that the package is no longer available from the Düsseldorf address as mentioned in the last paragraph of page 84, and so this information appears to be out of date.

The subject of constructive (or computational) algebraic number theory is rapidly developing branch of number theory and this book provides a quick introduction to this subject. Beginning with the basic notions, the author quickly takes the reader to the most recent developments in the subject. It is a suitable text for students who are familiar with some basic algebraic number theory, it contains a large number of exercises and some very explicit examples. Researchers in the field will also find the book stimulating. In recent years, number theory has found a number of applications in coding theory, cryptology and other branches of computer science and this book will also be valuable to researchers from these fields too.

The author has explained the fundamental ideas of the subject with remarkable clarity. The treatment of the subject, though lucid, is lacking in proofs – however this should not be considered a disadvantage, for the author gives detailed references to the proofs of the results which are used in the book. One thing, which we feel, is lacking: algorithms are presented in the last three chapters of the book without any reference to complexity analysis. Here the author should have mentioned if the analysis was not available or pointed to literature where it is carried out In a book as quintessentially algorithmic as this, the importance of complexity analysis need not be stressed.

We recommend this book as a 'must' for all those interested in computational aspects of algebraic number theory, and also for students of algebraic number theory. In recent years, there has been a resurgence of computational-experimental techniques in Number Theory. One need only recall the examples of Birch–Swinnerton–Dyer, Zagier conjectures which were discovered computationally and which have played a significant role in the development of the subject. This book is a good introduction to the computational aspects of the subject, written by one of the well-known experts in the area.

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Boffin: A Personal Story of the Early Days of Radar, Radio Astronomy and Quantum Optics. R. Hanbury Brown, FRS. Adam Hilger, Techno House, Redcliffe Way, Bristol BS1 6NX, England. 1991. Price: unknown.

It is well recognized that World War II provided the technical training ground and much of the impetus for the expanded conception of astronomy which emerged in the immediate post-war period. Many of the radio astronomy pioneers, for instance, worked during the war on developing the air defence system which we now know as radar. Many went on to make major contributions to these growing new fields and subsequently became well known in astronomy circles. Some of the radar figures, in particular, have documented their experiences, and this small book joins the others in providing a detailed, personal account of the seriousness, excitement and romance of those years.

Indeed, just over half of Hanbury-Brown's *Boffin* is devoted to these formative 7 or 8 war years, and he writes of them with an almost monkish sense of vocation. Born in India of an Army family, perhaps he came to it naturally. For one whose '... greatest anxiety ... was to be self-supporting because my step-father had disappeared in a cloud of debt when I was sixteen ...', it took a considerable faith or trust to quit school well short of the PhD and take a secret, low-paid job with the Air Ministry on the sole strength of Sir Henry Tizard's advice. 'Looking back', he says, 'I am glad I did; sometimes the morrow does 'take thought for things of itself'.

Within a fortnight he found himself in the places and among the people most closely associated with the British pre-war effort to cadge together a workable 'RDF' system – that is, Radiolocation and Direction Finding – for immediate use in the anticipated air war with Germany. This was 1936 in the parlors and stables of Bawdsey Manor in Suffolk and at a disused World War airfield on the nearby 'island' of Orfordness. 'No one who worked at Bawdsey in those early days will even forget the place', he writes. 'It was magical. The Manor was a fairy castle on a distant shore and had the quality of a dream ...' 'On the "island" there was ... a WWI aerodrome, ... vast stretches of windswept shingle and some wooden huts on whose walls there were still notices signed by the Station Adjutant in 1918. It was a desolate, forbidding place whose only redeeming features were the birds.'

This early effort under Sir Robert Watson-Watt was aimed entirely at the development of what we would now call ground-based radar (in whose words the latter was 'a synthetic palindrome *invented by our friends the Americans*'). Technically, the group worked on increasing the range of detection and on refining the means for determining the direction and height of the aircraft. The wavelength was decreased first from 50 metres to 26 metres and ultimately to 13 – then a challengingly high frequency – and transmitter power to the 100 kW level in 20 microsecond pulses. Members of the crew became used to stringing wires at the top of high towers and to sparing no effort to keep the cranky equipment working during the visits of the many air defence VIPs – including Winston Churchill – who came to inspect the work. The personal effect of this experience on Hanbury-Brown is telling

Later, when we got the whole radar working, we spent most of our time measuring its performance on target aircraft. I never got tired of watching the radar echo from an aircraft as it appeared first as a tiny blip in the noise on the cathode-ray tube, and then grew slowly into a big deflection as the aircraft came nearer. The strange new power to 'see' things at great distances, through clouds or darkness, was a magical extension of our senses....

Hanbury-Brown remarks at length about how technically amateurish and bureaucracy-bound this whole effort was, 'more suited to bird-watching than to the development of advanced electronics.' 'We had ... no proper workshop and ... few tools [and] also had very little of the test gear which, even in those days, one might reasonably expect to find in a modest radio laboratory... As for books, the only one I can remember seeing is a copy of the *Radio Amateur's Handbook* which belonged to [a colleague] who was a devoted ham.' 'At first I could not understand why anyone ... could allow this to happen when the work was so obviously urgent; ... all we had to do was to take a truck in to Ipswich or London and buy all the things which we lacked.' Their boss, however, a 'civil servant of many years standing', insisted that everything be done through 'proper channels', which were 'incredibly slow'.

The book goes on to retrace Hanbury-Brown's involvement in a number of other phases of radar development. Joining the airborne (AI – 'Air Interception' and ASV – 'Air to Surface Vessel') group under Dr E. G. 'Taffey' Bowen at Martlesham Heath, he helped push the wavelength down to 1.5 meters and build units which were small, light, rugged, and power efficient enough to be used effectively in aircraft. Indeed, the problem of adequate transmitter power initially seemed so daunting that the first realization put the receiver in the airplane, but kept the transmitter on the ground! Writing enthusiastically of this period the author tells us how interesting it was for an aviation enthusiast because all of the new aircraft – such as a Spitfire or a Hurricane – were brought to Martlesham to be 'put through their paces'.

By the time war was declared in September 1939, Brown could take satisfaction in having seen AI and ASV developed, installed, demonstrated and in service on RAF aircraft at the squadron level. He and his colleagues had demonstrated its utility for contour navigation, for locating features such as coastlines and towns, and had also managed to use it to detect surfaced submarines, a matter of some importance once the war began. Experience had shown, however, that the technical development was only the beginning of the work required, it was necessary to sell it again and again to operational units and to prepare manuals and train personnel in all aspects of its operation and maintenance. For this aspect of the radar effort the author expresses considerably less enthusiasm.

Nonetheless, it was just in this operations-related context that Brown spent most of the war years, often working and even living closely with the military units using the new radar and trying to improve its performance and reliability. It was then not a great leap to extend these concerns to other types of units, first the Navy and then the Army, and anticipate what further refinements of the technology would be militarily effective (i.e., IFF – 'identify friend from foe').

It is interesting to see in these recollections the mind of a physicist turned to problems of military import. Certainly this is implicit in the entire radar problem, but it did not end there. Brown was always ready to ask questions about the accuracy of the information that the radars gave and what was the military significance of these errors. He early realized that AI was useless without the orienting backup of the more powerful radars on the ground, and that even with them a fighter must be controlled 'with surprising accuracy, not only in *position*, but also in *speed, height* and *course*'.

All these experiences left Hanbury-Brown with a 'profound distrust of plans based on military exercises which in my experience are apt to be unrealistic. Fifty years later I now distrust plans based on what is expected to happen in a "limited" nuclear war or estimates of how well some new system of defence against missiles like SDI will perform.'

Nonetheless, the author apparently found it difficult to make a clean break from radar work immediately after the end of the war, first taking a position at the TRE in Malvern on the advice of Sir Robert Watson-Watt, and then joining his consulting firm several years later. Then, when the latter decided to relocate his firm to Canada in 1949, Brown approached old colleagues, first at Cal Tech and then at Manchester, about the possibility of finishing his long sidetracked PhD. Almost by accident, as he describes it, events took him to Jodrell where another old radar colleague, Bernard Lovell, was applying radar techniques to astronomy.

Again seemingly within a fortnight, Hanbury-Brown had joined the Jodrell group and was fully occupied with the radio astronomy work that would occupy him for the next dozen years. Originally motivated by the possibility of detecting radar echoes from cosmic ray trails, Lovell had quickly found meteors more fruitful; but before abandoning the initial project, a gigantic fixed paraboloid antenna 'with a diameter of 218 feet had been built, which was just then being put to the study of the strange new cosmic radio noise. The author recalls his fascination upon reading Grote Reber's extraordinary 1940 article in the *Proceeding of the Institute of Radio Engineers*, wherein he reported studying this radiation with a 30-foot homebuilt antenna in his Chicago-suburb back yard.

Joined almost immediately by the then research student Cyril Hazard, the two set about improving the performance of the paraboloid as a radio telescope by operating it at the shortest possible wavelength (1.89 metres) and learning to steer its beam in declination by painstakingly reorienting the guy wires supporting the 126-foot central mast which carried the feed antenna. In due course they were able to map a 30° wide strip on the northern sky centered on 53° declination with a resolution of about 2°. Their 'map' showed that cosmic radio signals divided between bright discrete sources and continuum radiation associated with our own Milky Way galaxy. This strip included such bright, then known, radio sources as Cygnus A and Cassiopeia A, and pointedly raised the question of which others could be identified with known optical objects.

One highly significant clue to the mystery of these 'radio stars' was their intrinsic angular sizes, which given the poor resolving power of the telescope were then completely unknown. The author tells us that he was determined to pursue this measurement 'from the moment that I first saw the two strongest sources in the sky'. This led, of course, to consideration of building an interferometer and, given that the sources could have angular sizes down to seconds of arc, the problem of correlating the signals of two antennas separated by tens, hundreds, or even thousands of kilometres. 'The problem,' he said, 'worried me for weeks and I could think of nothing else, until late one night in 1949 I suddenly thought,'

If the radiation from a discrete source in the sky is picked up at two different places on Earth, is there anything else besides the phase and amplitude of the signals we can compare to find the mutual coherence?

And to my mind came quite clearly the image of a man looking at the 'noise-like' signal received from a radio source on a cathode-ray tube. 'Supposing', I thought, 'there was another man many miles away looking at another identical cathode-ray tube, would he see the same 'noise-like' *signal? If in fact there is a similarity between what the two men see, could it perhaps, be used as a measure of mutual coherence?*

This now famous insight, of course, led Hanbury-Brown to a good deal of both success and difficulty, and ultimately prompted his pioneering work in quantum optics. Mathematical calculations showed that indeed a correlation was expected in the *intensities* of the two 'noise-like' signals produced by a cosmic radio source, but it was not clear initially how persistent this correlation would be when the signals contained other, uncorrelated noise contributions from the receiver or sky background, – and therefore whether it was a suitable basis for a practical measurement technique. To answer this question, Brown approached his old friend Vivian Bowden 'who seemed to know everyone', and he in turn produced the eccentric Richard Twiss.. The latter, after several false starts, promptly produced a rigorous mathematical theory of the intensity interferometer, which showed '... as I had feared, that it would not be sensitive enough to measure most radio sources, nevertheless it should be able to measure the two strong sources in Cygnus and Cassiopeia.'

On the strength of this analysis the author and two of his students, Roger Jennison and Mrinal Das Gupta, built the first intensity interferometer and used it to determine the angular sizes of the two brightest sources, which, surprisingly, were resolved with baselines of only a few kilometres. The results were reported at the 1952 URSI meeting in Sydney, and on the strength of this work, a much more ambitious program was begun of measuring the angular sizes of all the sources within the beam of the 218-foot telescope. This work, led by the author's colleague, Henry Palmer, succeeded in identifying a handful of sources with exceedingly small angular diameters, several of which were identified with star-like objects; these, in turn, were subsequently found to have large red-shifts and became some of the first examples of the completely different kind of object we now know as quasars.

The centrepiece of the book – and indeed Hanbury-Brown's scientific work – is the application of the intensity interferometer to optical wavelengths and the measurement of the diameters of main-sequence stars. Interestingly, he tells us that the idea first arose quite by chance in noticing one day in 1954 that the correlation of the two signals from a wildly scintillating radio source remained quite steady. This then sharpened the question of whether an optical intensity interferometer would be unaffected by the atmospheric 'twinkling' of star light. Calculations showed disappointingly that even the brightest stars would require mirrors of very large size – comparable to or exceeding those of the largest telescopes. It then 'took six months for the penny to drop and for us to realize that although we would need very large telescopes they could be very crude by normal astronomical standards. Their function would be simply to collect light from the star like rain in a bucket and pour it on to a detector; there was no need to form a conventional image of the star.'

The author's proposal to build an optical intensity interferometer, however, raised the now famous controversy which forms one of the foundations of quantum optics. For while radio scientists and engineers expected almost intuitively that radio *waves* would *remain coherent over transverse* separations of up to about λ/Θ (where λ is the wavelength and Θ the angular size of the source), physicists generally interpreted the quantum theory as precluding interference between two different photons. The discussion in *Boffin* of the nature of this controversy and the passions it raised among physicists is certainly engaging and will undoubtedly be of interest to historians of science.

Indeed, I clearly recall this controversy from my own graduate school days ten years later and a continent away. Hanbury-Brown spent years responding to the stormy objections of his critics, both theoretically and in the laboratory, and even cadged together a 'pilot model' consisting of borrowed Army searchlights, detectors and a linear amplifier. These vitiated the published arguments decrying the author's views on the nature of photons, but did not really end the controversy, for it operated on a deeper level in the minds of his critics: their faulty, but firmly held, mental pictures of what photons are. Thus began one of the second-tier revolutions in physics this century. Neither had my professors entirely resolved their own dissonant images of photons with the quantum mechanical injunction against holding such pictures, but by this time they were prepared to acknowledge that there was a problem!

The remainder of the book traces the author's efforts to build and operate the now famous intensity interferometer which he and his colleagues ultimately sited at Narrabri, Australia, his decision to go to Australia and stay on there for more than 20 years, and his later work in designing and attempting to finance an instrument of greater technical sophistication and astronomical capability.

Overall, *Boffin* is an engagingly personal book which traces a life dedicated to the pursuit of science. At several important points Hanbury-Brown tells us of his distaste for the routine and joy in designing and building complex instruments. At length it would seem that the author did again find satisfaction and even vocation in his pioneering work on quantum optics. He is also both candid in acknowledging his limitations as a physicist and mathematician and generous in giving credit to his colleagues and collaborators who did this part of the work. Hanbury-Brown's career should give pause to the conservative elite in any field of science, for his lack of advanced training in physics directly facilitated the insights and innovations for which he is now well known in this field.

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