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## THE ANDREWS' PROFESSORS OF ASTRONOMY AND DUNSINK OBSERVATORY, 1785 — 1985\*

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I must first express my thanks to the Provost and the Academic Council of the College for accepting my nomination as Andrews' Professor in the University in an Honorary capacity. This has enabled me to re-enter a collegiate body for the first time since 1951 when I left Cambridge University to follow an astronomical career at the Royal Greenwich Observatory and, in due course, at the Dublin Institute for Advanced Studies. I must also thank Dr. Peter Fox and Dr. Bernard Meehan for mounting the exhibition in the Long Room of the Library, which contains some of the items of which I shall speak. My thanks also go to Professor David Spearman and Professor Petros Florides for making the arrangements for this lecture.

Few of us can be unaware that the modern scientific view of the Universe has little resemblance to the view that mankind had of the known Universe in 1785. This was the year in which astronomical observations began at Dunsink Observatory, making it one of the oldest astronomical institutions still in existence.

It is my task tonight to trace something of the inspiration and the disappointment, the hard work and the occasional reward beyond measure that has accompanied the Andrews' Professors through 200 years. In general I will try to assume no more in my audience than an awareness of one or two of the principal notions of our science, without any detailed knowledge. Within this compass I hope simply to *indicate* the major achievements of the baker's dozen of personalities involved and to relate a *few* of the curious and entertaining sidelines that have come down to us. Finally, if I may, I shall speak a little about current developments in observing facilities.

The list of Andrews' Professors of the University of Dublin and the Senior Professors of the Dublin Institute for Advanced Studies that have held responsibility for Dunsink Observatory in 200 years is shown in Table 1. The age on taking up that responsibility is on average 32 years with a standard deviation of 8 years and on

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\* Text of a public lecture given in Trinity College, Dublin on 14th March, 1985.



Dunsink Observatory, March 1985, built 1785, Architect Graham Moyers.



Dunsink Directors 1785–1985: 1. First Andrews Professor, 1783–1790, Rev. Henry Ussher. *Andrews Professors and Royal Astronomers*: 2. 1790–1826, Rev. John Brinkley; 3. 1827–1865, Sir William Rowan Hamilton; 4. 1865–1874, Franz F. Brunnow; 5. 1874–1892, Sir Robert Stawell Ball; 6. 1892–1897, Arthur A. Rambaut; 7. 1897–1906, Charles Jasper Joly; 8. 1906–1912, Sir Edmund T. Whittaker; 9. 1912–1921, Henry C. Plummer. *Acting Director*: 10. 1921–1936, Charles Martin. *Senior Professors, School of Cosmic Physics*: 11. 1947–1957, Hermann A. Bruck; 12. 1958–1963, Mervyn A. Ellison; 13. 1964–, Patrick A. Wayman.

leaving it is 49 years with a standard deviation of 7 years. The duration in office, not including my own holding, is likewise an average of 14 years with a standard deviation of 11, being a distinctly non-normal distribution! I am the twelfth director of the Observatory and my tenure to date covers, to my astonishment, just over one-tenth of the 200-year period; I feel that this enables me to speak with authority, at any rate on the topic I have chosen.

Table 1

Directors of Dunsink Observatory

1785 – 1947: University of Dublin, Trinity College

1947 – 1985: Dublin Institute for Advanced Studies

| Title and Name                                                |     | Country<br>of Birth | Born | Died | Dates<br>in post |
|---------------------------------------------------------------|-----|---------------------|------|------|------------------|
| First <i>Andrews' Professor</i> :                             |     |                     |      |      |                  |
| Rev. Dr. Henry Ussher                                         | ... | Ireland             | 1741 | 1790 | 1783–1790        |
| <i>Royal Astronomers of Ireland and Andrews' Professors</i> : |     |                     |      |      |                  |
| Rev. Dr. John Brinkley                                        | ... | England             | 1766 | 1835 | 1790–1826        |
| Sir William Rowan Hamilton                                    | ... | Ireland             | 1805 | 1865 | 1827–1865        |
| Dr. Franz Friedrich Brunnov                                   | ... | Germany             | 1821 | 1891 | 1865–1874        |
| Sir Robert Stawell Ball                                       | ... | Ireland             | 1840 | 1913 | 1874–1892        |
| Dr. Arthur Alcock Rambaut                                     | ... | Ireland             | 1859 | 1923 | 1892–1897        |
| Dr. Charles Jasper Joly                                       | ... | Ireland             | 1864 | 1906 | 1897–1906        |
| Sir Edmund Taylor Whittaker                                   | ... | England             | 1873 | 1956 | 1906–1912        |
| Dr. Henry Crozier Plummer                                     | ... | England             | 1875 | 1946 | 1912–1921        |

*Senior Professors, School of Cosmic Physics, Dublin Institute for Advanced Studies :*

|                             |     |         |      |      |           |
|-----------------------------|-----|---------|------|------|-----------|
| Dr. Hermann Alexander Bruck | ... | Germany | 1905 | –    | 1947–1957 |
| Dr. Mervyn Archdall Ellison | ... | Ireland | 1910 | 1963 | 1958–1963 |
| Dr. Patrick Arthur Wayman * | ... | England | 1927 | –    | 1964–     |

\* Tenth Andrews' Professor from 1st October, 1984 (Honorary).

Rev. Henry Ussher, who lived from 1741 to 1790, was distantly related to the famous Archbishop James Ussher of Armagh of the 17th Century, after whom this theatre is named and whose library formed the foundation of the library of our College. Henry Ussher was a Fellow and then a Senior Fellow of the College as well as being at various times Professor of Divinity, Senior Dean, University Proctor, a Preacher of the University and, from 1783, nominated as the first Andrews' Professor of Astronomy.

Ussher's achievement was to plan the building of Dunsink Observatory, with the assistance of the architect Graham Moyers, following lines that were set out by

Nevil Maskelyne, Astronomer Royal of England. A description of Ussher's Meridian Room and the circumstance of building the Observatory on the chosen site appears as the very first contribution to the Transactions of the Royal Irish Academy, an institution that also commemorates its bicentenary in 1985. The site of Dunsink was a place for quarrying limestone and this material provided both the building stone for the Observatory and the bedrock on which the instruments rested. Ussher's account contains many points still of interest because it reads as a personal narrative, which indeed it is, rather than a scientific paper. One point that emerges from it is a pre-occupation with meteorology, for this was a special interest of Henry Ussher that qualified him for the post. I must point out that Nevil Maskelyne, working at Greenwich along the lines so ably laid down and demonstrated by his predecessor James Bradley, had properly identified what has come to be termed *local refraction*, that is, non-homogeneity in the atmosphere, as a prime limiting factor to accuracy of positional measurement in astronomy. Thus Ussher sought to achieve special treatment of that problem in his design for ventilation by special louvred semi-circular openings and, as far as I am aware, the meridian room at Dunsink was the first observing room in the world in which meteorological factors were taken into account.

Ussher relates how the two principal instruments, for determining (a) time of transit across the local meridian and (b) elevation at or near meridian transit, were ordered from Jesse Ramsden of London, "without limitation as regards price". He also ordered two fine clocks by John Arnold of London, two of perhaps ten astronomical regulators made by Arnold & Son, which exist in the meridian room to this day in perfect working order. Thus Ussher's foundation was thorough, expensive, but somewhat pedestrian, for Ramsden was already elderly—he died in 1800—and his designs, though excellent in workmanship, were by no means up to date (for instance the telescope of the large circle finished by Ramsden's successor in business, Matthew Berge, in 1808, was not provided with an achromatic doublet lens as its objective).

The foundation of the Observatory had been by the bitterly contested will of Provost Francis Andrews (d. 1774) the builder of the Provost's house and the Front Range. This robust, legal and parliamentary personality, celebrated apparently for his conviviality and as a good trencherman, was a classical scholar of achievement, but seems not to have included astronomy among his principal interests. Nevertheless he had travelled widely in Europe, and it is probable that he had become aware of the widespread impact on philosophy that had been caused by the work of Galileo, Kepler and Newton, and he seems to have considered that no educated person should be denied acquaintance with the succinct mathematical notation that, in one sweep, had dispelled the obfuscation of two millenia. Newton's laws of motion were based partly on Galileo's physical experiments, and Newton's law of gravity was (in a sense) derived from Kepler's empirical laws of planetary motion, which in their turn were based on the results of Tycho Brahe's observational work; these laws made inappropriate the speculation (as distinct from the observational work) of most writers in astronomy from Babylonian days to the work of Christopher Clavius of Bamberg, 1601, seventy-six years after Copernicus' death, the oldest book at Dunsink Observatory, in which no mention of Nicholas Copernicus occurs.

It was Hely Hutchinson, a formidable and opinionated Provost, who appointed

Ussher. Hutchinson was wont to invoke the Provost's Veto, when the Board of the College voted to take some action which was not to his liking, either intellectually or in a political context. It is said that he imposed his veto in favour of Ussher, when Ussher was put forward for Fellowship, on account of Ussher's willingness to vote for Hutchinson's son in parliamentary elections. Romney Robinson of Armagh is understood to have written "John Hely Hutchinson was the most shameless jobber in an age of jobbery. He swayed so many votes in the House of Commons that the Government were compelled to give all that he asked for".

The Provost's use of the veto was embodied in the 17th Century College Constitution associated with Archbishop Laud. It was hardly used by any Provost other than Hutchinson and yet he used it *again* in the case of Ussher's *successor*, as we shall see. The foundation of Dunsink, too, had been a celebrated legal wrangle because much of the property bequeathed by Francis Andrews to his, rather distant, relations was found to be College property, not his to dispose of. His private property was left for his mother's use with reversion to the College for founding the Observatory. A sum of £3,000 and an income of £250 was intended for the purpose. After the case had been finally settled, in 1782, substantially in favour of the College, the original sum seems to have been left intact but the actual cost of construction in 1785 ran to £8,000. During 1786 there are entries in the Board's Minutes, the Register, to the need for all work at Dunsink to be measured and assessed 'at the usual Dublin prices', before the outstanding bills were paid.

It is clear from these Minutes that involving itself in an expensive property five miles away was a risky undertaking for the Board. We know almost exactly everything that Ussher did in the first five years through a diary, called 'Miscellanies' which becomes in due course a meticulous meteorological record and, from 1788, an observing book that stops on 5 May 1790, three days before Henry Ussher's death. Two matters that are of particular interest in this book may be mentioned. In the fly-leaf section there are recorded observations by Francis Beaufort, the famous Hydrographer of the Royal Navy, son of a Church of Ireland clergyman of Collon, Co. Louth, who himself had strong scientific interests. It seems that the only real scientific training that Beaufort had, apart from his work as a midshipman in the Navy, was at the hands of Henry Ussher for five months in 1788 at Dunsink, where he learnt about finding astronomical positions and about meteorology. It is tempting to guess that the mighty strong winds mentioned in Ussher's diary inspired Beaufort to suggest his 'Scale of Wind-Strength'.

The other item is extraordinary. A label is glued inside the cover that reads: "This book was never seen by me till March 1827; it having been retained at Armagh during the times of Dr. Hamilton, Dr. Davenport and Dr. Robinson. Had I seen it early, it would have possessed much interest". The note is signed by John Brinkley who left Dunsink in 1827 to become Bishop of Cloyne as a successor in the see of Bishop Berkeley. I could easily devote the whole of this lecture to John Brinkley; it was he whom Hely Hutchinson secured as Ussher's successor in 1790 when he determined to veto the Board's customary choice of one of its own, John Stack, for the vacant Chair. If the vacancy had extended more than six months, the Chancellor of

the University could nominate the person to be appointed. Brinkley had been suggested by Maskelyne at the special request of Hutchinson and the question was asked in the *Freeman's Journal* of the day why an Irishman could not have been found. John Brinkley was only 24 at the time but he may have pretended to have been older. His date of birth in 1766 is given correctly on a plaque in Cloyne Cathedral but is said in the *Dictionary of National Biography* to be wrong by three years. In fact, his birth was obscure, being out of wedlock; his maternal grandfather, a butcher in Suffolk, was John Brinkley also. Nothing other than the name, John Toler, is known of his father, and nothing of the patron who paid for his education in mathematics to a high standard and at Caius College, Cambridge, where he graduated as Senior Wrangler. He impressed Maskelyne and he became a famous astronomer of his day working tirelessly with the instruments at Dunsink, including the large Ramsden Circle used for determining the north polar distances of stars.

In an effort to enhance the standing of the Professorship, Hely Hutchinson, after securing Brinkley's appointment, arranged that Letters Patent of George III in 1792 would create the title Royal Astronomer of Ireland to be bestowed on the Andrews' Professor 'for ever after'. Coupled with this honour was a series of duties of which one paragraph I will read:

The said Professor, with the help of his assistant, shall make regular observations of the heavenly bodies, and record them in the order of time, in bound books prepared for the purpose, particularly meridian observations of the sun and moon, every day, when the weather permits; and of the planets in their principal positions; and the transits of the principal fixed stars, and of such as are nearest the equator for settling the right ascensions of the sun, moon and planets; eclipses of the sun and moon and Jupiter's satellites; occultations of fixed stars and planets by the moon; and comparisons of comets (whenever they appear) with fixed stars in right ascension and declination, in order to settle their places in the heavens and determine their motions and theories.

This and much more, was written into the Statutory Provisions of the College and although, in principle, they could be altered or made less specific, no action was ever taken.

Brinkley thus became the first Royal Astronomer of Ireland and he was followed by seven others. The relevant Statute was removed from the College Constitution in 1966, so that the title Royal Astronomer of Ireland no longer exists.

Brinkley made observations systematically, evaluated new good figures for astronomical constants concerning nutation, aberration, refraction, the obliquity of the ecliptic, and the precession of the equinoxes, and he developed the use of statistical procedures for analysing observations, for which work he was awarded the Copley medal of the Royal Society in 1822. He received the Cunningham Medal of the Royal Irish Academy in 1818 for a paper concerning the advance of lunar perigee, due to the combined gravity of the Sun-Earth-Moon system.

Entering into his main aim, using the Ramsden Circle intensively, but not able to carry out reduction and correction for *all* his observations, Brinkley picked out some bright stars in which he suspected annual variation of north-polar distance which he attributed to parallax, that is a direct measure of stellar distance that had not been achieved up to that time.

This first came to notice in 1815 and from that year until 1827 when he resigned his professorship he engaged in a celebrated controversy with John Pond, successor to Maskelyne as Astronomer Royal at Greenwich. Brinkley was wrong in attributing his variations of position to parallax but the reason for the differences has never been fully explained. I believe that the existing observing books of Brinkley contain so many unreduced observations that it would be feasible to identify the cause of variations from the data obtained. He *did* actually observe 61 Cygni A & B, the first star to have a parallax announced (by Bessel) in 1838, but his observations did not, apparently, indicate a measurable parallax. Certainly Brinkley became a much respected practical and mathematical astronomer. He was the only President of the Royal Astronomical Society actually resident in Ireland—in two years he only presided once and this was after he became Bishop of Cloyne. Ordained while still at Cambridge, he had built himself into an ecclesiastical career and his children and grand-children were active in the Church of Ireland; his grandson Walter Stephen Brinkley was Treasurer to the Church Ecclesiastical Commissioners.

On Brinkley's departure another extraordinary sequence of events took place. It was known well in advance that Brinkley was going to leave Dunsink. As a youngster William Hamilton, with every promise of genius, destined to become Ireland's most renowned mathematician and scientist of the 19th century, was befriended by John Brinkley. It is pleasant to find that Brinkley corresponded and conversed with Hamilton apparently on a basis of mutual respect and equality, in spite of an age difference of forty years. This confirms the comment on Brinkley's memorial plaque that he was 'benevolent and disinterested' (but certainly *not* uninterested!).

Brinkley, however, did not favour Hamilton as his successor; he thought he was too young and too brilliant to be burdened with the duties of running a practical observatory. There was an assistant called Charles Thompson who had been in the post since 1817 and Hamilton would have to oversee his work as well as maintain a substantial household. Acting in an advisory capacity, the Provost now being Samuel Kyle, it seems that both Herschel and Brewster favoured a rival candidate, George B. Airy, who already held the Lucasian professorship of mathematics at Cambridge although at that time he had not become director of the University Observatory there. Airy was subsequently a major scientific figure as Astronomer Royal of England.

It was Boyton, Hamilton's tutor, himself a competent mathematician, who took the front running to have Hamilton appointed at the incredibly early age of 21, even before he had graduated Artis Baccalaureas. Hamilton was in turn a youthful genius, an earnest but pleasant young student, an eager mathematician, a senior colleague, and eventually, maturing in his mid-fifties, a doyen scientist. Hamilton's serious mathematics began at the age of 15 when he wrote a paper "On Caustics", an optical and geometrical topic, not a chemical one. He spotted an error in Laplace's *Mécanique Céleste* at the age of sixteen—he brought this to Brinkley's notice—but found him absent when he called at the Observatory and only met Brinkley a year or so later. He gained real fame in his early twenties by skilful handling of the behaviour of light; he had been successful in describing in mathematical detail the phenomenon of birefringence in crystals, or double refraction. This was long before Maxwell's equations

were available to describe the transmission of electromagnetic waves. Hamilton's theories of light were built upon the mathematics of an *elastic medium* which was a mechanism postulated principally by Fresnel. The response of an anisotropic crystalline material, which we now see as a tensor relationship between an electrical vector and its dielectric response, was seen by Fresnel as a result of an *ellipsoid of elasticity*. This led to the mathematical representation adopted by Hamilton. With his marvellous notation, possibly springing from his love of poetry and language, Hamilton succeeded in predicting a particular phenomenon of birefringence which became known as *conical refraction*. Within a few months the prediction was brilliantly confirmed experimentally by Humphrey Lloyd, Professor of Natural Philosophy in Trinity College, and Hamilton's fame was assured. Airy at Cambridge, and Whewell, also at Cambridge, were most impressed by this prediction, because the mathematics was so abstruse that it could hardly be expected to yield so directly a new physical phenomenon. Physics textbooks often describe conical refraction, but most of these explanations are without any of the vigour Hamilton employed in his description, and are sometimes even erroneous.

So William Rowan Hamilton worked in relative isolation at Dunsink, producing first his Theory of Systems of Rays, published in the Transactions of the Royal Irish Academy while he was still in his early twenties, and yet it was the first long, closely argued, well printed, mathematical paper in those Transactions. How his seniors must have been in awe of such a prodigy! This was followed by everlasting contributions to Mechanics, which have flowed naturally into modern theoretical physics, particularly into Schroedinger's quantum mechanics, because of the particular form of Hamilton's equations of motion. Hamilton's Equations, a derivative of the Lagrangian Equations of motion, stand as his best-known and most useful contribution to mechanics, but the algebraic notation of quaternions, which dominated Hamilton's researches from 1843 to his death in 1865, is sometimes described as his most notable contribution. Certainly it encompassed for the first time what we recognize as vector algebra. Hamilton's moment of discovery, said to have taken place when walking with his wife on the bank of the Royal Canal near Broome Bridge, refers to the incorporation of non-commutative algebra, where

$$a \times b \neq b \times a.$$

The mystic relationship

$$\mathbf{i}^2 = \mathbf{j}^2 = \mathbf{k}^2 = \mathbf{ijk} = -1$$

$$\mathbf{ij} = -\mathbf{ji} = \mathbf{k}$$

$$\mathbf{jk} = -\mathbf{kj} = \mathbf{i}$$

$$\mathbf{ki} = -\mathbf{ik} = \mathbf{j}$$

is intelligible in terms of familiar scalars and vectors if we write Hamilton's quaternions  $q$  symbolically as a sum of a scalar and a vector

$$q = s + \mathbf{v}$$

and we define a quaternion product

$$q_3 = q_1 q_2 = s_3 + \mathbf{v}_3$$

where

$$s_3 = s_1 s_2 - (\mathbf{v}_1 \cdot \mathbf{v}_2)$$

and

$$\mathbf{v}_3 = s_1 \mathbf{v}_2 + s_2 \mathbf{v}_1 + (\mathbf{v}_1 \times \mathbf{v}_2)$$

In Hamilton's notation,  $i$ ,  $j$  and  $k$  are *quaternions* each with zero values to 3 out of 4 components, and *not* simply unit vectors. If we think of  $i$ ,  $j$  and  $k$  as the unit vectors  $\mathbf{i}$ ,  $\mathbf{j}$ ,  $\mathbf{k}$ ,  $(\mathbf{i} \cdot \mathbf{i}) = 1$ ; it is the minus sign in the product rule that gives the key. This minus sign is also an inhibition to common sense because it implies  $\text{Energy} = \frac{1}{2} m v^2$  as *negative* if  $v$  is a measure of a velocity vector  $\mathbf{v}$ .

Many and varied are the tales told of Hamilton. Edmund Whittaker, who became Andrews' Professor in 1906, said that when he arrived the locality of Dunsink was full of memories of Hamilton's peculiarities, all relating to at least 40 years earlier! Two must suffice here; as a young man Hamilton was quite active and energetic in sports such as leaping, vaulting, running and swimming, and it is noted by Piazzi Smyth, writing in the 1870s, that Hamilton, when in his twenties, had hopped on one leg all round the high balustrade at roof level of the main building at Dunsink. This would seem incredibly foolhardy even on the part of a youngster, let alone for an academic of genius. The second incident refers to his later years which were affected by loneliness and sadness through the problems his wife Helen faced. She complained bitterly in a letter written from England that the visiting servants of Hamilton's former student and confrère Aubrey de Vere, quarrelled with and caused trouble with their own servants. This illustrates the range of problems that must have faced Helen Hamilton, who married William in 1833, six years after he had first come to Dunsink, six years in which the household was run by William's sisters, particularly his one elder sister, Sydney, who eventually, after many years in various endeavours, found her forte as a superintendent of a mental institution in New Zealand. William assumed that his sisters would stay on after he was married since he couldn't see how the shy Helen could manage, but of course they did not; Helen had difficulty and often temporarily left her husband, so Hamilton was frequently lonely. They remained devoted to each other, in spite of Hamilton's romantic but innocent relationships with some other women, and they had three children.

Hamilton had few students. Boyton had secured his appointment to the Observatory because he thought he would work best in isolation. Hamilton never pressed his candidacy for a Fellowship. In 1853 a Royal Commission reported on Trinity College, Dublin. The Commission was critical of Hamilton's management of the Observatory because few of the specific requirements of the Statutory Provisions were being completely fulfilled. Nevertheless they badly underestimated what *was* being done in practical astronomy. Be that as it may be, they recognized his genius. There had been proposals, in 1843, that Hamilton should become Professor of Mathematics in the College, that James McCullagh should become Professor of Natural Philosophy, and that Dr. Romney Robinson of Armagh be offered the Andrews' Professorship. If effected, this proposal would have altered markedly the

course of astronomy at Dunsink, but whether Hamilton would have attracted brilliant students in College remains quite uncertain. The 1853 Commission recommended added practical workers to be introduced but this was never done.

Brunnow (1865–1874) and Ball (1874–1892) instigated a new era in observational work. Two new major instruments were provided, one of which, the South telescope, remains still in working order. It was built by Thomas Grubb of Dublin, an engineer to the Bank of Ireland who made and maintained fine machines for printing bank notes, and who had developed the construction of telescopes. He gained special fame about 1874 by securing the contract for all the telescopes and domes at a gigantic observatory to be built in Vienna, an edifice that still exists as an Institute of Astronomy. His work was continued by his son Howard, who became Sir Howard Grubb, and the firm continued, from 1925, in Newcastle-upon-Tyne, up to this very year of 1985, under the name of Sir Howard Grubb, Parsons and Co. associated with C. A. Parsons, Ltd., of steam turbine fame, originating with the family of the Earls of Rosse at Birr Castle, Co. Offaly.

The new telescope at Dunsink used a 12-inch lens donated by Sir James South, which was made by Cauchoix of Paris in 1832. It had been used in a telescope made by Troughton, which South, being irascible by nature, had rejected as unsatisfactory. Greatly to his annoyance he had lost a legal case based on a report by Airy and Sheepshanks, and broke up the offending telescope in his fury. Grubb made the telescope in 1853 for William Dargan's Dublin Exposition on Leinster Lawn of that year, and a fine description is to be found in the catalogue of that exhibition but the lens was not finally donated to the University until 1863. It was made clear that Hamilton could not be entrusted with such a practical project. The telescope dome was built as quickly as possible under Brunnow and completed in 1868. It exists today as a fine example of Grubb's early work.

Also provided by 1872 was a new transit circle by Pistor and Martins, capable of high accuracy in both co-ordinates. It was used for the construction of catalogues of star places for a variety of purposes which I will not now explain and for the regulation of a new sidereal clock by Dent as accurately as possible. At this time there was no general method of regulating Public Clocks in Dublin, and Dublin was 'behind' cities such as Glasgow, Edinburgh and Liverpool in this respect. An electric control system was inaugurated by Ball, although the scheme originated in Brunnow's time, controlling clocks in the G.P.O., the Ballast Office of the Port & Docks Board, and in Trinity College. It also controlled the fall of a time ball intended to assist mariners to set their deck watches before leaving port. The power supply was a row of liquid batteries recharged by chemicals and there was a single telegraph line passing through each controlled clock and earth return. What we would now call a 'pulse', then called a 'current', went from the Observatory each second and influenced all the pendulums so as to synchronise them; each pendulum bob was a large horseshoe magnet and the current kept it in phase, or it was supposed to, if all was working well.

There was endless trouble with the signals, with the line, and with the required maintenance, and there exists a magnificent collection of correspondence between the parties concerned, preserved by the staff of the Port & Docks Board. It has been

pointed out by William Stuart of Leixlip, a horologist, that all the while that the Dunsink Time Service ran (1874–1937) an equally accurate, or at any rate an adequately accurate source, was provided in Dublin by the railway companies who transported a first-class watch under lock and key each and every night by the Irish Mail from Greenwich via Paddington to Kingstown. However that may be, the Observatory gained much publicity for itself by determining time by observing clock stars with the Pistor and Martins transit circle, securing some observations most weeks. The accuracy aimed at was 1 second of time.

Sir Robert Ball was the subject of a discourse by Gordon Herries Davies on Trinity Monday 1984. Ball had gained experience as tutor to the children of the Third Earl of Rosse, including the astronomically active fourth Earl and the inventor of the steam turbine C. A. Parsons. At the time of the vacancy caused by the resignation of F. F. Brunnow he was Professor of Mathematics and Mechanics in the Royal College of Science in Dublin, later to be incorporated into University College. He was an analytical mathematician of considerable skill and he concentrated his academic work on a field of geometric algebra called "*The Theory of Screws*" which, I would estimate, though I may be wrong, had limited application. It deals symbolically with displacements, rotations, and twists and their mechanical analogues, forces, couples and wrenches in three dimensions.

In 1884 the British Association met in Montreal and a party of some ten or twelve Dublin scientists travelled from Liverpool. Ball kept a fascinating diary of his trip which is set out in a separate article below.

Ball writes of his developing style of lecturing. On 28th August, in Montreal, Ball replied to a letter waiting for him from a lecture agent in Boston "who proposes to make lecture engagements for me at 10% commission. I have sent him full particulars and have asked for £40 a lecture". He never undertook a lecture without what he considered an appropriate fee and he made a personal fortune. He also wrote many popular books, and examples can easily be picked up in secondhand bookshops today. Here are a few titles from his total list of twenty-two titles:

*Story of the Heavens*  
*The Earth's Beginning*  
*Great Astronomers*  
*The Story of the Sun*  
*Star-Land*  
*Popular Guide to the Heavens*  
*In Starry Realm*  
*A Primer of Astronomy*

Two of his professional writings are:

*Spherical Astronomy*  
*The Theory of Screws.*

Many of these were written after Ball was appointed to the Lowndean Professorship of Astronomy in Cambridge in 1892 at the age of 52; he died in 1913. Around the turn of the century he was one of the professors who was particularly welcoming to a newcomer in his first visit to Cambridge, Ernest Rutherford, and Rutherford always remembered his kindness.

I will pass relatively briefly over Arthur Rambaut (1892–1897) and Charles Jasper Joly (1897–1906). C. J. Joly and John Joly, famous as a physicist as well as a geologist, were second cousins and were descended from Jean Jasper Joly (1740–1823) their great-grandfather, who was associated with the Duke of Leinster, and who was founder of the Irish branch of a great French family traced back to the 14th century. He was eventually Doorkeeper to the House of Lords in Dublin with a salary of £100; he was associated also with the development of Harcourt Terrace and ‘Joly’s Field’ which was a favourite duelling site at one time.

Charles Joly was a distinguished mathematician who edited a new edition of Hamilton’s *Elements of Quaternions* and he carried out a solar eclipse expedition to Spain in 1900. The first mechanical calculating machine at Dunsink was acquired in his time.

During the time of Rambaut and Joly the observing work on the Zodiacal Catalogue was started. This catalogue was designed to provide accurate star positions for faint stars in the band of sky over which the planets and minor planets pass. The accurate star positions were needed first for an instrument called the heliometer and later for photography so that solar-system bodies could have their position accurately recorded. The Dunsink contribution to this catalogue was a very large one and the observations, running to many thousands each year were mostly carried out by Mr. Charles Martin. Charles Martin came from Greenwich as an assistant in 1895 under Arthur Rambaut, and continued under three other Andrews’ Professors, Joly, Whittaker and Plummer, before becoming Acting Director in 1921. The Zodiacal Zone Catalogue was used for many years as the best reference work available for star positions used in the treatment of observations of lunar occultations of stars, and Moon positions generally. The problem of the motion of the Moon and how accurately it may be predicted has long been a key problem in solar-system dynamics. It has been connected with problems of the tides, of deformation of the Earth, of the definition of the unit of time and a number of other geodetic and geophysical problems.

C. J. Joly died of typhoid fever, said to have been due to contamination of the water supply to the Observatory. For many years there existed a large cast-iron tank taking the water from the roof, making an alternative water supply available. I assumed that this was put in following Professor Joly’s death, and this is probably so. I find however, that the Board recommended this work to be done in 1892, fourteen years before the sad death of the Andrews’ Professor. I may say that Miss Jessie Joly, a daughter, who had contracted the fever before Professor Joly, still lives in Ireland.

I come now to the second greatest of the Andrews’ Professors, Edmund Taylor Whittaker (1873–1956) who was in the post for just six years, 1906 to 1912. He came to Dublin within six months of Joly’s death and he came with a reputation for fine mathematical work already established. His achievement in those six years was astonishing. With the help of Charles Martin, he continued with the established observing programmes on the Transit Circle and the time service to Dublin and he commenced using the 15-inch Roberts reflector, installed in the time of Arthur Rambaut, for measuring the brightness of stars. The use of photography and the

possibility of photographic exposures being spoilt incurred a new difficulty. Apart from increasing sky-illumination by street-lights, which must still have been relatively insignificant in 1908, there was a problem associated with trespass through the Observatory grounds using a public footpath from Dunsink to Dunsinea. The College, in fact the Andrews' Professor, maintained that the path was for access to the Observatory from Ashtown and Dunsinea only and was not a footpath *through* the Observatory grounds. The few resident householders to the north of Dunsink thought otherwise. Eventually, it appears, a legal injunction was sought and the result, favourable to the College, was recorded in the Minutes of the Observatory Board, 1st July, 1910:

"The legal steps taken by the Board to secure the privacy of the Observatory and protect it as a photographic station from the brilliant lights of trespassing bicyclists have been crowned with success".

As well as this practical work, Edmund Whittaker wrote his *magnum opus*—*A History of the Theories of the Aether and Electricity*—published in 1910. This was re-written in 2-volume form, to take into account the progress of relativity and quantum theory, in 1951, the first volume being *The Classical Theories* and, in 1953, the second volume *The Modern Theories, 1900–1926*. This work is a fascinating scholarly record of many aspects of mathematical physics applied to physical phenomena. I cannot speak authoritatively on Edmund Whittaker's work generally, which included the editing of A. S. Eddington's posthumous and controversial work *Fundamental Theory*, but I would like to draw attention to some passages in Whittaker's *History of the Theories of the Aether and Electricity* that have come to my notice, particularly since they are adjunct to astronomical ideas.

In the Chapter entitled "From Bradley to Fresnel", covering the period 1720 to 1820, say, Whittaker traces in 33 pages the reasoning that led up to the famous discussions of the wave theory of light, establishing it as an explanation of the phenomena of diffraction; he summarizes Fresnel's work on the elastic medium analogy, which was the basis for Hamilton's treatment of birefringence:

"Fresnel's investigation can scarcely be called a dynamical theory in the strict sense, as the qualities of the medium are not defined. His method was to work backwards from the known properties of light, in the hope of arriving at a mechanism to which they could be attributed; he succeeded in accounting for the phenomena in terms of a few simple principles, but was not able to specify an aether which would in turn account for these principles".

On the use of the term Aether, by 1953 he had to issue an apologium:

"As everyone knows, the aether played a great part in the physics of the nineteenth century; but in the first decade of the twentieth, chiefly as a result of the failure of attempts to observe the Earth's motion relative to the aether, and the acceptance of the principle that such attempts must always fail, the word 'aether' fell out of favour, and it became customary to refer to the interplanetary spaces as 'vacuous'. With the development of quantum electrodynamics, the vacuum has come to be regarded as the seat of the 'zero-point' oscillations of the electromagnetic field, and of a 'polarisation' corresponding to a dielectric constant different from unity. It seems absurd to retain the name 'vacuum' for an entity so rich in physical properties, and the historical word 'aether' may fitly be retained".

On a more direct astronomical theme he talks about theories of gravitation. The topic concerns what is called the secular acceleration of the Moon—

“In 1905 P. H. Cowell re-determined from ancient eclipses the observed secular acceleration of the Sun. These matters were discussed by J. K. Fotheringham in 1920 and in 1939 by H. Spencer Jones, who showed that the secular acceleration of the Sun, Mercury and Venus are proportional to their mean motions, and can be accounted for by the retardation of the Earth’s axial rotation by tidal friction”. (In other words a secular change in the diurnal rotation period of the Earth, defining the unit of time).

Now, the relationships established are quite relevant to an understanding of the Earth’s interior. Again, in remarking that in 1910 Cowell and Crommelin revealed the effect of suggested non-gravitational forces in the motion of Halley’s Comet, Whittaker was involving a subject that, in the years from 1968, became a topic deeply investigated by my colleague at Dunsink, Professor Tao Kiang: the residuals in the orbital variations of Halley’s Comet.

The point I wish to make is that Whittaker, although his prime interests were always with mathematics, and indeed he had been a professor of mathematics for many years rather than an astronomer, was anxious, even as late as 1953, to link astronomical data with mathematical method and to make deductions in other fields, such as geophysical understanding of the Earth. I have to remark further about Edmund Whittaker that he gave fine lecture courses in Trinity College on Spectroscopy, Astrophysics and Electro-Optics. He was trying to convey to students the importance of the physics of the astronomical environment that had increased largely as a result of the study of astronomical spectra and associated laboratory spectra. One cannot appreciate astrophysics without an understanding of spectrum features and relations between atoms and stars, a subject beautifully developed in the 1920’s and 1930’s coincident in time with the emergence of quantum theory calculations of atomic structure. With the development of massive computing power, this is a subject of continuing and renewed interest.

These lectures were attended by Eamon de Valera when he was a Professor of Mathematics at the Carysfort Training College for Primary Teachers at Blackrock. De Valera became fascinated with the mathematical work of Hamilton and appreciated the symbolic manipulations represented by quaternion algebra and other parts of Hamilton’s work. During these years he was trying to learn Irish, to appreciate Celtic traditions, and to improve his mathematical standing. Edmund Whittaker acted as a sponsor for at least two applications that de Valera made for senior posts in the university colleges in Cork and Galway, from one of which he withdrew and for the other he was not successful. I have the printed reference here; it reads:

“Mr. Edward de Valera has attended several of my Professorial Courses of lectures on Spectroscopy, Astrophysics and Electro-Optics during the past two years. In the personal intercourse which has thus been brought about, I have been much impressed by the intellectual vigour with which he has interested himself in the most difficult problems of Natural Philosophy. His knowledge is both broad and deep, and I am confident that in any educational position he will exercise the best of influences over those with whom he is brought into contact”.

There is an entry in the Dunsink Visitors' Book of E. de Valera, for 5 June 1909. One can speculate how different the history of Ireland might have been if one of these appointments away from Dublin had been made.

Edmund Whittaker left Dunsink in 1912 to take up the Professorship of Mathematics at Edinburgh. He remained always a great friend of Dublin and he actively encouraged Eamon de Valera to found the Dublin Institute for Advanced Studies.

After Whittaker, Henry Crozier Plummer came from Oxford University and carried on through World War I at Dunsink with Charles Martin. A radio apparatus for receiving time signals was confiscated by the authorities in 1914 and returned after the War. Plummer did very good work with equipment which by that time required modernisation. He became an authority in several branches of astronomy including his postulation of the pulsation theory for cepheid variable stars, along with that of H. Shapley, an idea which greatly assisted the work of Arthur Eddington on the theory of stellar structure.

Plummer resigned in 1921; he was a bachelor and did not care too much for the life at Dunsink and with the Anglo Irish Treaty he left for Woolwich Military Academy. He later became President of the Royal Astronomical Society. Trinity College did not fill the vacancy; Charles Martin, as Acting Director, 'held the fort', for fifteen years. He supervised the time service and he had assistance in this task from Frederick J. O'Connor from 1923. He was not an academic but he was a person of considerable achievement and great industry and was able to provide the flight plan for the Junkers aircraft "Bremen" that made the first East-West crossing of the Atlantic Ocean in 1928. In 1936 Martin died, after spending his whole adult life working at Dunsink, and Trinity College decided to discontinue any astronomical activity and to lease the land and houses as a temporary measure. In the meantime de Valera, remembering his active work under Whittaker, sought thereafter the re-opening of Dunsink, in some way to be debated.

It certainly seems that his studious pursuits in the years around 1910 made a deep impression on de Valera and resulted in his resolve to found the Dublin Institute for Advanced Studies in 1940 and to cause the creation of the School of Cosmic Physics in 1947. It is, of course, of great interest to pursue the question of how the required Acts of the Oireachtas were passed that set up the Institute and how Dunsink Observatory was purchased by the State from Trinity College for its then market value of £5,000. The instruments and the buildings were totally neglected, but renovation was possible. It was stoutly undertaken by Professor Hermann A. Brück who was the first Senior Professor in the Astronomy Section of the School of Cosmic Physics, from 1947. In 1957 Professor Brück was appointed Astronomer Royal of Scotland, and Professor of Astronomy in the University of Edinburgh, a dual function, and early in 1958 there came from the Royal Observatory Edinburgh, Mervyn Archdall Ellison, son of Rev. William F. A. Ellison, a former director of Armagh Observatory in Northern Ireland. Mervyn Ellison died in 1963 at the early age of 53 and I was appointed from August 1964, having previously been at the Royal Greenwich Observatory at Herstmonceux Castle in Sussex.

I cannot, in the time available, do justice to the large responsibility assumed by the Dublin Institute for Advanced Studies and the work carried out over 38 years under three Senior Professors. I am able just to list the astronomical topics that feature in the Annual Reports of the Astronomy Section between 1950 and 1983 (Table 2); this does not include the technique-oriented and historical topics described in the reports. Instead, I would like to say something of the future, and in particular as it concerns the optical telescopes now going into use in the Canary Islands.

Table 2

## Astronomical Research at Dunsink Observatory, 1950–1983

(Items in italics are major interests that occur over several years).

|         |                                                              |
|---------|--------------------------------------------------------------|
| 1950/51 | Photoelectric record of scintillation.                       |
| 1951/52 | Profile of Hydrogen Alpha line in solar prominences.         |
| 1951/52 | <i>Flash Spectra of solar chromosphere (eclipses).</i>       |
| 1952/53 | <i>Line Intensities in the near u.v. solar spectrum.</i>     |
| 1955/56 | Co-operative observations of 12 Lacertae, etc.               |
| 1955/56 | Solar Flare Patrol (spectroheliograph).                      |
| 1957/58 | Photographs of trails of artificial satellites.              |
| 1958/59 | <i>Solar Photographs in H-alpha light, Cape Town Patrol.</i> |
| 1959/60 | Sudden Enhancements of Atmospherics record.                  |
| 1960/61 | <i>Solar Flare investigations.</i>                           |
| 1964/65 | Doppler shifts in solar absorption lines.                    |
| 1965/66 | Radio events and flare activity.                             |
| 1965/66 | Inertial frame of reference.                                 |
| 1965/66 | <i>Cepheid variable stars in the Magellanic Clouds.</i>      |
| 1966/67 | Hyades Cluster modulus.                                      |
| 1966/67 | Discovery of a K0 Flare Star ('Butler's star').              |
| 1966/67 | Ellipticity of Omega Centauri.                               |
| 1966/67 | Random fragmentation in galaxy formation.                    |
| 1967/68 | Photometry of flare stars (b, v, r).                         |
| 1967/68 | Monte Carlo methods for double-star orbit statistics.        |
| 1967/68 | Lick Observatory counts of galaxies.                         |
| 1967/68 | Haro galaxy 'jets'.                                          |
| 1967/68 | Auto-correlation of galaxy cluster counts.                   |
| 1968/69 | Solar filtergram sequences.                                  |
| 1968/69 | Association between pulsars and Chinese 'guest stars'.       |
| 1968/69 | Short-period variables in the Magellanic Clouds.             |
| 1969/70 | <i>Historic Orbit of Comet Halley.</i>                       |
| 1970/71 | The symbiotic star HV 13055.                                 |
| 1970/71 | Estimates of Magellanic Cloud reddening ratios.              |
| 1970/71 | Distribution of the asteroids.                               |
| 1971/72 | <i>Light-flashes from the Galactic Centre.</i>               |
| 1972/73 | Optical counterpart of SMC X-1.                              |
| 1972/73 | Distribution of Quasi-stellar radio sources.                 |
| 1972/73 | Existence of the 'Megalithic Yard'.                          |
| 1973/74 | Orion Nebular Emission lines.                                |
| 1974    | Oblique Rotator models of Ap stars.                          |

|      |                                                    |
|------|----------------------------------------------------|
| 1976 | Intermediate-latitude OB star data.                |
| 1976 | Optical counterpart of an X-ray burster?           |
| 1976 | Infrared radiation of asteroids.                   |
| 1976 | Bivariate distributions of galaxy data.            |
| 1977 | <i>Period-change in Magellanic Cloud cepheids.</i> |
| 1977 | <i>Stability of asteroid orbits.</i>               |
| 1977 | Diatom molecule calculations.                      |
| 1978 | Co-ordinate transformations.                       |
| 1979 | Seeing tests on La Palma.                          |
| 1979 | Triaxial models of galaxies.                       |
| 1979 | Chinese records of occultations.                   |
| 1980 | CCD observations of clusters of galaxies.          |
| 1980 | <i>Values of the deceleration parameter.</i>       |
| 1982 | <i>Seyfert galaxy data.</i>                        |
| 1983 | <i>Photometry of Ap stars.</i>                     |
| 1983 | Cerenkov line emission from quasars.               |

In 1979, with the express support of the National Board for Science and Technology, an agreement was entered into by the Institute and the NBST jointly with the Science and Engineering Research Council of the United Kingdom to meet one-tenth of the cost of the 1-metre optical telescope, designed for astrometric and photometric work and built by Grubb Parsons in Newcastle, due to be erected on the highest ridge called the Roque de los Muchachos, of the Spanish Island of La Palma in the Canary Islands. (This is not to be confused with the port of Las Palmas in Grand Canary).

The site was chosen by the UK Science Research Council after a series of test expeditions had been carried out in various places in the N. hemisphere, including the islands of Hawaii. La Palma was judged to be only marginally inferior to the much higher and more distant (from Europe) peak of Mauna Kea in Hawaii. In 1984 regular scheduling by the United Kingdom of three excellently equipped modern telescopes on La Palma began. In spite of the customary logistic and technical problems associated with any new project such as this one, the promise of the site seems to be fulfilled. As well as clear skies and absence of cloud, the desire is for especially steady atmospheric conditions and in this respect tests with the working telescopes have been very encouraging.

Although the actual agreement specifies the share available to Irish observers with the 1-m telescope, the situation calls for an introductory period, at any rate, in which specific proposals are made by Irish scientists either working by themselves or in conjunction with United Kingdom or other observers, to the Panel for the Allocation of Telescope Time of the SERC, for use of any of the facilities available in competition with other workers elsewhere. Only after a period of time, say three years, would an assessment be made as to whether the allocations are working out on a fair basis. So far, three Irish proposals and some joint Irish-U.K. proposals have been accepted and have been carried out satisfactorily. The largest of these has been the construction by the Physics Department of University College, Dublin, of a Charge-Coupled Device Camera for producing the equivalent of photographs of faint objects at very high efficiency, linear in response and stable in repeatability, in digital form on diskettes, by the use of a stand-alone microcomputer driving the CCD on the

telescope. This work was carried out at the telescope by B. McBreen, T. P. Ray and L. Metcalfe between 19 and 28 February, 1985, and, in spite of this being the worst period for winter weather on the mountain-top, many promising records were secured. B. D. Jordan of Dunsink took an important share of the construction and testing work for this camera.

It is important to notice that I refer to Irish observers rather than Dunsink observers. It has been evident for many years that interest in astronomy is so wide and the benefit for general collaboration so promising, that it is quite necessary for the Astronomy Section of the Institute to extend its activities to take into account the interests of several university departments as well as its own parochial interests. Fortunately, the Establishment Order founding the School of Cosmic Physics not only permits the Section to appoint suitable Research Associates from other institutions to share its facilities and activities, but *requires* the Astronomy Section to provide for the needs of students in the Dublin Universities. Thus the DIAS-NBST-SERC agreement was entered into on behalf of all interested Irish investigators and the funds made available to the Astronomy Section of the School of Cosmic Physics are, as far as possible, administered with this aim in view.

A final word should be said concerning the role of space vehicles. It is clear that much new work in astronomy and astrophysics is dependent upon the magnificent opportunities presented by the use of modern techniques in vehicles outside our own limiting atmosphere. Not only are vast new regions of the electromagnetic spectrum, from  $\gamma$ -rays to radio wavelengths, made ever more profitable, but in the traditional optical range of wavelengths the disturbances of the atmosphere are virtually eliminated so that on the one hand a Space Telescope capable of resolving objects down to a few hundredths of an arc second is being constructed, and on the other hand the very traditional field of positional astronomy is going to be utterly revolutionized by the Hipparcos astrometric satellite.

I am glad to be able to report that in 1984 two satellite projects, one with the *EXOSAT* X-ray observatory satellite (by P. Callanan and R. M. Redfern) and one with the International Ultraviolet Explorer (by H. P. Deasy and C. J. Butler) were executed by members of the Astronomy Section and its Research Associates. One of these programmes derived from the interest developed since 1965 in the cepheid variable stars, the stability of their oscillations and the possibility of evidence for loss of mass by these stars. The other, using X-ray data, concerned the identification and investigation of the little-known sources of X-rays, intermittent as they are, located in globular clusters.

Both cepheid variables and globular clusters have properties that have been established painstakingly over the years by optical astronomy—a very influential body of data, but only a fraction of the vast body of data available as the legacy of decades of work in optical astronomy with ground-based telescopes. What is more, almost every newly-discovered phenomenon or new type of astronomical object—and there have been many such discoveries in the past thirty years—has required immediate intensive use of ground-based facilities for its further investigation, or even confirmation. Thus first-class optical facilities, using really up-to-date modern techniques, mostly

based on computer circuits, are ever more and more in demand, in order to interpret new types of data provided by satellite vehicles of all kinds.

The flexible scheduling of modern telescopes, each with dozens of users in any period of a few years, as on La Palma, but also as at any modern optical observatory, is effective in meeting this very need. There is rapid orienting of results, needed to cope with the modern pace of developments; there can often be a direct relationship to the physics of the problem, also rapidly evolving; and there is no need for the systematic and meticulous solving of logistic and semi-political problems that is required for the enormously expensive task of sending up space vehicles. (The development of the 'observatory' satellites as against the one-programme type of satellite experiment meets the same requirement of flexibility.)

Knowledge of the Universe has always, or at any rate ever since about 1500 BC, had a direct, if not rapid, influence on the development of mankind but sometimes people fear the type of knowledge revealed by astronomy. "He knew the stars too well, to be fearful of the night" is the astronomer's epitaph. The high-energy particles, the theories of element formation, the astronomical evidence for the hot big-bang origin of the universe, the probable existence of degenerate matter in the form of black holes, possible forthcoming solar-system changes, all these studies have developed enormously during the 37 years I have been associated with astronomy. It is essential for a modern country that is to take part in the intellectual progress of mankind to have a firm base representing knowledge in astronomy. Always working with considerable constraints, but always striving after high standards, Dunsink Observatory has been engaged in this task for 200 years. It temporarily faltered from 1921 to 1947, but, under new management yet with its original base, it took up its task again and can be said to be as promising now as at any time in the past, so great is the momentum of our time.

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