CLASSICS IN RADIO ASTRONOMY

STUDIES IN THE HISTORY
OF MODERN SCIENCE

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VOLUME 10

Karl Guthe Jansky (1905–1950) and his “merry-go-round” antenna at Bell Telephone Laboratories in Holmdel, New Jersey, U.S.A. (1933).

CLASSICS IN RADIO ASTRONOMY

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TABLE OF CONTENTS

ACKNOWLEDGMENTS	xi
PREFACE	xv
KEY	xix
INTRODUCTION	xxi
I. GALACTIC BACKGROUND RADIATION	1
A. The Beginning of Radio Astronomy	5
1. JANSKY, K. G., 1932, Directional Studies of Atmospherics at High Frequencies	10
2. JANSKY, K. G., 1933, Electrical Disturbances Apparently of Extraterrestrial Origin	23
3. JANSKY, K. G., 1935, A Note on the Source of Interstellar Interference	36
B. First Maps of the Galaxy	42
4. REBER, G., 1940, Cosmic Static	46
5. REBER, G., 1940, Cosmic Static	56
6. REBER, G., 1944, Cosmic Static	61
7. REBER, G., 1948, Cosmic Static	70
C. Free-Free Emission Theory	80
8. HENYEY, L. G. and KEENAN, P. C., 1940, Interstellar Radiation from Free Electrons and Hydrogen Atoms	81
D. Synchrotron Radiation and Cosmic Rays	88
9. KIEPENHEUER, K. O., 1950, Cosmic Rays as the Source of General Galactic Radio Emission	90
10. GINZBURG, V. L., 1951, Cosmic Rays as the Source of Galactic Radio Emission	93

II. TECHNIQUES	101
E. The Dicke Radiometer	105
11. DICKE, R. H., 1946, The Measurement of Thermal Radiation at Microwave Frequencies	106
F. The Phase-Switched Interferometer	114
12. RYLE, M., 1952, A New Radio Interferometer and its Application to the Observation of Weak Radio Stars	116
III. THE SOLAR SYSTEM	141
G. Early Solar Searches	145
13. WILSING, J. and SCHEINER, J., 1896, On an Attempt to Detect Electrodynanic Solar Radiation and on the Change in Contact Resistance when Illuminating Two Conductors by Electric Radiation	147
14. NORDMANN, C., 1902, A Search for Hertzian Waves Emanating from the Sun	158
15. DESLANDRES, H. and DÉCOMBE, L., 1902, On the Search for Hertzian Radiation Emanating from the Sun	161
H. Detection of the Sun	164
16. HEY, J. S., 1946, Solar Radiations in the 4–6 Metre Radio Wave-Length Band	166
17. SOUTHWORTH, G. C., 1945, Microwave Radiation from the Sun (with Erratum)	168
I. First Solar Interferometry	182
18. RYLE, M. and VONBERG, D. D., 1946, Solar Radiation on 175 Mc/s	184
19. MCCREADY, L. L., PAWSEY, J. L., and PAYNE-SCOTT, R., 1947, Solar Radiation at Radio Frequencies and its Relation to Sunspots	188
J. The Hot Solar Corona	208
20. MARTYN, D. F., 1946, Temperature Radiation from the Quiet Sun in the Radio Spectrum	210
21. PAWSEY, J. L., 1946, Observation of Million Degree Thermal Radiation from the Sun at a Wave-Length of 1.5 Metres	215
K. Lunar Radiation	217
22. DICKE, R. H. and BERINGER, R., 1946, Microwave Radiation from the Sun and Moon	218

TABLE OF CONTENTS

ix

IV. DISCRETE SOURCES	221
L. Discovery and First Optical Identifications	225
23. HEY, J. S., PARSONS, S. J., and PHILLIPS, J. W., 1946, Fluctuations in Cosmic Radiation at Radio-Frequencies	228
24. BOLTON, J. G. and STANLEY, G. J., 1948, Variable Source of Radio-Frequency Radiation in the Constellation of Cygnus	231
25. RYLE, M. and SMITH, F. G., 1948, A New Intense Source of Radio-Frequency Radiation in the Constellation of Cassiopeia	234
26. BOLTON, J. G., STANLEY, G. J., and SLEE, O. B., 1949, Positions of Three Discrete Sources of Galactic Radio-Frequency Radiation	239
M. Synchrotron Radiation	242
27. ALFVÉN, H. and HERLOFSON, N., 1950, Cosmic Radiation and Radio Stars	243
N. Optical Identification of Cas A and Cyg A	245
28. SMITH, F. G., 1951, An Accurate Determination of the Positions of Four Radio Stars	248
29. BAADE, W. and MINKOWSKI, R., 1954, Identification of the Radio Sources in Cassiopeia, Cygnus A, and Puppis A	251
O. Source Structure	273
30. HANBURY BROWN, R., JENNISON, R. C. and DAS GUPTA, M. K., 1952, Apparent Angular Sizes of Discrete Radio Sources	275
31. MILLS, B. Y., 1952, Apparent Angular Sizes of Discrete Radio Sources	282
32. SMITH, F. G., 1952, Apparent Angular Sizes of Discrete Radio Sources	287
33. JENNISON, R. C. and DAS GUPTA, M. K., 1953, Fine Structure of Extra-Terrestrial Radio Source Cygnus I	291
V. SPECTROSCOPY	297
P. Prediction of the 21-cm Line	299
34. VAN DE HULST, H. C., 1945, The Origin of Radio Waves from Space	302
Q. Prediction of Molecular Line Emission	317
35. SHKLOVSKY, I. S., 1949, Monochromatic Radio Emission from the Galaxy and the Possibility of its Observation	318

R. Discovery of the 21-cm Line	325
36. EWEN, H. I. and PURCELL, E. M., 1951, Radiation from Galactic Hydrogen at 1420 Mc/s	328
37. MULLER, C. A. and OORT, J. H., 1951, The Interstellar Hydrogen Line at 1420 Mc/s and an Estimate of Galactic Rotation (with a short note from J. L. Pawsey)	331
REFERENCES	337
NAME INDEX	345
SUBJECT INDEX	000

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The old dream of wireless communication through space has now been realized in an entirely different manner than many had expected. The cosmic shortwaves bring us neither the stockmarket nor jazz from distant worlds. With soft noises they rather tell the physicist of the endless love play between electrons and protons.

A. UNSÖLD (1946)

PREFACE

Radio techniques were the first to lead astronomy away from the quiescent and limited Universe revealed by traditional observations at optical wavelengths. In the earliest days of radio astronomy, a handful of radiophysicists and engineers made one startling discovery after another as they opened up the radio sky. With this collection of classic papers and the extensive introductory material, the reader can experience these exciting discoveries, as well as understand the developing techniques and follow the motivations which prompted the various lines of inquiry. For instance he or she will follow in detail the several attempts to detect radio waves from the sun at the turn of the century; the unravelling by Jansky of a “steady hiss type static”; the incredible story of Reber who built a 9 meter dish in his backyard in 1937 and then mapped the Milky Way; the vital discoveries by Hey and colleagues of radio bursts from the Sun and of a discrete source in the constellation of Cygnus; the development of receivers and interferometry in the post-war years by the groups led by Ryle in Cambridge and Pawsey in Sydney; the first measurements and exciting identifications of Taurus A (the Crab Nebula), Centaurus A, Virgo A, Cassiopeia A, and Cygnus A, the last opening the field of radio cosmology; the early development of synchrotron theory; and the prediction and discovery seven years later of the 21 cm line of neutral hydrogen.

My aim in this volume has simply been to make these classics more widely accessible and more appreciated in their scientific and historical context. Webster defines *classic* as “of the highest quality or rank; having recognized and permanent value; of enduring interest and appeal”. The papers included in this volume have indeed been primarily selected on precisely these criteria as applied to journal articles in the field of radio astronomy over the period 1896 to 1954. Practitioners as well as students of astronomy, physics, radio science and engineering, and history of science should find the collection of value. Even today’s radio astronomer, immersed in the latest issue of *Nature* or *Astrophysical Journal Letters*, often has little knowledge of how his own science has developed. While some may occasionally pay homage to these classics in their own modern publications, I suspect that very few have ever actually sat down and *read* the papers to which they refer. In fact, too often a

classic paper might be operationally defined as one whose contribution is generally judged to be so important, so historic and so seminal, that one somehow knows the contents without the bother of reading it for himself!

The collection is devoted solely to those papers whose main thrust is concerned with observations of natural radio emission from extraterrestrial sources. Papers dealing with radar astronomy have not been included; this in particular eliminates both lunar and meteor radar studies. With this exception, the choice of papers runs the entire gamut of observational and theoretical radio astronomical investigations up until the early 1950s. This cutoff date is rather arbitrary; in fact, an earlier version of this book (prepared in 1975) included 54 papers and extended until 1958, but as a result of the present-day economics of publishing, this version was never able to see the light of day. Note also that different research fields within radio astronomy are represented by papers from somewhat differing periods; this has been done in order to achieve a reasonable balance and to emphasize the pioneering papers. For example, the last included paper concerning solar observations was published in 1947, that for spectral line observations and theory in 1951, and that for radio sources in 1954.

The choice of papers was long and carefully considered. Papers which are primarily summaries of research (as often found in the proceedings of meetings) or reviews are not eligible for inclusion. The most important criterion was that the candidate paper should be historically and scientifically significant, i.e., that it represent a quantum leap forward in the development of radio astronomy. Ideally, papers should represent more than a simple report of a detection and should pay attention to astronomical interpretation of the radio observations. Finally, I have given weight not only to the paper as it stands alone, but also to how well it fits into the developmental sequence of its field.

Each section and paper is preceded by introductory remarks in which I have summarized the importance of the following papers to both history and science, explaining how they came about and where they fit into their contemporary science and into ours. Taken as a whole, this text effectively traces the highlights of the development of the field, but it should be understood that it by no means represents a complete history. In a similar vein the References, Name Index, and Subject Index have been created solely for the purpose of their use in connection with this volume; they are not intended to be complete in any sense.

I have felt it important, for the sake of accuracy and faithfulness to the originals, to reprint all papers in their entirety and not to re-draw figures; in

fact, most articles are presented as photographic reprints of the original journal pages, giving the reader a better historical sense. Six papers appear in full translation for the first time. The only modifications are new notes inserted where it is thought that they lend to the reader's understanding without substantially detracting from the flow of the original paper.

An additional criterion — unfortunate, but necessary — was the length of the candidate papers. The total collection was required to be of a reasonable length and yet in some sense remain complete. When the choice was between two papers of equal merit, the shorter has been included. The inclusion of each of the few longer articles was deemed compelling. An incomplete list of papers which would have been included if they had been shorter includes (see References): Reber (1942), Ryle and Vonberg (1948), Stanley and Slee (1950), Ryle, Smith and Elsmore (1950), Mills (1952a) and Shklovsky (1952a).

While I have attempted to apply my criteria as uniformly as possible, it is realized that choices cannot help but be somewhat subjective. My guess is that another person making a similar selection of 37 papers would probably agree on $\sim 70\%$ of the selection and would want a different "other 30%". It is nevertheless not obvious *which* 70% would be common to the two selections. It can thus be appreciated that absence of a person's name or of a particular article proves little except the necessary subjectivity and tight constraints inherent in the selection process for such a volume. It should also be emphasized that it is relatively easy for a young whippersnapper in the 1980s to sit back and correct mistakes, criticize, and, in general, kibitz from the vantage point of "20-20 hindsight". Where I have done this, it has always been my goal to shed light on the historical development as I see it; in no way do I intend to detract from the foresight, creativity, ingenuity, and plain hard work of the scientists and engineers involved.

This volume can be profitably studied along side of Lang and Gingerich's recent *Source Book* (1979) of reprints concerning twentieth-century astronomy of all kinds. In fact, ten of the selections here are also found in that volume, but usually in abridged form and with less extensive commentary. That volume is recommended to provide a broader context for the development of radio astronomy, as well as touching on some of the further highlights of the field, extending as far as the pulsar era in 1968.

An endeavor of this sort is never possible without help from many others. Pat Kimpton and Helga Byhre have been indispensable in the preparation of the manuscript at my home base. I have also received considerable assistance from the Kapteyn Institute in Groningen, the Institute of Astronomy at Cam-

bridge University, and the Radiophysics Division of CSIRO near Sydney. Barbara Sullivan has aided my research in many ways, both in substance and in spirit. Gerald Holton and Robert S. Cohen have been very helpful in bringing this volume into existence. Advice concerning the selection has been generously given by David O. Edge, James S. Hey, Frank J. Kerr, and Gert Westerhout. I have been aided with various aspects of the translations by Karl-Heinz Böhm, Tjeerd de Graaf, Thomas L. Hankins, Joke Huizinga, and Robert A. Schommer. Furthermore, detailed criticisms of the manuscript by Edge, Kerr and Schommer have improved its accuracy and style.

I also want to thank the many people around the world who have over the past decade discussed the development of radio astronomy with me. Most of the material which I have gathered from them will be incorporated into a future monograph on the worldwide history and development of radio and radar astronomy. Finally, I urge contact from anyone who wishes either to correct or to add to what I have written, or to inform concerning any aspect of the history of the field.

February 1981

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KEY

The book is divided into five Parts by topic; within each Part papers are, in general, chronologically arranged except in a few instances where it was thought more logical otherwise. Parts and sections are preceded by introductory remarks. Editor's notes and amendments within the original articles are indicated by a ★ in the text and a bold number in the outside margin; these notes are then gathered together immediately following each paper. Editorial remarks within the translated articles are enclosed in brackets [].

The papers in this volume and all articles referred to in the editor's remarks and notes are listed (by year) in the References section. The Name Index includes names mentioned in the editor's remarks, as well as the authors of the papers in this volume. On the other hand, the Subject Index is more extensive and refers to the actual contents of the original papers as well as to the editor's remarks.

INTRODUCTION

Shortly after Heinrich Hertz's laboratory experiments in 1887 conclusively demonstrated the existence of the radio waves predicted by James Clerk Maxwell's theory of electromagnetic radiation, unsuccessful attempts to detect radio waves emitted from the sun were made in England, Germany, and France. Yet notwithstanding the tremendous growth of radio technology, there seem to have been no further searches for extraterrestrial radio radiation during the period 1902–1932. The first discovery (in 1932) in fact was accidental; it was made by an American radio engineer named Karl Jansky who was studying the nature of the interference occurring on the recently inaugurated trans-Atlantic radio telephone service. Despite his recognition of the importance of his discovery and many attempts to interest radio engineers, astronomers, and physicists, Jansky's work was not appreciated. The radio engineers and astronomers simply did not know enough of each other's discipline to realize the potential of this discovery. In that situation it might well have fallen to the physicists to forge the link, but perhaps they were too preoccupied with the many fundamental discoveries being made in their own bailiwick at that time. 1932 has, in fact, been called the *annus mirabilis* of nuclear and particle physics: witness Harold Urey and deuterium, James Chadwick and the neutron, Carl Anderson and the positron, and John Cockcroft and E. T. S. Walton and the first disintegration of nuclei, all discoveries taking place in the same year as Jansky's recording of a "steady hiss type static of unknown origin".

In the ensuing decade, only one man, Grote Reber, recognized the importance of this extraterrestrial radiation and carried out extensive investigations as best he could with limited resources. Not until the accelerated research of World War II did Jansky's discovery become more than an idle curiosity. The intense wartime development of the techniques of radar and of radio communication led to a situation afterwards in which many physicists and engineers, highly trained in radio techniques and looking for suitable fields of research, finally began to open up the domain of extraterrestrial radio emission.

Radio technology opened up approximately ten new octaves of the electromagnetic spectrum to astronomical scrutiny. It soon became apparent

Fig. 1. Radio brightness contours at a wavelength of 1.9 m from Reber (1944; Paper 6) superimposed on the outlines of the Milky Way as given in Norton's Star Atlas (Northcott and Williamson, 1948).

Fig. 2. A representation of Reber's 1.9-m survey as given by him to an engineering audience (Reber, 1948b). The strength of radio emission as a function of longitude in the galactic plane is indicated as a "galactic power pattern". Galactic longitudes and constellations are also given.

that the information gathered from radio observations of both the usual astronomical objects as well as entire new classes of objects called "radio sources" was extremely useful. Yet despite the excitement abounding in radio astronomy, it was not until the late 1950s that the discipline was fully accepted by the astronomical establishment. A couple exceptions only prove the rule — for example, the fact that the first thorough review of radio astronomy was co-authored by an optical astronomer (Reber and Greenstein 1947). Otto Struve (1897–1963) was another astronomer who recognized the importance of these radio data, but even he laid his prejudices bare in a 1949 review when

he referred on the one hand to “astronomers” and on the other to “radio technicians”. A graphic example of the communication problem between the two camps in the late 1940s is given by two representations of Reber’s 1944 survey of the galactic plane at 160 MHz (Paper 6). In Figure 1, Northcott and Williamson (1948) appealed to the optical astronomers by sketching in the features of the optical Milky Way for comparison with Reber’s map, now plotted in galactic coordinates. Meanwhile, Reber (1948b) was transforming precisely the same survey data into an equivalent “antenna pattern of the galaxy” (Figure 2) for the edification of radio engineers!

The papers in this collection bear testimony that startling observational discoveries have not been infrequent in the history of radio astronomy. Another way to state this is that, with the notable exception of the field of spectroscopy, the radio observers have, in general, been several steps ahead of the theorists. This situation arose as the engineers and radiophysicists methodically improved their techniques and opened new vistas with ever increasing sensitivity and better angular resolution. Greater sensitivity was aided by low-noise receivers and larger collecting areas while improved resolution was achieved with the techniques of interferometry and the quest for shorter wavelengths. These trends apply equally to both the era covered by this volume as well as subsequent years. The available technology has always strongly influenced the direction of the observations, which in turn blaze the path for our understanding of the astronomy. An idea of the incredible progress in radio astronomy since the early 1950s can be gained by noting that the papers included in this collection almost all concern observations taken under the following constraints: wavelength ≥ 21 cm, detectable flux ≥ 20 Jy,¹ and resolution ≥ 1 arcmin.

NOTE

¹ Jy = Jansky $\equiv 10^{-26}$ W m⁻² Hz⁻¹ .