NRAO ONLINE 28

IAU Commission 40 President's Report, J.L. Pawsey, IAU Dublin 29 August to 5 September 1955
Appendix 2 in the IAU report of the IAU 1955 General Assembly

Pawsey's report was completed in late 1954, to be presented in August 1955 at the IAU in Dublin. Pawsey's history of radio astronomy presents his view of the achievements of radio astronomers in the first decade of the post WWII renaissance [1].

QUOTE:

> **INTRODUCTION**
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> Since its birth in 1932 with Jansky's discovery of cosmic radio waves, radio astronomy has developed sufficiently to permit an assessment of its place in astronomy. It is now clear that radio observations can supply important information not available optically so that the combination of radio with optical observations is indispensable in furthering our understanding of the universe. This is now widely recognised as evidenced by the existence of numerous radio observatories throughout the world. There are at least thirty-two of these distributed among fourteen countries. But it is only recently that trained astronomers have begun to play an effective role in the science. The early discoveries were made by American radio engineers; most of the currently available observations were made by Australian and English radio physicists; we are now at the stage where experienced astronomers, especially from the U.S.S.R., the U.S.A., and Holland, are making major contributions, particularly in interpretation. Radio astronomy, if it is to develop properly, must depend on a blending of radio invention and astronomical insight. There is already a considerable literature on radio astronomy, including recent books and integrating papers. In this report we shall not attempt the detailed account of recent work, which is the proper function of these papers, but present a very broad outline in an attempt to set the subject in perspective and to pick out the main questions of today. A further section deals with international collaboration …

[1] **IXth General Assembly - Transactions of the IAU Vol. IX B. Proceedings of the 9th General Assembly** Dublin, Ireland, August 29 - September 5, 1955 Ed., P.Th. Oosterhoff Cambridge University Press 1 Jan 1957, p. 563. This was the first report submitted by the Commission 40 President. Edge and Mulkay, 1976, p. 73 reported that Pawsey described it as " a very broad outline, in an attempt to set the subject in perspective and to pick out the main questions of today".

AN OUTLINE OF RADIO ASTRONOMY (prepared by Pawsey earlier in 1954)

Radio astronomy may be defined as astronomy utilising observations of radio waves. These observations fall into two distinct categories: observations of radio waves emitted naturally by the astronomical bodies studied, and observations of radio echoes. The first, analogous to those of optical astronomy, have been applied to the Moon, the Sun, objects in our galaxy, and external galaxies. The second, those of the radar method, are inherently limited to the nearer objects and so have been applied in astronomy only to meteors and the Moon. Thus the great bulk of observations are based on naturally emitted radio waves. The value of the observations depends on the great difference in wave-length between radio waves and light, differences which involve radical differences in emission and propagation so that radio observations yield information complementary to that obtained from light.

Matter emits radio waves thermally in accordance with the normal radiation laws. The spectrum of this radiation in astronomy is usually continuous, but a single spectral line, the 1420 MHz line of atomic hydrogen, is found in emission and absorption from interstellar matter. In addition non-thermal emission mechanisms must operate in the Sun and cosmic sources. In cosmic sources the spectrum of the non-thermal component is continuous; in the Sun it can show narrow bands, but the frequencies of such bands continually change.

Radio propagation differs from optical propagation in two important respects. First, highly rarefied ionised gases which freely transmit light may absorb and emit, or be completely opaque to, radio waves. Secondly, clouds of solid particles (e.g. interstellar dust clouds) which absorb light may be transparent to radio waves.

Radio observations have been made of the galaxy and external galaxies, of the Sun, of the Moon, and of meteors. In addition propagation effects in the terrestrial ionosphere have been recognised and applied to yield information about it. Brief resumes of current knowledge of each of these subjects are given below.

COSMIC RADIO WAVES: THE CONTINUOUS SPECTRUM

The continuous radiation is distributed over the sky with a concentration towards the plane of the Milky Way and a dominant maximum in the direction of the galactic centre.

This distribution conforms sufficiently well with the disposition of our galaxy to leave no doubt that most of the radiation originates in matter distributed widely throughout the galaxy. It is not yet possible to say to what extent the distribution conforms with those of particular classes of objects because the resolution of the equipment used for most of the published surveys has been inadequate (beam-widths of 10 or 20 degrees). The published contours may be seriously in error. There must also be an extragalactic component, but its magnitude is uncertain.

A most unexpected feature of the radiation is its high intensity at the lower frequencies. At 9 MHz, for example, the brightness temperature over the whole sky averages about a million degrees Kelvin. Theory shows that ionised interstellar hydrogen, HII regions, must emit and absorb radio waves, but these high brightness temperatures give conclusive evidence for the existence of a further, non-thermal, emission mechanism. **The nature of this mechanism is still unknown. An interesting hypothesis which links these very high brightness temperatures with the tremendous energies of cosmic rays was put forward by H. Alfvén and N. Herlofson, in relation to discrete sources. They suggested that the emission may be from electrons with relativistic energies spiralling round lines of magnetic force in interstellar space. This mechanism has been further studied and extended to other circumstances, even to clusters of galaxies, by other workers, notably by I. S. Shklovskii in a series of papers**. [our emphasis]

The spectra from different parts of the sky differ and it is from a study of such clues that one may hope to determine the relative roles of thermal and nonthermal emission and of absorption. Similarly, polarisation may give important clues but no observation of polarisation which is other than random has yet been described. This may either be because the radiation is emitted with random polarisation or because, in the observations, a large number of independent sources combined to give a random resultant. [Note no mention of Faraday rotation effects.]

Observations indicate numerous discrete sources of small angular extent superposed on a continuous background. But the angular resolution is not sufficient to decide if the background is really continuous or made up of numerous faint sources similar to the known ones. Positions of one or two hundred have been published and several dozen have been identified with optical objects. These numbers may be expected soon to increase greatly owing to observations taken with the large Cambridge and Sydney aerial systems. M. Ryle has stated that he expects to locate 1700 from the Cambridge work. Flux densities range up to about that of the Sun. Observed angular sizes range from one minute of arc to several degrees, and this suggests that none is of stellar dimensions. The sources are distributed widely over the sky and arc believed to fall into two classes: a more intense class (Class I) concentrated towards the galactic plane and towards the centre of the galaxy, and a less intense class (Class II) isotropically distributed. The former are likely to be galactic sources, the latter external galaxies.

The classification was originally based on statistics, but it is supported by identifications. The identified objects fall into five groups:

(1) Remnants of supernovae (e.g. the Crab nebula).
(2) Peculiar galactic nebulae (e.g. the Cassiopeia source).
(3) Peculiar external galaxies (e.g. the colliding galaxies in Cygnus, and M 87).
(4) Normal galaxies (e.g. the Andromeda nebula, and the Clouds of Magellan)

(5) HII regions (e.g. the Orion nebula)

Of these groups, (1) to (3) tend to be of very high intensity at the longer wave-lengths. The characteristic feature appears to be the existence of interstellar gas with very high internal velocities (10000 km/sec). Such high velocities imply enormous energies. Among the identified galactic sources the remnants of supernovae obviously have such energies available. I. S. Shklovsky has given reasons for supposing that a number of the other sources, for example, that in Cassiopeia, are also remnants of supernovae, but this view has not been accepted by Baade and Minkowski. Similarly in the case of the extragalactic sources the colliding galaxies have fully adequate energy available, but the energy source in other cases is obscure. In this connexion the ratio of energies emitted in the radio and optical parts of the spectrum is of interest. This ratio is of order 10^{-6} overall for our galaxy and some other normal spirals; it is 10^{-3} for several of the intense sources; and it is actually about unity for the Cygnus source.

Group (5) are observed to be prominent at the higher frequencies (wave-lengths 10 and 20 cm) and it appears that in them the principal emission mechanism is thermal (free-free transitions).

The nature of the mechanism, or mechanisms, responsible for high Intensity cosmic radio waves (background and sources) is an outstanding problem of radio astronomy. In this branch of radio astronomy discoveries have tended to pose new problems-mechanisms of origin, the nature of emitting objects, the types of population in which such objects occur-rather than give answers to old ones. When these new questions are answered we can expect many more direct contributions to astrophysics.

The hope of answering these questions depends on the proper merging of facts from three distinct disciplines: on more precise and comprehensive radio observations, on better understanding of radio-wave phenomena in highly rarefied gases, and on optical astronomy. Of these the line of progress of the first is obvious. It is clear that surveys with much greater resolution are required at a number of wave-lengths to give the distribution and the spectra of both discrete sources and background. Further, this is now technically feasible and beginnings have already been made in Cambridge, Sydney and Manchester. But the programme indicated is extensive ... co-operative planning between observatories is desirable.

When these questions are answered, what then? First, because with radio waves we can see without obscuration through the galaxy, there should result a wealth of detail on galactic structure. Secondly, we may extend the limits of the observable universe. For example, the Cygnus source, the colliding galaxies, which is at a distance of 30 million parsecs[2], has a flux density 10^3 or 10^4 times the threshold for detection. A similar object,

[2] The modern distance is 232 million parsecs.

if it exists, would be detectable far beyond the threshold of optical visibility. But so far, we lack criteria to determine distances of sources which are not identified optically.

COSMIC RADIO WAVES: THE 1420 HYDROGEN LINE

Observations of this line, unlike those of the continuous spectrum, do not suffer from the handicap that the source is unknown. The line originates in interstellar clouds of neutral atomic hydrogen. Since it permits direct observations for the first time of this form of matter, a form which comprises something like half the mass of the known universe, its importance in astronomy can scarcely be overestimated. And in few branches of astronomy has such spectacular progress been made as that in the three years since the first detection of the line by H. I. Ewen and E. M. Purcell.

The radiation has been studied in some detail in emission from the region near the galactic equator and from the Clouds of Magellan. It is very weak, peak brightness temperatures being commonly from 10 to 100 K, and in consequence observations are difficult. The emission is believed to be determined by collisions and so depends on the kinetic temperature of the gas. The natural line-profile is extremely narrow and the spread of observed profiles, normally of a few hundred kHz in width, is due to differing line-of-sight velocities of the contributing matter.

More recently line absorption has been observed. This is recognisable where an intense source of continuous radiation lies beyond the absorbing hydrogen. In practice sufficiently intense sources are restricted to the more intense discrete sources of continuous radiation. In such cases it becomes possible to observe both the absorption profile and the emission profile (of the gas in the immediate vicinity). Such information, together with reasonable postulates as to temperature distributions, can lead to firm estimates of the kinetic temperature of the gas and to information about the relative position along the line of sight of the discrete source and the atomic hydrogen.

The first astronomical problem to which 1420 MHz observations have been applied is the delineation of the spiral structure of our galaxy. A line-profile in a direction near the galactic equator typically shows several peaks. Each peak is attributed to a concentration of interstellar hydrogen with the line-of-sight velocity corresponding to the frequency-displacement of the peak. Now the principal component of velocity is that due to galactic rotation. Since the rotational characteristics are known, at least approximately, it is possible to deduce the expected line-of-sight velocity for an object at any position. Conversely, applying the concept to the available observations near the galactic plane, the line-of-sight velocity gives the position. Following this idea the concentration of hydrogen causing the peak in the profile can be located. Further observations in different directions indicate that in the vicinity of the galactic plane vast elongated masses of hydrogen extend around the galaxy. These clearly indicate spiral structure, the great gaseous arms presumably delineating also the distribution of the population I stars characteristic of spiral arms. This simple argument can be applied only to regions further from the galactic centre than is the Sun because there are within this distance two alternative positions. Other arguments are being employed to resolve this ambiguity and determine the structure inside.

The current position is that numerous observations taken in Holland and a few in Australia have shown the existence of a number of arms which, in the region external to the solar orbit, have been traced around to the far side of the galaxy. The observed structure is complex and the longer arms, which should best show the gross features, are nearly concentric circles about the galactic centre. In particular the evidence as to whether the spiral is left-handed or right-handed is not yet conclusive. Present opinion is that in relation to the sense of galactic rotation the arms are trailing (as a catherine-wheel).

The broad objective of this work is the complete determination of the distribution and motion of interstellar hydrogen within our galaxy. This has obvious implications concerning galactic structure, dynamics, and history. Such a project requires a vast number of observations and, because the desired results do not follow uniquely from the observations, demands a combination of imagination and critical care in interpretation. But a mere three years of observations of the 1420 MHz line has given us a knowledge of the distribution of hydrogen throughout the galaxy comparable with the knowledge of stellar distribution obtained optically throughout the whole history of astronomy.

The second problem which has been studied is the distribution of interstellar hydrogen in the Magellanic Clouds. Here we see the hydrogen in relation not to small details but to whole galaxies. Each of these galaxies is found to be embedded in a vast cloud of hydrogen extending far beyond the bright optical region. In the denser central regions these clouds are about equally dense despite considerable differences in the stellar populations and dust content of the two Clouds. In addition to estimates of the amount of hydrogen present, the observations give line-of-sight velocities from which the rotational characteristics of each of the Clouds have been determined. This leads to estimates of total mass, stars plus gas. Deductions as to detailed structure may be expected when more refined observations are obtained. It is clear that such detailed observations are likely to yield a remarkably complete three-dimensional picture of the structure of these galaxies.

Successful observations like these suggest the extension of the techniques to many other more distant galaxies. But here serious observational difficulties appear. More distant galaxies are smaller in angular size and demand very large aerials to resolve the individual parts, or even to detect them. So far no other galaxies have been detected.

There is little doubt that the larger aerials becoming available, together with improved techniques, will permit detection of a number of the nearer galaxies, but this number is likely to be seriously limited unless sensitivity and resolving power can be considerably increased. Such observations, however, may throw light on one of the classic problems of astronomy, the redshift of distant galaxies. Observations of the corresponding radio-frequency shift would conclusively test whether this shift accurately follows the Doppler displacement law. The possibility of the detection of other spectral lines has been suggested by several authors, but no successful observations have yet been reported.

THE SUN

The radio emission from the Sun comprises a steady background coming from the whole Sun together with intense localised disturbances with durations ranging from seconds to months. The former component is clue to thermal emission from the hot ionized gases of the solar atmosphere and through its study information can be obtained about temperature and density distributions in the solar atmosphere. The mechanism of origin of the disturbed components is still not settled and interpretation of observations in terms of physical conditions in the Sun is consequently handicapped. In addition to observations of solar emission, information about the outer corona has been derived from observations of the occultation of a radio source. The radar or echo method has not yet been applied to the study of the Sun, but is believed to be feasible, though powerful equipment would be required.

The study of the distribution of the background emission requires very high angular resolution, and two elegant techniques have been applied for obtaining the two-dimensional brightness distribution. The results show extension beyond the photosphere and, at decimetre wave-lengths, strong limb-brightening in the neighbourhood of the equator but not at the poles. The marked asymmetry shows that two-dimensional surveys are essential and that one-dimensional observations, for example, eclipse observations at a single station, can be interpreted only with the help of supplementary information. But, in this role, eclipse observations are valuable.

It is not yet known if the background varies throughout the sunspot cycle; the above results apply to sunspot minimum. Corresponding results near maximum will be more difficult to obtain because of the greater difficulty involved in eliminating the effect of the more numerous disturbances.

The radio-brightness distribution over the solar disk at a given wave- length depends on the distribution of electron density and temperature in the solar atmosphere and changes markedly with wave-length owing to the rapid increase of height of origin with increasing wave-length. The actual density and temperature distribution must conform with the distributions of brightness at all wave-lengths, and a model of the solar atmosphere which does not take into account radio data over a wide range of wave-lengths must be seriously open to doubt. At present the available radio data cover a limited wave-length range and it is to be hoped that good observations covering the full range will shortly be taken. The time will then be ripe for the derivation of a reliable model of the solar atmosphere.

The occultation observations have shown that the influence of the Sun extends to far greater distances, about 10 solar radii, than had been expected. This influence has been explained in terms of irregularities in the outer corona, a sort of turbidity effect. Such effects have been observed at each of the three occultations for which successful observations were taken, which suggests that turbidity effects are normal.

The emission from disturbed areas may be divided into various classes. We shall consider a class characteristic of decimetre wave-lengths, the "slowly varying component", and a class including various sorts of intense bursts which are typically observed on metre wave-lengths. These disturbances are related in diverse ways with optical solar activity and the relations with flares are particularly interesting.

The slowly varying component is due to the occurrence of highly emitting regions which are closely connected with sunspots and probably even more closely with Ca and H plages. These regions have diameters of the order of 5 minutes of arc; they have brightness temperatures in the range 0.5 to 10 million degrees Kelvin; and they tend to persist for weeks or months. The current explanation of the phenomenon is that the emission is thermal emission from regions in the lower corona of greater than normal density and temperature (Waldmeier's "coronal condensations"). This explanation is very plausible, but has not yet been subjected to the obvious observational test of comparing optical and radio observations of the same region.

Observations of the intense metre wave-length bursts have been very much curtailed over the past few years by their rarity during sunspot minimum, but with the approaching maximum they should again offer a fruitful field for research. The characteristic features of these bursts are the great intensities (flux densities range up to a million times that of the quiet Sun and brightness temperatures up to 10^{10} or even 10^{15} K) and the rapid rates of change (durations of the order of seconds or minutes).

These features appear incompatible with an origin in thermal emission from hot gas and two rival theories have been hotly debated, a microscopic and a macroscopic theory. The first considers the burst to be due to incoherent emission from extremely energetic electrons, the second that it is due to groups of electrons moving coherently and emitting in-phase radiation, e.g. plasma oscillations. The recent observational evidence that certain bursts include a fundamental and second harmonic strongly supports the plasma- oscillation interpretation, at least for the bursts concerned.

The available observations on bursts are not comprehensive. Thus the size of the emitting area is known to be small with respect to the solar disk, but the sources have not been resolved; the sources of certain bursts (outbursts) have been observed to move rapidly over the solar disk while others, presumed similar, have been shown to have a progressive drift in frequency toward the lower frequencies; some bursts have circular (or elliptical) polarisation, certain evidence of magnetic fields, others have random. On the radio side the subject requires simultaneous observations of all the features of particular bursts. The optical side presents a challenge. Is it possible to observe a peculiarity in the light, e.g. in the spectrum, from the actual region in which a radio burst is being generated? The difficulties are twofold. First, a burst is a localised, short duration, unpredictable phenomenon. Secondly, the region is probably well up in the corona. But if such observations are possible they are likely to be of outstanding importance.

Despite the gaps in information, two most interesting hypotheses have been formulated about two classes of bursts. One class (the outburst, Wild's "Type II") is thought to be due to the disturbance caused by the passage up through the solar corona with velocities of the order of 1000 km/s of the clouds of corpuscles responsible for the great magnetic storms and associated aurora. Another class of burst (Wild's ''Type Ill burst") is supposed to be similarly caused by even faster particles with a velocity of about one-fifth of the velocity of light. Now bursts of these two classes sometimes occur together in association with a solar flare. The further suggestion is made that the two may originate in a common explosive disturbance which gives rise simultaneously to a high-velocity and a low-velocity stream of particles. The high-velocity stream, it is suggested, may have some connexion with the cosmic ray increases observed to accompany certain solar flares.

[The text continued with descriptions of radio emission from the Moon, meteors and the ionosphere, followed by technical development.]

INTERNATIONAL COLLABORATION

Radio astronomy was pioneered by radio engineers and physicists rather than by astronomers and as a result another international union, the Union Radio Scientifique Internationale (URSI) is vitally interested. In fact Commission V of URSI and Commission 40 of the IAU have almost identical interests and a large proportion of common members. This may be illogical, but it is not clear that any good would be done by an attempt at rationalisation. The good feature of the current arrangement is that radio astronomers who are able to attend meetings of both unions and so mix with both radio research workers and astronomers. It seems best to carry on the present arrangement, but to attempt progressively to channel basically astronomical questions to the IAU and radio ones to URSI. The items which follow are ones in which international collaboration may be required and which should be considered by the IAU.

TERMINOLOGY AND UNITS

URSI and the IAU have each considered this question, and URSI has approved a report which gives matters on which substantial unanimity was reached. It is recommended that the IAU should consider this report and, if in agreement, should endorse it. It would of course be in order for the IAU to recommend amendments or additions. It may be worth noting that a point which was discussed by URSI but rejected because of lack of unanimity was the introduction of a short term for the rather clumsy mks unit of flux density (watts m^{-2} Hz^{-1}). The term "Jansky" was considered as commemorating the founder of radio astronomy. The other important unit, that of brightness (watts m^{-2} Hz^{-1} $steradian^{-1}$) would have become "Jansky per steradian".[3]

RECOGNITION OF AND DESIGNATION OF DISCRETE RADIO SOURCES

The early surveys of discrete sources of cosmic radio waves suffered from considerable inaccuracy, and when the areas of two surveys overlap the weaker sources do not show a one-to-one correspondence. This is probably clue to confusion between complex groups of sources, some of the positions shown being “blends” of several sources, and the blending process fortunately being different in the different surveys. This confusion should ultimately be resolved by higher resolution surveys, but there are at present a moderate number of reliably known sources. Which of these should be so considered is only known to those working in the field. In consequence the publication of a list of reliably known sources was considered by URSI [Sydney URSI 1952], and because the question is of astronomical rather than radio interest, referred to the IAU. The President of Commission 40 accepted the suggestion, and with the help of an expert committee

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[3] This awkward unit was never adopted. The modern "Jansky" unit retains the mks unit: one Jansky is 10^{-26} watts m^{-2} Hz^{-1}. Much of this work ("vexing matter of terminology", Edge and Mulkay (1976), page 60) was done by Frank Kerr, Chairman of URSI Sub-Commission 40. The report was adopted at the URSI General Assembly in August 1954. Numerous useful definitions were, in fact, adopted: including polarisation conventions, definition of temperature (e.g.) "brightness temperature." The question of radio astronomical "magnitudes was also discussed, a concept that was discontinued in the next decade. (see NAA C3830, C6/4D)

had a list prepared.[4] It is recommended that the question of issuing further lists in the future should be considered when further surveys become available.[5]

In this list a new system of catalogue numbers for sources has been adopted. This is explained in the preamble to the list. Individual workers should, as in the past, use their own systems for newly discovered sources. They would create confusion if they independently adopted this system for new ones.

Selected areas and discrete sources for standardisation of measurements

Radio measurements of flux density and brightness are notoriously difficult and it is certain that greater use should be made of intercomparison with other cosmic sources. To facilitate flux density measurements of both solar and cosmic sources, it is recommended that the IAU should prepare a list of standard discrete sources; and similarly for brightness, a list of standard areas in the sky. The latter should be selected separately for continuous cosmic emission and for the 1420 MHz hydrogen line as the technical requirements differ.

International planning of research programmes

In the course of its history the IAU has arranged a great many co-operative observations. Some of the results of these have been excellent in giving more complete information, others have hampered research by suppressing individual initiative through the burden of a vast programme of routine observations. It is essential to consider the pros and cons of co-operative research in relation to each individual project. There are two types of problem in which international planning can be peculiarly useful: ones in

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[4] The publication of the IAU "A Catalogue of Reliably Known Discrete Sources of Cosmic Radio Waves" occurred in the *Astrophysical Journal* (Vol 121, January 1955, p. 1 to 5) authored by Pawsey. List 1 had 8 entries while list 2 had 9 and list 3, 21. The errors ranged from 1 to 30 arc min (list 1), 0.5 to 1 degree (list 2) and one to several degrees (list 3). The Chair of the Committee had been Bolton with members Hanbury Brown, F.G. Smith and B.Y. Mills. Based on evidence from the NAA C3830 C25/3 documents, Mills did much of the final work on this project as Bolton was working with the Cloud Physics group of CSIRO in 1953 to 1955.

[5] As Edge and Mulkay (1976, "Astronomy transformed. The emergence of radio astronomy in Britain." New York: Wiley, p. 62,429) pointed out: "And, indeed, some desultory lists were published, but as the uncertainties of radio source survey were revealed in the mid-1950s, enthusiasm waned. At its 1958 meeting, Commission 40 (Radio Astronomy, at the Moscow IAU) was able to agree to give “rational numbers to [only six] standard sources. But even these were abandoned …" The 3C source list appeared in 1959; this catalogue became the unofficial approved list. Edge and Mulkay also reported the Royal Astronomical Society did not approve the publication of the IAU approved list in when this request was discussed in May 1954, contrary to the practice of the *Astrophysical Journal* with the Pawsey catalogue in January 1955.

which the whole picture can only be seen from the combination of observations taken in different parts of the Earth, and those which are so tedious that the work can only be completed in a reasonable time if it is shared between a number of observatories. In radio astronomy there is already one co-operative project, the continuous recording at different longitudes of the intensity of solar radio waves on a number of wave-lengths. This project is organised through a sub-committee of URSI-Chainnan A.H. de Voogt and the results are edited by S. F. Smerd and published in the *Quarterly Bulletin on Solar Activity.* In this case the results not only have application to solar physics but the information on solar disturbances may be useful in radio communication. Since the project is operating it would appear unnecessary for the IAU to take any action unless members should wish to criticise the plan or recommend modifications. Another subject which requires consideration is the determination of the detailed distribution and spectra of cosmic radio waves over the sky (requiring observations from both northern and southern observatories). Because of the lack of standardisation in techniques it would appear desirable to hold discussions on the type of information required and to leave the detailed planning to informal discussion. A suggestion for the requirements of such surveys is for contour maps showing detail to at least I degree over the whole sky at frequencies at intervals of 2 or 3 to I. These should range from the lowest feasible (e.g. IO or 20 MHz), to at least 1420 MHz (e.g. 20, 40, 80, 160, 300, 600, 1420 MHz). Note that a frequency in the immediate vicinity of 1420MHz is required for interpretation of hydrogen line observations. Planning is required so that northern and southern surveys should be made on similar frequencies with sufficient overlap for mutual checking. The need for cooperative planning is especially evident in investigations such as the scintillation of radio stars, ionospheric absorption, and the rotation of the plane of polarisation of Moon echoes. These matters are of interest to IAU members, but it would appear best, in view of their being of geophysical rather than astronomical interest, to refer them to URSI should any formal action be required.

BIBLIOGRAPHICAL NOTES

A comprehensive bibliography of radio astronomy (exclusive of meteors) under the title *Bibliography of Extra-terrestrial Radio Noise* (including abstracts) has been prepared by Martha E. Stahr-Carpenter and was issued as a part of the report of Commission V of URSI (1950). Supplements are issued from time to time. Those interested in obtaining this most useful reference work should communicate with the editor (address: Dept. of Astronomy, Cornell University, Ithaca, New York, U.S.A.). Important papers on radio astronomy are frequently found outside the normal astronomical journals, particularly in the *Australian Journal of Physics* (formerly *Australian Journal of Scientific Research,* A), *Comptes Rendus*(Paris), *Comptes Rendus de t'Academie des Sciences de l'U.R.S.S. (Doklady Akademii Nauk, S.S.S.R.), Nature, Proceedings of the Physical Society, Proceedings of the Royal Society, Philosophical Magazine* and *Physical Review.* Brief reports of the work of radio observatories in British countries are given each year in *Monthly Notices of the Royal Astronomical Society* with those of other observatories.

[Pawsey listed three recent books and nine “integrating papers” which summarised recent developments in radio astronomy. The books were Lovell and Clegg, *Radio Astronomy,* from 1952, Pawsey and Bracewell, *Radio Astronomy,* from 1955 and Shklovsky, *Radio Astronomy*, from 1955.]

END QUOTE