components:

(i) A component showing concentration towards the galactic plane arising in a spatial distribution of emission similar to that of the distribution of mass in the Galaxy. This accounts for most of the radiation at latitudes less than 30°.

(ii) A substantially isotropic component, possibly originating in extra-galactic sources. Shklovsky in 1952 proposed that this emission arises in a spherical distribution in the Galaxy, a suggestion that has received support from the observation of such a distribution in the Andromeda nebula by Baldwin in 1954.

In order to investigate this distribution of emission in the Galaxy, an analysis has been made of the radiation from areas at galactic latitudes greater than 30°, where the contribution from (i) is only a small fraction of the total emission. The angular distributions of emission which would be observed from simple spherical models having uniform emission per unit volume have been compared with the observations and it has been found that a model of radius 16 kps. agrees closely with the observations at all latitudes above 30°. Although a good fit may thus be obtained using a model having uniform emission per unit volume, an equally good fit may be found for a limited range of other models. The derived curves are insensitive to the distribution of the source of emission in the outer parts of the sphere. Some of the radiation could, for example, originate in extragalactic sources. A range of possible models may be derived having different contributions from extragalactic sources. This contribution cannot, however, exceed 500° K at 81·5 Mc/s. Estimates of the integrated radiation from extragalactic sources obtained in other ways suggest that it must be at least 150° K. We have therefore a limited range of models whose constants are summarised as follows:

Assumed extragalactic radiation	*Radius of sphere*	*Emission per unit volume*
150° K.	14·5 kps.	
300° K.	13	$1 \cdot 8 \times 10^8$ watts ster^{-1}
500° K.	11	(c/s)$^{-1}$ps.$^{-3}$

Other simple models have been considered in some of which the shape of the distribution is assumed to be a flattened ellipsoid and in others the emission per unit volume is assumed to be a function of the distance from the centre of the Galaxy. These models do not fit the observations as closely as does the uniform spherical model. It has been possible to place an upper limit to the ellipticity of the distribution and to show that the emission per unit volume cannot vary by more than a factor of two between 4 and 10 kps. from the galactic centre.

If the effects of this distribution are subtracted from the observed contours, the resulting contours of brightness at galactic latitudes less than 30° agree well with those predicted by Westerhout and Oort, allowance having been made for the additional radiation from the narrow belt of emission, 2° in width, lying along the galactic plane.

Using the values derived from the present measurements, the total power emitted by the main components of the galactic radio emission have been calculated and are given by:

Spherical distribution	R = 11 kps.	$1 \cdot 0 \times 10^{21}$ watts ster.$^{-1}$(c/s)$^{-1}$
	R = 14·5 kps.	$2 \cdot 3 \times 10^{21}$
Westerhout and Oort distribution		$0 \cdot 3 \times 10^{21}$

The narrow belt of emission referred to above, associated with the regions of ionized hydrogen in the Galaxy, contributes only about 5 per cent of the total radiation.

The President. This paper is now open for discussion. Is the visual part of the Galaxy inside your spherical distribution?

Mr. Baldwin. The spherical distribution is larger than the main visual part of the Galaxy.

Prof. H. Bondi. To me it seems to be an odd procedure to throw away the chief and most prominent feature of the distribution as being unexplained, and then to draw conclusions from the quality of fit of hypothetical curves to the remainder. Is the basis of this procedure some idea that unexplained causes can cause major, but not minor distortions of the curve?

Mr. Baldwin. The nature of the spherical distribution in the Galaxy has been deduced from the distribution of the radiation in roughly half the sky visible from Cambridge. This spherical distribution accounts for approximately 80 per cent of the total radio emission from the Galaxy.

Prof. A. C. B. Lovell. It is of great interest that these results show a spherical distribution similar to the one round the Andromeda nebula. I would like to ask whether you still require a distribution of sources of the kind proposed by Oort and Westerhout.

Mr. Baldwin. Yes. The high temperature component along the galactic plane is too wide to be associated with the layer of interstellar hydrogen.

Prof. R. O. Redman. Could not the galactic plane component be accounted for by varying the relative contributions of the interstellar hydrogen and the spherical component?

Mr. Baldwin. No. The angular width of the observed distribution is too great, even after allowing for the effects of finite resolving power.

Prof. Lovell. The question of the necessity of the Oort-Westerhout model is fundamental since the answer to it determines whether the emission is related to the mass of the Galaxy. Mr. Baldwin has not corrected his observations for the beam width of the radio telescope, and I would like to ask if it is certain that this does not influence the conclusion about extension of the high temperature component around the galactic plane.

Mr. Baldwin. In this connection it must be mentioned that the extended source is confirmed by the French work at 900 Mc/s and also by the interferometric observations of Scheuer and Ryle at 81·5 Mc/s.

Prof. Allen. What is the temperature of the coldest part, and is the value obtained as accurate as that given by your estimate of the absolute accuracy?

Mr. Baldwin. Yes. The lowest temperature is 880° K.

Dr. R. Q. Twiss. Would a comparison with the French work give information on the spectral distribution?

Mr. Baldwin. Yes. A comparison indicates a variation as $\lambda^{2\cdot5}$.

Prof. Redman. Does this law hold for all the components?

Mr. Baldwin. It does not hold for the interstellar hydrogen. The frequency-variation of the other components is consistent with radio star sources.

The President. If there is no more discussion we return our thanks to Mr. Baldwin. The next paper, by F. G. Smith, P. A. O'Brien and J. E. Baldwin on "The radio source at the galactic centre", will be presented by Dr. Smith.

Dr. F. G. Smith. The discrete source of radio emission in Sagittarius is among the most intense in the whole sky, but it is difficult to observe owing to its situation in the belt of emission from ionized hydrogen and other sources associated with the galactic plane. The observations described in this paper were made at frequencies of 38, 81·5, 210, and 500 Mc/s.; at these low frequencies it is particularly difficult to obtain sufficient aerial resolving power to distinguish the discrete source from the background. Interferometer aerials were therefore used, and at 38 Mc/s. and 210 Mc/s. spacings up to 60 were used, sufficient to resolve the source completely. At 81·5 Mc/s. various sections of the large interferometer aerial were used.

These observations gave the following values of the flux density and of the diameter (to half-brightness) of the source:

Freq. (*Mc/s.*)	*Flux density* $10^{-22} w.m.^{-2}(c/s)^{-1} \pm 20\%$	*Diameter*
38	1·0	2°·0
81·5	1·0	—
210	1·0	1°·1
500	0·73	—

The spectrum of the source may now be found by combining these results with observations at 1420 Mc/s. by Hagen, Lilley and McClain and at 3200 Mc/s. by Haddock, Mayer and Sloanaker. In calculating the flux density at these frequencies it has been assumed that the source is 1°·1 in diameter throughout, corresponding to the measured diameter at 210 Mc/s. At the lower frequencies some absorption may be expected to occur in the galactic plane, and the optical depth at 38 Mc/s would be expected to be about unity if the source is as far distant as the galactic centre. In the spectrum which we suggest the intensity at 38 Mc/s has accordingly been increased by a factor of 2·5. Absorption of this order would also account for the larger diameter observed at this frequency.

The suggestion has been made by Williams and Davies that in spite of the remarkable coincidence in position this source is not at the centre of the Galaxy, but considerably nearer. Their proposed distance of about 3 Kpcs. is based on a measurement of the depth and width of the absorption line at 1420 Mc/s. They point out that an *H* II region exists at their suggested location.

Our observations at low frequencies have led us to suggest a spectrum where flux density varies as $\lambda^{-0\cdot4}$, which is closer to the spectra of the non-thermal discrete sources than to that of ionized hydrogen. The source observed at these frequencies cannot in any case be an ionized hydrogen region radiating thermally, since the brightness temperature exceeds 10^5 °K, ten times greater than that expected and observed from other such regions.

The position of the source was measured on all four frequencies, and clear support was found for previous suggestions that the source lies very closely in the direction of the galactic centre. It seems that it might still be considered as being in fact at the centre, at which distance it would have a diameter of 150 pcs.

Prof. Lovell. Two of my colleagues at the Jodrell Bank Experimental Station have measured the distance of this source by the absorption method, and find that it is only 3 kiloparsecs from the Sun, which is about one-third of the distance to the galactic centre. They have suggested that the source is a region of ionized hydrogen which by a coincidence is in the direction of the galactic centre. The present communication from Dr. Smith attempts to show that this conclusion is impossible on the grounds that the spectral index of the source is 0·4. This conclusion, however, is open to serious criticism on the two following grounds: Firstly, the slope at the low frequency end is based on a measurement at 38 Mc/s, but this measurement has been multiplied by a factor of about 2·5 to allow for an assumed opacity for the interstellar gas. In deriving this factor it is assumed that the source is at the galactic centre, a result which is contradicted by the Jodrell Bank measurements. Secondly, the slope at the high frequency end is based on the assumption that the angular diameter is unchanged in the region of 3000 mc/s from that observed at 200 mc/s. The correction to the measured intensity is very sensitive indeed to this assumption, and a factor of the order of 8 is involved. The workers at N.R.L. who have done these high frequency measurements do not believe this scaling is justified since their results indicate that the size of the source on 3000 mc/s may differ considerably from that at lower frequencies.

Finally, it is important to mention that the recent work in Australia at 3·7 metres with the Mills Cross, which produces a very narrow beam width of only 50 minutes, shows that there is a minimum in the intensity of the signal at the position of the source which Dr. Smith claims to represent the galactic centre. It seems evident that the situation in this region is highly complex, and that the results obtained by various workers depend a good deal on the frequency and width of the beam used.

Dr. Smith. I agree that the spectrum is sensitive at the low frequency end to the absorption correction. At the high frequency end the observations have already been corrected for source diameter, and it is impossible to reconcile the whole range of observations with a spectral index of zero. The observed brightness temperatures at 38, 81·5, and 210 Mc/s. exceed 10^5 °K, which is too great in any case for thermal emission from a hydrogen cloud. The Australian workers have shown us a preliminary sketch of their results at 80 Mc/s., but their suggested brightness distribution in this region of the sky does not correspond with our records obtained with considerable resolving power at 81·5 Mc/s. Their new aerial system works on an entirely different principle and it has not yet been possible to compare results in detail.

Dr. M. J. Seaton. Did I understand correctly that the suggestion of

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a thermal *H* II region source was rejected because the temperature of 10^5 °K. would be too high ?

Dr. Smith. Yes. It has been found that *H* II regions normally show a temperature of 10^4 °K in radio emission, in good agreement with optical results.

Dr. Seaton. For all but the brightest *H* II regions the temperature of 10^4 °K is not obtained directly from observations but is deduced using the theoretical relation between electron temperature in the *H* II region and the colour temperature of the exciting radiation. However, due to the efficiency of cooling mechanisms, the electron temperature does not rise much above 10^4 °K even if the colour temperature becomes very great indeed. I agree that a kinetic temperature greatly exceeding 10^4 °K would be improbable for an *H* II region.

Prof. Redman. A source at the galactic centre would not be surprising in view of the peculiarities of the nucleus of the Andromeda nebula.

The President. We are grateful to the authors for this paper and to Dr. Smith for his account. We now have a paper by H. W. Newton and A. S. Milsom on "Note on the observed differences in spottedness of the Sun's northern and southern hemispheres". Mr. Milsom is here to read it.

Mr. Milsom. This investigation originated during the preparation of a table contained in a special volume, recently published, entitled "Greenwich Sunspot and Geomagnetic-Storm Data, 1874—1954". This table lists the annual mean daily sunspot areas, separated into northern and southern hemispheres, expressed as a fraction of the total area north plus south (i.e. N/(N + S) and S/(N + S), respectively).

The differences of the fractions (N − S)/(N + S) were plotted for each cycle, account being taken of the fact that the points at sunspot minimum were of low numerical weight. In addition, the spots at minimum were allocated to their appropriate cycles, old or new. The main feature of the diagram was the progressive change of slope from negative to positive over the seven cycles covered by the data.

A second diagram showed the very close agreement between spot areas and facula areas, when the latter are treated in the same way.

To extend the data to earlier years an examination was made of Schwabe's drawings for the three cycles 1833–67. The remaining cycle 1867–78 was covered by making use of Spörer's drawings. Since spot areas, separated into north and south, were not readily available for the period, spot counts were used. A scatter diagram showed that the two indices were sufficiently correlated for this procedure to be valid. Plotting the values of (N − S)/(N + S) for these earlier cycles made it apparent that the change of slope shown by the Greenwich data was not continued back.

There was, however, one interesting feature concerning all eleven cycles. This was exhibited graphically by comparing the slopes of each cycle with the corresponding mean annual sunspot number for the year of maximum. The two curves had a correlation coefficient of about + 0·8, indicating, for instance, that a very active 11-year cycle, as defined by a high maximum, would be expected to have a southern excess at the beginning and a northern excess at the end.

The President. Are there any comments on this paper ?

Mr. H. W. Newton. We were disappointed not to find the pattern of the change of slope carried backwards to the earlier cycles. I wish to emphasize that the slope results do not show a 22 year cycle.

Prof. Allen. I would have been more surprised if the change of slope had continued farther back!

Mr. Newton. Can Mr. Milsom say how the first spots of the present cycle are behaving?

Mr. Milsom. The slope seems to have reversed.

The President. We thank Mr. Newton and Mr. Milsom for their paper. Dr. Gething will now describe his paper on the "Greenwich observations of the horizontal and vertical diameters of the Sun".

Dr. P. J. D. Gething. This paper is concerned with observations of the solar diameter made with the Airy transit circle at Greenwich. The transit circle possesses certain advantages in the determination of diameter, since there is no question of a determination of scale as there would be in the measurement of photographic plates. Transit circle measurements of diameter are strongly affected by personality differences between observers and by an irradiation term. Both of these effects can be larger than the p.e. of a single observation of diameter, which is just under $1''$.

A series of Italian papers has claimed that observations made with a transit instrument at the Rome Observatory show a twenty-two-year and an eight-year period in the horizontal semi-diameter, with an amplitude of a few tenths of a second. It has been claimed that the Greenwich observations also show evidence of the same periods. There is, however, little agreement between the Italian and Greenwich results; the amplitude of the variations is three times larger for the Italian results.

I decided to examine the Greenwich observations afresh, with two guiding principles. One was that if there are variations in horizontal diameter there are also likely to be variations in vertical diameter, which were not measured or considered at Rome. Secondly, for the discussion of personality differences it is desirable to use only observers with long periods of service whose observations were made at about the same period. Attention was confined to measurements made after the introduction of the moving wire micrometer in 1915, so that the observations considered covered the period 1915 to 1937. Observations were first corrected for irradiation and then for personality differences.

The resulting extreme values obtained are

$$\left.\begin{array}{l} 1923{\cdot}0 : 960''{\cdot}68 \pm 0''{\cdot}05 \\ 1934{\cdot}0 : 960''{\cdot}98 \pm 0''{\cdot}03 \end{array}\right\} \text{Horizontal}$$

$$\left.\begin{array}{l} 1818{\cdot}0 : 960''{\cdot}89 \pm 0''{\cdot}02 \\ 1936{\cdot}0 : 961''{\cdot}48 \pm 0''{\cdot}04 \end{array}\right\} \text{Vertical}$$

The p.e.'s are calculated on the assumption that the p.e. of a single observation is $\pm\ 0''{\cdot}44$ in horizontal semi-diameter and $\pm\ 0''{\cdot}32$ in vertical semi-diameter: they do not include the effects of possible random and systematic errors in the personality corrections applied.

The results for the individual observers scatter considerably, rendering the range in horizontal semi-diameters not significant. For the vertical semi-diameters there appears to be a progressive change, confirmed by all observers, equivalent to an increase of about $0''{\cdot}03$ per year in the semi-diameter. It is not possible to say whether the drift should be interpreted as a real change in the diameter of the Sun, as an instrumental or atmospheric effect, or as a drift in the mean personality. There does not appear to be any marked drift in the vertical semi-diameters uncorrected for personality. The possibility of changes in mean semi-diameters of two or three tenths of a second due to personality changes cannot be excluded. Thus, the Greenwich observations considered here do not provide any clear evidence of the existence of real variation in the size of the Sun.

Mr. W. P. Hirst. Were the observations corrected for differential refraction ?

Dr. Gething. The limbs were corrected separately.

The President. We thank Dr. Gething for his paper. The meeting is now adjourned until 1955 November 11.

MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday, 1955 November 11 at $16^h\ 30^m$

Professor Sir HAROLD JEFFREYS, *President*, in the Chair

Secretaries: C. W. ALLEN
A. HUNTER

The minutes of the previous meeting were read, confirmed and signed.

The President. It is with regret that I have to announce the death of Dr. Eugene Delporte, Honorary Director of the Royal Observatory of Belgium, and an Associate of the Society. I will ask Fellows to stand in silence in his memory.

The President. Our first paper this afternoon is by Mr. Gold, on "The lunar surface".

Mr. T. Gold. In this paper the assumption that the craters are the results of meteoritic impacts is adopted and additional considerations are given in support of this; further, the point of view is developed that the great majority, and perhaps all, of the lunar features can be attributed to external influences only. This would be desirable, for the lunar highlands seem to possess a degree of stability far greater than that of any areas on the Earth, judged by the fact that circular markings have remained circular over periods probably longer than the entire geological record. This would seem to be in conflict with the suggestion that the huge flat plains on the Moon had resulted from outpourings of lava on a vastly greater scale than any such occurrences on the Earth.

It can be shown from a consideration of the physical processes in a high velocity impact that the shapes of lunar craters, even including the details of a central peak and frequently a steep crater within that, can be reasonably interpreted. An object striking a surface at a speed greatly in excess of the speed of sound in the materials, sets up a shock-wave that serves to accelerate the material in the path of the missile. The intensity of that