his discovery of an exoplanet. Ironically, the people who gave him the hardest time were the proponents of the space mission called *Eddington*. *Eddington* is now called *PLATO*.

Dr. Mortier. Back in the day this was a really hard sell. In Europe, we found that the Americans were technologically ahead of us and were searching for a long-period Jupiter with their spectrographs. In Europe they were looking for short periods and that is when they found it. It only took the Americans a couple of months to find another six more hot Jupiters that were in their data all along.

Dr. Wheat. I know that *Kepler* looked at stars which are quite distant. It seems to me that we should be looking in the zone within 25 to 50 light years of the Sun. Is there any prioritization of that particular zone?

Dr. Mortier. The biggest downside of *Kepler* is that these stars are all too faint for us. For thousands of Earth-size planets that they found we can't get masses at all. *PLATO* has been re-designed to focus on bright stars, *TESS* and *CHEOPS* also. However, there is such a thing as being too bright from space, so it's a matter of finding a balance. With *HARPS3* from the ground we are definitely going to look close by, but that is purely from a photon perspective. The *HARPS3* sample is limited to stars brighter than *V* magnitude 7·5 whilst the space missions have looked at magnitude 7 and fainter.

The President. Watch this space over the next ten years. Thank you very much again [applause]. May I remind you that there is a drinks reception about to begin in the RAS Council Room. The next A & G Highlights meeting will be on Friday, November 10th. I look forward to seeing all of you then.

LETTERS FROM DUN ECHT: A NETWORKED OBSERVATORY

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The Archives of the Royal Observatory Edinburgh preserve the out-going letters of Lord Lindsay's private observatory at Dun Echt, providing a detailed picture of its development and operation during its twenty-year (1872–1892) existence. Nearly all were written by the two astronomers in charge, David Gill until mid-1876, followed by Ralph Copeland until the observatory's merger with the Royal Observatory. Here we look primarily at their communications with other astronomers to consider how the observatory maintained its connections with the astronomical world through correspondence and the exchange of telegrams using the Science Observer code devised in Boston, as well as the publication of the *Dun Echt Circulars* and *Copernicus*. Also quoted are some letters which fill the gaps in the published accounts of the observatory to round out our picture of its operation.

Introduction: the Dun Echt letter books

The private observatory at Dun Echt, 12 miles east of Aberdeen, established and maintained by Lord James Ludovic Lindsay (who became 26th Earl of Crawford on the death of his father in 1880)[1] was "a Grand Amateur's observatory insofar as it was the property of a single enthusiastic individual, yet it was a professional one in the respect that it had a properly salaried Director who undertook the business of research."[2]. Besides the formal reports included in the annual Reports of Council published by the Royal Astronomical Society in its *Monthly Notices*, we can gain a vivid insight into the day-to-day running of the observatory from the preserved copies of practically all of the letters written by (mostly) the two astronomers employed by Lindsay to direct his observatory. The first of those was David Gill, who was largely responsible for setting up the observatory and subsequently went on to a distinguished career as Her Majesty's Astronomer at the Cape of Good Hope[3,4]. In 1876, he was succeeded at Dun Echt by Ralph Copeland, who had led an adventurous early life[5,6] and who would go on to become Astronomer Royal for Scotland, effectively 'inheriting' the Dun Echt instruments and library which Lord Crawford presented to the Nation for the revitalization of the Royal Observatory Edinburgh[7]. Both men had participated in Lindsay's Transit of Venus expedition[8].

The out-going letters were written in ink and the copies were made by pressing moistened tracing paper against them. This produced mirror images usually visible through the tracing paper, but many are blurry where the ink has run over the years, sometimes from page to page, making reading difficult. The sheets of tracing paper were numbered and bound into volumes, typically a thousand in each. Unfortunately, the incoming letters were not archived to anything like the same extent; the relatively small number surviving are on a variety of sizes of paper including notelets and could not easily have been bound in sequence even if they had been retained. Fortunately, however, we have letters from Lord Lindsay to Copeland in the first few years of his tenure which are certainly informative — not only about the work of the observatory but also goings-on at the Council of the Royal Astronomical Society on which Lindsay served for many years, being President in 1878–80. In the case of Gill, the account of his early career by Haley[9] cites many incoming letters retrieved from the Royal Geographical Society archive, which complement the letters in the ROE archives.

The Dun Echt letters covered a wide range of topics, two categories of which are particularly interesting for the historian of the observatory: those to telescope and instrument manufacturers, and to astronomers in Britain and overseas. Those to the telescope and instrument makers, particularly Howard Grubb of Dublin, T. Cooke and Sons of York, Troughton & Simms, and Adam Hilger show Gill and Copeland to be excellent instrumentalists, providing detailed suggestions but exacting in their requirements. After his appointment to the Cape, Gill continued his dealings and friendship with Grubb, and pointed the way to many improvements in Grubb's designs[10]. The substantial body of letters to instrument makers, often with sketches, is worthy of a separate study; the present one is primarily concerned with the astronomical correspondence. In the early years of the observatory, much of this was connected with preparations for the 1874 Transit of Venus expedition and later even more with the subsequent reduction of the observations, which continued for some years.

Gill's letters, 1872–1876

Most of David Gill's letters were concerned with the setting up of the observatory and instruments. He also wrote frequently to Lord Lindsay, who was often away from Dun Echt, keeping him appraised of progress. Beside the specification and acquisition of the instruments, and building of the observatory, there was little time to consider its scientific programme beyond the forthcoming Transit of Venus. At the beginning of 1872, however, before most instruments were delivered, Lindsay intimated to George Airy, the Astronomer Royal, his willingness that the Dun Echt observatory could take up the systematic observations of Jupiter's satellites that Airy had advocated[11] at the RAS. As Lindsay was about to depart for the Continent, he asked Gill to follow this up with Airy. On January 23rd, Gill wrote to Airy[12] giving a detailed account of the proposed instrumentation and resources. In line with his own views on the division of labour amongst observatories, Airy replied[13] advising Gill to devote the work of the Dun Echt Observatory to observations with equatorial telescopes, as Gill had not "yet learnt what soul-wearing work is the reduction of meridional observations".

Gill's astronomical preparations for the Transit of Venus were centred on the determination of the longitude of their observing station at Belmont on Mauritius and observations of Juno around the time of its 1874 opposition, which would provide an alternative determination of the solar parallax, independent of observations at other stations. In a letter[14] to Professor Auwers of Berlin, Gill wrote that he had succeeded in collecting upwards of 50 chronometers for the expedition and these were now in the hands of Mr. Hartnup of the Liverpool Observatory to have their rates ascertained at all temperatures. He had studied the circumstances of the opposition of Juno with considerable care, determining the differences in parallax for observation altitudes of 20–40° and making a catalogue of stars close to the predicted path of Juno and to be observed with it for every day from the 10th October, finding that on every night there were sufficient suitable stars for comparison. Such observations would provide an alternative determination of the solar parallax. These preparations were also communicated[15] to the RAS. Gill wrote[16] to Airy in May expecting to confirm the cooperation with the British Transit group in Egypt in determining the longitude of Aden using telegraphic exchange of signals, but was dismayed to learn that this would not now occur. In another letter to Auwers[17], who was Secretary of the German Transit of Venus Commission, Gill expressed his disappointment with Airy's decision and asked for his assistance.

We do not know at what stage Ralph Copeland, then assistant astronomer at Dunsink, was invited to join the expedition, but when Gill learnt of it, he wrote[18] welcoming him. He asked him to acquire a number of books and then proceeded to give him advice on suitable clothing! This included, for observing, trousers with a scarf to "protect the abdomen from cold drafts at night", a light suit or two of tweed, a light coat or two, and white duck trousers and a solar topee or pith hat. This may have been a joke, but perhaps Gill was unaware that Copeland had previously worked in the Australian gold fields and on a sheep farm, in the Arctic during winter, and had observed with the Leviathan of Parsonstown perched 30 ft above the ground (ref. 6). He then went on to describe the instrument Copeland would use for the transit and a detailed plan of the observations he was expected to make. In his next letter to Copeland[19] three days later, he wrote: "Airy has done his best to stump us, after leading us to imagine that he w^{d} be prepared to exchange signals from Suez with me at Aden in Jan^{y}. Now he says that as the telegraphic determination of the longitude

of Alexandria is likely to be successful, the work of the British Egyptian Station will be over immediately after the transit and it will be out of the question to keep the instrument and observers there until January." He described his proposal to Auwers for the cooperation with the German observers on Mauritius on their return journey and also to van der Sande Bakhuizen of Leiden regarding the junction of the longitudes of the Dutch station on Réunion and Mauritius.

After the transit and work in Egypt, Gill returned to Dun Echt almost exactly a year later. A letter to John Russell Hind[20], Superintendent of the Nautical Almanac, shows that Gill as busy as ever: "I have now returned home. I had intended to call for you in London but had so much time clearing my goods and chattels at the Docks, that I had only time to make a few visits to Chronometer makers that were absolutely necessary, see Simms and attend the Greenwich Visitation, when I hoped to meet you — and be off to meet Lord Lindsay here depositing my chronometers by the way at Liverpool, to have their temp^{tr} coefficients redetermined." In Dun Echt, however, he found that the climate had changed. Lady Crawford, Lindsay's mother, had insisted that the Gills made over a larger portion of the Astronomer's House to Henry Carpenter and his family (Haley, ref. 9). Carpenter, who had started at Greenwich as Boy Computer and rose to be an observer, was taken on by Lindsay in 1874 as First Assistant to Gill and took care of the observatory while Lindsay and Gill were away on the transit expedition. Also, Lady Crawford objected to the use of her stables for the carriages and horses of Gill's visitors, so that when Henry Russell, Director of the Sydney Observatory, was expected to visit, Gill asked Mr. Walker in Aberdeen[21] to direct his visitor to the appropriate coach to Echt or, if hiring a carriage, to ensure that the horses were put up at the inn and not the farm stables. Matters came to a head after Gill had given a talk to the Aberdeen Philosophical Society against the wishes of Lord Lindsay, causing the latter to give Gill six months notice of dismissal (ref. 9). Despite this, the two men remained very good friends.

During the notice period, Gill continued correspondence regarding reduction of the transit expedition observations, with one significant change: from 1876 January 28 he wrote frequently, almost twice a week, to Henry Carpenter, implying that the latter had moved away from Dun Echt. Gill's letters seldom give the recipients' addresses, but when Copeland took over from Gill later in the year, and also wrote frequently to Carpenter, he used an address in Leatherhead, Surrey. Carpenter was the principal computer, but the work was spread out amongst others: Gill sent a cheque for £12 in a letter[22] to Hind for payment of his computer and, responding to some calculations done by a J. Harding[23] of Trafalgar Rd., Greenwich, added that there was a great deal of work to follow and asked if Harding knew anyone who would be suitable for some easy computing. Although the letters to Carpenter were necessarily very detailed, they were not impersonal: Gill writing at the end of one letter[24] "We are much concerned to hear Mrs Carpenter does not do as well as you wish. Let us always hear how she and baby are doing and give our kindest regards." There were also frustrations; in one of his many letters to Copeland, Gill wrote[25], "I have yr note, and much regret to hear that such a hash has been made of the daily stars places. I have not looked into mine yet for I thought Carpenter wd have been perfectly reliable in such work." Such problems were probably inevitable for remote working without the chance to clarify possible misunderstandings in person.

Encouraged by the results of his Juno observations, Gill wrote to Airy[26], proposing a scheme to be submitted to him. This would be the observation

of one of the minor planets discovered by Watson* whose eccentricity was so small that in April '78 its distance from the Earth would be 0·65 AU. From what he remembered Watson telling him when they were in Egypt together the previous April, the planet would be in opposition in April 1877, at 8th mag and –30° declination. Should the Juno observations show the accuracy of the method (for determination of the solar parallax), would Airy be disposed to sanction the application of the method also to this minor planet? From a latitude of about –19° this planet as well as Mars could be observed with great advantage — obtaining independent determinations of the parallax from each. For an observing station, Gill suggested the Table Land of N Queensland, in latitude –19° and with excellent communication with Brisbane by steamer and good road by bullock drays, and according to Gill's two brothers, a cloudless sky every night excepting in December–February.

Later letters to Copeland included reference to the transition between the two at Dun Echt. For example, on 1876 May 16 Gill wrote[27] that he would be moving out on the 23rd June and would stay a few weeks in Aberdeen after he left, so that he could be able to give Copeland any assistance in explaining matters — and then he meant to "take a little house in some quiet country place for a month or two, and stick at the book until it was finished". He was confining himself to doing only what could not be done away from the observatory — "and this with my lameness (for I still come to the Observatory in y^{r} Belmont Observing Chair with a bit added mounted in a wheelbarrow) will prevent my leaving the Observatory in the apple-pie order I would have wished".

Gill's correspondence shows that he was on easy terms with the leading astronomers of the day, such as Airy, Auwers, and van der Sande Bakhuizen; there is banter and humour in letters to his friends. He was probably closest to Grubb, to whom he wrote a letter[28] of condolence after a family tragedy, and to whom he disclosed ambition in another[29] commenting on Piazzi Smyth's tribulations: "Poor Piazzi — still more Mrs Piazzi !!! — I draw a veil over a scene so harrowing. He won't resign tho — & I'm not ready for the post yet — if he^{d} hold on for another ten years I should like it very well."

Letters from the first years of Copeland's tenure 1876–1877

The first of Ralph Copeland's letters in the archive[30] was to Professor Klinkerfues at Göttingen, under whom he had studied for his PhD, and a few days later he wrote[31] the first of his many letters to the bookseller Robert Peppmüller, also in Göttingen and written in German, ordering scientific books for Lord Lindsay. In this, Lindsay was following the interests of his father, the 25th Earl of Crawford, who had built up a famous library of beautiful and rare books[32], which became complemented by Lindsay's collection. The letter books are full of orders to Continental and British booksellers, mostly to Peppmüller, who sometimes acted as agent for purchases from other German dealers[33]. Other dealers were used, such the London dealer in rare books, Bernard Quaritch, who supplied a first edition of Flamsteed's *Historia Coelestis*[34].

He also wrote[35] to William Yeats of the Aberdeen firm of Yeats & Spottiswood, who handled the observatory's legal and financial matters, with a list of Lindsay's valuations of his instruments, for insurance. Copeland followed this with a letter[36] which included a sketch of the observatory showing the locations of the instruments to be insured (Fig. 1). The following year, he wrote concerning insurance of the buildings[37] and arrangements for the Fire Engine[38].

*James Craig Watson (1838–80) of Ann Arbor discovered 22 minor planets, 16 before 1875.

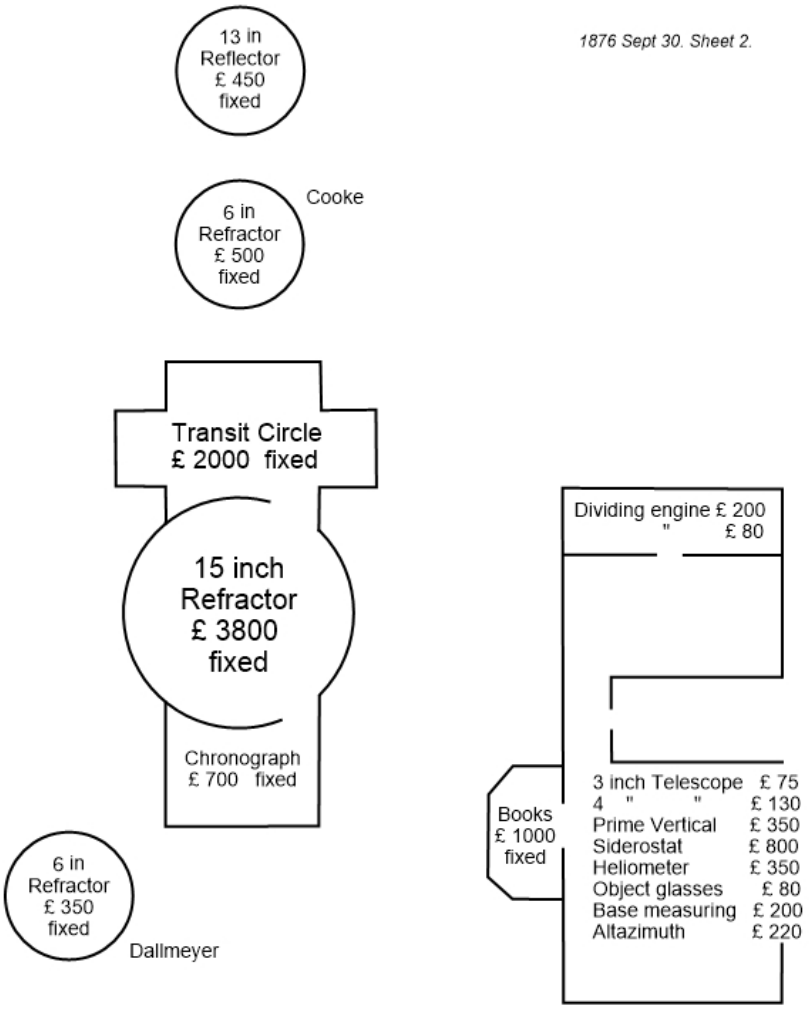

FIG. 1

Re-drawing of sketch in Copeland's letter (ref. 36) to Yeats & Spottiswood showing locations of the fixed instruments and listing the others, together with their values for insurance. This can be compared with the view in Plate C of ref. 1.

Yeats needed some reassurance about storage of photographic chemicals — but apparently not for the gunpowder which Copeland periodically ordered for the time gun[39] operated by the observatory.

Also in 1876, Lindsay wrote[40] that Lord Crawford (his father) had approved the appointment of Mr. R. Copeland as a computer. We know this to be Copeland's nephew Robert from a letter[41] regarding the Belmont time reductions addressed to "My dear Nephew". The initial appointment was for

the winter or until Mr. Lohse (J. Gerhard Lohse, to be assistant astronomer) could be appointed. From a letter[42] by Copeland to Yeats we learn that Robert Copeland was paid £9 for the winter and that Mr. Lohse started on 1877 April 1 at £120 per annum; but from later correspondence it is evident that Robert's employment continued more or less continuously for many years.

In 1877 April, Lindsay wrote[43] that the council of the RAS had decided to give Gill £500 for his opposition-of-Mars expedition and asked Copeland to arrange for the cases of the Heliometer, the 6-inch equatorial mounting, and the iron work of the 4″ which Lindsay had used in Mauritius to be got out and packed for Gill's expedition. Ten days later, Copeland wrote[44] to Gill that the traction engine had left that morning with the equipment, giving a full inventory.

Not listed here are Copeland's many letters to Henry Carpenter regarding reduction of the Transit-of-Venus data and to Thomas Cooke & Sons and other suppliers regarding the observatory's instrumentation as he familiarized himself with it.

The 1878 Transit of Mercury and visiting astronomers

Lord Lindsay organized a coordinated series of observations of the 1878 May 6 Transit of Mercury from Dun Echt. In a letter[45] to Copeland he wrote that he planned to participate in it himself if at all possible and listed the instruments available, allocating observers to them, *e.g.*, Copeland to the Dallmeyer 6″ with micrometer, Mr. Lohse (Copeland's assistant) to the 4″ Cooke, himself to the 6″ Cooke, and so forth. He would get Davis, his photographer, and Carpenter to join them at Dun Echt, and considered asking Ranyard (Arthur Cowper Ranyard, lawyer and astronomer) and perhaps another astronomer to join them. Ranyard did participate, and the observations were reported to the RAS and published in the *MNRAS*[46,47].

On June 28th, the Rev James Virtue of Dumfries observed Jupiter with Copeland at Dun Echt[48]. In July, Copeland wrote[49] to Virtue regarding the latter's possible discovery of nebulae, patiently giving advice on observing techniques. We read of an intriguing caution to visitors to the observatory in Copeland's letter[50] to the secretary of the Aberdeen Philosophical Society regarding their proposed visit on June 8th: as he had made preparations for working the large magnet, members of the proposed party should leave their watches at home because he had found that the magnet deranged any watches brought within its range.

Copeland wrote to more amateur astronomers who had contacted the observatory, such as John Birmingham of Tuam, regarding possible duplicity of one of his red stars[51], reporting his own spectroscopic observations of it[52] (which showed nothing exceptional) — but determination of the longitude of the Belmont observing station *via* Moon culminations remained a problem. He asked[53] Professor Peters of the Kiel Observatory to place a notice in the *Astronomische Nachrichten*, which he edited, requesting astronomers who may be in possession of unpublished meridian observations of the Moon or of occultations of fixed stars in the months of November and December 1874, made at observatories the longitudes of which had been determined by telegraph, to let Copeland have copies of the data.

In 1879 February, Gill was appointed Her Majesty's Astronomer at the Cape. Some days later, Lindsay wrote[54] to Copeland telling him that Gill had bought the Heliometer for £200 and asking Copeland to pack it up and send it to Grubb, at Gill's expense. Grubb made an equatorial stand for it and the instrument was used by Gill at the Cape for measuring stellar parallax[55].

Dun Echt Circulars and Copernicus

In 1879 November, Lindsay initiated the series of *Dun Echt Circulars* to inform astronomers of the appearance of comets and other phenomena requiring prompt communication to other observers. His announcement in *Nature*[56] must have drawn an unfavourable response from the Smithsonian Institution, causing Copeland to draft a reply[57] which he initially sent to Lindsay[58] for approval[59] before posting it. He made the point that the *Circulars* were intended to supply information on astronomical discoveries to every owner of a telescope in the British Islands who communicates an address for the purpose, more especially to all those amateurs who may not be in communication with a government observatory. The Smithsonian scheme, on the other hand, guaranteed communication of astronomical discoveries between the United States and five European government observatories, but with no provision for wider distribution this side of the Atlantic.

The first *Dun Echt Circular* reported the discovery of a new planetary nebula or nebular star by the Rev. Thomas W. Webb. After a delay caused by bad weather, Copeland wrote[60] to Webb on 24th November identifying his object as Durchmusterung +41° No 4004, reporting that its spectrum was sensibly monochromatic seen through a low-powered spectroscope and commenting that there seemed to be a link between the last stage of Nova Cygni and the smaller planetary nebulae. On the same date, *Dun Echt Circular No 1* was issued reporting the discovery and giving the identification, position, and spectral information. Also on the 24th, Copeland wrote[61] giving the same information to J. L. E. Dreyer at Dunsink, who included the object in his catalogue of nebulae[62] as NGC 7027, the name by which it is generally known today.

At first the *Circulars* were intended chiefly for amateur astronomers. When the journal *Copernicus* (initially called *Urania*) was started by Copeland and Dreyer in 1881, Lord Crawford (as Lindsay had now become) agreed to a plan by which any urgent communication to the journal appeared forthwith in a *Circular*[63]. Hence *Circulars* were distributed to *Copernicus* subscribers. Although it included papers by the Dun Echt observers, *Copernicus* was an international journal, publishing a wide variety of contributions, some written in French and German. Unfortunately, the editors appear to have had difficulty in filling the issues: as Copeland wrote[64] to Ranyard "Can you by any possibility let us have a paper, long or short, for 'Copernicus'? We are somewhat badly off for contributions", and as *Copernicus* was not financially viable, it ceased publication after three years.

The *Circulars* continued for the life of the observatory and were printed on site using a Squintani 'Model No. 3' printer. Specialized fonts were an issue; on 1881 May 16 Copeland wrote to Squintani[65] ordering large quantities of type including accented characters, remarking that when he had printed some German, he had had to put in all the ö and ä by hand with a colon. He enclosed the latest *Dun Echt Circular* as a specimen of "work with one of your old No 3s". Lindsay appreciated his efforts, writing[66] "you are really becoming a first rate compositor".

A total of 179 *Circulars* were issued, the last being on 1890 January 29. The mailing list[67] included about 200 recipients, and many *Circulars* also appeared in the *Astronomical Register*. The effort and cost of distribution must have caused some concern because in 1886 January, Copeland wrote to a number of recipients, *e.g.*, to Mr. Cattermole[68] of Norwich, along the following lines: in accordance with Lord Crawford's scheme of 1879 November 1 the Dun Echt circulars are distributed gratis to all applicants "who would be likely to make

useful observations". It had become obvious that this could not practically be made to include everyone interested in astronomy; but pending any arrangement for a wider distribution, the recipient was invited to send, say, a score of addressed wrappers in which to enclose a corresponding number of circulars as they appeared.

Astronomical correspondence 1879–1882

At this time, the subject matter of the astronomical correspondence from Dun Echt was becoming much broader than that concerned with the Transit-of-Venus reductions. For example, Copeland corresponded with Professor Edward Pickering of Harvard regarding emission-line spectra[69] and giving details of his observations[70] of Nova Cygni. Nearer home, he sent detailed observations of two bright meteors[71,72] to William Denning of Bristol, asking for details of any observations of these. The 'Great Southern' Comet of 1880 led to a flurry of correspondence: Copeland wrote[73] to the watchmaker-astronomer Henry Pratt of Brighton drawing attention to telegraphed reports of it, estimating its position and motion, and asking Pratt to try and observe it on the southern horizon in the early evening twilight. He also corresponded[74] with Hind regarding the latest reported observation and its discrepancy with previously determined elements. Hind must have computed new elements and sent them to Copeland who reported[75] that he had tried to observe the comet from Dun Echt but was thwarted by the hazy sky and long twilight, so he had sent a predicted place to Dr. Schmidt, Director of the National Observatory at Athens.

In parallel was correspondence with Joseph Baxendell of Southport, who had contacted Lindsay with a query, possibly from learning of the *Dun Echt Circulars*. Copeland wrote[76] that he observed his suspected nova with the spectroscope but saw nothing very striking. He was uncertain whether it was advisable to send out a *Circular* respecting the new variables if they were not actual novae but would hesitate no longer if Baxendell noted anything particularly remarkable, writing "Such discoveries seem to me to be infinitely more interesting than the discovery of a small asteroid". After receiving Baxendell's paper on U Sagittae, Copeland wrote[77] that he would like to get out a *Circular* on his two new variables — which he did: *Dun Echt Circular No. 6*. Their correspondence included discussion of comets, Copeland writing[78] in October thanking Baxendell for a telegram helping him to pick up the new comet (1880d) without delay and observe its spectrum[79]. Other correspondents introduced through their queries were William Franks of Leicester, to whom Copeland sent[80] the positions of five double stars he was interested in, and James Robertson of Coupar Angus regarding a variable star[81]. In both cases, their correspondence continued for some years, latterly about comets. In other cases, we have only a single letter, such as that[82] to James Skinner of Inverurie giving extended advice on the use of his spectroscope. Sadly, we do not know how Mr. Skinner used his instrument — there appears to be no more correspondence.

Astronomical Telegrams and the Science Observer Code

Astronomers used telegrams for exchanging information on discoveries but the telegram format was not suitable for numerical data and there were attempts to overcome this. One plan was presented to the RAS at its 1880 December meeting[83], but in a letter[84] to Ranyard, who was on the RAS Council at the time, Copeland was very critical "… in spite of the high authority supporting it, contains all the worst features of the old order which have led to so much

blundering and sheer waste of observing time." He went on to give an example of the blunder the plan would introduce.

At about this time, Seth Chandler and John Ritchie Jr. of the Boston Scientific Society developed a code ('The Science Observer Code') for the telegraphic transmission of cometary orbits, tailored to the transmission of numerical data. This was quite separate from the Smithsonian scheme mentioned above. To test the usefulness of the code, which was based on the location of words in a particular dictionary — *Worcester's Comprehensive Dictionary*, Boston, 1876 — to convey each set of five digits[85], Chandler and Richie arranged with Lord Crawford for the receipt and publication of cable messages containing orbits computed in the United States and *vice versa*. For example, *Dun Echt Circular No. 17* quoted the elements and ephemeris of Swift's Comet received by cable from Boston using the Science Observer Code, followed by new observations from Dun Echt and revised elements and ephemeris derived by Lohse and Copeland[86]. At the meeting of the *Astronomische Gesellschaft* in 1881 September, Chandler and Ritchie[87] drew attention to the tests between Boston and Dun Echt, and Copeland gave an exposition of the code, including examples for communicating cometary elements and ephemerides.[88] As further demonstrations of the usefulness of the code, the *Dun Echt Circulars Nos. 45–48*[89] quoted positions, elements, and ephemerides of Comet Wells (1882a) received from Boston or Vienna where it was used.

Copeland was enthusiastic about extending the use of the code: in a letter[90] to Ritchie he suggested there could be support at the Cape, Australia, and Brazil. He also wrote[91] to Professor Edmund Weiss, Director of the Vienna Observatory, accepting his offer to exchange astronomical telegrams, commenting that the Smithsonian telegrams never reached Dun Echt directly but occasionally were sent on from Greenwich — which was not satisfactory, *e.g.*, a most important telegram from the Cape giving particulars of Comet 1881b was merely communicated to the *Times*, a journal seldom seen at Dun Echt. He then gave a detailed exposition of the Science Observer Code.

The Brazilian connection may date back five years to a conversation between the Emperor of Brazil and Otto Struve, when the former said that he intended to visit the observatory at Echt[92]. The visit seems not to have occurred, and the exchange of telegrams was initiated by a letter from Luis Cruls, recently appointed Director of the Imperial Observatory, to Lord Crawford. In his reply on Crawford's behalf, Copeland[93] raised the question of their telegraphic address. He then wrote[94] to the agents in Aberdeen who handled the Dun Echt telegram traffic, explaining that the observatory would wish to send telegrams to the Imperial Observatory but that the latter had proposed a telegraphic address of six words. This would cost 39/4 (£1·97) to transmit, making a serious inroad on the £25 which the Brazilian government proposed to remit as prepayment for their messages, so he asked his agents to enquire at the telegraph office as to what would be the shortest address they could use with safety. In a further letter to Cruls[95], he wrote that he had written to Boston, asking Mr. Ritchie to send two sets of instructions and two dictionaries to him and asking him if he could register a short address with his telegraph station. The arrangements worked well when Cruls observed Comet Wells (1882a) the night after receiving a telegram[96], and telegraphed his discovery of a comet in September[97].

Co-ordination of comet hunting

In a more organized engagement with the amateur observers, Copeland sought to enlist the aid of a number of his correspondents in a systematic

search for new comets. This arose from a letter from William Denning in 1882 May, in which he wrote that he would have to give up searching for comets. Copeland replied[98] that he felt that Lord Crawford would be glad for Dun Echt observatory to take in hand the organization of comet seeking but pointed out the difficulty of comet seeking from Dun Echt in the summer months owing to the lightness of the sky. After suggesting comet seeking in postscripts to letters about Comet Wells to James Robertson[99] and Isaac Ward[100], Copeland wrote again[101] to Denning asking for names of astronomers who might be interested in searching for comets.

On 1882 August 14, Copeland wrote to sound out astronomers whose names had been given to him. In his letter[102] to Miss Mary Ashley, for example, Copeland wrote that he was anxious to make Dun Echt a central station where every effort would be made to determine places of any object discovered, whether comet or nebula. They would also keep a constant appendix to the Gen. Cat. of nebulae and Mr. Dreyer's supplement. If Miss Ashley's local surroundings permitted it, he would be glad if she could watch some southern part of the heavens, as she was nearly 6° further south than Dun Echt (she lived in Bath, coincidentally in King William Street, only a few doors away from the house occupied by William and Caroline Herschel a century earlier). He wrote similarly to A. S. Williams[103], living in Brighton, also asking him to consider a southerly region given his location, and to W. S. Franks[104] of Leicester and Rev. J. J. M. Perry[105] of Alnwick (St Paul's Vicarage, not to be confused with Father Perry of Stonyhurst). The responses must have been positive because he wrote again[106] on September 7 setting out the distribution of fields set out in Table I as likely to suit the observers and asking for a response if any region was inconvenient. In response to a query from Miss Ashley, Copeland explained[107] that the extra space WSW to SSW in her field was to cover the gap in Mr. Williams's field.

TABLE I

Proposed distribution of fields for comet hunting

Field	*Observer*
26°S – 5°S (partly obstructed in SW)	A. S. Williams (West Brighton)
5°S – 10°N (& down to horizon WSW–SSW)	Miss M. Ashley (Bath)
10°N – 25°N	Rev. J. J. M. Perry (Alnwick)
25°N – 45°N	W. S. Franks (Leicester)
45°N – 55°N	J. Robertson (Coupar Angus)
55°N – 65°N	I. W. Ward (Belfast)
65°N – pole, + low down to North	Dun Echt observers

The 1882 comets and Transit of Venus expedition

In parallel with this activity, Copeland was engaged in extensive correspondence[108] with T. Cooke & Sons regarding the design of a new spectrograph for Dun Echt and was also immersed in preparations for his expedition to Jamaica to observe the Transit of Venus on 1882 December 6, preparing and packing equipment, arranging transport, *etc.* Spectroscopic observations of Comet Wells approaching perihelion caused him to postpone a visit to Oxford to meet with Edward Stone FRS[109], organizer of British government expeditions to observe the 1882 transit, and his co-observer Captain Mackinlay[110]. In letters to Professor Bredichin[111] of Moscow and Thomas W. Backhouse[112] of Sunderland, Copeland described how on June 6th

before sunrise he and Lohse observed spectacular sodium-*D* emission lines in the spectrum of the comet. Full details of the observations were published in *Copernicus*[113], as were those of the 'Great Comet', almost certainly[114] that discovered by Cruls. Copeland's observation of this was only made possible with a recently telegraphed position from the astronomer and telescope maker A. A. Common[115].

After Copeland's departure for Jamaica in October, Gerhard Lohse took over the correspondence and issue of the *Dun Echt Circulars*. To extend the network of observatories exchanging telegrams, he wrote[116] to Dr. Sergei Glasenapp, Director of the St. Petersburg University Observatory, regarding routing, short telegraphic addresses, transmission costs, and advantages of the "Science Observer Code". He also wrote[117] to Ritchie in Boston informing him of the contact and asking for copies of the code and dictionaries to send to Glasenapp.

A letter[118] to John Robertson of Coupar Angus regarding his proposed visit to Dun Echt gives a view of the limited options for public transport to and from the observatory. He was advised to take the 'Cluny Coach' leaving Aberdeen each afternoon and taking two hours to reach Waterton of Echt, where there was an inn and where he could ask directions for the 20-minute walk through the park to the observatory. If he stayed two nights there would be opportunities of viewing the stars and time to look over the observatory during the day between, taking the coach back to Aberdeen on the third morning.

The next topic to feature in Lohse's correspondence was Copeland's extension of his Transit of Venus trip to visit Quito in order to test its suitability for astronomical observations. Lohse wrote to Copeland[119] regarding the packing and shipping of the additional equipment he had requested for his observations — as well as his passport. Other correspondents included A. A. Common regarding a possible double star, and Miss Ashley, regarding identification of a nebula she had observed. In each case, Lohse reported observations he made aiming to resolve their queries — continuing the Dun Echt tradition of responding to and helping amateur astronomers. He wrote to W. S. Franks, one of the 'comet seekers', regarding his difficulties in covering his zone (Table I) and to a new correspondent, the Rev. H. Dowsett of Ramsbottom, regarding identification of an occulted star he had observed.

Copeland's correspondence after his return from the Americas

Copeland returned home on September 1: he had started on his return journey on July 3rd but, missing the Royal Mail steamer at Colon, went on to New York and spent 17 days in the northern states[120], where he visited a number of observatories, examining their instrumentation[121]. Amongst his first letters written after his return was one to Messrs Cooke & Sons asking about the state of the spectrograph they were building for Dun Echt. He also mentioned that he had a few beetles from Bolivia for one of their staff[122].

His astronomical correspondence focussed on comets, with letters to Annibale Riccò of Palermo[123], regarding the spectrum of the Great Comet (of 1882), and to John Rand Capron of Guildford[124] and Charles Prince of Crowborough[125] regarding the comet whose discovery by Brooks had been reported in *Dun Echt Circular No. 78*, giving his own measured coordinates. Copeland issued a stream of *Circulars*, giving elements, ephemerides, new positions and, in *No. 81*, noted that the elements showed great resemblance to those of Comet Pons of 1812, the return of which had been expected[126]. Early in 1884, he replied to two 'new' correspondents, the Rev. A. F. Hill of Aberdeen[127] and the pioneering

astrophotographer Isaac Roberts[128], regarding their observations of this comet and inviting the former to visit Dun Echt when the large refractor was again available.

He also had to expand the team of 'comet seekers' (Table I) following the news from W. S. Franks that he was having difficulties covering his zone, beginning by sounding out G. D. Harding of Fishponds, near Bristol, who had applied to receive the *Circulars*[129]. After further correspondence with Franks[130], it was agreed that his zone would be reduced to 39°N–45°N. The new 25°N–32°N and 32°N–39°N zones were allocated to the Rev. W. J. Roome of Aldershot[131] and G. D. Harding[132].

At around this time, the Rev. T. E. Espin, then of Birkenhead, telegraphed with coordinates of a possibly new nebulous object. Copeland and Lohse were unable to see anything from Dun Echt nor find anything in the catalogues at the place telegraphed, but gave details, including sketches[133], of a previously observed nebula, now known as NGC 1999, about 15′ away. Another detailed response was to Miss Ashley[134] about her observation of the nucleus of M61. Copeland summarized the findings of different observers, including John Herschel, who described it as bi-nuclear, and undertook to have a good look at it in a few months' time. Evidently, Dun Echt was becoming known as the observatory ready and willing to check possible discoveries using the telescope or the library, and disseminate them if appropriate

Arising from his South American travels, Copeland wrote to Lazarus Fletcher[135] at the British Museum, Keeper of Minerals, enclosing a small fragment of a meteorite for his inspection. If it proved to be genuine, Copeland would like it back to make some spectroscopic experiments. He had a piece weighing about 5 lbs at Dun Echt and estimated the parent block to weigh 70 lbs. He concluded "If there has been no confusion about picking up the right stone, it will be necessary to proceed quietly & cautiously to secure the part now in South America." In response[136] to a letter from Edward Pickering of Harvard about 'Mountain Astronomy', he gave positions of two of the most striking emission-line objects he had discovered in his experiments with the prism in the Andes, and wrote that he would be publishing a full account in *Copernicus*. The following year[137], he asked Pickering to forward a set of his Notes and Suggestions about Variable Stars to John Robertson, Coupar Angus, Scotland. He wrote that, with next to no means, Robertson had purchased a telescope and observed sun-spots on every fine day for more than seven years and asked Pickering for advice on the best line Robertson should take having 1 to 2 hours available each evening using a telescope without an equatorial mount. As Pickering's plans for 'Mountain Astronomy' progressed, Copeland wrote again[138] with copies of his papers on his experiences in the Andes and remarked on the range of heights accessible on the Mollendo–Puno railway. In a subsequent letter[139], he gave the names of people connected with the railway — Mr. McCord, General Supervisor of Traffic, station-masters, line inspectors, *etc.* — who could collect meteorological data in the region to aid selection of an observing site.

This correspondence was interspersed with the continued stream of orders to booksellers and letters tying up loose ends of the reductions of the 1874 Transit observations, *e.g.*, to Oudemans[140] of Utrecht regarding the exact location of his station in Aden and including exchanges with David Gill[141] regarding Vol III of the *Dun Echt Publications* which described the determination of the positions of the various observing stations. Copeland wrote appreciably to A. A. Common[142] regarding his silvering of the siderostat mirror, but most of the instrument-related correspondence was to Thomas Cooke & Sons concerning

the new spectroscope for the 15-inch. Some letters concerned details of the design but as time went on the date of delivery became ever more pressing[143] as he and Lord Crawford wanted it to be available at Dun Echt for the British Association meeting being held in Aberdeen in 1885 September.

This was a busy time for astronomers: what we now know to be a supernova (S And) erupted in the Andromeda nebula. Copeland observed it on September 1 but was disappointed by its spectrum: it showed no striking lines like those seen in previous 'new' stars[144]. Earlier that day he had received notice of the new star by telegram from Kiel, had written a report on the announcement, together with background information, which he sent[145] to the editor of *The Scotsman* and also issued *Dun Echt Circular No. 97*. Following an exchange of communications[146] with Isaac Ward of Belfast, who had first observed the new star on August 19th, and the measurement of its position relative to the nucleus of the nebula by Crawford and himself, Copeland issued *Circular No. 98* reporting these results. He remained puzzled by the spectrum, *e.g.*, to the Rev. J. M. Perry, he wrote[147] "The spectrum is indeed very difficult to deal with, being quite unlike that of a genuine nova like Schmidt's".

Catalogue of the Library and an eclipse expedition

In 1887 January, Copeland wrote to Edmond & Spark[148] of Aberdeen accepting their tender for the printing of the *Observatory Catalogue*. Over the previous decade or so, a catalogue on cards was gradually built up by many hands, including for a while a James Mitchell of the Academy of the Paulines at Catterick, to whom Copeland wrote[149] giving very detailed instructions as to the index-card format. The printed *Catalogue* took about two years to produce with numerous letters from Copeland to Edmond & Spark regarding format, proofs, and corrections, leading to a comprehensive publication[150].

Also in 1887, Copeland wrote to the Secretary of the RAS, Edward Knobel[151], offering himself as one of the Society's two candidates for Prof. Bredichin's hospitality to observe the forthcoming solar eclipse from his country seat Pogoste, near Kineshma on the Volga, which lay very close to the central line of totality[152]. The RAS Council accepted Copeland's offer and nominated Father Stephen Perry of Stonyhurst as their other observer. Copeland wrote[153] to Perry, who was an experienced eclipse observer, asking him to suggest the most promising lines of investigation and listing the equipment which he could draw upon. Copeland made arrangements for the shipping of equipment and wrote again to Bredichin[154] giving the dimensions of the equipment he was bringing and his plans to travel with it *via* Hull and St Petersburg. Unfortunately, bad weather at the critical time prevented him from getting useful observations (ref. 152).

Connections with the observatory continued to expand, with new correspondents including Lord McLaren in Edinburgh, Kenneth Tarrant at Pinner, and C. W. Tweedale at Crawshawbooth. Lord McLaren visited the observatory at Dun Echt at least twice and Copeland gave advice on instrumentation[155]. He also attempted to acquire a set of Argelander's star maps for McLaren[156]. The connection continued: in 1889, when Copeland became Director of the Royal Observatory Edinburgh, he and McLaren viewed potential sites for the new observatory together and were on the committee that finally chose the Blackford Hill site[157]. Tarrant was an experienced observer and the correspondence centred on measures of close double stars[158]. Tweedale, on the other hand, was inexperienced and the correspondence was sparked by his supposed discovery of a comet which turned out, after detective work by

Copeland, to be a ghost image inside his telescope[159]. What is striking about these letters is Copeland's friendliness and encouragement despite the wild-goose chase. At the same time, Copeland was in correspondence with Miss Agnes Clerke[160] regarding variations in the emission-line spectrum of γ Cas. Of the long-standing correspondents, the Rev. T. E. Espin, now at Wolsingham (Tow Law observatory), was most frequent, initially about red stars he had observed[161], and latterly about emission-line stars[162].

Conclusions

Copeland's letters are more formal in style than Gill's, with none of the banter amongst friends, but very supportive and patient with inexperienced observers. The only personal touch occurs in a letter to John Hind reporting observations of a comet received from Rome and remarking "there would seem to be traces of a nucleus at the centre: but as we have a little daughter 36 hours old I cannot ask Mrs Copeland to puzzle out the somewhat illegible Italian."

The letters show that the Dun Echt Observatory, despite its relative geographic isolation, to be closely linked with the astronomical community. Reduction of the 1874 transit observations strengthened connections with major Continental observatories while active prosecution of the use of the Science Observer Code for astronomical telegrams developed connections further afield. While producing professional-level astronomy, the observatory was embedded in the amateur community — letters often refer to incoming reports of observations as well as queries, promptly answered by means of new observations or reference to the comprehensive library at Dun Echt. The *Dun Echt Circulars*, aimed squarely at observers, must have been invaluable to many of them.

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REDISCUSSION OF ECLIPSING BINARIES. PAPER 17: THE F-TYPE TWIN SYSTEM CW ERIDANI

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CW Eri is a detached eclipsing binary system of two F-type stars with an orbital period of 2·728 d. Light-curves from two sectors of observations with the *Transiting Exoplanet Survey Satellite* (*TESS*) and previously published radial-velocity data are analysed to determine the system's physical properties to high precision. We find the masses of the two stars to be $1{\cdot}568 \pm 0{\cdot}016\ M_{\odot}$ and $1{\cdot}314 \pm 0{\cdot}010\ M_{\odot}$, the radii to be $2{\cdot}105 \pm 0{\cdot}007\ R_{\odot}$ and $1{\cdot}481 \pm 0{\cdot}005\ R_{\odot}$ and the system's orbit to have an eccentricity of $0{\cdot}0131 \pm 0{\cdot}0007$. The quality of the *TESS* photometry allows the definition of a new high-precision orbital ephemeris; however, no evidence of pulsation is found. We derive a distance to the system of $191{\cdot}7 \pm 3{\cdot}8$ pc, a value consistent with the *Gaia* DR3 parallax which yields a distance of $187{\cdot}9^{+0{\cdot}6}_{-0{\cdot}9}$ pc. The measured parameters of both stellar components are found to be in agreement with theoretical predictions for a solar chemical composition and an age of 1·7 Gyr.

Introduction

Detached eclipsing binaries (dEBs) are a vital source of stellar parameters as they allow direct measurement of the component stars' physical properties when combining light-curves and radial-velocity (RV) observations[1–3]. Detached systems are particularly useful as, in the absence of mass transfer, the components are representative of single stars and are therefore an invaluable source of data for testing and refining stellar-evolution models[4,5].