Ralph Copeland (1837–1905): Versatile astronomer and resourceful traveller

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On 1853 July 7 Ralph Copeland, two months shy of his 16th birthday, left Liverpool on the clipper ship *Star of the East*, bound for Melbourne and the Australian gold rush. Forty years later he was Astronomer Royal for Scotland responsible for the Royal Observatory on Calton Hill in Edinburgh and the development of the new Royal Observatory nearing completion on Blackford Hill to the south of the city. In between, he worked on a sheep farm, participated in a German Arctic expedition, discovered galaxies with the largest telescope in the world, made pioneering astronomical observations in the Andes, and observed the spectra of numerous novae and comets. He participated in two expeditions to observe transits of Venus and four to observe solar eclipses. Yet for all his many remarkable achievements Copeland appears to have been largely neglected by biographers, and this paper is an attempt to rectify that.

1. Introduction

Ralph Copeland (Figure 1) was born on 1837 September 3 at Moorside Farm, Woodplumpton, in Lancashire.[1] His parents, Robert Copeland (1797–1840) of Blackburn, and Elizabeth Milner (1802–59), of Kirkham, had married in St Michael's, Kirkham, on 1819 November 16. Robert was recorded as 'grocer' on the marriage license and reported to be the only son of Mr Thomas Copeland of Clifton, near Preston.[2,3] Elizabeth was the youngest daughter of Mr William Milner of Newton, near Kirkham.

Robert and Elizabeth's first six children were baptized at Chapel Street Independent, Blackburn, which tells us that the family were Dissenters. Their abode was given as Blackburn for the first four baptisms, up to 1828 August, and as Woodplumpton for the last two, from 1830 July. The last baptism was also recorded as having taken place at Zion Chapel, Kirkham, when Robert's occupation was given as 'farmer'.[4] One more child was baptized there but the Zion Chapel records end in mid-1837, before Ralph was born, so we have no record of his baptism.

In 1840, when Ralph was three years old, he lost his father.[5] His mother, Elizabeth, took over the farm and was recorded as a farmer in the 1841 census.[6] Ralph received his first instruction from a hand-loom weaver and then, aged 8, went to grammar school at Kirkham.[7] The census for 1851, however, records Ralph, age 13, to be boarding, along with two other boys, in the household of Thomas Hayes, Vicar of Bracewell, Skipton.[8] This was the Bracewell Boarding School, said 'to have sent forth several good scholars, including Clergymen, and also the late Astronomer Royal for Scotland, Sir [*sic*] Ralph Copeland'.[9]

Bracewell seems a long way from Woodplumpton but Ralph's uncle, Rev. Richard Milner, was the Perpetual Curate of Gill, very near by, and probably knew Thomas Hayes from their student days at St John's College, Cambridge.[10] It is likely that Milner was responsible for this arrangement, helping with Ralph's upbringing after the death of his father. Ralph must have visited the Milner family often and got to know his cousins – including Susanna Milner, whom he married some years later.

In 1853 July, two years after being recorded as boarding in Bracewell and two months before his 16th birthday, Ralph Copeland left Liverpool on the *Star of the East* for Melbourne. In 1851, gold had been discovered at Ballarat, then at Mount Alexander and Bendigo, and there was a steady rise in interest in Britain, which rose to a frenzy when eight tons of gold arrived from Victoria in 1852 April.

In May, an issue of *Household Words*, a popular weekly 'conducted by' Charles Dickens, gave a lively account of the beginnings of the gold rush and a vivid description of conditions in the gold fields,[11] but reassured readers that 'The contrast is very great between the orderly

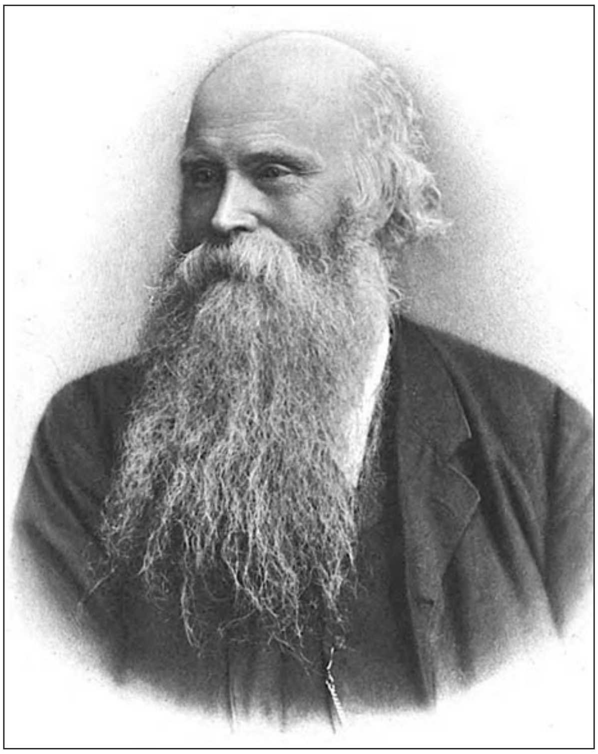


Fig. 1: Ralph Copeland seen c.1895, when he was in his late fifties, from J. L. E. Dreyer's obituary of him in the German journal Vierteljahrsschrift der Astronomischen Gesellschaft (ref. 1).

behaviour at the gold fields in Australia, and the disorders of California'.

Another issue of *Household Words* gave advice to emigrants as to what to take with them: 'A single man should be in light marching order, and should endeavour to take no more clothes than he could, at a pinch, make up in a bundle and carry, groaning, on his back for a mile.' [12] Stirring words for anyone with a sense of adventure, which Ralph evidently had. Whether or not he read *Household Words*, he breathed the excitement in the air and preferred the Gold Rush on the other side of the world over apprenticeship to his oldest brother Thomas at a cotton mill in Blackburn.[13]

2. Formative Years: Australia, Gorton, and Göttingen

The Unassisted Inward Passenger Lists to Victoria 1852–1923 in the Public Records Office of Victoria has the entry: 'COPELAND RALPH SEP 1853 STAR OF THE EAST'. Frustratingly, we know nothing about the arrangements for his travel apart from the fact that the full fare was paid, and that he turned 16 during the voyage. Did he travel on his own or with a group?

We do at least have an account of the journey from another passenger in a letter home.[14] The writer considered the *Star of the East* to be a fine vessel but was not impressed with its operation:

> Our ship was so badly stowed that it took all hands every day, from the day we left Liverpool until we arrived in Melbourne, to break out provisions and water for the passengers so that the Captain had no chance to take advantage of the winds, for there were no men to work the ship. I'm sure if our ship had been worked as she ought to have been ... instead of 75 days to Melbourne, she would have done it under 60 days. I shall never want you to step your foot on board an emigrant ship, unless in the 1st cabin, for all the places of iniquity my eyes ever beheld, an emigrant ship is the worst, men and women packed indiscriminately together, married couples and young girls, and I am sure some of the girls will have cause to remember the STAR OF THE EAST.

The cramped and chaotic conditions on the emigrant ships, their hasty conversion from cargo ships to pack in as many emigrants as possible, and the scramble to get berths on them during the gold rush are breathlessly described in *Household Words*.[15]

Another issue of *Household Words* described the conditions awaiting the 16-year-old Ralph in Melbourne:

> From every part of the world as well as from Great Britain, vessels are daily pouring in, filled with living cargoes, to swell the houseless number. I have, not once, but frequently within the last month, counted in the daily returns of published arrivals, from two to three thousand passengers and emigrants in a single day, and we are told that this is as yet but the commencement. What to do with this superabundance of population is now the great question – where to lodge them, and how to feed them? Immense numbers, it is true, hurry at once to the mines without delaying in Melbourne, and the once lonely road from thence to Forest Creek and the Bendigo Diggings, is now little less thronged than that between London and Epsom on a Derby day, although with a somewhat different-looking class of travellers.[16]

Ralph Copeland did not go to Bendigo, but to Omeo, about 250 miles north-east of Melbourne.[17] In 1851 alluvial deposits of gold had been found in tributaries of the Livingstone Creek, Omeo, and he may have known of the 1852 report in the *Manchester Times*: 'A new place, called Lake Omeo diggings, has come to light lately, said to exceed all former discoveries. It is somewhere near the boundary between Sydney and Victoria districts; and should it become true, gold will become quite disgusting'.[18] How Copeland got to Omeo, and what he did when he got there, we do not know; although he wrote extensively about his later travels, he could not be persuaded to write about his early adventures.[19]

We do at least know how he came to leave the diggings. According to his daughter Fanny's unpublished autobiography, Copeland's adventures in the goldfields ended with a shot wound in the leg. 'His companions put him to bed in a stuffy little cabin, tied up the wound anyhow and sat around sympathetically waiting for blood poisoning to set in.' [20] Fortunately, a grizzled Zulu strode into the cabin and took command, demanding clean water and clean rags. He washed the wound thoroughly, bandaged it carefully, and repeated the process on the following day.

The wound soon healed and, shortly afterwards, Copeland and the Zulu went to work on a sheep farm run 'by a hefty amazon called Mother Brown'. His obituary in *The Scotsman* names the owner of the sheep farm as Mr Malcolm M'Farlane and states that Copeland returned to the Omeo diggings in 1856, where he was made a member of the 'Vigilance Committee' among the miners – a handful of young men who constituted an unofficial, secret court 'which enforced respect for life and property with a strong hand'.[21,22]

From his RAS obituary by J. L. E. Dreyer we learn that Copeland developed his interest in astronomy while working on the sheep farm – probably inspired by the clear skies – and that, at his request, his mother sent him some books and a small telescope with which he made 'his first acquaintance of the heavens'.[23]

2.1. *Return to England from Australia*

In 1858 he decided to return to England. He left Melbourne on the *Sultana* on June 24, reaching Liverpool, via Cape Horn, on October 1.[24,25] On the voyage he extended his astronomical interests, making experiments on the visibility of stars in daylight in the tropics and studying the appearance and rapid development of Donati's Comet.[26] Soon after his return to England his mother died, in 1859 January, and in July the farm was put up for sale.[27,28]

Copeland had wished to enter Cambridge University, perhaps at the suggestion of his uncle and future father-in-law, the Rev. Richard Milner, who was himself a Cambridge graduate. Instead, he entered the works of Beyer, Peacock & Co., locomotive engineers, as a volunteer-apprentice.[29] What prompted this change of plan we do not know;[30] but he was described as 'engineer' in the report of his marriage to his cousin Susanna Milner on 1859 December 26 at the Parish Church of St Mary-le-Gill where her father was the incumbent.[31] The engineering know-how he gained during this apprenticeship would stand him in good stead later in his career, particularly when dealing with astronomical instrumentation.

Together with some fellow-apprentices, including Fred Holloway with whom he corresponded into his last years,[32] Copeland set up a small observatory having a 5-inch refractor by Cooke at West Gorton near Manchester. Copeland's first recorded observation was of a staggered occultation of Kappa Cancri by the Moon on 1863 April 26, which was communicated to the Royal Astronomical Society by W. R. Dawes.[33] The report was followed by a series of confirmations and contradictions in the *Monthly Notices*. The *Bright Star Catalogue* lists Kappa Cancri as a double with a magnitude difference of 0.2 and separation of 0.3 seconds of arc; Copeland's estimate of a half-second step in the timing of the occultation is compatible with this separation.[34]

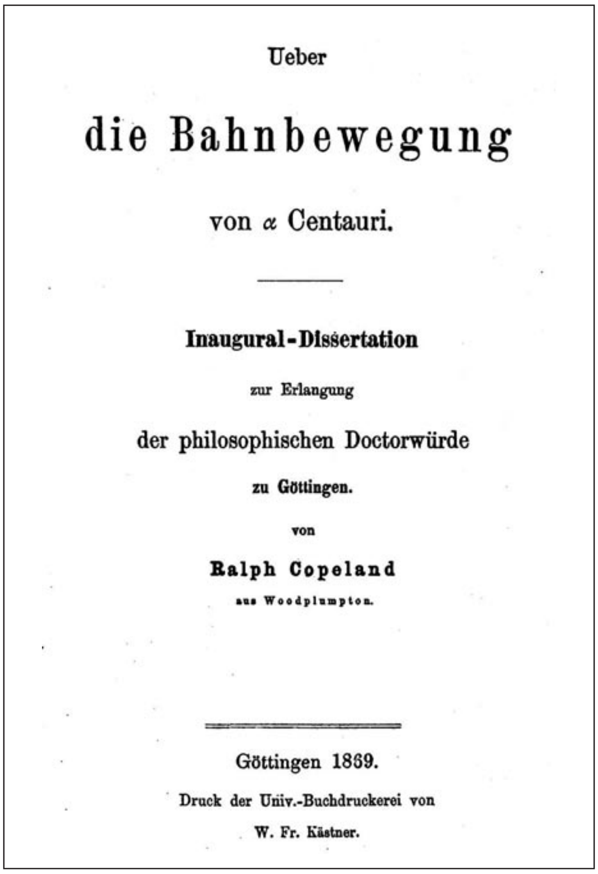
The Copelands' first child, Elizabeth, was born in Gorton in early 1861. A second child followed three years later, and was baptized John Herschel Copeland at St Mark, Gorton, on 1864 February 24,[35] but died later in the year. Sir John Herschel was then the grand old man of British science, and the naming of the Copelands' son after him clearly indicates Ralph's admiration, but there is no record of any contact between the two.

At around this time Copeland decided to devote his life to astronomy, being also influenced by the bad prospects for trade in Lancashire due to the cotton famine during the American Civil War. His first move was to obtain training in astronomy suited to his observing and instrumental interests. He did this not in England but at the University of Göttingen in Germany.

2.2. *Move to Göttingen*

In the mid-nineteenth century German universities were attracting students from all over the world to their graduate schools, where they could study for the modern PhD degree under academics who themselves had research experience.[36] After spending the winter in the house of a country clergyman in Hesse-Cassel in order to become familiar with the German language, Copeland moved his young family to Göttingen where he enrolled in the University in the spring of 1865. There he attended lec-

Fig. 2: Title page of Copeland's thesis on the orbital motion of Alpha Centauri, undertaken at the University of Göttingen.



Ueber

die Bahnbewegung

von α Centauri.

Inaugural-Dissertation

zur Erlangung

der philosophischen Doctorwürde

zu Göttingen.

von

Ralph Copeland

aus Woodplumpton.

Göttingen 1869.

Druck der Univ.-Buchdruckerei von

W. Fr. Kästner.

tures by Ernst Friedrich Wilhelm Klinkerfues (1827–84) and Wilhelm Eduard Weber (1804–91) and gained practical experience with astronomical instrumentation.[37] Copeland developed a life-long friendship with Klinkerfues. Fanny Copeland recalled that, when the family was at Dun Echt, they received huge parcels of Christmas presents from 'Uncle Klinkerfues'.[38]

Another son, Richard Ralph Copeland, was born at Göttingen in 1866 July. Tragically, Susanna died four months later of tuberculosis, leaving Ralph with an infant son and a five-year old daughter.[39] We do not know what arrangements he made for care of the children – there is no record of any family involvement – which became ever more pressing when he participated in an arduous observing programme and was then absent for 15 months on an Arctic expedition.

2.3. *Zone catalogue and PhD*

The University Observatory at Göttingen was equipped with two meridian circles, built by Repsold and Reichenbach in 1818 and 1819 respectively. In 1867 June, Copeland and a fellow student, Carl Börgen (1843–1909), embarked on a major project using the Reichenbach meridian circle: a survey of all stars down to 9th magnitude in the −1° and −0° zones of the Bonner Durchmusterung (BD), intended to be part of the programme being organized by the Astronomische Gesellschaft (AG) to observe all stars north of −2°. Observing continued through 1868, when Copeland took up residence in the observatory, and was completed in 1869 January, a total of 131 nights of observation having been shared between the two men.

Because the details of the AG programme had not yet been settled at the time the two students started, they consulted Professor Carl Bruhns (1830–81) of Leipzig as to the observing procedure adopted there and decided to follow it themselves. In the event their catalogue, 'Mean places of stars in zones −0° and −1° in the Bonner Durchmusterung brighter than $9^{m}0$ reduced to 1875',[40] published in 1869, was not accepted by the Council of the AG as part of their undertaking, because it used stars from the *Nautical Almanac* as standards. The zone was later assigned to Nikolajew Observatory in the Ukraine, but the Göttingen catalogue remained the modern authority for their zone for the next 30 years, until the Nikolajew catalogue was finally published.[41]

At the same time, Copeland completed his PhD thesis on the orbital motion of Alpha Centauri in which he derived its orbital elements from historical and modern data (Figure 2).[42]

2.4. *Call of the Arctic*

Also studying astronomy at Göttingen in the winter of 1867–8 was the German polar explorer Carl Christian Koldewey (1837–1908).[43] He had led the first German Arctic Expedition in the summer of 1868 and, in planning the second, consulted Börgen as to the feasibility of measuring an arc of meridian as part of it. Börgen

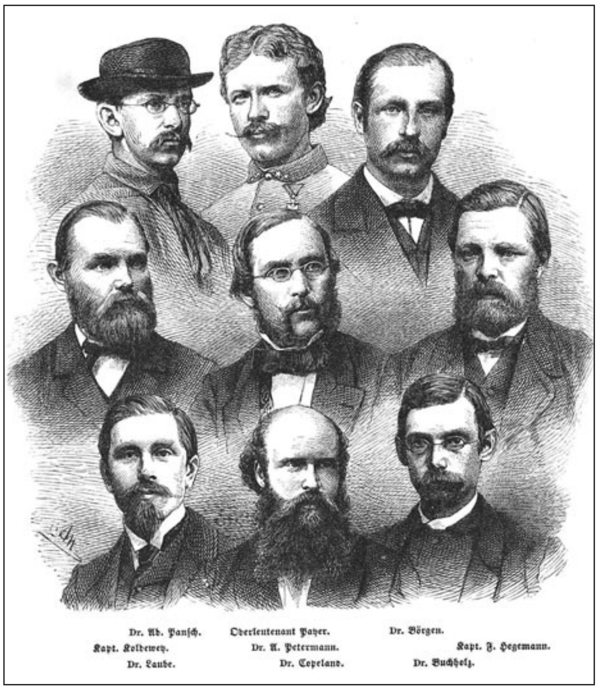


Fig. 3: Copeland seen bottom centre among the officers and scientists of the Second German North Polar Expedition in 1869–70. This is apparently the earliest surviving image of Copeland. Pansch, Payer, and Börgen are in the top row, and Koldewey at centre left (ref. 48).

pointed out that it would be impossible to reach results of permanent value, since the expedition would not be devoted to this work alone. However, noted Börgen, it would be most useful to make a detailed geodetic reconnaissance on which at some future time a regular measurement of an arc could be based. He would be disposed to join the expedition, together with Copeland, since one astronomer could not carry out the work alone.

On hearing this the same evening, Copeland was at once fired with enthusiasm at the prospect of taking part in a scientific investigation of a novel kind, and spent half the night talking about the methods to be followed and the instruments to be used.[44] His enthusiasm could well be traced back to his earliest recollection: that of two ladies, sisters of Captain Henry Foster (1796–1831), a native of Woodplumpton, who had accompanied William Edward Parry (1790–1855) on his third Arctic voyage in 1821–3.[45]

As part of their preparation, Börgen and Copeland compiled a short history of over-wintering in polar regions.[46] It referred to the imminent expedition which was planned to over-winter and presented reports of previous experiences to show how unfounded was the widespread belief that Europeans could not endure winter in that climate. They also set out the scientific work that would be carried out by the forthcoming expedition, pointing out that wintering in the Arctic region would give the best opportunity to study the nature of the northern lights with appropriate instruments. The discussion included the geodetic programme: there had long been a desire to determine the physical length of a degree at high latitudes, on either Spitsbergen or Greenland, and they gave reasons why the east coast of Greenland would be a good location for such a survey as part of the expedition.

3. The second German North Polar Expedition

The second German North Polar Expedition departed from Bremerhaven on 1869 June 15, seen off by King William of Prussia. The principal ship, the *Germania*, was specially built for the expedition, having a hull reinforced with iron plates to withstand the ice and, as well as sails, an engine and screw for manoeuvring in the ice. The second ship, the *Hansa*, carried stores for the *Germania*, and was intended to return to Germany at the end of the summer. Besides Copeland and Börgen the other scientific members of the expedition on the *Germania* were Lieutenant Julius Payer (1841–1915), Alpine explorer and topographer, and Adolf Pansch (1841–87), surgeon to the *Germania*, who was to cover zoology, botany, ethnography, and anthropology.[47] An engraving of the officers and scientists on the two ships forms the frontispiece of the popular edition of the expedition report (Figure 3).[48]

Their first destination was Sabine island on the east coast of Greenland (latitude 74½° north) but the *Germania* and *Hansa* became separated in ice and fog on July 20 due to misunderstanding of a signal, never to meet again. Unknown to those on the *Germania*, the *Hansa* was subsequently caught and crushed in ice but its crew survived on an ice floe for seven months before rescue and eventual return to Germany.[49]

The *Germania* continued to Greenland, which they reached on August 5. After it became clear that the *Hansa* would not be joining them with its stores, including coal for *Germania's* boiler, it was necessary to curtail exploring with the ship to save fuel and instead make do with sledge expeditions. Later in August the two astronomers, together with a crew member, explored Shannon Island (north-east of Sabine) with a view to finding sites for a baseline and triangles for the geodetic survey, but without success.[50]

Copeland also contributed with his rifle: he gives an exciting account of a hunt during which he and the ship's stoker, Louis Wagner, shot three musk oxen.[51] They cut their throats and rolled them some hundred feet down a steep slope. Then followed the work of skinning, falling mainly to Copeland, who was more experienced. They were approached by a large polar bear. Copeland shot him and opened his jugular vein. The carcasses were too heavy to move so they returned next morning with seven men, two boats, and a light sledge to collect the meat, heads, and skins.

3.1. *A winter in the Arctic*

The *Germania* lodged in ice for winter in a creek they called Germania Harbour on the south-east corner of Sabine island (Figure 4). The ship was unfitted down to the lower masts and shrouds, leaving the fore topmast as a lofty point for observing air currents and electricity. Everything not required for wintering was taken on land and secured to provide space on deck, which was covered with a heavy tent. Two observatories – astronomical and magnetic – were built of stone on shore near the ship. Rows of ice blocks and rope were erected between them and the ship to help men get to and fro in bad weather and in the dark.[52]

Copeland was one of five men on a sledge expedition led by Koldewey to explore Clavering Island off the north-eastern coast of Greenland.[53] On the second morning, October 28, they set off at 3.00 a.m. in moonlight. As daylight appeared, Copeland was attacked by a polar bear which galloped up to within five paces, then raised itself and struck him down with both fore-paws. Copeland had no time to load his gun but, as the creature caught his clothes, he swung the butt-end of his gun across its snout – and the bear ran away. The party then kept their weapons loaded on the sledge.

In his report of their travels, Koldewey also described the privations: when camping, the party was so closely packed in the tent that the pulling-off of boots could only be accomplished by sitting on one's neighbour. There was always the risk of knocking over the lamp, an uncovered tin dish filled with bear's grease, which twice set fire to the tent. The provision of drinking water by melting snow depended on the limited amount of fuel for the spirit lamp with the result that the men were thirsty most of the time. Provisions were short and by the end consisted mainly of reindeer flesh, 'which caused a dysentery that not even opium could assuage'.[54]

Work on the geodetic survey had stopped in the autumn and the winter was devoted to meteorological, magnetic, and astronomical observations. Copeland reported that the northern lights were very frequent, and that the convergence of the streamers was found to coincide with the direction of the freely suspended magnetic needle.[55] Spectroscopic examination of the auroral light fixed the wavelength of the green line at 1245 of Kirchhoff's scale.[56]

3.2. *Börgen carried off by a polar bear*

After the Sun reappeared in early February the survey stations closer to the ship were definitively selected and marked with either stone cairns or the metal drums in which provisions had been stored. On March 6, however, plans were thrown in disarray when Börgen was seriously injured.

Returning to the ship from the observatory after observing the occultation of a star by the Moon he was attacked by a polar bear, which started to carry him off. Koldewey on the ship heard his cries. The crew went out and fired shots to scare the bear, which dropped Börgen – but then grabbed him again and continued dragging him off. After a few more shots the bear let go again and ran away. Börgen was recovered and taken back to the ship where he was treated by Dr Pansch. The bear had torn his scalp in several places and there were about 20

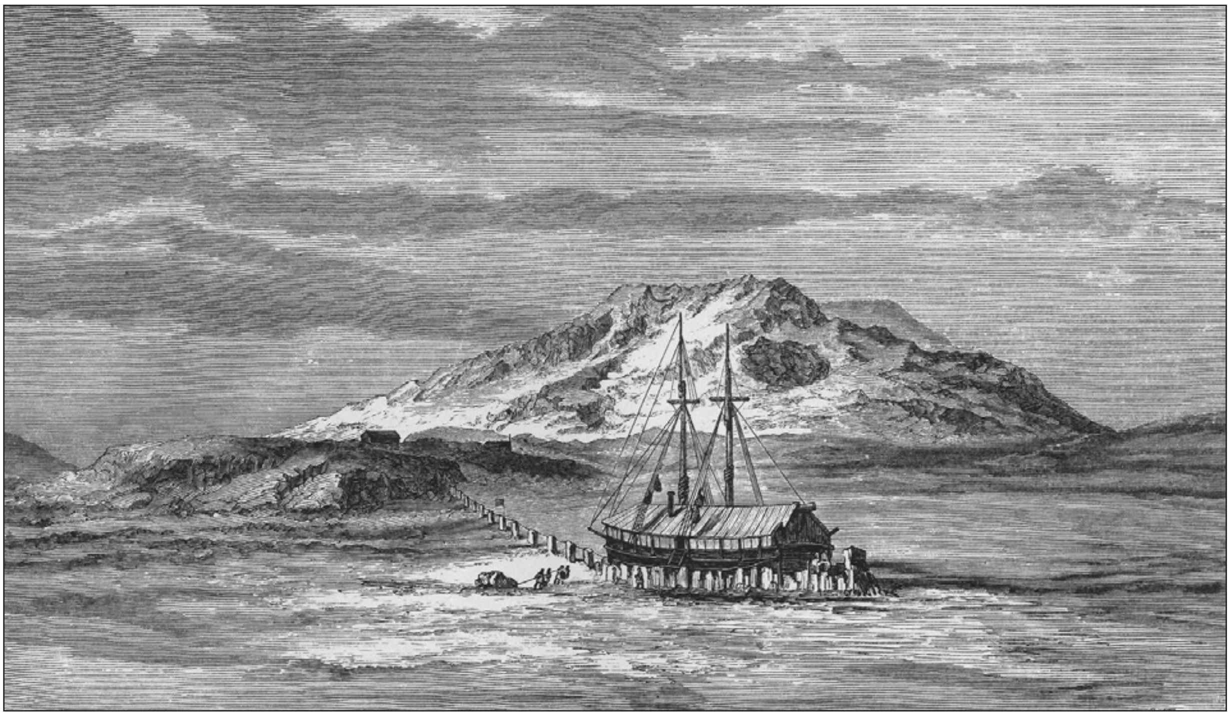


Fig. 4: Copeland's ship Germania lodged in the ice at Sabine Island, north-east Greenland, for the winter of 1869–70. The masts were reduced and a tent of strong sail cloth was erected over the deck. On the shore behind the ship can be seen two small stone buildings, the magnetic and astronomical observatories, connected to the ship by a row of blocks of ice and a rope to guide the observers in the dark. This illustration comes from Captain Koldewey's book 'The German Arctic expedition of 1869–70' (ref. 43).

other wounds, mostly from being dragged along the ice.[57]

In time, his wounds healed but thereafter he had to open and shut one of his eyelids by hand. Years later, Fanny recalled that when Börgen visited Copeland in Dunsink she climbed on his knee and asked him to open and shut his eye with a finger.[58]

3.3. *Resumption of geodetic observations*

Continuing the geodetic work, Copeland had to make field trips without Börgen. During April Copeland made a number of expeditions to expand the network of stations, checking their visibility and optimizing the network of triangles. Angles were measured with a theodolite with 5-inch circles. In the meantime Börgen had recovered and began to resume work.

In early May, the measurement of the 709-metre-long baseline was carried out and on May 14 they were able to start the sledge journey to the north. The plan was to set up the stations on the way there, between which the angles could be measured on the way back. All the angles at sixteen out of seventeen selected stations were measured. The latitude of the north end, on a mountain they called Muschelberg on account of the many fossilized shells they found there, was determined as 75° 11′ 30″.1.[59] The overall length of the arc was thus 39′ 14″.2.

They had planned to go farther north but the season was too far advanced and the sledge kept breaking through the ice, so they hurried back to the ship, which they reached on June 17. A report of the survey, including a detailed map showing the stations and triangles, was written by Börgen.[60]

In July, the ice near the ship began to break up and on July 22 the *Germania* left its winter harbour and set off north. Unfortunately, the way was blocked by pack ice and the crew instead turned south. Their exploration was rewarded by discovery of a large fjord, which they named after Kaiser Franz-Joseph. On August 12 Copeland, Payer, and a young crew member, Peter Ellinger, climbed up the glacier to a peak, now named Payer's peak (6,493 ft, 1,979 m), which remained the highest recorded climb within the Arctic Circle for over 50 years.[61] They saw countless summits around the horizon, of which they named the highest (near 11,000 ft, 3,350 m) Petermann's Peak after the German geographer August Heinrich Petermann (1822–78), the originator of the German Arctic expeditions.[62]

Since the end of July the *Germania's* boiler had become increasingly unreliable so it was decided to return home. The expedition docked in Bremerhaven on September 11, to learn that the Franco-Prussian War had broken out, and that the *Hansa* had been crushed in the ice but the crew saved.[63]

Copeland seems then to have returned to Göttingen and his children, whom he had not seen for more than a year, and set about looking for a position where he could continue astronomy. In due course he obtained one as assistant astronomer at Lord Rosse's observatory at Birr Castle, Ireland. At the same time he must have made or renewed acquaintance with Anna Bertha

Fig. 5: The 72-inch (1.8-m) Leviathan of Parsonstown in c.1885 with Lawrence Parsons, fourth Earl of Rosse, at the eyepiece. Copeland used this for observations of satellites of Uranus, Jupiter and galaxies. The cross-bar used for tracking can be seen about a third of the way down the tube. (National Library of Ireland)

Theodora Benfey (1847–1938), daughter of Theodor Benfey, a distinguished orientalist and professor at Göttingen University, whom he subsequently married.

4. Astronomy at Birr Castle and Dunsink Observatory

In 1871 January Copeland took up his appointment as assistant astronomer at Birr.[64] Over the years, Lord Rosse had employed a series of assistants, and the position became vacant in 1869 when Charles Edward Burton (1846–82) had to leave because of ill health.[65] Given Copeland's mechanical experience, it is likely that the engineering tradition at Birr attracted him as much as the astronomy.[66]

The observatory had become famous for the large telescopes built by the 3rd Earl of Rosse, William Parsons (1800–67), especially the 72-inch (1.8-m) 'Leviathan of Parsonstown'. The latter saw first light in 1845 February and remained the largest telescope in the world for over 70 years. The Leviathan had allowed the discovery of the spiral structure of nebulae, beginning with Parsons' observation of M51 in 1845.[67]

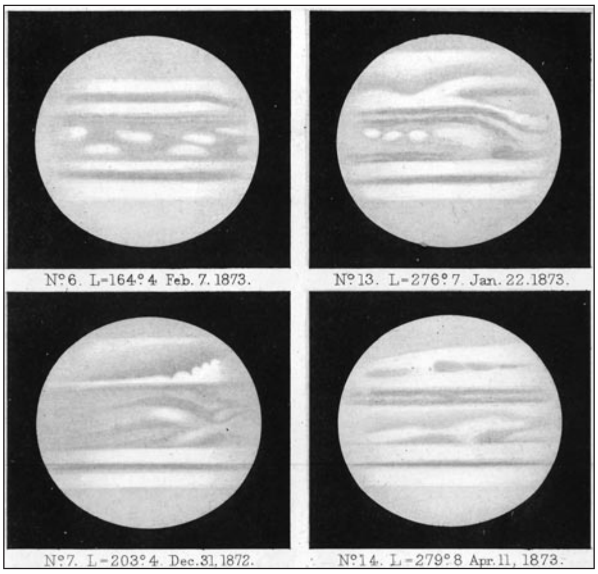
By the time Copeland started at Birr, William Parsons had died and his eldest son Lawrence (1840–1908) had succeeded him both as 4th Earl and in the pursuit of engineering and astronomical excellence. Lawrence Parsons had initiated a programme of measuring the radiant heat from the Moon using the 36-inch (0.9-m) telescope and thermopiles. Copeland's first duties were directed to this programme and his contributions to the observing and reductions were warmly acknowledged in the Earl's report of the results.[68]

In 1871 December Copeland married Theodora Benfey.[69] Their first daughter, Fanny Susannah Copeland (1872–1970), was born at Birr the following year. He received an invitation to join the 1872 Austro-Hungarian Arctic expedition, but being now settled at Birr with a growing family he declined.[70]

4.1. *Observing with the Leviathan*

In 1872 January Copeland began observing the satellites of Uranus, primarily Oberon and Titania, with the Leviathan. The telescope was cumbersome to use. It tilted north–south in altitude between its massive 56-ft-high walls like a transit instrument but, being mounted on a universal joint, could also pan in azimuth between the walls allowing an object to be tracked for about 40 minutes (Figure 5).

Fig. 6: Sketches of Jupiter made by Copeland with the Leviathan around the time of the giant planet's opposition in late 1872 and early 1873. Magnifying powers up to ×650 were used (ref. 72).



In preparation for an observation, the tube was raised to the required elevation and moved to the eastern wall to catch the target at the beginning of its transit. It had a Newtonian focus, with the eyepiece on the west side, and three observing galleries to give the observer access to it depending on the elevation.

Four men were required to assist the observer.[71] One stood at the winch to raise or lower the tube, another at the lower end of the instrument to move it eastward or westward as requested by the astronomer, while a third moved the observer's gallery in or out from the wall to keep the observer conveniently near the eyepiece. The fourth looked after the lamps and attended to minor matters. For tracking, the observer turned a handle near the eyepiece, and the tube moved along a cross-bar with a cog wheel. From the measurements of position angles and separations with the micrometer, Copeland derived orbits for Oberon and Titania and hence estimated the mass of Uranus.

Copeland made 19 sketches of Jupiter around the time of its opposition between 1872 December and 1873 April. From notes of the colours he executed watercolours the next morning which were published as chromolithographs (Figure 6).[72] The observing was facilitated by the application of a clock movement to the telescope, but the limited tracking range precluded study of changes during any one night as the planet rotated. Nevertheless, the observations showed up longer-term changes and allowed re-examination of the rotation period.

However, the principal use of the telescope remained to survey and draw all the brighter nebulae catalogued by the Herschels. There was no systematic search for new nebulae, but in the course of the programme many were discovered and were designated 'nova' in the records. Copeland discovered 35 new nebulae including, in 1874, the group in Leo now known as Copeland's Septet (Table 1).[73]

A feel for the process can be gauged from the record of his observations on 1874 February 9 (Figure 7).[74]

Table 1

Galaxies discovered by Copeland at Birr

NGC	RA (2000)	Dec	Original
3743	11h 35m 57s	21° 43′ 22″	α
3745	11h 35m 57s	21° 43′ 22″	β
3746	11h 37m 44s	22° 00′ 36″	γ
3748	11h 37m 49s	22° 01′ 33″	δ
3750	11h 37m 52s	21° 58′ 27″	ε
3751	11h 37m 54s	21° 56′ 11″	ζ
3753	11h 37m 54s	21° 58′ 53″	η
3754	11h 37m 55s	21° 59′ 08″	θ
3758	11h 36m 29s	21° 35′ 45″	ι

The coordinates given here are correct, unlike those in the original NGC (see ref 74). Greek letters follow his original notation; galaxies α and ι are not members of the Septet. See the sketch of the group in Figure 7.

Expanding the abbreviations, we have for the first three nebulae:

> Set for 2464.[75] Found a nebula [ε], preceding Bright, little brighter in the middle, star in Pos. angle 23°.8, distance 109″.3, another [η] preceding Faint, same star Pos. angle 5°.5, distance 71″.7. Third nebula preceding [γ], pretty bright, considerably large, gradually little brighter in the middle, elongated 90°±, same star in Pos. angle 100°.4, Dist 148″.4. The star has a very red star 8.9 mag in Pos. angle 153°.3, Dist. 526″.8 [or 17s.08 following, 470″.6 south. 8.9 mag star = BD +22°2380]. None of the 3 nebulae have Nuclei.

Copeland's galaxies ε, η, and γ are now known as NGC 3750, NGC 3753, and NGC 3746 respectively. Other

1874, Feb. 9. Set for 2464. Found a neb [ε], p B, 1 b M, * in Pos. 23°·8, Dist. 109″·3, another [η] p F, same * Pos. 5°·5, Dist. 71″·7. Third neb p [γ], p B, c L, glbM, E 90°±, same * in Pos. 100°·4, Dist. 148″·4. The * has a very red * 8·9m in Pos. 153°·3, Dist. 526″·8 [or 17s·08 f, 470″·6 s. * 8·9m=B. D. + 22°, 2380]. None of the 3 neb have Nucl.

1874, Mar. 18. Found a neb [ι], pB, S, R, smbM, Nucl. not stellar.

	* 8m Pos.	81°·6	Dist. 161″·2
	* 12m	207·4	63·0
* 9m from * 8m		303·9	671·0 [or 40s·20 p 374″·5 n]
Neb[α], F, S, R, from * 9m		322·5	78·1

[* 9m is=B.D.+22°, 2377].

1874, April 5. Group of neb measured from a * 10·11m.

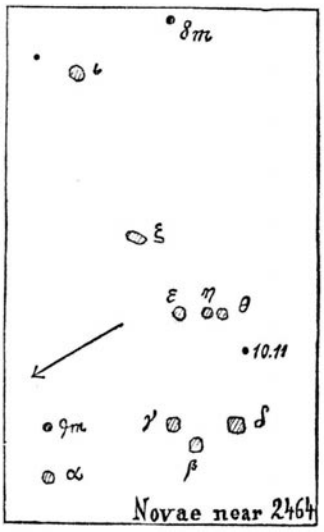


Fig. 7: Copeland's description of the galaxies making up Copeland's Septet as published in The Scientific Transactions of the Royal Dublin Society in 1879 (ref. 74). The sketch accompanying the descriptions is probably by J. L. E. Dreyer. The nebulae labelled α and ι (NGC 3743 and 3758, at bottom left and top left of the diagram) are not members of the Septet.

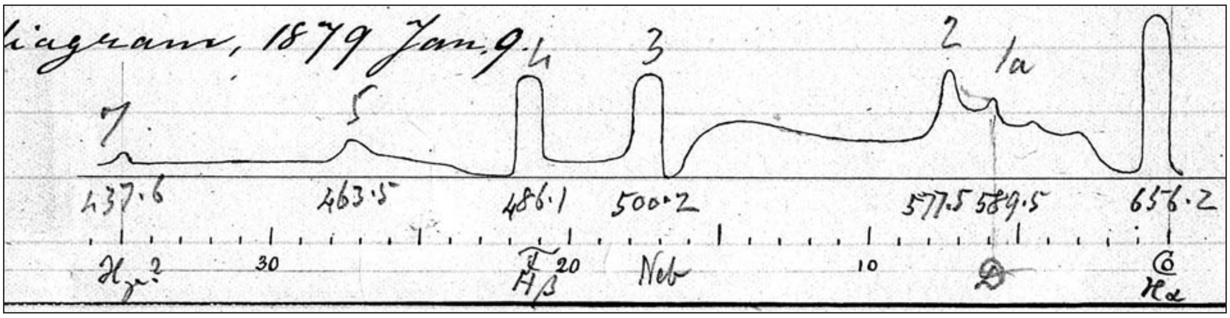


Fig. 8: Emission-line spectrum of Nova Cygni with annotations by Copeland. Wavelengths are in nanometres. The year written at the top, evidently added later, is incorrect; it should be 1877. (From 'Dunecht observations, Schmidt's Nova Cygni', A206 in the ROE Archives)

members of the Septet are NGC 3745, NGC 3748, NGC 3751, and NGC 3754 (his β, δ, ζ, and θ). Making micrometer measurements and notes of faint nebulae was, of course, very different from comparable observations of bright planets because the observer had to retain his dark adaptation, all the while working on a gallery suspended about 30 feet above the ground.

4.2. *Move to Dunsink, and the 1874 transit of Venus*

In the spring of 1874 Copeland moved from Birr to the Dunsink Observatory of Trinity College Dublin where he became Assistant to its director, the German-born astronomer Franz Friedrich Ernst Brünnow (1821–91).[76] The ever-adventurous Copeland was given leave of absence to accompany Lord Lindsay (James Ludovic Lindsay, later Lord Crawford) (1847–1913) on his expedition to observe the transit of Venus in December that year, one of eight teams of observers from Britain.[77] They left for Mauritius on Lindsay's yacht *Venus* on July 9, arriving there on November 2.

On the way they called at the island of Trindade in the South Atlantic, where Copeland and Lindsay collected specimens of birds and plants. Copeland discovered a giant tree fern, now called *Cyathea copelandii*, groves of which are found only in the higher and almost inaccessible parts of that island.[78] On the day of the transit, December 9, Copeland observed with a 6-inch equatorial and double-image micrometer, but the observations were only partly successful owing to cloudy weather.[79]

While Copeland was in Mauritius, his wife returned to Göttingen with Elizabeth, Richard, and Fanny, partly to see her people and partly to be away from Ireland which was then in the throes of Fenian troubles. Copeland returned from Mauritius to take his family back to Ireland but Elizabeth stayed in Göttingen to finish her education. Fanny recalled her first impressions of her father on his return from Mauritius: 'Tall, (six ft and broad shouldered in proportion) and had a flaming red beard'. Old friends called him 'Barbarossa'.[80]

While Copeland was away, the Irish astronomer Robert Stawell Ball (1840–1913) succeeded Brünnow as Director of Dunsink Observatory.[81] Ball, who had been an assistant to Lord Rosse in 1865–67, was favourably impressed by Copeland and later described him as a man of very extensive scientific attainments with a very useful practical knowledge of instruments.[82] Ball reported that, in the course of a walk through a forest in Mauritius, Copeland had found bushes covered with spider cocoons. He had filled an envelope with them and gave Ball a few when he came back from which they furnished the spider wires in the transit circle at Dunsink.

Copeland must have treasured the stock: many years later, when he was Director of the Royal Observatory, Edinburgh, he noted in his Diary for 1894: 'Oct 26. After repeated disappointment with the transit wires, devoted the whole morning to replacing three of them by webs of a Mauritian spider. In the evening it was found that these webs answered most satisfactorily.'[83]

At Dunsink, Copeland observed red stars with the transit circle and on 1876 May 2 Theodora gave birth to their second daughter, Paula Theodora. But Theodora was unhappy in Dunsink, and in the summer of that year they moved to Lord Lindsay's observatory on his estate at Dun Echt, Aberdeenshire, where Copeland took up an appointment as Director in succession to David Gill (1843–1914).[84,85]

5. Copeland at Lord Lindsay's observatory (1876–88)

The private observatory built up from 1872 by Lord Lindsay at Dun Echt was very different from Lord Rosse's at Birr. Instead of large telescopes constructed on the demesne, the equipment at Dun Echt had been acquired by Lord Lindsay, with the aid of David Gill, from the best English and continental instrument-makers.[86] Besides the meridian instruments there were equatorially mounted 6-inch and 15-inch refractors.

Copeland soon employed the latter in a major investigation, tracking the evolution of the spectrum of the bright nova later designated Q Cygni. It was discovered at third magnitude by the German astronomer Johann Friedrich Julius Schmidt (1825–84) in Athens on 1876 November 24, but slowness of communication and poor weather did not allow Copeland to observe it until 1877 January 2. By then the nova had already faded to seventh magnitude, but he and Jacob Gerhard Lohse (1851–1941), another graduate of Göttingen who had joined the observatory in 1877, were able to measure

Table 2		
Comets observed by Ralph Copeland and J. Gerhard Lohse at Dun Echt		
Comet	**Discoverer**	**Month(s) observed and results**
1877b	F. A. T. Winnecke	April–May: spectrum, three emission bands
1877c	Alphonse Borrelly	May: spectrum, bands at different positions
1879d	Johann Palisa	August: positions, elements, ephemeris; September–October, spectrum, comet bands; August–October: positions using micrometer
1880b	J. M. Schäberle	April-May: description, elements, ephemeris for May–November
1880d	Ernst Hartwig	October: spectrum, three emission bands
1880e	Lewis Swift	November: elements
1880f	C. F. Pechüle	December: spectrum, faint, three bands
1881a	Lewis Swift	May: elements
1881 III	John Tebbutt	July–August: usual emission bands, faint fourth band in the blue
1881c IV	J. M. Schäberle	August: three emission bands.
1881f	W. F. Denning	October: elements, ephemeris
1882 I	C. S. Wells	April–June: spectra, sodium D lines as well as comet bands
1882 II 'Great'	W. H. Finlay	September–October: D lines, also E and other prominent iron lines
1884 III	Max Wolf	September: positions
1888e	E. E. Barnard	November: spectrum, weak bands

five bright emission lines with a Vogel spectroscope (Figure 8).[87]

Copeland and Lohse identified two of the five lines with hydrogen (Hα and Hβ), while another, at 502 nm, was found to be close to the brightest line seen in gaseous nebulae, and the remaining two (579 and 464 nm) were identified with emission lines seen in the recently discovered Wolf–Rayet stars.

Further observations at Dun Echt showed the spectrum to be evolving: the hydrogen lines faded and by January 19 the line at 500 nm was the brightest. After February 16 the nova became lost in the twilight. When it was recovered in September, the spectrum showed only the 500-nm line, for which a final wavelength of 500.2 ± 0.4 nm was derived, in excellent agreement with the 500.7-nm nebular line now identified with doubly ionized oxygen [OIII].[88]

This investigation was published in *Copernicus*, a journal established in 1881 and edited by Copeland and the Danish-born astronomer John Louis Emil Dreyer (1852–1926) who succeeded Copeland at Birr and then at Dunsink. Although it included papers by the Dun Echt observers, it was an international journal, publishing a wide variety of contributions, some in French and German. Unfortunately, it was not financially viable, and ceased publication after three years.

Longer-lasting was the series of brief *Dun Echt Circulars*, initiated by Lord Lindsay in 1879 to inform astronomers of the appearance of comets and other temporary phenomena. The mailing list included about 200 recipients.[89] Many Circulars also appeared in the *Astronomical Register*, a journal for amateur astronomers published monthly between 1863 and 1886.

At the same time that the first *Dun Echt Circulars* were issued, Seth Carlo Chandler (1846–1913) and John Ritchie (1853–1939) of the Boston Scientific Society developed a code (the Science Observer Code) for the telegraphic transmission of cometary orbits. To test the usefulness of the code, which was based on the location of words in a dictionary to convey each set of five digits, they arranged with Lord Crawford for the receipt and publication of cable messages containing orbits computed in the United States and vice versa.[90,91]

For example, *Dun Echt Circular* No. 17, issued on 1881 May 9, 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.[92] At the meeting of the Astronomische Gesellschaft in 1881 September, Chandler and Ritchie drew attention to the tests between Boston and Dun Echt and Copeland gave a thorough exposition of the code, including examples for communicating cometary elements and ephemerides.[93,94]

5.1. *Cometary observations at Dun Echt*

The observation of comets and determination of their elements was a growing part of the programme at Dun Echt (Table 2). In 1877 April and May Copeland and Lohse observed the spectra of Winnecke's (1877b) and Borrelly's (1877c) comets, each showing three 'bright' bands but at different wavelengths.[95] In 1879, Copeland and Lohse observed the spectrum of Palisa's comet, which showed the comet bands.[96] Earlier, they measured its position and determined the elements of its orbit.[97]

Similarly, they observed and computed elements for two comets in 1880 (1880b Schäberle,[98] and 1880e Swift[99]), and observed three comets in 1881 (1881b, f, and g).[100] They reported the discovery of sodium D emission lines in Comet Wells (1882 I) and the Great Comet of 1882 (1882 II).[101]

The latter was observed in daylight on September 18, just one day after perihelion. The D emission lines were observed to lie just to the red of the corresponding absorption lines from the scattered solar spectrum, indicating a recession velocity of between 37 and 46 mile/s (60–74 km/s). Next in intensity came several lines in the green, each of which also lay just to the red of scattered solar absorption lines, all at the same displacements. These they identified as iron lines, which became controversial,[102] but possible mechanisms for driving some iron lines into emission when a comet is extremely close to the Sun (as was Comet 1882 II when observed by Copeland and Lohse) were demonstrated in 1962 by Greenstein and Arpigny.[103]

In parallel with the Dun Echt observations Copeland set out to coordinate systematic searches for comets, suggesting declination zones to various observers, and making Dun Echt a central station where places of newly discovered comets and nebulae would be measured.[104] Dun Echt may have been geographically isolated but it was closely networked with astronomers in Britain and overseas.

In 1879, Copeland had his first official dealings with the Royal Observatory in Edinburgh. The Astronomer Royal for Scotland, Charles Piazzi Smyth (1819–1900), recorded: 'An announcement from Lord Lindsay that he has been deputed by the Home Secretary to examine the equatorial [telescope, a long-standing bone of contention] and report the cost of completing it for work – will therefore come, with some preliminaries, on [Monday] May 19.'[105]

On May 15 he noted: 'Dr Copeland, Lord Lindsay's chief observer arrived to make the required preliminary examinations', and the following two days 'Dr C hard at work in Dome, with myself and assistants, examining, trying cleaning &c all parts'. This is more friendly than Piazzi Smyth's entry on the commission itself ('They had a long meeting, partly in the Dome, partly in the computing room. I am not present at it or on it, although I receive them within the Obsy …'), suggesting considerable tact and good nature on Copeland's part, given that Piazzi Smyth was at that time mired in quarrels.[106]

5.2. *Travel and observing in the Andes*

Copeland observed his second transit of Venus in 1882 December as chief of a Government expedition to Jamaica which was part of the British contribution to an international campaign; he was assisted in his observations by Captain George Mackinlay of the Royal Artillery.[107,108] Copeland set out from Dun Echt in October, taking the same instrument that he used for the 1874 transit, namely the 6-inch refractor on an equatorial mount. While he was away, Theodora and the children made an extended visit to her family in Göttingen.[109]

After successfully observing the transit, Copeland set off on his own to South America with a view to testing the astronomical capabilities and climate of the elevated situation of Quito, in the Andes mountains of Ecuador. He took with him the 6-inch refractor (but not its equatorial mount, which he considered too heavy for mules), the Vogel spectroscope, and various meteorological instruments. The cost of this expedition was met by Lord Crawford.

His journey took him by sea to the Isthmus of Panama, crossing it, and taking another steamer to Guyaquil, the main port of Ecuador. The political volatility of the region threw up unexpected obstacles that required all his considerable resourcefulness to

Fig. 9: Sketch from Copeland's pocket notebook of a sunspot observed at Puno on 1883 March 31, with an unsilvered diagonal plane ×163. (ROE Archives: 199, Observations in Puno and Vincocaya)

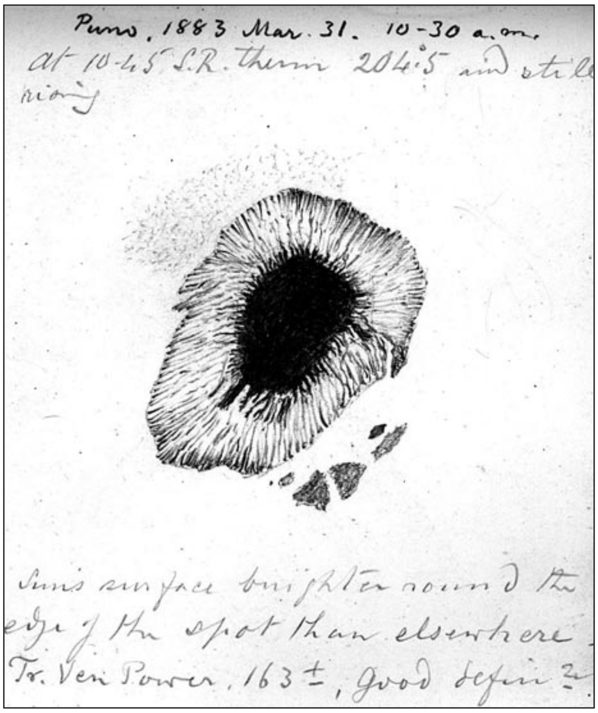


Table 3				
Wolf–Rayet stars discovered by Ralph Copeland in Puno, Peru, giving his designations, modern names, and wavelengths of emission lines where measured				
Name of star or coordinates (1883)	**Modern name**	**Line wavelengths (nm)**		
γ Argus	γ Velorum	580.9	566.8	464.6
Stone 9168	WR 79	580.9	569.2	465.1
13h 10m 37s, −57° 31′	WR 52	575.3	—	463.3
11h 05m 19s, −60° 21′	WR 42	—	—	—
08h 51m 01s, −47° 08′	WR 14	573	—	463.3
10h 36m 54s, −58° 08′	WR 23	—	—	—

overcome. When he reached Guyaquil on 1883 January 1 the country was in a state of revolution. Forced to change his plans, he continued down the coast by steamer to Lima in neighbouring Peru.

There he was frustrated again by more political conflict: the upper part of the Trans-Andean Railway was closed because of a war between Peru and Chile. He continued further down the coast to Mollendo in southern Peru, the port for Arequipa and Puno on the westerns shore of Lake Titicaca. He was granted a permit to cross the Chilean blockade at Mollendo by the Chilean commander-in-chief. In Lima he had had the good fortune to fall in with the lessee of the Mollendo Railway, Mr John Thorndike, who offered him valuable assistance.

Copeland published an extensive report on his travels in *Copernicus*, reporting detailed meteorological, and astronomical observations.[110] He also published a more descriptive two-part narrative in the *Deutsche Geographische Blätter*.[111] This account begins with his landing in Mollendo on February 2, reporting that the Chilean gunboat enforcing the blockade of the city was at sea, and the English captain of the steamer did not want to waste time waiting for its return, so he allowed passengers with permits to land and continued on his voyage.

The weekly train for the interior left the following morning. Copeland's account in the *Deutsche Geographische Blätter* gives a detailed description of the journey, the terrain, and vegetation as the train climbed from the coast to Arequipa, altitude 7,660 ft (2,335 m).[112] In Arequipa he noted the use of sillar, a volcanic tuff, as the common building material and of stone arches in the construction of house roofs and churches to withstand earthquakes. The Jesuit church had stood for two centuries but showed many cracks. He was in Arequipa at the time of Carnival but was not appreciative of the traditional practice of dousing passers-by with water from eggshells or buckets: 'It's no fun being pelted with eggs filled with all sorts of dyes or even more questionable liquids.'[113]

Copeland was unable to make astronomical observations during his stay in Arequipa because most of his equipment was in a bonded truck which had been shunted off the train en route. But on the recommendation of Mr Thorndike he consulted the mechanical engineers of the railway, who 'transformed a 6-inch lathe into a very fair equatorial mounting by simply reversing the fast head-stock and adapting a cross-axis to the face-plate'.[114]

On February 9 he reached Vincocaya, the highest station (14,360 ft, 4,380 m) on the line, where he stayed the night. The weather was so bad that he left the telescope and heavy equipment there and went on to Puno the following day from where he crossed Lake Titicaca on a steamer and went on to La Paz in Bolivia by stagecoach. The journey, terrain, geology, vegetation, animals, and people are all described with close interest in his report; Copeland was evidently very observant.

The weather in La Paz was no better, so after two weeks he returned to Puno. On the way back across Lake Titicaca he stopped at the island of Coati (or Koati) to examine the ruins of the Temple of the Moon and the nearby stone terraces, which he found particularly impressive.[115] From Puno he continued westwards to Vincocaya where he erected the telescope in the hope of being able to begin observations.[116] But the weather was still bad, with thunderstorms, rain, and snow, so after two weeks he packed up his equipment and went back to Puno, where the weather was reported to be better.

In Puno, he erected his telescope in a corrugated iron hut within the railway station enclosure. By removing the roof of the hut and giving the lathe-bed mounting a suitable inclination on some heavy iron castings (he was now at latitude 16° south), the telescope was readied for observing. To examine the seeing, he observed a number of close double stars, some discovered to be such in the process, measuring separations as small as 0″.8 for β Muscae, ψ Argus (= ψ Velorum), and ε Lupi.[117] He also observed and sketched a spectacular sunspot (Figure 9). To test the clarity of the air, Copeland observed bright stars and Jupiter in daylight.

He had intended to observe the spectrum of the remarkable variable star η Argus (the present-day η Carinae), famous for its eruption in 1843, but had failed to bring a chart with him, having hoped to find one in the library at Quito. He was unable to distinguish it from the other stars in the region by spectroscopic scanning. This was, though, more than compensated for by his sight of the spectrum of γ Argus (now γ Velorum): 'Its intensely bright line in the blue, and the gorgeous group of three bright lines in the yellow and orange, render its spectrum incomparably the most brilliant and striking in the whole heavens.'[118]

The extraordinary beauty of the spectrum inspired him to search for more such stars. In sweeps of the neighbourhood he discovered another five and identified them as Wolf–Rayet stars, i.e. hot, luminous stars

Fig. 10: Copeland with the Cooke spectroscope attached to the 15-inch refractor at the new Royal Observatory Edinburgh in about 1898 after its transfer from Dun Echt. (ROE archives)

with intense stellar winds that are believed to be a late stage in the evolution of O-type stars (Table 3).

In June he returned to Vincocaya where he was able to attach the telescope to the lightweight mounting and clock drive which had been sent out from Dun Echt, and with this he measured the wavelengths of the bright lines. The lines are now known to be from carbon ions (CIV at 580.8, CIII at 569.7, and CIII+IV at 465.0 nm).[119] We can see the accuracy of Copeland's wavelengths for the first two stars in Table 3; he was unable to separate the first two transitions in the other two stars. He observed a fourth, narrower line at 590 nm in γ Argus; this was the D3 line now identified with helium.

Besides the Wolf–Rayet stars, he discovered a number of planetary nebulae and observed and described the spectra of numerous other stars. He also observed the spectrum of lightning during a violent thunderstorm, identifying a number of nitrogen lines. Also in Vincocaya he used the Browning spectroscope that had been sent out from Dun Echt to observe the Sun, hoping to see emission lines from the corona. He detected emission in the C (Hα), F (Hβ), and D3 lines from solar prominences but never from the corona.

After a spell of observing in good weather Copeland left Vincocaya on June 28 for Mollendo, where he boarded a ship for the south. This stopped at Arica in northern Chile. From there he went to Tacna, just across the border in southern Peru, for a week, awaiting the arrival of the northbound steamer. His report includes extensive recording of meteorological data, temperatures, relative humidities, and atmospheric pressures at Puno, Vincocaya, La Paz, and, briefly, at Arequipa, Mollendo, and Tacna.[120]

Regarding the choice of observing stations, he judged that Vincocaya offered no advantage over Puno because of its greater range of temperature and prevalence of dust. He suggested that the summit of one of the islands on Lake Titicaca would offer advantages of more stable temperatures and less dust and concluded that it was possible to observe for nearly nine months of the year. Although La Paz and Arequipa offered more facilities, he considered them hemmed-in by mountains and was concerned about earthquakes in Arequipa. In the event, Harvard College Observatory established its southern station (known as the Boyden station) in Arequipa in 1890 and the Astrophysical Observatory Potsdam chose La Paz in 1926, opting for the locations with the better facilities.

5.3. *Return to Dun Echt*

On the way home, Copeland reached New York at the beginning of August and visited a number of eastern North American and Canadian observatories, surveying their instrumentation, before reaching home on 1883 September 1, nearly a year after his departure.[121]

Back in Dun Echt he continued coordination of comet searching[122] and made sweeps for more objects with remarkable spectra, discovering more planetary nebulae and another Wolf–Rayet star,[123] and continued observing comets and novae.

One reported nova, since given the variable star designation S And and now known to be a supernova, was in the Andromeda nebula. Dun Echt received news of it on 1885 September 1, with a request to investigate.[124] Copeland's observation that night found the spectrum to have little or nothing in common with that of Schmidt's Nova Cygni (see above) in its earlier stages. Together with Lord Crawford and Ludwig Wilhelm Emil Ernst Becker (1860–1947)[125] he accurately measured the position of the nova.[126]

Continued spectroscopy as the supernova faded allowed measurement of three weak emission bands which Copeland associated with bands he later measured in the spectrum of the Mira variable U Orionis, which was initially believed to be a nova.[127] Copeland was cautious of his identification but confident of his wavelengths, and in their review marking the centenary of the eruption G. de Vaucouleurs and H. G. Corwin found them and those of other historical observers to be consistent with those of Type I supernovae.[128]

In 1886–87 Copeland observed the Orion nebula with the new Cooke spectrograph on the 15-inch (Figure 10), leading to his most important discovery, that of helium in the nebula from the D3 line at 587.4 nm.[129] This provided a link between gaseous nebulae, the Sun, and Wolf–Rayet stars (he had observed the D3 line in γ Argus at Vincocaya), showing the widespread presence of helium. On one night he observed what turned out to be another, faint helium line near 448 nm. Encouraged by this discovery, he began a regular spectroscopic survey of the brighter nebulae. This could have yielded valuable results, but he had to set it aside in favour of other work.[130]

Later in 1887 Copeland represented the Royal Astronomical Society at the first of his eclipse expeditions: to Pogoste, near Kineshma, some 335 km (208 miles) north-east of Moscow. He made elaborate preparations to observe the event but on the day of the event, August 19, the weather was so bad that no usable results were obtained.[131]

All this time, Copeland was deeply involved in cataloguing the Dun Echt library, a unique collection of nearly 11,000 astronomical books, pamphlets, and manuscripts, many dating back to the 15th and 16th centuries and of considerable value. In this task he was assisted by his nephew Robert Copeland.[132] He was also responsible for ordering books: for example, in the 12 months following his return from the Andes he wrote 14 letters to booksellers in Britain and the continent, ordering over 150 books.[133] By the time this massive enterprise was completed with the publication of the *Catalogue of the Crawford Library* in 1890, an unexpected turn of events had placed the collection in Copeland's hands.[134]

6. Directorship and transformation of the Royal Observatory Edinburgh

In 1888 Piazzi Smyth resigned as Astronomer Royal for Scotland. The Royal Observatory was in poor condition and a Royal Commission on Scottish Universities recommended its abolition as a national institution. Lord Crawford was outraged at the prospect of Scotland losing its national observatory and offered to donate the instruments and library of his own observatory at Dun Echt to the nation on condition that the Edinburgh establishment thus enriched should be the publicly maintained Royal Observatory on Calton Hill – a donation that was accepted.[135]

In 1888 December Ralph Copeland was appointed Astronomer Royal and Professor of Practical Astronomy in the University of Edinburgh.[136] He took up his post in

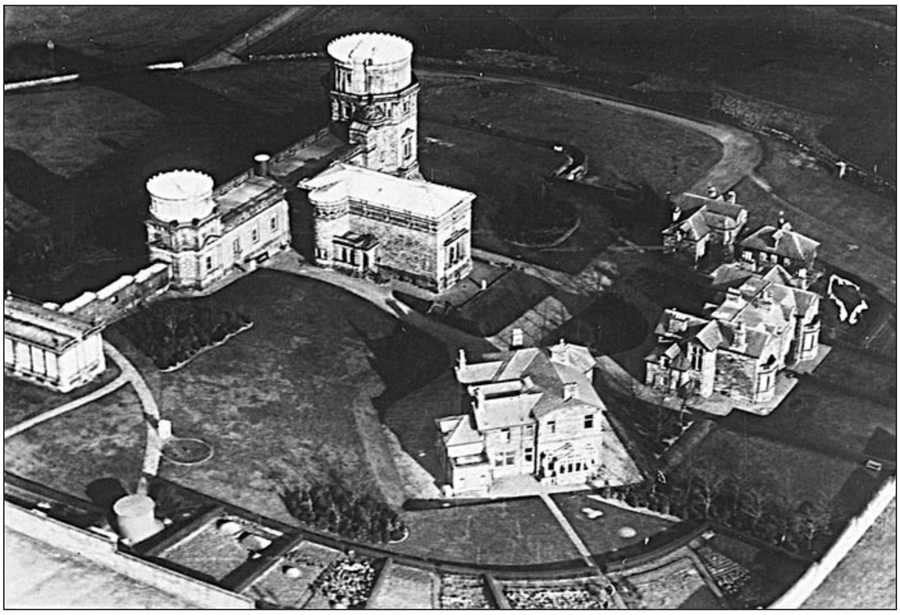


Fig. 11: The Royal Observatory Edinburgh seen from the air in about 1920. The house in the foreground was the Astronomer Royal's residence until 1975 and is now named Copeland House. The turret to the left (west) on the main building holds the 24-inch reflector (from Calton Hill). In the one on the right (east) is the 15-inch refractor from Dun Echt. Far left, reached by a passage, is the Transit House. The turret in the left foreground holds the 12-inch reflector; between it and the Main Building is the meteorological station. (ROE Archives)

early 1889, which came with an official residence in the Astronomer Royal's house in Royal Terrace close to the Royal Observatory. His first task was the selection of a suitable site for the new observatory, away from the smoke of the city centre but close enough to the university to allow him to fulfil his teaching duties. At the same time, the routine work of the existing observatory on Calton Hill, such as provision of the time service, had to be continued.

He recorded his activities in 1889–90 in a Day Book in the Observatory's 'Equatorial Book'.[137] The entries include numerous visits to the hills to the south and west of the city between 1889 February and June, both on his own and accompanied by members of a committee including Lord Crawford, Professor Peter Tait (Natural Philosophy, University of Edinburgh), Lord John McLaren (Court of Session and an amateur astronomer), and Mr John Reid, the Queen's Remembrancer (an officer representing the Crown's interests). Eventually, on June 17, the committee approved the eastern end of Blackford Hill as the most convenient and suitable site.

A few days earlier, Copeland had recorded: 'Fine and calm. City full of smoke, but could see N. Berwick Law from Blackford Hill'.[138] As the site was close to a railway line, its stability against transmission of vibrations when heavy trains were passing was tested and confirmed by observations through a transit instrument brought from Dun Echt and also from reflections in a bowl of mercury.[139,140] Thereafter plans for the buildings could proceed. To guide the design of the new building, Copeland visited several recently built observatories on the Continent.[141]

Interspersed with his activities regarding the site and building for the new observatory, Copeland's Day Book records numerous entries between May and August detailing cleaning and silvering the mirror of the Calton Hill 24-inch reflector. At the beginning of the University's winter session that year he reinstated astronomy lectures after many years of neglect by Piazzi Smyth. In December, he was elected a Fellow of the Royal Society of Edinburgh, and later served as its Vice-President in 1892–96 and 1898–1903.[142]

Copeland's Day Book entries for 1890 report numerous meetings with Lords Crawford and McLaren, Professor Tait, the architect Walter Wood Robertson (1845–1907), and Reginald MacLeod, who succeeded John Reid as the Queen's Remembrancer in 1889, as the plans for the new Observatory were developed. The final plans and estimates were settled in 1890 August.[143]

In 1891 August Copeland read a paper and exhibited a model at the Cardiff meeting of the British Association reporting experiments to replicate the bright streaks on the Moon with a 22-inch plaster model having tiny spherules of glass attached. Like the bright streaks, these were found to be inconspicuous under cross light, but brightest when illuminated from the front.[144]

On 1892 February 1 Copeland received an anonymous postcard alerting him to the appearance of a nova in Auriga. Examination of its spectrum through the 24-inch reflector on Calton Hill showed an emission line spectrum with the C (Hα) line being intense.[145] The next day Lugwig Becker went to Dun Echt to observe the spectrum using the 15-inch refractor and Grubb spectrograph, while Copeland remained in Edinburgh to use the equipment on Calton Hill for a light curve and spectrum using his Vogel spectroscope.[146] He also identified the sender of the postcard as the Scottish amateur astronomer Thomas David Anderson (1853–1932) and persuaded him to write to *Nature* describing the circumstances of his discovery.[147]

Meanwhile, from examination of photographic plates at Harvard, E. C. Pickering found that the nova was invisible up to 1891 December 1 but bright on December 10, reaching maximum near December 18.[148] It became known as Nova Aurigae 1891 and was given the variable-star designation T Aurigae.

During the night of March 7–8 a fire broke out in Copeland's house. He wrote in his Diary:

> March 7 Went to bed at 15 Royal Terrace about 12-30 p.m. – everything in the house at that time appearing to be as usual. Mar 8. About 4-30 a.m. an alarm of fire was given ... The fire must have been burning fiercely for some time, as it had obtained a firm hold of the south-west corner of the house from the basement to the roof – five stories [*sic*] in all. The wooden lining of the roof contributed much to the spread of the fire. By the time that the inmates of the upper part of the house, six in number, had collected in the communicating front rooms of the second floor the smoke had become so suffocatingly dense that it appeared in the highest degree undesirable to rush down the long stone staircase. We therefore decided to descend to the balcony of one of the first-floor windows by the aid of sheets knotted together. … A good many books are more or less disfigured by water, fire and smoke, but happily all the finer parts of the library are absolutely intact.[149]

The Scotsman reported that the Library of valuable scientific literature, at street level in the house, included the Crawford Collection and that the books were removed to the greenhouse at the rear of the building shortly after the outbreak occurred.[150] Fanny, then in Berlin studying music, received a telegram after the fire: 'Fire. No one hurt. All birds dead. Dog saved'.[151]

On March 11 Copeland attended a meeting of the Site and Plans Committee of the new Observatory, again discussing costs. Mr Robertson, the architect, was requested to lessen the requirements by paring as much as possible without interfering with the essential portions of the buildings. Preparations continued: on July 2 Copeland recorded visiting Blackford Hill where a tramline was being constructed up the face of the hill from the railway line for the transport of stone and other heavy building material.[152] Also in July he visited

Figure12: Copeland and his wife Theodora in front of the astronomer's house at Dun Echt in 1888. Standing on the left is their daughter Paula (12) while the children on the right are Theodore (9) and Agnes (6); their oldest daughter Fanny was in Germany continuing her education at the time. The young woman at the back may be Copeland's daughter Elizabeth from his first marriage; her brother Richard was also away. (ROE Archives)

Dublin for the tercentenary celebrations of Trinity College, and then his old places of work at Birr and Dunsink.[153] On July 27 he was in Lancaster to open the Greg Observatory.[154]

For a few days in August, in between visits to Blackford Hill and other duties, Copeland was at Dun Echt again and, with his old colleague Gerhard Lohse, used the 15-inch refractor to observe Nova Aurigae, measuring emission lines at 500.3 and 495.3 nm on August 25 and 26, demonstrating that the nova was now shining as a gas nebula. Under very good conditions on August 28, Copeland observed another line at 580.1 nm, which he identified with that seen in the spectra of Nova Cygni and the Wolf–Rayet stars.[155]

6.1. *Building the new Observatory*

On 1892 October 4 the first stone of the new Observatory was laid on the concrete bedding, apparently without ceremony. Following his visit on October 9 Copeland recorded that the stonework of the East Tower was progressing, a steam crane and two hand cranes had been erected, and that the foundations of the main building were completed.

The need to save costs was relentless. He recorded that on 1893 March 20 the Observatory Plans Committee held a meeting in the office of the Queen's Remembrancer at which the proposed plans of the new domes were discussed. To lessen the cost of the smaller dome, an attempt was to be made to adapt some portions of the Dun Echt dome. On March 29, he and Sir Howard Grubb (from Dublin) went to Dun Echt to examine that dome, but concluded that not much of it could be reused. Copeland was back in Dun Echt in July for the dismounting of the 15-inch refractor prior to its transfer to the new Observatory.[156]

In 1893 August Copeland visited the German Naval Observatory in Hamburg to look at instruments and domes and to see Captain Koldewey, who had recently retired as its Director. Also, in Berlin, he visited Arthur Auwers (1838–1915) to discuss the re-reduction of positional measurements made in 1835–45 by Thomas Henderson (1798–1844), Piazzi Smyth's predecessor, from Calton Hill. He then visited the spectroscopist Hermann Carl Vogel (1841–1907) at Potsdam Observatory, followed by a stay at the Naval Observatory at Wilhelmshaven where his old colleague Carl Börgen was Director.

In 1893 October he resumed teaching – four lectures a week and meeting the class at the Observatory on Friday evenings – and monitoring the building work on Blackford Hill. This pattern continued in 1894 as the new Observatory neared completion. In the summer he travelled around the west of Scotland and the north and east of Ireland to interview people who had

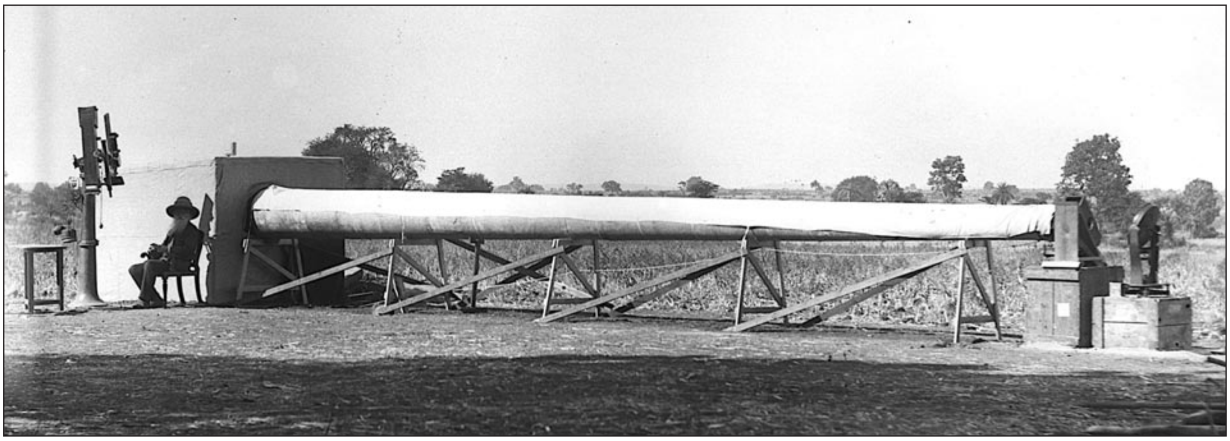


Fig. 13: The 40-foot solar camera with Dallmeyer 4-inch photographic lens at Ghoglee, India, in 1898. Copeland is seated in front of the dark-room containing the focus and is ready to use the telescopes next to him for optical and ultraviolet spectroscopy. (ROE archives)

seen the brilliant meteor on May 19 at 8 p.m. and computed its path.[157]

Since 1852, the Royal Observatory had provided a time service for the city and its port of Leith, signalled by a time ball on the Nelson Monument on Calton Hill that was dropped at a precise time each day. From 1861 this was augmented by a gun fired from Edinburgh Castle, controlled by a cable from Calton Hill.[158]

The continuation of this by the new Observatory must have been questioned because Copeland's Diary for 1895 April 8 records that he called on the Queen's Remembrancer and explained to him the true importance of the time service. He pointed out that the signal was for the use of the Royal Navy and also for merchant shipping, not just for the town. The time gun was supplied with powder by the Treasury and the gun was fired by the military under instructions from the War Office, so that it was a State undertaking in the hands of the Government Astronomer.

He also went to London to meet Lord Crawford, the Under Secretary for Scotland and the Hydrographer to the Admiralty, who all agreed that the time service ought to be continued from the new Observatory. So the Post Office provided wires from Blackford Hill to the Edinburgh General Post Office and Nelson Monument and on November 8 the time-ball dropped and the Castle gun fired for the first time following time signals from Blackford Hill.[159]

Setting up of the new Observatory and installation of the equipment continued during 1895. Copeland moved into the substantial Astronomer Royal's house in the grounds in May.[160] A few months later, Jacob Karl Ernst Halm (1866–1944) from Strasbourg Observatory arrived to take up the position of senior assistant.[161]

The first months of 1896 saw the last major installation: that of the 24-inch reflector transferred from Calton Hill. At last, on 1896 April 7, the new Royal Observatory was formally opened by Lord Balfour of Burleigh, Secretary for Scotland, in front of distinguished guests. Copeland, the architect W. W. Robertson, and Lord Crawford spoke on the history of the observatory, the design of the new building, and the circumstances of the new establishment.[162]

Now that the Royal Observatory was complete and the telescopes installed, one might have expected Copeland to resume his spectroscopic observations undertaken at Dun Echt, such as the survey of brighter nebulae begun after his discovery of helium lines in the Orion nebula. Sadly, as his friend and obituarist Dreyer observed, Copeland's energy and capacity for work had now declined, because the heart disease to which he eventually succumbed had already begun to undermine his strength.[163] His Diary entries ceased during 1896.

6.2. *Eclipse expeditions*

He did, however, undertake three more eclipse expeditions. The first, to Vadsø in northern Norway to observe the total eclipse on 1896 August 8, was supported by a grant from the Royal Society of Edinburgh.[164] On July 18 Copeland sailed from Newcastle accompanied by his son Theodore (1879–1952) as a volunteer, the ROE Second Assistant Andrew James Ramsay (1862–99), and observatory engineer James McPherson.

Their equipment, sent on ahead, included a 40-ft long-focus camera of 4 inches (100 mm) aperture with a moving plate-holder in an improvised dark-room at the focus, the 6-inch (150-mm) Simms telescope with an objective prism for spectroscopy of the chromosphere, another telescope of 1.8 inches (46 mm) aperture with a quartz objective and Iceland-spar prism for ultraviolet spectroscopy, and two more cameras for direct imaging. Unfortunately, the weather was unfavourable at the critical time and no useful results were obtained. On the way back, at the port of Vardø, Copeland had the consolation of welcoming the polar explorer Fridtjof Nansen on his return from his polar expedition of 1893–96.[165]

The following year, Nansen visited Copeland at the Observatory and examined some of Julius Payer's maps of the Arctic.[166] During his expedition, Nansen had found that the northern part of Payer's map of Franz Josef Land was too inaccurate to be of much use. This came as a painful surprise to Copeland who had a high

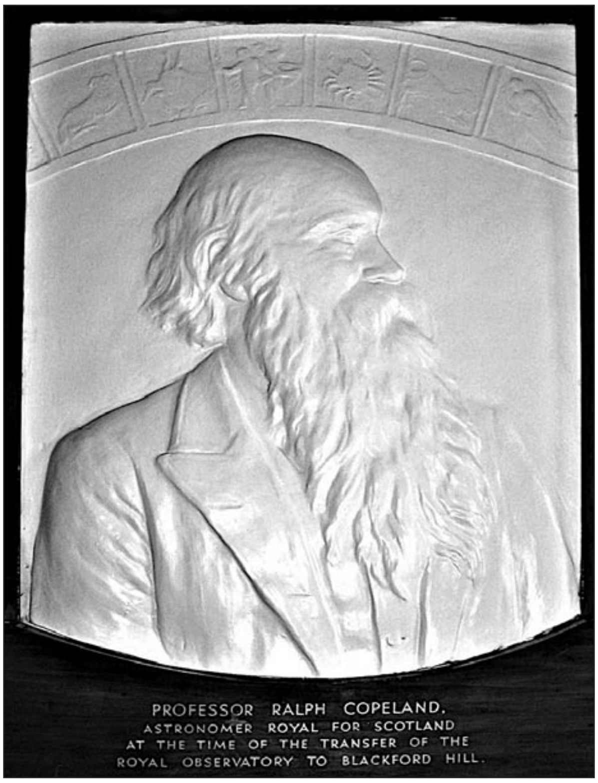


Fig. 14: Mural sculpture of Ralph Copeland in the main entrance lobby of the new Royal Observatory building (Author's photograph)

opinion of Payer dating from their experiences during the Arctic expedition. He therefore borrowed and re-examined Payer's original survey records from the Royal Geographic Society from which he produced an improved map.[167]

At the invitation of the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society, Copeland took part in an expedition to observe the total solar eclipse of 1898 January 22 from India. The equipment was similar to that he had taken to Vadsø, including the 40-ft long-focus camera for large-scale imaging (Figure 13) and telescopes for optical and ultraviolet spectroscopy. He was again accompanied by the engineer James McPherson. Copeland chose to observe from Ghoglee, 16 miles (26 km) north-west of Nagpur, some distance from other major groups of observers in case one or another was thwarted by bad weather. In the event the weather was good and he obtained useful observations.[168]

Also in 1898 Copeland initiated a major observational programme with the transit circle, the determination of the positions of stars near the ecliptic. This was suggested to him by Sir David Gill to provide a suitable reference system for precise observations of the major planets using the heliometer. Halm began the observing in May, but it was not completed until 1908, after Copeland had died and Halm had left for the Royal Observatory at the Cape.[169]

Copeland next accepted an invitation by the Joint Permanent Eclipse Committee to take part in observing the total solar eclipse of 1900 May 28 from Santa Pola, on the south-east coast of Spain, together with Sir Norman Lockyer and his team. The Admiralty had put HMS *Theseus* at the disposal of the Joint Committee, which conveyed the observers and their equipment from Gibraltar to Santa Pola and whose crew helped with haulage of equipment. Copeland's equipment comprised the 40-ft horizontal camera, operated by the experienced James McPherson in its improvised dark-room, and the Iceland spar and quartz prismatic camera for ultraviolet spectroscopy. Again, the weather was favourable, and good images and spectra were obtained. Copeland's report on this expedition was, like that of the Ghoglee expedition, preliminary and essentially narrative.[170]

Copeland's final investigation, fittingly, used the 15-inch refractor from Dun Echt for spectroscopy of the nova now known as GK Persei, discovered by Thomas Anderson of Edinburgh in the early hours of 1901 February 22. When observed later on February 22 it showed a continuous spectrum, quite unlike that of Anderson's previous discovery, Nova Aurigae. On close inspection Halm noticed weak absorption features, confirmed by Copeland.

The next few nights were overcast. When observed on February 27 the spectrum had changed profoundly to resemble that of Nova Aurigae at its brightest, with strong emission lines. Nearly all the emission lines were very broad, having deep black lines on the blue sides. In his contribution to the Royal Society of Edinburgh, Copeland suggested that the dark lines were from absorption by the same kind of material responsible for the emission spectrum, but of lower temperature and being carried towards us at 800 mile/s (1,300 km/s) relative to the emission-line source.[171] He found it remarkable that this nova should show 'a displacement of nearly the same amount and towards the same side' as Nova Aurigae.

One can speculate that, had Copeland been in his prime, he would have made the jump to the interpretation of the line profiles as arising from a rapidly expanding sphere of hot gas. Unfortunately, he had a severe attack of influenza in the middle of 1901 from which he never fully recovered and it was Halm who interpreted what we now call the P Cygni line profiles.[172,173]

While attempting to recuperate from his illness in Wiesbaden in 1902 May, Copeland suffered an attack of angina pectoris after hurrying to catch a train. The attacks continued and in 1904 he had to relinquish his lecturing and practical work with students to Dr Halm.

Despite his illness, during his last few years Copeland remained mentally active by taking up the study of Persian, and was delighted to be able to read *Omar Khayyam* in the original language.[174] His condition that year was such that his son Theodore, who was an Assistant Commissioner and Sub-Judge at Kohat in the North-West Frontier Province of India, took three months' special leave to visit him.[175]

His health seemed to improve and he was tolerably well in the summer of 1905, but his heart condition worsened and he died on October 27 that year. He was buried in Morningside Cemetery, where he was later joined by his daughters Paula and Agnes in 1910 and 1929, and his wife Theodora in 1938.

7. Ralph Copeland's legacy

Ralph Copeland's gravestone is in Morningside Cemetery but his true memorial is the Royal Observatory on Blackford Hill. He played a key role in the realization of Lord Crawford's benefaction through choice of site, design of buildings, dealings with the Queen's Remembrancer regarding costs, and responsibility for the transfer of equipment and instruments to the new observatory and their installation. At the same time, he reinstated astronomical teaching at the University, including practical work.

Of his own astronomical work, one can point to the discovery of helium in the Orion nebula, the spectroscopic evolution of novae, and spectroscopy of comets – but no new concepts. As remarked by Dreyer, 'his published papers are not as numerous as his friends could have wished, but his anxiety to perfect his results as far as possible, before printing them, of late years frequently led to a paper being laid aside and never published'.[176]

He was certainly an excellent observer, whether of galaxies discovered with the Leviathan (including Copeland's Septet) or accurate wavelengths of emission lines, as well as a resourceful instrumentalist, witness the use of a lathe for an equatorial telescope mount in the Andes. He demonstrated the improved image quality achievable at high altitude and discussed the merits of high-altitude sites for astronomy.

His catalogue of the Dun Echt astronomical library, now the Crawford Collection at the Royal Observatory Edinburgh, is 'one of the most valuable guides to astronomical literature, especially previous to the year 1700'.[177] Finally, Copeland remained an authority on Arctic exploration, being a member of the committee which launched the 1902–04 Scottish Antarctic Expedition in 1894 January.[178]

We can leave the last word with Dreyer, who concluded his RAS obituary of Copeland as follows:

> His character was open, sincere, and generous, he was always anxious to befriend and help anybody whenever he could, and he never shirked any trouble or work to answer inquiries even from people who had no claim on his time. He will be remembered with warm affection by all who had more than a passing acquaintance with him.

Acknowledgements

It is a pleasure to thank Karen Moran, Librarian at the Royal Observatory Edinburgh, for her expert help with the ROE Archive material, and Gillian Wright, Director of the UK Astronomy Technology Centre, for permission to reproduce images from the Archive. My interest in Copeland was sparked by his being listed as a discoverer of Wolf–Rayet stars in the bibliographies compiled by Karel van der Hucht and my exploration of the circumstances of these discoveries for a talk I gave in Karel's honour on the occasion of his retirement.

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97 Copeland, R., and Lohse, J. G., 'Observations, Elements and Ephemeris of Palisa's Comet', *Astronomische Nachrichten*, 95 (1879), p. 315.

98 Copeland, R., and Lohse, J. G., 'Observations of Comet b 1880 (Schäberle)', *Astronomische Nachrichten*, 97 (1880), p. 221,

99 Copeland, R., and Lohse, J. G., 'Elemente und Ephemeride des Cometen e 1880', *Astronomische Nachrichten*, 98 (1880), 325–6.

100 Crawford and Balcarres, Earl of, 'Observations of Comets 1881b, f and g', *Copernicus*, 2 (1882), p. 42.

101 Copeland, R., and Lohse, J. G., 'Spectroscopic observations of comets 1881–82', *Copernicus*, 2 (1882), p. 225.

102 Swings, P., 'The spectra of the comets', *Vistas in Astronomy*, 2 (1956), 958–81.

103 Greenstein, J. L., and Arpigny, C., 'The Visual Region of the Spectrum of Comet Mrkos (1957d)', *Astrophysical Journal*, 135 (1962), 892–905. Since then, the spectrum of another Sun-grazing comet, Ikeya-Seki (1965f), has been found to show iron lines in emission (Dufay, J., Swings, P., and Fehrenbach, Ch., *Astrophysical Journal*, 142 (1965), p. 1698).

104 Letter: Copeland to Miss Mary Ashley, 16 New King St, Bath, 1882 August 14, *Dun Echt Letter Books*, ROE Archives 28, 189, p. 760. For more on Miss Ashley see Kinder, A., *Journal of the British*

Astronomical Association, 108 (1998), p. 338.

105 *Equatorial Book Vol. 2, 1879–1888*, (ROE Archives, 17.95), p. 1. Besides notes on the equatorial telescope by Piazzi Smyth, this contains much information on the transition period from Piazzi Smyth to Copeland and also Copeland's own Day Book for 1889 and 1890.

106 Brück, H. A., and Brück, M. T., 1988, *The Peripatetic Astronomer, The Life of Charles Piazzi Smyth* (Adam Hilger, 1988), 196–7.

107 Brück (1992, ref. 84), p. 121.

108 Stone, E. J., Langley, S. P., Birmingham, J., 'Transit of Venus, 1882–British Expeditions', *Nature*, 27 (1882), 177–80.

109 Copeland, Fanny, op. cit. (ref. 20), 50 ff.

110 Copeland, R., 'An account of some recent astronomical experiments at high elevations in the Andes', *Copernicus*, 3 (1884), 193–231.

111 Copeland, R., 'Reisebriefe aus Südamerika', *Deutsche Geographische Blätter*, 6 (1883), 105–116 and 219–223.

112 Including the large breakfast served at Cachondo (3,250 ft): soup, puchero (traditional stew), fish, beefsteak, coffee, Peruvian wine, and hot pisco, the indigenous liquor.

113 Copeland (1883, ref. 111), p. 110. The original quote in German is: 'Es kein Vergnügen macht, sich mit Eiern bewerfen zu lassen, die mit allerlei Farbstoffen oder noch bedenklicheren Flüssigkeiten gefüllt sind'.

114 Copeland (1884, ref. 110), pp. 194 and 199. His earlier railway engineering experience must have smoothed the path here. The main wheel of the lathe was used as an hour circle: 'it had the awkward number of 63 teeth, but by increasing the hour angle by 1/20th part each tooth of the wheel corresponded to 24 minutes of this augmented time and admitted of easy subdivision'.

115 Copeland (1883, ref. 111), p. 222.

116 Copeland (1884, ref. 110), p. 195.

117 Ibid., p. 200.

118 Ibid., 204–5. Copeland later learned that the Italian astronomer Lorenzo Respighi (1824–89) had first seen this spectrum in 1871. His observing notes giving finding charts and sketches of the spectra are in the ROE Archives: 199, Wooden Box 2, small leather-bound notebook, labelled 'Observations in Puno and Vincocaya'.

119 Beals, C. S., 'The Wolf–Rayet stars', *Publications of the Dominion Astrophysical Observatory*, 4 (1930), 271–301; Edlén, B., and Stenman, J., *Zeitschrift für Physik*, 66 (1930), 328–38; Edlén, B., 'Highly ionised carbon, nitrogen, and oxygen in Wolf–Rayet stars', *The Observatory*, 55 (1932), 115–6.

120 Copeland (1884, ref. 110), 213–29.

121 Copeland, R., 'Notes on a recent visit to some North American observatories', *Copernicus*, 3 (1884), 133–45.

122 Letters: Copeland to Rev W. J. Roome of Aldershot, 1883 November 12, asking him to take over the zone bounded by 25° and 32° N which had become vacant; on the same date, Copeland to G. D. Harding of Fishponds, near Bristol, asking him to take the 32°–39° N zone (*Dun Echt Letter Books*, ROE Archives 29, 190, pp. 182–3 and 184).

123 Copeland, R., 'Spectroscopic observations made at the Earl of Crawford's Observatory, Dun Echt', *Monthly Notices of the Royal Astronomical Society*, 45 (1884), 90–91.

124 Copeland, R., 'On Hartwig's Nova Andromedae', *Monthly Notices of the Royal Astronomical Society*, 47 (1886), 49–61.

125 Ludwig Becker, a graduate of Bonn University, succeeded Gerhard Lohse at Dun Echt in 1885. He joined the Royal Observatory staff at the transition but left in 1893 to become Regius Professor of Astronomy at Glasgow University.

126 Copeland, R., *Astronomische Nachrichten*, 112 (1885), p. 286 (Dun Echt Circular 98).

127 Copeland, R., 'Mr Gore's Nova Orionis', *Monthly Notices of the Royal Astronomical Society*, 46 (1885), p. 109; and ref. 125.

128 de Vaucouleurs, G., and Corwin, H. G., 'S Andromedae 1885: A Centennial Review', *Astrophysical Journal*, 295 (1985), 287–304. These authors also analysed the historical photometry and produced a definitive light curve.

129 Copeland, R., 'Note on the visible Spectrum of the Great Nebula in Orion', *Monthly Notices of the Royal Astronomical Society*, 48 (1888), 360–2.

130 Dreyer (1906, ref. 1), p. 170.

131 Copeland, R., 'The total solar eclipse of 1887, August 19', *Monthly Notices of the Royal Astronomical Society*, 48 (1887), 48–51.

132 Brück (1992, ref. 84), p. 125.

133 *Dun Echt Letter Book 1883–1886*, ROE Archives, 29.190. The same period saw almost as many letters to Thomas Cooke and Son, York, regarding the spectroscope they were building for the observatory.

134 Copeland, Ralph, *Catalogue of the Crawford Library of the Royal Observatory Edinburgh, by authority of Her Majesty's Government*, 1890.

135 Brück (1992, ref. 84), p. 126.

136 *The Morning Post*, 1888 December 18, p. 4, and other newspapers on the same date.

137 *Equatorial Book Vol. 2* (ref. 103); Copeland's 'Day Book' starts on p. 171.

138 North Berwick Law, a volcanic plug about 20 miles (30 km) north-east of Blackford Hill.

139 'Royal Observatory Edinburgh, (Report for 1889)', *Monthly Notices of the Royal Astronomical Society*, 50 (1890), p. 189.

140 Copeland's 'Day Book' in *Equatorial Book Vol. 2*, (ref. 103).

141 Brück (1992, ref. 84), p. 128. These visits are not recorded in the Day Book and may have taken place between appointment and his entering into the post.

142 Waterston, C. D., and Shearer, A. Macmillan, 2006, *Biographical Index of Former Fellows of the Royal Society of Edinburgh 1783–2002*, Part 1, A–J, p. 203.

143 Copeland, R., *Diary* (ref. 83).

144 Copeland, R., 'On the probable Nature of the Bright Streaks on the Moon', *Report of the sixty-first meeting of the British Association for the Advancement of Science* (John Murray, 1892), p. 576.

145 Copeland, R., *Astronomische Nachrichten*, 129 (1892), p. 59.

146 Copeland, R., and Becker, L., 'On the New Star in the Constellation Auriga', *Transactions of the Royal Society of Edinburgh*, 37 (1892), 51–8. Based on a paper Copeland read to the Society on 1892 February 15 together with several postscripts. Also *Astronomy and Astro-physics*, 11 (1892), 593–602; this volume contains many observational studies of the nova.

147 Anderson, T. D., 'The New Star in Auriga', *Nature*, 45 (1892), p. 365.

148 Pickering, E. C., 'The New Star in Auriga', *Astronomy and Astro-physics*, 11 (1892), 228–31.

149 Copeland, R., *Diary*, (ref. 83).

150 *The Scotsman*, 1892 March 9, p. 6.

151 Copeland, Fanny, op. cit. (ref. 20), p. 101.

152 Copeland, R., *Diary* (ref. 83).

153 Brück (1982, ref. 84), p. 129.

154 Copeland, R., *Diary* (ref. 83). For the Greg Observatory, see Wade, P., 'Lancaster's lost observatory', *Journal of the British Astronomical Association*, 102 (1992), 160–2.

155 Copeland, R., 'Nebular Spectrum of Nova Aurigae', *Nature*, 26 (1893), p. 464.

156 Copeland, R., *Diary* (ref. 83).

157 Dreyer (1906, ref. 1), p. 172.

158 Brück and Brück, op. cit. (ref. 106), 24–25.

159 Copeland, R., *Diary* (ref. 83).

160 Ibid. The Astronomer Royal's house was repurposed for office space in 1975 and from 2014 September 26 named Copeland House. A plaque was unveiled by the Astronomer Royal for Scotland John Brown and Copeland's great-granddaughter Mary Barkworth.

161 Brück (1992, ref. 84), p. 128.

162 *The Scotsman*, 1896 April 8, p. 8.

163 Dreyer (1906, ref. 1), p. 172.

164 Copeland, R., *Diary* (ref. 83).

165 Copeland, R., and Ramsay, A. J., 'Notes on the Total Eclipse of the Sun, 8th August 1896', *Proceedings of the Royal Society of Edinburgh*, 21 (1897), 489–96. This report gives a detailed description of the equipment.

166 *The Scotsman*, 1897 February 15, p. 5.

167 Copeland, Ralph, 'On a Revised Map of Kaiser Franz Josef Land, Based on Oberlieutenant Payer's Original Survey', *The Geographical Journal*, 10 (1897), 180–191.

168 Copeland, R., 'Total Solar Eclipse of January 22, 1898', *Proceedings of the Royal Society*, 64 (1899), 21–26.

169 'Catalogue of 2713 Zodiacal Stars for the equinox 1900.0', *Annals of the Royal Observatory Edinburgh*, III, (1910).

170 Copeland, R., 'Preliminary note on observations of the total solar eclipse of 1900 May 28', *Proceedings of the Royal Society*, 67 (1900), 385–91.

171 Copeland, R., 'Note on the New Star in Perseus', *Proceedings of the Royal Society of Edinburgh*, 23 (1901), 365–9.

172 Dreyer (1907, ref. 1), p. 237.

173 Halm, J., 'On Professor Seeliger's Theory of Temporary Stars', *Proceedings of the Royal Society of Edinburgh*, 25 (1904), 513–52.

174 Dreyer (1906, ref. 1), p. 174.

175 Copeland, R., letter to Fred Holloway, 1904 November 20, https://www.ericpercival.co.uk/Copeland/RC%20letters/letter9.htm
Fred Holloway was the friend with whom he set up the observatory at Gorton in about 1860.

176 Dreyer (1907, ref. 1), p. 238.

177 Dreyer (1907, ref. 1), p. 236.

178 Copeland, R., *Diary* (ref. 83). His support was commemorated in the name of the magnetic observatory hut built on Laurie Island, South Orkneys, by the Scottish Antarctic Expedition – see Brown, R. N. R., et al., *The voyage of the 'Scotia'; being the record of the voyage of exploration in Antarctic seas* (Blackwood, 1906), p. 108.

179 Dreyer (1906, ref. 1), p. 174.

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Peredur Williams is an Emeritus Researcher in the University of Edinburgh Institute for Astronomy, located at the Royal Observatory Edinburgh. After first degrees at the University of Cape Town and a PhD and Fellowship at Cambridge, in 1974 he joined the group at the ROE developing and testing infrared instrumentation. From 1978, he helped commission the UK Infrared Telescope and served UKIRT as a staff astronomer resident in Hilo, Hawaii, in 1979–85. Back at the ROE, he supported operation of UKIRT, then the JCMT and, eventually, the Astronomy Division. Following the restructuring of the ROE, he took a position in the Institute for Astronomy until retirement in 2010. His research has focused on the episodes of dust formation by Wolf–Rayet stars related to their membership of colliding-wind binaries and the discovery of such systems through outbursts in their infrared emission. These systems have long periods, up to decades, and the research continues. His historical interests focus on astronomical spectroscopy.