

JOURNAL OF ASTRONOMICAL HISTORY AND HERITAGE

The Lindsay Symposium Issue



Vol. 10 No. 3

November 2007

JOURNAL OF ASTRONOMICAL HISTORY AND HERITAGE

ISSN 1440-2807

EDITOR

Dr Wayne ORCHISTON (Australia)

ASSOCIATE EDITOR

Dr Hilmar DUERBECK (Germany)

EDITORIAL BOARD

Dr David ANDREWS (England)

Dr Alan BATTEN (Canada)

Dr Mary BRÜCK (Scotland)

Dr Allan CHAPMAN (England)

Dr Suzanne DÉBARBAT (France)

Dr Wolfgang DICK (Germany)

Dr Steven DICK (USA)

Professor Bambang HIDAYAT (Indonesia)

Professor Rajesh KOCHHAR (India)

Professor LIU Ciyuan (China)

Dr Tsuko NAKAMURA (Japan)

Professor NHA Il-Seong (Korea)

Professor F. Richard STEPHENSON (England)

Professor Richard STROM (The Netherlands)

Professor Brian WARNER (South Africa)

Associate-Professor Graeme WHITE (Australia)

The *Journal of Astronomical History and Heritage* (*JAH*²) was founded in 1998, and from 2007 is published three times yearly, in March, July and November. It features review papers, research papers, short communications, correspondence, IAU reports, and book reviews. From 2007, *JAH*² is available in paper form, or electronically, on a CD.

Papers on all aspects of astronomical history are considered, including studies that place the evolution of astronomy in political, economic and cultural contexts. Papers on astronomical heritage may deal with historic telescopes and observatories, conservation projects (including the conversion of historic observatories into museums of astronomy), and historical or industrial archaeological investigations of astronomical sites and buildings. All papers are refereed prior to publication. There are no page charges, and *in lieu* of reprints authors are sent a pdf or Word camera-ready version of their paper.

A 'Guide for Authors' is on the *JAH*² web site ('History Astro. Journal') at

www.jcu.edu.au/astronomy

and should be followed carefully when preparing manuscripts. Papers and book reviews should be e-mailed to the Editor, Dr Wayne Orchiston (Wayne.Orchiston@jcu.edu.au), or posted to him at

Centre for Astronomy,
James Cook University,
Townsville,
Queensland 4811,
Australia.

Enquiries concerning subscriptions, review copies of books, advertising space, back numbers or missing issues of the *Journal* also should be directed to Dr Orchiston.

The annual subscription rates for Volume 11 (2008) are:

AU\$200:00 for institutions

AU\$88:00 for individuals

© Centre for Astronomy at James Cook University. The views and opinions expressed in this *Journal* are not necessarily those of the Centre for Astronomy, the Editors or the Editorial Board.

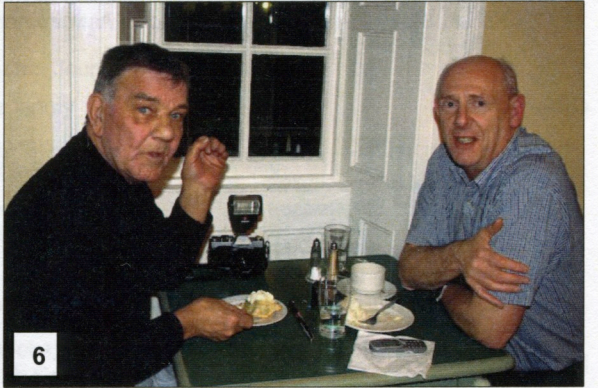
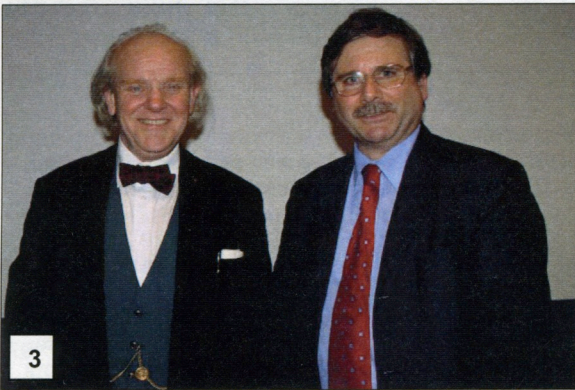
COVER PHOTOGRAPH

This photograph shows part of the main building at the Armagh Observatory, which, along with the Armagh Planetarium, lies in 14 acres of attractive landscaped grounds close to the centre of the city of Armagh in Northern Ireland. A modern astronomical research institute with a rich heritage, the Observatory was founded by Archbishop Richard Robinson in 1789. Current research themes are Solar System science, solar physics, and stellar and Galactic astrophysics. In addition, the Observatory maintains the longest meteorological series from a single site in Ireland, and one of the longest in the British Isles. On the lower right hand side of the cover is an image of Dr Eric Mervyn Lindsay, who is widely regarded as one of the most progressive of the Observatory's Directors. On 26 January 2007 the Observatory held a Symposium to celebrate the centennial of Lindsay's birth, and historical papers from that meeting feature in this issue of *JAH*².

CONTENTS

	Page
Papers From the Lindsay Symposium	
The Lindsay Centennial Symposium. Eric Mervyn Lindsay and Astronomy in Ireland <i>Mark E. Bailey</i>	163
Armagh, Dunsink and the Early Days of the Irish Astronomical Society <i>Mary (Máire) Brück</i>	167
The Armagh-Dunsink-Harvard Telescope: From Dream to Oblivion <i>C. John Butler</i>	173
Under Irish Skies <i>Patrick Corvan</i>	179
Family Memories of a Very Special Uncle <i>Robin Lindsay, Jack Lindsay, and Mary Lindsay</i>	187
Dr Eric Lindsay (1907–1974): A Personal View <i>John C. McConnell</i>	190
Dr Eric Lindsay: Personal Recollections <i>Derek McNally</i>	193
Dr Eric Lindsay: A, B, C, D ... to Z. A Personal Recollection <i>Terry Moseley</i>	194
Remembering Eric and Sylvia Lindsay During the War Years <i>Donald S. Nicholson</i>	197
Sir Robert Stawell Ball (1840-1913): Royal Astronomer in Ireland and Astronomy's Public Voice <i>Allan Chapman</i>	198
Other Papers	
Variations in the Earth's Clock Error ΔT Between AD 300 and 800 from Observations of Solar and Lunar Eclipses <i>F. Richard Stephenson</i>	211
Highlighting the History of French Radio Astronomy. 3: The Würzburg Antennas at Marcoussis, Meudon and Nançay <i>Wayne Orchiston, James Lequeux, Jean-Louis Steinberg and Jean Delannoy</i>	221
Book Reviews	
<i>A Descriptive Catalogue of Greco-Roman Comets from 500 B.C. to A.D. 400</i> , by John T. Ramsey <i>David Hughes</i>	246
<i>The Sun Kings. The Unexpected Tragedy of Richard Carrington and the Tale of How Modern Astronomy Began</i> , by Stuart Clark <i>Wayne Orchiston</i>	246
<i>The Telescope. Its History, Technology, and Future</i> , by Geoff Andersen <i>David Blank</i>	247
<i>Living Amongst the Stars at the Johannesburg Observatory</i> , by Dirk J. Vermeulen <i>Wayne Orchiston</i>	247
Index	248

A SELECTION OF PHOTOGRAPHS FROM THE LINDSAY CENTENNIAL SYMPOSIUM



1 (left to right): Professor Tom Ray (Dublin Institute for Advanced Studies), Mr Tom Hanney and Ms Mary Bunting (Joint Secretaries of the North/South Ministerial Council), Dr Mary Brück (University of Edinburgh), Professor Mark Bailey (Armagh Observatory) and Dr Niall Holohan (North/South Ministerial Council) at the opening of the Symposium.

2: Members of the Lindsay family at the Symposium.

3 (left to right): Dr Allan Chapman (Oxford University) and Professor Mark Bailey.

4 (left to right): James O'Connor and Dr Mary Brück.

5 (left to right): John McConnell, Dr Allan Chapman and Dr Mary Brück.

6 (left to right): Patrick Corvan and Terry Moseley.

7 (left to right): Drs Fred Byrne, John Butler and Ian Elliott, and Armagh Observatory staff members David Pérez-Suárez, Martin Murphy and Geoff Coxhead.



For further images, and for videos and other information about the Symposium, see the following web-site:

<http://star.arm.ac.uk/lindsay/>

**THE LINDSAY CENTENNIAL SYMPOSIUM.
ERIC MERVYN LINDSAY AND ASTRONOMY IN IRELAND.
Report and Selected Contributions from a Conference held
in Armagh on 26 January 2007 to Celebrate the
100th Anniversary of the Birth of E.M. Lindsay,
Seventh Director of Armagh Observatory**

Mark E. Bailey

*Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland, UK.
E-mail: meb@arm.ac.uk*

Abstract: The Lindsay Centennial Symposium celebrates the wider importance of astronomy in Ireland and its unique role in advancing our understanding of the world in which we all live. Astronomy is an international endeavour that transcends political boundaries and helps to draw people together. Virtually every country in the world—and Ireland is no exception—looks to astronomy as part of its national heritage and as an activity, in common with other nations, that goes back almost to the dawn of civilization. In Ireland, astronomy can be traced back more than five thousand years to the time of the construction of megalithic monuments, such as the famous passage-tomb at Newgrange. More recently, Ireland was home to the largest optical telescope in the world, the so-called ‘Leviathan of Parsonstown’. Lindsay played a major role in advancing Irish astronomy. He recognized, very early on, that astronomy is not merely a national activity, but an international one as well, and one that on the island of Ireland must include close collaboration between the two jurisdictions: Northern Ireland and the Republic of Ireland. Astronomy attracts people, young and old, into science and to a more scientific way of thinking; it addresses issues of major significance for culture and for our understanding of mankind’s place in the Universe; and provides young people with challenges in science and mathematics that are of the utmost technical difficulty and which bring important practical benefits to society. The occasion of the 100th anniversary of Lindsay’s birth is a time of great optimism for political and economic developments on the island of Ireland, and especially for the growth of astronomy on both sides of the Border and as part of Ireland’s involvement in wider European science.

Keywords: Irish astronomy, biography, Eric Mervyn Lindsay, Armagh Observatory, Dunsink Observatory, South African astronomy, amateur astronomy, astronomy and society, education and public outreach

1 MESSAGE FROM PATRICK MOORE

“I am particularly sorry that I cannot be with you today on this great occasion. Eric Lindsay was a close friend of mine, and I was very glad to work with him at the founding of the Planetarium. He was a great astronomer, and also a great friend. He carried out work of great importance, and he was also one of the best at bringing astronomy to the people.

I am proud to have known him. He is greatly missed by us all, but he and his work will not be forgotten.”

Patrick Moore
Selsey
23 January 2007

**2 INTRODUCTORY REMARKS BY MARK BAILEY:
“THE IMPORTANCE OF IRISH ASTRONOMY”**

It is a pleasure to welcome you to today’s celebration of the 100th anniversary of the birth of Dr Eric Mervyn Lindsay (see Figure 1), and to thank so many of you for being here today and for your enthusiastic support for this meeting.

As you know, Ireland has a long history of interest in astronomy—stretching back more than five thousand years to the famous megalithic monument of Newgrange and other early astronomical sites. More recently, Ireland and Northern Ireland have laid claim to a proud tradition of scientific and technological innovation. In astronomy this includes the largest telescope in the world for 72 years from 1845, the great 72-inch reflector or ‘Leviathan of Parsonstown’, in Birr, Co. Offaly, and the record of its two astro-

nomical observatories—Dunsink and Armagh—which date respectively from 1783 and 1789. The work of these ‘sister’ observatories in the intervening two hundred years illustrates the strength and vitality of Irish astronomy throughout this period, a project that has now been augmented by burgeoning university groups on both sides of the Border. The past two hundred years have seen a revolution in mankind’s understanding of the Solar System and the wider Universe, an activity in which Irish astronomy has played a very significant role.



Figure 1: Dr Lindsay, Patrick Moore and Cardinal Conway (left to right) in conversation in the grounds of the Armagh Observatory in February 1967.

Of course, Ireland—like Britain—does not have the best weather to pursue astronomy, and the growing light pollution associated with increasing urbanization means that many of us no longer enjoy the very dark skies that we remember as children. The modern astronomer has to visit remote high-altitude sites to get the best observing conditions, and increasingly—to avoid the vagaries of the opacity of the Earth's protective atmosphere—uses instruments on board satellites or spacecraft, rather than the ground.

Nowadays, we take these advances for granted, and sometimes forget the heritage on which they are based. Today's meeting provides us with an opportunity to look back at the foundations of modern Irish astronomy—how we got where we are today—and at the same time to look forward with anticipation to the results of more recent research.



Figure 2: E.M. Lindsay in his study at Armagh Observatory. "I divide mankind into two classes: those who are interested in astronomy, and those who are not. And this division cuts across all races, nations and social groups ..."

A second theme running through today's meeting is the importance of government support for 'pure' science. The fortunes of Ireland's two observatories during the twentieth century amply illustrate this so far as astronomy is concerned. Astronomy is not expensive in the big scheme of things, but it is probably not exaggerating to say that many university groups and national observatories, even now when astronomy is so successful, are struggling for funds. One reason for this is that, at first sight, most astronomical research produces few immediately applicable, 'useful' results!

Nevertheless, astronomy plays a unique cultural role. First, it is the same dark sky that is visible from here, or Hawaii, or wherever, that has been experienced by all cultures at all times, influencing all peoples and civilizations in their respective religious and philosophical thinking from the dawn of time. "It is indeed a feeble light that reaches us from the starry sky", said the Nobel physicist Jean Perrin, "but what

would human thought have achieved if we could not see the stars?"

Secondly it seems important to highlight the fact that astronomy does in fact bring occasional very important benefits: 'spin-offs', if you like. While it is difficult to quantify the economic rate of return from investment in a 'pure' science such as astronomy, there is no question that discoveries in the subject occasionally have the potential for massive social and economic impact. For example, the effects of the variable Sun and most other 'extraterrestrial' effects on climate are still so poorly known that they are routinely ignored in calculations of predicted global warming; yet, what caused the Ice Age? Similarly, we now know that comets and asteroids can run into the Earth with occasionally catastrophic consequences, influencing not just the economy—that would be the least of our worries—but the evolution of life itself.

Another example—and one about which Eric Lindsay (Figure 2) would have had a very clear view—is the interest and fascination that many people have in astronomy at some point in their lives, and the capacity of astronomy to inspire people, both young and old, steering them towards science and towards a more scientific way of thinking. Both Ireland and Northern Ireland face the same problem of decreasing numbers of students choosing to study the so-called 'hard' sciences, such as physics, mathematics and engineering. These are areas of key importance if we are to compete internationally in the twenty-first century global market. It is no accident that many former pure Physics university departments are now offering either Astronomy degrees or combined Physics and Astronomy degrees. Astronomy has mass appeal!

Finally, astronomy is an international venture. I have mentioned how access to dark skies is the one part of our natural environment that has been experienced, equally, by all cultures at all times. Similarly, international collaboration in astronomy, involving cross-border exchanges of personnel, ideas, funds and equipment, is—and always has been—the norm. There are many examples where astronomical projects, as in the Lindsay era with construction of the Armagh-Dunsink-Harvard Telescope in Bloemfontein, South Africa, have played an important role in providing tangible political benefits in terms of greater co-operation and mutual understanding.

On this note, and especially considering Lindsay's international astronomical interests and his equal devotion to Irish and Northern Irish astronomy, it seems entirely appropriate that the Lindsay Centennial Symposium should be formally opened by the Joint Secretaries of the North/South Ministerial Council, first Mary Bunting (Northern Secretary) and then Tom Hanney (Southern Secretary).

3 OPENING ADDRESS BY NORTHERN SECRETARY, MARY BUNTING

Good Morning everyone and thank you, Mark, for your very inspirational opening comments. Indeed, many of the themes that Mark has drawn on provide a very fitting beginning for the Symposium. Tom Hanney and I are delighted to be here this morning to open this very important event and it's absolutely wonderful to see so many people from different parts of Ireland and internationally.

When Mark was speaking he mentioned the role that astronomy can play in inspiring people, in bringing people together, and as a mechanism for mutual co-operation and benefit. I think that this is very true, and certainly the work that Dr Lindsay did in his time was an inspiration to everyone. It is a pity that people in Northern Ireland don't know more about the wonderful people who have done so much to put Northern Ireland on the map both in the UK and Europe, and indeed in the world. I think that his pioneering North/South work, which Mark mentioned in terms of the work between Armagh and Dunsink Observatories, and his work in South Africa, amply demonstrate how important it is that people don't allow borders to artificially cloud the good work that can be done when they work cooperatively.

We are very proud of Dr Lindsay in Northern Ireland. He is one of a number of leading scientific minds that this small place has produced, and we should celebrate the work that he did and the heritage that he has developed. Indeed, we are very pleased to be here in Armagh. When I came here last January I was struck by the fact that we have the two churches—it is the ecclesiastical capital of Ireland—and in many ways it is also the leading centre for astronomy in Ireland. I suppose you could say that it is a truly heavenly place! And we have grown to really enjoy our time here and recognise the potential in Armagh to develop this cooperative North/South work.

We are also very hopeful that over the coming days we will begin to see the light behind the shadow. This reflects another of Dr Lindsay's statements that struck me, "... that where there is a shadow, there must be light." In the Northern Ireland context we have had a lot of shadows, and so let us hope that we are now coming out from that period and into the light of a more fruitful, happy and peaceful place for all the people.

The work that you do in promoting science with young people is also very important, and I think that at this time in the history of Ireland we are beginning to recognise that if we are to develop our economy—both North and South—we really do need more young people pursuing careers in science and technology. And there is no better way than astronomy to bring people into science.

I was struck by what you said there, Mark, as a maths and physics student myself way back in the 1970s. There were very few of us around at that time and I know just how hard it can be for many young people. Astronomy does play a very important role in bringing people in; we need to bring more people in; and we need to build on the inspiring work of people like Dr Lindsay and yourselves if we are to compete effectively in the global economy—where other countries are churning out science and technology graduates by the thousands. So it is a very important contribution that you are making to that. It is interesting also to realise that there have been so many people I didn't know about until I was preparing for this event today, and that Patrick Moore had such a close association with Armagh: another very inspirational person and inspirational leader.

So, I wish you well with your symposium. It is going to be hard going. I have seen the programme

and you will be hard at it right through until later on tonight, but I am sure you will enjoy it; indeed, as would anyone who is interested in astronomy. So good luck with your work and have a really good day. Thank you very much Mark!

4 OPENING ADDRESS BY SOUTHERN SECRETARY, TOM HANNEY

Thank you very much for the invitation to address this Lindsay Centennial Symposium. It is an honour for Mary and me to have been asked to do this, especially when I think that before this invitation both Mary and I would have admitted to ignorance about the existence of Dr Lindsay. But now, having read so much about him, I think we both tend to see him as an inspiration for the work that we are undertaking here in Armagh. We are certainly inspired by his drive, by his determination and vision. And, as you have pointed out in the background literature, he was also somebody committed to North/South cooperation in astronomy at a time when North/South cooperation hardly existed on the island of Ireland.

The North/South Ministerial Council for those here who are not familiar with it, is an all-Ireland institution established under the Good Friday Agreement, and we are located here in Armagh, a close neighbour of the Observatory. Our objective at the North/South Ministerial Council is to foster mutually beneficial relations between Northern Ireland and Ireland on a wide range of issues. Even though the institutions of the Good Friday Agreement are currently suspended, it doesn't mean that Mary and I have nothing to do here in Armagh. In fact there is a wide range of ongoing cooperation to take care of. Currently, it is true to say that relations between North and South on a wide range of issues including energy, communications, trade, investment, the environment and so on have probably never been closer.

In many ways this cooperation is advancing without the direct involvement of Governments. For example, in the business sector North/South cooperation is at an all-time high, including trade and investment flows. However, much more can and will be done. At the North/South Ministerial Council we are looking forward to the future and we hope to see an Assembly and Executive in place in Belfast by the end of March.

Last year, the two Governments published a very important document. It was a comprehensive study of the all-island economy, and identified a very wide range of areas where we can cooperate together in the future. We are looking forward to restoration to try to take this document forward. Also, just last week the Irish Government published its National Development Plan which envisages the expenditure of 184 billion Euro in Ireland over the next seven years, and for the first time the National Development Plan includes a chapter on North/South cooperation. Under this the Irish Government has committed to spending substantial sums of money on projects within Northern Ireland that are mutually beneficial to both sides of the island, and again at the North/South Ministerial Council we look forward to taking this work forward.

Much of the success of our work in Armagh will depend on the success of the outcome of the current political process. While I know that astronomers would very much frown on the sister pseudo-science

of astrology, I think that we at the North/South Ministerial Council would be very interested to know if you astronomers charting the movements of the stars could tell us whether we will see Dr Paisley and Martin McGuinness in office in Belfast at the end of March. Perhaps conjunctions of Mars and Venus might facilitate the outcome!

On a more serious note, it is an honour to speak at this conference. When Dr Lindsay came to Armagh relations between North and South were in a very poor state. I was therefore very interested to read that the North/South agreement relating to the establishment of the Armagh-Dunsink-Harvard Telescope in South Africa was potentially the first North/South Agreement ever. It is a very important document. I think we should probably have a framed copy of it in the entrance to the North/South Ministerial Council here in Armagh.

Just as North and South have come closer together in order to cooperate in the face of the earthly challenge of globalisation, I think it is very important that we should come closer together as efforts are made to chart the heavens and unlock its secrets. Certainly at the North/South Ministerial Council we are very willing to work closely with Mark and his team here and to try and develop the current system of Lindsay Scholarships. For our part, we are taking this issue up with Dublin now and I think we would very much hope to see development of the Lindsay Scholarship scheme in the future, perhaps awarding more scholarships. This is something that we would like to take up with Mark and his team after the Lindsay Centennial Conference. So I wish you all the best in your work in the coming day and an enjoyable Symposium, and it has been a pleasure to be here. Thank you.

5 ACKNOWLEDGEMENTS

On behalf of everyone at Armagh Observatory, I want first of all to thank everyone who attended and contributed to today's events, making it a most remarkable and memorable meeting. I also want to thank Bebe Ishak and John McFarland, whose idea it was last October/November to organize a conference to celebrate the 100th anniversary of Lindsay's birth, and for helping to drive forward so effectively the

arrangements for the meeting. Virtually every Observatory Ph.D. student and a large number of members of staff have been involved in one way or another, whether in designing the original poster for the meeting or providing research talks and posters of their own, or in some other matter. Aileen McKee has ably managed all the local arrangements and not only produced the final copy of the programme but also provided an extremely helpful transcript of the oral contributions, some of which are included as part of these Proceedings. Thanks too are due to Martin Murphy and Geoff Coxhead, for ensuring the smooth operation of all the technical aspects of the meeting; and particularly to Máire Brück, Pat Corvan and John McConnell for permission to use historic images from their personal collections. Full details of the original programme for the meeting, including the Book of Abstracts of contributed talks, and images, slides and a video record of the meeting, are also available from the Armagh Observatory web-site, at: <http://star.arm.ac.uk/lindsay/>. Finally, I thank John Butler, Pat Corvan and John McFarland for their care in reading this manuscript, which has helped to remove any minor errors and inconsistencies.

Mark E. Bailey
Armagh Observatory
June 2007

Professor Mark E. Bailey is Director of the Armagh Observatory in Northern Ireland, and a Vice-President of the Royal Astronomical Society. He obtained his Ph.D. at the University of Edinburgh in 1978 with a thesis on the evolution of active galactic nuclei, but his current research focuses on issues closer to home: solar system astronomy, the origin and dynamical evolution of comets, asteroids and meteoroids, and solar system–Earth interrelationships, including aspects of the comet and asteroid impact hazard. In addition to nearly a hundred refereed scientific papers, he has co-edited several books and conference proceedings and is co-author of *The Origin of Comets* (Pergamon, 1990). In 1990, he was honoured by the IAU when minor planet (4050) was named 'Mebailey', and in 2007 he received an MBE.

ARMAGH, DUNSINK AND THE EARLY DAYS OF THE IRISH ASTRONOMICAL SOCIETY

Mary (Máire) Brück

'Craigower', Penicuik, Midlothian EH26 9LA, Scotland, UK.

E-mail: mtb@roe.ac.uk

Abstract: The revival of astronomy at the historic Irish observatories of Armagh and Dunsink in the 1940s is recalled, with particular reference to the energetic initiatives of Eric Lindsay, both scientific and cultural, including the Armagh-Dunsink-Harvard Telescope in South Africa, the first such international collaboration in the history of astronomy.

Keywords: Eric Mervyn Lindsay, Hermann Brück, Armagh Observatory, Dunsink Observatory, Irish astronomy, amateur astronomy

1 INTRODUCTION

I am greatly honoured to be invited to this celebration of the centenary of the birth of Eric Lindsay, and to reminisce a little on the early days of Armagh Observatory which he effectively re-founded in its present modern form. It is hard to believe that it is more than thirty years since his death, so vivid, so unforgettable is his image in my mind. I knew him since 1950 when I came to Dunsink, to my first post, and even better after I married Hermann Brück, his opposite number in Dunsink and his intimate friend (Figure 1). If Hermann were still with us, it would be he, not me, who would be here to recount their experiences as they set about revitalizing "Ireland's two once-great observatories." This year is also the fiftieth anniversary of the first Sputnik which went up in October 1957, the year that my husband and I moved from Dunsink to Edinburgh.



Figure 1: Hermann Brück and Eric Lindsay at Dunsink, 1948.



Figure 2: Dunsink Observatory in 1952.

2 ERIC LINDSAY AND IRISH ASTRONOMY

Both observatories, Armagh and Dunsink (see Figure 2), were by then fully functional, small observatories certainly, but with a good foothold on the international stage. All that transformation had come about within the previous ten years, and it is that decade, from 1947-1957, that I would like to recollect. Eric Lindsay raised Armagh from obscurity and Hermann Brück (Figure 3) did the same for Ireland's other observatory south of the border which was even more neglected, having stood idle for over a quarter of a century. The two observatories had a lot in common historically. Both were founded at the end of the eighteenth century, Dunsink around 1783 and Armagh in 1789. During much of the nineteenth century both made important contributions to astronomy, but declined rapidly in the twentieth century and ceased to have any impact. The original buildings survived, designed as observatories always were in those days as a residence for the astronomer in charge, with a telescope in its dome on the roof, so that the 'great man' could go observing at night direct from his dinner table. The buildings are still in use, though no longer family residences as they were in our time.

In the late 1930s, the young Eric Lindsay was appointed Director of Armagh Observatory. He was a product of the great Harvard school of astronomy in its golden age and Ireland's only professional astronomer; but the place he took over was woefully short of modern equipment, and in any case, he was unable to take up his duties on account of war work in London. As soon as the War was over, Eric set about realizing his dream of re-establishing his lovely historic observatory.

atory as a modern institution and of doing research along the lines he had done at Harvard and at Harvard's astronomical outstation in Bloemfontein in South Africa. The adventurous solution which he worked out with his friend and former Professor at Harvard, the charismatic Harlow Shapley, involved joining forces with Harvard to acquire a new ultra-modern telescope which would be set up in Bloemfontein in order to observe the southern skies.



Figure 3: Éamon de Valera and Hermann Brück, in 1962, on one of Hermann's visits to Dublin from Edinburgh.

The advantage of South Africa—apart of course from the weather—was that one could observe from that latitude the most densely-populated areas of the Milky Way; and also our Galaxy's satellite galaxies, the Magellanic Clouds, which were, and still are, of particular interest to astronomers and cosmologists. The type of telescope that he and Shapley had in mind was a Schmidt: this is effectively a wide-angle camera; invented only in the nineteen-thirties, it solved the problem of how to produce sharp images of stars over a wide area of sky. Astronomers at the great Palomar Observatory in California were producing wonderful photographs with their large Schmidt telescope and were mapping the sky as visible from California. There was no equivalent instrument to capture the southern skies. The Lindsay scheme went further: it proposed that the project should be an all-Ireland one.

It was a bold plan. The two parts of Ireland were, officially at least, barely on speaking terms in those days; but Eric Lindsay was a devoted Irishman in the best sense of the word, and an optimist. "The stars are the same when you cross the border. There are no boundaries in the sky ..." he pointed out to the Taoiseach, Éamon de Valera (Figure 4), to whom the idea vastly appealed on political as well as scientific grounds. And he succeeded.



Figure 4: Eric Lindsay and Éamon de Valera during the early 1960s.

The story was recounted by Otto Struve, President of the International Astronomical Union, at the General Assembly in Dublin in 1955, and is published in the Union's Transactions. In the spring of 1946 a group of senior American astronomers was *en route* to Europe in order to renew contacts with their European colleagues which had been broken by the War. The group, including Struve and Shapley, found themselves stranded by fog at Shannon Airport. There, at the airport, they recognized the unmistakable tall bespectacled figure of the Irish Prime Minister who was waiting to meet important dignitaries from Rome.

The name de Valera may not mean as much to the present generation as it did fifty or sixty years ago. Eamon de Valera was the dominant figure in Irish politics south of the border for decades. He also had a serious interest in mathematics and astronomy; he had studied in his youth with the illustrious mathematician Sir Edmund Whittaker, then Director of Dunsink Observatory and Professor at Trinity College Dublin, and when he reached high office, Whittaker was his close adviser on matters connected with the revival of Irish science. De Valera founded the Dublin Institute for Advanced Studies, which includes the School of Theoretical Physics, during the War years, and he had an ambition that went back even earlier to acquire Dunsink Observatory for the nation.

Shapley promptly introduced himself to Mr de Valera, and that chance meeting in the fog at Shannon set the ball rolling. Eric Lindsay did the rest. All he put on record, in his modest way, was that it was his task to bring about the cooperation of the two Irish Governments, and that the negotiations occupied some considerable time. An agreement to provide the money for the shared telescope was signed by Mr de Valera and the Northern Ireland Minister for Finance on behalf of their two Governments. It was a triumph for Eric Lindsay's power of diplomacy, and his irresistible charm. Two historic 'firsts' were made by that agreement: it produced the world's first international telescope, and it was, reputedly, the first occasion when the two Irish Governments did business together. There is surely a lesson here: perhaps our country needs more Eric Lindsays and fewer politicians.

The practicalities at the Irish end were entirely in Eric Lindsay's hands. The telescope, known as the Armagh-Dunsink-Harvard or ADH Telescope (Figure 5), was constructed in the United States. It was completed and formally accepted by Harlow Shapley on behalf of the three participants in March 1950 in the presence of the British, Irish and South African Consuls in New York. The ceremony made news worldwide, including of course the Irish papers. When it came to installing the telescope in Bloemfontein, the responsibility fell to Eric and his Harvard colleague Bart Bok (Figure 6). Bart was a native of The Netherlands, an enthusiastic supporter of both Armagh and Dunsink, and a delightful personal friend whom my husband knew well from earlier days in Germany.

Meantime, Dunsink Observatory had been re-established, and, again, Mr de Valera was the prime mover. In 1946, just about the time the ADH plan was being sealed, Mr de Valera acquired the observatory premises, which was at the time rented out as a private residence, for the Institute. The route by which he was

then led to Hermann Brück seems to have been the grapevine: at any rate the first move was made by de Valera personally, who simply telephoned Brück at the Observatory in Cambridge saying, “Mr de Valera speaking”, and invited him there and then to come to see him in Dublin. All negotiations were done man to man; that was de Valera’s way. The re-opening of Dunsink Observatory was announced in the press on 13 October 1947, and it generated immense public interest. The Observatory would be open to the public for viewing the stars; and a world-famous Irish-American telescope was to be built in South Africa. I possess a fat book of newspaper cuttings from that period to prove it.

The reaction was the same in Armagh and Belfast. In 1948, the International Astronomical Union, that ‘United Nations’ of astronomy, held its first post-war meeting in Zurich. The papers reported that “Ireland was represented by Professor Brück, Dr Butler and Mr O’Connor from Dunsink and Dr Lindsay from Armagh.” That same summer, when Eric Lindsay’s brother-in-law, the distinguished American astronomer Carl Seyfert, gave a public lecture in Armagh, the Belfast Telegraph reported the presence of astronomers from Armagh and Dunsink observatories, as well as “... many amateur astronomers from Northern Ireland and Eire.” It is clear that from the start, astronomy—both professional and amateur—was truly an all-Ireland activity that knew no border, just as Eric had envisaged.



Figure 5: The Armagh-Dunsink-Harvard Telescope, showing Hugh Butler and Eric Lindsay, 1951.

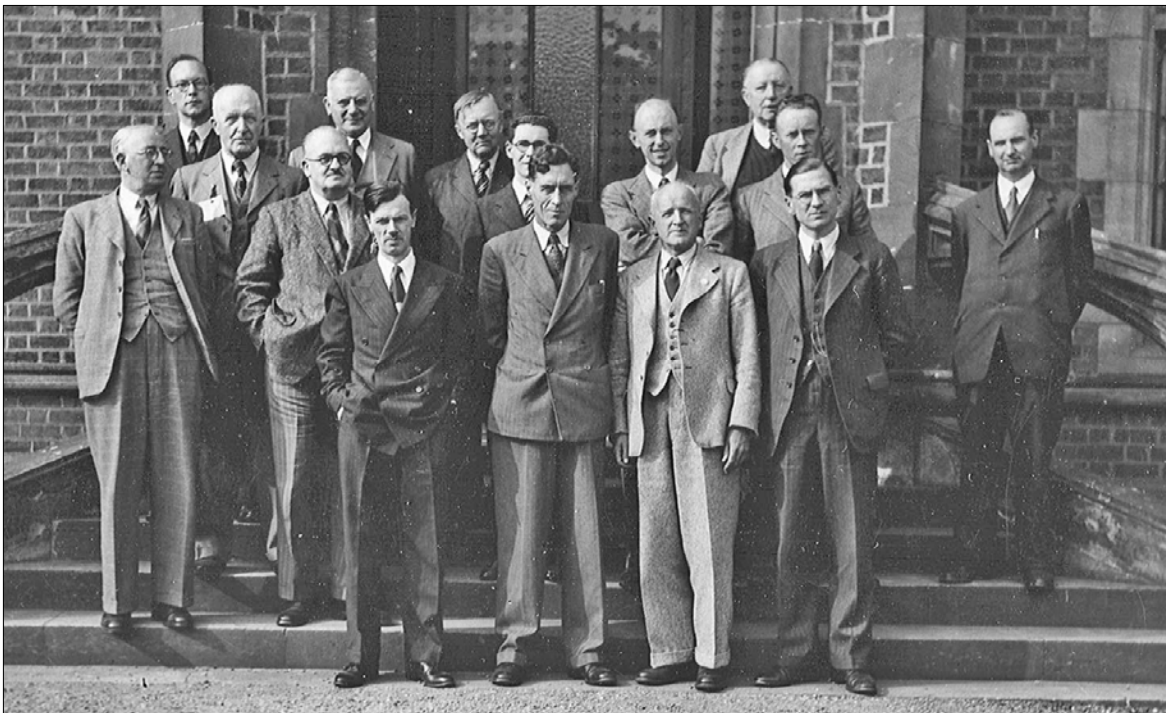
Dunsink’s tiny staff laboured on to get the old instruments working and new ones in place. When the ADH Telescope was ready, Harvard and Armagh had the first observational stints. Then it was Dunsink’s turn, and Hugh Butler, the Chief Assistant, spent several months in Bloemfontein in 1951-1952, with Eric, who had stayed on to introduce him to the instrument and to work with him.



Figure 6: Bart Bok together with the Dunsink Observatory staff, taken in Hermann Brück’s office during Bok’s visit in July 1953. The entire staff is included. Left to right: Gwen Butler, Peter Brück, Máire Brück, Bart Bok, G. McGreevy (vacation student from St. Patrick’s College, Maynooth), Gordon Thompson, Fred O’Connor, Patrick Murphy (Technician), and Hugh Butler.



Figure 8: Meetings of the Irish Astronomical Society around 1950: Society Dinner in Dublin on 7 May 1951 (above), and visit of the Society on 14 May 1949 to Queen's University Belfast (below). Many of the people in the upper image can be identified by comparison with the same image reproduced on page 26 in James O'Connor's book *The Irish Astronomical Society: A History, 1937-2006* (2006). Similarly, the lower image shows in the front row (left to right): Eric Lindsay, Patrick (later Lord) Blackett, Richard Hayward and Hermann Brück. Other members present include Muiris Maclonnraic (extreme left), Vincent Deasy (extreme right), John H. McElderry (third from left), Ernst Öpik (middle, back row), and Hugh Butler (behind Richard Hayward).



Hugh's photographs were, in the main, beautiful celestial vistas which were copied and displayed in our Visitors' exhibition (e.g. Figure 7). Dunsink's second stint, in 1955, was manned by Gordon Thompson, a young assistant, a native of Belfast. He observed several open star clusters in the Milky Way for the Dunsink programme, but the analysis of these photographs could not be completed at the time for want of certain auxiliary data. These were not available for some years; and the work was actually finished in Edinburgh; so, though I myself never used the ADH Telescope, I can say that I did have a small share in the results that came out of it. The ADH Telescope, as you will hear presently, figured dominantly in the Armagh and Dunsink research programmes for the rest of its existence.

The enthusiasm for astronomy in Ireland never flagged: every comet announced, every eclipse, every meteor shower, every sunspot or aurora borealis was of interest and was snatched upon by the media. A new 'buzzword' I hear today to describe the task of engaging the interest of the public in science is 'outreach'. We had no need of such exhortation in the 1950s. We had the Irish Astronomical Society, an enthusiastic amateur group that had existed for several years in Dublin, and whose story you will shortly hear about from James O'Connor, the society's historian.

The Society was an undoubted factor in the renaissance of Irish astronomy. Eric Lindsay was an ardent believer in the importance of amateur collaboration in astronomy, as you will hear, and on his urging, the Society extended its activities to include fellow star-lovers in the North. "The success of any society or indeed community," said Eric, "depends on those few whose idealism finds expression not in getting, but in giving." The Society had branches in Dublin and Belfast, and soon also in Armagh, Derry, and for a while in Clonmel. Eric Lindsay was designated President and H.A. Brück Vice-President. Brück gave lectures to the Society in Dublin, Armagh and Belfast in January 1948, and in April, the newspapers reported that "... close on 100 members of the Irish Astronomical Society from Dublin, Belfast and Armagh toured the Observatory at Dunsink." In June the Society met at Armagh; and so on, in different venues (Figure 8).

When the Royal Astronomical Society of London ventured with some trepidation to hold its first meeting on foreign soil in 1950 (Figure 9), it was the Irish Astronomical Society, not the academic establishment, that organized the Public Lecture by the Astronomer Royal, Sir Harold Spencer Jones. The Lecture was crowded out, like a pop concert. It was about this time, too, that Eric Lindsay suggested a planetarium for Armagh which he hoped would be another all-Ireland educational institution. In the event, this special ambition of his took a long time to materialize, and Eric personally raised the funds without support from the Irish Government.

The *Irish Astronomical Journal*, the Society's own magazine, was founded in 1950, with an editorial board consisting of Brück and Lindsay, representing the two Irish Observatories. It was a splendid example of active collaboration of professional and amateur astronomers, and, on another level, of the united character of science in a politically but not intellectually divided Ireland. The design of the cover by the young

gifted Belfast artist Raymond Piper showed the two observatories linked by the ADH Telescope, symbolizing this collaboration (Figures 10 and 11).



Figure 7. The Large Magellanic Cloud, photographed with the Armagh-Dunsink-Harvard Telescope.

The journal survived, despite many vicissitudes, until the year 2000. When we left Dunsink in 1957, we were both made Life Members of the Society. I am delighted to say that I am still a member, possibly one of the oldest by now, and that I have been receiving my regular newsletter without fail all these fifty years.

Our personal links with Armagh Observatory also endured. In the Dunsink era, my husband and Eric Lindsay were members of each other's Boards of Governors; they saw each other frequently, supported each other, and spoke often on the telephone. When we moved away, Eric invited Hermann to stay on as a Governor of Armagh Observatory, and this he did, not only throughout Eric's lifetime, but for many years afterwards, until the toll of age made travelling difficult, a total of 35 years.



Figure 9: RAS visit to Dunsink in 1950. Shown (left to right) are Máire Conway (now Brück), Professor Guthrie (Magee College), Dr Featherstone, Professor W.H. McCrea, Dr M.A. Ellison, Dr D. Menzel, unidentified, Col. K.E. Edgeworth.

When Eric died, the tributes of his staff and friends in astronomy at home and abroad were published in a special number of the *Irish Astronomical Journal* in 1975. The 20 plus contributors vied with each other to find words to express their memories of him: joyfulness, cheerfulness, humour, warmth, optimism, charm. I would like to read out all of what my husband wrote, but here is an extract that I think sums it up:

Eric's many astronomical plans and activities owed much of their success to his remarkable personality, to his great charm which everyone felt with whom he came in contact. His manner won him friends all over the world; it was simply impossible not to like Eric. He found it easy to establish happy personal contacts with people of all sorts, and personal relations were what mattered to him. He was fortunate, of course, in living at a time when relations between people could still play a major role in science, when the new bureaucracy had not yet taken over.

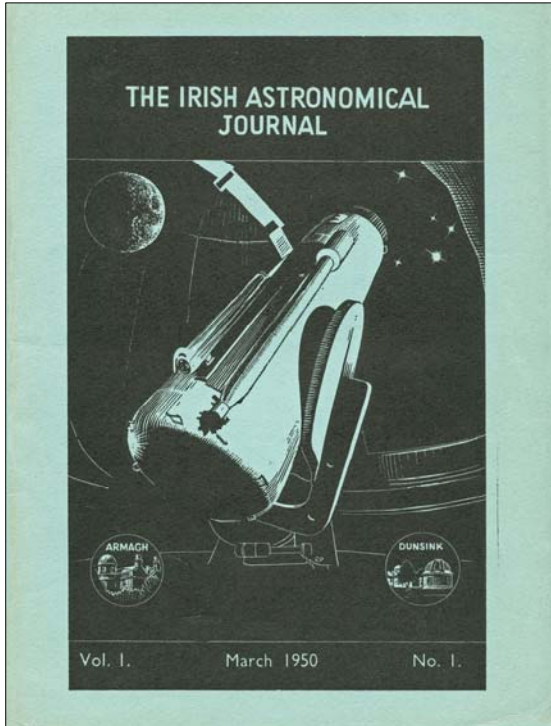


Figure 10: The cover of the *Irish Astronomical Journal*, designed by the Belfast artist Raymond Piper.

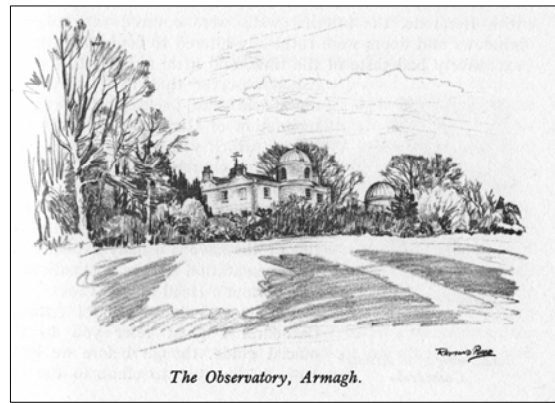


Figure 11: Piper's drawing of the Armagh Observatory, part of which was used on the cover of the *Irish Astronomical Journal*.

I would like to see that volume reprinted, as there is little any of us here can add to the picture of Eric Lindsay given there by his contemporaries who wrote with full hearts. What we can do, however, is to recognize his legacy, and the manner in which his spirit continues to pervade the Observatory which he virtually founded.

Mary (Máire) Brück, formerly Senior Lecturer in Astronomy at the University of Edinburgh, now retired, began her astronomical career at Dunsink Observatory, Dublin. She is a member of the Editorial Board of the *Journal of Astronomical History and Heritage*, and is an Honorary Fellow in the College of Science and Engineering, University of Edinburgh. She has a special interest in women astronomers of the past, and is the author of *Agnes Mary Clerke and the Rise of Astrophysics* (CUP, 2002).

THE ARMAGH-DUNSINK-HARVARD TELESCOPE: FROM DREAM TO OBLIVION

C. John Butler

Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland, UK.

E-mail: cjb@arm.ac.uk

Abstract: The Armagh-Dunsink-Harvard (ADH) Telescope was an instrument with a checkered history that, unlike many telescopes that have a productive life of many decades, has now all but faded from memory. Nevertheless, its story is worth telling, if for no other reason than the part it played in Irish and international astronomy in the crucial years following the Second World War.

Keywords: Baker-Schmidt telescopes, ADH Telescope, Boyden Observatory, Armagh Observatory, Dunsink Observatory, Harvard Observatory, Irish astronomy, Eric Mervyn Lindsay

1 INTRODUCTION

Astronomers in Ireland in the nineteenth century had facilities second to none and they made important contributions to the emerging disciplines of cosmology, solar physics and stellar photometry. However, as the land tenure system in Ireland was revolutionised around the turn of the century with tenant farmers now freeholders, the landed gentry, deprived of their rental income, could no longer afford to support private observatories. Even public observatories, such as Armagh, founded in 1789 by the Church of Ireland Archbishop, Richard Robinson, and Dunsink, founded in 1783 by Trinity College, Dublin, were to some extent funded by land entitlements and could no longer afford to employ staff or buy the new equipment so essential for their daily work (Bennett, 1990; Butler, 1990). By the beginning of the Second World War, Dunsink and all the richly furnished private observatories were closed and there was only one professional astronomer on the whole island, namely Dr Eric Lindsay at Armagh. One of his recognised achievements was his part in the setting up of a large Schmidt telescope, the ADH, in South Africa.

2 THE GENESIS OF THE ADH TELESCOPE

Lindsay had been at the Harvard southern station, Boyden, for three years in the mid-1930s, working as an Assistant to Dr J.S. Paraskevopoulos. In November 1937 he moved to Armagh to take over the Directorship of the Observatory there, an organisation which at that time was, for all intents and purposes, a one-man show. Whilst at Harvard and later at Boyden, Lindsay had become familiar with the revolutionary new Schmidt telescope design and was aware of its benefits for an observatory such as Harvard with its traditional involvement in stellar surveys. Shapley, the Director at Harvard, was conscious of the lack of large telescopes in the Southern Hemisphere, and initially he planned to convert the 60-inch Rockefeller Telescope at Boyden into a Super-Schmidt system. However, Bart Bok, then at Harvard, and Lindsay (Figure 1), by now living in Ireland, preferred a new Schmidt telescope. Together with Shapley, they dreamed up a plan to build a new telescope in which Armagh would share observing time and costs with Harvard (Bok, 1943). During the following years, both Lindsay and the Harvard astronomers became heavily involved in the war effort; Lindsay was attached to the British Admiralty, while Bok was engaged in teaching navigation. There was little time for astronomical research, and the

provision of new telescopes was an impossible goal. Finally, in April 1946, with the Second World War behind them, Shapley (1946a) wrote to Lindsay with some rough dimensions for the telescope optics and concluded: "All this is fun to work and dream on — spectra, spectrophotometry, variable stars, standard photometry, galactic structure, nebulosities — gosh!" At last the project could move forward, with the newly-reopened Dunsink Observatory an additional prospective partner.



Figure 1: Bart Bok (left) and Eric Lindsay (right) with Eamon de Valera (centre) Taoiseach (Prime Minister) of the Republic of Ireland 1937-1948, 1951-1954 and 1957-1959 (photograph circa 1961, courtesy of P. Corvan).

A chance encounter between Shapley and the Irish Prime Minister, Eamon de Valera, at Shannon Airport (Shapley, 1946b; 1953) played its part in advancing the case for the ADH Telescope. Shapley and some astronomical colleagues were marooned in Shannon by fog whilst *en route* to Copenhagen and De Valera was awaiting the arrival of a party of Bishops from Rome. De Valera, who had been a student of Edmund Whitaker at Dunsink in his youth, was keen to encourage original research in mathematics and allied sciences in Ireland and had already founded the Dublin Institute for Advanced Studies for this purpose. Shapley, recognising De Valera, introduced himself and proceeded to discuss some of Lindsay's ideas for the reopening of Dunsink and the joint telescope project with Harvard. De Valera was not in a position to give the go ahead on the ADH Telescope there and then and it took some time and effort for him to win the support of the other members of his cabinet but it is evident from Shapley's description of the event that he was able to convince De Valera that Harvard was fully behind the project. Shapley, now more confident that the new telescope had a good chance of success, took

advantage of an opportunity just six weeks later, to buy for less than \$2,000, a Pyrex blank for the 36-inch primary mirror (Shapley, 1946c).

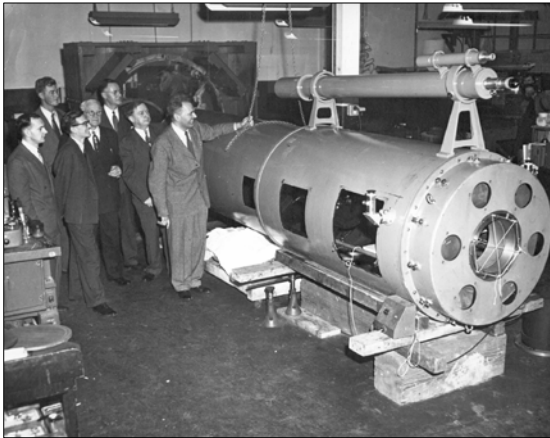


Figure 2: The tube of the ADH telescope at the Perkin-Elmer Corporation's works (February 1950). Standing by the telescope (left to right) are: Kevin Rush (Irish Consul in New York), Peter Lindhorse (South African Vice-Consul), John Dawson (British Vice-Consul), Charles Elmer and Richard Perkin (co-founders of Perkin-Elmer Corporation), Harlow Shapley (Director of Harvard Observatory) and Bart Bok (photograph courtesy of Armagh Observatory).

Meanwhile, in Ireland, Lindsay was pressing the authorities, north and south, to support the project as part of the revitalisation of Armagh and Dunsink Observatories (Bennett, 1990). Early in February 1947, Lindsay (1947) wrote that the legal advisors to the two governments had met for the first time ever to confirm arrangements. Throughout these negotiations, there were some reservations regarding Harvard's long-term commitment to the project, as Harvard would not accept permanency in its support for the ADH Telescope. In retrospect, this apparent lack of commitment should have rung alarm bells with Lindsay. However, it seems not to have done so, or at least if it did, he kept any reservations to himself. The signing of the ADH Agreement by the Archbishop of Armagh, representing the Board of Governors of Armagh Observatory, the Registrar of the Dublin Institute for Advanced Studies and the President of Harvard College in August 1947 represented a major achievement for Lindsay and in retrospect was a milestone in cross-border cooperation in Ireland. Dr D. MacGrianna, Registrar of the DIAS, wrote:

We are certain that the new telescope, as an instrument, and mounted as it will be in the southern hemisphere, will provide our newly re-opened Dunsink Observatory with material of the highest value for fundamental astronomical research. In the close collaboration which, we are happy to note, will exist between the three observatories in the running of the telescope, we may see perhaps the first instance on a small scale of the establishment of one of those international observatories which, apart from their immediate astronomical advantages, are to serve the cause of goodwill among nations, and in whose establishment your astronomers are taking such a prominent part. We are looking forward to the erection of the Armagh-Dunsink-Harvard Telescope which will add another happy link to the many which bind this country to the United States. (Cited by Shapley, 1948a).

The way was now clear for this new collaboration

between the scientists of Ireland and the USA, and De Valera likewise was impressed that the coming together of the two Irish governments had been for an intellectual project.

3 THE DESIGN, CONSTRUCTION AND ERECTION OF THE ADH TELESCOPE

Bok and Shapley, with James Baker, soon got to grips with the finer details of the design for the new telescope which was to be a two-mirror Cassegrain Schmidt with a 0.9m spherical primary, a 0.43m spherical secondary and a corrector plate of 0.8m aperture. The design produced a flat field with a plate scale of 68"/mm. In January 1948, a contract price was fixed with the Perkin Elmer Corporation (Shapley, 1948b), and by the summer of 1949 the telescope was nearing completion (see Figure 2). After tests at the optical works by Bok, it was packed for transport to South Africa. The cases arrived in Bloemfontein in October 1950 and within two months the telescope had been placed on the former mounting of the Bruce Telescope (Figure 3), which now had to support almost twice the weight it had previously. This problem was further exacerbated by the later addition of an objective prism and its associated counterweights. With a drive that was already rather worn in some places, the decision taken for financial reasons to place the ADH Telescope on an old mounting proved to be a mistake that would haunt the telescope for the rest of its active life. Another 'saving' that was to prove detrimental to the telescope's performance was the run-off roof observatory commonly used by Harvard. This required that the telescope be left in a horizontal position when not in use, with the optical elements supported on their edges and gradually deforming under their own weight. This was most likely the cause of the increase in astigmatism as the telescope aged. But, these problems were for the future.

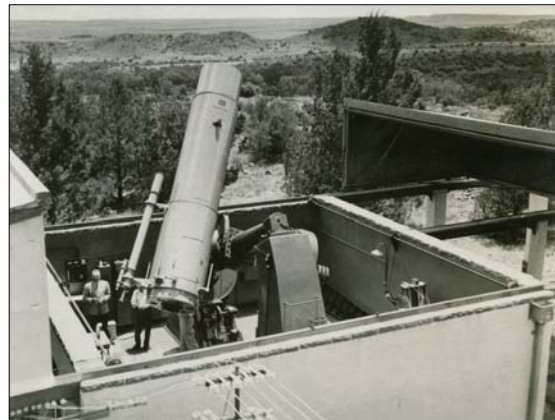


Figure 3: The ADH Telescope erected at Boyden Observatory. Bart Bok stands to the left with John S. Paraskevopoulos partially obscured by the telescope (photograph courtesy of Armagh Observatory).

4 EARLY OBSERVATIONS AND PROBLEMS WITH ALIGNMENT

Early exposures with the 10-inch diameter round plates taken by Bok had excellent quality stellar images and everyone was delighted. Lindsay (1953) published a paper demonstrating to all the exceptional capabilities of the ADH Telescope, which truly seemed to usher in a new era in Southern Hemisphere

astronomy (see Figure 4). One of the projects considered at this time was to supplement, with ADH plates of the southern sky, the Palomar Sky Survey, then underway in the Northern Hemisphere. However, with photographic plates at \$2 each and the proportion of exposed plates that were of good quality probably less than half, it was quickly realised that a budget way beyond that available to the ADH partners was required. The National Geographic Society which was already committed to the Palomar Schmidt, turned down a request for funding. In spite of this setback, observational programmes were initiated by all three partners; Armagh and Harvard cooperated on a survey of the Galactic Plane and a survey of southern galactic clusters was started by Dunsink. Bart Bok and Paul Hodge from Harvard, Eric Lindsay from Armagh and Hugh Butler and Gordon Thompson from Dunsink all travelled to Boyden in order to take up their allocations of telescope time.

It was during these early years of the instrument's working life that the initial indication of problems with the ADH Telescope surfaced. First, there was the rapid change in focus, due mainly to the large temperature drop that occurs shortly after nightfall at Boyden during the clear winter season. This can be easily 15–20° C over a couple of hours. Bok substantially alleviated this problem by fitting a knife-edge test device, however with the focus changing so rapidly even this could not ensure good focus over a long exposure of 30 to 60 minutes. The worm drive was responsible for other problems, including the occasional floating of the telescope near the meridian. Yet more difficulties arose with the stability of the optical alignment. With three optical elements and a plate holder to consider, it was not easy to develop a procedure that ensured all were correctly centred and adjusted relative to the optical axis. Though the alignment had been good when Bok and Paraskevopoulos first installed the telescope, later observers found it difficult to re-establish this level of perfection once an optical component had been adjusted. Both Hugh Butler and Eric Lindsay seem to have had such problems, and eventually rumours spread that all was not well with the ADH Telescope. Attempts to overcome these problems occupied the astronomers for the first two or three years after the installation of the telescope. However, they were soon to be overshadowed by a bombshell that arrived on Lindsay's desk in Armagh from the new Director of Harvard Observatory, Donald Menzel.

5 FUNDING THE BOYDEN OBSERVATORY

Menzel's letter (1953) stated that the closure of Boyden Observatory was imminent and Harvard was to withdraw from its operations in South Africa. Lindsay was devastated by the news, not only for Irish astronomy, but also because of the enormous personal efforts he had made. It was the ultimate betrayal and he blamed Menzel whom he believed had never been a friend of Boyden. In addition, he felt completely let down by his old *alma mater* Harvard. After his exhaustive efforts to convince the two Irish governments to support the ADH Telescope, now the principal partner, whose prestige was so important to them, was pulling out. There was some suspicion that the teething troubles with the Telescope and the detrimental rumours passing amongst American astronomers, were a part of the background to the decision. Lindsay's

suspicions were confirmed a month later when Bok reported that Sergei Gaposchkin had returned from Pasadena with the news that the astronomers there had told him that "... the ADH is no good." (Bok, 1953).

Lindsay wrote to Harvard, expressing his extreme disappointment and asking the Harvard authorities to reconsider their decision. He raised the possibility of UNESCO funding for Boyden, following a suggestion by Bill McCrea some years earlier of a United Nations Observatory. Bart Bok, as always in touch with events, replied that it was most unlikely that Harvard would reconsider, however they were prepared to give a breathing space (until June 1954) for efforts to find US or foreign institutions willing to take over. After initial proposals by Bok and Lindblad (then President of the ICSU and a former President of the IAU), and with no concrete proposals a year later, Harvard was frustrated by lack of progress and eventually gave 31 December 1954 as the absolute deadline for a pull-out.



Figure 4: The Eta Carinae Nebula, as it appears on ADH plate No. H20 (photograph courtesy of Armagh Observatory).

A meeting in Hamburg was hastily arranged between Harvard personnel and representatives of several European countries including Germany, France, Belgium, Sweden, The Netherlands, and Ireland. Lindsay was in South Africa at the time so Hermann Brück, Director of Dunsink, represented both Irish observatories. Brück knew many of the Continental astronomers involved from his early years in Germany, and he had taken an active part in bringing them together. It was agreed that Belgium, Germany and Sweden would take over the running and financing of the Boyden Observatory. Initially the two Irish observatories were not expected to provide financial support due to their ownership of the ADH Telescope, however, subsequently, they did become contributors. And despite the fact that it was relieved of financial obligations, Harvard continued its Boyden involvement until its interests were taken over a few years later by its sister institution in Cambridge (Mass.), the Smithsonian Astrophysical Observatory.

With the future of Boyden secured, a new complement of Continental astronomers now had access to the facilities of the Observatory. In particular, Swedish astronomers from Stockholm who were active in galactic structure research made observations with the ADH Telescope. Amongst the original stakeholders of the Telescope, however, changes were afoot. In 1957, Bok moved from Harvard to become Director at

Mount Stromlo Observatory in Australia and Brück moved to the Royal Observatory Edinburgh, and was soon followed by several other former Dunsink staff members, including Michael Smyth, Gordon Thompson (then in Cambridge) and Máire Brück. Hugh Butler had already moved to Edinburgh. The new Director at Dunsink, Mervyn Ellison, was a solar physicist and, although he never broke the connection with Boyden, did not use its facilities. In Armagh, Lindsay by now had health problems and he ceased to observe, although he did continue to use ADH spectral plates in order to work on Magellanic Cloud emission regions. With its recent history of problems, the ADH Telescope had an uncertain future. However, a revival of interest was shortly to take place.



Figure 5: David Andrews using the small centering telescope to check the alignment of the ADH Telescope in 1966 (photograph supplied by the author).

6 NEW PROCEDURES FOR THE ALIGNMENT OF THE TELESCOPE AND FOR PHOTOMETRY

David Andrews, who joined the staff at Armagh in 1963, quickly became immersed in observations with the telescope and was to play an important part in its continuing story (see Andrews, 1998). After the death of Paraskevopoulos in 1951, no permanent successor was appointed by Harvard to the Boyden Directorship. First Bok then Lindsay acted as temporary Superintendent of Boyden's activities on Harvard's behalf. This tradition of temporary appointments continued into the Boyden Council era. In 1964/1965, it was the turn of Jean Dommaget from the Observatoire Royal de Belgique. Dommaget was an enthusiastic observer and together with Andrews, took a fresh look at the alignment problems of the ADH Telescope.

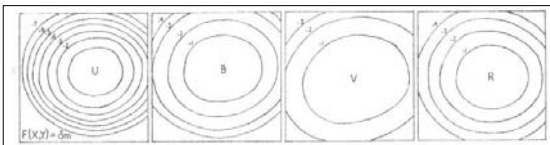


Figure 6: Averaged contour diagrams of the position dependent correction for vignetting and focus $f(X,Y)$ determined by Butler's method from ADH plates. Contours are at intervals of 0.1 magnitude and are different for each colour (after Andrews, 1971).

The original method devised by Perkin Elmer fixed the position of the secondary mirror with respect to the primary using a metal measuring rod and centered it by sighting its edge through the hole in the centre of the primary. When first carried out by Bok and Paraskevopoulos this procedure appeared to work well, but later attempts by others were less successful. The

Dommaget and Andrews procedure, on the other hand, used the flat side of the corrector plate as its fundamental reference surface. With a small centering telescope mounted on three adjustable feet, the secondary and primary mirrors were viewed through the lightly-figured corrector plate (see Figure 5). The alignment procedure proceeded step by step, first centering the secondary with respect to the corrector plate, next adjusting the tilt of the primary and the secondary, and finally the plateholder (Andrews and Dommaget, 1965). A further test developed later by the author used out-of-focus images to confirm when alignment was complete. With this procedure, the alignment of the telescope could be quickly checked and adjusted and the way was open for increased use of the ADH Telescope.

Another important development at this time was the arrival in Ireland from the Royal Observatory Greenwich of Patrick Wayman, who was appointed Director of Dunsink after the death of Ellison (Wayman, 1987). Wayman was an expert in the Schmidt-Cassegrain design and had made a thorough study of its potential whilst a research student in Cambridge. He pointed out that the large secondary mirror of the ADH Telescope, with a diameter half that of the primary, gave rise to substantial vignetting beyond the central 1° field. This was a significant deficiency of Baker's design and one that had been seriously underestimated by him in his initial calculations of the telescope's performance (Baker, 1947). Wayman visited Boyden in 1964 and decided to base Dunsink's main observational programme there. After discussions with Michael Feast at the Radcliffe Observatory, he proposed an observational programme on Cepheid variable stars in the Magellanic Clouds, using these as a stepping stone to the more distant Universe. In late 1964, the author moved from Edinburgh to Dunsink to join Wayman in this project.

Conscious of the need to measure faint stars in the Magellanic Clouds that could not be seen in the eyepiece of the 60-inch telescope, Wayman designed an offset photometer head that could be used either to measure faint Cepheids directly or to provide photoelectric sequences to calibrate ADH plates. An initial survey by the author suggested that the best approach would be to establish a number of sequences containing stars in the range 12–18 magnitude near to the centre of the ADH fields and to make zero-point corrections with respect to this central area to correct for vignetting. In 1965/1966 an extensive programme of observations to obtain the U, B, V and R photoelectric magnitudes of standard stars in three areas (one in the SMC and two in the LMC) using the offset photometer on the 60-inch telescope was undertaken. During the same season about 100 ADH plates of reasonable quality, in four colours, were obtained of each region.

A comprehensive reduction routine (Butler, 1972) for the calibration of ADH plates was developed and implemented on the IBM 1620 computer at Dunsink Observatory during 1967/1968. This was basically a multiple regression routine to establish the coefficients in an equation relating the standard magnitudes determined photoelectrically to the diameters of the stellar images (Θ) measured by an iris diaphragm photometer. The basic equation (Equation 1, below) had three

parts, a polynomial in θ (Equation 2), a position-dependent part (Equation 3) which corrected for vignetting and focus variation across the plate (see Figure 6) and two further terms which were linearly dependent on the colour (B-V) of the star and the background photographic fog level:

$$V = f(\theta) + f(X,Y) + f(\text{col}) + f(\text{den}) \quad (1)$$

where

$$f(\theta) = a + b\theta + c\theta^2 + d\theta^3 + \dots + n\theta^n \quad (2)$$

and

$$f(X,Y) = eX^2 + gY^2 + hXY + iX + jY \quad (3)$$

The procedure gave photographic magnitudes over the whole 2.8 degree field accurate to ~ 0.04 magnitude over the range $V = 12-16$ and ~ 0.1 magnitude for fainter stars, which was quite adequate to define the periods and light curves of the Magellanic Cloud Classical Cepheids. A programme which used basically the same techniques for a study of flare stars in the neighbourhood of the Orion Nebula was successfully completed by Andrews. These two observing programmes were undertaken with the ADH Telescope in 1965-1967, and involved in excess of 600 photographic plates. The success of the new alignment and plate reduction methods proved that, with care and perseverance, the ADH Telescope was now capable of fulfilling its original promise of making a significant contribution to Southern Hemisphere astronomy.

7 A NEW LIFE FOR THE ADH TELESCOPE?

Another development at this time, which encouraged astronomers at Dunsink and Armagh Observatories to believe that the ADH Telescope could have a bright future, was the realisation that unlike classical Schmidt telescopes, this telescope was well suited for new developments in electronic detectors that were destined to supersede photography. With its flat and easily accessible focus, the ADH Telescope could be used without major modification for a variety of applications involving the modern generation of detectors, including image tubes and CCDs. In a first attempt to use the ADH Telescope in this way, Dunsink's Brendan Byrne installed a pair of large photomultiplier tubes at the focus in 1971 (see Figure 7). These tubes, and their associated electronics, monitored the light from two $\sim 1^\circ$ diameter areas of the sky, one to be centred on the Galactic Centre and the other on a nearby comparison region. The object of the programme was to capture any short optical bursts which might be produced by the gravitational collapse of stars as they fell into the supposed black hole at the centre of our Galaxy. In fact, during the ~ 200 hours of observation, no optical bursts that could be unambiguously identified as from a gravitational event were detected (Byrne, 1974). Though this programme did not exploit the imaging capability of the ADH Telescope, it represented a pioneering use of the telescope. A later proposal by Hawkins and Butler to place a McMullan Spectrocon Image Tube at the focus of the telescope did not materialise, although this detector was used on the 60-inch reflector at Boyden Observatory.

With brighter prospects for the ADH Telescope, Wayman was asked by the Boyden Council to prepare a report on its condition and make suggestions for its improvement. In this report, dated December 1973, he outlined the many problems associated with the

telescope and how each could be overcome (Wayman, 1973). In general, it was an optimistic report in that the benefits from further investment in the telescope would probably outweigh the difficulties and expense. A renovation along the lines he suggested would require: (1) a new mounting and drive, (2) a proper dome or turret in which the telescope could be stored vertically when not in use, (3) a redesigned tube with focus correction, and (4) a new cell for the primary mirror with dynamic edge support. Other suggestions of a more minor nature would complete the exercise. In fact the Boyden Council was not able to commit funds at that time, and none of these modifications was carried out. Nonetheless, a modification of the existing run-off roof to allow the ADH Telescope to stand vertically with the roof closed was implemented with the result that the primary mirror now rested horizontally when not in use. This appeared to significantly reduce the astigmatism of the primary mirror.

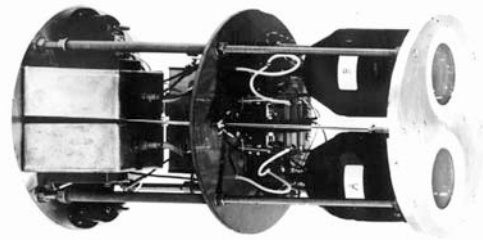


Figure 7: The twin photomultiplier assembly used by Brendan Byrne with the ADH Telescope to search for optical bursts associated with gravitational events in 1971 (courtesy of Mrs G. Byrne).

8 BOYDEN OBSERVATORY AFTER 1970 AND THE REMOVAL OF THE ADH TELESCOPE

Once again, however, any long-term plans for major improvement were thwarted by more intractable administrative and political considerations. By the mid-1970s, after the Smithsonian had finally relinquished all remaining US interests, it was evident that the Continental European partners in Boyden had decided to withdraw from operations in South Africa in order to join the new European Southern Observatory in Chile. In 1976 they formally left the Boyden Council, with only the two Irish observatories and the University of the Orange Free State (UOFS) remaining. With mounting political pressure at home for a suspension of co-operation with South African institutions and difficulty in maintaining a viable facility at Boyden, in 1978 the two Irish observatories finally left the UOFS the sole occupier of the Boyden Observatory. During the previous decade, whilst Boyden was in decline, astronomical facilities which were jointly operated by international consortia had become the norm. While the UK and Australia set up the Anglo-Australian Observatory and the UK and Spain the Roque de los Muchachos Observatory in La Palma, ESO was steadily accumulating more participating observatories within Europe. Staff at these observatories were provided with new telescopes and the latest ancillary equipment at a cost well beyond the resources available to Boyden.

With the eclipse of the Boyden Observatory it was decided by the Irish observatories to remove the ADH Telescope and offer it to any other observatory which would accommodate it, in return for a small amount of

Irish observing time on the re-erected instrument. Initially Mexico intended to install the telescope at its new observatory in Baja California, then Brazil, Uruguay, and finally Yugoslavia, showed interest. However, once they became familiar with the history of the telescope and the costs of renovation, all subsequently lost interest. In 1981 the telescope's optics were removed and shipped to Ireland to await a decision on their new home, but sadly this decision never came and the optical elements have remained in storage at Dunsink ever since.

There is one final addendum to our story. In August 2004, after observing at the South African Astronomical Observatory in Sutherland, the author visited Boyden, which is now thriving once more as a research and educational centre. Sadly, nobody there remembered the ADH Telescope, only an apocryphal story about the remains of the dismantled telescope falling from the back of a lorry and rolling into the scrub on the side of Harvard Kopje during its journey to the scrap-yard! The telescope—for which there had been such great expectations—had met an ignominious end. It was reminiscent of a failed attempt by another Armagh Director, Thomas Romney Robinson, a century earlier, to revolutionise Southern Hemisphere astronomy with the Great Melbourne Telescope (which was built by Thomas Grubb of Dublin in 1869). After a similarly troubled life, with its full potential never realised, this pioneering instrument finally came to grief in January 2003 when a major bush fire swept through Mount Stromlo Observatory, near Canberra (see Frame and Faulkner, 2003).

9 THE LEGACY OF THE ADH TELESCOPE

Although the working life of the ADH Telescope is now over, its memory remains. It made significant contributions to Southern Hemisphere astronomy, in particular to studies of the Magellanic Clouds, galactic structure and southern clusters. The addition of an objective prism early in its career provided an unparalleled facility for southern spectral survey work which was not replicated elsewhere until prisms were mounted on the UK and ESO Schmidts a decade or more later. Astronomers from many institutions—not just those from countries which supported the Boyden Observatory—used material gathered by the ADH Telescope and, through this use, it became a truly international telescope. However, from an Irish perspective, probably its most enduring legacy will be its role as a focus for the revival of Irish astronomy in the mid-twentieth century and the impetus this gave to international co-operation in astronomy through the foundation of the Boyden Council. Neither can we forget the small part it played in overcoming the mutual suspicions of two Irish governments at a time when they barely acknowledged each other's existence.

10 ACKNOWLEDGMENTS

We wish to acknowledge the following for permission to reproduce images: Mrs G. Byrne, Dr M. Brück, Dr A.D. Andrews and Mr P. Corvan. We thank Dr M. Brück for comments on a previous draft. Research at Armagh Observatory is funded by the Department of Culture, Arts and Leisure for Northern Ireland.

11 REFERENCES

The following abbreviation is used:

LC = Lindsay Correspondence 1934-1959, Armagh Observatory Archives.

Andrews, A.D., 1971. A Photometric Study of Orion Flare Stars. Unpublished Ph.D. Thesis, Dublin University.

Andrews, A.D., 1998. The Boyden Observatory. *Irish Astronomical Journal*, 25, 129-166.

Andrews, A.D., and Dommanget, J., 1965. Alignment of the ADH Baker-Schmidt Telescope. *Irish Astronomical Journal*, 7, 73-79.

Baker, J.G., 1947. Letter to H. Shapley dated 18 June. In LC. Bennett, J.A., 1990. *Church, State and Astronomy in Ireland*. Armagh, Armagh Observatory.

Bok, B.J., 1943. Letter to E.M. Lindsay dated 21 July. In LC. Bok, B.J., 1953. Letter to E.M. Lindsay dated 11 March. In LC.

Butler, C.J., 1972. Reduction of iris diaphragm measurements to magnitude. *Irish Astronomical Journal*, 10, 251-262.

Butler, C.J., 1990. Seeing Stars, Catalogue of an Exhibition to Commemorate the Bicentenary of Armagh Observatory. Armagh Observatory. (Internet accessible version: <http://star.arm.ac.uk/history/history.html>)

Byrne, P.B., 1974. A Search for Optical Evidence of Condensed Matter. Unpublished Ph.D. Thesis, Dublin University.

Frame, T., and Faulkner, D., 2003. *Stromlo. An Australian Observatory*. Sydney, Allen and Unwin.

Lindsay, E.M., 1953. The ADH (Armagh-Dunsink-Harvard) Telescope. *Irish Astronomical Journal*, 2, 140-146.

Lindsay, E.M., 1947. Letter to B.J. Bok dated 5 February. In LC.

Menzel, D., 1953. Letter to E.M. Lindsay, dated 2 February. In LC.

Shapley, H., 1946a. Letter to E.M. Lindsay, dated 1 April. In LC.

Shapley, H., 1946b. Letter to E.M. Lindsay, dated 6 April. In LC.

Shapley, H., 1946c. Letter to E.M. Lindsay, dated 12 May. In LC.

Shapley, H., 1948a. Letter to E.M. Lindsay, dated 27 January. In LC.

Shapley, H., 1948b. Letter to E.M. Lindsay, dated 11 January. In LC.

Shapley, H., 1953. Letter to E.M. Lindsay, dated 23 April. In LC.

Wayman, P.A., 1973. Comments on the Armagh-Dunsink-Harvard Telescope and a proposed limited renovation. Presented to the Boyden Council on 10 December. Armagh Observatory Archives.

Wayman, P.A., 1987. *Dunsink Observatory, 1785-1985*. Dublin, Dublin Institute for Advanced Studies.

Dr C. John Butler is Emeritus Research Fellow at Armagh Observatory. From 1964 to 1973 he was first a Scholar and later a Post-Doctoral Fellow at the Dublin Institute for Advanced Studies. For his Ph.D. thesis on Cepheid Variables in the Magellanic Clouds he made photoelectric and photographic observations at the Boyden Observatory. In late 1973, he moved to Armagh where his astronomical work was principally concerned with coordinated multi-wavelength observations of late-type active stars from satellites and ground-based telescopes. Here, the long meteorological series maintained since 1796 and their possible value for climate change studies attracted his attention, and in the last decade or two he has undertaken a programme for their standardization and analysis. He has also worked with Eric Palle on the influence of solar activity on climate change through a possible link between cosmic rays and cloud cover. In 2005, he was honoured by the IAU when minor planet 26891 was named 'Johnbutler', and in 2006 he received an MBE.

UNDER IRISH SKIES

Patrick Corvan

Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland, UK.

Abstract: This short memoir, written to commemorate the centenary of the birth of Eric Mervyn Lindsay, highlights the association and friendship of the author with Dr Lindsay for more than twenty-one years, and records the enormous debt owed to him for revealing to a very young teenager the beauty and mystery of the Universe.

Keywords: Eric Mervyn Lindsay, Armagh Observatory, Irish astronomy, amateur astronomy

1 INTRODUCTION

This short memoir is written to highlight the association and friendship that I enjoyed with Eric Lindsay for over twenty-one years, and to commemorate the centenary of his birth. Also, I want to record the enormous debt I owe him for revealing to a very young teenager the beauty and mystery of the Universe.

In the early spring of 1953, two school friends—Jackie Geraghty and the late Bobby Hamilton—and I had made an appointment to attend one of the Open Nights that were regular events in the public calendar of the Armagh Observatory. These evenings, held between the months of October to April, had been instigated by Eric Lindsay in the early years of his Directorship, and over the years had proved extremely popular, despite the generally unfavourable weather conditions prevailing in this country. On this particular day, 21 April, we anxiously watched the sky throughout the day and hoped that it would remain clear. When the time approached to make our way to the Observatory, conditions could not have been better. As we walked up the long driveway and glanced up at the sky with a beautiful first-quarter Moon hanging in a deep blue sky, I knew that it was going to be a successful evening. Little did we realize just how successful it was to be; it was but the beginning of a great adventure, “An adventure of the spirit”, as Dr Öpik succinctly described it.

In those days, the public entrance to the Observatory was on the South side of the main building. As we approached, we noticed two men engaged in conversation, standing at the doorway of the former transit rooms. I have to confess that for my part I was somewhat nervous at the time, as Dr Lindsay introduced himself and his companion, a Senator from New York. He then outlined the programme for the evening.

We made our way inside to one of the rooms, which had originally housed the Jones transit instrument, but which had been converted into a display area and small museum. This room contained a long table, on top of which were placed a row of light-boxes, and around the walls a selection of large, black-and-white transparencies, which when lit from behind created an extraordinary three-dimensional effect.

After we signed the Visitors Book, Dr Lindsay switched on the power to the light-boxes, to reveal a number of photographic plates of different shapes and sizes, though mainly circular. For the next hour or so, Lindsay explained in great detail the various features visible on each plate, which we examined by means of a small eye-piece.

I found out sometime later that this very eye-piece had been used by the famous Harvard astronomer

Annie Jump Cannon when compiling the Henry Draper Catalogue. All these photographic plates had been taken with the various telescopes at Harvard’s Boyden Station near Bloemfontein, South Africa. This well-known out-station of the Harvard College Observatory had been transferred from Peru to South Africa in 1927, at the time of Harlow Shapley’s Directorship. Shapley was to play a major role in Lindsay’s future career.



Figure 1: Patrick Corvan (centre) and his friends Jackie Geraghty and Seamus McGrath using the 10-inch Grubb refractor in May 1954 (Corvan Collection).

These plates were used by Eric Lindsay for his various research programmes on the southern Milky Way and the Magellanic Clouds. However, a small selection had been specially taken with the Armagh-Dunsink-Harvard (ADH) flat-field Schmidt camera for display purposes. Even after almost fifty-four years, one image in particular stands out in my memory, and that is of the Sagittarius region. The 25 cm (10-inch) plate was peppered with black dots impossible to count, or so I thought. This was our first introduction to the methods used by astronomers to try and understand the wide variety of objects that populate the Universe.

By now it was quite dark outside, and Dr Lindsay informed us that it was now time to make our way out to the telescope dome. Imagine, if you can, a young teenager of 13 seeing for the first time a large refractor on its massive mounting. Words fail to describe adequately the sight of the venerable Grubb telescope. As I stood in the dome in the dim light, Lindsay

climbed a small set of steps to open the shutter and then rotate the dome in the direction of the Moon, which was to be the first target of the evening.

When it came to my turn at the telescope, what met my eye was a revelation. I had, of course, seen pictures of the Moon in books, but to actually see the detail of the lunar surface as revealed in the telescope was completely different and a great thrill. By means of the declination rod and the continuous cord for the right ascension motion, I moved the telescope slowly over the surface, stopping now and then to examine some particularly interesting feature. I found the whole experience so incredible that when I asked Dr Lindsay if I could have another look at the Moon he readily consented. After we were well satisfied, the refractor was positioned on the next object for study, which Dr Lindsay informed us was to be the planet Saturn.



Figure 2: Eric Mervyn Lindsay (right) and colleagues at the 1954 AGM of the Irish Astronomical Society at Belfast Castle on Saturday 10th April. Standing, left to right, are: Mr John H. McEldery, Mr Aidan P. Fitzgerald, Miss Vera Northridge, Miss Mary Brück, Dr Máire Brück, Mr Richard Hayward, Professor Hermann Brück, Miss Sheelagh Grew, Miss Zoe Irwin, Mr Bill R. Mackle, Mr Bill Farquharson, Mr Bill Lynn, Mr Muiris Maclonraic, Brigadier K.M. Papworth, Mr Vincent Deasy (Uinsíonn S. Déiseach), Mr Peter Brück, Dr Eric M. Lindsay and Dr Ernst J. Öpik (Corvan Collection).

How can I properly describe the visual impact of viewing the ‘ringed planet’ for the first time? No description, even by a seasoned observer, can convey that experience. I could hardly believe that I was looking at an object some 800 million miles away from our home planet, and in the telescope it looked so near. Dr Lindsay pointed out the very subtle detail present on the disc and the ring system, as I continued to look at something that seemed so unreal to the mind and eye. From an aesthetic point of view, Saturn is, without doubt, the most beautiful of the planets.

Our final object for the evening was Alpha Geminorum (Castor), in the constellation of Gemini. As Lindsay explained, in his clear and precise manner, “This star is what astronomers call a binary system, that is, two stars which revolve around their common centre of gravity. At a distance from the Earth of 45 light years, or 270 billion miles,¹ they orbit each other in a period of 420 years. There is also a fainter, distant member of the system, Castor C (magnitude 9.1), which is 72 arc-seconds away. It is probably orbiting the main pair in a period of around 10,000 years, and

this too is a spectroscopic binary. Castor is a truly remarkable, multiple star system, with six separate companions, four comparatively bright and white, and two dim and red.” In the telescope, however, all one could see were two fuzzy points of light.

Unfortunately, it was now time to bring the observing session to an end. No better introduction to astronomy could have been wished for than under the guidance of Eric Lindsay. It was a fascinating and awesome experience. From that time on I became a devotee of astronomy. I very much doubt if Dr Lindsay realized how over-awed I was of him at that time; in fact, he was to occupy a unique and exalted position for me for the rest of his life.

2 THE IRISH ASTRONOMICAL SOCIETY

In the summer of that same year (1953), the late Sheelagh Grew, long-time Secretary at the Observatory, invited us to join the Armagh Centre of the Irish Astronomical Society. By that time another school friend, Seamus McGrath, had joined our little group. The subscription was the princely sum of two shillings and sixpence (12.5p in today’s money). Meetings were held twice a month in one of the classrooms of the local Armstrong Primary School. Unfortunately, our Junior Membership did not include the *Irish Astronomical Journal*, which had been instigated by Lindsay around 1950.

The first lecture of the 1953/1954 season was to be delivered by Aidan Fitzgerald, one of the most prominent members of the Society. The title of his lecture was: “The Story of the Spirals — From Parsonstown to Palomar”. It was on this occasion that I saw Dr Öpik and his wife for the first time. After the talk, which was excellent—typically Fitzgerald—we were all invited by Dr Lindsay to the Observatory for tea; and again we had the opportunity to inspect a selection of photographic plates put on display for the benefit of the members.

As on my first visit to the Observatory, Dr Lindsay acted as guide. The willingness patiently to explain every detail was, I discovered, a personal characteristic of Lindsay, and was readily extended to anyone who was genuinely interested in astronomy. He was always approachable and always kind.

I have since met many amateurs and even a few professional astronomers who owe their first introduction to astronomy to Eric Lindsay. He once said to me, “I divide mankind into two classes: those who are interested in astronomy, and those who are not. And this division cuts across all races, nations and social groups. There are those who have a genuine interest in astronomy, they may be poor people, not learned, not even articulate; but they want to learn. There are others, some of them quite charming people, some of them quite distinguished people, but they are not really interested.” For Lindsay, *interest*, not social background, was all important!

Many times over the years, I have reflected on this question: if it had been cloudy on that Tuesday evening in 1953 or had I been shown around the Observatory by someone else, would the experience have left such a deep impression on my young mind as it obviously did? Some will remark, no doubt, that this is just pointless speculation. Be this as it may, one

thing is certain: looking back almost fifty-four years later, it was indeed my good fortune to come under the influence of Eric M. Lindsay. That event—the introduction at so early an age to the beauty of the night sky and its mysteries—was destined to change my outlook on life in a way matched by few subsequent events. This was, of course, due in no small measure to Lindsay’s natural ability to convey the most complicated and abstract ideas in language that could be understood by the thinking listener or reader.

The next important event was the AGM of the whole Irish Astronomical Society, held at Belfast Castle in April 1954 (Figure 2). I doubt if the four of us could have been any more excited if we had been going to Rome or New York. We journeyed by train from Armagh, full of anticipation as to what would transpire at the meeting. Before the proceedings got underway and the main lecture, Eric Lindsay introduced the four of us to Professor Hermann Brück, the eminent Director of Dunsink Observatory. He was a most friendly and charming Prussian gentleman. He was the second German astronomer to be appointed to head our National Observatory, the first being Franz Brünnow. Herman Brück came from a military family, his father having lost his life in action on the Eastern front in the First World War. Born on 15 August 1905 in the Berlin district of Charlottenburg, he had an eventful career working at the Potsdam Astrophysical Observatory, the Vatican Observatory, and before coming to Ireland, the Cambridge Observatory in England. In the course of an interesting conversation, he informed us that his family did not approve of his interest in astronomy, and when his parents were asleep he would get out of bed and climb to the attic, open a small window, and gaze at the stars.

Professor Brück was the main speaker at the AGM, and the subject of his talk was “Solar Phenomena with Reference to the Dunsink Observatory’s Solar Expedition to Khartoum in the Anglo-Egyptian Sudan”. In the course of his presentation, two fascinating cine-sequences were screened: that of Dr Bernard Lyot (from Meudon Observatory) ascending the Pic du Midi with equipment on his back for the Observatory atop the mountain, and the latest time-lapse footage from the McMath-Hulbert Solar Observatory (on Lake Angelus, Michigan) of a very active arch-prominence at the edge of the Sun. This was the first of a number of AGMs that I attended until the Society was dissolved as an all-Ireland society in the early 1960s, to the regret of all concerned.

The next important occasion that was to have consequences for me as an amateur astronomer was when Patrick Moore came over from England to give two lectures, the first in Belfast and the second the following evening (on 28 October 1954) before the Armagh Centre. Patrick was well known on both sides of the Irish Sea among amateur groups, but not to the wider public. At the time, he had published approximately three books, mainly on his favourite topics: the Moon and planets. His television programme, “The Sky at Night”—which was to make him a household name—still lay some years in the future. The title of Patrick’s talk was “The Moon World”, and because my experience of observing the Moon the year before with the Grubb refractor was still fresh in my memory I found his talk informative and extremely interesting.

After he finished his lecture and during the traditional cup of tea, Moore came over to me and my friends and introduced himself. Following a friendly conversation lasting several minutes, he invited us to write to him as often as we liked if we had any questions on astronomy in general or the Moon or planets in particular. I have to say that we were delighted to have the opportunity to do so. Patrick produced his calling card, and gave one to each of us. I think I have his card among the letters I received from him over the years. Unfortunately, Dr Lindsay was absent on that occasion, as he was at the Boyden Station using the ADH Telescope for a number of observing programmes.

Towards the end of the following month my friends and I received a very pleasant surprise: an offer from Patrick of a 6-inch mirror blank if we would be interested in turning it into a telescope mirror. Naturally, we jumped at the chance to have our own telescope, as there was no way that we could afford to buy one. However, we were left in a bit of a quandary as to what to do with the gift. We had never worked a mirror blank before, and frankly had not the slightest notion where to begin; and, anyway, we had no suitable place where we could work on it.

Dr Lindsay had by that time returned from the Boyden Station, so we nervously approached him for advice. In typical ‘Lindsay’ fashion he not only placed the old Observatory workshop at our disposal, but bought out of his own pocket all the necessary grades of carborundum and polishing material. We also had the considerable practical advice and guidance of Franklin E. Kameny, from the Graduate School of Harvard University, who was then a temporary member of staff of the Observatory. He was here for one year, and was also involved in finishing off his Ph.D. thesis on T Tauri variables.

So the four of us set to work, learning the art of turning a glass blank into a functional mirror. Each day, for the next several months, we would spend a few hours grinding the blank—ever so slowly—to the required parabolic figure, and at regular intervals we would use the Foucault test to check how our work was progressing. It was a thoroughly enjoyable and novel experience, and my mind was forever focused on the day when we would have our own telescope.

3 ERIC LINDSAY: THE ASTRONOMER AND THE MAN

Throughout this time, my three friends and I enjoyed the hospitality and friendship of Eric Lindsay. From time to time he would call into the workshop to enquire how we were progressing with the different stages of the grinding process. If he thought we had worked too long, he would ask us to take a short break and would either take us out to the Grubb for some observing, or lead us out to the lawn and teach us to identify the constellations.

Eric Lindsay was one of that rare breed of professional astronomers who knew their way around the heavens. If cloudy, he would on occasion invite us to his study for refreshments and the delightful experience of hearing him recite passages from some of his favourite poets, namely Wordsworth, Goldsmith and Yeats. He would often say at the time that he enjoyed

Wordsworth so much for his “feeling for nature”, Goldsmith for his “depth and conciseness of thought” and Yeats for his “fantasy”. To Lindsay, astronomy was as poetical as poetry, and an impractical love of knowledge and beauty of nature inspired his working life. In due course, we finished the grinding and polishing stages, and ended up with a good working mirror and the congratulations of both Drs Lindsay and Öpik.



Dr. Shapley at the binocular microscope for studying photographic plates. This instrument, used at the Observatory on loan from Harvard College Observatory, to aid in a programme on galactic structure, April 1959.



Figure 3: Harlow Shapley at Armagh Observatory in April 1959, with the binocular microscope on loan from Harvard College Observatory.

As the years followed and my visits to the Observatory became more frequent, I came to learn more of Eric Lindsay, the astronomer and the man. Many Saturday afternoons were spent in his company, listening in fascination as he recalled his student days in Ireland, and in America at Harvard, as well as his time at Boyden before the War.

I think it is worth recalling the circumstances whereby Eric Lindsay first met Dr Harlow Shapley (Figure 3), the famous Director of the Harvard College Observatory, and who was to have such a profound influence on the changing fortunes of post-war Irish astronomy. As a postgraduate student of 22 from the Queen’s University, Belfast, Lindsay had obtained a Fellowship to study for his Ph.D. at the Graduate School of

Harvard University. His Ph.D. supervisor was Bart J. Bok, a specialist in Milky Way structure, who himself had arrived a short time before from the Netherlands.

Lindsay arrived in late October 1929, and being a stranger he did not know his way around the Observatory so he rang the door-bell of the first building he came to. Presently the door opened to reveal a man of average height. In the semi-darkness Lindsay did not recognize the figure, so he immediately introduced himself, “I’m Lindsay from Ireland”. One can well imagine his surprise when, with equal speed, came the reply, “Well, I’m Shapley from Harvard”. So began in this very simple way an association that was to last until Shapley’s death in October 1972.

Few people today appreciate the paramount role that Dr Shapley played in the career of Eric Lindsay. When, in 1934, Lindsay was awarded his Ph.D., Shapley secured a position for him as Chief Assistant under Dr John S. Papaskovopoulos at Harvard’s Boyden Station in South Africa. This was a young Eric Lindsay’s first introduction to the marvels of the southern Milky Way and its two companions, the Magellanic Clouds. The instrumentation available at Boyden comprised a 60-inch reflector, the 24-inch Bruce astrograph, a 13-inch Clark photovisual refractor and the 10-inch Metcalf astrograph, thus duplicating the instruments found at the Harvard home base. The rationale behind this was to achieve a homogeneous survey of the skies of both hemispheres.

When the Revd William F. Ellison died on the last day of 1936, Eric Lindsay informed Shapley that he was applying for the only astronomical position vacant in Ireland, namely the Directorship of the Armagh Observatory in his native County Armagh. The other Irish Observatory, at Dunsink, was closed the year before following the death of the Acting Director, Charles Martin. It is worth remembering that Lindsay was to play a major part in its re-opening, in 1947, against strong opposition from certain members of de Valera’s government. When Shapley realized that Lindsay was serious about trying for Armagh, he was heard to remark, “That fool Lindsay has gone and ruined himself!”, but some time later he told one of his close associates, “Maybe he will make something of it, after all.” How right he was!

Only a man with a close attachment to his homeland would contemplate giving up a position at an observatory with such excellent equipment for its time and on a site with near-perfect observing conditions. Eric Lindsay was under no illusions that after the many advantages of the Harvard and Boyden Observatories, Armagh would seem very primitive—to put it mildly. Luckily for Armagh, Lindsay had all the necessary gifts needed to be a successful Director: he was an able administrator, and had an easy way with people, great perseverance, total dedication to the Observatory and a deep love for its traditions. It is not often that one finds such qualities in abundance, and in the one person.

What Eric M. Lindsay accomplished over the next thirty-seven years is comparable in many ways to the proverbial Phoenix rising from the ashes. Lindsay arrived in Ireland to take up his new position in November 1937 to find a rather depressing situation awaiting him. Nothing had been added by way of new equipment since 1885 (when the 10-inch Grubb re-

fractor was erected in July of that year). This is the telescope that was used by John L.E. Dreyer for the measurement of double stars (with a micrometer that was gifted by Howard Grubb) and to check the entries for his NGC and IC catalogues.

The other instrument that Lindsay found at the Observatory was an 18-inch Calver reflector, which had been the personal property of his immediate predecessor, Ellison, who upon taking up his duties as Director had presented the Calver as a gift to the Observatory. As far as I have been able to ascertain, very little serious work was done with it, apart from some observations of Mars during the opposition of 1924 by Ellison's son, Mervyn.²

The challenge facing Lindsay was enormous as he began to plan and organize to put Armagh back on the astronomical map. Just as he was making good progress, the war clouds were beginning to appear over Europe, which would mean a major interruption to the lives of not only astronomers but millions of people all over the world as well. However, in the meantime Eric Lindsay had been invited to take part in the 4th Harvard Starcount Circuit, with Armagh being designated the areas of Ophiuchus, Sagittarius and the Southern Coalsack. Ophiuchus was a familiar region for Lindsay, for during his Harvard days, through starcounts, he had been one of the first to reveal the extent of this great dark nebula complex. To aid Armagh in this programme, Harvard placed on long-term loan a mounted binocular microscope, with X and Y movement and the necessary selection of photographic plates (see Figure 3). During the course of this survey, Lindsay discovered a minor flare of nebulosity in the Coalsack.

When war did come, on 3 September 1939, it took Lindsay—as well as astronomers from every other country involved in the conflict—away from their astronomical research, in Lindsay's case, to Operational Research in the British Admiralty, in Whitehall. Everything had to be put on hold for the next six years. When the war eventually ended in 1945, Lindsay, as part of Admiral Lord Mountbatten's staff, was given the task of interrogating Großadmiral Karl Dönitz, former Commander-in-Chief of the German Navy, and last Head of State of the German Reich. Lindsay, however, declined the honour. In conversation about this period, he told me that he "... had little taste for this sort of activity." Throughout this period, Lindsay kept Shapley and others at Harvard well informed of his progress and of his plans for the future of Irish astronomy.

Armed with the knowledge that Éamon de Valera was planning to re-open Dunsink Observatory as part of the School of Cosmic Physics of the Dublin Institute for Advanced Studies, Lindsay saw this as a golden opportunity to bring in, as a partner, the country's oldest observatory to his scheme to set up, at the Boyden Station, a telescope of novel design in an excellent climate and at nominal cost to the two Irish observatories, thus guaranteeing them access to forefront instrumentation. And so it was that for the next twenty-five years the Armagh-Dunsink-Harvard Telescope (Figure 4) at Boyden was the Irish observatories' main source of astronomical data, while minor research projects were carried out with the instruments located back at the home observatories.

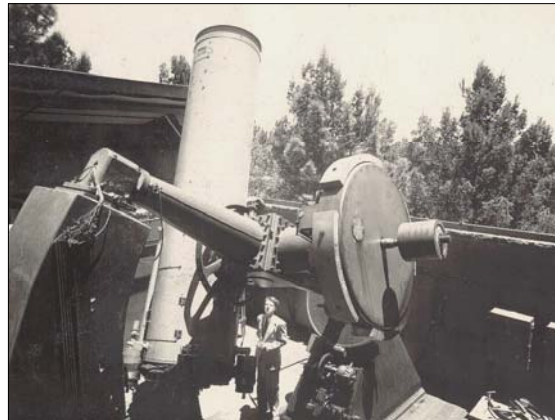


Figure 4: Lindsay at the Armagh-Dunsink-Harvard Telescope, at Bloemfontein (South Africa) in 1952.

It was Dr Lindsay's strong belief that the home observatory should have small, but effective, instrumentation to take full advantage of any interesting objects that might appear in the sky, such as comets, novae or unusual variable stars. I remember once being invited to take part in a programme to search for Wolf-Rayet stars in Cygnus, using the Armagh Schmidt camera (Figures 5 and 6). Unfortunately, I had to decline this offer due to the nature of my employment. In those days the skies at Armagh were quite dark, unlike today, and it was easy to count at least 13 stars in the Pleiades star cluster with the naked eye. To give another example of just how good the conditions were in those days: on two separate occasions I had no difficulty in spotting the planet Uranus and the two main satellites of Jupiter without optical aid. And, of course, useful observations were still possible with small telescopes (see Figure 7).



Figure 5: The 12/18-inch Schmidt camera at Armagh (in the 1980s) (Corvan Collection).



Figure 6: Pat Corvan and Eric Lindsay beside the dome of the 12/18-inch Schmidt camera at Armagh Observatory, March 1964 (Corvan Collection).

In late August and early September 1955 the International Astronomical Union held its 9th General Assembly in Dublin, the only time so far that it has done so in Ireland. The delegates spent a day at Armagh as guests of the old City Council. My friends and I waited at the Railway Station as 600 conference participants arrived, including among them some of the world's most famous astronomers. I remember standing near Dr Carl Seyfert, the first to draw attention (in 1943) to the peculiar class of galaxy displaying high-excitation emission lines in their central regions that now bears his name, the so-called 'Seyfert' galaxies. His wife, who was also present, was the sister of Mrs Lindsay, and both had worked under Shapley at Harvard. In fact, Sylvia Lindsay had discovered the first dwarf galaxy on an unusually sensitive Bruce plate exposure of the southern constellation of Fornax. The guests wandered over the instrument lawn, into the telescope domes, and viewed a major display that had been organized in the lobby room. The astronomers showed keen interest in Dr Öpik's rocking meteor camera. It was certainly an occasion I will never forget.



Figure 7: Pat Corvan observing with the 10-inch Grubb refractor on 2 March 1969 (Corvan Collection).

The next memorable event was the appearance of my first comet, Arend-Roland, which was a reasonably bright object during the spring of 1957. Lindsay used the Armagh Schmidt to good effect by securing a fine

series of plates. He realized that when the comet was to pass through the plane of the Earth's orbit a telegraph pole would be in the way. So, in the interests of science, the pole had to be sacrificed! Fortunately, it was completely clear over Armagh at the time, though cloudy over the rest of Europe, and the result was some of the best photographs ever taken of the so-called anti-tail or 'counter tail', which gave the comet its unique appearance. A short time later, Lindsay presented me with a nice print from the plate he had taken when the comet had passed through the plane of the Earth's orbit on 25 April 1957 (see Figure 8).

One strange episode in connection with Eric Lindsay that I now have to relate occurred during the late 1950s. At that time there was a period of political unrest, and it was Lindsay's habit to ride round the Observatory grounds at night wearing a white sheet. Knowing of the legend of the ghost at the Observatory, he hoped that this nightly apparition would deter unwelcome visitors. On one of these 'phantom rides', Lindsay was unaware that at the same time an RUC constable was patrolling the grounds. When the policeman saw the ghostly figure move towards him, true to his training he used his baton to maximum effect. Fortunately Dr Lindsay was not badly hurt, but the ghostly apparition was never seen again!

One of the most remarkable occasions within my experience was the arrival of Dr Harlow Shapley in April 1959, for a three-month stay at the Observatory. He had accepted Dr Lindsay's invitation to work with him on a study of the Large Magellanic Cloud. Armagh had accumulated a unique collection of photographic plates secured with the ADH Telescope. It was while Shapley was here that I was introduced to him, through Dr Lindsay—who, as always, realised that the opportunity to meet one of the truly great astronomers of the twentieth century was not to be missed by a young amateur. I had several conversations with Dr Shapley, and it was a delight to be in his presence, for he was a man of great humour.

Shapley (Figure 9) had a very interesting career. He started as a student at the University of Missouri Observatory, and then moved to Princeton to work for his doctorate under Henry Norris Russell, one of the most brilliant astronomers of his generation. On Russell's recommendation, George E. Hale, the founding father and Director of the Mount Wilson Observatory, invited Shapley to join the staff. Harlow Shapley worked there from 1914 to 1921, using the 60-inch reflector on the study of cluster variables, to calculate their distances. It was while engaged in this research that he made one of the most important discoveries in the history of astronomy, namely that our Sun was not at the centre of the Milky Way, as proposed by Jacobus C. Kapteyn, but was located some way out from the centre. He made this discovery by studying the distribution of clusters in space, and found that they were asymmetrically distributed with respect to location of the Sun.

During his stay at Armagh, Shapley gave a number of lectures, which I was very fortunate to be able to attend. While in Armagh, he had his office in what is now the display room. One day I called in to see him, only to find him engaged in revising his book, *Galaxies*. It was one of the Harvard Books on Astronomy, originally published in 1943, and the new edition

came out in 1961. Even today it makes interesting reading. Dr Shapley came back to Armagh for a second visit the following year in order to finish off the work with Dr Lindsay on the distribution of globular clusters in the Large Magellanic Cloud. Later, this was published as a landmark catalogue.

It was shortly after I was introduced to Dr Shapley that Dr Lindsay became very seriously ill. A shadow of gloom descended over the Observatory, despite the fact that for a short time this small observatory was directed by such a distinguished American astronomer. It was about this time that Shapley made the now famous remark regarding the Armagh Observatory: that he considered it "... the nicest little observatory in the Solar System." This represented quite a change of attitude given his 1937 remark!

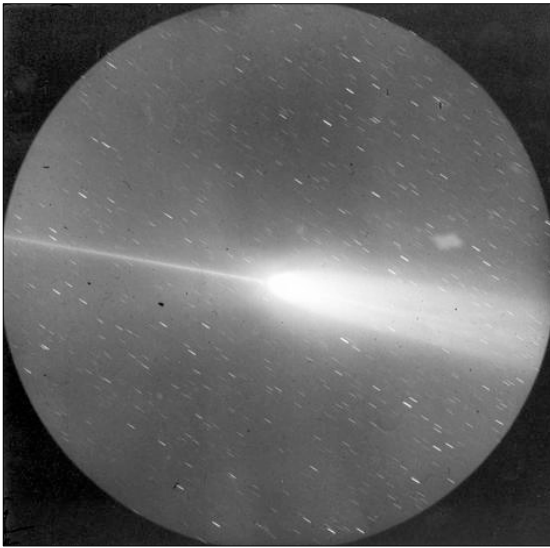


Figure 8: Comet C/1956 R1 Arend-Roland, taken by E.M. Lindsay with the Armagh 12/18-inch Schmidt camera at the Armagh Observatory on 25 April 1957 (Corvan Collection).

For over twenty-seven years Eric Lindsay played a prominent part in the Irish Astronomical Society following its reconstitution as an all-Ireland society in 1946. It was therefore little surprise that he was elected its first President; before that time, the only centres of astronomical activity had been Dublin and Belfast. From the time he returned to Ireland, Lindsay had a strong desire to create conditions conducive to the development of amateur astronomy in this country. As he saw it, although the country was divided politically there was no reason why astronomy on a professional and amateur level could not be organized on an 'all-Ireland' basis. The first meeting of the Council of the Irish Astronomical Society was held at Armagh Observatory on 14 June 1947. I like to think that this was just one more tribute to Lindsay for all he had done.

Lindsay was also a prime mover in founding the *Irish Astronomical Journal*, which for the first nine years of its existence was a vehicle for the activities of the Society. Under the editorship of Dr Ernst Öpik (Figure 10), it soon became a gold mine of astronomical originality. It is to be deeply regretted that this publication ceased in 2000.



Figure 9: Dr Harlow Shapley at Harvard, in 1932 (Corvan Collection).



Figure 10: Dr Ernst Öpik in the Armagh Observatory Library.

Though Lindsay never liked public speaking, he was a fine lecturer, as testified by the large attendances at his talks. In the eleven-year period from 1949 to 1959, until the Armagh Centre became defunct, he delivered a total of ten lectures before members of the local Group. He had a fluency of style which commanded the attention of his audience, young and old alike. For us junior members, Eric Lindsay's lectures were special events that we looked forward to with keen anticipation. From the time I entered the scene in late 1953, I never knew him to miss a meeting, apart from the few occasions when he was away at the Boyden Station on observational work. He was very keen to

organize an observing section within the Armagh Centre, but unfortunately for us young members nothing ever came of it, presumably because there was no-one around experienced enough or willing to take us under their wing and train us in the art of practical astronomy.

Young amateurs as well as the general public fare much better today. The excellent facilities of the Armagh Planetarium are at the disposal of Irish amateurs. They have unequalled opportunities to engage in their hobby, and all because of one man, Eric Mervyn Lindsay (Figure 11), who envisaged all this before some of us were born.

Shortly after the Armagh Centre ceased to function, knowing of my bitter disappointment, Lindsay very generously presented me with a set of the *Irish Astronomical Journal*, covering the years 1950 to 1959. For me, they are a tangible reminder of the kindness of Eric Lindsay.



Figure 11: Eric Mervyn Lindsay (1907-1974) (from the Corvan Collection).

Everyone that has been a frequent visitor to the Observatory has heard of the ghost which is supposed to haunt the place. During one of many conversations with Dr Lindsay I remember him telling me of his experience one night. It was his habit—dating from his Harvard days—to work late at night in his study, enjoying the peace and quiet. He never explained the nature of what he was engaged in that particular night; he could have been working on a report, or scanning a photographic plate with the binocular microscope. In

any case, he was engrossed in what he was doing, but in the course of time he became aware of a ‘presence’ in the room. The more he tried to ignore it the more ‘it’ made its presence felt, until whatever it was became so overwhelming that Dr Lindsay had to leave his study; and until his own death he would never work later than 11.30 at night. Knowing Dr Lindsay as I did, he certainly was not a man of a nervous disposition. Was this the ghost of the Reverend William Davenport making its rounds?

4 CONCLUDING REMARKS

I have to confess that even after all these years since his death on 27 July 1974 I still miss Eric Lindsay’s friendly smile and the wave of his hand in recognition as he stood by the window of his study. The Saturday conversations I miss equally so. In one of the last meetings I had with him, I asked if he would write his autobiography when he retired; the reply I received was, “No, I will grow tomatoes.”

As I write this memoir, I have before me a photograph of Eric Lindsay standing beside the ADH Telescope with control box in hand (see Figure 4), and for me this is how I will remember him best. Most of what he worked so hard at and over so many years to achieve is no more. The ADH Telescope is no longer a working instrument, and the Boyden connection was severed a short two years after his death. I am reminded of the old maxim: *sic transit gloria mundi*.

To those who knew Eric Lindsay well, he was “... an historian and visionary; strategist and educator; builder of organizations and critic of officialdom; internationalist and lover of his native place.” Eric Lindsay’s passion, intellect and determination are an enduring inspiration to everyone who cares about Ireland’s astronomical heritage. He has truly earned a niche in the history of Irish astronomy, not so much for his outstanding astronomical discoveries or lack of them, but rather for the pre-eminent part he played in the re-birth of astronomy in this country. And for this he should be best remembered.

5 NOTES

1. Lindsay used the English billion to mean a million million.
2. Mervyn Ellison was destined to become the Director of Dunsink Observatory three decades later, earning for the family the unusual distinction of supplying Directors to both of the Irish Observatories.

Patrick G. Corvan was born in Cheltenham, Gloucestershire, on 18 March 1940. He became interested in astronomy at the early age of eleven, and has a passion for astronomical history, especially in the era of the great visual observers of the Moon and planets during the eighteenth and nineteenth centuries. He was on the staff of the Armagh Planetarium for almost thirty years, and has been associated with the Armagh Observatory for well over fifty years. In 2005, the year of his retirement, he was honoured by the IAU when minor planet (8515) was named ‘Corvan’.

FAMILY MEMORIES OF A VERY SPECIAL UNCLE

Robin Lindsay, Jack Lindsay, and Mary Lindsay

Dr Mary Lindsay, c/o The Director, Armagh Observatory, College Hill,
Armagh BT61 9DG, Northern Ireland, UK.

Abstract: Robin started with an inscription from the Valley of the Kings “speak my name and I shall live”, and said this was happening that day for Mervyn. He then showed the photograph of the Lindsay family taken about 1912 when Mervyn was about five and talked about some members of the family. Robin and his brother Jack described the various stories about a meteorite landing in Northern Ireland near Armagh and Mervyn being asked to value it. In a discussion, Mervyn told Robin that his knowledge of the stars had strengthened his belief in a Divine Creator. Robin described Mervyn as a very caring man who made anyone talking to him feel special. He concluded that those who sought a monument to Mervyn should look around them at the Observatory in Armagh.

Keywords: Eric Mervyn Lindsay, Lindsay Family, Armagh Observatory, amateur astronomy, Irish astronomy

1 FAMILY SUMMARY OF AN ORAL CONTRIBUTION BY ROBIN LINDSAY

The thought that immediately came into Robin’s mind as he listened to the Lindsay Centennial Symposium presentations was an inscription in the Valley of the Kings: “Speak my name, and I shall live”. The name of Eric Mervyn Lindsay was spoken many times that day, and this gave him—and other family members—great pleasure.

Robin introduced his subject by presenting the Lindsay family into which Mervyn had been born, with reference to the photograph shown here in Figure 1. This was probably taken around 1912, at The Grange, Loch Gall, where Mervyn’s father, Richard, was headmaster. The School had been given to him on

his marriage to Susan Best, one of several sisters of Lord Justice Best (two of whom each had a grandson at the Symposium; five of Susan’s grand-children and one great grandson were also present). The photograph shows the twelve surviving children (Frances Herbert, born in 1886, had died aged six months), and their parents, Richard and Susan.

They were quite a family, and must have taken some bringing up! Standing in the back row on the left is George Edwin who served as a doctor in the Royal Army Medical Corps (RAMC) in the Great War. Doctors were scarce and he exasperated his seniors by rescuing patients under fire; however he got a medal. After the war he settled down as a General Practitioner in Penarth.



Figure 1: The Lindsay family c.1912. Shown (left to right) are: Pooler (Indian Army, retired as Brigadier); George Edwin (Doctor); James (Lawyer); Bea (travelled widely before returning to Hannavale); Flo (the eldest of the family, who married an Episcopalian Minister); Susan (née Best, mother of the family and Robin Lindsay’s grandmother); Fred (Headmaster of a preparatory school in Dorset, surrogate father to the family and Robin Lindsay’s father); Eric Mervyn Lindsay (about the age of five); Cecilia (Business Woman); Gwen (Nurse); Richard (father of the family and Robin Lindsay’s grandfather); Harold (Medical Missionary); Norman (Indian Army, retired as Captain); and Robert (Civil Engineer).

Next to him is Flo, the eldest of the family, born in 1885. She was very bright and got a university scholarship. She married an Episcopalian minister, later a Canon, and died quite young from pneumonia. (She was not divorced, as suggested by Robin Lindsay, but her daughter was.)

In the middle is Robin's father, Fred, whose three surviving children, Mary, Robin and Jack, were at the Symposium along with one grandson, Jack's son, James. As the eldest boy, Fred contributed to the upbringing of the younger members of the family. He bought Hannavale House near Portadown for his parents to live in after they retired, and for other members of the family. He was head of a preparatory school in Dorset. Robin described him as a great personality who had a remarkable way with people.

On his left is Gwen who became a nurse. She nursed a famous cricketer, Lord Harris, and then retired to Hannavale.

Standing on the right is Norman, who was an extremely kind man. He was in the Indian Army and retired as a Captain. He worked in Belfast and lived at Hannavale. Known as "The Captain", he was pleased that the local Orange Lodge asked him to take the salute when they marched past on 12 July. He organized the New Year's Day Hunt for the Harriers from Hannavale.

Pooler is sitting on the left in the front row. He made his career in the Indian Army, fought in Burma during the Second World War, and then was Commander of the Quetta area. He retired as a Brigadier and lived with his family in Suffolk.

James, standing next to Bea, was a successful lawyer and followed his uncle as Assessor to the Primate and Chancellor to the Diocese of Armagh. He was Editor of the *Northern Ireland Legal Quarterly*.

Bea travelled and held various posts, but found her métier when she came back to take over from her mother as Chatelaine at Hannavale, where she loved having family and friends visiting, and took a particular interest in her nephews and nieces—and made sure we all learnt to swim!

Cecilia, sitting between her parents, was a very able business woman in Ireland and Australia. She married and had children.

Harold was the other doctor in the family and qualified at Belfast. He was a medical missionary in Moma Boya, Peru, for twenty years, and a park there was recently named after him. He came back to Scotland and lived with his family at Dornoch as Medical Officer of Health for Sutherland. Two of his three surviving children, Susan and James, were at the Symposium.

Robert took a degree in Civil Engineering at Queen's University, Belfast. He had a successful career in charge of the railways in Northern Ireland and building bridges for them, including one over the Bann at Coleraine which lifted up to let ships go by.

Eric Mervyn aged about five is in the centre of the picture, his mother holding his hand.

This, then, was the family in which Eric Mervyn Lindsay grew up. They looked after each other, with the older ones helping with education of the younger

ones. When Mervyn started at Queen's University, his eldest brother, Fred, gave him ten pounds—the equivalent of about a thousand pounds today—to be used in an emergency. After Harvard, when he had qualified as an astronomer, Mervyn proudly offered it back to Fred but was told to keep it.

Mervyn's fascination with the stars does not seem to have been greatly encouraged at home. When he was young, his father would sometimes beat him when he found him up looking at the stars when he should have been in bed! He evidently did not realize that this was a family trait, as his first cousin, John McConnell's father, became interested in the stars quite independently and handed this on to his son (see John McConnell's paper, "Dr Eric Mervyn Lindsay: A Personal View", on pages 191-192.)

Mervyn's older nephews and nieces used to enjoy staying at the Observatory with Mervyn and his wife Sylvia. She was an astronomer in her own right and an important part of his life. She was fiercely protective of him and his work, and helped him to keep a balance between his research and his enjoyment of meeting people from all walks of life. After Mervyn died, Sylvia returned to the United States, and was very good to Patrick and Norman, and also Mary, when they visited her in America.

Mervyn was also an extremely kind man. When, after the war, he heard that Professor Öpik (who had examined him for his Ph.D.) was in an internment camp, he secured his release and brought him to Armagh. This led to a great contribution both to astronomy and to Armagh.

Mervyn had great charm and we used to enjoy talking to him and listening to him. He had a nice sense of humour and the capacity to make everybody he met feel they were special. His nephew, Alan, the son of Robert Lindsay, recalled that although Mervyn was so intelligent, he never seemed to mind questions that arose from ignorance or lack of knowledge, for he was a humble man. Another nephew, Norman (the son of Harold), said that Mervyn was his hero and remembered him talking about a discovery that he had missed, which was found later by somebody else, and telling his father, Harold, that instead of answering the whole paper in his final examination at Harvard he had only answered one question, but had still passed. Susan remembers that he quite often came to Hannavale and would sit down at the piano and play hymns. Yet another nephew, Patrick (the son of Pooler), remembers that Mervyn believed that art and science were intellectually inseparable. All of Mervyn's nephews and nieces have recalled the pleasure of being shown round the Observatory by him, and all enjoyed talking to him and listening to him.

Mervyn loved the stars and wanted to share this love. He instigated and encouraged local amateur astronomy groups; he lectured to prisoners; and with Patrick Moore he founded the Armagh Planetarium. He wanted the Northern and Southern governments to work together for the good of astronomy in Ireland and achieved this to a remarkable degree, enhanced perhaps by his friendship with De Valera, who was a mathematician as well as a politician.

There is an apocryphal story that a meteorite once fell in the garden of an old lady in Ulster, and when

someone from Queen's University asked if they could have it she said "Certainly not". Mervyn then went to see her and was asked in for tea. They talked, and as he left she gave the meteorite to him. Robin did not know if this story was true or not, and so he asked his brother, Jack, to give his version of it.

Jack Lindsay: Well I remember Mervyn came over for our mother's funeral, and he told us that a meteorite had fallen recently in a field and was retrieved by the farmer. Mervyn was invited to tea by the farmer, but no mention was made of meteorites until after the tea had been consumed and partially digested, at which point Mervyn was asked for his opinion on its value. He said that on the one hand it is a rock and as such valueless, but on the other hand it had come from the celestial spheres and was invaluable, so he was forced to conclude that its value lay somewhere between those two extremes. The farmer was so grateful that he presented the meteorite to the Observatory. Uncle Mervyn then said that Queen's University borrowed the meteorite in order to carry out a non-destructive examination of it, but when it came back to the Observatory it had a large chip out of it. That's the story I heard from the horse's mouth! What I hadn't realised until today was that perhaps the meteorite had split up into two pieces, which would correlate with what you've just told us.

Robin Lindsay: Did anyone see the broadcast which Mervyn made one Christmas about the Star of Bethlehem? It was on Ulster TV. I was sitting in Hannavale and suddenly Mervyn appeared on the television. This is what he said: "The Star of Bethlehem could not have been a conjunction of planets because those men from the East knew what the planets were going to do and that would not have made them get excited. It would have been, he thought, a supernova, which blew up into great brightness and then later faded away and left a black hole." That was his view, and I remember ringing him up and talking about it, and he said that the Chinese kept very good records of the stars and they recorded a supernova around the time of the birth of Jesus. So there is something for us to think about. I also said to him in this context: "Does your knowledge of the stars help you or make you believe in a Divine Creator?", and he replied with an unhesitating "Yes". I found that most moving.

And so, as I look again at my family, I see Mervyn as an extraordinary person. He had a quality with people similar to that which was found in the Queen Mother: when he was with them he totally concentrated on them, and they felt that they were the only

person in the world that mattered. He was a great man and could walk with Kings, but at the same time keep the common touch.

Finally, if we are seeking a monument for Mervyn we should look around at Armagh Observatory and let "Si monumentum requiris, circumspice" be testimony to the marvellous man whom we have been honouring today.

2 NOTES

1. To his nieces and nephews, Eric Mervyn Lindsay was known as Mervyn rather than Eric.

Robin Lindsay attended his father's preparatory school in Dorset, and after Cambridge he started teaching and gradually took over the school from his father and set his own stamp on it. His Headmastership was characterised by the school excelling in scholarship and sport. His particular interest in the teaching of mathematics led to his being an advisor to the Incorporated Association of Preparatory Schools (IAPS), and he arranged conferences for them on this subject. He was given a "Services to Schools' Rugby" award, and was a selector for schoolboy and adult teams, including those against South Africa and the All Blacks. He is an enthusiastic member of the Marylebone Cricket Club (MCC).

Another son of Fred Lindsay, Jack Lindsay, also went to his father's school, and after Cambridge he, too, became a schoolmaster. He was an active member of the Association of Science Teachers and demonstrated at the annual Members Exhibitions of the Association. He contributed papers concerned with research and teaching, including some on the Moon and tides, and carried out some experiments in electricity for Brian Chapman (the brother of Allan Chapman). He is interested in Natural Sciences and is a keen ornithologist.

Dr Mary Lindsay also attended her father's school (she was the only girl at the time). She subsequently qualified in medicine at Queen's University, Belfast, and worked in paediatrics, general practice, adult psychiatry and child psychiatry. She was a Consultant in Child Psychiatry in the NHS for twenty-five years and was elected an FRCP. She continued to work for another fifteen years after retirement. She married Tony Balfour, FRCPATH, FRAS, a pathologist who was Chairman of the local astronomical society for several years and President of the Federation of Astronomical Societies (FAS) for a while.

DR ERIC MERVYN LINDSAY (1907-1974): A PERSONAL VIEW

John C. McConnell

56 The Meadows, Maghaberry, Moira, Co. Down, BT67 0JY, Northern Ireland, UK.

E-mail: johnmcconnell9929@hotmail.com

Abstract: Images, anecdotes and personal reminiscences of meetings with Eric Mervyn Lindsay are related by an amateur astronomer and second cousin to Lindsay.

Keywords: Eric Mervyn Lindsay, Armagh Observatory, Lindsay Family, amateur astronomy, Irish astronomy

1 INTRODUCTION

It was always a proud delight of mine when I discovered in the 1960s, that Dr Eric Mervyn Lindsay was related on my father's side of the family. This was also a bonus as I had started my interest in amateur astronomy in 1957, the year of Comet Arend-Roland, which I shall say more about later. Mervyn—as he was known to the family—was the youngest of the thirteen children of Richard and Susan (née Best) Lindsay, and was born on 26 January 1907 at the Grange, near Portadown, County Armagh.

Figure 1 in the preceding article (see page 187) shows Mervyn, standing front centre, at the age of four or five.¹ His mother, Susan, is in the centre of the photograph, holding his hand. For whatever reason, one member of the family is missing in this photograph; I have never managed to find out why.

My grandmother, Elizabeth (née Best) McConnell and Mervyn's mother were sisters, and their brother (Mervyn's uncle) was the Rt. Hon. Richard Best (see Figure 1 here), Lord Justice of Appeal (1925-1939), and the first Attorney General in what was the 'new' Northern Ireland Parliament in 1922.



Figure 1: The Rt. Hon. Richard Best, Lord Justice of Appeal (1925-1939).

2 RECOLLECTIONS OF DR LINDSAY

Elizabeth married John McConnell in 1895 and my father, William, was born in 1904 three years before Mervyn Lindsay. As I gained my first knowledge of

astronomy from my father it was inevitable, with this background, that it should surface somewhere. I can well remember the long conversations Mervyn and my father had about family history, and numerous times I was told off by both for butting in. Indeed, my father used to say, "You could have told Mervyn was a Best by looking at the back of his neck!" I have to say that I never noticed this; I might have the same characteristic myself!

Figure 2 shows the McConnell family taken about 1910. My father is pictured centre, wearing what appears to be a sailor outfit with a big hat, while the youngest member, Emma, who was also born in 1907, is standing front left. The resemblance between Mervyn's mother and my grandmother is striking.

I don't remember my grandfather, as he died in 1921, nor my grandmother who died in 1947, a year after I was born. But I did get the opportunity to quiz my aunts many times; sadly, the last died a few years ago while well into her nineties. Unfortunately, it can also be sad that people don't take the opportunity of putting their family history down on paper, so inevitably there are gaps, but I feel lucky to have made some progress.

Back in the 1960s the old 10-inch Grubb refractor at Armagh Observatory wasn't in the gleaming condition it is today, but I will never forget my first look at the Moon through this excellent instrument, with Dr Lindsay by my side! What a pity I didn't have a camera. My family and I visited the Observatory on many occasions, and I shall always hold those memories very dear.

On one occasion shortly before his death, Mervyn sat in the lovely Drawing Room telling stories of how he and other members of staff had removed a telegraph pole that happened to be in line of sight with the Schmidt Camera and Comet Arend-Roland. The resulting plates of Comet Arend-Roland 1957 III (e.g. see page 185) are said to be among the best in the world showing the famous 'spike' emanating from the head, which is caused by material spread out along the comet's orbit. Mervyn also mentioned his novel attempts to deter courting couples from using the observatory grounds: he cut holes in a sheet, and with this over his head he rode round the grounds on a bicycle!

On this last visit, I was lucky enough to have a small black and white camera with me, and asked if I might take his photograph. He led the way to his study, and I gingerly squeezed myself into the corner of the room in order to get him seated at his desk. I was just about to take the shot when a shout rang out, "Hold on till I get a pencil and make myself intelligent looking"! The resulting photograph is shown as Figure 3.



Figure 2: The McConnell family ca 1910. Note the resemblance between the author's grandmother, Elizabeth (left) and Mervyn's mother (see Figure 1 on page 187). William McConnell (John McConnell's father) is shown third from the right, while his sister, Emma, is third from the left.

Finally, in Figure 4 is lunar crater Lindsay, which was named in his honour. I look at it often, and remember three things about Dr Eric Mervyn Lindsay:

- his enormous intellect;
- his infectious dry sense of humour; and
- a great friend who is still sadly missed.

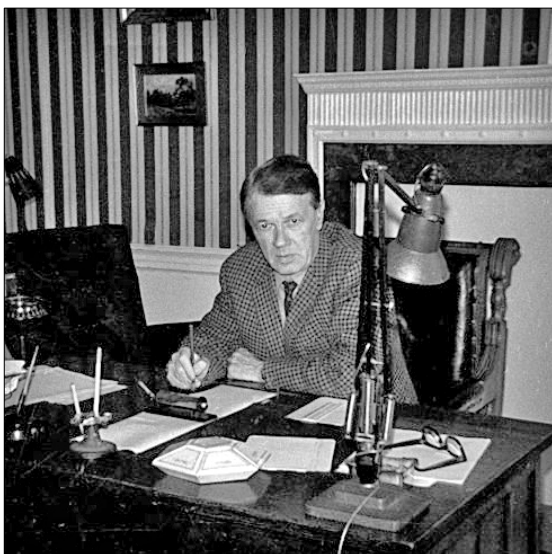


Figure 3: Mervyn Lindsay at his desk in 1971.

3 NOTES

1. For more information on the people shown in this image see the article "Family Memories of a Very Special Uncle" on pages 187-189.

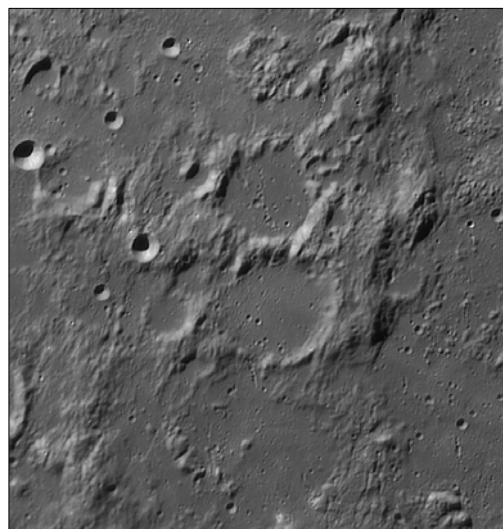


Figure 4: Lunar crater Lindsay is the upper of the pair of craters at centre. Image specially taken for the author by Wesley Higgins of Tecumseh, Oklahoma, USA, using an 18-inch reflector and Infinity 2-1m camera, Multiple Alignment Point Processing (40 points), stack of 500 frames, 2007 August 3.

John McConnell, a second cousin to Eric Lindsay, has been interested in astronomy for more than fifty years. He has a keen interest in the Moon, particularly lunar chemistry and geology, and also in the history of astronomy in Ireland. These interests are complemented by a photographic collection which includes images that illustrate the many changes that have occurred in Irish astronomy over the past half-century. John has

been a Fellow of the Royal Astronomical Society for many years, and he served as Chairman of the East Antrim Astronomical Society for eight years. His work for the Northern Ireland astronomical community was recognized by the award in 1999 of the Aidan P. Fitzgerald Medal of the Irish Astronomical Association. In 2001, he was honoured by the IAU when minor planet (9929) was named 'McConnell'.

DR ERIC LINDSAY: PERSONAL RECOLLECTIONS

Derek McNally

17 Greenfield, Hatfield, Herts, AL9 5HW, England, UK.

E-mail: dmn@star.herts.ac.uk

Abstract: Personal recollections of Eric Lindsay are related by Derek McNally, a former Director of the University of London Observatory.

Keywords: Eric Mervyn Lindsay, Ernst Öpik, William McCrea

Eric Lindsay was a highly charming man. He was responsible for getting me interested in astronomy. Indeed, I had thought of Armagh when I finished at Queen's University Belfast (QUB) in 1957, although Dunsink was a more interesting prospect. But I finally succumbed to Bill McCrea as my chances for a Ph.D. were better outside the Irish observatories in those days.

However, Eric helped me enormously in crystal-lizing my ideas. Time was no object for him if he was helping a young person (much to his secretary's disgust). I had been very taken with the seminars that the Armagh people gave at QUB as an undergraduate, and astronomy seemed an exciting way to go—even if I had sworn that astronomy was a 'no-go area' at school.

Eric Lindsay and Ernst Öpik were 'star turns' (at the risk of a pun). Eric believed that physicists were not quite *au fait* with indices—so he wrote out all the zeros for their benefit. One could see Ernst count the zeros and then interrupt: "n zeros too many/too few, Eric, I think".

Sometimes they would dispute fine issues of esoteric (or so it seemed) astrophysics, oblivious of the audience. Astronomy was both entertaining science and entertaining.

We also came to expect 'long' seminars from Ernst, and of course the reciprocal double act. So those two have much to answer for.

Once an accredited astronomer, I found Eric's secretary much less protective of him. But he was still the

source of much good advice—although opportunities to meet him declined as a consequence of geography.

When Bill McCrea was Professor of Mathematics in Belfast, he got on very well with Eric. Bill recounts that Eric did not fit easily into military discipline during World War II. Apparently Eric was often found wanting in the saluting of senior officers—a smile and a nod did for Eric!

You can see I have some very warm memories of the Armagh crowd in the 1950s and 1960s; had it not been for Eric I might have ended up at Culham, in search of fusion-generated power. What an escape!

Derek McNally has spent much of his astronomical working life at the University of London Observatory, serving both as Assistant Director and Director. During the 1960s his research focused on the interstellar medium and star formation, but in the 1970s he turned towards observations of interstellar spectra—in particular the enigmatic diffuse interstellar bands. He has also been much concerned with tertiary education in astronomy through the astronomy degree at University College London. He has served as Secretary and Treasurer of the Royal Astronomical Society and as General Secretary of the International Astronomical Union (1988–1991), and was honoured by the IAU when minor planet (4326) was named 'McNally'. In retirement he has been concerned with adverse environmental impacts on astronomy and the protection of observational astronomy.

DR ERIC LINDSAY: A, B, C, D ... to Z. A PERSONAL RECOLLECTION

Terry Moseley

6 Collinbridge Drive, Newtownabbey, Co. Antrim, BT36 7SX, Northern Ireland, UK.

E-mail: terrymosel@aol.com

Abstract: Personal recollections of Eric Lindsay are related by amateur astronomer and member of the Irish Astronomical Association, Terry Moseley.

Keywords: Eric Mervyn Lindsay, Armagh Observatory, Armagh Planetarium, amateur astronomy

It is an honour to be able to pay this short personal tribute to Dr Lindsay. And thanks also to Pat Corvan, a very old friend of mine, and fellow amateur observer, for some additional information which I'll be recounting.

Firstly, don't worry—I won't be going through the whole alphabet! And secondly, the anecdotes won't be in strict alphabetical order—although I will finish with the 'Z'.

I was lucky enough to grow up beside Armagh Observatory, in a big old house called 'The Pavilion', now sadly demolished to provide the site for the Secondary School and College. I lived there until I was 10. As there was only an empty field in between, the Lindsays were my next-door neighbours. So my earliest recollections of them are in that context, not through astronomy.

Dr Lindsay's son, Derek, who is sadly no longer with us, was a year or two older than me, but we still used to occasionally play together. In my first visit to the Observatory grounds, I spied something I had never seen before—large clumps of bamboo! Up until then, I had thought it grew only in China. But when I saw it, one thought only entered my mind—a fishing rod. Not having the money to buy a proper rod, I was determined to make one. So, early one summer morning, before anyone else was up, I sneaked into the grounds and cut the longest sturdiest piece of bamboo I could find. So my first clear recollection of the Lindsays is one of stealing from the Observatory garden! Mark, you can invoice me later. I'm sure that if I had asked Dr Lindsay he would have been happy to give it to me, but I was too scared and too shy to ask. That was the 'B'.

One evening Derek called for me and asked would I like to go and look at a new comet that had just been discovered. I had no real idea what a comet was, but I had seen the mysterious domes at the Observatory, and knew that there were telescopes inside, so of course I said 'yes'. Obviously 'C' is for Comet. But it could also be for 'calamity', as I was totally underwhelmed!

I can't remember the comet, or even what year it was, but all I saw was a dim fuzzy little smudge in the eyepiece. Maybe that's why I had no further interest in astronomy until I was about 18. And in case you are wondering, it wasn't the lovely and spectacular Comet Arend-Roland which appeared in 1957—I had moved away to a different address by the time it appeared. And you'll all be aware that one of the best photographs of a comet's 'anti-tail' was taken by Eric Lindsay with the 12/18-inch Schmidt here at the Observatory.

Eric Lindsay didn't let things get in his way, not even telegraph poles. During the apparition of Comet Arend-Roland there was a particular pole which was blocking the best view of the Comet from the dome. Yes, you're ahead of me ... he subsequently blamed the felling of the pole on vandals, and who am I to disagree?

Have any of you read *The Dangerous Book for Boys*? It's a rebellion against the over-protective nanny-state that we now live in, where youngsters growing up have to be protected against everything, from nettles to knocked knuckles. It wasn't like that in my day! And that brings me to the 'A'. Dr Lindsay bought Derek a birthday present of a proper archery set, with real steel-tipped arrows. The bow was so powerful that we soon started losing arrows in the trees and shrubbery surrounding the Observatory building. So, the only solution, like Wernher von Braun, was to shoot them straight up and see how high we could fire them.

I well remember playing with Derek on the Observatory lawn a game of 'Sagittarius Chicken': the aim was to fire the arrow straight up, stand still, and see how close to where we were standing the arrow would come down! The best shots landed within about 6 feet. Only if we thought it was going to be a direct hit did we chicken out and run for it! And I'm still here, without a hole in my head, to show that I survived. Now, you're not even allowed into the domes in case you bump your head on the telescope!

Which brings me to the next item. As you know, Patrick Moore came to Armagh in August 1965 as the first Director of the Planetarium. Having just got interested in astronomy, I wrote to Patrick, and to cut a long story short, I immediately started doing serious observing with Patrick using his telescopes. Then Dr Lindsay suggested that we could use the Observatory's 10-inch (25cm) Grubb refractor, which was sitting there unused.

It had a proper dome, and a better horizon than any of Patrick's telescopes. So, along with Pat Corvan, another local amateur, we started doing serious observations, mainly of Jupiter and Saturn, but also of the Moon, the other planets, variable stars, novae, etc. Dr Lindsay would occasionally come out and join us for a chat—or to check up on how we were using his telescope! I was always impressed by how he encouraged and valued our amateur visual observations, when he himself was doing work at a truly professional level. We even published several papers in the *Irish Astronomical Journal* based on our observations. And yes, we did bump our heads on the telescope tube, many

many times. And, no, we never even thought about making a claim!

Of course Patrick was not always there, and I remember that there was something that I particularly wanted to observe one night when he was going to be away. So with great trepidation I rang Dr Lindsay and asked if I could use the telescope on my own. He asked me what I knew about the operation of the telescope, opening and closing the dome, winding up the clockwork, setting the drive at the correct speed, etc., and then said I could come up and he would meet me at the dome just for a final check.

When he saw that I 'knew the ropes'—almost literally, as one used a rope on a pulley to turn the dome—he very kindly said that I could use the telescope any time I wanted, on my own. Imagine what that meant to a young amateur, just about three months after starting in astronomy: being given unlimited access to a telescope at one of only two professional observatories in Ireland! Eric was always very keen to encourage amateurs in astronomy, but it would be rare for that sort of thing to happen nowadays.

On one exceptionally clear night in mid-winter I observed Jupiter continuously from dusk to dawn, a total of 12h 20m. After locking up etc., I was leaving the Observatory at about 8.15 a.m., and Dr Lindsay saw me and asked what I was doing there at that time of the morning, so I explained that I'd just had a great all-night session, observing Jupiter for well over a complete rotation of the planet, and had obtained about 130 surface transit observations. He hardly believed me, so I showed him my observations. Then he said, "Terry, I wish that there were more professional astronomers who had as much dedication as you—well done." That was typical of his attitude, and it was tremendous encouragement for a young astronomer.

After Patrick's arrival in Armagh it was decided to revive the moribund Armagh Centre of the Irish Astronomical Society, and soon we had a good series of lectures going, featuring Dr Lindsay, Professor Ópik, Patrick, and other luminaries. After a while, they must have been running out of proper speakers because Patrick asked me to give a lecture on observing Jupiter.

Patrick had great confidence in me, but I wasn't so sure. After all, I was a 19-year old amateur, with only about one year's experience in astronomy. So I approached Dr Lindsay and said "Look, Patrick has asked me to do this, but I'm not sure I can talk to a group including top professionals like yourself." He replied, "Don't worry, Patrick and I both suggested you at the same time—I know you can do it, and you probably know more about the subject than people like me!"

So my first ever public lecture was to an audience including Eric Lindsay, Professor Ópik, Dr David Andrews, Patrick Moore and a few other local astronomers whom I can't recall. I was shaking, but afterwards Dr Lindsay asked me an easy question which I was able to answer, and at the end he came up to me and complimented me; again typical of his warmth and humanity, and encouragement. I never forgot that.

'D' is for Delphinus. In 1967, the English amateur, George Alcock, discovered a very unusual nova in Delphinus. We immediately started observing it, and

it soon began to behave very oddly, showing a long flat peak, then further brightenings, and didn't reach maximum magnitude until some months after its discovery. I remember standing on the Observatory lawn late one evening, checking it with my binoculars, when Eric came to talk to me. I explained that I'd already observed it earlier that evening, but was having another look. He asked if I was going to record the observation, and I said "No, I'd recorded my magnitude estimate a few hours earlier". He then said something else that has always stuck with me: "An observation that isn't recorded isn't worth making at all. *Always* record every one of your observations, as soon afterwards as possible." And I've always tried to follow that advice.

There was some political unrest here in the 1950s, with a period of IRA bombings and shootings. The Observatory was never attacked, perhaps due to some unusual action by Eric Lindsay himself. According to Pat Corvan, at night he used to cover himself with a white sheet, and ride round the grounds on a bicycle to frighten off any intruders! But one night a local policeman was patrolling, saw the ghost on the bicycle, and being obviously well-trained he gave him a sharp rap on the head with his truncheon as he went past. Nowadays, of course, the matter would immediately be referred to the Police Ombudsman, but I think that in those simpler days neither constable nor Director said any more about it!

Dr Lindsay was also a man of great honesty and integrity. The philanthropist, Chester Beatty, gave a grant of £10,000—which was a lot of money in those days—towards a new mounting for the ADH Telescope in Bloemfontein. But Patrick Wayman, then Director at Dunsink, didn't act promptly enough, and the money could not be spent for that purpose. Rather than try to use it for something else, Dr Lindsay very honestly returned the whole £10,000.

One day in 1968 I'll never forget: I was sick in bed with flu when my mother came in and said "Dr Lindsay is here to see you—can I bring him in?" "Oh, 'expletive deleted'," I thought, "what have I done?" I must have damaged the telescope somehow! Or I've left the dome open, and it has rained and everything is ruined. Or I've left the door unlocked, and someone got in and stole the telescope! You've no idea what terrors were going through my mind!

Anyway, Eric came in and said, "Do you know that Patrick Moore is leaving at the end of May, and that the new Director of the Planetarium will be Dr Tom Rackham from Jodrell Bank?" "Yes", I said. "Well, Tom can't take up the post until October, and I'd like you to be the Interim Director until then." If I hadn't already been in bed, I'd have collapsed! I had been helping Patrick out with star shows in the Planetarium when he was overwhelmed, or away on business, so I had some presenting experience, but to be asked to step into Patrick's shoes as Director was an incredible honour and responsibility. I was just about to say "Yes, of course!", when he said "And we'll pay you £1,000". I would have done it for free! How about that for a summer job for a student? But that again was typical of Eric: no snobbery—I was just a humble amateur with only an O-level in physics, but he thought that I could do the job, and that was all that mattered to him.

Finally to the 'Z'. One clear evening when there was no Moon nor any planets visible I said to Patrick "What else can I observe?" "How about variable stars?", he replied. "OK", said I. So he pulled out a selection of BAA variable star charts and said "Have a look at these."

I had always been fascinated by eruptive variables, so when I spotted one called TZ Persei, which was a Z-Cam type, I said I'd like to have a go at that one. Patrick laughed. He said, "You know that that's right in the Milky Way, and it's normally below 14th magnitude? That's not a good one to start with—you'll never find it!" So of course that was a challenge I couldn't resist, and I'm glad to say that I did indeed find it after about 10 minutes: it was on the edge of the double cluster in Perseus, and was about magnitude 14.3, at 'standstill'.

That was before light pollution struck Armagh, and I doubt if you could see it now, even at maximum. It remains my favourite variable star, and it sort of encapsulates all my favourite memories at Armagh: the generosity of Eric Lindsay for letting us use the telescope unsupervised; the lovely clear dark nights; the

camaraderie between Patrick, Pat Corvan and myself; the good relations between the amateurs and the professionals; and the wise and fatherly presence of Eric Lindsay over all.

Terry Moseley is a member of Northern Ireland's amateur astronomical community, with a record extending to the mid-1960s. An assiduous observer, he has served as President of the Irish Astronomical Association (IAA) three times, and also as Observing Section Director and Public Relations Officer. He received the Aidan P. Fitzgerald medal of the IAA in 1992. Under his leadership the Association's journal *Stardust* has become one of the leading amateur astronomy journals in the UK, and the IAA one of the leading groups in the UK and Ireland. At the Whirlpool Star Party in Birr, County Offaly, on the night of 15/16 September 2001 he became the first amateur astronomer to observe through the recently-restored six-foot reflector, the 'Leviathan of Parsonstown'. In 2003, he was honoured by the IAU when minor planet (16693) was named 'Moseley'.

REMEMBERING ERIC AND SYLVIA LINDSAY DURING THE WAR YEARS

Donald S. Nicholson

*Associate Deputy Director for External Affairs, Mount Wilson Institute,
2124 Linda Flora Dr., Los Angeles, CA 90077, USA.*

E-mail: dnich@alumni.caltech.edu

Abstract: Don Nicholson recalls his WWII service in Northern Ireland and time spent in Armagh with the Lindsays discussing astronomy and enjoying their hospitality.

Keywords: Eric Mervyn Lindsay, Sylvia M. Lindsay, Armagh Observatory, WWII

During WWII I spent from July 1942 to July 1943 in Northern Ireland as a member of the United States Army Air Force. For much of that time I was stationed as a liaison officer with the RAF at Stormont Castle in Belfast. There was, in Belfast, a facility run by the American Red Cross. Since I could have mail delivered there I became acquainted with many of the volunteers. One of them was Sylvia Lindsay, the American-born wife of Dr Eric Lindsay, the Director of the Armagh Observatory. My father, Seth Nicholson, was a member of the staff of the Mount Wilson Observatory and known to Dr Lindsay through their mutual friend, Harlow Shapley. A connection with the Lindsays was quickly established and I was invited to spend as much free time as I had at the Observatory. During those days free time was hardly a common commodity so it was not very often that I was able to get down to Armagh. When I did, however, the Lindsay's hospitality was like an elixir to me. We spent many hours talking astronomy and remembering our many shared friends. I would bring the Lindsays up-to-date with developments at Mount Wilson and they would counter with stories of the tribulations of doing astronomy under wartime restrictions, which stories I could pass back to my parents. I remember vividly the

beautiful Observatory buildings and the surrounding park-like grounds. However tenuous it was, a direct connection between astronomy on each side of the Atlantic did exist for a short time during that difficult period. The fortunes of war, however, found me transferred to England and later to the Soviet Union. It was not until some years later on a visit to Ireland with my wife that I was able to meet again with the Lindsays and to enjoy again their gracious hospitality. They will be long remembered by those who knew them and by others who have been influenced by their example.

Donald (Don) Nicholson, a retired optical engineer, is currently Associate Deputy Director for External Affairs of the Mount Wilson Institute and President of the Mount Wilson Observatory Association. He is a Fellow Emeritus of the Optical Society of America. The son of Dr Seth B. Nicholson of the Mount Wilson Observatory he has had a life-long association with that Observatory. During WWII he served with the United States Army Air Force in the European Theater including a year in Northern Ireland. His present interests are with the history of astronomy in the twentieth century and the encouragement of public interest and participation in astronomy.

SIR ROBERT STAWELL BALL (1840–1913): ROYAL ASTRONOMER IN IRELAND AND ASTRONOMY'S PUBLIC VOICE

Allan Chapman

Wadham College, University of Oxford, Oxford, OX1 3PN, England, UK.

Abstract: Nineteenth-century Ireland, and especially Dublin, had a vibrant scientific tradition. And astronomy in particular was seriously cultivated, being part of an Irish tradition extending back to early medieval times. This paper examines principally the career of Sir Robert Stawell Ball, who, while holding three prestigious posts in Ireland, namely those of Andrews Professor at Trinity College, Dublin, Royal Astronomer of Ireland, and Director of the Dunsink Observatory, became famous for his genius as a popular astronomical interpreter, lecturer, and writer. The paper looks at Ball's wider career, the circumstances that provided a receptive market for astronomical information across the English-speaking world, and his massive outreach as both a lecturer and a writer.

Keywords: Irish astronomy, Dunsink Observatory, Armagh Observatory, Birr Castle, Robert Ball, biography, education and public outreach, nineteenth century astronomy

1 INTRODUCTION

Long before Dr Eric Lindsay became Director of Armagh Observatory, Ireland had a distinguished history in astronomy. It is all the more pity, therefore, that when modern scholars write on the history and achievements of Ireland, their attention invariably comes to focus upon only two, albeit high-profile, topics. One of these is literature, from the Bardic traditions to James Joyce and W. B. Yeats; the other is Ireland's long, complicated, and troubled political history, from Strongbow in the twelfth century down to Sinn Féin and the 'peace process' today. Yet unless an author is writing specifically upon the history of science, mention is rarely made of Irish scientific achievement, especially contributions to astronomy and its related sciences such as optics, physics, and telescope-making, and the communication of astronomical ideas to the general public.

2 THE FOUNDATIONS OF IRISH ASTRONOMY

Who was the first astronomical Irishman? It is hard to be certain, but it cannot be denied that the unknown individual or individuals who laid out the midwinter sunrise alignment at Newgrange around 3,200 BC must have been amongst the first (O'Kelly and O'Kelly, 1982). In more recent times, however, we know that Irish monks before AD 450 and during the following 'saints and scholars' period, were familiar with the elaborate processes by which one calculated the date of Easter for a given year from the spring equinox and the lunar cycle (see Croinin, 1995). This technique was largely regularised by the Venerable Bede of Jarrow in Northumbria around AD 700, and it came to be used across Europe, including Ireland (Ward, 1990: 27-34). What is more, the author of the most widely-read textbook on astronomy in medieval Europe was reputedly an Irishman (although some scholars have claimed that he was a native of Halifax, Yorkshire). He was John of the Holy Wood, Latinized to Johannes de Sacro Bosco, whose *De Sphaera Mundi* of ca. AD 1240 came to be universally known simply as 'Sacrobosco' and was still readily available, by now in printed form, until at least as late as 1647 (Pedersen, 2004).¹ Then in the late seventeenth century there was William Molyneux of Dublin, an astronomer and correspondent of both John Flamsteed and Edmond Halley, whose *Dioptrica Nova* (1693) was the first complete optical treatise to be written in the English language.

It was in the late eighteenth century, however, that Irish astronomy really began to develop. For while Ptolemaic astronomy would have been routinely taught to undergraduates at the early Trinity College, Dublin, after its foundation in 1591—perhaps from printed copies of Sacrobosco and more certainly from Ptolemy—it was the founding of two major observatories that firmly established modern research astronomy upon Irish soil. In 1783 Trinity College founded Dunsink Observatory, accommodated in elegant buildings and containing state-of-the-art research instruments, five miles north-west of Dublin (Ball, 1895: 233ff; Wayman, 1987). This was to be used by Trinity's Andrews Professor of Astronomy, and 91 years after its establishment, would come to be directed by Professor Sir Robert Stawell Ball. The other was Armagh Observatory, founded by Archbishop Robinson of Armagh in 1789-1791, though it only really became fit for major astronomical research after one of Robinson's successors, Archbishop Lord John Beresford, effectively re-endowed it in 1827. The formidable Revd Dr Thomas Romney Robinson (no relation of the founder), and himself a Trinity College man, would direct Armagh between 1823 and 1882, and would be succeeded by Eric Lindsay in 1937.

Indeed, it is interesting to note that Armagh Observatory was founded by, and effectively re-equipped by two Archbishops of Armagh, while both Dunsink and Armagh had Observatory Directors who were Church of Ireland clergymen: the Revd Dr Ussher at Dunsink and T.R. Robinson at Armagh (Ball, 1883; Bennett, 1990). For in the eighteenth and nineteenth centuries people saw astronomy as a theologically-potent subject, as the logical and mathematical mind of man observed, calculated, and thought its way towards an understanding of the logical and mathematical mind of God, to see astronomy as a truly sublime science.

Both Armagh and Dunsink, as well as several private observatories operated by independent gentlemen, were equipped with instruments for the undertaking of positional astronomy. Dunsink, for instance, had an 8-foot-diameter meridian circle built by Jesse Ramsden and Matthew Berge of London which, in 1808, was one of the most advanced astronomical instruments in Europe, while in 1827 Armagh obtained a fine mural circle and transit by Thomas Jones of London, as well as precision clocks and achromatic telescopes. In fact, in the decades immediately following their foundation,

both Dunsink and Armagh had better and more modern instruments than were available to the Astronomer Royal at Greenwich, for the great north- and south-facing quadrants at the Royal Observatory, which were built in 1725 and 1750 respectively, had become out of date—albeit venerable antiques—by the time they were replaced after 1813 (Howse, 1975: 25–26).

Positional astronomy reigned supreme in 1780. The angular positions of the fixed stars were mapped and tabulated, hopefully to within an arc-second of accuracy, in right ascension and declination, and against this stellar ‘framework’ the positions of the Sun, the Moon, the planets, comets and (after 1801) the minor planets, would be measured. It was all part of the wider process of quantifying the Newtonian Universe: before Newton’s theories could be demonstrated as a fact of nature it was first necessary to obtain primary observational data of the highest quality to feed into the equations. Since ancient times, astronomy has earned—and has always retained—its credibility as the most advanced of the sciences, by first harvesting observational data of the highest accuracy before going on to use it to construct theories of the Universe.

Once Dunsink and Armagh Observatories led the way, nineteenth-century Ireland underwent a veritable blossoming in astronomy. At the academic collegiate level the Cork brewer, William Horatio Crawford, founded an astronomical observatory as part of Queen’s College at Cork in 1878 (now University College Cork), an observatory, in fact, with a fascinating architecture in so far as the design was based on an ancient Irish church and cost £10,000. Its long lancet windows were really the slits for the transit instrument, and it was only the dome on the top of the central tower that disclosed its astronomical purpose. The Crawford Observatory comprised a wonderful fusion of modern-day scientific features and ecclesiastical and antiquarian elements (Dreyer, 1884; Grubb, 1880; *The Irish Builder*, 1879).²

Then, in addition to academic foundations, during the nineteenth century Ireland witnessed a flourishing of ‘Grand Amateur’ independently-funded serious research astronomy. Some of these astronomers were comparatively modest in their resources, whilst others were very wealthy. John Birmingham, for instance, was a moderately well-off country gentleman of Tuam in the west of Ireland, who owned a 4.5-inch Cooke refractor and some other relatively modest instruments (Mohr 2004). But Birmingham knew the night sky like the back of his hand, and in 1866 he shot to international fame in the scientific world when he discovered a nova in Corona Borealis. This achievement, in fact, would have been impossible for anyone who did not possess a detailed knowledge of the night sky and an intimate familiarity with star places and brightnesses.

And then there was John William Clerke, who managed the local bank in Skibbereen. He also owned a remarkably good set of scientific instruments, including a 4-inch refractor and, amongst other things, ran the local time service for the neighbourhood (Brück, 2002: 16–18). Clerke was a Protestant graduate of Trinity College, Dublin, but married into the Roman Catholic Deasy brewing family of Clonakilty. Indeed, this harmonious mixed marriage between two middle-

class families itself suggests that we need perhaps to re-evaluate some popular misconceptions about Protestant-Catholic relations in Ireland, at least for the period before the Famine. But one of the astonishing astronomical fruits of the Clerke-Deasy marriage was the daughter, Agnes Clerke, who became in the 1880s (albeit then living in London) what might quite rightly be called the first proper historian of nineteenth-century astronomy, and in particular of astrophysics (Clerke, 1885; see, also, Brück, 2002, 2004).



Figure 1: The restored 72-inch reflecting telescope at Birr on 30 June 1997. Standing in front of the telescope (left to right) are Michael Hoskin, Sir Bernard Lovell and Patrick Wayman (photograph courtesy Mark Bailey).

In addition to these more modest amateurs, Ireland possessed three of the most outstanding ‘Grand Amateurs’ who flourished within Britain and Ireland in the nineteenth century. No one, of course, needs to be told of what Lord Rosse did, for his now-restored great 72-inch telescope is in itself an Irish national monument (see Figure 1). And then there was Edward Joshua Cooper of Markree Castle (County Sligo) who—with the assistance of his paid astronomer, Andrew Graham—compiled a major catalogue of more than 60,000 ecliptic stars (Cooper, 1851–1856) and between the late 1830s and 1860 undertook a long-term programme for the discovery of asteroids (Chapman, 1998: 48–50, 320–21; Glass, 1997: 13–16). Then at Daramona House (County Westmeath) in the 1880s and 1890s, William Edward Wilson (an uncle of Kenneth Essex Edgeworth) collaborated with scientists who included George Francis FitzGerald and George Minchin, and in the mid-1890s made some of the first photometric assessments of stellar brightnesses, although they had been preceded by earlier measure-

ments made in Dublin. He also made pioneering contributions to solar physics and celestial photography (Butler, 1986; Butler and Elliott, 1993; Elliott, 2004).

Victorian Dublin was also the home of one of the most outstanding firms of optical engineers: that of Thomas and his son Sir Howard Grubb. In the early 1830s Thomas Grubb was making his money as a manufacturer of iron-bed billiard tables and from general engineering work; in 1840 he became ‘Engineer to the Bank of Ireland’ where he designed machinery for engraving, printing, and numbering banknotes (Glass, 1997: 21-22). But in 1834 Cooper of Markree commissioned him to build an iron and stone equatorial mount for the 13.3-inch, 25 ft 3 inches focal length achromatic object glass which he had recently acquired from the eminent Parisian optician Robert Aglaé Cauchoix. The success of this instrument led to more astronomical commissions coming in, including an early one for a reflecting telescope from Thomas Romney Robinson of Armagh (Glass, 1997: 13-16). And after making a name for themselves as telescope engineers who mounted other people’s optics, Thomas, and especially Sir Howard, went on to establish a major reputation for the manufacture in their own right of some of the finest-quality large-aperture achromatic lenses and mirrors of the age.

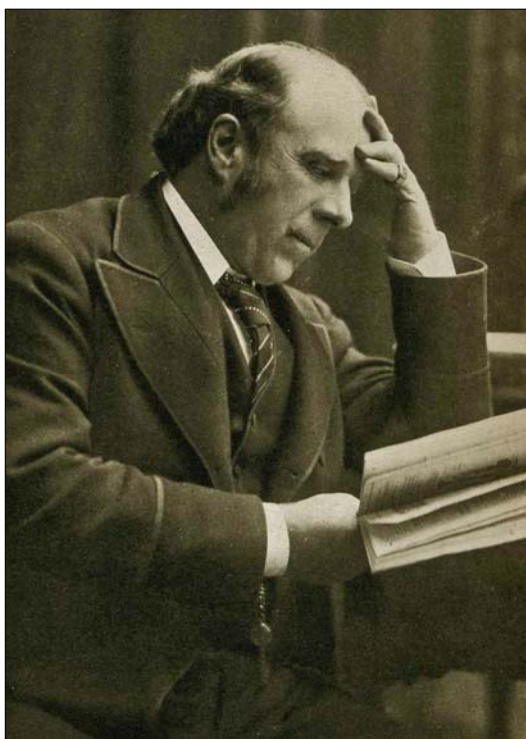


Figure 2: Portrait of Sir Robert Stawell Ball (after Ball, 1915: Frontispiece).

In addition to these above-mentioned Irish astronomers, scientists and precision engineers, there were many more, for it is important to realise that Sir Robert Stawell Ball (Figure 2) was not a ‘one-off’ so much as the product of a varied and vibrant tradition of Irish science, a tradition which, in Dublin in particular, comprised a rich assortment of figures—one of whom, in the medical world for instance, was the eminent surgeon Sir William Wilde, who was Oscar’s father (McGeachie, 2004; Wilson, 1942).

3 SIR ROBERT STAWELL BALL³

One might argue that astronomy was in the ancestry of Sir Robert Stawell Ball. And while it is true that his father, Dr Robert Ball, owned a modest telescope, his real astronomical lineage had made its first public appearance in the 1660s when two of his ancestors, Dr Peter and William Ball, a pair of astronomical brothers from Mamhead, near Exeter, Devonshire, made important observations of Saturn and its rings with a long telescope and communicated them to the *Philosophical Transactions of the Royal Society* (Ball, 1915: 1, 2, 9; Ball and Ball, 1665). Indeed, Peter and William Ball were prominent early and original Fellows of the Royal Society, and were friends of Dr Robert Hooke. And as was the case with so many gentry families looking for opportunities, it was a later seventeenth-century Ball who emigrated to Ireland in the hope of making his fortune, settling in Youghal, and it was from this connection that Sir Robert sprang.

Sir Robert’s father, Dr Robert Ball, had come up from Youghal to Dublin in 1827 to take up a post in Dublin Castle, becoming what might be called a civil servant. Yet as Sir Robert tells us, his father was not really suited to office work, being much more interested in science, and his wider contributions to Irish science and culture had been recognised by the bestowal of a doctorate from Trinity College in 1850 (Ball, 1915: 7-9; Ball, 1927). Indeed, from the 1830s to his sudden death in 1857, Dr Ball had been something of a driving force in Irish cultural life. He had, amongst other things, been the founding Secretary of the Dublin Zoo and Botanical Gardens, and seemed to know everybody who was anybody in Dublin, including scientists, professors, judges, medical men, and that redoubtable ecclesiastical eccentric, the Rt Revd Thomas Whateley, Archbishop of Dublin, with whom the Balls dined from time to time.

Sir Robert’s parents had met at a British Association for the Advancement of Science meeting which took place in Bristol in 1836. On that occasion, the visiting Dr Ball had been entertained by a family living in Queen’s Square, Bristol, where he had met his future wife, Amelia Gresley Helicar, who also had an interest in science. The couple subsequently married, settling in a large house at No. 3 Granby Row, Dublin, and their first son Robert (the astronomer) was born on 1 July 1840. Many decades later, when the British Association was again meeting in Bristol, he told a group of Association members that he was truly a child of the British Association (Ball, 1915: 8-9). Ball was descended, therefore, from a quite comfortably-off and well-known family, and following the sudden death of Dr Ball—whose interests were in natural history rather than physics—young Robert was proud to recall the names of those eminent men of science who had sent condolences to his mother. Sir Richard Owen, the illustrious comparative anatomist, in particular had drawn attention to Dr Ball’s achievements, and had generally visited at 3 Granby Row whenever he was in Dublin.

Sir Robert Ball was, as a subsequent obituarist was to put it, “... the typical Irishman of convention, and his geniality and sense of humour, which were always combined with shrewdness, made him universally popular.” (Ball, 1927). He was, amongst other things, a born raconteur, but he also possessed an acute eye

for human idiosyncrasy. It is also clear that Dr Ball himself was no dour stick, and one senses from his son's subsequent recollections that he had a distinctly scatty sense of humour which his son inherited. Indeed, it seems that one rarely had to probe deeply to find a captivating strain of eccentricity in Victorian Dublin, from Archbishop Whateley's invitation of celebrity mediums to his Palace to try out theologically heterodox séances to a passion for 'charades' and parlour games in the houses of the great and good of Dublin (Ball, 1915: 43-61). It is important to understand a man's personality, background and driving forces if one wishes to make a balanced assessment of his achievements. Robert Stawell Ball was the child of a cultured family living in a world where colourful personal traits, firm friendships, intellectual rigour, courtesy—and fun—were both accepted and respected. And if his education and First Class Degree from Trinity College after 1857 helped to define him as a scientist, so his genial personality, love of telling stories and acute social sense were essential to his subsequent career, first as a tutor, then as a university teacher of brilliance, and by the 1880s as a mesmerising public lecturer.

As a boy and a youth, his mediocre performance as a classical scholar had failed to display his brilliance at Dr Brindley's private school, Tarvin Hall, near Chester, where he had been sent by his parents to obtain his secondary education. His conspicuous gifts for mathematics, mechanics, and experimental science, so it seemed, cut little ice there (Ball, 1915: 18-26). But upon his return to Ireland following his father's death, and his entrance into Trinity as an undergraduate, Ball began to find his intellectual feet. His gift for friendship stood him in good stead, not to mention the good intentions of several Trinity professors who had been friends of his father, and who provided help. But it was at Trinity that Ball's mathematical and scientific talents were properly recognised, while a formative event during his student years had been his reading of the Cincinnati Observatory Director, Ormsby MacKnight Mitchel's *The Orbs of Heaven* (English edition, 1853), which fired his astronomical imagination. Ball also won a series of prestigious scholarships—the Lloyd Exhibition, Gold Medallist in Mathematics, and University Student—which gave him a £100 *per annum* scholarship income for seven years, and enabled him to live without burdening his widowed mother. After completing his degree, he apparently continuing to live at home, at 3 Granby Row—which was a short walk from Trinity—and he was able to undertake independent 'postgraduate' studies (Ball, 1915: 31-32).

Then in 1865, a job opportunity came his way, on the recommendation of his Trinity friend, Dr Johnstone Stoney. William Parsons, Third Earl of Rosse, was looking for a tutor for his youngest sons Randal, Clere, and Charles, and the 25-year-old Ball got the job. Moving to Birr, Ball soon made firm friends with the Earl, who also gave him pretty well full rein with the 72-inch telescope (Figure 3). What an inducement, indeed, to do serious astronomy—having the world's largest telescope at one's personal disposal whenever the Earl himself was not observing! And as the Earl and Countess Mary—herself an expert photographer with serious scientific interests—spent part of each year in London, mainly when Parliament was in

session and the Earl was sitting as Irish Representative Peer in the House of Lords, Ball often travelled with them.

As a former President of the Royal Society, Lord Rosse knew everyone in British science, and made sure that Ball met everybody of note, especially in astronomy. It was in the company of Lord Rosse, for instance, that Ball visited the astrophysical observatory at Tulse Hill in South London, and met its owner, the famous [Sir] William Huggins. Lord Rosse also introduced Ball to their fellow Irish astronomer and nova discoverer, John Birmingham of Tuam (Ball, 1915: 62-79, especially 74; Mohr, 2004).

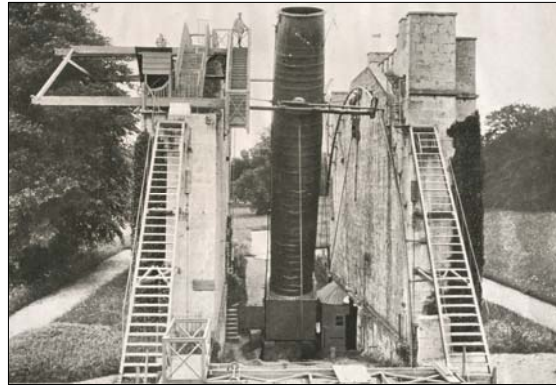


Figure 3: Lord Rosse's 72-inch telescope at Birr Castle (after Ball, 1915).

On the night of 13 November 1866, Ball kept watch for a hoped-for shower of meteors from the constellation of Leo. There had been impressive showers in 1833 and in 1800 (see Dick, 1998), and astronomers wondered, following the suggestion of the German astronomer, Heinrich Olbers, in 1833, if there would be another show in 1866 (Ball, 1915: 70-74; see, also, McCall et al., 2006). There was indeed, and it was spectacular. Ball left a vivid description of the meteor storm which developed as the night of 13 November progressed, and he was one of many astronomers who helped, thereafter, to advance the science of meteor studies, with the realisation that in addition to sporadics there were, perhaps, swarms of meteoroids orbiting around the Sun, and when these swarms crossed the Earth's orbit they would burn up in our upper atmosphere and produce spectacular meteor storms. In 1869 Ball's friend Johnstone Stoney delivered a lecture in which he discussed the possibility of meteor showers being caused by shoals of matter orbiting in space and entering the Earth's atmosphere, while Stoney and the Irish astronomer A.M.W. Downing would become the first, in principle, to use the Leonids as a way of predicting meteor storms (Ball, 1915: 70-72). And nearly two decades later, Ball (1885) would devote a 40-page chapter to 'Shooting Stars' in his best-selling book, *The Story of the Heavens*.

It was also at Birr Castle that Ball undertook his first original piece of research in that branch of mathematical astronomy which he most loved: geometry. From January 1866 to August 1867, he used the great Rosse telescope to observe and measure with a micrometer the exact position angles of numerous small nebulae. Because the telescope was mounted in the altazimuth and not in the equatorial plane, it was necessary to make corrections when reducing the

positions of these and other nebulae in order to establish their precise right ascensions and declinations.

Lord Rosse died (at Birr Castle) on 31 October 1867, following a surgical operation on his knee which seems to have gone wrong—as was not infrequent in that pre-antiseptic era of surgery. Lord Joseph Lister had only just published his preliminary researches into surgical sepsis prevention in March 1867, and it would take a good few years before his ideas about germ infection became generally accepted. Yet Ball's two years at Birr Castle had 'put him on the map' as an astronomer, not to mention his making long-standing friendships with his pupils. One of them, the Hon. Sir Charles Parsons, would go on to become one of the greatest mechanical engineers of his day, and invent the steam turbine engine. It was Parsons' steam launch, *Turbinia*, in fact, which out-raced every ship in the Royal Navy at the Spithead Review in 1897, and a decade later would lead to a revolution in marine engine design (Scaife, 2000).

Back in Dublin, Ball soon found opportunities opening up before him, and in 1867 he was appointed to the Chair of Mathematics and Mechanics at the newly-established Royal College of Science, Dublin. It was in this post that Ball's gifts as a public lecturer soon made themselves obvious, and won him students. But in this respect, Ball had much more than a ready tongue and a pleasing manner: he meticulously prepared his materials, using diagrams, drawings, and lantern slides to communicate concepts in physics and mathematics to his students. And having a permanent job, he now got married, to Miss Frances Elizabeth Steele, who came—like Ball himself—from learned public Dublin, for her father was Curator of the National Museum of Ireland. They enjoyed a long and a happy marriage, and just as Dr Valentine and Sir Charles amongst Ball's own brothers won knighthoods and Fellowships of the Royal Society, so his own children seem to have been successful; it was Robert's son, Valentine, who edited the papers and reminiscences of his father (Ball, 1915: 11).

4 EARLY ACADEMIC CAREER AND RESEARCHES

Although Ball's public academic career began when he was appointed to the Royal College of Science Chair in 1867, his rise to public prominence began in 1874 when he succeeded Dr Franz Friedrich Brünnow as the prestigious Andrews Professor of Astronomy at Trinity College. This was one of the great astronomical chairs, and the foremost astronomical professorship in Ireland, carrying with it the title 'Royal Astronomer of Ireland'. A year later, while still no more than 34 years old, Ball was elected a Fellow of the Royal Society and, in addition to teaching duties in Trinity, became Director of the Dunsink Observatory, which carried with it a fine residence, several acres of land, elegant gardens and stables, and all the necessary appurtenances whereby one might truly live like a gentleman.⁴ But because research was becoming increasingly seen as a defining function of a university professor, Ball felt obliged to find suitable research projects on which to work and, hopefully, make original discoveries.

For six decades up to his death in 1882, Ball's 'opposite number' in Irish astronomy, Thomas Rom-

ney Robinson, had been assiduously observing at Armagh. Most of Robinson's work was devoted to astrometry, such as measuring the right ascensions and declinations of celestial objects and determining the elements of binary star systems. But by 1874, such work—ground-breaking though it might have been in 1830, and useful as it still was—had in many ways become routine.

During the 1860s, a revolution had taken place in astronomy, bringing into life the new sciences of solar physics and astrophysics, with their cascades of spectacular discoveries and their demand for new technologies such as large spectroscopes, photographic apparatus and adjacent chemical laboratories to maintain the research momentum. But in this 'new astronomy' it was the independently-wealthy and therefore administratively-unencumbered 'Grand Amateurs' who had staked out the original territory and had already stolen the lead, and not the academically-accountable public and university observatories. For people like William Huggins (whose private Tulse Hill Observatory in London was visited by Lord Rosse and Ball, probably in 1866), the Americans Lewis Rutherford and Henry Draper, and to some extent the Italian Jesuit Father Angelo Secchi (whose Vatican Observatory stellar spectroscopic researches were funded by the Roman Catholic Church), were all independent scientists, accountable to no Boards of Governors for their time and provision of resources. Indeed, it was not until astrophysics had already proved itself as an awe-inspiring branch of science that any institution (other than the Vatican) was established for its further study, and this came about with the founding of the Potsdam Astrophysical Observatory, in Germany, in 1874.

Robert Ball knew that his professorial resources at Dunsink would not enable him to work in the new science of astrophysics, for Dunsink's instrumentation (just like that of Armagh), excellent as it was in its way, was designed for meridian and astrometric research, and the money was not available to equip the Observatory for astrophysical work. Ball therefore endeavoured to find a serious branch of astronomical research which was firmly within the resources of his institution, and in which he could make a major contribution to the knowledge of the Universe.

One might suggest that his chosen line of research was made in accordance with two factors. One was the instrumental strength of the Dunsink Observatory, and the other was his own natural turn of mind as a scientist. Instrumentally speaking, Dunsink had an excellent 11.75-inch refractor, the object glass of which had been made in Paris 40 years before by the renowned Cauchoix (Figure 4). Having been owned originally by the cantankerous Sir James South, and subsequently presented by him to Trinity College, Dublin, in 1863, it had been beautifully re-mounted soon after in a fine clock-driven iron equatorial mount by Thomas Grubb (Ball, 1897: 12-14; Glass, 1997: 29-32). So Ball had at his disposal a fine old lens which still gave crisp star images, and was set in a beautifully-engineered mount of the latest design. The telescope is still in full working order at Dunsink,⁵ and Ball (1885) supplied a pair of detailed engravings of the interior and exterior of the dome and telescope in his *Story of the Heavens*.

And this chimed in nicely with Ball's scientific interests, for at heart he was a geometer and a theoretical mathematician, with a love of fine technology, who enjoyed the business of astronomical observation. He was not by instinct an experimental physicist, as the new breed of astrophysicists tended to be. Indeed, when he was in Canada and in the United States in 1884, being genuinely impressed by the wonders of multiplex telegraphy and other electromagnetic demonstrations at American scientific institutions, he often lamented his ignorance of electrical physics and its related science and technologies, and, in his travel diary, he noted the need, upon returning to Ireland, to read up on these fascinating subjects (Wayman, 1986).

Considering these factors, therefore, one can understand why Ball decided to pursue astrometric research at Dunsink, where the 11.75-inch refractor—in conjunction with precision micrometers—could be used to detect and to quantify tiny positional changes between the fixed stars. Central to these researches was his project to re-determine several important stellar parallaxes, and most notably that of 61 Cygni (which was first determined by Friedrich Wilhelm Bessel in 1838). But what in many ways must have been more exhausting, from the sheer range and routine of the measurements that had to be made, was the determination of the relative positions, over time, of 368 small red stars (F.W.D. and G.T.B., 1915: xviii; Knobel, 1915: 231-233).

The measurement of the positions of the small red stars promised, in 1874, to be cosmologically significant, for the Italian astronomer, Giovanni Schiaparelli,⁶ had suggested that the small red stars might well form part of a local star cluster to which the Sun could also belong. And if we and this local cluster were moving through space as a gravitational 'family', as it were, then the 368 red stars should display no parallaxes, or else very similar ones as observed against non-red stars that were not part of the cloud. Yet after a decade of meticulous measurement, it became clear that the 368 small red stars did not appear to form part of a cluster. Of course—as Ball was aware—*disproving* a theory also constituted an advancement of knowledge, although his negative results must have been deeply discouraging.

The rest of Ball's career as an observational astronomer at Dunsink, and between 1892 and 1913 as Lowndean Professor at Cambridge, was largely devoted to the meticulous measurement of the parallaxes of a wide variety of stars, for it was from such measurements that astronomers could discover their distances. But this work was seriously affected by the deterioration of his right eye after 1883, the increasingly painful state of which required its surgical removal in 1897. And by the time that he was working at the much better-equipped Cambridge University Observatory,⁷ he was able to use photography as a faster, more time-saving and more accurate method to determine stellar parallaxes than the older 'eye at the micrometer eyepiece' visual technique. By using photography, a star field could be photographed exactly with a 20- or 30-minute guided exposure, and the resulting plate could then be measured at leisure during daylight hours on a specially-devised plate-measuring machine. At Cambridge, however, Ball seems to have done relatively little observing himself, leaving much of the

parallax work, for instance, to his junior colleagues, Arthur Robert Hinks and Henry Norris Russell (F.W.D. and G.T.B., 1915: xix). By the late 1890s, with impaired eyesight and an established international reputation as a writer and lecturer on astronomy, it seems to have been teaching that had the greatest claim upon his time and energies. In this context, his *A Treatise on Spherical Astronomy* (Ball, 1908) was written especially for the use of university students.



Figure 4: The 11.75-inch refractor at Dunsink Observatory, known as the 'South Telescope' after Sir James South who in 1863 presented the lens, made by Cauchoix of Paris in 1829, to Dublin University. It was installed by Thomas Grubb of Dublin in 1868, and was a favourite instrument of Robert Ball. It is still in place. When it was made, the lens was the largest object glass in existence and was used in 1830 by Sir John Herschel to discover the sixth star in the Trapezium in the Orion Nebula. This photograph was taken in the 1950s by Hermann Brück (courtesy of Mary Brück).

5 SIR ROBERT BALL, THE ASTRONOMICAL COMMUNICATOR

Ball's contemporary and enduring historical reputation lies not in his achievements as an observational astronomer, observatory director or theoretical geometer, but as a teacher and interpreter of astronomy. Of course, the appellation 'populariser' springs to mind, and while Sir Robert himself would have eagerly embraced this title, we must not forget that in the century and more since he was active, the term 'populariser' has slid down-market somewhat, and now often carries the overtone of professional 'presenter' rather than front-rank expert discussing state-of-the-art learning, as it did in Victorian times. An indication of this change of usage, indeed, is that when the Irish astronomical historian Agnes Clerke (1885) published her *Popular*

History of Astronomy during the Nineteenth Century she was not averse to using the word ‘Popular’ in the title of a major and quite monumental work of scholarship that described, interpreted and argued its way through the momentous intellectual and technical changes through which astronomy had passed since 1800, and was aimed at a cultivated and literate audience.

But terminology apart, it is clear that Robert Ball was a natural communicator (Figure 5) who was at pains to constantly perfect his art, both as a way of communicating the subject to the wider world and of making a very substantial additional income.

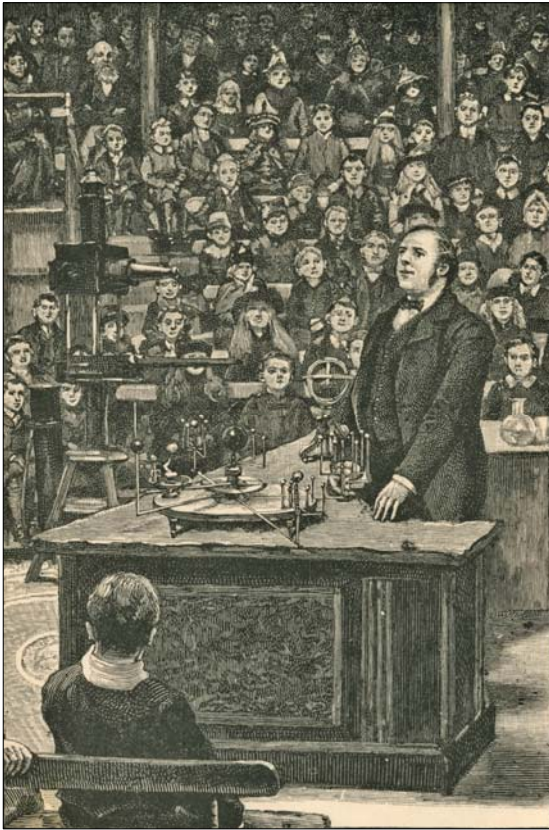


Figure 5: Sir Robert Stawell Ball lecturing to young people at the Royal Institution, London (after Ball, 1889a: Frontispiece; courtesy B. Bartlett).

Ball’s gift as a communicator first seems to have manifested itself around 1859, when, as a Trinity College undergraduate, he delivered an impressive talk on “The Gulf Stream” to a meeting of the Dublin Philosophical Society (Ball, 1915: 118). And then, of course, he became a skilled and confident tutor to the three younger Rosse sons, and had a lifelong effect upon them. Thereafter, both as Professor at the Royal College of Science and as Andrews Professor at Trinity, he became noted not only for the verbal clarity of his lectures, but for the extent to which he would go to devise visual aids to get across complex ideas. These included working models, lantern slides, and even lantern slides with moving parts which simulated—let us say—planetary motion when projected onto the screen. But perhaps even more than all of these things, Robert Ball very clearly *enjoyed* lecturing, and seems to have loved it more and more as the years went by and he became a stunning master of his art.

His first paid lecture—which did little more than cover his expenses with its 14 shillings payment—was given at the Belfast Athenaeum on 4 February 1869 (Ball, 1915: 118). Then, in 1874, he received an invitation to lecture to the Birmingham and Midland Institute. And as he had just taken up his Andrews Professorship at Trinity, he felt it only right that he should speak on an astronomical event, instead of the talk on mechanics which he had been originally requested to deliver, and so he lectured very successfully on the transit of Venus of that year.

But Ball’s enduring career as a lecturer to non-academic audiences really blossomed after 1879, when Richard Anthony Proctor (see Hutchins, 2004) left England to embark on a world lecture tour and needed a replacement for the Gilchrist Trust Lectures, which he was due to deliver. Proctor, who was only three years older than Ball, already enjoyed an illustrious reputation as a serious popular lecturer, although unlike the genial Irishman, he had a difficult and prickly side which won him many enemies in the Royal Astronomical Society and elsewhere. So his world tour of 1879 was something of an escape from the scientific controversies in which he was enmeshed in London. The Gilchrist Trust was a charity that aimed to put on lectures directed mainly at working-class audiences, operating through Mechanics’ Institutions, chapels and other venues. The first of Ball’s Gilchrist Lectures was delivered in Rochdale on 27 January 1880 (Ball, 1915: 216–217), with succeeding lectures in Blackburn and other towns in Lancashire, Yorkshire and elsewhere. The Gilchrist Lectures drew huge crowds, and on one occasion, Ball later recorded, a lecture started 20 minutes before the scheduled time because at that time the hall was already so tightly packed that the chairman declared “Not a single human being can get in, so why delay?” (Ball, 1915: 216). Thus it soon became obvious that in addition to being engaged by what was a charitable body, Ball could also attract serious paying audiences, and his career as a lecturer was born.

In Victorian times, the public lecture—like the sermon—was not only a major instrument of communicating ideas but was a popular social occasion as well (e.g. see Inkster, 1978, 1980). Lectures on all manner of topics were on offer on the commercial circuit, and just like TV agents today, profit-making lecture agencies abounded, especially across the English-speaking world. Explorers, missionaries, military heroes and scientists all offered their wares, and in a major city, such as Manchester or Belfast, a person might choose whether he or she wanted to listen to a lecture on the Solar System, the life of Nelson, ancient Egypt or travels in China. And crucial to this lecture industry was a burgeoning communication system, and a society which had more leisure and more spare cash in its pocket to spend on stimulating nights out. Nor would Ball or any of his fellow-lecturers have got anywhere without a fast and reliable railway system, cheap newspapers and magazines, and the electric telegraph to publicise impending performances, not to mention a host of spacious and comfortable venues (town halls, Free Trade Halls, theatres, institutes, chapels and such) which could seat 1,000 or more people. And by 1884, when Ball embarked upon his first lecture tour of Canada and the USA, fast and luxurious ocean liners and a parallel infrastructure in

the New World and Australia meant that one could comfortably and profitably lecture one's way around the world if one had the standing to attract paying audiences. Indeed, it had been Charles Dickens who led the way with his American tours of 1842 and 1867, where he read selections from his novels, and was mobbed in the streets by ecstatic fans (Ackroyd, 1991). Then two years before Ball, in 1882, Oscar Wilde had embarked upon his own outrageous American tour in the wake of Gilbert and Sullivan's box-office success, *Patience*, lecturing on poetry and aesthetics, resplendent in a get-up somewhat resembling a Little Lord Fauntleroy suit, complete with knee breeches and velvet jacket, with long hair and carrying lilies (Ellmann, 1987).

By 1884, America was fully geared up to mass entertainment of all kinds, with an abundance of comforts and novelties. Some American cities had electric lighting and telephones, while the Madison Square Theatre in New York, even had an ice-blower-cooled air-conditioning system to provide relief from the fierce summer heat (Wayman, 1986: 188). Sir Robert comments on these and other novelties (such as receiving invitations by telephone) in his travel diaries, not to mention details of luxury liners, hotels and restaurants, for he very much enjoyed the luxuries of life.

Over the years, Ball built up a repertoire of lectures which could pack a large theatre, and in his son's *Reminiscences* in particular one learns much about his lecturing circuit. "A Glimpse Through the Corridors of Time", for instance, given to inaugurate the new Lecture Hall at the Birmingham Midland Institute on 24 October 1881, became a perennially popular component of his repertoire. Dealing with the history of the Solar System as it was then understood in terms of gravitational physics, it brought the audience face to face with big concepts regarding time and space. Subsequent lectures on the Moon, the Earth as an astronomical body, volcanoes, the physics and chemistry of the stars, and many more besides indicated that he possessed a formidable armoury of material.

But what was Ball really like as a lecturer? An early glimpse is to be found in some of the reviews published following his first American lectures in 1884. The *Boston Herald* for 15 October 1884, for instance, described him in a recent performance in that city as having hesitant speech, and being "... sometimes clergymanic." On 21 October, on the same lecture tour, he admitted in his diary "I know I stammered and hesitated horribly." These are interesting comments to read about a man who was already reckoned to be a skilled lecturer, although he had to admit that his lecture topic (21 October) on the "Conservation and Dissipation of Energy" was an "... uphill task ...", and no doubt much more demanding on his audience than a well-presented tour of the Solar System (Wayman, 1986: 193).

But what always strikes one is Ball's genuine modesty and willingness to learn from his critics. For Sir Robert was no flouncing celebrity, given to sulking or crying if criticised, but an honest-to-goodness practical man who recognised that the audience paid and that he was the piper, whose tune must be sweet if he was to stay in business. Indeed, taking recent newspaper criticism on board, on 25 October he resolved upon

four points of technique to observe in future lectures. They were: (1) write out lectures and do not improvise; (2) do not speculate, but concentrate on maximum clarity; (3) avoid digressions; and (4) do not make jokes if the joke serves no purpose, otherwise it will only detract from a clear exposition (Wayman, 1986: 194). Indeed, these guidelines are just as good for a lecturer to follow today as they were over 120 years ago, because they are about common sense, and clarity as against showiness.

In that pre-microphone age, Ball took it for granted that clarity of diction and a good, clear, projected delivery were fundamental. And while he eschewed improvised or *ex tempore* lectures, he admitted that, by practice and by sheer repetition, he came to know his various lectures off by heart, so that he often *could* lecture without notes. Across a public lecture career that spans from the 1870s through to 1910, it has been estimated that Ball delivered more than 2,500 lectures (Jones, 2005: 35); we do know that he gave 700 alone between 1874 and 1884 (Ball, 1915: 224). And during the 30-odd years of his career, it has been estimated that around one million people, on both sides of the Atlantic, heard him lecture (Jones, 2005: 35).

Why did he do it, and considering the fact that he was a full-time academic astronomer, in Dublin and, after 1892, in Cambridge—and not a professional lecturer—how did he find the time to lecture so often away from his formal academic bases? Yet in the much more leisurely world of Victorian academe, he seems to have experienced no special difficulty in dividing his year between university teaching and lecture tours. It is notable that after completing his parallax measures of 61 Cygni and other stars in the mid-1880s, he does not seem to have done any more serious astronomical research, which is all the more remarkable, indeed, since he had gravitated to Great Britain's premier university observatory directorship upon becoming Lowndean Professor at Cambridge. But in Cambridge observational research was conducted under Ball's direction, rather than by him personally. In this respect, there were some parallels to Sir George Biddell Airy's management of the Royal Observatory, Greenwich, between 1835 and 1881, for Airy himself hardly ever touched a telescope, although he managed a highly-efficient team of observers.⁸

One reason why Ball lectured so much was because he enjoyed it, for once an art has become second nature to its practitioner it becomes an aspect of one's self-expression. As he once told an enquirer into his mastery of his art, he no more tired of lecturing than a skilled golfer (and Sir Robert loved golf) got tired of potting balls, or 'W.G.' (Dr William Grace, the legendary cricketer) got bored with scoring centuries. So lecturing became a part of his personal expression (Ball, 1915: 220).

But perhaps the real driving force was financial profit, for Ball did not generally lecture gratis, knowing full well how to argue with agents or impressarios in order to obtain the highest fee. When chided about being mercenary, he replied that he lectured "... on behalf of a certain married lady with five children who is solely dependent upon her husband for support ...", since he had a wife and family to maintain (Ball, 1915: 224). He did, however, deliver lectures to charitable bodies for which he claimed no fee. And as he clearly

enjoyed life's luxuries, one can understand how he found a bare professorial salary inadequate and in need of augmentation from elsewhere. Fond of lecturing as he was, Sir Robert would not board a train to cross the country to a lecture venue until his fee and expenses had been agreed upon. And he was not always cheap. In 1908, for example, the Manchester Astronomical Society (1903-1909) minute books record that an attempt to bring him to the City to deliver a public lecture had to be abandoned because the Society could not meet the high fee which he was demanding. Sadly, the exact sum that he asked for is not recorded, but there are several other occasions when explicit sums were discussed. On the other hand, in 1901 Sir Robert lectured gratis in Cardiff, probably to the Astronomical Society of Wales (*The Cambrian Natural Observer*, 1901), and he returned to London by the night train.

Even at the outset of his public lecturing career, on 28 August 1884, Sir Robert certainly knew how to charge. Having recently arrived in Montreal as part of the delegation of scientists attending the British Association for the Advancement of Science meeting in Canada, on that day he was approached by a Boston lecture agent. Ball said that he was willing to lecture at £40 a time, with the agent receiving a 10% commission. However, the tour was a little slow in getting off the ground—understandably so, perhaps, for Ball planned on earning in one hour almost as much as a British labourer would earn in a year—but things eventually took off and by 31 October, when he was preparing to sail home to Ireland, he noted: "... after the lecture [in Boston] I was handed a cheque for 1,000 dollars. I believe that this is the largest sum I have ever received at once." (Wayman, 1986: 195). This would have been equivalent to about £250 sterling. Teething troubles over, the amiable and amenable Ball soon adapted to his American audiences, and on 27 October, towards the end of his tour, he wrote: "I believe I would make £100 a week if I stayed here." (Wayman, 1986: 194-195).

Quite apart from the very lucrative lecture circuit, Ball clearly appreciated the Americans and the Canadians, and he met and socialised with numerous scientists, including Asaph Hall (the discoverer of the Martian satellites) and Charles Young (the spectroscopist who confirmed the presence of the 'reversing layer' in the solar atmosphere). Indeed, he styled the company of his new American friends "... perhaps the most intellectual society I have ever had the good fortune of meeting." (Wayman, 1986: 190). He was also struck by the engaging modesty of these individuals, for when one was dining or talking with a group of American *savants* there seemed to be no one-upmanship or desire to dominate the conversation. Quite simply, they got on well together and discussed ideas in a fair manner. One also wonders to what extent Ball's own jovial personality may have contributed to the merriness of these gatherings. Indeed, Ball was to make return visits to Canada and the USA in 1887 and 1901, and it is apparent that in addition to the dollars, he clearly liked the Americans and felt comfortable with them. In this context, on 14 January 1902 he remarked to a friend as the ship *S.S. Saxonia* approached Ireland after what must have been an exhausting eleven-week tour,⁹ that although he had delivered 48 lectures, shaken hundreds of hands and "... spoken to many thousands ...", he had not seen a

single 'American'. "The American I have *not* seen is the tall, swaggering, tobacco-chewing Uncle Sam of the stage and fiction. I have met scores of the most charming, well-bred, well-educated and cultivated people that this earth can show, but of the dollar-worshipping vulgarian that the American is reputed to be at home I know nothing." (Ball, 1915: 352-353).

Ball lectured at all the great venues of the Victorian and subsequent ages. He regularly addressed the British Association at its annual meetings around Britain, gave Friday Night Discourses at the Royal Institution (see Figure 5), and in 1907 even gave a lecture to 950 prisoners in Dartmoor Gaol. As he amusingly told his son Bill (William Valentine Ball) beforehand, he was going to address a distinguished audience, containing lawyers, clergymen, and other professionals, for as the Governor had mentioned to him, men from such backgrounds would be included amongst his jailbird listeners! (Ball, 1915: 238-239). He was also a gifted lecturer to children, and gave no less than three sets of the celebrated Royal Institution Lectures to young people, in 1881, 1887, and 1898. His best-selling book, *Star-Land* (Ball, 1889a), was the written-up version of his 1887 Children's Lectures, while his very last public lecture, in November 1910, was delivered for the N.S.P.C.C. charity, with tickets selling at 7/6 each (Ball, 1915: 225; Jones, 2005).

Ball kept lecturing because, as he frankly admitted, it was a reliable—and pleasant—way of generating money. But having captivated his audiences on the lecture platform, he realised that he could both acquire further funds and educate a wider public by writing books. He was as facile a writer as he was a lecturer, and from 1885 produced a dozen popular books, in addition to his academic works. As one might expect, when an author feels obliged to generate new popular texts on what is, after all, a very technical subject, there is inevitably a good deal of reworking of familiar material intended for different readerships. His most famous book, *The Story of the Heavens* (Ball, 1885, and subsequent editions), in many ways says it all, with a masterly, equation-free and anecdotal text that teaches the reader pretty well all there was then to know about the Sun, the Earth, the Solar System, stars, nebulae, and deep space, along with an historically-valuable chapter on telescopes and observatories.

He also covered similar ground in his extremely successful *Star-Land* ... (Ball, 1889a), but this was aimed at a younger readership in the wake of his Royal Institution Childrens' Lectures of 1887—which he admits were in themselves a virtual repeat of the lecture series of 1881 (see Ball, 1889a: Preface). A lot of familiar material about the Solar System and gravity also appears in *The Story of the Sun* (Ball, 1893b), plus a new and state-of-the-art treatment of solar physics and spectroscopy, while his *In Starry Realms* (Ball, 1892b) reprints a collection of papers on a wide variety of astronomical topics which he had previously published in magazines such as the *Contemporary Review*, *MacMillan's Magazine*, *Good Words* and *Girls' Own Paper*. And his last Royal Institution Childrens' Lecture Series provided the material for *The Earth's Beginning* (Ball, 1901), which dealt with the origins of the Universe as then understood, spiral nebulae, the Sun, the Solar System, the Earth, earthquakes, and volcanoes. The explosion of the Indo-

nesian island Krakatoa in 1883 had clearly galvanised British public attention, and several of Ball's books deal with the explosion in varying degrees of detail. *In Starry Realms*, for instance, devotes an entire 23-page chapter to the subject of Krakatoa before progressing to a chapter dealing with a wholly different subject: "Darwinism and its Relation to Other Branches of Science".

A Popular Guide to the Heavens, A Series of Eighty-three Plates (Ball, 1905) was in many respects a valedictory work, as the 1910 edition was published within three years of Ball's death. And while confessedly derivative in character, and acknowledging the published works of many of his contemporaries, it was nonetheless an invaluable and sumptuously-produced 'guide to the study of the sky', with detailed regional star charts and photographs which could be used by the aspiring student to find his or her way around the night sky, recognise its principal features, and learn something about the latest discoveries and ideas.

Ball even ventured into the realm of astronomical biography in *Great Astronomers* (1895), where in nineteen chapters he looked at a succession of astronomers starting with Ptolemy, and concluding with John Couch Adams. Though most of the material would have already been fairly well known—at least on an academic level—the book is especially insightful when dealing with Irish astronomers such as John Brinkley (an Englishman by birth) and Sir William Rowan Hamilton (both of whom had preceded Ball both as Andrews Professor and Dunsink Observatory Director), Lord Rosse, who had been his patron and encourager and Adams, whom he succeeded in Cambridge.¹⁰

From an examination of the above, one can come to understand the wider dynamics of Ball's career. His Andrews Chair, Dunsink Directorship, title as Royal Astronomer [*not* Astronomer Royal] of Ireland, and later his Lowndean Chair and Cambridge University Directorship, not to mention his acknowledged brilliance as a university teacher, gave him impeccable academic credentials, but only a modest professional income. It was, however, his popular books that brought both international fame and profit, especially as a given body of research and preparation could be easily made to yield multiple profits. For first of all, Ball would put together a lecture which in itself might go on generating hundreds of pounds by regular repeats as the years went by. Secondly, that lecture could be given a further lease of life in a popular periodical, such as *Macmillan's Magazine*. And thirdly, its contents could be rounded up into a volume of popular essays such as *In Starry Realms*. The Sun, the Moon, the planets, nebulae, Krakatoa and many other topics received this threefold treatment, generating fresh money at each turn. Fortunately, late Victorian Britain had a sufficiently economically, intellectually and regionally diverse population as to enable a popular topic to be addressed to a fourfold paying audience: in lectures, magazines, handsome hard-backed books, and to children.

And just as Ball could demand hefty fees for his lectures, so his books sold not only well, but expensively. The revised 1893 edition of *The Story of the Heavens*, for instance, was sold by Cassell and Company for 12/6 [65p]; the sumptuous *The Story of the Sun*, with its gorgeous full colour plates, for 21/-

(£1.05); while by 1893 *Star-Land* had already sold 20,000 copies and was still going for 6 shillings (30p) a copy.¹¹ I have not been able to discover the royalties that Ball was able to negotiate with Cassells, Isbister, George Phillips and his other publishers, but knowing what we do about his hard-nosed dealings with lecture agents, one suspects that they were very favourable.

In some ways, therefore, it is rather surprising that at his death in 1913 Ball's estate was valued at only £12,045 (Wayman, 2004), although we do not know what monies might have been apportioned beforehand. And while £12,045 was a very handsome sum at that time, one might have expected a larger *post mortem* estate considering his high earning capacity over nearly 30 years. But then again, as he always pointed out, he had a wife and family to maintain and one suspects that he adopted a very high standard of living as a necessary reflection of his status.

6 SUBSEQUENT CAREER

It is not without irony that a man who was so much devoted to a clear, popular understanding of science should have given over his original creative research energies to a branch of mathematical learning which was virtually incomprehensible to all but academic mathematicians. This was his famous 'Theory of Screws'. His ideas in this field were first stimulated in 1869 by Dr Johnstone Stoney in Dublin, and over the years came to be explored in a series of erudite mathematical papers and books that were a million miles away from the works of his popular fame (Ball, 1915: 83-84).

I could not begin to give an account of his Theory of Screws (see Ball, 1900b), although it is important to make it clear that the 'Screws' in question were not of the woodworking variety. They were, rather, mathematical expressions of the torques, vibrations, and wrenches that could pass through a solid extended body that was itself at rest. For this was pure analytical geometry, with no ostensible application to anything, and so abstruse that he told his son Valentine, who was no mathematician, "If I were to begin speaking now, and continued to expound the subject for about six months without interruption, you might have some faint glimmering of what it means." (Ball, 1915: 245). Yet this is what, so he tells us, occupied his mind when it was not devoted to more practical or didactic subjects, for Ball had a sustained and deeply serious commitment to pure mathematics of the most abstract and 'useless' kind. Was his Theory of Screws, along with those other branches of pure mathematics in which he delighted, a sort of intellectual sanctuary into which he retreated when all the talking, handshaking, and public adulation were over for the day? I find this contrast between his outer and inner intellectual lives truly fascinating.

The public Sir Robert, however, was very much of an affable performer. And when not performing before an audience, he loved golf and photography, at both of which he excelled. In 1885, when he succeeded John Tyndall on the Commission of Irish Lights, one of his annual delights was the round-Ireland cruise of the Commissioners (Ball, 1915: 246-266), as it was their job to visit, inspect, and report on each of the many lighthouses around the Irish coast. The cruise, in the luxuriously-appointed Commissioners' steam

yacht *Princess Alexandra* always took place around midsummer, to maximise the natural daylight, and was clearly a pleasant social affair in the ambiance of what seems like a floating gentlemen's club (Figure 6). Not only would visits be made to dangerous outlying lighthouses, but the vessel would often pull into the many small ports around the Irish coast, where the Commissioners would be entertained by the local gentry. One gets the feeling that much was eaten and drunk during the *Princess Alexandra* cruises, and that they also served to supply Ball with a growing fund of humorous and instructive stories about Irish life. Ball continued to cross the Irish Sea to join the Lights Commissioners even after he had moved to Cambridge, and he made his last cruise in 1912.



Figure 6: Sir Robert Ball in holiday mood on the Irish Lights Board steam yacht, *Princess Alexandra*, around 1890 (after Ball, 1915).

Jolly as the Lights Cruises no doubt were, we must not forget that their purpose and business were in deadly earnest, for as everyone knew, sailors' lives depended on lighthouses and their reliability. And as Ball made clear, the late nineteenth century was a time of rapid development in lighthouse technology, as different illuminants, such as oil, coal gas and electricity, were being experimented with, while complementary innovations in lighthouse optics were being made, with the aim of sending out the life-saving beams of light across the greatest possible sea distance (Ball, 1915: 246–248).

Although he spent the last 23 years of his life as a Cambridge don, Ball never ceased to be—as shown above—the archetypal genial, silver-tongued Irishman, and nowhere is this caught better than in the 'Spy' cartoon entitled 'Popular Astronomy' (Figure 7). Here we see the portly Sir Robert, immaculately dressed in a grey morning suit with frock coat, his ample corporation matching the curve of a large celestial globe standing slightly behind him, and with a broad

smile extending across his somewhat flushed cheeks. And although he had lost an eye through disease, his life seems to have been a very happy one, with a good marriage, and children who were themselves successful.

Sir Robert Stawell Ball died in Cambridge on 25 November 1913. And as he had been a Fellow of King's College and a worshipper in its Chapel, his funeral was held there on the 29th, with his favourite hymn, 'Rock of Ages', being sung by the College Choir. He was buried in St. Giles' Churchyard, Cambridge, close to his professional predecessor, John Couch Adams (Ball, 1915: 286).

7 NOTES

1. The author of the original *Dictionary of National Biography* (Oxford, 1880s) thinks that Sacrobosco was a Yorkshire man, but Olaf Pedersen (2004) says that there is no clear pre-sixteenth century source for Sacrobosco's place of birth.
2. I am indebted to Tony Ryan and Dr Ian Elliott for this information.
3. For the details of Ball's career see Ball, 1915: 80–135; Ball, 1927; Chapman, 2006; F.W.D. and G.T.B., 1915; Jones, 2005; Knobel, 1915; Ruis-Castell, 2004; and Wayman, 2004.
4. For the description of the Astronomer's elegant residence I am indebted to Dr Mary Brück, who told me in a private communication (29 September, 2007) that when her late husband, Professor Hermann Brück, became Director, his onetime predecessor, Sir Edmund Whittaker, extolled the Observatory as a place where one "... lived like a gentleman."
5. I had the pleasure of examining this historic telescope in 2004, although on that occasion clouds made it impossible to observe.
6. In 1877 Schiaparelli would amaze astronomers and popularisers when they misinterpreted the meaning of the word *canali*, the lines he claimed to have discovered on Mars.
7. Ball succeeded John Couch Adams, who had first computed the position of the then unknown planet Neptune in 1845–1846.
8. Airy never claimed to be a working observer himself (seeing practical observation as a skill rather than an intellectual activity) so much as the meticulous manager and coordinator of a team of efficient and disciplined observers at Greenwich. Indeed, in 1847 Sir James South complained to the Admiralty that the Astronomer Royal did not observe.
9. During this long voyage, 61-year-old Sir Robert Ball was found to be suffering from diabetes.
10. In addition to the aforementioned titles, Ball also wrote the following popular books: *Astronomy* (Ball, 1877), *Elements of Astronomy* (Ball, 1880), *Time and Tide: A Romance of the Moon* (Ball, 1889b), *The Cause of an Ice Age* (Ball, 1891), *An Atlas of Astronomy* (Ball, 1892a; from 1895 this was titled *The Wonders of the Heavens*), *In the High Heavens* (Ball, 1893a), and *A Primer of Astronomy* (Ball, 1900a).
11. These prices were extracted from the advertisement sheets that followed the Index in the new and revised 1893 edition of *The Story of the Heavens*.

12. *Note added in proofs:* I am indebted to Ian Elliott and David Spearman, who have found from Trinity College Dublin records that whilst he was Andrews Professor of Astronomy at TCD Ball received £700 per year for the support of himself, his Assistant and the gardener, the Assistant also receiving a further sum up to £110 per year from College funds.

8 ACKNOWLEDGEMENTS

I wish to express my appreciation to the following, who have, in various ways, provided me with valuable insight and assistance in the writing of this paper: Ian Elliott, Mary Brück, John Butler, Peter Hingley, Mary Chibnall, and Mark Hurn. I also express my appreciation to the editors, Mark Bailey, Hilmar Duerbeck and Wayne Orchiston, for their tolerance and their support.



Figure 7: The cartoon by ‘Spy’ of Sir Robert Ball that appeared in the magazine *Vanity Fair* in 1904 (courtesy Gerry Morris).

9 REFERENCES

- Ackroyd, Peter, 1991. *Dickens*. London, Minerva.
- Ball, Peter, and Ball, William, 1666. Of an observation, not long since, made in England, of Saturn. *Philosophical Transactions of the Royal Society*, 1, 9, 152-153.
- Ball, R.S., 1877. *Astronomy*. London, Longmans, Green & Co.
- Ball, R.S., 1880. *Elements of Astronomy*. London, Longmans, Green & Co.
- Ball, R.S., 1883. Thomas Romney Robinson (obituary). *Monthly Notices of the Royal Astronomical Society*, 43, 181-183.
- Ball, R.S., 1885. *The Story of the Heavens*. London, Cassell.
- Ball, R.S., 1889a. *Star-Land, Being Talks with Young People about the Wonders of the Heavens*. London, Cassell.
- Ball, R.S., 1889b. *Time and Tide: A Romance of the Moon*. London, S.P.C.K.
- Ball, R.S., 1891. *The Cause of an Ice Age*. [Modern Science Volume 1]. London, Kegan Paul & Co.
- Ball, R.S., 1892a. *An Atlas of Astronomy ...* London, Philip (From 1895 this was published as *A Popular Guide to the Heavens*.)
- Ball, R.S., 1892b. *In Starry Realms*. London, Isbister.
- Ball, R.S., 1893a. *In the High Heavens*. London, Isbister.
- Ball, R.S., 1893b. *The Story of the Sun*. London, Cassell & Co.
- Ball, R.S. 1895. *Great Astronomers*. London, Isbister.
- Ball, R.S., 1900a. *A Primer of Astronomy*. Cambridge, Cambridge University Press.
- Ball, R.S., 1900b. *A Treatise on the Theory of Screws*. Cambridge, Cambridge University Press.
- Ball, R.S., 1901. *The Earth’s Beginning*. London, Cassell & Co.
- Ball, R.S., 1905. *A Popular Guide to the Heavens*. London, G. Philip & Co.
- Ball, R.S., 1908. *A Treatise on Spherical Astronomy*. Cambridge, Cambridge University Press.
- Ball, W. Valentine, 1915. *Reminiscences and Letters of Sir Robert Ball*. London, Cassell.
- Ball, W. Valentine (?), 1927. Robert Stawell Ball. In *Dictionary of National Biography 1912-1921*. London, University Press, Humphrey Milford.
- Bennett, J.A. 1990. *Church, State and Astronomy in Ireland: 200 Years of Armagh Observatory*. Belfast, Armagh Observatory.
- Brück, M., 2002. *Agnes Mary Clerke and the Rise of Astrophysics*. Cambridge, Cambridge University Press.
- Brück, M., 2004. Agnes Mary Clerke: ever-popular historian of astronomy. *The Antiquarian Astronomer*, 1, 2-4.
- Butler, C.J., 1986. Early photoelectric photometry in Dublin and Daramona. *The Irish Astronomical Journal*, 17, 373-377.
- Butler, C.J., and Elliott, I., 1993. Biographical and historical notes on the pioneers of photometry in Ireland. In *Stellar Photometry: Current Techniques and Future Developments* (Proceedings IAU. Colloquium No. 136). Cambridge, Cambridge University Press. Pp. 3-12.
- Chapman, A., 1998. *The Victorian Amateur Astronomer. Independent Astronomical Research in Britain, 1820-1920*. Chichester, Praxis-Wiley.
- Chapman, A., 2006. Ireland’s astronomical muse: Sir Robert Stawell Ball and the Victorian world of astronomy. In Moore, Sir Patrick, and Mason, John (eds.). *2007 Yearbook of Astronomy*. London, Macmillan. Pp. 253-264.
- Clerke, A.M., 1885. *A Popular History of Astronomy during the Nineteenth Century*. Edinburgh, Adam and Charles Black.
- Cooper, E.J., 1851-1856. *Catalogue of Stars near the Ecliptic observed at Markree during the Years 1848, 1849 and 1850 ...* 4 volumes. Dublin, A. Thom.
- Croinin, D.O., 1995. *Early Medieval Ireland, 400-1200*. London, Longman History of Ireland.
- Dick, S.J., 1998. Observation and interpretation of the Leonid meteors over the last millennium. *Journal of Astronomical History and Heritage*, 1, 1-20.
- Dreyer, J.L.E., 1884. Observatory. In *Encyclopaedia Britannica. Volume 17 (Ninth Edition)*. Edinburgh, Adam and Charles Black. Pp. 710-711.
- Elliott, Ian, 2004. William E. Wilson and his contemporaries. *The Antiquarian Astronomer*, 1, 11-12.
- Ellmann, R., 1987. *Oscar Wilde*. London, Penguin.
- F.W.D., and G.T.B., 1915. Sir Robert S. Ball (obituary). *Proceedings of the Royal Society of London, Series A*, 91, xvii-xxi.
- Glass, I.S., 1997. *Victorian Telescope Makers. The Lives and*

- Letters of Thomas and Howard Grubb*. London, Institute of Physics.
- Grubb, H., 1880. On the equatorial telescope and on the new observatory of the Queen's College, Cork. *Scientific Proceedings of the Royal Dublin Society*, 2, 347-369.
- Howse, D., 1975. *Greenwich Observatory, Volume 3: The Buildings and Instruments*. London, Taylor and Francis.
- Hutchins, R., 2004. Richard A. Proctor. In *Oxford Dictionary of National Biography*. Oxford, Oxford University Press.
- Inkster, I., 1978. Robert Goodacre's astronomy lectures (1823-1825), and the structure of scientific culture in Philadelphia. *Annals of Science*, 35, 353-363.
- Inkster, I., 1980. Robert Goodacre (1777–1835) and popular astronomy. *Journal of the British Astronomical Association*, 90, 245-252.
- Jones, R., 2005. Sir Robert Ball: Victorian astronomer and lecturer par excellence. *The Antiquarian Astronomer*, 2, 27-36.
- Knobel, E.B., 1915. R.S. Ball (obituary). *Monthly Notices of the Royal Astronomical Society*, 75, 230-236.
- McCall, G.J.H., Bowden, A.J., and Howarth, R.J. (eds.), 2006. *The History of Meteoritics and Key Meteorite Collections: Fireballs, Falls and Finds*. London, Geological Society.
- McGeachie, J., 2004. Sir William Robert Wills Wilde (1815-76). In *Oxford Dictionary of National Biography*. Oxford, Oxford University Press.
- Manchester Astronomical Society, 'Minute Book 1903-1909'. Account of meeting on 18 September 1908. Original in the Manchester City Library, AS. 472.
- Mitchell, O.M., 1853. *The Orbs of Heaven*. London, Ingram, Cooke & Co.
- Mohr, P., 2004. A star of the western sky: John Birmingham, astronomer and poet. *The Antiquarian Astronomer*, 1, 23-33.
- Molyneux, William, 1693. *Dioptrica Nova: A Treatise of Dioptricks*. London, Benj. Tooke.
- O'Kelly, M.J., and O'Kelly, C., 1982. *Newgrange – Archaeology, Art and Legend*. London, Thames and Hudson.
- Pedersen, O., 2004. Sacrobosco. In *Oxford Dictionary of National Biography*. Oxford, Oxford University Press.
- Ruiz-Castell, P., 2004. Astronomy and its audiences: Robert Ball and popular astronomy in Victorian Britain. *The Antiquarian Astronomer*, 1, 34-39.
- Scaife, W.G., 2000. *From Galaxies to Turbines: Science, Technology and the Parsons Family*. Bristol and Philadelphia, Institute of Physics.
- South, Sir James, 1847. Letter to the Admiralty, dated 12 March. Original in the Royal Greenwich Observatory: (RGO) 6, 2/251-258.
- The Cambrian Natural Observer, IV, New Series 2*, May 1901, pp. 39-40.
- The Irish Builder*, 1 May, 130, and 1 December, 376 (1879).
- Ward, B., S.L.G., 1990. *The Venerable Bede*. London, Geoffrey Chapman, Cassells.
- Wayman, P.A., 1986. A visit to Canada in 1884 by Sir Robert Ball. *The Irish Astronomical Journal*, 17, 185-196.
- Wayman, P.A., 1987. *Dunsink Observatory, 1785-1985: A Bicentennial History*. Dublin, Dublin Institute of Advanced Studies; Royal Dublin Society.
- Wayman, P.A., 2004. Robert Stawell Ball. In *Oxford Dictionary of National Biography*. Oxford, Oxford University Press.
- Wilson, T.G., 1942. *Victorian Doctor: Being the Life of Sir William Wilde*. London, Methuen.

Allan Chapman is an historian of science at Oxford University. His main area of research lies in the history of astronomy and instrumentation. The seventeenth and nineteenth centuries are his principal periods of study, and in the latter, the development of the self-funded, or 'Grand Amateur', tradition of astronomical research in particular. He is a former Professor of Gresham College, London, and since 2002 has been proud to serve as Inaugural Honorary President of the Society for the History of Astronomy. He is also Honorary Vice-President of the William Herschel Society (Bath) and is on the Editorial Board of the *Journal of Astronomical History and Heritage*.

VARIATIONS IN THE EARTH'S CLOCK ERROR ΔT BETWEEN AD 300 AND 800 AS DEDUCED FROM OBSERVATIONS OF SOLAR AND LUNAR ECLIPSES

F. Richard Stephenson

Department of East Asian Studies, Durham University, Elvet Hill, Durham DH1 3TH, England; and Centre for Astronomy, James Cook University, Townsville, Queensland 4811, Australia.

E-mail: f.r.stephenson@durham.ac.uk

Abstract: Historical observations of solar and lunar eclipses provide the most effective method of tracing fluctuations in the Earth's rate of rotation in the pre-telescopic period. However, the temporal distribution of these data—some of which extend back to 700 BC—is far from uniform. Between AD 300 and 800, no more than about fifty usable observations are preserved. Analysis of these data enables variations in the Earth's clock error, ΔT , to be enumerated with tolerable precision during this interval. It is shown that departures from a parabolic fit are fairly small.

Keywords: China, ΔT , Earth rotation, eclipses, Europe

1 INTRODUCTION

As has been appreciated since the eighteenth century, the length of the day (LOD) is by no means constant. Variations in the LOD are produced by lunar and solar tides, as well as by several non-tidal mechanisms. These variations are relatively small, with amplitudes at the millisecond level. However, over many centuries their cumulative effect—the Earth's rotational clock error, usually known as ΔT —may amount to several hours. ΔT is defined as the difference between Terrestrial Time (TT: based on the motion of the Moon and planets) and Universal Time (UT: as measured by the Earth's rotation).

For most of the period since the advent of telescopic astronomy, timings of occultations of stars by the Moon are the most effective way of determining ΔT . These observations enable the variations in this parameter to be charted in detail since around AD 1800 and with fair precision over the previous two centuries (Stephenson and Morrison, 1984). However, in the pre-telescopic period observations of eclipses have proved to be much more useful than occultations. The determination of ΔT over the past few millennia is not only of considerable geophysical significance. Accurate knowledge of the Earth's clock error also enables improved computation of the circumstances of ancient eclipses and other astronomical phenomena, which can be of help in investigating the reliability and accuracy of early observations and also dating historical events.

Numerous observations of solar and lunar eclipses are recorded in ancient and medieval history: notably from Babylon, China, Europe and the Arab lands. Several hundred of these observations are sufficiently precise to enable variations in the Earth's rate of rotation to be investigated in detail. (For a comprehensive discussion see the author's monograph: Stephenson, 1997). Timings of solar and lunar eclipses yield individual results for ΔT , while untimed observations of total or near-total solar eclipses enable limits to be assigned to the value of ΔT . However, untimed reports of lunar eclipse are of little utility since the degree of obscuration of the Moon is independent of ΔT .

Analysis of the various eclipse observations indicates that throughout the interval from 700 BC to AD

1600 the parameter ΔT approximated to the following parabola:

$$\Delta T = 32t^2 \text{ sec} \quad (1)$$

Here t is measured in centuries from the standard reference epoch AD 1820. By fitting spline functions to the data, long-term variations about the mean parabola have been detected (e.g. Morrison and Stephenson, 2001; Stephenson and Morrison, 1995). However, the results of these investigations reveal that the amplitude of the variations did not exceed about 500 sec at any time during the period covered by the observations (see, also, Morrison and Stephenson, 2005; Stephenson, 2006).

Most of the extant eclipse observations originate from two distinct periods: from 700 BC to 50 BC and again from AD 800 to 1600. As a result, the form of the ΔT variations during both of these periods is fairly well-defined. However, between about 50 BC and AD 800, there is a significant lacuna in the available data. This deficiency is particularly serious between 50 BC and AD 300—during which period scarcely any eclipse observations of real value in the study of Earth's past rotation are preserved. The subsequent interval of 500 years is more productive, but even over this period no more than about 50 useful records are extant. Hence in order to study the behaviour of ΔT between AD 300 and 800 it is necessary to investigate each available observation with special care. These data are the subject of the present paper.

In our detailed studies of variations in the Earth's rate of rotation since 700 BC, Leslie Morrison and I included nearly forty eclipse observations made between AD 300 and 800 (e.g. Morrison and Stephenson, 2001; Stephenson and Morrison, 1995). The various data from this period which we investigated originated mainly from China, but a few observations from Europe were also included. In the current paper, I have reanalysed each of the individual observations which we used in our previous researches, reinterpreting some of the records. I have also included some hitherto unused data—also from China. During the selected period, there are no useful observations from Korea, while only a single (brief) report of a total solar eclipse from Japan (in AD 628) merits consideration.

For all eclipse computations, I have adopted a value for the lunar acceleration of -26.0 arcsec/cy²; this is very close to the results derived from lunar laser ranging (Chapront, Chapront-Touze and Francou, 2002; Williams and Dickey, 2003).

2 EUROPEAN RECORDS

Between AD 300 and 800, it would appear that usable observations of only two eclipses—both solar—were recorded in European history. In each case the place of observation is well-established and the date is secure.

2.1 AD 364 June 16

This eclipse was observed by the astronomer Theon of Alexandria, who measured the times of the principal phases. Theon's observations are recorded in Book 6 of his *Commentary* on Ptolemy's *Almagest*, which was written around AD 370. In reporting the eclipse, Theon closely followed the style of the eclipse records cited by Ptolemy himself. Thus Theon quoted the year as the 1,112th year from the era of Nabonassar, which corresponds to AD 364; Theon also cited the date within that year as the 22nd day of the ancient Egyptian month Payni. The equivalent date on the Julian Calendar may thus be reduced to AD 364 June 16. Modern astronomical computations confirm that this eclipse date is exactly correct. The place of observation is certainly Alexandria (latitude = 31.22° N, longitude = 29.92° E), where Theon lived. The degree of obscuration of the Sun would be quite small at Alexandria; for example, using equation (1) the computed magnitude there would be only about 0.38. However, Theon does not give an estimate of the eclipse magnitude, concentrating instead on the measured times.

Fotheringham (1920) translated the relevant part of Theon's report as follows:

And moreover, we observed with the greatest certainty the time of beginning of contact, reckoned by civil and apparent time, as $2\frac{1}{6}$ equinoctial hours after midday, and the time of the middle of the eclipse as $3\frac{1}{2}$ hours, and the time of complete restoration as $4\frac{1}{2}$ hours approximately after the said midday on the 22nd of Payni.

In his translation, based on the Basel edition of Theon—which was published in AD 1538—Fotheringham noted that the time of first contact was measured in equinoctial (= equal) hours. However, Rome (1950) remarks that the Basel edition is rather unreliable. He asserts that in the best manuscript of Theon's *Commentary* the term rendered 'equinoctial' (*ismerinai*) is absent. Rome further points out that Theon, in comparing his measurements of the times of the various phases with the calculated figures based on the tables in Ptolemy's *Almagest*, specifically used seasonal (*emkairikai*) hours. There are thus sound reasons for assuming that all three times measured by Theon were quoted in seasonal (i.e. unequal) hours—each equal to one-twelfth of the interval from sunrise to sunset. In my previous publications—both alone and jointly with Leslie Morrison—I was unaware of the Rome (1950) reference, and thus incorrectly assumed that Theon had used equal hours.

The interval from sunrise to sunset at Alexandria on the day of the eclipse may be calculated as 14.20 h; hence the length of each (daylight) seasonal hour would be 1.18 h. The local apparent times of the three

phases at Alexandria may thus be deduced from Theon's measurements as 15.35 h, 16.50 h and 17.32 h respectively. Comparing the measured times with their computed equivalents, the three ΔT results derived from Theon's individual measurements are respectively: 6,800 sec, 6,000 sec and 6,100 sec.

Theon also observed the total lunar eclipse of AD 364 November 26, but unfortunately he does not record any measurements in his *Commentary*. Instead he merely asserts that the observed times agree with calculation based on Ptolemy's tables. No other eclipse observations (solar or lunar) are recorded by Theon.

2.2 AD 484 January 14

This eclipse, which was total on the Earth's surface, was observed to be extremely large at Athens. The event was recorded by Marinus Neapolitanus in his *Life of Proclus*. The eminent philosopher Proclus was Head of the Platonic Academy at Athens. On his death, which occurred on AD 485 April 17, his pupil Marinus succeeded him in this position. In describing the eclipse, Marinus—who may well have been an eyewitness—wrote as follows:

A year before his death there were various omens. There was an eclipse of the Sun which was so pronounced as to turn day into night and the darkness was deep enough for the stars to be visible; it occurred in the eastern horn of the sign of Capricorn. (Trans. Rosan, 1949: 34).

The only large eclipse visible at Athens—the sole feasible place of observation—for several years around this time took place on AD 484 January 14, and thus not much more than a year before Proclus died; at the time, the Sun (longitude = 295°) was indeed in the sign Capricorn (longitude range 270 – 300°). Hence there can be no doubt about the identity of the eclipse. Preliminary computation using equation (1) indicates that maximum phase occurred close to sunrise. At Athens in January the Sun remains hidden for more than half an hour after sunrise owing to the proximity of Mt Hymettus, so that only the later stages of a sunrise eclipse would be directly visible. This would account for the lack of reference to the degree of obscuration of the Sun at maximal phase.

It would appear from the description—"day into night" and "darkness deep enough for the stars (plural: *asteres*) to be visible"—that the eclipse was either total or on the verge of totality at Athens. This is confirmed by consideration of the visibility of planets and stars. Computation reveals that no planet or star brighter than magnitude 0 would be above the visible horizon around the time of greatest phase. Mercury (magnitude = +0.3, located 25° to the west of the Sun) would be well placed for observation. However, Venus—some 10° to the east of the Sun—would be hidden behind Mt Hymettus.

If the eclipse were fully total at Athens (latitude = 37.98° N, longitude = 23.73° E), a value of ΔT between 4,500 sec and 5,450 sec would be required. For ΔT within this range, the solar altitude at maximal phase would have been low: between 0.3° and 3.6° . If an eclipse of magnitude at least 0.99 is assumed, the derived ΔT limits should be slightly widened to between 4,150 and 5,800 sec. It seems unlikely that a significantly smaller phase could have produced the observed effects.

3 CHINESE RECORDS OF SOLAR AND LUNAR ECLIPSES

At this period, the principal sources of Chinese eclipse records are the official dynastic histories. In these works, observations of eclipses—of both Sun and Moon—are mainly quoted in treatises devoted to a specific subject: usually monographs on astronomy/astrology (*tianwen zhi*), the calendar (*luli zhi*) or the ‘five elements’ (*wuxing zhi*). (N.B. the five elements were water, metal, fire, wood and earth). The eclipse reports in these treatises may be assumed to be based on the records of the court astronomers who made their observations from the imperial observatory at the capital. The records often give careful descriptions of eclipses, sometimes quoting technical information such as the R.A. of the Sun and an estimate of the magnitude and time of occurrence. Reports of solar eclipses are also regularly cited in the imperial annals (*benji*). However, these entries are often devoid of technical details: see Section 4 below.

3.1 Chinese Timings of Solar Eclipses

The earliest record of an eclipse time in Chinese history dates from 134 BC. This was of a solar eclipse and the time of end was estimated to the nearest *shi* (double hour). Each of the twelve double hours was of equal length. The first *shi*, named *zi*, was centred on midnight; it covered the interval from 11 p.m. to 1 a.m. For a full list of the double hours see Table 1. In the centuries following 134 BC, occasional solar eclipse times were quoted to the nearest *shi*, but prior to AD 585 there are only two instances in which higher precision is used: in AD 193 and 493. The eclipse of AD 493 was said to begin at the start of the double hour *wei* (13–15 h). However, in AD 193—and on several dates from AD 585 onwards—solar eclipse times are expressed in both double hours and *ke* (marks). There were 100 marks in a full day and night; the *ke* was thus equal to 0.24 h. For a detailed discussion, see Stephenson (1997: 274ff) and Steele (2000: 178ff).

Between AD 300 and 800, four eclipses of the Sun were timed to the nearest mark, as cited in the official histories of the period. The Julian dates of these events are as follows: AD 585 July 31, 586 December 16, 594 July 23 and 761 August 5. The first three eclipses occurred during the Sui Dynasty and are reported in the calendar treatise (Chapter 17) of the *Suishu*. At this period, the Chinese capital was the then recently-constructed city of Daxing (now Xi’an: latitude = 34.27° N, longitude = 108.90° E). The eclipse of AD 761, which was total, took place during the subsequent Tang Dynasty. Careful timings of the various stages of this event are reported in the astronomical treatise (Chapter 36) of the *Jiu Tangshu*. At this date the capital was Chang’an, built on the site of the Sui capital of Daxing. Only four years prior to the eclipse (AD 757), this city had been restored as the seat of government after its capture by rebels in AD 755.¹

Previously I had rejected most of the above solar timings since I was under the impression that their interpretation was ambiguous. However, I have since benefitted considerably from discussions with Donald Starr of the Department of East Asian Studies, Durham University. The following revised translations owe much to his help:

(i) AD 585 July 31: Kaihuang reign period, 5th year, 6th month, 30th day ... The Sun began to be eclipsed after 6 marks in the hour of *wu*; the loss began from the NW edge; it was $\frac{1}{15}$ (eclipsed). Then after 1 mark in the hour of *wei* it began to reappear. At 5 marks (in the hour of *wei*) it was restored to fullness. (*Suishu*: 17).

(ii) AD 586 December 16: Kaihuang reign period, 6th year, 10th month, 30th day, *dingchou* ... It was seen during the observations that when the Sun rose 1 *zhang* (roughly 10°?) above the mountains, at 2 marks in the hour of *chen*, the eclipse began. The loss began from due west; it was $\frac{2}{3}$ eclipsed. After 2 marks in the hour of *chen* it began to reappear. At the entrance to 3 marks in the hour of *si* it was restored to fullness. (*Suishu*: 17).

(iii) AD 594 July 23: Kaihuang reign period, 14th year, 7th month, the first day of the month ... After the 3rd mark in the hour of *wei* the Sun began to be eclipsed. It began from the NW. The Sun was about half eclipsed; then it entered the clouds and was not seen. The eclipse was briefly seen again but it still had not reached fullness. Then it was immediately obscured by clouds. (*Suishu*: 17).

(iv) AD 761 August 5: Shangyuan reign period, 2nd year, 7th month, day *guiwei*, the first day of the month. The Sun was eclipsed; the large stars were all seen. The Astronomer Royal, Chu Dan, reported: “On day *guiwei* the Sun diminished. Precisely (*zheng*) after 6 marks in the hour of *chen*, the loss began. Precisely after 1 mark in the hour of *si* it was total. At 1 mark before the hour of *wu* it was restored to fullness.” (*Jiu Tangshu*: 36).

Table 1: The twelve double hours.

Double Hour	Local Time (h)
<i>zi</i>	23 – 01
<i>chou</i>	01 – 03
<i>yin</i>	03 – 05
<i>mao</i>	05 – 07
<i>chen</i>	07 – 09
<i>si</i>	09 – 11
<i>wu</i>	11 – 13
<i>wei</i>	13 – 15
<i>shen</i>	15 – 17
<i>yu</i>	17 – 19
<i>xu</i>	19 – 21
<i>hai</i>	21 – 23

For a fifth solar eclipse, observed in AD 768, only an *interval* of time is accurately recorded; the actual local time is only approximately cited, rendering the observation of no real value in the determination of ΔT . Although I shall not discuss this eclipse further, I give below a translation of the text:

AD 768 March 23. Dali reign period, 3rd year, 3rd month, day *yisi*, the first day of the month. From the hour of *wu* it was deficient. After a further 1 mark (*zhi hou yi ke*) it was eclipsed to the extent of $6\frac{1}{2}$ tenths. (*Jiu Tangshu*: 36).

As Needham *et al.* (1986, 199ff.) have emphasized, *ke* were time-intervals, rather than specific moments. Hence an observation said to be made ‘at’ a particular mark could have been made at any time between the beginning and end of that mark. Under these circumstances, when comparing observation with computation it seems most appropriate to take the midpoint of the relevant interval. However, when an observation was said to occur either ‘at the entrance to’ (*ru*) or ‘after’ (*hou*) a particular mark I have assumed the beginning or end of that interval.

The report in AD 586 evidently contains a mistake in citing either the time of first contact or maximal phase since the two times are almost identical (respectively “at 2 marks in the hour of *chen*” and “after 2 marks in the hour of *chen*”). Computation indicates that sunrise at Chang’an on December 16 (assuming a level horizon) would occur at a local time of 7.07 h. near the start of the (double) hour of *chen*. Hence, since the angular equivalent of the linear unit *zhang* can only be crudely estimated, the recorded time for first contact of “2 marks in the hour of *chen*” would seem reasonable. This suggests that the recorded time of maximal phase may be significantly in error. However, it seems best to retain both measurements in subsequent analysis.

Table 2: ΔT values derived from Chinese solar eclipse times recorded in a primary source.

Year	Contact	Double Hour	Mark	Meas LT (h)	ΔT (sec)
493	1	<i>wei</i>	(begin)	13.3	5,200
585	1	<i>wu</i>	6+	12.68	10,100
585	M	<i>wei</i>	1+	13.48	10,400
585	4	<i>wei</i>	5	14.32	10,400
586	1	<i>chen</i>	2	7.60	3,700
586	M	<i>chen</i>	2+	7.72	6,900
586	4	<i>si</i>	3–	9.72	4,900
594	1	<i>wei</i>	3+	13.96	6,300
761	1	<i>chen</i>	6+	8.68	2,300
761	M	<i>si</i>	1+	9.48	3,600
761	4	<i>wu</i>	–1	10.96	3,300

Although the eclipse of AD 761 was recorded as total, the computed semi-duration of the total phase on the central line was only about 2 minutes. Hence in the determination of ΔT from the timing of the onset of totality I have neglected this very short interval. Two of the measurements for this eclipse use the term *zheng* (“precisely”), implying that they were regarded as particularly accurate.

In addition to the above measurements, a solar eclipse timing noted in astronomical treatise (Chapter 12) of the *Nanqishu* also merits investigation. The account of the eclipse of AD 493 January 4 in this treatise relates that “... it was not until the start of the hour *wei* that it was seen that the Sun began to be eclipsed”. The capital of the time was Jiankang (now Nanjing; latitude = 32.03° N, longitude = 118.78° E). The double hour *wei* extended from 13 h to 15 h. Assuming that the observation was made midway through the first third of the double hour *wei*, and thus at approximately 13.3 h, a value for ΔT of around 5,200 sec may be deduced.

Table 3: ΔT values derived from Chinese solar eclipse times recorded in a secondary source: the *Yuanshi*.

Year	Contact	Double Hour	Mark	Meas LT (h)	ΔT (sec)
680	M	<i>si</i>	4	10.08	2,500
700	M	<i>shen</i>	(begin)	15.3	3,500
702	M	<i>shen</i>	3	15.84	2,300
721	M	<i>wu</i>	3+	11.96	2,300

The significant details of the selected timed observations between AD 493 and 761, together with the results of analysis, are summarised in Table 2. In this table I have listed column by column: the year of observation; contact (1 = beginning, M = maximal

phase, 4 = end); double hour; number of marks within the double hour; equivalent measured local time; and the computed value of ΔT . In column 4, a minus sign or plus sign following the appropriate mark indicates an observation at the start or end of that mark. For 4th contact in AD 761, the minus sign *before* the mark number indicates that the observation was said to be made 1 mark before the hour cited.

Additional observations are to be found in the *Shoushili*, the calendar treatise (Chapter 53) of the *Yuanshi*—the official history of the Yuan Dynasty (AD 1261 to 1367). In this treatise, many solar and lunar eclipse times are compiled—some from earlier dynasties; the objective was to test the accuracy of existing eclipse tables. Seven observations of solar eclipses prior to AD 1000 are recorded in this work. These are all from the Tang Dynasty. The Julian dates are: AD 680 November 27, 681 November 16, 691 May 4, 700 May 23, 702 September 26, 707 July 4 and 721 September 26. Presumably, each observation was made at the Tang capital of Chang’an. However, although each eclipse is also reported in the astronomical treatises of both the *Jiu Tangshu* and the *Xin Tangshu*, these works make no mention of any measurements of eclipse times on these dates. Hence corroborative information is lacking.

The *Yuanshi* treatise notes only the time of maximal phase in each case. For instance, the report of the solar eclipse of AD 680 November 27 may be translated as follows:

Tang Dynasty. Yonglong reign period, first year, *gengchen*, 11th month, day *renshen*, the first day of the month. (The Sun) was eclipsed. At 4 marks in the hour of *si*, it reached its maximum. (*Yuanshi*: 53).

For the eclipses of AD 681 and 707, only very approximate times—to the nearest double hour—are quoted in the *Yuanshi*. Hence these two records will not be considered further. The report in AD 700 notes the time as the beginning of the hour *shen*; in this case (as for the eclipse of AD 493 discussed above) I have estimated the time as 0.3 h after the start of the double hour. On the four remaining dates AD 680, 691, 702 and 721, times are given to the nearest mark. Preliminary computations using equation (1) indicate that in AD 691 the eclipse would reach its maximum nearly half an hour before the Sun rose at the Chinese capital of Chang’an. Hence it would be impossible to estimate the time of maximal phase; the recorded time presumably relates to the greatest visible phase—an indeterminate moment. I have thus rejected the observation.

Investigation of the four selected eclipses (AD 680, 700, 702 and 721) is summarised in Table 3. In each case the Tang capital was Chang’an. Data tabulated are as follows: year of observation; contact (M = maximal phase); double hour; number of marks within the double hour; equivalent measured local time; and the result derived for ΔT .

3.2 Chinese Timings of Lunar Eclipses

Reports in Chinese history of fairly precise timings of lunar eclipses—to the nearest 20 or 30 minutes—commence in AD 434. Between this date and AD 596 several times are measured to the nearest fifth of a night watch. Unfortunately, after AD 596, no further lunar eclipse timings are preserved until after AD 900.

By then it had become customary to quote measurements in double hours and marks, as for solar eclipses.

Unlike marks, night watches were not of fixed length but varied with the seasons. The night from dusk to dawn—specifically lasting from 2.5 marks (or 0.6 hours) after sunset to 2.5 marks before sunrise—was subdivided into five equal watches (*geng*). Each of these units was in turn divided into five equal intervals, variously termed *chang* (calls), *chou* (rods), or *tian* (points) in different dynasties. The length of one of these subdivisions varied from about 20 minutes in summer to 30 minutes in winter. As in the case of marks, “calls” (or their equivalent units) were time-intervals. Hence I have assumed that each observation was made at the mid-point of the appropriate time-interval.

The precise Julian dates of the various eclipses are as follows: AD 434 September 5, 437 January 8, 437 July 3, 440 October 26 (all reported in Chapter 12 of the *Songshu*); 543 May 5 (*Yuanshi*, Chapter 53); and 585 January 21, 592 August 28, 593 August 18, 595 December 22 and 596 December 11 (all cited in Chapter 17 of the *Suishu*). The place of observation for the earlier observations—up to and including AD 543—was Jiankang, the capital of the Song and Liang Dynasties. However, the later observations were all made at the Sui capital of Daxing.

As an example, I have selected the account of the eclipse of AD 434 September 5. This was predicted to occur around sunrise (when the new astronomical day began), but was actually observed towards the end of the previous calendar day:

Yuanjia reign period, 11th year, 7th month, 16th day, full Moon. The Moon was eclipsed. The calculated time was the (double) hour of *mao* (5–7 a.m.). On the 15th day, at the second call of the fourth watch, at the start of the hour of *chou* (soon after 1 a.m.) the eclipse began. At the 4th call the eclipse was total ... (*Songshu*: 12).

Two of the lunar observations require special comment. In AD 595, it was reported that the eclipse began after (*hou*) the fourth division of the first watch. On this occasion, I have assumed the end of the fourth division, rather than the middle. Further, in AD 596 it is stated that in the first division of the third watch the Moon was seen through clouds to be already $\frac{3}{15}$ eclipsed. Since the computed interval between 1st and 2nd contact was 1.08 h, and the Moon passed almost centrally through the Earth’s shadow, I have assumed that true first contact would have occurred 0.22 h before the observed LT of 22.97 h and thus around 22.75 h.

In Table 4, the following details are listed, column by column, for each individual measurement: year of occurrence; contact (1 = beginning, 2 = start of totality, 4 = end of eclipse, M = maximal phase of a partial eclipse); number of watch; number of division; measured local time (LT) and result for ΔT in seconds.

4 UNTIMED CHINESE RECORDS OF LARGE SOLAR ECLIPSES

Several total or near-total eclipses are recorded in Chinese history during the interval from AD 300 to 800. An observation of a *total* eclipse can be used to establish limits to the value of ΔT at that date without the need for measurements of time. Alternatively, a

careful observation of a large *partial* eclipse may rule out a discrete range of ΔT values. The standard term to describe a total eclipse is *ji*. This is an archaic expression, use of which can be traced back as far as the 8th century BC in China. Some large partial eclipses are carefully described using the term *bujin rugou* (“not complete and like a hook”). A less definitive expressions is “almost complete” (*ji jin*).

Table 4: ΔT values derived from Chinese timings of lunar eclipses.

Year	CT	Watch	Div	LT (h)	ΔT (sec)
434	1	IV	2	1.61	1,700
434	2	IV	4	2.42	2,800
437a	2	I	3	18.95	7,500
437b	1	II	4	21.97	6,000
437b	2	III	1	22.99	6,500
440	1	II	1	20.71	6,200
440	M	II	3	21.65	8,100
543	1	III	3	0.00	4,600
585	1	I	1	18.01	5,900
585	M	I	4	19.51	5,800
585	4	II	1	20.51	7,100
592	1	I	3	20.07	5,800
593	1	V	1	3.03	4,700
595	1	I	4+	19.60	5,400
595	M	II	3	21.41	4,000
595	4	III	1	22.96	3,500
596	1	III	1–	22.75	4,600
596	4	IV	3	2.58	4,800

4.1 Total Solar Eclipses

In the various official histories of China, accounts of eclipses of the Sun which allege totality come into two main categories. Most accounts merely note that an eclipse was total (*ji*), without supplementary description. However, occasional reports provide additional supporting evidence such as the visibility of several stars. Before proceeding further, it seems important to consider the reliability of the very brief observations in the first of these categories.

Between AD 300 and 800, as many as seven eclipses are recorded simply as total (*ji*), without any qualifying details. Computation reveals that two of these events, occurring on AD 522 June 10 and 756 October 28, were indeed total on the Earth’s surface. However, the remaining five were only *annular*. The Julian dates of these latter eclipses, together with the computed magnitudes in the zone of annularity (figures which are independent of ΔT) are as follows: AD 306 July 27 (0.94), 360 August 28 (0.93), 516 April 16 (0.94), 562 October 14 (0.98) and AD 616 May 21 (0.97). Central annular eclipses, in which the Sun is reduced to a bright ring, are rare at any one place, on average occurring once every 220 years or so (Stephenson, 1997: 54). Hence the probability that five eclipses were annular at the appropriate Chinese capital in a period of about 300 years is rather low.

Annular eclipses are by no means as spectacular as their total counterparts. Hence although accounts of total solar eclipses occur frequently in early literature, descriptions of the ring phase are extremely rare. Throughout Chinese history there appears to be no

evidence to suggest that *ji* (“total”) was ever used as a technical term to indicate a central annular eclipse as well as one that was fully total. On the contrary, an account of the annular eclipse of AD 1292 January 21 in the astronomical treatise (Chapter 48) of the *Yuanshi* clearly describes the ring phase (“the Sun’s body was like a golden ring”). Furthermore, this same text specifically asserts that the eclipse “was not able to be total (*bu neng ji*)”. Investigation of two of the seven allegedly total eclipses listed above (the *annular* eclipses of AD 360 and 562) is also helpful in assessing the reliability of brief reports of totality.

In all, three separate Chinese accounts of the eclipse of AD 360 are preserved. The imperial annals (Chapter 8) of the *Jinshu* allege totality (using the term *ji*), but make no further comment. However, the corresponding account in the five element treatise of the *Songshu* (Chapter 34: section on Jin eclipse records) declares that the eclipse was partial—i.e. “not complete and like a hook”. The astronomical treatise (Chapter 12) of the *Jinshu* confirms that the eclipse was “almost complete”. The capital of the time, where the observation evidently took place, was Luoyang.

Referring now to the annular eclipse of AD 562, computation shows that the magnitude cannot have attained more than 0.50 at the capital of Jiankang (latitude 32.0° N) for any value of ΔT . This eclipse would only be central far to the south; the track of annularity could never have reached further north than latitude 16° N. It seems plausible to infer that this report represents a prediction rather than an observation. Serious attempts at eclipse prediction in China can be traced at least to the Later Han Dynasty (AD 23–220).

The above considerations suggest that the reliability of eclipse records which merely mention the term *ji* (“total”) without confirmatory details is questionable. I shall therefore disregard such reports in the determination of ΔT . This remark will also apply to the only Japanese report of a total solar eclipse during the selected period. Occurring on a Julian date equivalent to AD 628 April 10, this is recorded in the *Nihon Shoki* simply as “complete” (*jin*), without any further description. Further, the place of observation is doubtful: possibly Asakusa (latitude = 34.50° N, longitude = 135.83° E) or perhaps Dazaifu (latitude = 33.52° N, longitude = 130.53° E). In this context, it should be stressed that accounts of celestial phenomena in the various East Asian histories are often no more than brief summaries of the original reports, possibly with the loss of important information. It seems plausible that if an editor lacked the necessary astronomical knowledge he may simply have recorded any unusually large eclipse mentioned in his sources as total.

Fortunately, detailed descriptions of two total solar eclipses observed in China are preserved in the period under discussion: AD 454 August 10 and 761 August 5. In both instances, because of the reported visibility of several stars, we can be much more confident that the extant record of totality is reliable. In this section I have thus restricted my attention to deriving ΔT limits from these two observations.

4.1.1 The Total Solar Eclipse of AD 454 August 10

The five element treatise in the *Songshu* notes the visibility of various stars by day at this total eclipse:

Xiaojian reign period, 1st year, 7th month, day *bingxu*, the first day of the month. The Sun was eclipsed; it was total. The constellations (*xiu*) were brightly lit. (*Songshu*: 34).

Although the year and lunar month are both correct in the above record, the cyclical day is in error; in place of *bingxu* it is necessary to read *bingshen*, which was, in fact, the first day of the 7th lunar month. Evidently a minor scribal error is responsible. Brief reports of this same eclipse are contained in the imperial annals of both the *Songshu* (Chapter 6) and *Nanshi* (Chapter 2). Each source gives the correct date as “7th month, day *bingshen*, the first day of the month.” When this date is converted to the Julian calendar (i.e. AD 454 August 10), it agrees exactly with the computed date of a total solar eclipse visible in China.

The astronomical treatise of the *Songshu* also describes a total solar eclipse which it assigns to the previous year:

Yuanjia reign period, 30th year, 7th month, day *xinchou*, the Sun was eclipsed; it was total and all the stars were seen. (*Songshu*: 34).

This entry is not found in the annals of either the *Songshu* or *Nanshi*. The above date corresponds to AD 453 August 20: precisely twelve lunar months (i.e. one lunar year) before the eclipse of AD 454 August 10. However, there was no eclipse on (or near) that day. Since the only total solar eclipse visible in China for several years around this time occurred in AD 454, it would appear that the compilers of the *Songshi* treatise must have mistakenly filed two separate reports of the same event one year apart.

The assertion of totality in both entries in the astronomical treatise is affirmed by the visibility of many stars. It may further be presumed that in AD 454 totality was witnessed at the capital of the time: Jiankang. Although this is not directly stated in the records, no other place of observation is specified. By comparison, in reporting the solar eclipse of AD 429 December 12, the same treatise of the *Songshu* (Chapter 34), although noting that the eclipse was “not complete and like a hook”, added that “... in Hebei province (in northern China) the Earth was in darkness”. Evidently the description of the partial phase in AD 429 represents the observation at Jiankang.

Somewhat unusually, the configuration of the eclipse track in AD 454 over the Earth’s surface was such that two discrete ranges of ΔT are indicated by the one observation of totality at Jiankang: values of ΔT either between 6,150 and 7,900 sec or between 50 and 1,800 sec would satisfy the observation. The former limits would apply if the eclipse occurred in the early morning (around 8.00 a.m.) the latter in the late morning (around 10.30 a.m.). Unfortunately, the time of day is not recorded, so that both alternatives need to be considered further (see Section 5).

4.1.2 The Total Solar Eclipse of AD 761 August 5

The measured times of this eclipse, as reported in the *tianwen zhi* of the *Jiu Tangshu*, have already been discussed in Section 3.1. However, it seems appropriate to repeat the translation here:

Shangyuan reign period, 2nd year, 7th month, day *guiwei*, the first day of the month. The Sun was

eclipsed; the large stars were all seen. The Astronomer Royal, Chu Dan, reported: “On day *guiwei* the Sun diminished. Precisely after 6 marks in the hour of *chen*, the loss began. Precisely after 1 mark in the hour of *si* it was total. At 1 mark before the hour of *wu* it was restored to fullness.” (*Jiu Tangshu*: 36).

A further account of the same eclipse is to be found in the *tianwen zhi* of the *Xin Tangshu*:

Shangyuan reign period, 2nd year, 7th month, day *guiwei*, the first day of the month. The Sun was eclipsed; it was total. The large stars were all seen. It was 4 deg in *Zhang* (lunar lodge). (*Xin Tangshu*: 32).

Both the incidence of totality and the visibility of “all the large stars” are also briefly reported in the annals (Chapter 10) of the *Jiu Tangshu*. There can thus be no reasonable doubt that the total phase was witnessed at the Tang capital of Chang’an. Computation shows that the eclipse would only be total at Chang’an for values of ΔT between 1,700 and 3,250 sec.

4.2 Very Large Partial Solar Eclipses

Between AD 350 and 800, five eclipses were clearly described as partial, in each case using the expression “not complete and like a hook”. The Julian dates of these events are as follows: AD 360 August 28; 429 December 12; 702 September 26; 729 October 27; and 754 June 25. On the first two dates, the Chinese capital was Jiankang; on the remaining dates the seat of government was Chang’an.

As noted previously (Section 4.1), the first of these eclipses was annular; all the rest were total on the Earth’s surface. The statement in the *Jin* annals that the eclipse of AD 360 was “total” is contradicted in the treatises of both the *Songshu* and *Jinshu*. However, there are no conflicting accounts of the partial phase eclipse of AD 429 (also reported in the *Songshu*) or the three later eclipses of AD 702, 729 and 754 (all recorded in Tang history).

Prior to the Tang Dynasty (which commenced in AD 618), the various imperial annals never describe partial solar eclipses; if the phase was not said to be total, only the mere occurrence of an eclipse is mentioned. However, the Tang annals give detailed descriptions of three partial eclipses: occurring in AD 702, 729 and 754.

The annals (Chapter 6) of the *Jiu Tangshu* record the eclipse of AD 702 in unusual detail: “It was not complete and like a hook; it was seen at the capital and in the four directions.” Similar accounts of a partial phase (i.e. “not complete and like a hook”) are to be found in the *Jiu Tangshu* annals (Chapters 6 and 9) in both AD 729 and 754, but without any comment on the place of observation. The astronomical treatise of the *Xin Tangshu* (Chapter 32) confirms that each of the three eclipses was partial: “almost total” in both AD 702 and 754; and “not complete and like a hook” in AD 729. In each case an estimate of the right ascension of the Sun is quoted to the nearest degree, indicative of an observation by the official astronomers at Chang’an.

According to the *Songshu* treatise (Chapter 34), a star (or stars) was observed during the partial eclipse in AD 429. Computation reveals that on this occasion the track of totality on the terrestrial surface did not extend

further south than latitude 35.0° N. Thus on any value of ΔT the umbral shadow would pass to the north of the Song capital of Jiankang (latitude = 32.0°). Similarly, in AD 754, the zone of totality did not extend further north than 30.0° N, and thus significantly to the south of Chang’an (latitude = 34.3°). Therefore both eclipses would be no more than partial at the respective Chinese capitals, regardless of the value of ΔT . All that can be deduced here is that the report of a partial eclipse in the appropriate official history is confirmed in each case. Computation indicates that the magnitude at Jiankang in AD 429 could never have exceeded 0.94; that at Chang’an in AD 754 would not be greater than 0.86.

Hence there now remain only three partial eclipses which can be used to set viable limits to ΔT : AD 360, 702 and 729. For the first of these events, any value of ΔT less than 7,100 sec or greater than 9,400 sec would produce a partial eclipse at Jiankang. However, all intermediate results (i.e. between 7,100 and 9,400 sec) would render the eclipse annular there, and are thus invalid. Similarly, in AD 702 ΔT could be either less than 1,450 sec or greater than 2,750 sec; results between 1,450 and 2,750 sec are excluded since they would lead to a total eclipse at Chang’an. Finally, in AD 729, only values of ΔT less than 400 sec or greater than 1,200 sec can achieve a partial eclipse at Chang’an.

It is unfortunate that none of the records indicates whether the upper or lower part of the Sun was covered during the eclipse. Such details would have led to only a single range of acceptable ΔT values; however, information of this type tends to be extremely rare throughout ancient or medieval history.

5 DISCUSSION OF RESULTS

The ΔT values and limits derived above are depicted in Figure 1. In this diagram, results obtained from solar eclipse timings are shown by open circles, those from lunar eclipse timings by shaded circles. Heavy vertical lines terminated at each end by short horizontal bars denote limits to ΔT determined from total solar eclipses. Broken vertical lines, each terminated at one end by a horizontal bar and at the other end by an arrow head (the latter implying that they extend beyond the upper or lower edge of the diagram), indicate the set of values of ΔT which ensure a partial eclipse. The mean long-term parabola, $\Delta T = 32t^2$ sec, is also shown for comparison.

In Figure 1, the various ΔT values include more than ten results derived from previously unused timings—mainly of solar eclipses. Over the brief period from AD 585 to AD 596, seventeen separate results obtained from solar and lunar timings (as tabulated in Tables 2 and 4) are displayed in the diagram. These observations are all derived from the same source: the calendar treatise (Chapter 17) of the *Suishu*. Over the relatively brief interval of 12 years which the observations cover, it is probable that the timings would be made by much the same group of court astronomers at the Sui capital of Daxing.

In general, both the solar and lunar timings between AD 585 and 596 provide a reasonably self-consistent set of ΔT results. However—as reference to Table 2 shows—there are three obvious exceptions: in each case observations of the solar eclipse of AD 585. The

three reported times of this event all lead to very high figures for ΔT of between 10,100 and 10,400 sec; these are well above the region covered by Figure 1. Clearly the scatter of the remaining fourteen ΔT values is rather large (emphasizing the low precision of measurement). However, applying equal weights, these data yield a useful mean result for ΔT of $5,200 \pm 300$ sec at the epoch AD 590. This solution, shown by a short dotted line in Figure 1, is in close accord with the figure deduced from Equation (1) at this date: i.e. 4,850 sec.

A plausible explanation of the three anomalous observations of the solar eclipse of AD 585 is a series of scribal errors. Making the simple assumption that each recorded measurement is exactly 1 double hour too early leads to results for ΔT in AD 585 of 4,400, 5,000 and 5,300 sec. These figures are in close accord with those derived from the remaining solar and lunar data in the *Suishu* calendar treatise.

The dates of the nineteen eclipse timings preserved from other periods between AD 300 and 800 (including the three European measurements in AD 364) are much more widespread. Hence the observations can give no more than a general indication of the variation of ΔT over this interval. As is apparent from Figure 1, most of the ΔT values derived from these data roughly follow the long-term parabolic trend. However, the two results from AD 434 are particularly discordant: these are based on measurements of separate stages of the same lunar eclipse (first and second contact). Presumably scribal errors are responsible. It is curious that the most discordant measurements in each of the two Chinese groups of data discussed above are the very earliest: respective dates of AD 585 and 434.

Limits to ΔT as derived from observations of six solar eclipses (three total and three partial) are displayed in Figure 1. For each of the total eclipses of AD 484 and 761, only one set of values of ΔT can satisfy the observation. However, for the total solar eclipse of AD 454 and the partial eclipses of AD 360, 702 and 729, there are two separate regions of solution space. Denoted (a) and (b) for each date, these are separated by wide exclusion zones of width between about 1,000 and 4,000 sec. It is thus necessary to decide between each of the four pairs of alternatives (a) and (b). For AD 360, only solution (a) is shown in Figure 1; the alternative—AD 360(b) (greater than 9,400 sec)—lies well above the region covered by the diagram.

Selection between AD 454(a) and (b) and between AD 729(a) and (b) presents few problems. In each case, effective comparison can be made with a unique set of limits obtained from an observation of totality only a few decades later (respectively in AD 484 and 761). Choice of the alternative limits AD 454(a) and AD 729(a) would necessitate two separate sharp rises in ΔT —each by at least 1,500 sec in only about 30 years. Comparison with the results obtained from several hundred eclipse observations between 700 BC and 50 BC and from AD 800 to 1600 reveals that such rapid changes are unprecedented. As noted earlier (Section 1), at no time during these two periods do the extensive sets of data reveal any evidence of departure from the mean long-term parabola by more than about 500 sec. Further, in these same two lengthy intervals there is no suggestion of any rise in ΔT , only slow variations in the rate of decline (Morrison and Stephenson, 2001; Stephenson and Morrison, 1995).

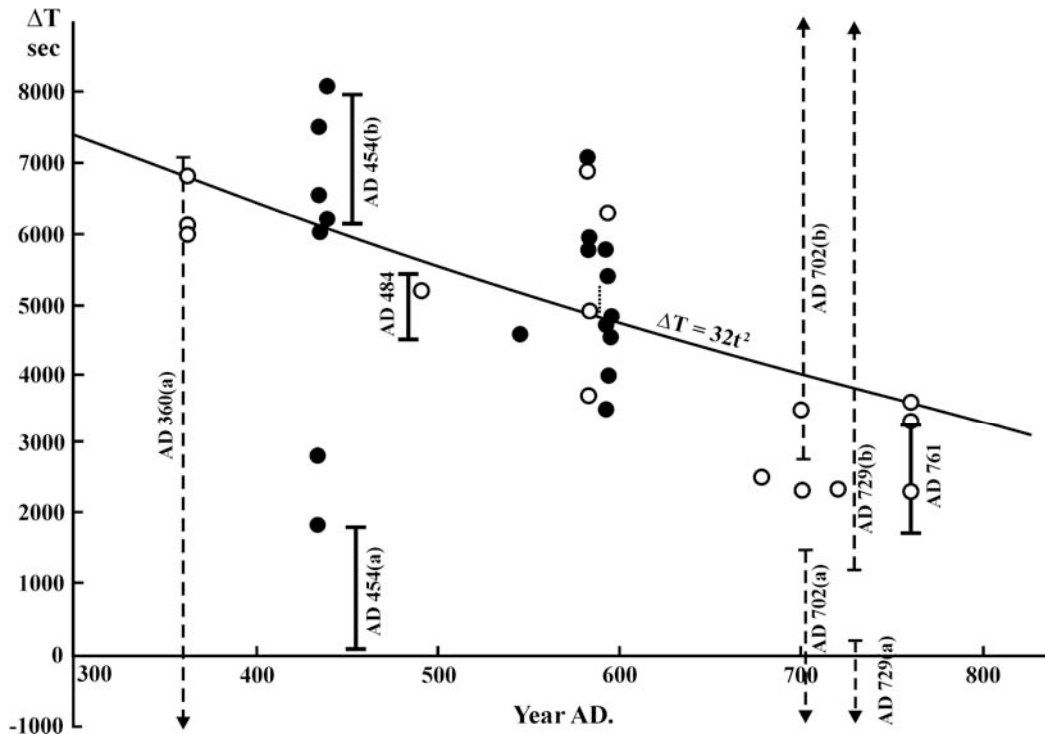


Figure 1: ΔT values and limits derived from solar and lunar eclipse observations between AD 300 and 800.

Hence, rather than invoking major variations in ΔT between AD 300 and 800—which would require complex geophysical explanations—there are sound reasons for rejecting AD 454(a) and AD 729(a) and selecting the alternatives AD 454(b) and AD 729(b). The solution AD 454(b) is in slight discord with that for AD 484, but if a magnitude of 0.99 (rather than full totality) at Athens in AD 484 is accepted—as discussed in Section 3.1—the upper limit to ΔT at that date would be 5,800 sec. This revised limit would be in very close agreement with the AD 454 lower limit.

Acceptance of AD 702(a) rather than AD 702 (b) would only require a minor rise in ΔT between this date and AD 761. Nevertheless, the fact that AD 702(a) lies about 2500 sec below the long-term parabola is probably sufficient reason for rejecting this solution and preferring AD 702(b) instead. Similarly, solution AD 360(b)—which is beyond the upper edge of Figure 1—lies roughly 2,500 sec above the mean parabola and hence may also be rejected.

Figure 2 is copied from Figure 1 but with the discarded (a) solutions—for AD 454, 702 and 729—removed for clarity. It is apparent that the limits set by the five eclipses of AD 360 (partial), 454 (total), 484 (total), 702 (partial) and 761 (total)—together with the mean solution based on most of the timings at Jiankang around AD 590—define a fairly narrow region of ΔT deviating by no more than about 500 sec from the mean long-term parabola. This result is in accord with the variations noted in the centuries prior to AD 300 and after AD 800.

In summary, the various eclipse observations between AD 300 and 800—both timed and untimed—indicate a gradual decline in ΔT , fairly close to the long-term trend.

Kawabata *et al.* (2004) focused their attention on reports of only three solar eclipses—AD 616 (an annular eclipse, but recorded as total in China), AD 628 (total in Japan), and AD 702 (nearly total in China). From their analysis of these observations (together with a reported occultation of Mars by the almost full Moon in AD 681), Kawabata *et al.* proposed a sharp reduction in ΔT in the 7th century AD to between about 2,700 and 3,000 sec. This would require a marked increase in the moment of inertia of the Earth. According to Kawabata *et al.*, a possible explanation is a general rise in sea-level due to an increase in global temperature.

However, as noted above (Section 4.1), the records in both AD 616 and 628 are of questionable reliability; in particular, they merely mention that the eclipse was total without giving any further details. Further it would be difficult for the unaided eye to decide whether a close approach of the bright lunar disc to Mars was an occultation or merely an appulse. The present analysis of a much larger body of data does not support the conclusions of Kawabata *et al.* It is surely important to consider all of the available eclipse data, rather than selecting a few specific examples.

6 CONCLUSION

Over the five centuries covered by the present investigation, eclipse observations reveal that variations in ΔT about the mean long-term parabola $32t^2$ were fairly small, probably at no time exceeding 500 sec. In particular, there is no need to assume any major variations in the Earth's rate of rotation throughout the period covered by the diagram. Hence for historical researches on eclipses and other celestial phenomena throughout the whole of the period from 700 BC to AD 1600, use of Equation (1) is probably satisfactory for most purposes.

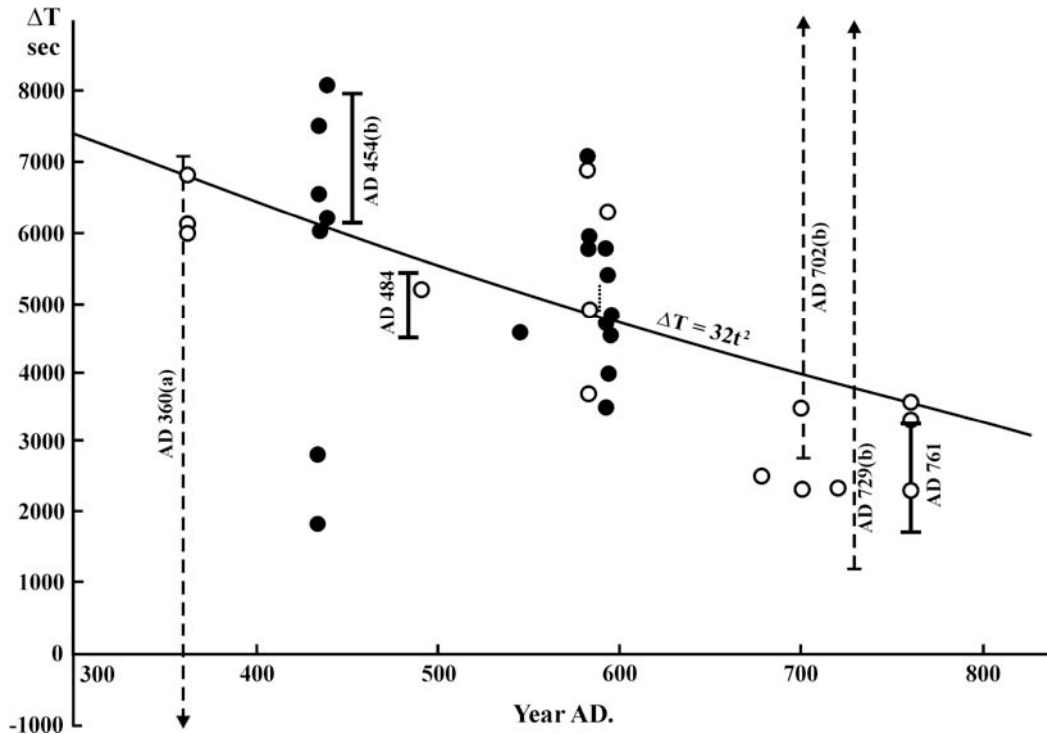


Figure 2: Edited version of Figure 1, with highly discordant sets of limits removed.

7 NOTES

1. It should be mentioned that there are two official histories of the Tang Dynasty. These are the *Jiu Tangshu (Old History of the Tang)*, completed in AD 945, and the *Xin Tangshu (New History of the Tang)*, completed in AD 1060.

8 ACKNOWLEDGMENTS

This research commenced whilst I was a Visiting Professor at the National Astronomical Observatory of Japan (NAOJ) in Tokyo, and was been completed during my tenure of a Leverhulme Emeritus Fellowship at Durham. I am very grateful for these awards and for the opportunities which they have provided. I also wish to express my gratitude to Mr Donald Starr for valuable discussion and for help in translating some of the more difficult Chinese texts. My sincere thanks are also due to both Dr Leslie Morrison and Dr John Steele for reading this paper and offering several valuable comments.

9 REFERENCES

- Chapront, J., Chapront Touze, M., and Francou, G., 2002. A new determination of lunar orbital parameters, precession constant and tidal acceleration from LLR measurements. *Astronomy and Astrophysics*, 387, 700-709.
- Fotheringham, J.K., 1920. A solution of ancient eclipses of the Sun. *Monthly Notices of the Royal Astronomical Society*, 81, 104-126.
- Kawabata, K., Tanikawa, K., and Soma, M., 2004. TT-UT in the seventh century derived from astronomical records in the *Nihongi*, the *Suishu*, and the *Jiu-* and *Xin-Tangshu*. In Orchiston, W., Stephenson, F.R., Débarbat, S. and Nha, I-S. (eds). *Astronomical Instruments and Archives from the Asia-Pacific Region*. Seoul, IAU Commission 41. Pp. 113-118.
- Morrison, L.V., and Stephenson, F.R., 2001. Historical eclipses and the variability of the Earth's rotation. *Journal of Geodynamics*, 32, 247-265.
- Morrison, L.V., and Stephenson, F.R., 2005. Historical values of the Earth's clock error. *Journal for the History of Astronomy*, 35, 329-336.
- Needham, J., Wang Ling, and Price, D.J. de S., 1986. *Heavenly Clockwork*. Cambridge, Cambridge University Press.
- Rome, A., 1950. The calculation of an eclipse of the Sun according to Theon of Alexandria. *Proceedings of the International Congress of Mathematicians, 1950*. Providence, R.I. Pp. 209-219.
- Rosan, L.J., 1949. *The Philosophy of Proclus*. New York, Cosmos.
- Steele, J.M., 2000. *Observations and Predictions of Eclipse Times by Early Astronomers*. Dordrecht, Kluwer.
- Stephenson, F.R., 1997. *Historical Eclipses and Earth's Rotation*. Cambridge, Cambridge University Press.
- Stephenson, F.R., 2006. Babylonian timings of eclipse contacts and the study of Earth's past rotation. *Journal of Astronomical History and Heritage*, 9, 145-150.
- Stephenson, F.R., and Morrison, L.V., 1984. Long term changes in the rotation of the Earth: 700 BC to AD 1980. *Philosophical Transactions of the Royal Society of London, Series A*, 313, 47-70.
- Stephenson, F.R., and Morrison, L.V., 1995. Long term fluctuations in the Earth's rotation: 700 BC to AD 1990. *Philosophical Transactions of the Royal Society of London, Series A*, 351, 165-202.
- Williams, J.G., and Dickey, J.O., 2003. Lunar geophysics, geodesy and dynamics. In Noomen, R., Klosko, S., Noll, C. and Pearlman, M. (eds.). *Proceedings of the 13th International Workshop on Laser Ranging*. Washington, NASA. Pp. 75-86.

F. Richard Stephenson is Emeritus Professor at Durham University, a Leverhulme Emeritus Fellow, and an Adjunct Professor in the Centre for Astronomy at James Cook University, Townsville, Australia. His research interests relate primarily to Applied Historical Astronomy, and he has published numerous papers and books, including *Historical Eclipses and Earth's Rotation* (1997) and *Historical Supernovae and their Remnants* (2002, co-authored by David Green). Richard is a former President of IAU Commission 41 and he is an Advisory Editor for the *Journal for the History of Astronomy* and is on the Editorial Board of the *Journal of Astronomical History and Heritage*.

HIGHLIGHTING THE HISTORY OF FRENCH RADIO ASTRONOMY. 3: THE WÜRZBURG ANTENNAS AT MARCOUSSIS, MEUDON AND NANÇAY

Wayne Orchiston

Centre for Astronomy, James Cook University, Townsville, Queensland 4811, Australia.

E-mail: Wayne.Orchiston@jcu.edu.au

James Lequeux

LERMA, Paris Observatory, 61 av de l'Observatoire, 75014, Paris, France.

E-mail: James.Lequeux@obspm.fr

Jean-Louis Steinberg

Paris Observatory (Meudon), Place Jules Janssen, F-92 195 Meudon Cedex, France.

E-mail: chapias1922@orange.fr

and

Jean Delannoy

244 Chemin de Clos-Marchand, 38330 St. Ismier, France.

E-mail: sylv.delannoy@infonie.fr

Abstract: During the 1940s and 1950s ex-World War II 7.5m Würzburg radar antennas played a crucial role in the early development of radio astronomy in a number of European nations. One of these was France, where three different antennas began to be used during the late 1940s. Two of these were associated with the École Normale Supérieure in Paris, and were initially sited at Marcoussis, near Paris, before being transferred to the Nançay field station in 1957. The third Würzburg antenna was used by staff from the Institut d'Astrophysique de Paris, and was installed at Meudon Observatory on the outskirts of Paris. This paper describes the three antennas, lists the personnel involved, discusses the observations made, evaluates the significance of this research in a national and international context, and comments on their current whereabouts.

Keywords: Würzburg antenna, École Normale Supérieure, Institut d'Astrophysique de Paris, Marcoussis, Nançay, Meudon Observatory, solar radio astronomy, galactic radio astronomy, extragalactic radio astronomy.

1. INTRODUCTION

In the first two decades following World War II, Australia, England, France, Holland, Japan, Norway, Russia and the USA all made important contributions in the newly-emerging field of radio astronomy (e.g. see Burke, 2005; Edge and Mulkay, 1976; Orchiston and Slee, 2005; Strom, 2004; and Sullivan, 1984).

A notable feature of these developments in England, France, Holland, Norway and Russia was the role played by 7.5m Würzburg radar antennas (see Dagkesamanskii, 2007; Edge and Mulkay, 1976; Radhakrishnan, 2006; Smith, 2007; Van Woerden and Strom, 2006). At the end of the War, there were more than 600 abandoned Würzburg *Riese* radar antennas in the Channel Islands, France, Belgium, the Netherlands, Germany, Poland, Sweden, Norway and Austria (see <http://atlantikwall.info/radar/radar.htm>), and so there was the potential for some of these to be salvaged and committed to peacetime research in radio astronomy.

Australia was the only nation prominent in early radio astronomy to place no reliance whatsoever upon these antennas (e.g. see Orchiston et al., 2006), but it is significant that soon after the War ended the 'founding father' of Australian radio astronomy, Joe Pawsey, did in fact investigate the possibility of securing Würzburg antennas and re-locating them to Sydney.

In this paper we investigate the role played by three Würzburg *Riese* antennas in early French astron-

omy.¹ Different localities mentioned in the text are shown in Figure 1.

2. RADIO ASTRONOMY AND THE ÉCOLE NORMALE SUPÉRIEURE

2.1 Introduction

In 1945 Yves Rocard (Figure 2),² Director of 'le Service de Recherche de la Marine Nationale', was appointed Director of the Physics Laboratory at the École Normale Supérieure (henceforth ENS) in Paris. During the War, while Professor of Physics at the Sorbonne, Rocard was a member of an underground British intelligence network in France spying on German radar. In 1943 he was secretly flown to Britain where he worked on radar (Steinberg, 2001). There he became aware of the British detection of metre-wave solar radio emission in 1942, and realised that this could be a fertile research field in the post-War era.

Rocard therefore decided to form a radio astronomy group at the Physics Laboratory in 1946. At the time, staff were wandering the corridors of this new facility wondering what sort of research to get involved in, and Rocard independently approached Jean-François Denisse and Jean-Louis Steinberg suggesting they take up radio astronomy—which they previously had not even heard of. Both readily agreed, and they were soon joined by J. Arzac, E.-J. Blum, A. Boisshot, E. Le Roux and P. Simon (Denisse, 1984).



Figure 1: Map of localities mentioned in the text; the inset map shows France (outline map courtesy of www.theodora.com/maps, used with permission).



Figure 2: Yves Rocard, 1903-1992, Director of the Physics Laboratory at the École Normale Supérieure, and ‘founding father’ of French radio astronomy. This photograph was taken soon after the end of World War II (courtesy: Université Pierre et Marie Curie).

The new radio astronomy team began by erecting a US Air Force 1.5m equatorially-mounted searchlight mirror and an equatorially-mounted array of six Yagi antennas on the roof of the Physics Laboratory (Arsac et al., 1953). The ‘searchlight antenna’ radio telescope was specifically installed so that the fledging radio astronomers could gain experience in the design and construction of instrumentation (Steinberg, 2004a), although it was subsequently used for solar studies. Denisse (1984: 304) reminds us that

During the war years, French research had been isolated from the scientific and technical advances that ensured the rapid development of radio astronomy in the Anglo-Saxon world. [So] The first objective of the group was

therefore to make up for the delays in the French program.

Denisse (ibid.) mentions that a 3m Würzburg dish was also mounted on the roof of the Physics Laboratory, and Steinberg (2001, 2004a) provides confirmation of this. We know that this radio telescope was used for solar research at 1,000 MHz.

2.2 The Marcoussis Würzburg Antennas

After the War Rocard was quick to appreciate the research potential of the 3m and 7.5m German radar antennas that had been abandoned following the War. At the end of hostilities British forces located three of the 7.5m antennas on the French coast. Realising that these three dishes could not easily be transferred to England, the British decided to give them to the French Army, which subsequently distributed them among the French armed forces. The Navy and one of the other armed forces did not want their Würzburg antennas so Rocard made use of his senior naval ranking and his network of service contacts to lay claim to them.

Steinberg was then instructed by Rocard to mount one of the antennas on the roof of the Physics Laboratory in Paris, so he and Seligman (from the Navy) drove to the railway yards at Sevran-Livry in northern Paris where the antenna was in pieces on four railway wagons. One held the cabin, the mounting was on the second wagon, and the dish—which was divided into three parts—was on the third and fourth wagons. Each wagon listed the weight of its load, and upon totalling these Steinberg came up with an overall figure of ~25 tons for the antenna.

Steinberg immediately advised Rocard the antenna was too heavy for the Physics Laboratory roof so Rocard arranged for it to be erected at Marcoussis, a

site ~20km south of Paris which was owned by the Centre de Recherche de la Marine. Rocard had a high position in the Naval Research Department, and Marcoussis was a Naval Research Laboratory. The antenna (which was mounted on a wagon) was installed there on a short set of railway tracks, and later a second Würzburg antenna was placed on a fixed concrete block several hundred metres away.

2.3 Research at Marcoussis

Figure 3 shows the first of the Würzburg antennas installed at Marcoussis. At this time, French radio astronomy focussed on solar research (Denisse, 1984; Orchiston and Steinberg, 2007), and the first serious attempt to carry out research with this radio telescope occurred at 158 MHz on 28 April 1949 when there was a partial solar eclipse visible from Paris.³ Unfortunately, fluctuations in the noise level of ~20% were recorded before and after the eclipse, which meant that the chart record could not be used to investigate the relationship between the eclipse curve and optical features visible on the Sun's disk at the time (Laffineur et al., 1949, 1950; Steinberg, 1953).

By the time the second Würzburg dish was installed, Marius Laffineur from the Institut d'Astrophysique de Paris had developed an electro-mechanical computer drive for a third Würzburg antenna, which was sited at Meudon Observatory, and the ENS contracted him to build a similar drive for the second Marcoussis Würzburg (Steinberg, 2001). Meanwhile, E. Le Roux set to work and constructed a 900 MHz receiver for the first of the two antennas (ibid.), and a stabilised power supply (M. Pick, pers. comm., 2006).

Steinberg (2001: 511) notes that while at Marcoussis the first of the two Würzburg antennas "... was used to observe galactic radiation for the first time in our group ..." (cf. Steinberg, 2004b). This occurred between 1954 and 1956 when it was used to study the Galactic Plane at 900 MHz. This project was led by Steinberg, with assistance from three research students from the ENS, J. Delannoy, J. Lequeux and B. Morlet, who were charged with assessing the properties of the Würzburg antenna and 900 MHz receiver and making various measurements. At this time, the Würzburg was essentially the unmodified wartime radar antenna (except for the new radio astronomy receiver and 900 MHz dipole at the focal point), with the original drive and selsyns to measure azimuth and elevation. Lequeux's first task was to prepare a graph that could be used to convert these units to Hour Angle and Declination, and vice versa.

A transmitter located on a hillside a few kilometres distant was used to calibrate the system. The antenna was moved in various directions and the incoming signal strength was measured. Vertical scans were also made to record radiation from the ground and from the sky (for details see Delannoy et al, 1957). For the galactic observations, parallel scans were made with the antenna fixed and centred on a succession of selected positions. As the sky moved through the beam the output was plotted on a chart recorder, which automatically inserted time marks, but the antenna position for each scan had to be written in by hand. Lequeux and Delannoy recall that by present-day standards the manual reduction of these early observations was rather painful!



Figure 3: The first of the 7.5m Würzburg antennas mounted on a wagon at Marcoussis and ready for use. Providing an indication of scale is a youthful Jean-Louis Steinberg (courtesy: Observatoire de Paris, Meudon).

The initial galactic survey extended from 17h to 21h in Right Ascension, and the results were reported in a paper published in *Comptes Rendus de l'Académie des Sciences* in 1955 (Denisse et al., 1955). This was one of the earliest non-solar French radio astronomy papers (but see the short paper by Blum et al., 1954).

In their paper, Denisse et al. (1955) included an isophote plot of the Galactic Plane at 900 MHz, and this is reproduced here in Figure 4. They also commented that

The emission at 33 cm, due principally to ionized hydrogen,⁴ was observed along the entire length of the galactic equator visible from Paris; until now this result had only been obtained at wavelengths above a metre (from radio sources) and at 21 cm (hydrogen line emission). (Denisse et al., 1955: 279; our translation).

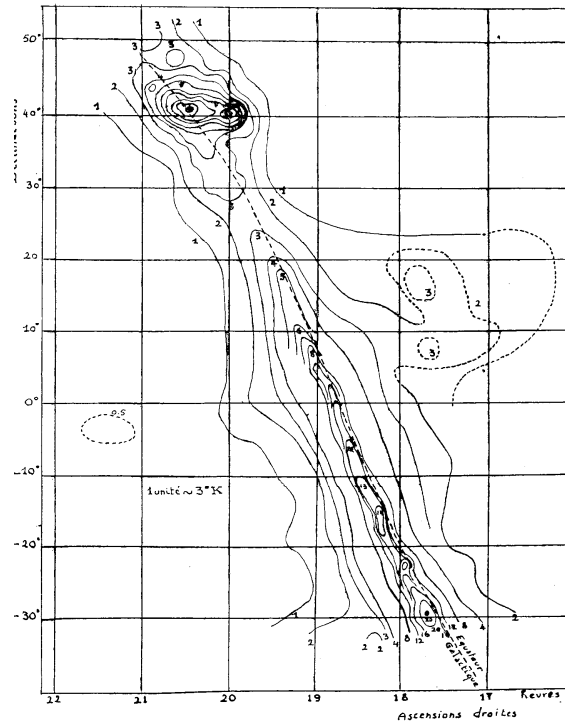


Figure 4: Isophote plot of 900 MHz emission along the Galactic Plane, between R.A. ~16h 30m and 21h 30m, showing a number of discrete sources (after Denisse et al., 1955: 279).

Denisse et al. (1955) also provide a list of the discrete sources detected in the course of the Galactic Plane survey, and these are shown in Table 1. Cygnus A, Cygnus X, Cassiopeia A and Taurus A were well-known to radio astronomers at the time the Marcoussis survey was carried out, but this was not so of Sagittarius A. This discrete source is associated with the Galactic Centre, and although first identified by Piddington and Minnett in 1951 at 1,210 MHz, their paper appeared in a comparatively new Australian scientific journal that was almost unknown to international colleagues.⁵ Subsequently, the existence of Sagittarius A was confirmed by McGee and Bolton (1954) and McGee, Slee and Stanley (1955), and although Bolton actually played no part in this research project (see Orchiston and Slee, 2002) the Australian Sagittarius A identification only became widely-known to the astronomical community when the brief report by him and McGee appeared in *Nature*; this occurred just a short time before Denisse et al. (1955) published their French results.

Table 1: 900 MHz discrete sources along the Galactic Plane identified by Denisse et al. (1955).

No.	R.A.		Dec		Source
	h	m	°	'	
1	17	41	07	35	New source
2	17	43	-29	10	Sagittarius A
3	17	47	16	30	New source
4	17	57	-23	00	M20
5	18	15	-15, -18		M17 nebulae
6	20	00	40	35	Cygnus A
7	20	27	40	45	Cygnus X
8	20	35	48	00	New source
9	20	53	43	45	North American Nebula
10	20	57	50	30	New source
11	21	27	-03	30	New source
12	23	24	58	30	Cassiopeia A
13	05	30	21	35	Taurus A
14	05	32	-05	30	Orion Nebula

Denisse et al. (1957) subsequently published a further paper reporting an extension of their earlier Galactic Plane survey at 900 MHz using one of the Marcoussis Würzburg antennas. Their paper includes two isophote plots, one extending from ~19h 30m in R.A. to 6h and the other from 4h to 8h; the former is reproduced here in Figure 5, and reveals the existence of a number of discrete sources. The authors provided a list of the most conspicuous sources, and these are shown here in Table 2. They also included new more precise flux density values for sources 6, 8, 10 and 12-14 listed in Table 1.

Table 2: 900 MHz discrete sources along the Galactic Plane identified by Denisse et al. (1957).

No.	R.A.		Dec		Source*
	h	m	°	'	
15	20	55	47	00	
16	22	36	64	30	
17	00	20	65	30	Associated with SN1572
18	02	16	62	30	Perhaps HB No. 3
19	03	20	56	00	Perhaps HB No. 7
20	04	51	47	30	Perhaps HB No. 9
21	06	30	05	00	Rosette Nebula

* HB = Hanbury Brown and Hazard (1953).

When discussing the isophote plots, Denisse et al. (1957: 3033; our translation) specifically comment on the

... distinct non-symmetrical structure that extends between Cassiopeia and the North Pole and which was also observed by E.J. Blum at a wavelength of 1.77m. It is perhaps significant to consider that this extensive source is situated in the opposite direction to the Magellanic Clouds [when viewed] in relation to the centre of the Galaxy.

Later observations by other radio astronomers would confirm the existence of this ‘North Polar Spur’, which we now know to be the most conspicuous part of the edge of a giant bubble that is also seen in X-rays and is called Loop I. It was probably produced by a series of supernovae and stellar winds from the nearby Sco-Cen OB association.

In a final short section of their paper, Denisse et al. provide a fascinating comment on the level of galactic background radiation detected in the course of their 900 MHz survey. They reported that when they observed away from the Galactic Plane

Our measurements however allowed us to show that the brightness temperature of the sky is less than 3° K and that variations from one place to another are less than 0.5° K. (Denisse et al., 1957: 3033; our translation).

In the light of Wilson and Penzias’ later pronouncement this would appear to be a very significant result except that in another more definitive account of this 900 MHz French research, Delannoy et al. (1957: 236; our translation) discuss problems associated with accurately measuring the sky background radiation level and conclude:

The preceding discussions reveal that the principal error is the one that results from the measurement of ρ (of the order of 8%) and that all we can conclude is that the temperature of the sky at 900 MHz is certainly not greater than twenty degrees Kelvin.

This differs markedly from their initial assessment.

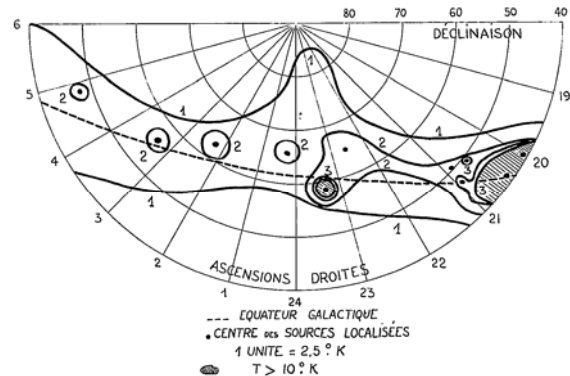


Figure 5: Isophote plot of 900 MHz emission between R.A. ~19h 30m and 6h, showing a number of discrete sources (after Denisse et al., 1957: 3031).

In a perceptive paper published in 1954, Hanbury Brown showed that “... the remnants of supernovae may be expected to form a population of radio sources with characteristics similar to those which have been observed close to the galactic plane.” (Hanbury Brown, 1954: 191). This discovery is consistent with the Marcoussis results, with at least three different supernova remnants represented in Tables 1 and 2

(above). The best-known of these is Taurus A, which was first associated with the AD 1054 supernova by Bolton, Stanley and Slee in 1949.

On 24 January 1956 Taurus A was occulted by the Moon, and this event was observed from Marcoussis with a solar radiometer at 169 MHz and with one of the two Würzburg antennas at 900 MHz (Figure 6). Boischoot et al. (1956: 1851; our translation) found that at this frequency

... the influence of the outer [optical] filaments was not negligible. In effect the first contact (arc I in the figure 3 [reproduced here as Figure 7]) occurred at the moment when these started to be occulted and the radio-emitting centre of the nebula at 900 MHz also corresponded rather precisely with the centre of the mass of the most brilliant filaments.

In the days before radio astronomers had access to sub-milliarcsecond resolution, lunar occultations offered a particularly elegant way of investigating the position and structure of any extended radio source that happened to lie along the Ecliptic. Fortunately, Taurus A was one of these.

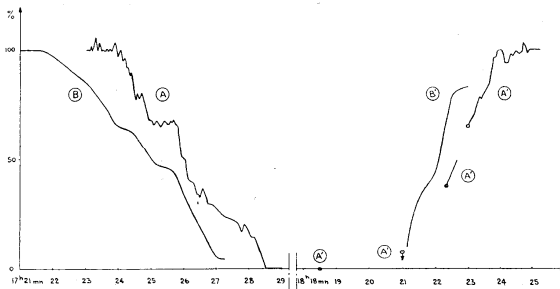


Figure 6: Marcoussis occultation curves for Taurus A obtained at 169 MHz (A-A') and 900 MHz (B-B') on 24 January 1956 (after Boischoot et al., 1956: 1849).

3. URSI AND THE FOUNDING OF NANÇAY

In 1952, the URSI Congress was held in Sydney, Australia (Bolton, 1953; Kerr, 1953), the first time that this meeting was sited outside of Europe or North America. Australia's selection as the host nation reflected its ongoing research record in ionospheric physics and its role as one of the leading nations involved in the emerging field of radio astronomy. For an interesting recent perspective on the Sydney URSI meeting by someone who was actually there, see Robinson (2002).

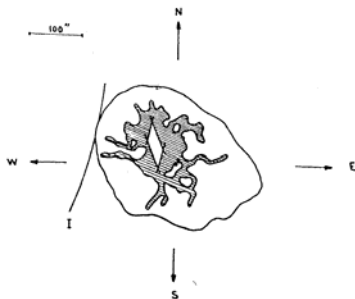


Figure 7: The Crab Nebula showing the distribution of the most brilliant optical filaments (hatched), the envelope encompassing the outer optical filaments, and the centre of the radio emission (the 'trapezium' within the hatched area). Arc I indicates the position of the lunar limb at the time of first contact at 900 MHz during the 1956 occultation (after Boischoot et al., 1956: 1851).



Figure 8: 'Chris' Christiansen and his 32-element East-West 1,420 MHz solar grating array at Potts Hill, Sydney (courtesy: ATNF Historical Photographic Archive).

Marius Laffineur from the Institut d'Astrophysique de Paris and Jean-Louis Steinberg from the ENS were the only radio astronomers in the French delegation (but there were others from non-radio astronomy areas). Actually, there was insufficient Government funding for both radio astronomers to attend so Steinberg obtained financial support from a private French electronics firm he did contract work for.⁶

The URSI program included visits to a number of the field stations maintained by the CSIRO's Division of Radiophysics in and near Sydney, and Laffineur and Steinberg were impressed by the Australian radio telescopes that they saw and heard about, particularly Christiansen's 1,420 MHz solar grating array at Potts Hill (see Figure 8, and Christiansen, 1953; Christiansen and Warburton, 1953). They decided that more elaborate French instrumentation was required and that a specialised observatory, with abundant land, and at a radio-quiet site, was essential. A few days after returning to Paris, Steinberg approached Rocard about obtaining such a site. Rocard asked him to prepare a budget, which he did with considerable difficulty. It totalled 25 million in 1952 French francs, which was equivalent to 2.6 million francs in 2001—a truly phenomenal sum. A few weeks later Rocard had a commitment for the funding through the Ministry of National Education, which preferred to finance a large and very visible project rather than dozens of smaller ones. Rocard told Steinberg that he had 25 million francs to spend and to "... do what you want but keep me informed." Later Steinberg (2001: 512) would write: "It was an incredible sign of confidence since all our team were in their early 30s. The sum of 25 million ... was enormous as compared to most scientific project budgets." The result was the 150 hectare Nançay field station, 190 km to the south of Paris, which was established by the Physics Laboratory of the ENS in 1953.

At this time the Director of the Paris Observatory, André Danjon, wanted to set up a radio astronomy group at the Meudon branch of the Observatory, for he realised that this new discipline could make important contributions to solar physics and astrophysics. He

proceeded to invite Denisse and Blum to join the Observatory's staff, and in 1954 they accepted; soon they were followed by Steinberg and other members of the ENS group. In addition, the Nançay facility was also transferred to the care of the Observatory.

It might seem strange that Rocard was prepared to part with his new field station and to let one of his prize research groups defect to a rival institution, but the fact is that he was non-territorial by nature, and he also was interested in continually developing new research areas. Thus, he had no intention of retaining radio astronomy forever, and at the time of the Paris Observatory initiative he was keen to develop semiconductor research and needed more space for this in the Physics Laboratory. The final 'crunch' came when he informed the radio astronomy group that he wanted to erect military equipment at Nançay to detect atomic bomb tests. Steinberg vehemently disagreed with this decision and insisted that Nançay remain non-military and accessible to international scholars. This stance did not please Rocard, who made it clear that the era of co-operation was over. He then proceeded to withdraw various facilities from the radio astronomers, and to cut off access to the workshop (although he did allow the workshop to complete the Nançay 2-element 3cm interferometer). It was only when the interferometer was finished that Steinberg and other staff from the ENS transferred to Paris Observatory.



Figure 9: Close up of the two Würzburg antennas at Nançay.

4. PARIS OBSERVATORY AND NANÇAY

4.1 Introduction

When Paris Observatory gained access to the Nançay field station the intention was to erect 1,500m long E-W and N-S solar arrays, and a variable-baseline interferometer for non-solar work, but both projects required several years of design studies so a start was made with smaller instruments, including solar antennas relocated from Marcoussis.

4.2 The Würzburg 2-Element Variable Baseline Interferometer

Eventually the Marcoussis Würzburg dishes were transferred to Nançay, and they were mounted equatorially on a 1,480m long E-W railway track and a 380m long N-S railway track constructed in 1957-1959 (see Figure 9), giving maximal resolutions of 17.4" and 67" on the E-W and N-S baselines respectively at 1,420 MHz. Under the very best circumstances, it was possible to measure sources with flux densities as low as 1.4 Jy. Le Roux oversaw the development of this instrument and a new 1,420 MHz receiver (Steinberg, 2001), but the 6m gauge railway

track was designed by an engineer from the National Railways.

Most of the electronics were built by Le Roux (see Lequeux et al., 1959), and the only major problem encountered was that the phase was not stable but drifted slowly due to temperature variations, even though a phase-lock system was in place (see Arzac, 1959). Lequeux recalls that when he was fortunate enough to see interference fringes he had to add them together in order to increase the signal-to-noise ratio, and to facilitate this Marc Vinokur built an ingenious integrating 'machine' that sampled the signal every twentieth fringe, converted the analog signal into digital and added the fringe signals together with twenty special electronic tubes developed in England which had phosphorus displays.⁷ To input and continuously update the fringe frequency, Lequeux used a frequency synthesizer that he adjusted manually using a navy chronometer and tables! Due to the phase shift, Lequeux's procedure was to integrate separately the first and second halves of each observation, measure the phase shift, and correct for this in the final result. Surprisingly, this worked rather well, but because he could not control the phase all he ended up with was an amplitude visibility curve. Jacques Arzac developed an algorithm that was used to recover a 1-D profile from this alone, but of course this included a directional ambiguity. Calculations were performed on an IBM 650, which was the first scientific computer to be installed at Meudon.

The interferometer became operational in April 1959, and was used for continuum observations at 1,420 MHz; between October 1959 and the end of 1962 these formed the basis of Lequeux's doctoral research. By present-day standards, observing was a tedious affair. Lequeux remembers that for each baseline change he had to move the antennas along the railway track using a cable which was attached to a truck. He then had to measure the positions of the two antennas and plug in the mains power and coaxial cable for the local oscillator reference and the signal at posts that were spaced at 50m intervals along the track. During each observation he would go on foot, by bicycle or in a car (depending on the distance involved) to the two antennas, point them at the designated Right Ascension and Declination, make some electronic adjustments, and then rush back to the central cabin to adjust the delay line and start the integration. On average the integration time was ~1hr.

The first series of scientific observations made with the Nançay facility was an attempt to measure the angular sizes of five different well-known discrete sources, Cygnus A, Sagittarius A, Virgo A, and the remnants associated with supernovae of AD 1572 and 1604. Observations were carried out from April 1959, at 1420 MHz, and Biraud et al. (1960: 116) noted that

The detection of weak sources is limited by noise, but an integrating system allows us to detect sources whose flux density is as low as $7 \times 10^{-26} \text{ w m}^{-2} (\text{c/s})^{-1}$. No phase determinations are yet available, and we measure only the modulus of the Fourier transform of the strip brightness distribution of the source ... measurements have been made with aerial separations in the range 41λ to 2080λ (440 m) on the East-West baseline.

The curve obtained for Cygnus A was found to be similar to those derived by other investigators, while Sagittarius A suggested the existence of two sources,

with E-W halfwidths of $\sim 28'$ and $3.5'$ and flux densities of 680 and 280 Jy respectively. Biraud et al. identified the smaller source with Drake's narrow thermal source at the centre of our Galaxy. In this case, the source has an E-W diameter of 8.6 pc, which is similar to the dimensions of the nucleus of M31, and "... we think they are bodies of the same kind. If the radiation of the central source is indeed thermal, with an assumed electron temperature of $10,000^\circ$ K, we derive an emission measure of $4.4 \times 10^6 \text{ cm}^{-6} \text{ pc}$ and a mean electron density of 960 cm^{-3} ." (Biraud et al., 1960: 117). The Virgo A visibility curve was also found to originate from two superimposed sources: "... a halo approximately gaussian in shape with a halfwidth of $10'$ and a flux density of $74 \times 10^{-26} \text{ w m}^{-2}(\text{c/s})^{-1}$, and a very intense and narrow source with an E-W halfwidth of $40''$ (if gaussian) and flux density of $112 \times 10^{-26} \text{ w m}^{-2}(\text{c/s})^{-1}$." (ibid.). The narrow source was thought to be connected with the jet that is associated with the nebula. Although both of the SNRs were detected, an angular size ($6'$) was obtained for just one, SNR 1572. Its flux density was measured at 39 Jy, while SNR 1604 produced a flux density of ~ 12 Jy at 1,420 MHz.

Heidmann and Lequeux (1961) also investigated the radio source Hercules A with the Würzburg Interferometer, using baselines from 43λ to $6,950 \lambda$. The visibility curve suggested two sources with E-W halfwidths of $0.8'$, separated by $1.8'$ and at a position angle of $98 \pm 5^\circ$. The flux density was noted as 3% that of Cygnus A, or 42 Jy at 1,420 MHz.

In another paper published in 1961, Lequeux and Heidmann report on their measures of a number of strong discrete radio sources using the Würzburg Interferometer. From a plot of the amplitude of the interference fringes as a function of distance and the resulting integrated brightness distribution in an E-W direction for Cygnus A, they identified the existence of a sharp outer shock front which is separated from the inner regions of the source by an angular distance of between 90 and $108''$.

Observations of Virgo A, with an interferometer spacing exceeding 300λ confirmed the existence of two source components—as reported previously by Biraud et al. (1960)—except that the new interference fringes (Figure 10) indicated two gaussian sources with halfwidths of $23''$ and separated by $31''$. The source Ophiuchus C (3C 353) was observed and also was found to comprise two adjacent sources, with halfwidths of $74''$ and separated by $136''$. Hydra A also appeared to be a double source, one component having a halfwidth of $42''$, while the other was not resolvable at the longest baseline used for the observations. Bootes A was also unresolved at this spacing, while 04 N3A and 3C 273 produced source diameters of $15.5''$ and $21''$ respectively.

In 1962, Lequeux (1962a) brought together his accumulated observations made with the Würzburg Variable Baseline Interferometer and published these in the *Annales d'Astrophysique*. This long paper is primarily based upon his doctoral research, and is split into two parts: the first deals with galactic sources and the second with extragalactic sources. In both sections he elaborates on the previously-published findings reported in Biraud et al. (1960), Heidmann and Lequeux (1961) and Lequeux and Heidmann (1961).

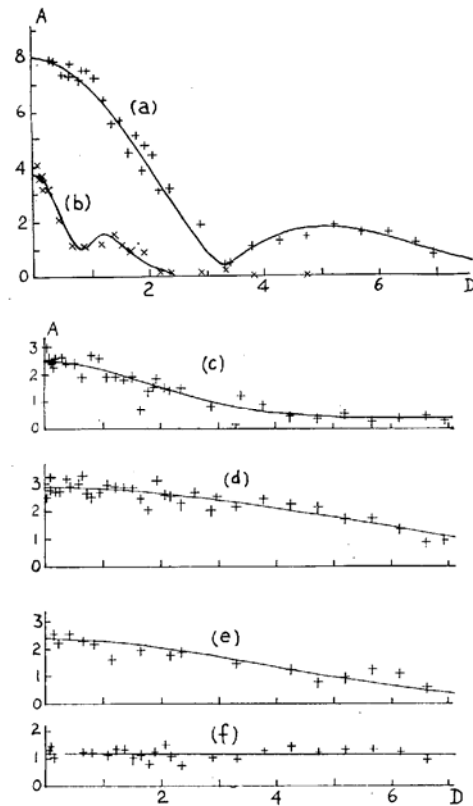


Figure 10: Plots of amplitude (A) of the interference fringes as a function of interferometer spacing (D, in 1000s of λ) for Virgo A (a), Ophiuchus C (b), Hydra A (c), 04 N3A (d), 3C 273 (e) and Bootes A (f) (after Lequeux and Heidmann, 1961: 806).

Lequeux begins by presenting visibility curves for eight different thermal galactic radio sources known to be associated with HII regions, and these are shown here in Figure 11 (the W series of sources being from Westerhout's 1958 catalog).⁸ Meanwhile, source flux densities and E-W dimensions are listed in Table 3.

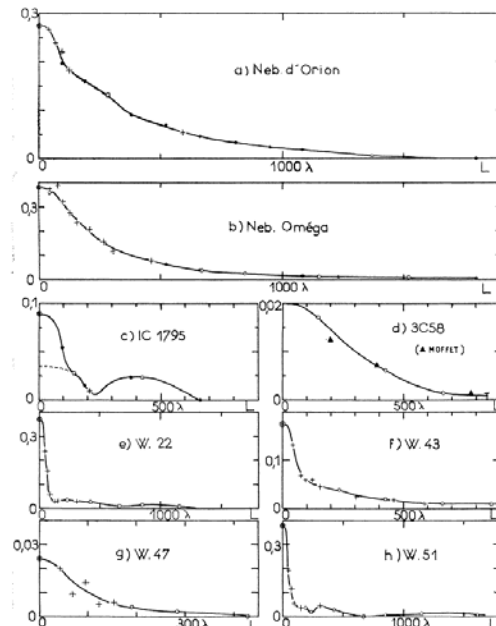


Figure 11: Visibility curves for selected galactic radio sources (after Lequeux, 1962a: 224).

Table 3: 1,420 MHz galactic thermal sources observed at Nançay (after Lequeux, 1962a: 226).

Source	Identification	Flux Density	E-W Dimensions
3C 58 ⁷	----	30 Jy	5'
IC 1795	IC 1795	134 Jy	18'; double source, each 3' and separated by 7.6'
Orion Nebula	NGC 1976	410 Jy	complex, ~4'
W22	NGC 6357	555 Jy	broad 34', narrow 3'
Omega Nebula	NGC 6618	570 Jy	complex, ~5.8'
W 43	----	270 Jy	broad 33', narrow 5'
W 47	----	35 Jy	broad 20', narrow 5'
W 49	3C 398	84 Jy	very complex, ~20'
W 51	----	560 Jy	broad 40', narrow 3'

From the Orion Nebula curve in Figure 11 Lequeux derived an E-W size of 4', and when he compared his E-W profile for this source with the model developed by Menon (1961) for the same frequency, "The accord between the observations and the model can be considered excellent, except at large distances from the centre where the observational results and the model are both uncertain." (Lequeux, 1962a: 226; our translation). In addition, Lequeux (ibid.) confirmed the values for the electron density and the emission measure reported by Menon.

Some of the other sources listed in Table 3 display a feature that was found to be common for galactic thermal sources: they "...are in general composed of an intense small nucleus superimposed on an extended component." (Lequeux, 1962a: 221; our translation). This is indicated in the extreme right-hand column in the Table.

Table 4 lists non-thermal galactic sources observed at Nançay, and contains four known supernova remnants (the two SNRs and Taurus A and Cassiopeia A) plus two other sources.⁹ Visibility curves for all six sources are shown in Figure 12.

Table 4: 1,420 MHz galactic non-thermal sources observed at Nançay (after Lequeux, 1962a: 228).

Source	Flux Density	Spectral Index	Diameter
SNR 1572	43.5 Jy	-0.7	broad ~8', narrow ~1.8'
IC 443	170 Jy	-0.4	40'
Taurus A (Crab Nebula)	880 Jy	-0.26 ± 0.03	3.9' × 2.7', P.A. 126°
SNR 1604	12.7 ± 1.5 Jy	-0.7	2.2'
W 44 (3C 392)	180 Jy	-0.5	broad ~16', narrow ~4'
Cassiopeia A	2450 Jy	-0.78 ± 0.02	4'

The results for Taurus A (associated with the Crab Nebula and SN 1054) were very interesting in that they indicated an elliptical source with a similar orientation to its optical counterpart. This is shown in Figure 13, where the 101 MHz isophote of Mills (1953) is also included. Lequeux (1962a: 230; our translation) concludes that "... it seems that decisive

progress will not be possible on the theory of the Crab Nebula until one can arrange for reliable isophote plots at several frequencies to be obtained with a resolution of at least 30" in two directions."

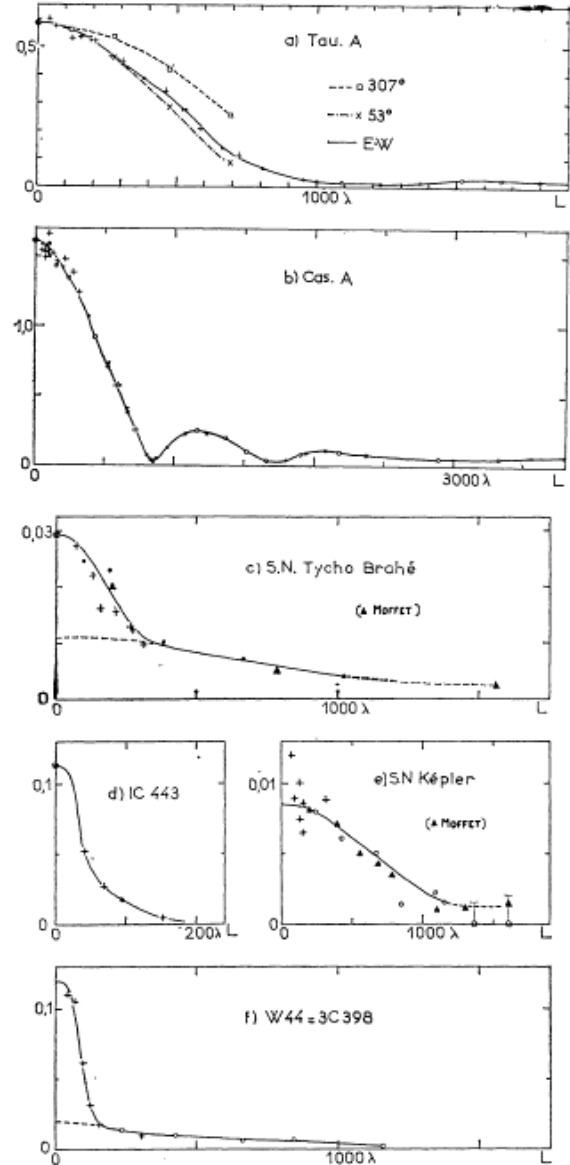


Figure 12: Visibility curves for selected non-thermal galactic radio sources (after Lequeux, 1962a: 229).

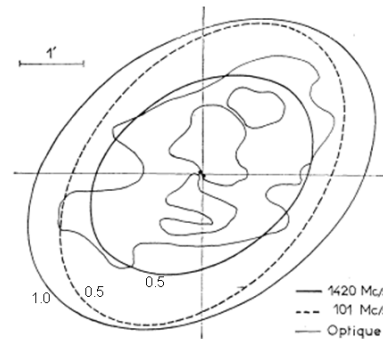


Figure 13: A comparison of the optical continuum of the Crab Nebula and 101 MHz and 1,420 MHz isophotes for Taurus A (after Lequeux, 1962a: 229).

Cassiopeia A is the only other SNR in Table 4 for which there was a relative abundance of data at 1,420 MHz. Lequeux (1962a: 230; our translation) found that

The dimensions and form of the radio source do not vary with frequency: the visibility curve at 1420 MHz does not differ significantly from those that have been obtained at 127 and 3000 MHz ... However we do not find in our measures the “depression” of the visibility curve observed at 127 MHz for interferometer spacings of the order of 500λ ; it is true that this effect is limited by experimental errors in the 127 MHz measures.

Lequeux derived a spectral index of -0.78 ± 0.02 for Cassiopeia A (Table 4), and noted that while certain authors expect that the slope of this spectrum and those obtained for other SNRs will decrease with the passage of time, this is very unlikely. He also showed this source to be a thin spherical shell, and adopting the principles advanced by Shklovsky calculated that its annual decrease in flux is 1.7%.

Of the remaining sources in Table 4, Lequeux (1962a: 233; our translation) specifically mentions that W44 has “... a complex structure that has some analogies with the supernova of Tycho Brahe [i.e. SN 1572]: but the report of its dimensions and the flux density values of its components are not the same.”

In his long 1962 paper, Lequeux assigns a separate section to his observations of Sagittarius A, the discrete ‘source’ located at the centre of our Galaxy. The Nançay observations confirmed the existence of two small sources, as reported earlier by Biraud et al. (1960). The 1962 paper contains revised flux densities of 730 and 300 Jy for these two sources, and also indicates that they are superimposed on a large non-thermal background source measuring about $1^\circ \times 2^\circ$. The low elevation of the Galactic Centre above the horizon at Nançay and the shortness of the N-S interferometer baseline only allowed for fringes to be obtained inclined by -19° and $+19^\circ$ with respect to the N-S direction, which was a limitation on the 2-D description of the course. However,

These measurements show that the large source is highly asymmetrical: if one can visualize an ellipse with an axis in the Galactic Plane its diameter is $50'$ in the direction of the Plane and $17'$ in the perpendicular direction. In contrast, the small source appears to be circular ... (Lequeux, 1962a: 234; our translation).

Lequeux (ibid.) proceeded to compare and contrast his measurements with those obtained by Pariiskii at other wavelengths and at higher resolution, and he then combined all the observations to prepare spectra for the two sources. The smaller intense source at the very centre of the Galaxy was found to be thermal, while the larger nearby source exhibited a non-thermal spectrum (see Figure 14). Lequeux then proceeded to compare and contrast his observations with those published by Drake who, with a resolution of $6' \times 6'$, detected four different sources (which he labelled A and B₁, B₂ and B₃). In the light of our present very detailed knowledge of Sagittarius A accumulated through VLBI and with the VLA, it is fascinating to read about these early formative investigations of this region.

The final section of Lequeux’s classic paper deals with extragalactic radio sources observed at Nançay with the Würzburg Variable Baseline Interferometer, and begins with the following warning: “Despite the

accumulation of a very considerable number of observations, our knowledge of the extragalactic radio sources remains rudimentary.” (Lequeux, 1962a: 236; our translation). Table 5 lists the 25 different sources that Lequeux investigated, along with their 1,420 MHz flux densities and diameters, plus details of source structure, and their spectral indices. Some of the material in this table was reported previously in the papers by Heidmann and Lequeux (1961) and Lequeux and Heidmann (1961).

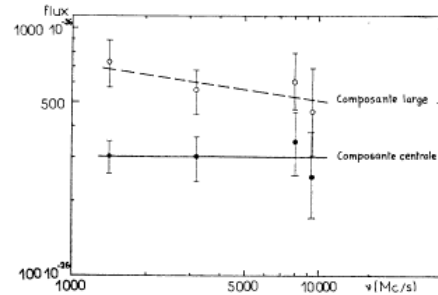


Figure 14: Spectra of the two components of Sagittarius A (after Lequeux, 1962a: 234).

The dual nature of Virgo-A was confirmed, with the two components referred to as the ‘radio halo’ and ‘radio jet’, respectively. Revised flux density values for the two components of 80 Jy and 120 Jy were reported, and dimensions of $10' \times 5.5'$ were obtained for the size of the ‘halo’. Figure 15 shows the visibility curve obtained for the ‘radio jet’ and its E-W profile; the latter suggests a double structure that is right at the limit of resolution of the Nançay interferometer. In trying to interpret the jet, several different models were investigated, but the solution of the numerical analysis was inconclusive: “None of the models gave a double structure or results that were compatible with our observations, but [despite this] we are still convinced that the jet is double.” (Lequeux, 1962a: 238; our translation). As a first approximation, Lequeux (ibid.) suggested the existence of two similarly-sized sources $23''$ in diameter and separated by $31''$, with individual flux densities of 65 and 55 Jy.

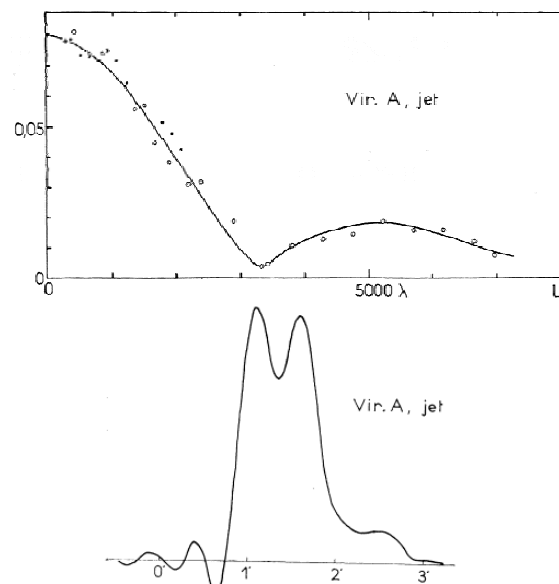


Figure 15: Visibility curve for the Virgo A jet and its E-W profile (after Lequeux, 1962a: 239-240).

Table 5: Extragalactic sources observed at Nançay (after Lequeux, 1962a: 237).

Source	Flux Density (Jy)	E-W Diameter	Structure	Spectral Index	Comments
3C 33	11.00 ± 1.5	Double	Each component $<20''$ diameter with E-W separation of $1.1'$	0.74	Optical identification
3C 48	15.0 ± 2.0	See text	See text	0.55	Optical identification
3C 66	10.0 ± 3.0	Double?	Complex; large component $>10'$	0.55	Optical identification; double source, flux of small source 3.3 ± 0.6 Jy.
NGC1275c	9.0 ± 1.0	$<12'$		----	See text
a	3.9 ± 1.5	$<2'?$		0.55	
b	$7.5?$	$30'?$?	
3C 98	10.5 ± 2.5	Complex	Large component $3'$, small component $<30''$	0.65	Optical identification; double source
3C 111	13.5 ± 2.5	Double		0.73	
3C 123	45.0 ± 2.0	Double	Each component $5''$ diameter with E-W separation of $2.5''$	0.66	
3C 134	9.8 ± 1.3	$39'' \pm 14''$	Double, almost N-S	0.95	
3C 147	18.9 ± 1.5	$<10''$		0.37	
3C 161	12.0 ± 1.5	$<10''$		0.67	Complex structure
3C 196	12.0 ± 1.0	$<5''$		0.79	
Hydra A	39.0 ± 2.0	Halo	Large component $42''$ diameter and flux 31 Jy, small component $10''$ diameter and flux 8 Jy	0.87	Perhaps a large halo
3C 273	37.5 ± 2.0	Double	Diameters of components $\sim 4''$ with E-W separation of $14''$	0.44	See the earlier result in Lequeux and Heidmann (1961)
Virgo A	200	Halo	Halo $10' \times 5.5'$, position angle $\sim 70^\circ$, flux density 80 Jy; double jet, components $23''$ with $33''$ separation at position angle $285 \pm 15^\circ$; flux densities of 65 and 55 Jy	See text	Traces of structure and a halo
Coma A	3.8 ± 0.5	$<1'$		0.42 ± 0.15	See text
.....D	3.0 ± 0.5	$<1'$		0.55 ± 0.15	
.....C	$7.5?$	$\sim 40'?$?	
3C 286	13.4 ± 0.7	$8'' \pm 4''$		0.43	
3C 295	17.7 ± 0.6	$<5''$		0.65	Optical identification
Hercules A	45.0 ± 2.0	Double	Components $47''$ diameter with $111''$ separation at position angle $98 \pm 5^\circ$; flux densities of 25 and 20 Jy	0.96	Optical identification
3C 353	54.0 ± 4.0	Double	Components $74''$ diameter with $136''$ separation; flux densities of 36 and 18 Jy	0.68	Optical identification
3C 380	13.7 ± 1.2	$12'' \pm 5''$		0.75	
Cygnus A	1500	Double	Components $25''$ diameter with $106''$ separation at position angle 110° ; flux densities of 830 and 600 Jy	0.81 (after 2,000 MHz)	Components with extremely sharp edges extending along the same axis, with the point of emission between the two components
3C 409	13.0 ± 0.9	$18'' \pm 6''$		1.00	Perhaps double
3C 433	9.9 ± 0.9	$16'' \pm 5''$		0.84	Optical identification
3C 444	10.5 ± 1.5	Double	Components $\sim 15''$ diameter with $24''$ separation	0.7?	Optical identification
3C 452	7.5 ± 2.0	Complex		0.83	

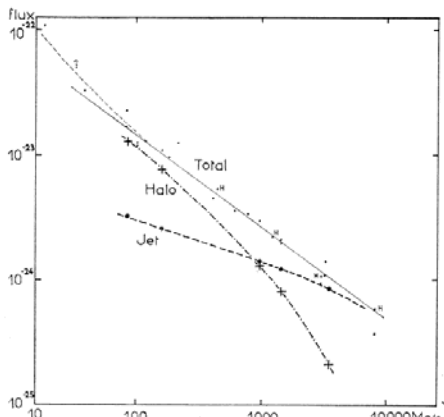


Figure 16: Spectra of the components of Virgo A (after Lequeux, 1962a: 242).

Upon combining the Nançay observations with those reported at other wavelengths by Mills, Moffet, Palmer and Pariiskii, Lequeux was able to investigate the spectra of the Virgo A components and show that these exhibited two very different curves (see Figure 16):

One can see that the spectral index of the jet is constant with a value of 0.33 at frequencies below 2,000 MHz; above 8,000 MHz, where one can utilize reliable flux measures (those of Heesch which form a coherent group and have been reduced with care, are indicated by the letter "H"), virtually all of the flux originates from the jet; the curvature of the spectrum takes place between 2,000 and 8,000 MHz, let us say mostly near 3,000 MHz. (Lequeux, 1962a: 243; our translation).

Lequeux (1962a) then devotes three and a half pages to a theoretical study of the physical processes associated in the generation of the radio emission from

Virgo A, based in part on the investigations of other scholars.

Cygnus A was another discrete source that was studied in detail at Nançay. From the visibility curve, Lequeux (1962a) derived an E-W profile for Cygnus A (Figure 17) which indicated two components, each $\sim 25''$ in diameter and with sharp external edges, separated from one another by $100''$, and connected by what has been described as an 'emissive bridge' (Figure 18). The Nançay observations also confirmed that the separation between the two source components appeared to vary with frequency, an interesting phenomenon reported earlier by Jennison and Latham (1959). In his theoretical consideration of Cygnus A, Lequeux (1962a: 248; our translation) states:

The existence of two components is very common among extragalactic radio sources: Shklovsky (1960b) imagines that this structure corresponds to the injection by the galaxy (identified without ambiguity in the case of Cygnus A and in several other cases also) of two clouds of gas containing a magnetic field and relativistic particles. This injection, of which the origin is still unknown (supernovae, magneto-hydrodynamic effects on a large scale?), would occur in two mutually-opposing directions, limited no doubt by the magnetic field of the galaxy and in the intergalactic medium ...

Nevertheless, the properties of Cygnus A do not seem to support this hypothesis: to explain the variations in the source with frequency we have to admit that there is a notable loss of emission in the central regions alone, or by ionizing collisions in the outer regions alone, which appears too arbitrary.

After spending almost two pages on a theoretical discussion of Cygnus A, Lequeux (1962a: 250; our translation) concludes: "Of course, the theoretical interpretation of Cygnus A that we have presented (or sketched) is very debatable and it seems premature to subject it to calculation. Many other aspects still require elucidation ..."

In his brief discussion of Hercules A, Lequeux confirms the findings reported earlier in Heidmann and Lequeux (1961) and notes that these are in accord with recent results published by the Caltech group. Lequeux (1962a: 251) concludes that Hercules A should be considered a typical double radio source.

The source Ophiuchus C (3C 353) was reported on originally by Lequeux and Heidmann (1961), and in his long 1962 paper Lequeux merely confirms that this is a double source and repeats the parameters presented previously.

3C 33 is another extragalactic source listed in Table 5 with a visibility curve that clearly indicates a double structure. Lequeux (1962a: 251; our translation) concludes that "The E-W separation of the components is of the order of $69''$ and their diameters are certainly less than $20''$. The fluxes of the two components differ little, by no more than a factor of 2." He notes that his Nançay findings are in accord with those reported by the Caltech group.

Visibility curves were also published for 3C 66, 3C 98 and 3C 111 (see Figure 19), and these three sources are discussed together by Lequeux (1962a). Despite their low flux densities, he considers that all three are double sources, in agreement with results published by the Caltech radio astronomers. Both 3C 66 and 3C 98 seem to comprise a large component and a small component.

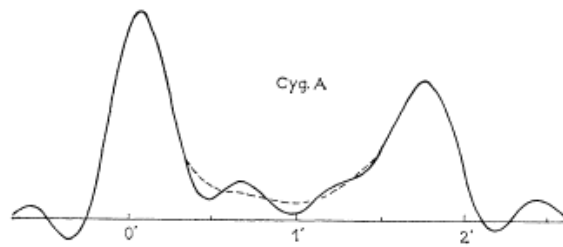


Figure 17: The E-W profile of Cygnus A at 1,420 MHz (after Lequeux, 1962a: 247).

The Nançay visibility curves for 3C 123 and 3C 273 at the maximal interferometer spacing of $7,000 \lambda$ show that these sources are still not resolved (re 3C 273 cf. Lequeux and Heidmann, 1961), but data provided by the Jodrell Bank radio astronomers indicate that these are both double sources. Meanwhile, Caltech data also indicate that 3C 134 is a double source, although this structure is not obvious from the published Nançay visibility curve (see Lequeux, 1962a: 252).

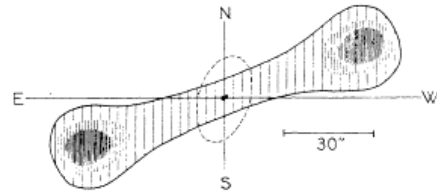


Figure 18: The suggested structure of Cygnus A, with the optical object shown in the centre (after Lequeux, 1962a: 247).

3C 444 is another source investigated at Nançay, and the associated E-W visibility curve

... indicates a source that is probably double, with an EW separation of about $24''$; the diameter of the components, while very difficult to estimate, is without doubt of the order of $15''$. (Lequeux, 1962a: 253; our translation).

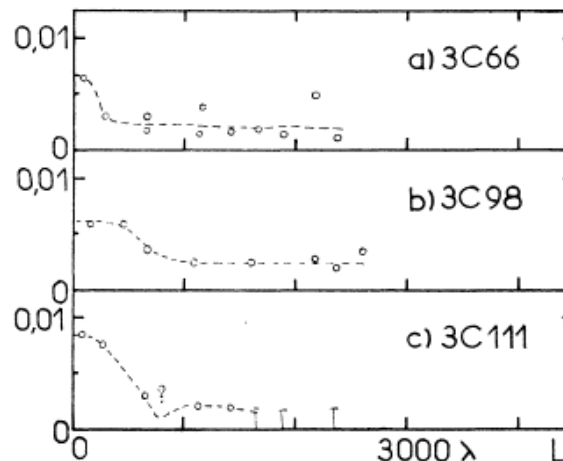


Figure 19: Visibility curves for 3C 66, 3C 98 and 3C 111 (after Lequeux, 1962a: 251).

The region around NGC 1275 in Perseus is a complex one, and observations conducted at Cambridge and Green Bank revealed the existence of three different radio sources. Lequeux's observations at Nançay confirmed this source complexity: in the visibility curve, which is reproduced here in Figure 20,

... one can see oscillations that correspond to the presence of the small sources *a* and *c*, while the existence of the large source *b* is indicated by the very weak spaced-out measurements. The numbers inserted along the top of the diagram indicate for each measurement the number of fringes which were used in the integration. (Lequeux, 1962a: 255; our translation).

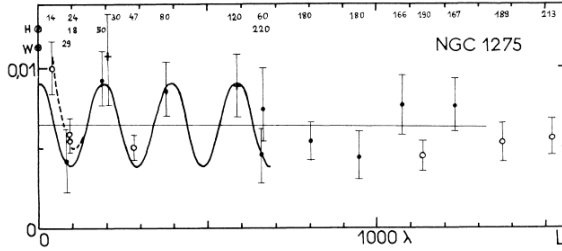


Figure 20: Visibility curve for the region around NGC 1275 (after Lequeux, 1962a: 256).

This visibility curve corresponds to two sources with unequal flux densities, and separated by $18'$. Lequeux (1962a: 257; our translation) notes that NGC 1275 is the only known example of a double galaxy where the components are in motion at a relatively high speed (at least $3,000$ km/s), and "... this is therefore the only case where we are justified in explaining the radio emission in terms of a collision between two galaxies."

The double nature of Hydra A was already reported by Lequeux and Heidmann (1961), and in his long 1962 paper Lequeux repeats their earlier findings, but within the context of recent results for this source published by Jodrell Bank and Caltech colleagues.

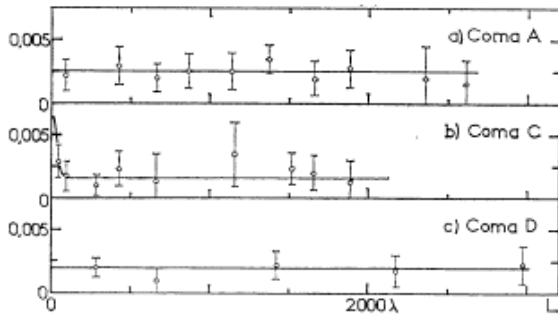


Figure 21: Visibility curves for radio sources in the Coma Cluster (after Lequeux, 1962a: 257).

Large, Mathewson and Haslam (1959) observed the Coma Cluster at 408 MHz and identified three different sources which they designated A, C and D. Lequeux observed these three sources with the Nançay Würzburg interferometer, deriving the visibility curves illustrated in Figure 21. From these, Lequeux concluded (1962a: 258; our translation) that

Sources A and C are separated by a distance of $68' \pm 12'$... Curve 39 *a* [i.e. a] in Figure 21] is not affected by the presence of source C, which is large, for all the spacings at which we took measurements. To the contrary, in curve 39 *b* [i.e. b] in Figure 21] source A contributes to the fringes with 65% of its flux. Finally, source D ... [c] in Figure 21] was well isolated from A and C by our antennas.

One can see that sources A and D are very small: their diameters are certainly less than $1'$. One can estimate their fluxes from curves *a* and *c* ... [at] respectively 3.8 ± 0.05 Jy and 3.0 ± 0.5 Jy.

Finally, Lequeux (1962a) noted that there were a number of weak extragalactic radio sources studied at Nançay that could not be resolved at the longest interferometer spacing. Visibility curves for nine of these are reproduced here in Figure 22. Subsequent investigations by other astronomers would reveal most of these unresolved sources to be quasars.¹⁰

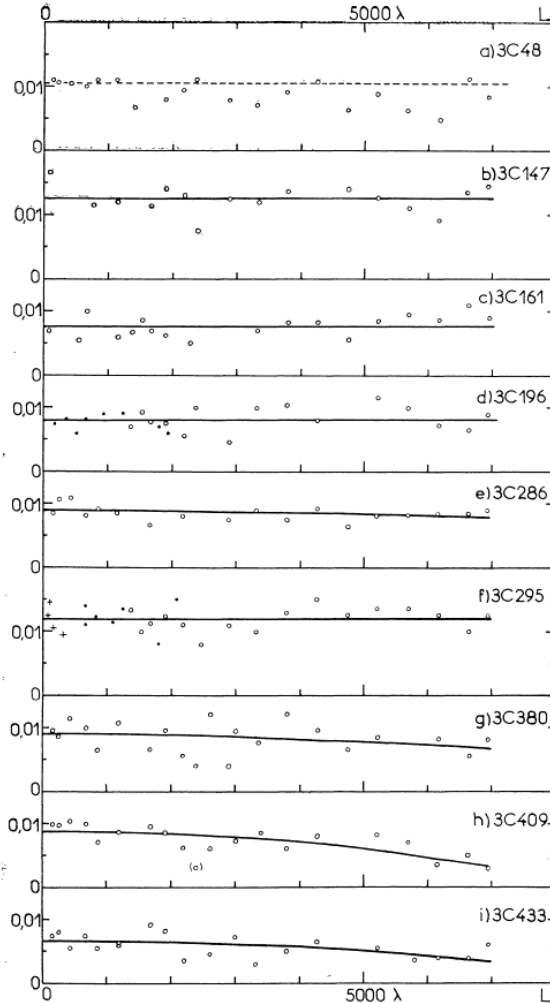


Figure 22: Visibility curves for nine unresolved extragalactic sources (after Lequeux, 1962a: 254).

This brings to a close our discussion of Lequeux's long 1962 paper, but it does not mark the end of the Würzburg Variable Baseline Interferometer at Nançay, which was used for one final research project. In 1962 Lequeux used this radio telescope to measure the 2-D size of the active galaxy, M82. Because of the low flux density (8 Jy) this proved to be very difficult, but Lequeux (1962b) detected an approximately circular source $45''$ in diameter, which is much smaller than the optical galaxy. We now know that this source contains many HII regions and many regions of star-formation, hence its relatively flat spectrum.

It should be noted that during the late 1950s and early 1960s there was strong international competition for galactic and extragalactic interferometric observations. This derived, on the one hand, from Jodrell Bank, where they had excellent resolution and sensitivity but lacked absolute phase, and on the other hand, from Caltech, where the Owens Valley Interferometer

(comprising two 90-ft dishes) had superior sensitivity and good phase stability but lower resolution than the Nançay Variable Baseline Interferometer could offer. The Jodrell Bank group started early and concentrated—initially at least—on high-resolution observations of a few bright sources (Jennison and Das Gupta, 1953; but cf. Allen et al., 1962). The Owens Valley Interferometer was operational from 1960, and initially it was used for positional measurements that led to the optical identification of a number of extragalactic sources; later it was employed for continuum and H-line observations (see Cohen, 1994).

It soon became clear that the special niche occupied by the Nançay Variable Baseline Interferometer would vanish in the face of competition from the Owens Valley radio telescope, and when the last serious observations were made in 1962 this marked the successful end of its important 13-year contribution to French and international science.¹¹ Seen in retrospect, the most valuable results obtained with the Nançay radio telescope relate to the structure of Sagittarius A and extragalactic sources like Cygnus A, Virgo A and M82, and to the finding that a number of sources (which subsequently turned out to be quasars) were still unresolved at the highest possible resolution.

5 THE INSTITUT D'ASTROPHYSIQUE DE PARIS' WÜRZBURG ANTENNA

5.1 Introduction

In immediate post-War France there were two active fledgling radio astronomy groups: the larger, vibrant team at the ENS led by Denisse and Steinberg (which we have already discussed) and a much smaller group led by Marius Laffineur¹² at the Institut d'Astrophysique de Paris (henceforth IAP) in Paris. Laffineur was a radio engineer who (just like his ENS colleagues) had to learn his astronomy 'on the run', but his commitment to this new field was such that he ended up putting his solar radio astronomy research conducted in 1948-1950 towards a Doctor of Engineering degree at the University of Paris.

Through the French Army, one of the three 7.5m Würzburg antennas secured by British forces at the end of WWII was acquired by the IAP and from 1948 would become the work horse for Laffineur's early investigations in radio astronomy. In the published version of his doctoral thesis, he describes this instrument:

The mirror (*pl. II*), of very neat construction was originally intended as a device to track rockets. With a full diameter of 7.45 m, the very rigid paraboloid (*pl. III*) was composed of juxtaposed aluminium beams, covered by square mesh panels. The mesh holes are 10 mm in diameter and between them are strips of metal on average 2 mm wide. The focal distance is 1.70 m.

The vertical distance from the edge of the parabola to the base is 1.90 m, so the focal plane is below the rim of the parabola.

After construction, the surface precision was ± 1 cm, which allows use of the mirror down to a wavelength of 8 cm ...

Extending from the base of the mirror is a very rigid steel tube support, with the same axis of revolution as that of the parabola. The 555 Mc/s dipole is attached to the end of a copper tube ...

A disk of solid aluminium forms the secondary reflector (*pl. IV*) and is located a quarter-wavelength from

the dipole, [and] we have assumed but without checking ... that the presence of this reflector reduces the radiation resistance from the dipole to half of its theoretical value ... (Laffineur, 1954: 21, 24; our translation).



Figure 23: The 7.5m Würzburg antenna at Meudon Observatory (courtesy: Observatoire de Paris, Meudon).

The original intention was to install this antenna on the roof of the Institute building in downtown Paris, but the load bearing of the building prevented this and Laffineur arranged for it to be located in the spacious grounds of the Meudon Observatory where there was land available (see Figure 23).¹³ Dispensing with the original drive, Laffineur developed an ingenious electro-mechanical equatorial computer drive for this antenna. This so-called 'equatorial pilot' (Figure 24), was located in the rotating cabin to the rear of the dish, and

In spite of this situation, to assure that it can point in a fixed direction in relation to the stars, it is placed on a mobile disk that has a vertical axis that is inclined at an angle of $48^{\circ} 48'$ which corresponds to the latitude of Meudon Observatory ... The vertical axle fixed to the floor is equipped at its upper end with a disk of the same diameter (*pl. V, fig. 1*) the two disks being linked by a perforated steel strap. When the cabin and the antenna rotate to some angle around the vertical, the disk supporting the equatorial pilot turns, relative to the cabin by an equal angle and in the opposite direction, thereby assuring the invariability of the direction of the polar axis ... (Laffineur, 1954: 25; our translation).

The concept of an 'equatorial pilot' may have inspired the 'master equatorial' that was later installed on the altazimuth-mounted 64m Parkes Radio Telescope in Australia, even though this was of a very different design (see Bowen and Minnett, 1963).

The Meudon Würzburg antenna was to serve Laffineur well, and in introducing his research programs to his colleagues he explains that

It is in the framework of astronomical research, with the advice, encouragement and kindly support from the French astronomers that we have undertaken this very modest work, in ... a vast field of research with the immediate aim the observation of solar emission and of its influence on the as yet unexplored longer wavelengths and incidental observations of the Milky Way at the same frequencies. (Laffineur, 1954: 3; our translation).

5.2 The 1949, 1952 and 1954 Solar Eclipses

Between 1949 and 1954 (inclusive) French radio astronomers observed four different solar eclipses with a view to (a) pinpointing the positions of localized

regions responsible for generating solar radio emission, and (b) investigating the distribution of radio brightness across the solar disk. The Meudon Würzburg radio telescope was used to observe three of these events (see Orchiston and Steinberg, 2007).

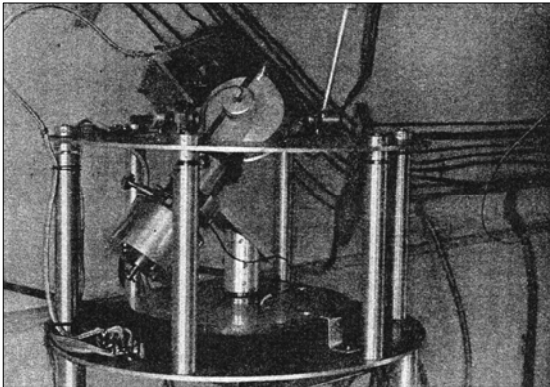


Figure 24: The Meudon Würzburg's 'equatorial pilot' (after Laffineur, 1954: Plate V).

The 28 April 1949 partial solar eclipse was observed at 555 MHz (see Laffineur et al., 1949, 1950; Steinberg, 1953), and the shape of the resulting eclipse curve (Figure 25) was "... incompatible with the hypothesis of a [radio] Sun of uniform brightness." (Laffineur et al, 1950: 339; our translation) or an annular disk of uniform brightness. Rather the eclipse curve suggested that "It is necessary to suppose that at least a part of the solar radio emission derived from non-uniform sources distributed over the solar disk." (ibid.). Chromospheric plages were invoked to partially explain this discrepancy, but Laffineur et al. (1950) cautioned that the interpretation of radio data from relatively small-phase partial solar eclipses like the 1949 one generated various difficulties, so the results reported should be seen as provisional.

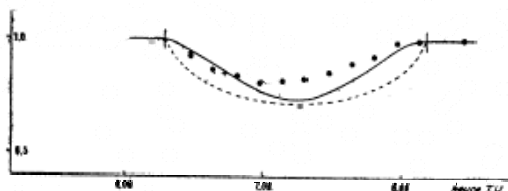


Figure 25: The dots show the 555 MHz 28 April 1949 eclipse curve, while the solid curve indicates the profile expected from a disk of uniform brightness and the dashed line the expected profile if the radio emission derived from an annular ring (after Laffineur et al., 1950: 338).

On 25 February 1952 a solar eclipse was visible in Africa (where it was total) and from Europe (where it was partial), and observations at 255 MHz were made with the Meudon Würzburg antenna. The radio astronomers noted that "At the maximum of the partial eclipse at radio wavelengths, 13 minutes after the optical event, the remaining radio emission was 83% that recorded when the Sun was not in eclipse." (Laffineur et al., 1952: 1529; our translation).

The last partial solar eclipse observed with the Meudon antenna took place on 30 June 1954, and while Laffineur and his colleagues tracked it from the line of totality in Sweden, Begot and Christiansen used the Paris-based radio telescope to observe at both 255 MHz and 545 MHz (Coupiac et al., 1955). Although

successful eclipse curves were obtained at both frequencies (Figure 26), no attempt was made to interpret these in terms of localised radio-emitting regions or the shape and size of the radio corona.

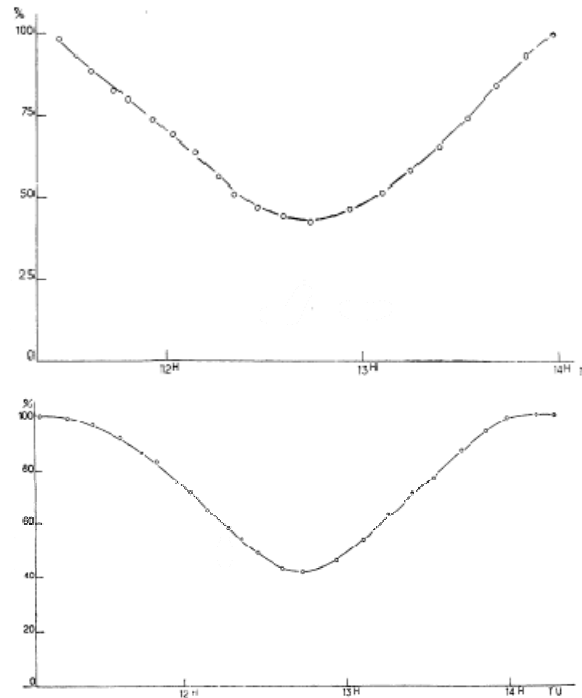


Figure 26: The 255 MHz (bottom) and 545 MHz (top) eclipse curves obtained at Meudon on 30 June 1954 (after Coupiac et al., 1955: 277).

5.3 Other Solar Observations

Between 9 September and 5 October 1948 Laffineur and Jakob Houtgast used the Meudon antenna to monitor the Sun at 555 MHz, and they subsequently reported their observations in *Annales d'Astrophysique* (Laffineur and Houtgast, 1949). From regular observations, they determined a value of $T_e = 240,000$ K for the quiescent Sun at this time, and compared this with values of 500,000 K and 100,000 K obtained by the Australian radio astronomers, Lehany and Yabsley (1948; 1949), at 600 MHz and 1,200 MHz respectively. In stark contrast was the figure of 10^6 K reported by Pawsey (1946) for 200 MHz, which corresponded with the value predicted—on theoretical ground—by D.F. Martyn (1946). On 24 May 1949 Laffineur (1954: 31) made further observations from Meudon at 555 MHz and obtained a value for the quiet Sun of 524,000 K. Surprisingly, in his paper Laffineur makes no attempt to explain the discrepancy between the 1948 and 1949 results or to correlate these figures with variations in sunspot area.

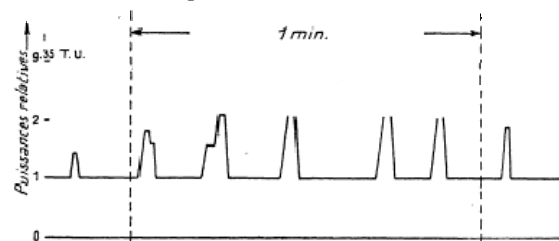


Figure 27: A group of solar bursts recorded at 555 MHz on 16 September 1948 (after Laffineur and Houtgast, 1949: 142).

During their monitoring period in 1948, Laffineur and Houtgast noted a number of occasions on 16, 17 and 23 September and on 4 October when there were significant variations in the level of incident radiation. Most of these came in the form of intense bursts of short duration (i.e. $t \leq 1$ min) as illustrated in Figure 27, but of particular interest was the outburst recorded on 17 September, which was also detected by Cambridge radio astronomers at 175 and 80 MHz and was accompanied by terrestrial effects associated with solar flare activity (see Figure 28). The comparative scarcity of bursts at 555 MHz compared favourably with the findings of Lehany and Yabsley in 1947. Observing at 600 MHz, they only occasionally recorded

Isolated disturbances ... mainly of low intensity and fairly short duration. In some instances they were definitely associated with chromospheric flares and sudden daylight radio fadeouts ... (Lehany and Yabsley, 1949: 58).

Laffineur and Houtgast also found the events of 4 October 1948 (Figures 29 and 30) of special interest. They reported:

This was the most disturbed day of this period of investigation (fig. 7 [= Figure 29 here]). During the intervals when there were bursts, the voltmeter was fairly calm (fig. 8 [= Figure 30 here] except towards 15 h 22m, (fig. 8 a), before a burst and after the bursts of 15 h 24 up until 15 h 40 (fig. 8 b). The intensity varied between 1 and 1.4. The most remarkable disturbance occurred at 15 h 22 m 30 s. The needle of the voltmeter began to quiver, vibrating with a small amplitude and at a frequency that we estimated at 20 periods/second. The frequency of the vibration decreased then in a way continued while the amplitude increased. After the last oscillation (of intensity 2), the deviation remained constant for about 3 seconds then fell back to its initial level. *This phenomenon appears to be due to inter-*

ference between two coherent beams but with a variable phase difference at the start? If the origin is in the solar atmosphere, which is our belief, [then] this observation is very important. (Laffineur and Houtgast, 1949: 143-144; our translation; our italics).

As a result of later observations, mainly by Australian and French radio astronomers, we can now associate the various events that Laffineur and Houtgast recorded with bursts of spectral Type III, but we can offer no obvious explanation for the anomalous burst recorded on 4 October.

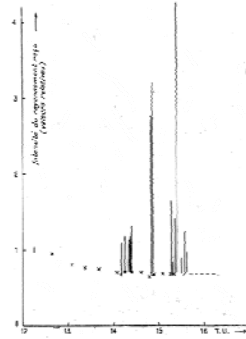


Figure 29: The 555 MHz solar events of 4 October 1948 (after Laffineur and Houtgast, 1949: 145).

Laffineur conducted further observations of solar bursts in 1949, and published these in 1954. A distinct advantage on this occasion was the presence of a chart recorder, so there was no longer any need to manually record individual voltmeter readings. Moreover, the time-constant of the recorder allowed bursts with durations as small as 1 or 2 seconds to be recorded. In another key development, from 1950 simultaneous observations were made at 255 and 555 MHz using the same Würzburg antenna.

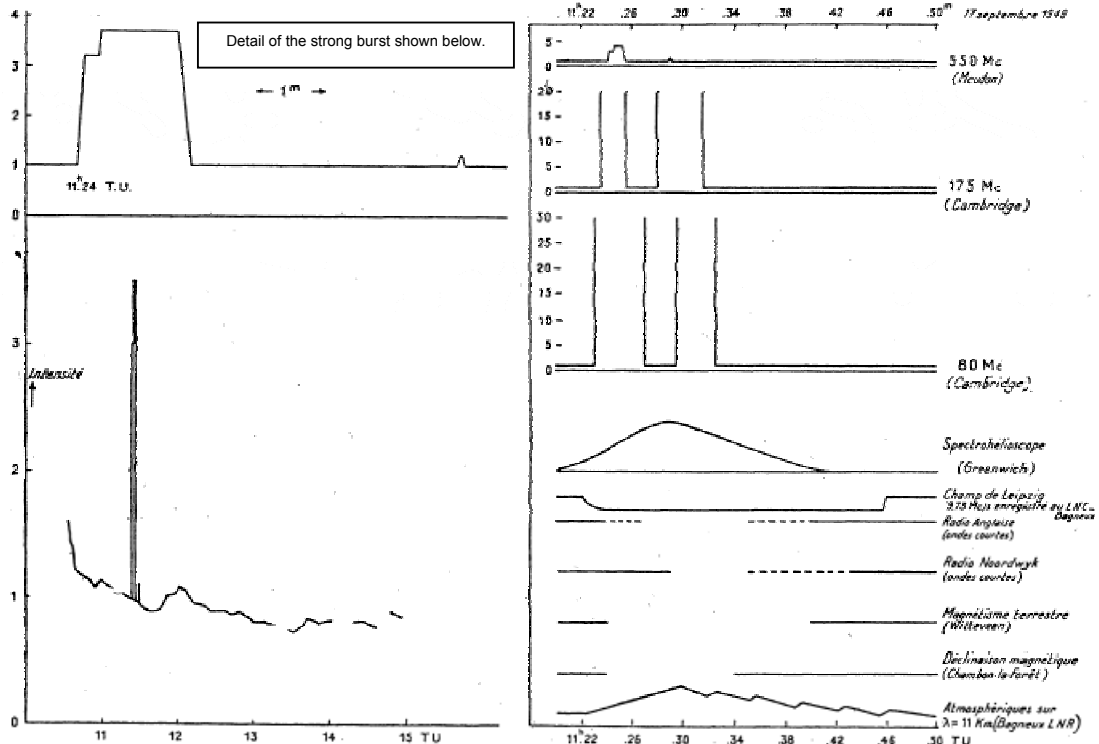


Figure 28: The solar event recorded at 555 MHz on 17 September 1948 (adapted from Laffineur and Houtgast, 1949: 143).

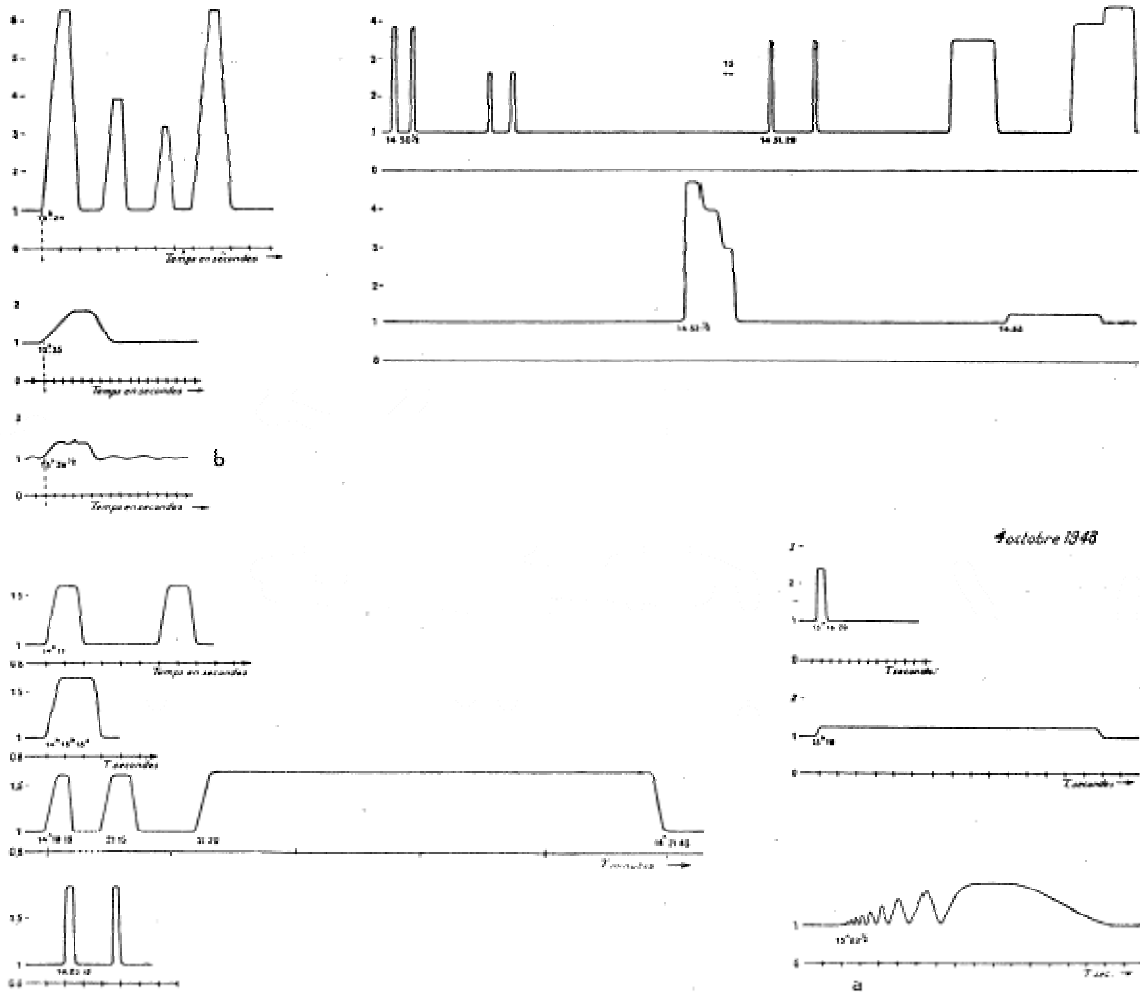


Figure 30: Detailed profiles of some of the 4 October 1948 bursts shown in Figure 29 (after Laffineur and Houtgast, 1949: 146).

In reviewing the 1949-1950 observations, Laffineur distinguished two different types of solar events, which he termed ‘Pointes d’intensité’ and ‘Sursauts’, and although the translated meanings are not the same, British and Australian solar radio astronomers would refer to these as ‘bursts’ and ‘outbursts’, respectively. The former lasted for up to 10 seconds duration, while some of Laffineur’s ‘sursauts’ persisted for tens of minutes to more than one hour.

The most notable outbursts or groups of bursts occurred on 26 March, 28 April, 8 May and 17 June 1949 and on 2, 3 and 15 August 1950, and all were associated with solar flares that produced the usual terrestrial effects. All of these radio events are illustrated in Laffineur’s paper, and the most interesting are reproduced here in Figures 31 to 34. The major outburst recorded on 8 May 1949 (Figure 32) is reminiscent of the event observed by Payne-Scott, Yabsley and Bolton on 21 May 1947, and it is interesting that there is a 3 minute delay between the start of the events at 73 MHz (as reported by Hey and included in Laffineur’s paper) and 555 MHz. Meanwhile, the very numerous nests of bursts recorded at 255 MHz on 2-3 August 1950 (see Figures 33 and 34) would seem to be a good French example of Payne-Scott’s ‘enhanced radiation’, which she describes as follows:

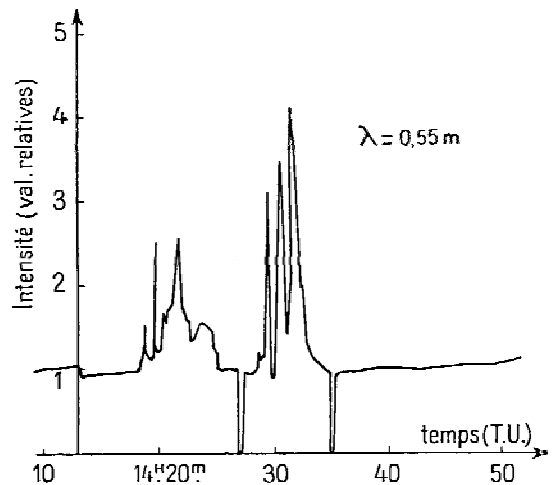


Figure 31: Solar bursts recorded at 555 MHz on 26 March 1949 (after Laffineur, 1954: Plate VII).

The intensity reaches a high level and remains there for hours or days on end; there are continual fluctuations in intensity, both long-term and short-term. The short-term increases are somewhat similar to [isolated] bursts ... but usually have a lower ratio of maximum to background radiation ... Superimposed on it may be bursts ... There may be short periods

during which the polarization is indefinite, either because two sources of opposite polarization are superimposed or because the radiation is linearly or randomly polarized, but for the great part of its life the enhanced level shows circular polarization of one sense or the other. (Payne-Scott, 1949: 216-217).¹⁴

Unfortunately, Laffineur did not have the necessary equipment required to measure the polarization of the solar bursts that he recorded. Meanwhile, Laffineur (1954: 51) claims that the most important difference between the chart records at the two frequencies on 3 August 1950 is that the 555 MHz event commenced 1 minute 10 seconds before its 255 MHz counterpart, but given the plethora of small short-duration bursts visible at both frequencies in Figure 34 we find it hard to support this interpretation.

With access to Meudon Observatory spectroheliograms of H α and CaII emission in the chromosphere, and the listings of optical events contained in the *Quarterly Bulletin of Solar Activity*, Laffineur was in an ideal position to investigate the relationship between bursts/outbursts and optical activity on the Sun. Assuming a *direct correlation* between optical activity and solar emission, he plotted the distribution on the solar disk of all bursts, groups of bursts and outbursts he recorded in 1949, based upon the positions of supposedly-associated optical activity (see Figure 35). However, there are two problems that he did not address: (1) as Christiansen et al. (1949), and others, had already shown, not all solar emission was associated with obvious optical activity (indeed, during the 1 November 1948 solar eclipse several 600 MHz radio-emitting regions with no obvious optical correlates were found to be located where sunspot groups had existed on the previous solar rotation, i.e. ~25-27 days earlier); and (2) since 600 MHz emission originated from the inner corona, those emitting regions associated with optical features on or near the limb would have been positioned beyond the edge of the optical Sun (e.g. see Christiansen et al., 1949: 515). This latter feature is an important point since many of Laffineur's 'radio-emitting regions' in Figure 35 are located near the limb of the Sun (cf. Laffineur, 1954: 37, Figure 20).

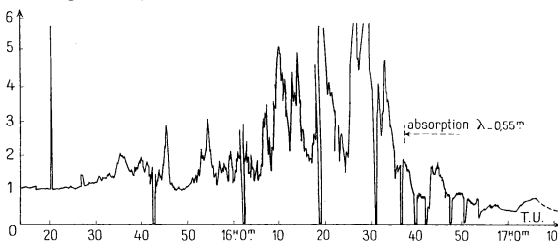


Figure 32: Solar outburst recorded at 555 MHz on 8 May 1949 (after Laffineur, 1954: Plate IX).

Although he did not allow for the aforementioned features, Laffineur proceeded to analyse the latitude, central meridian distance and solar quadrant positioning of his 'radio-emitting regions', and then came up with the following hypothesis:

In the case occupying us, suppose that the sunspots emit radio emission and that the emission is deflected by the magnetic field so that the preferred emission direction has an angle θ relative to the vertical, towards the East for example. The Earth will then be positioned in the

emission cone of those sunspots situated to the East in the northeastern hemisphere and, because of the reversal of polarity, also in those sunspots situated to the West in the south-western hemisphere (fig. 21). This explains the distribution that is actually observed.

Without pushing our hypothesis any further, we can insist on the fact that the observed distribution of solar radio emission seems to indicate that the emission is beamed [rather than isotropic]. (Laffineur, 1954: 39; our translation).

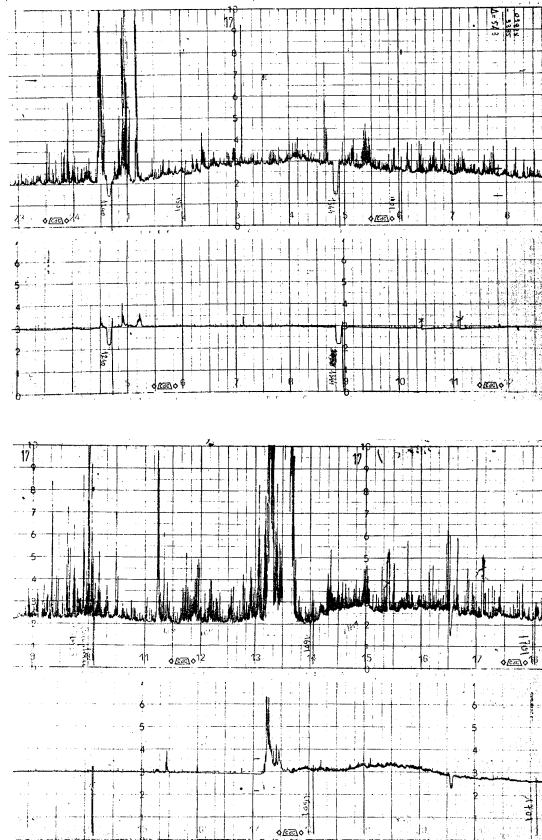


Figure 33: Solar bursts recorded at 255 MHz (upper curve) and 555 MHz (lower curve) on 2 August 1950; top: 12h 15m to 14h 50m; bottom: 14h 50m to 17h 01m (after Laffineur, 1954: 54-55).

In his long solar paper, Laffineur (1954: 4-6) mentions that he made unsuccessful attempts at Meudon to detect solar radio emission at 64 MHz using a half-wave antenna, but in 1947 he used a 64 MHz Yagi antenna at Haute Provence Observatory with some success.

In 1947 he also carried out solar observations with a 64 MHz interferometer comprising two Yagi antennas separated by 80m (or 17λ). Solar bursts were common at this frequency and at this time (e.g. see Payne-Scott, et al., 1947), so it is interesting that Laffineur did not publish any results deriving from these observations. Perhaps he produced results that did not add significantly to the existing body of knowledge, or maybe the observations were merely carried out in order to investigate the relative merits of using different antenna-receiving systems in radio astronomy rather than in a bid to make a serious contribution to solar radio astronomy. We will never know.

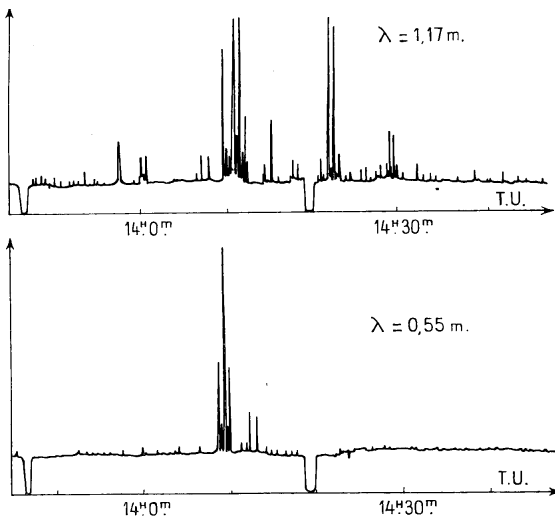


Figure 34: Solar bursts recorded at 255 MHz (top) and 555 MHz (bottom) on 3 August 1950 (after Laffineur, 1954: Plate XIII).

5.4 Non-Solar Observations

At the very end of their 1949 solar paper, Laffineur and Houtgast include a paragraph on their “Observations de la Voie Lactée” with the Meudon Würzburg antenna. They report that the incident radiation at 555 MHz from the Sagittarius region was <3% that received from the Sun (i.e. <75 K), and conclude that “This is a small value, but of the same order of magnitude, as that found by Dicke at much shorter wavelengths.” (Laffineur and Houtgast, 1949: 147; our translation).

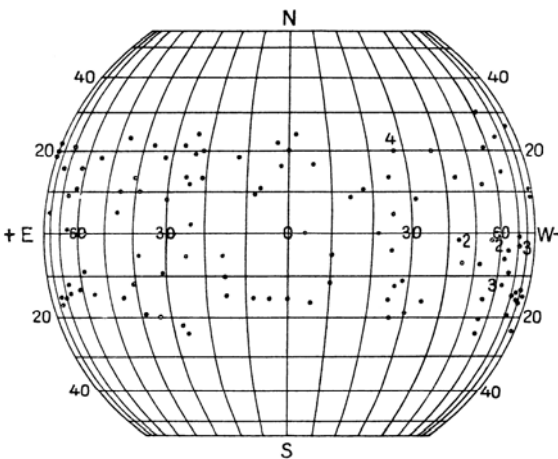


Figure 35: Positions projected onto the solar disk of radio-emitting regions detected at 555 MHz in 1949 (after Laffineur, 1954: 34).

6. DISCUSSION

6.1 The Fate of the Three Würzburg Antennas

Remarkably, all three French Würzburg antennas still exist. One of the two Nançay antennas is now preserved in the World War II Museum in Caen (Normandy). It was given to the Museum in the 1970s, and was installed on a concrete base (similar to the original one) in the dunes at this famous beach. An altazimuth mounting that mirrors the design of the original one is once more a feature of this historic instrument.

The second of the two Nançay Würzburg antennas is still at Nançay, but is slowly deteriorating (see Figure 36). This instrument and its Caen ‘twin’ played an important role in early French radio astronomy so we believe that it should be preserved at Nançay and used to interpret the early scientific history of the site, while the structural integrity of the instrument still makes this possible.

Of the three Würzburg antennas, the Meudon Observatory instrument made the longest contribution to international radio astronomy, albeit in a modest fashion in its ‘twilight years’. In 1962 this radio telescope was transferred to Bordeaux Observatory, where it was provided with an equatorial mounting (Figure 37) and from 1965 began monitoring solar radio emission at 930 MHz for 10-12 hours per day. Operating as a total power radiometer, it continued to provide daily flux density measurements through to 1990. These measurements were simply used to track the Sun’s output at 930 MHz; they did not constitute part of a major research program.



Figure 36: The sole remaining Würzburg antenna at Nançay (courtesy, Station de radioastronomie de Nançay, Observatoire de Paris, CNRS/INS).

6.2 Other Galactic and Extragalactic Research at Nançay During the Würzburg Era

One of the major solar radio telescopes erected at Nançay during the 1950s was a 1,550m long E-W oriented 32-element grating array that was inspired by Christiansen’s Australian analog at Potts Hill. Operating at 169 MHz, this produced 3.8’ E-W pencil beams 2° apart. Although designed for solar investigations, this high-resolution instrument potentially could be used for a variety of non-solar projects.

The first of these occurred in June 1957 when the Sun passed in front of the Crab Nebula (i.e. Taurus A), thereby providing an opportunity to investigate the structure of the outer corona. Unfortunately, reliable observations were only possible with the Nançay solar interferometer on two different days, June 11 and 13, and a measurable increase in the diameter of the source was noted on both occasions. But more notable was an “... actual *increase* of total flux received from

the Crab Nebula on the 13th; this result suggests that refractive processes in the corona might play an important role.” (Blum and Boischoot, 1957: 206).

Further coronal investigations utilising the Crab Nebula were made in June 1958, and these confirmed both the increase in source diameter and flux density as Taurus A approached the Sun. In Figure 38 the 1957 and 1958 data have been pooled, and it can be seen that both effects commenced when the source was at about $15R_{\odot}$. It is interesting to compare these French results with Slee’s conclusion based upon his observations of the same 1957 and 1958 events. In 1957 he carried out fan-beam, pencil-beam and interferometer observations at 85.5 MHz, while in 1958 only fan-beam and pencil-beam observations were made. He reported that

... the distribution of Crab nebula radiation is markedly affected by refraction and large-scale coronal irregularities. The secondary peak ... was recorded in both 1957 and 1958, and suggests the existence of semi-permanent regions in the corona of higher than average electron density. (Slee, 1959: 151).

He also found evidence of short-term changes in the transmission properties of the corona that were possibly linked to the ejection of disturbances from active regions on the Sun’s disk.



Figure 37: The ex-Meudon Würzburg antenna at Bordeaux Observatory (courtesy Bordeaux Observatory).

One of the most challenging problems facing radio astronomers in the 1940s and 50s was to identify optical correlates for the many discrete sources found in the course of the various sky surveys. Because of the comparative lack of resolution at radio wavelengths, it was difficult to determine the precise positions of most sources, but instruments like the Nançay 32-element E-W grating array (with its 3.8’ pencil beams) offered some hope. It is no surprise,

therefore, to learn that this instrument was used by Boischoot (1959) to investigate source positions in the late 1950s. He subsequently published a table containing 25 different sources between Declination $+60^{\circ}$ and -20° , listing for each the Right Ascension, Declination, diameter or an upper limit to this parameter, the flux density and any correlation that could be made with sources detected by previous investigators.

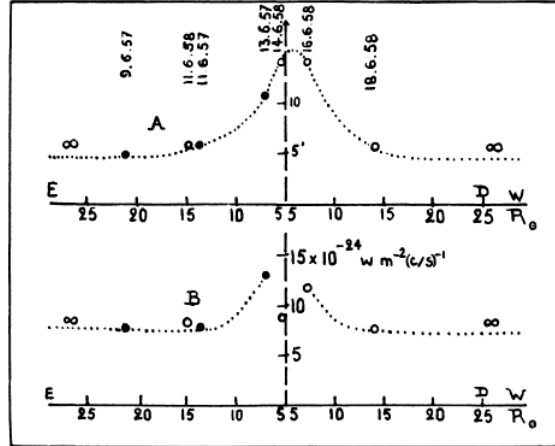


Figure 38: Variations in the apparent diameter (curve A) and flux density (curve B) of the Crab Nebula as it occulted by the Sun in 1957 and 1958 (after Blum and Boischoot, 1959: 283).

By the end of 1961 an eight-element array of equatorially-mounted dishes along a N-S baseline had been constructed at Nançay, and when combined with the original E-W array this offered a powerful new research tool for French radio astronomy. This new cross-grating interferometer (known affectionately as the ‘Grand Réseau Interférométrique’) operated at 169 MHz, and had a pencil beam with half-power widths of 3.4’ in an E-W direction and 7’ in a N-S direction. In 1961 and 1962 the Indian radio astronomer, Mohan Joshi (1962), used this array to measure the precise positions and flux densities of 112 different radio sources. He found that it was possible to correlate almost all of these with discrete sources already reported in the Cambridge 3C Catalogue (Edge et al., 1959) and the Australian catalog of Mills, Slee and Hill (1958).

Joshi also investigated the controversial position of the galaxy associated with the radio source, Hercules A. Figure 39 shows how the position derived at the Owens Valley Radio Observatory (cross number #1) correlated with Galaxy b, while the Cambridge 3C position (cross #2) clearly favoured Galaxy c. The very close correspondence between cross #3 (the Nançay result) and the Cambridge position leaves absolutely no doubt about the correct identification.

6.3 Paris Observatory, Nançay and ‘Le Grand Radiotélescope’

It was inevitable that the two Würzburg antennas at Nançay would eventually be superseded as the quest for improved sensitivity and resolution during the 1950s and into the 1960s saw the emergence worldwide of a variety of new innovative radio telescope designs. These included large single parabolas (as at Jodrell Bank and Parkes), cross-type radio telescopes (e.g. the Mills Cross at Fleurs, in Australia), several different types of variable baseline interferometer

(as at Cambridge University and the Owens Valley Radio Observatory), large fixed horizontal cylindrico-parabolic reflectors, and fixed curved collectors using tiltable plane mirrors and moving focal-plane systems. No longer was it adequate to simply recycle World War II equipment!

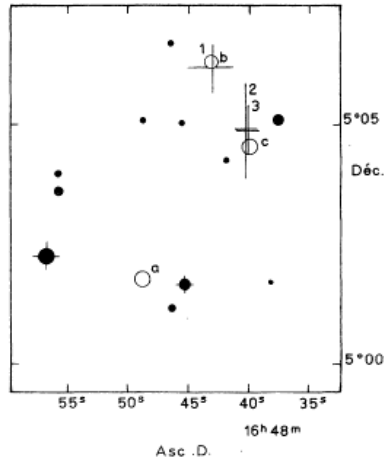


Figure 39: The region of the sky containing the discrete radio source Hercules A. Galaxies are marked by a, b and c and the crosses indicate source positions obtained by the Caltech (1), Cambridge (2) and Nançay (3) groups (after Joshi, 1962: 398).

Like their international colleagues, the Paris Observatory radio astronomers were keen to upgrade their instrumentation, especially following the detection of the H-line. For those involved in non-solar research the final choice lay between a large variable baseline interferometer and a fixed collector with a tiltable plane mirror and moving focal-plane system. The

latter option won out and ‘Le Grand Radiotélescope’ was constructed at Nançay (see Theureau and Cognard, 2004); although it became operational in 1965 it was only used on a regular basis from 1968. It is hoped that the history of this impressive instrument will be the subject of a later paper in this series.

6.4 The Institut d’Astrophysique de Paris and the Saint Michel Interferometer

Those in Laffineur’s much smaller radio astronomy group at the Institut d’Astrophysique de Paris also wished to up-grade their instrumentation, but their choice was to erect a 300 MHz 2-element interferometer with each component comprising a fixed horizontal cylindrico-parabolic reflector (Figure 40). The ‘Saint Michel Interferometer’ was set up at a field station at the Haute Provence Observatory, and began operating in 1959.

Each N-S oriented element was 60m in length and 32m in width, with the wire mesh supported by 128 wooden posts. Tall posts carried lines that supported 80 folded 300 MHz dipoles (Figure 41) 11.29m above the reflector, and each dipole could be electrically phased in order to steer the pencil beam in the meridian plane. The beamwidth was 1.5° . The two antennas were situated at the ends of a 1,100m E-W baseline. Incoming signals from the two elements were channeled into a receiver building (Figure 42) that was equidistant from the two antennas, and phase coherence was achieved by means of a microwave link, the first time such technology was used in French radio astronomy. For further technical details of this radio telescope see Laffineur and Coupiac (1967).

Laffineur and Coupiac mention (1967: 393; our translation) that

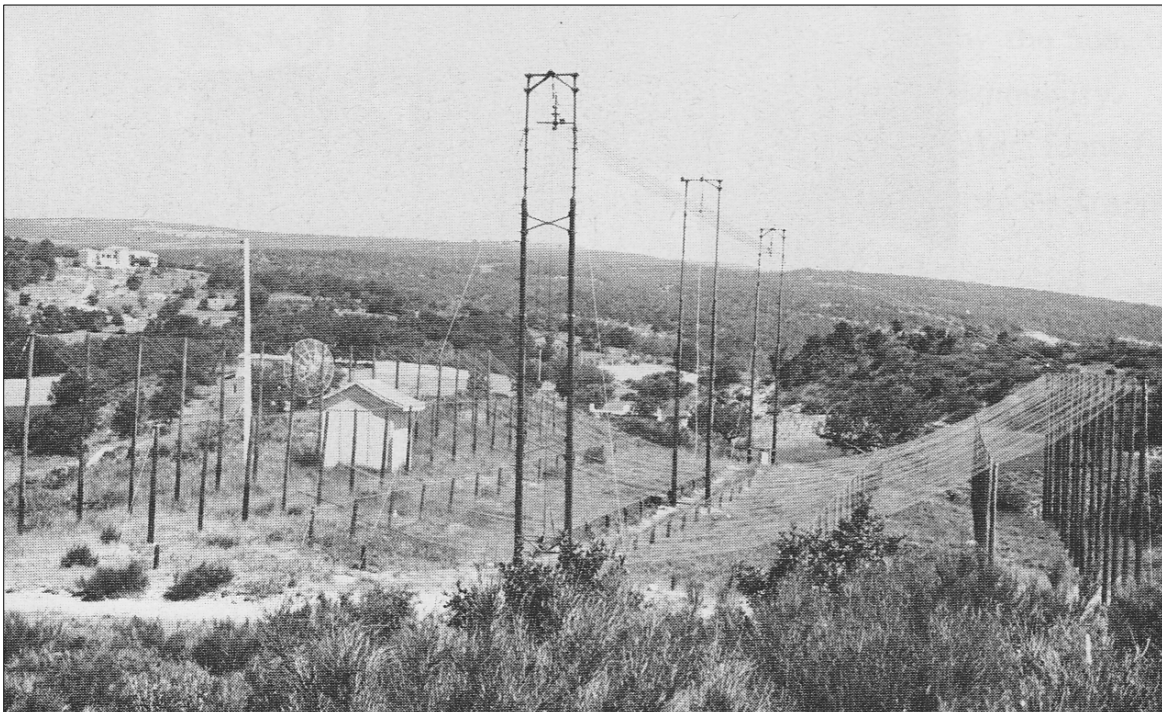


Figure 40: View of the 60m × 32m eastern element of the Saint Michel Interferometer, which was located at the Haute Provence Observatory (after Denisse, 1984: 312).

The idea of this type of antenna was first developed by one of us [i.e. Laffineur] around 1950 ... and has the principal advantage of being extremely economical whilst at the same time possessing two qualities that are favourable for research:

- a. — the possibility of being oriented in the plane of the meridian, without having to move the antennas.
- b. — good resolving power, comparable to a dish of 30m diameter.

In a telling comment, Laffineur (1961: 203; our italics) mentions that this radio telescope was “Built in 1955 for instrumental and astronomical research ...”, indicating that construction and fine-tuning of the system took several years and that science was not the sole motivating factor in establishing this impressive new radio telescope.

Once operational, the Saint Michel Interferometer was used between 1959 and March 1967 to conduct a survey of all sources $>1.6'$ in diameter and with flux densities of >9.5 Jy that passed through the beam. Because it functioned essentially as a transit instrument, the procedure was to observe the same strip of sky on three successive days or nights and to record any source interference fringes on the same chart record (e.g. see Figure 43). The maximum fringe amplitude disclosed the source’s right ascension and the positioning of the antenna beam its declination.

The resulting Saint Michel Catalogue contained 216 sources that also appeared in the 3C and Revised 3C Catalogues (see Laffineur and Coupiac, 1967: Table I), plus 40 additional sources that were not listed in either of the Cambridge Catalogues (Laffineur and Coupiac, 1967: Table III). Laffineur and Coupiac (1967) also recorded 39 different sources they felt definitely existed which were initially listed in the 3C Catalogue but were removed when the Revised 3C Catalogue was prepared (see Laffineur and Coupiac, 1967: Table IV). Finally, they noted that there were 108 different sources listed in the Revised 3C Catalogue that were not detected with the Saint Michel Interferometer (see Laffineur and Coupiac, 1967: Table II); most of these were small weak sources.

The 1967 Laffineur and Coupiac paper marked the last published research contribution from the Saint Michel Interferometer, which is a little surprising given that a follow-up paper on the spectra of the various sources detected at Saint Michel (300 MHz), Cambridge (178 MHz) and with the 85.5 MHz Mills Cross near Sydney would have been a very useful compilation. But it was not to be, and we must presume that Laffineur had other research commitments and priorities.

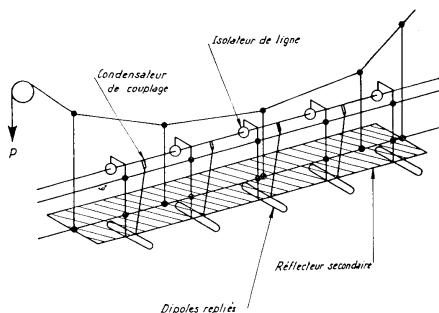


Figure 41: Schematic close-up of a section of the focal plane showing a number of dipoles (after Laffineur and Coupiac, 1967: 395).



Figure 42: The central receiver building, and microwave link tower (after Laffineur and Coupiac, 1967: 394).

We should also observe the sad fact that Laffineur’s group received little support from other staff members at the Institute of Astrophysics where the merits of radio astronomy were not fully appreciated, and the fact that Laffineur and Coupiac only used the Saint Michel Interferometer to produce a single catalogue of sources would have served to compound this perception. The truth is that Laffineur was a very good radio engineer, but few important scientific results flowed from the instruments he built. Had circumstances been different and personalities not been a factor, then Laffineur may have been tempted to join the fledgling radio astronomy group at the École Normale Supérieure, and in this supportive intellectual environment he could very well have flourished. Were this the case, the history of French radio astronomy would undoubtedly have a very different flavour!

As it was, when radio astronomy ceased at the Institut the Saint Michel Interferometer was dismantled, so neither of the antennas has survived.

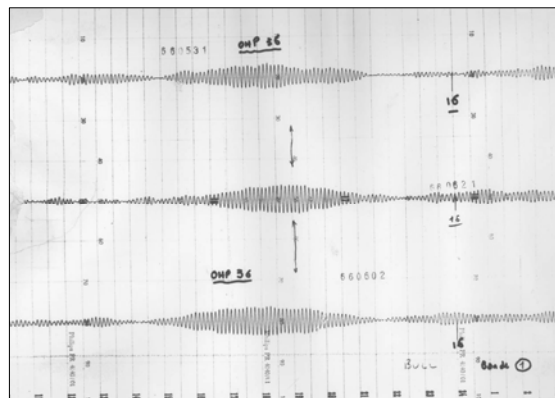


Figure 43: Chart record showing example of three successive days of observations, showing interference fringes from a number of weak sources (courtesy J. Clavier).

7. CONCLUDING REMARKS

In 1945 the defeated German army withdrew from the countries it had occupied, and it left behind a number of military radars. The Würzburg *Riese* radars contained a parabolic mirror 7.5 meters in diameter and could operate at 600 MHz (50cm). Actually their surface shape and structure were both good enough to be used down to 10cm wavelength, but their mount was altazimuth. In many countries these radar antennas contributed to early radio astronomy, and three of them were used in France.

One of the three was mounted at Meudon Observatory by M. Laffineur, who developed an ingenious electro-mechanical computer to point the antenna. Four solar eclipses were observed at 255 or 555 MHz between 1949 and 1954, in cooperation with foreign teams, so that the source regions of the radio emission could be localised and their positions compared with optical features. Laffineur and Coupiac also studied the brightness distribution across the solar disk and measured the brightness temperature of the Sun. The quiet Sun radiation temperature was found to be 240,000 K at 555 MHz. Intense solar bursts were also observed at both frequencies.

The two other Würzburg antennas were mounted at Marcoussis in a French Navy Research Center which was headed by Y. Rocard, who was also the Director of the Physics Laboratory at the École Normale Supérieure (ENS) in Paris. In the immediate post-war years, Rocard was one of very few French scientists who knew about radio astronomy, and he encouraged J.F. Denisse and J-L. Steinberg to build up a research team at the Laboratory and begin investigations in this exciting new field. The first Marcoussis Würzburg, which still retained its original WWII mounting, was fitted with a 900 MHz receiver built by E. Le Roux, and J. Lequeux and Le Roux then used this radio telescope to survey the Galaxy; they detected dozens of discrete sources many of which were new.

In 1953, the ENS group decided to build an observing station which could accommodate 2km long E-W and N-S antennas. Rocard obtained the money within a few weeks, and a parcel of land was found and bought near Nançay, south of Paris. The plan was to build a Christiansen-type cross array for solar studies at meter wavelengths and a variable-baseline interferometer using the two Marcoussis Würzburg antennas for galactic and extragalactic studies at decimetre wavelengths. In 1959 the interferometer became operational, and subsequently many continuum observations of discrete sources were made at 1,420 MHz. The angular resolution was good enough to allow an analysis of the structure of most of these sources. The variable baseline interferometer yielded a large quantity of new data, and resulted in a succession of publications.

Over the years, the three Würzburg antennas not only produced valuable scientific results; they also were used to train researchers and engineers intent on conceiving, building, testing and using new much more powerful French radio telescopes.

8. NOTES

1. This research evolved out of an IAU Historic Radio Astronomy Working Group project to survey surviving early French radio telescopes, and is the third paper in a series documenting early French radio astronomy. The first paper dealt with Nordmann's unsuccessful attempt to observe solar radio emission in 1901 (Débarbat, Lequeux, and Orchiston, 2007), and the second paper examined French solar eclipse observations made between 1949 and 1954 (Orchiston and Steinberg, 2007).
2. Yves Rocard was born in Vannes on 22 May 1903 and died in Paris on 16 March 1992. After studying science at the École Normale Supérieure (ENS), he completed doctoral degrees in mathematics and physics in 1927 and 1928, respectively. He was then responsible for classes—and subsequently for research—at the College of France. In 1939 he joined the Faculty of Science at Clermont-Ferrand, and during the War was active in the French resistance (which is when he became familiar with radar). Immediately after the War ended he became Director of the Physics Laboratory at the ENS, where he nurtured the development of the radio astronomy group headed by Jean-François Denisse and Jean-Louis Steinberg. At this time he was also involved in France's development of nuclear and hydrogen bombs and the construction of the Orsay linear accelerator. As further evidence of his versatility, in 1958 he began a career in geophysics. In 1973 at age 70 he retired from the ENS, but continued to conduct research in magnetism and biomagnetism. He died in 1992. This 'thumbnail sketch' is based on Rocard's published books and the 'Rocard' entry in Wikipedia.
3. Just 26% of the disk was masked at mid-eclipse.
4. Westerhout (1958) later showed that synchrotron emission accounted for about half of the galactic radiation at 1,390 MHz.
5. This was the *Australian Journal of Scientific Research*, which was launched by the Commonwealth Scientific and Industrial Research Organisation in 1948 in order to aid the international dissemination of research work carried out by the Organisation's staff and their university colleagues. While this aim may have been laudable, it took many years for this journal—rebadged as the *Australian Journal of Physics*—to gain international visibility (Sullivan, 2005). To partially offset this situation, the radio astronomers in the Division of Radiophysics were encouraged to immediately publicize their most important findings by means of short papers published in *Nature*.
6. This funding was conditional upon his visiting their Melbourne office during the trip. Steinberg found the office very poorly equipped, and reported on this at the Paris headquarters when he returned to France. They quickly had promotional material prepared in English and sent out to Australia.
7. This project was the mainstay of Vinokur's Doctor of Engineering thesis.
8. One of these sources, 3C 58, was later shown to be a non-thermal Crab-like SNR. Its flat spectrum was the reason that it was thought initially to be associated with an HII region.
9. Subsequently, all six sources were shown to be SNRs.
10. It is important to remember that the identification of the first quasar occurred one year after Lequeux's paper appeared in print (see Waluska, 2007).

11. In 1968-1969, Lequeux used this Californian radio telescope for a systematic study of normal galaxies in the radio continuum, a project beyond the reach of the old Nançay Variable Baseline Interferometer.
12. Marius Laffineur was born in 1904 and died in 1987. He trained in radio engineering and in 1946 joined the staff of the Institut d'Astrophysique de Paris. It was there that he became involved in radio astronomy, and the development of the Meudon Würzburg antenna and solar research carried out with it became the basis of his Doctor of Engineering which was awarded by the University of Paris. After building and carrying out a source survey with the Saint Michel Interferometer, Laffineur became disenchanted with radio astronomy and spent the remainder of his working life organising total solar eclipse expeditions in order to research the solar corona. By the time he retired in 1969 the first signs of Parkinson's Disease were apparent. His final eclipse expedition was in 1970, and he died in 1987. This 'thumbnail sketch' draws on Laffineur's published papers, data in personnel files at the Institut d'Astrophysique de Paris and information kindly supplied by Dr Serge Koutchmy (who worked with Laffineur).
13. Another factor associated with the choice of Meudon was the presence of the solar optical astronomy group there led by Bernard Lyot, who was one of Laffineur's friends.
14. Payne-Scott's 'enhanced emission' is best associated with solar emission of spectral Type I.

9. ACKNOWLEDGEMENTS

We are grateful to Danièle Destombes, Sandrine Marchal, Dominique Monseigny and Robert Zenagadin (Paris Observatory Library); Suzanne Débarbat (Paris Observatory); Gabriel Auxepaules (Paris Observatory, Nançay); Genevieve Sakarovitch (Library of the Institut d'Astrophysique de Paris); Jean-Pierre Clavier, Serge Koutchmy, Jean Mouette and François Sevre (Institut d'Astrophysique de Paris); Philippe Cais and Benjamin Quertier (Bordeaux Observatory); Hilmar Duerbeck (University of Muenster), Marsha Bishop (NRAO Library), and Harry Wendt (James Cook University) for their assistance. We also wish to thank the Australia Telescope National Facility (Sydney), Bordeaux Observatory, Institut d'Astrophysique de Paris, Paris Observatory and the Université Pierre et Marie Curie (Paris) for supplying Figures 2, 3, 8, 23, 24, 36, 37, 42 and 43.

In particular, we would like to acknowledge the Australia-France Co-operation Fund in Astronomy (Australia), France-Australia Program of International Cooperation in Science (PICS) with the support of CNRS/INSU and the French Ministry of Foreign Affairs (France), Paris Observatory and James Cook University for funding this project.

Finally, we wish to thank Monique Pick (Paris Observatory), Bruce Slee (Australia Telescope National Facility), Ron Stewart (James Cook University), Richard Strom (ASTRON, Netherlands) and Richard Wielebinski (Max-Planck-Institut für Radioastronomie, Germany) for commenting on the manuscript.

10. REFERENCES

Allen, L.R., Anderson, B., Conway, R.G., Palmer, H.P., Reddish, V.C., and Rowson, B., 1962. Observations of

- 384 radio sources at a frequency of 158 Mc/s with a long baseline interferometer. *Monthly Notices of the Royal Astronomical Society*, 124, 477-499.
- Arsac, J., 1959. Essai de détermination des très faibles diamètres apparents en radioastronomie. *Optica Acta*, 6, 77-98.
- Arsac, J., Blum, E.-J., Lestel, H., and Steinberg, J.-L., 1953. Sur deux radiomètres U.H.F. (160 MHz et 9.350 MHz) et quelques applications radioastronomiques. *Onde Electrique*, 33, 527-532.
- Biraud, F., Lequeux, J., and Le Roux, E., 1960. Interference measurements of Cygnus A, Sagittarius A, Virgo A and the supernovae of Tycho Brahe and Kepler. *Observatory*, 80, 116-118.
- Blum, E.-J., and Boisshot, A., 1957. Occultation of the Crab Nebula by the solar corona. *The Observatory*, 77, 205-206.
- Blum, E.-J., and Boisshot, A., 1959. Éclipse de la Nébuleuse du Crabe par la couronne solaire. In Bracewell, R. (ed.). *Paris Symposium on Radio Astronomy*. Stanford, Stanford University Press. Pp. 482-485.
- Blum, E.-J., Denisse, J.-F., and Steinberg, J.-L., 1954. Influence de l'ionosphère sur la réception du rayonnement galactique de fréquence de 29,5 MHz. *Comptes Rendus de l'Académie des Sciences*, 238, 1695-1697.
- Boisshot, A., 1959. Résultats préliminaires de l'observation des radiosources à l'aide de l'interféromètre de Nançay. In Bracewell, R. (ed.). *Paris Symposium on Radio Astronomy*. Stanford, Stanford University Press. Pp. 492-495.
- Boisshot, A., Blum, E.J., Ginat, M., and Le Roux, E., 1956. Observation d'une éclipse de la Nébuleuse du Crabe. *Comptes Rendus de l'Académie des Sciences*, 242, 1849-1852.
- Bolton, J.G., 1953. Radio astronomy at U.R.S.I. *The Observatory*, 73, 23-26.
- Bolton, J.G., and Stanley, G.J., 1949. The position and probable identification of the source of galactic radio-frequency radiation Taurus-A. *Australian Journal of Scientific Research*, A2, 139-148.
- Bolton, J.G., Stanley, G.J., and Slee, O.B., 1949. Positions of three discrete sources of galactic radio-frequency radiation. *Nature*, 164, 101-102.
- Bowen, E.G., and Minnett, H.C., 1963. The Australian 210-foot Radio Telescope. *Proceedings of the Institution of Radio Engineers Australia*, 24, 98-105.
- Burke, B., 2005. Early years of radio astronomy in the U.S. In Gurvits, L.I., Frey, S., and Rawlings, S. (eds.). *JENAM 2003. Radio Astronomy From Karl Jansky to Microjansky*. PA de Courtaboeuf, EDP Sciences. Pp. 27-56.
- Christiansen, W.N., 1953. A high-resolution aerial for radio astronomy. *Nature*, 171, 831-833.
- Christiansen, W.N., and Warburton, J.A., 1953. The distribution of radio brightness over the solar disk at a wavelength of 21 cm. Part I. A new highly directional aerial system. *Australian Journal of Physics*, 6, 190-202.
- Christiansen, W.N., Yabsley, D.E., and Mills, B.Y., 1949. Measurements of solar radiation at a wavelength of 50 centimetres during the eclipse of November 1, 1948. *Australian Journal of Scientific Research*, A2, 506-523.
- Cohen, M., 1994. The Owens Valley Radio Observatory: early years. *Engineering and Science*, 57, 9-25.
- Coupiac, P., Laffineur, M., and Vauquois, B., 1955. Observations radioélectriques de l'éclipse totale de Soleil du 30 Juin 1954. *Annales d'Astrophysique*, 18, 271-278.
- Dagkesamanskii, R.D., 2007. The Pushchino Radio Astronomy Observatory: origin and first decade's history. *Astronomische Nachrichten*, 328, 395-404.
- Débarbat, S., Lequeux, J., and Orchiston, W., 2007. Highlighting the history of French radio astronomy. 1: Nordmann's attempt to observe solar radio emission in 1901. *Journal of Astronomical History and Heritage*, 10, 3-10.
- Delannoy, J., Denisse, J.-F., Le Roux, E., and Morlet, B., 1957. Mesures absolues de faibles densités de flux de

- rayonnement à 900 MHz. *Annales d'Astrophysique*, 20, 222-237.
- Denisse, J-F., 1984. The early years of radio astronomy in France. In Sullivan, W.T. (ed.). *The Early Years of Radio Astronomy. Reflections Fifty Years after Jansky*. Cambridge, Cambridge University Press. Pp. 303-315.
- Denisse, J-F., Lequeux, J., and Le Roux, E., 1957. Nouvelles observations du rayonnement du ciel sur la longueur d'onde 33 cm. *Comptes Rendus de l'Académie des Sciences*, 244, 3030-3033.
- Denisse, J-F., Le Roux, E., and Steinberg, J-L., 1955. Observations du rayonnement galactique sur la longueur d'onde de 33 cm. *Comptes Rendus de l'Académie des Sciences*, 240, 278-280.
- Edge, D.O., and Mulkay, M.J., 1976. *Astronomy Transformed: The Emergence of Radio Astronomy in Britain*. New York, John Wiley.
- Edge, D.O., Shakeshaft, J.R., McAdam, W.B., Baldwin, J.E., and Archer, S., 1959. A survey of radio sources at a frequency of 178 Mc/s. *Memoirs of the Royal Astronomical Society*, 68, 37-60.
- Hanbury Brown, R., 1954. The remnants of supernovae as radio sources in the Galaxy. *The Observatory*, 74, 185-194.
- Hanbury Brown, R., and Hazard, C., 1953. A survey of 23 localized radio sources in the northern hemisphere. *Monthly Notices of the Royal Astronomical Society*, 113, 123-133.
- Heidmann, J., and Lequeux, J., 1961. Mesures interférométriques de la radiosource Hercules A à 1420 MHz. *Comptes Rendus de l'Académie des Sciences*, 253, 226-227.
- Jennison, R.C., and Das Gupta, M.K., 1953. Fine structure of extra-terrestrial radio source Cygnus I. *Nature*, 172, 996-997.
- Jennison, R.C., and Latham, V., 1959. The brightness distribution within the radio sources Cygnus A (19N4A) and Cassiopeia A (23N5A). *Monthly Notices of the Royal Astronomical Society*, 119, 174-183.
- Joshi, M., 1962. Mesures précises de position des radiosources à 169 MHz. *Annales d'Astrophysique*, 25, 377-399.
- Kerr, F.J., 1953. Radio astronomy at the URSI Assembly. *Sky & Telescope*, 12(3), 59-62, 70.
- Laffineur, M., 1954. Contribution à l'étude du rayonnement électromagnétique du Soleil sur ondes décimétriques. *Bulletin Astronomique*, 18, 1-57.
- Laffineur, M., 1961. Radio astronomy. *American Journal of Physics*, 29, 198-206.
- Laffineur, M., and Coupjac, P., 1967. Un radio interféromètre méridien à liaisons radioélectriques. Techniques et observations. *Bulletin de la Société Royale des Sciences de Liège*, 36, 393-417.
- Laffineur, M., and Houtgast, J., 1949. Observations du rayonnement solaire sur la longueur d'onde de 55 centimètres. *Annales d'Astrophysique*, 12, 137-147.
- Laffineur, M., Michard, R., Servajean, R., and Steinberg, J-L., 1950. Observations radioélectriques de l'éclipse de Soleil du 28 Avril 1949. *Annales d'Astrophysique*, 13, 337-341.
- Laffineur, M., Michard, R., Steinberg, J-L., and Zisler, S., 1949. Observations radioélectriques de l'éclipse de Soleil du 28 Avril 1949. *Comptes Rendus de l'Académie des Sciences*, 228, 1636-1637.
- Laffineur, M., Michard, R., Pecker, J-C., d'Azambuja, Dollfus, A., and Atanasijević, I., 1952. Observations combinées de l'éclipse totale de Soleil du 25 Février à Khartoum (Soudan) et de l'éclipse partielle au radio-télescope de l'Observatoire de Meudon. *Comptes Rendus de l'Académie des Sciences*, 234, 1528-1530.
- Large, M.I., Mathewson, D.S., and Haslam, C.G.T., 1959. A high-resolution survey of the Coma cluster of galaxies at 408 Mc/s. *Nature*, 183, 1663.
- Lehany, F.J., and Yabsley, D.E., 1948. A solar noise outburst at 600 Mc/s. and 1,200 Mc/s. *Nature*, 161, 645-646.
- Lehany, F.J., and Yabsley, D.E., 1949. Solar radiation at 1200 Mc/s., 600 Mc/s., and 200 Mc/s. *Australian Journal of Scientific Research*, A2, 48-62.
- Lequeux, J., 1962a. Mesures interférométriques à haute résolution du diamètre et de la structure des principales radiosources à 1420 MHz. *Annales d'Astrophysique*, 25, 221-260.
- Lequeux, J., 1962b. Observations interférométriques de la radiogalaxie M82 sur 1420 MHz, et comparaison avec objets semblables. *Comptes Rendus de l'Académie des Sciences*, 255, 1865-1867.
- Lequeux, J., and Heidmann, J., 1961. Mesures interférométriques de radiosources extragalactiques à 1420 MHz selon la direction Est-Ouest. *Comptes Rendus de l'Académie des Sciences*, 253, 804-806.
- Lequeux, J., Le Roux, E., and Vinokur, M., 1959. L'interféromètre à deux antennes à espacement variable de la station de radioastronomie de Nançay. *Comptes Rendus de l'Académie des Sciences*, 249, 634-636.
- McGee, R.X., and Bolton, J.G., 1954. Probable observation of the Galactic Nucleus at 400 Mc/s. *Nature*, 173, 985-987.
- McGee, R.X., Slee, O.B., and Stanley, G.J., 1955. Galactic survey at 400 Mc/s between declinations -17° and -49° . *Australian Journal of Physics*, 8, 347-367.
- Martyn, D.F., 1946. Temperature radiation from the quiet Sun in the radio spectrum. *Nature*, 158, 632-633.
- Menon, T.K., 1961. A model of the Orion Nebula derived from radio observations. *Publications of the National Radio Astronomy Observatory*, 1(1), 1-17.
- Mills, B.Y., 1953. The radio brightness distributions over four discrete sources of cosmic noise. *Australian Journal of Physics*, 6, 452-470.
- Mills, B.Y., Slee, O.B., and Hill, E.R., 1958. A catalogue of radio sources between declinations $+10^\circ$ and -20° . *Australian Journal of Physics*, 11, 360-387.
- Orchiston, W., and Slee, B., 2002. Ingenuity and initiative in Australian radio astronomy: the Dover Heights 'hole-in-the-ground' antenna. *Journal of Astronomical History and Heritage*, 5, 21-34.
- Orchiston, W., and Slee, B., 2005. The Radiophysics field stations and the early development of radio astronomy. In Orchiston, W. (ed.). *The New Astronomy: Opening the Electromagnetic Window and Expanding our View of Planet Earth*. Dordrecht, Springer. Pp. 119-168.
- Orchiston, W., and Steinberg, J-L., 2007. Highlighting the history of French radio astronomy. 2: The solar eclipse observations of 1949-1954. *Journal of Astronomical History and Heritage*, 10, 11-19.
- Orchiston, W., Slee, B., and Burman, R., 2006. The genesis of solar radio astronomy in Australia. *Journal of Astronomical History and Heritage*, 9, 35-56.
- Pawsey, J.L., 1946. Observation of million degree thermal radiation from the Sun at a wave-length of 1.5 metres. *Nature*, 158, 633-634.
- Payne-Scott, R., 1949. Bursts of solar radiation at metre wavelengths. *Australian Journal of Scientific Research*, A2, 214-227.
- Payne-Scott, R., Yabsley, D.E., and Bolton, J.G., 1947. Relative times of arrival of bursts of solar noise at different radio frequencies. *Nature*, 160, 256-257.
- Piddington, J.H., and Minnett, H.C., 1951. Observations of galactic radiation at frequencies of 1210 and 3000 Mc/s. *Australian Journal of Scientific Research*, A4, 459-475.
- Radhakrishnan, V., 2006. Olof Rydbeck and early Swedish radio astronomy: a personal perspective. *Journal of Astronomical History and Heritage*, 9, 139-144.
- Robinson, B., 2002. Recollections of the URSI Tenth General Assembly, Sydney, Australia, 1952. *Radio Science Bulletin*, 300, 22-30.

- Slee, O.B., 1959. Occultations of the Crab Nebula by the solar corona in June 1957 and 1958. *Australian Journal of Physics*, 12, 134-156.
- Smith, F.G., 2007. Early Cambridge radio astronomy. *Astronomische Nachrichten*, 328, 426-431.
- Steinberg, J.-L., 1953. Les récepteurs de bruits radioélectriques: III. Un radiomètre 1200 MHz et quelques applications. *Onde Electrique*, 33, 274-284.
- Steinberg, J.-L., 2001. The scientific career of a team leader. *Planetary and Space Science*, 49, 511-522.
- Steinberg, J.-L., 2004a. La création de la station de Nançay. *L'Astronomie*, 118, 626-631.
- Steinberg, J.-L., 2004b. Radioastronomie et interférométrie. *L'Astronomie*, 118, 622-625.
- Strom, R., 2004. Radio astronomy in Holland before 1960: just a bit more than HI. In Orchiston, W. (ed.). *The New Astronomy: Opening the Electromagnetic Window and Expanding our View of Planet Earth*. Dordrecht, Springer. Pp. 93-106.
- Sullivan, W.T. (ed.), 1984. *The Early Years of Radio Astronomy. Reflections Fifty Years after Jansky*. Cambridge, Cambridge University Press.
- Sullivan, W.T., 2005. The beginnings of Australian radio astronomy. *Journal of Astronomical History and Heritage*, 8, 11-32.
- Theureau, G., and Cognard, I., 2004. Le Grand Miroir. *L'Astronomie*, 118 (Janvier), 10-16.
- Van Woerden, H., and Strom, R., 2006. The beginnings of radio astronomy in the Netherlands. *Journal of Astronomical History and Heritage*, 9, 3-20.
- Waluska, E., 2007. Quasars and the Caltech-Carnegie connection. *Journal of Astronomical History and Heritage*, 10, 79-91.
- Web site: <http://atlantikwall.info/radar/radar.htm>
- Web site: http://fr.wikipedia.org/wiki/Yves_Rocard
- Westerhout, G., 1958. A survey of the continuous radiation from the galactic system at a frequency of 1390 Mc/s. *Bulletin Astronomical Institutes of the Netherlands*, 14, 215-264.

Dr Wayne Orchiston is a Senior Lecturer in Astronomy at James Cook University, Townsville. His main research interests relate to Cook voyage, Australian and New Zealand astronomical history, with emphasis on the history of radio astronomy, comets, historically-significant telescopes, early astronomical groups and societies, and transits of Venus. He has published extensively, and has edited the book *The New Astronomy. Opening the Electromagnetic Window and Expanding our View of Planet Earth* (2005). He also has a book on early Australian radio astronomy, co-authored by Woody Sullivan and Jessica Chapman, which will be published by Springer in 2007. He is the Chair of the IAU Working Group on Historic Radio Astronomy.

Dr James Lequeux belongs to the second generation of French radio astronomers, who were physicists rather than radio engineers but still lacked training in astronomy. He started research in radio astronomy with Jean-François Denisse in 1954, and in 1955 completed a Diplôme d'Études Supérieures based on work carried out with one of the Marcoussis Würzburg antennas. In 1959, after completing military training, he commenced Ph.D. research at Nançay with the two Würzburg antennas. He and Jean-Louis Steinberg produced the first French text book on radio astronomy in 1960. After a career in radio astronomy and in various fields of astrophysics, his post-retirement interests turned to history, and his 2005 book, *l'Univers Dévoilé*, is a history of astronomy from 1910 to the present day. James is now affiliated with the LERMA Department at the Paris Observatory.

Dr Jean-Louis Steinberg began working in radio astronomy with J.-F. Denisse and E.-J. Blum at the École Normale Supérieure after the War. On his return from the 1952 URSI Congress in Sydney, he began developing the Nançay radio astronomy field station, and from 1960 through to 1965 he and M. Parise led the design and construction in Nançay of 'Le Grand Radiotelescope'. In 1965, he began developing space research at Meudon Observatory. In 1960 Jean-Louis and J. Lequeux wrote a text book on radio astronomy, which was subsequently translated into English and Russian. In 1962 he was appointed Editor-in-Chief of *Annales d'Astrophysique*, which he and his wife ran until 1969. For the next five years he was one of the two Editors-in-Chief of *Astronomy and Astrophysics*. Jean-Louis has authored or co-authored about 80 scientific publications, and has received several scientific prizes and awards.

Jean Delannoy completed an undergraduate degree in Physics at the École Normale Supérieure, and in 1959 joined the Paris-Meudon Observatory (after returning from military duty in the Antarctic during the I.G.Y., in 1957-1958). Earlier, he had started working in radio astronomy with J.-F. Denisse and J.-L. Steinberg. Over the next twelve years he was involved in the development of various radio telescopes at the Nançay field station, and he then spent eight years at Bordeaux Observatory where a small 2-element interferometer was built and successfully tested. In 1979 he accepted the position of astronomer at IRAM (the Institute for Millimeter Radio Astronomy), and moved to Grenoble in 1980. There he helped build precision homological antennas—of 15m diameter and 50 micrometers surface accuracy—for the IRAM synthesis interferometer, until his retirement in 1992.

BOOK REVIEWS

***A Descriptive Catalogue of Greco-Roman Comets from 500 B.C. to A.D. 400*, by John T. Ramsey (Syllecta Classica Volume XV11, Classics Department, University of Iowa, 2006), pp. 242, paperback, US\$20, 151 x 229 mm.**

Accurate historical records of comets are of considerable interest both astronomically and ethnographically. Astronomically they provide a vital clue as to the rate at which comets were entering the inner Solar System in ancient times; the acuity of the observers of those days; the significance they placed on certain temporal, positional and physical cometary characteristics; the paths of apparitions of long- and short-period comets; and the rate at which cometary absolute brightness decays. Ethnographically they help us understand the significance of these fleeting, randomly-occurring and startling bodies in the scientific and astrological mindsets of specific civilisations. The word astrology should be stressed for comets were portentous, or, in the context of the book under review, *magnarum calamitatum praenuntiae*. In those days, if you saw a new comet, you quickly looked around for something bad to happen, and the innocent comet usually got the blame. Ignoring the frailty of humanity, comets were supposedly responsible for such things as the suicide of Cleopatra, the madness of Emperor Commodus, the siege of Mutina, the battle of Actium and a more general host of assorted droughts, plagues, fires, earthquakes, storms, revolts and other unspecified calamities. Then, just as now, what was of paramount interest to the media was 'bad', as opposed to 'good', news. And comets had badness in spades.

John T. Ramsey is a classics scholar at the University of Illinois in Chicago, and he spent years scouring Greco-Roman literature for cometary references. The present catalogue concentrates specifically on the comets recorded over a 900-year period centred on 0 BCE. It has been built on foundations laid by previous cometary cataloguers such as Alexandre-Guy Pingré (1783), Wilhelm Gündel (1921), Anthony Barrett (1978), Donald Yeomans (1991) and Garry Kronk (1999). Like Barrett, for each listed comet Ramsey gives the full Greek or Latin texts, together with an English translation. He also adds astronomical details, references to other contemporary (mainly Babylonian and Far Eastern) information sources, historical contexts and a discussion of possible uncertainties. The latter include a detailed analysis of possible date conflicts (this being quite serious because if an account in a specific year gives one date and another, in the same year, gives a different date it is difficult to decide if one or two comets occurred at that time). Some of the reports are from contemporary witnesses and others are derived from later documents. In certain cases, where a comet is described many times, often only one of the accounts is first hand and Ramsey then lists the accounts in order of date of composition.

Throughout any analysis such as this there is the problem of original mis-description. It is sometimes not clear whether the ancient record refers to a comet, or a bolide, a meteor shower or a nova. This new catalogue, for example, contains 33 reasonably confident cometary records, 18 'maybe comets' and 22 'other things'. The problem, needless to say, lies with the recorders. The majority of cometary reports were simply 'dire omen' appendages to general historical narratives. If momentous events did not coincide with the cometary sighting the news reporter of the time ignored the comet altogether and it went unrecorded. Conversely, the importance of certain wars and changes of ruler were magnified by

contemporary historians who simply invented a cometary appearance when none actually occurred. In fact only Aristotle, Pliny the Elder and the younger Seneca approached comets 'scientifically', as object worthy of study in their own right. Even then, the reports very rarely specify the season or month of the observation, and—unlike with Chinese records—the background constellation and direction of motion were usually ignored.

John Ramsey is to be congratulated on completing such a thorough and worthwhile task. The book is a joy to read and provides an illuminating window to historians of astronomy in general, and cometary science in particular. Like the reviewer, many historians of astronomy at school were forced to concentrate on mathematics and physics at the expense of Greek and Latin. To this end, Ramsey takes infinite pains with quotations and translations. These are augmented by detailed discussions in which facts and speculations are well separated. This is a work of impressive scholarship and will remain a useful reference for centuries.

David W. Hughes
University of Sheffield, England

***The Sun Kings. The Unexpected Tragedy of Richard Carrington and the Tale of How Modern Astronomy Began*, by Stuart Clark (Princeton, Princeton University Press, 2007), pp. xii + 211, ISBN-13: 978 0 691 12660 9 (hardback), US\$24.95, 165 x 242 mm.**

Although Richard Carrington's name is well known to solar astronomers as the first person to record one of those all-too-rare white light flares, I suspect that most of us know relatively little about him. So Clark's book is particularly welcome. Having said that, Clark does much more than flesh out Carrington the man and Carrington the astronomer, and this is reflected in the subtitle of the book, "The Unexpected Tragedy of Richard Carrington and the Tale of How Modern Astronomy Began".

Stuart Clark spreads his chronological net widely and wisely. After a brief introductory 'Prologue' which focuses on SOHO's exploits in 2003, he leaps back in time to 1859 for the first of twelve chapters, all but one of which deal with nineteenth century astronomy. Chapter 1 provides biographical information on Richard Carrington but it also documents the observation he made on 1 September 1859 that was to propel his name into the annals of astronomy. He was observing the Sun by the standard projection method from his private observatory at Redhill, Surrey, when at about 11:18 GMT he noticed

Without warning, two beads of searing white light, bright as forked lightning but rounded rather than jagged and persistent instead of fleeting, appeared over the monstrous sunspot group ... As he stared, dumb-founded, the two spots of light intensified and became kidney shaped. (Clark, 2007: 12-13).

Auroral displays witnessed across Europe the following nights and a magnetic anomaly registered at Kew at this time convinced Carrington that his observation was important, and he proceeded to describe it at the 11 November 1859 meeting of the RAS, where corroborative observations by another British amateur astronomer, named Hodgson, were also presented. Both accounts subsequently appeared in *Monthly Notices of the Royal Astronomical Society*, and soon after Carrington was elected a Fellow of the Royal Society.

In the next three chapters, Clark sketches developments that took place in solar astronomy between the late eighteenth century and Carrington's era, thereby providing a chronological context for the 1859 observations. He

then returns to Carrington, outlining the nature of his solar program from 1852 to 1859, before embarking on the impressive auroral displays and magnetic storms experienced worldwide on 28/29 August 1859, introducing readers to the foundations of solar spectroscopy, and recounting Warren de la Rue's pioneering efforts in solar photography. All this time, Carrington was suffering a personal crisis as the demands of the family's brewing business left him less and less time to devote to observational astronomy. On 24 March 1861 he made his last solar observation and less than four months later the instruments at his Redhill observatory went on sale. The 'unexpected tragedy' had materialized and Carrington was out of astronomy—but for a brief return in 1863.

The remaining chapters of this very readable book document progress in solar astronomy during the remainder of the nineteenth century, along with fascinating tidbits of Carrington's private life: his marriage to Rosa Rodway in 1869; her stabbing in 1871 by her lover, William Rodway (whom she passed off as her brother), and his attempted suicide; her death from a drug overdose in 1875; and Carrington's own death, by suicide, a few weeks later. There is also much about the strained relationship that existed between Carrington and that doyen of British astronomy, George Biddell Airy, and about Carrington's falling out with the RAS. In other words, *The Sun Kings* is about much more than mere solar astronomy.

I found this a fascinating book, and at just US\$24.95 it is very sensibly-priced. I wholeheartedly recommend it to anyone interested in the development of nineteenth century astronomy or the emergence of solar physics.

Wayne Orchiston

Centre for Astronomy, James Cook University, Australia

***The Telescope. Its History, Technology, and Future* by Geoff Andersen (Princeton, Princeton University Press, 2007), pp. 248, ISBN-13: 978 0 691 12979 2 (hard back), US\$29.95, 165 x 242 mm.**

The telescope will be 400 years old in 2008, so be prepared to see a plethora of new books on the topic at your local bookstore. This book by Geoff Andersen is likely to be one of the best. Andersen starts the story rolling by explaining how vision works, and he then discusses early naked eye astronomy and the subsequent research that has been carried out since then. The main part of the book is Chapters 4 to 7, which explain the basic physics behind how a telescope works. Andersen goes into more detail and care than is usual in a book at this level, explaining the related concepts of diffraction, reflection and refraction, as well as what he calls "when good telescopes go bad", which is about the various aberrations that can and do affect a telescope. Chapter 7, on interferometry, is particularly well written.

For those thinking of building their own observatory, Andersen gives advice on site selection and related issues. Later parts of the book go into applications of the telescope outside of astronomy, including surveillance, laser communication and remote sensing. It is nice to see these other topics, since most books on telescopes usually focus solely on astronomical topics. There are also chapters on adaptive and active optics, and the final chapter is on telescopes of the future.

There are some nice illustrations which help explain the concepts discussed. I particular liked the two photographs of the so-called 'Face on Mars', which were used to demonstrate the effects of increased resolution. They were taken at different times, but under similar lighting conditions. The Viking Orbiter in 1976 shows the now famous 'face' which is absent from the higher-resolution

photograph taken by the more recent Mars Global Surveyor Probe. However if you squint—or take off your spectacles—the 'face' re-appears!

There are very few mistakes that I spotted, although I am sure that the author in discussing spacecraft communication meant interplanetary not interstellar (p. 142).

The primary audience for this extremely reasonably-priced book is those amateur astronomers who want a more thorough than usual introduction to the telescope, and for them I thoroughly recommend it.

David Blank

Centre for Astronomy, James Cook University, Australia

***Living Among the Stars at the Johannesburg Observatory*, by Dirk Vermeulen (Johannesburg, Chris van Rensburg Publications, 2006). Pp. x + 134. ISBN 0 86846 107 5 (hardcover), R200+postage, 217 x 272 cm.**

When I was researching the life and times of R.T.A. Innes and his 1896 Cape Observatory appointment I had to make a hard decision: whether to include in my paper the fact that immediately before his departure Innes had his wife committed to a Sydney psychiatric hospital so that he could sail off to South Africa with his sons—and his mistress—or whether to focus solely on his astronomical achievements and leave out all mention of his hankering for heavenly bodies of a non-celestial kind. After discussing this delicate matter with Brian Warner I decided on the latter course of action, but I need not have worried for Dirk Vermeulen has included this fascinating trait of Innes' personality in his book about the Johannesburg (cum Transvaal, cum Union, cum Republic) Observatory. Innes, of course, was its founding Director.

So here we have an interesting book, with a very healthy mix of text and fabulous historical photographs that collectively document the history of the Observatory from its construction in 1904 to its close in 1971. Along the way, the rationale for the Observatory changed from meteorology to astronomy, as it acquired ever-larger telescopes, culminating in the 26.5-in Grubb refractor (which became operational in 1925, just eight years before Innes' death, at the age of 71).

Apart from Innes, there are also separate chapters on the subsequent Directors, H.E. Wood, W.H. van den Bos, W.S. Finsen and J. Hers, with information on their observational programs and other scientific achievements. We find, for example, that this Johannesburg observatory was responsible for the discovery of 148 new asteroids and 6,555 double stars (including Innes' identification of Proxima Centauri) and a handful of comets. We also learn about the Franklin-Adams photographic survey of the southern sky and that this observatory produced some of the best ever Earth-based coloured photographs of Mars, taken in 1956 and 1969. There are also eight pages on the changing nature of the Observatory's time service, and several pages deal with the close links between Holland's Leiden Observatory and the Union Observatory, which led to the founding of a southern station in Johannesburg. Incidentally, it was Leiden University which awarded an honorary D.Sc. degree to Innes in 1924—interesting recognition, surely, for a man who never received any tertiary training! The book ends with 14 pages about the post-1971 history of the site, and a collection of eight appendices (one of which details Innes' research on variations in the Earth's rate of rotation).

This is a beautifully prepared and presented book, and it belongs on the bookshelf of every astronomer interested in the history of South African astronomy.

Wayne Orchiston

Centre for Astronomy, James Cook University, Australia.

JOURNAL OF ASTRONOMICAL HISTORY AND HERITAGE

ISSN 1440-2807

INDEX VOLUME 10, 2007

Name	Page	Title	Page
Bailey, M.E.	163	<i>The Man Who Found Time. James Hutton and</i>	
Blank, D.	247	<i>the Discovery of the Earth's Antiquity</i>	74
Bonifácio, V.	101	<i>The Man Who Changed Everything: The Life of</i>	
Brosche, P.	133	<i>James Clerk Maxwell</i>	158
Brück, M.	74, 157, 167	<i>The Stargazer of Hardwicke: The Life and</i>	
Bryan, J.	31, 148	<i>Work of Thomas William Webb</i>	74
Butler, C.J.	173	<i>The Sun Kings. The Unexpected Tragedy of</i>	
Cartwright, S.	93	<i>Richard Carrington and the Tale of How</i>	
Chapman, A.	198	<i>Modern Astronomy Began</i>	246
Corbin, B.	72	<i>The Telescope. Its History, Technology, and</i>	
Corvan, P.	179	<i>Future</i>	247
Davenhall, C.	158	<i>Two Paths to Heaven's Gate</i>	157
Débarbat, S.	3	<i>Caveat Lector. Comments on Douglas J. Keenan,</i>	
Delannoy, J.	221	<i>'Astro-Historiographic Chronologies of Early</i>	
Fernandes, J.	101	<i>China are Unfounded'</i>	137
Gros, M.	159	<i>Defence of Planetary Conjunctions in Early</i>	
Hughes, D.W.	21, 93, 246	<i>Chinese Chronology is Unmerited</i>	142
Keenan, D.J.	142	<i>Demetrios Eginitis: Restorer of the Athens</i>	
Lequeux, J.	3, 221	<i>Observatory</i>	123
Lindsay, J.	187	<i>Dr Eric Lindsay: A, B, C, D ... to Z. A Personal</i>	
Lindsay, M.	187	<i>Recollection</i>	194
Lindsay, R.	187	<i>Dr Eric Lindsay: Personal Recollections</i>	193
Malaquias, I.	101	<i>Dr Eric Mervyn Lindsay (1907–1974): A Personal</i>	
Mattig, W.	73	<i>View</i>	190
Marsden, B.G.	21	<i>E.E. Barnard and the Eclipse of Iapetus in 1889</i>	31
McConnell, J.C.	190	<i>F.X. von Zach and the Fifth Continent</i>	133
MackKeown, P. K.	49	<i>Family Memories of a Very Special Uncle</i>	187
McNally, D.	193	<i>Highlighting the History of French Radio Astronomy.</i>	
Manimanis, V.N.	123	<i>1: Nordmann's Attempt to Observe Solar Radio</i>	
Mantarakis, P.	123	<i>Emission in 1901</i>	3
Moseley, T.	194	<i>Highlighting the History of French Radio Astronomy.</i>	
Nicholson, D.S.	197	<i>2: The Solar Eclipse Observations of 1949-1954</i>	11
O'Dell, C.R.	151	<i>Highlighting the History of French Radio Astronomy.</i>	
Orchiston, W.	3, 11, 157, 158, 221, 246, 247	<i>3: The Würzburg Antennas at Marcoussis,</i>	
Pankenier, D.W.	137	<i>Meudon and Nançay</i>	221
Pettersen, B.R.	115	<i>IAU Archives Working Group. Triennial Report</i>	
Schmidt, W.	73	<i>(2003–2006)</i>	72
Sheehan, W.	151	<i>John Michell, The Pleiades, and Odds of 496,000</i>	
Steinberg, J.-L.	11, 221	<i>to 1</i>	93
Stephenson, F.R.	74, 211	<i>Lowell Observatory Enters the Twentieth Century</i>	
Tenn, J.S.	65	<i>—In the 1950s</i>	65
Theodossiou, E. Th.	123	<i>Obituary: Donald Edward Osterbrock (1924-2007)</i>	151
Waluska, E.	79	<i>Planet, Asteroid, Minor Planet: A Case Study in</i>	
		<i>Astronomical Nomenclature</i>	21
		<i>Quasars and the Caltech-Carnegie Connection</i>	79
		<i>Remembering Eric and Sylvia Lindsay During the</i>	
		<i>War Years</i>	197
		<i>Sir Robert Ball (1840–1913): Royal Astronomer</i>	
		<i>In Ireland and Astronomy's Public Voice</i>	198
		<i>Stephen J. O'Meara and Ring Spokes before</i>	
		<i>Voyager 1</i>	148
		<i>Solar Photography in the Nineteenth Century:</i>	
		<i>The Case of the Infante D. Luis Observatory</i>	101
		<i>The Armagh-Dunsink-Harvard Telescope: From</i>	
		<i>Dream to Oblivion</i>	173
		<i>The Lindsay Centennial Symposium. Eric Mervyn</i>	
		<i>Lindsay and Astronomy in Ireland</i>	163
		<i>The Norwegian Naval Observatories</i>	115
		<i>Under Irish Skies</i>	179
		<i>Variations in the Earth's Clock Error ΔT between</i>	
		<i>AD 300 and 800 as Deduced from Observations</i>	
		<i>of Solar and Lunar Eclipses</i>	211
		<i>William Doberck — Double Star Astronomer</i>	49

CONTENTS

Papers From the Lindsay Symposium	Page
The Lindsay Centennial Symposium. Eric Mervyn Lindsay and Astronomy in Ireland <i>Mark E. Bailey</i>	163
Armagh, Dunsink and the Early Days of the Irish Astronomical Society <i>Mary (Máire) Brück</i>	167
The Armagh-Dunsink-Harvard Telescope: From Dream to Oblivion <i>C. John Butler</i>	173
Under Irish Skies <i>Patrick Corvan</i>	179
Family Memories of a Very Special Uncle <i>Robin Lindsay, Jack Lindsay, and Mary Lindsay</i>	187
Dr Eric Lindsay (1907–1974): A Personal View <i>John C. McConnell</i>	190
Dr Eric Lindsay: Personal Recollections <i>Derek McNally</i>	193
Dr Eric Lindsay: A, B, C, D ... to Z. A Personal Recollection <i>Terry Moseley</i>	194
Remembering Eric and Sylvia Lindsay During the War Years <i>Donald S. Nicholson</i>	197
Sir Robert Stawell Ball (1840-1913): Royal Astronomer in Ireland and Astronomy's Public Voice <i>Allan Chapman</i>	198
Other Papers	
Variations in the Earth's Clock Error ΔT Between AD 300 and 800 from Observations of Solar and Lunar Eclipses <i>F. Richard Stephenson</i>	211
Highlighting the History of French Radio Astronomy. 3: The Würzburg Antennas at Marcoussis, Meudon and Nançay <i>Wayne Orchiston, James Lequeux, Jean-Louis Steinberg and Jean Delannoy</i>	221
Book Reviews	
A Descriptive Catalogue of Greco-Roman Comets from 500 B.C. to A.D. 400, by John T. Ramsey <i>David Hughes</i>	246
The Sun Kings. The Unexpected Tragedy of Richard Carrington and the Tale of How Modern Astronomy Began, by Stuart Clark <i>Wayne Orchiston</i>	246
The Telescope. Its History, Technology, and Future, by Geoff Andersen <i>David Blank</i>	247
Living Amongst the Stars at the Johannesburg Observatory, by Dirk J. Vermeulen <i>Wayne Orchiston</i>	247
Index	248

