The Royal Observatory at the Cape of Good Hope

History and Heritage

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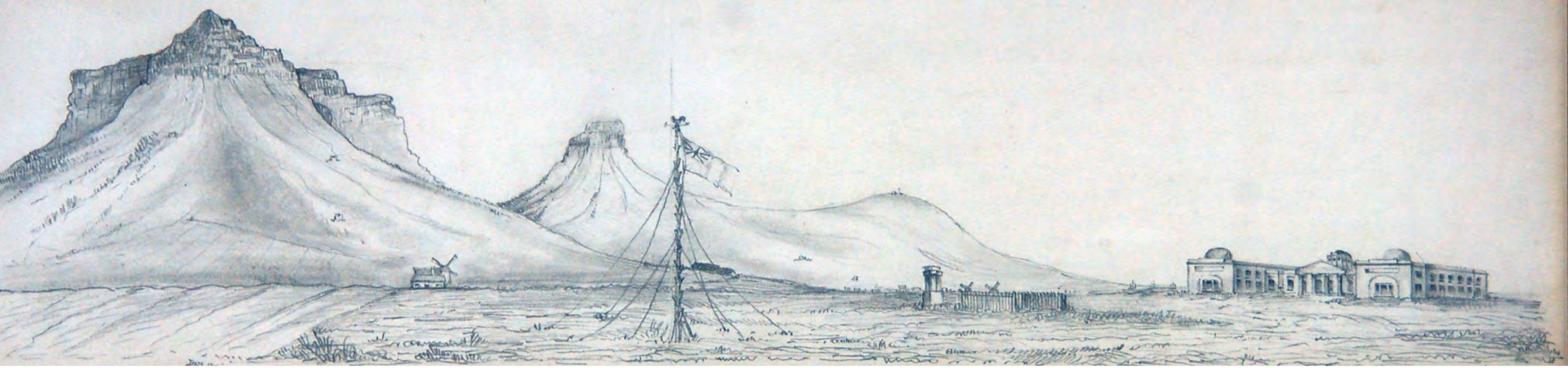
Contents



Introduction

The Royal Observatory, now part of the South African Astronomical Observatory, is the oldest scientific institution in the country and perhaps in the whole of Africa. It is an important heritage site, known for the science that was done here as well as for its architecture.

Founded in 1820 when the Cape of Good Hope was a British colony, the Royal Observatory was controlled by the Royal Navy and was intended for the improvement of navigation. Its job was to chart the southern skies and provide a time service for passing ships.

To do this well it was necessary to have one or more capable scientists in charge and, as time went on, they were to make a number of fundamental discoveries. Particularly, we can think of Thomas Henderson who in 1832–33, only a few years after its completion, made the first measurements that could be used to find the distance of a star, namely Alpha Centauri. As things turned out, this remained the nearest star known for almost a century and even now it is the second closest despite many searches for a closer one.

At the height of its fame, in the last decades of the nineteenth century, the Royal Observatory under the direction of Sir David Gill was admired worldwide for its innovative technology and especially for its leadership in the fields of astronomical photography and the cataloguing of massive numbers of stars. This was to remain its forte for many years.

The reputation of the Royal Observatory was such around the year 1900 that it attracted a number of distinguished researchers to work here. However, by this time, the cataloguing of star positions had ceased to be the frontier of astronomical science. Thanks in part to the emergence of large telescopes in the United States and the brilliant observational discoveries made with them, interest had turned towards astrophysics – that is, understanding the physics of the stars rather than measuring their positions.

The Royal Navy did not consider this to be within their remit but one of Gill's admirers, the wealthy British amateur astronomer Frank McClean, generously donated a large telescope and spectrograph suited to astrophysical work. Visitors and new appointees were encouraged to devote themselves to such studies. For example, McClean himself discovered the element oxygen in stars. Joseph Lunt, one of the Assistants, demonstrated the presence of silicon and europium. The Chief Assistant, Joseph Halm, was a pioneer of stellar dynamics and also found the relation between mass and luminosity obeyed by stars, a discovery that helped to understand how they evolve.

Although in the middle of the 20th century much of the Observatory's work had become rather pedestrian, being devoted to the routine production of accurate positions and spectra of the bright stars, in one area it was predominant, namely that of the measurement of their precise magnitudes (apparent brightnesses). This was thanks to Dr A W J Cousins, a South African born electrical engineer who joined in 1947. His work was appreciated worldwide because such measurements are of fundamental importance in the study of the physics of stars and in working out the size of the Universe.

In 1951 the Royal Observatory became entitled to a share of the privately owned Radcliffe telescope in Pretoria, then at 1.9-m the fifth largest in the world, considerably enhancing its observational capabilities.

The Royal Observatory, Cape of Good Hope, in 1842 or 1843, seen from behind a hedge. This is the oldest photograph of any observatory and is one of the first photographs taken in South Africa. The photographer was Charles Piazzi Smyth (see page 14).

By 1960 it had become impossible at the Cape and other city observatories to study faint astronomical objects because of increasing air and light pollution. Street and other lighting made the sky too bright to be able to discern distant stars and galaxies.

Though the Observatory had made proposals to set up a new establishment far from the city and had investigated several dark sites, in the late 1960s the British astronomical community announced that they would withdraw from the Cape in order to put their resources into a new large telescope in Australia. Politics also played a large part in this decision.

Hauling down the Union Jack at the end of the day.

However, thanks to a South African initiative, a new joint entity was created that combined the Royal Observatory with the wholly South African owned Republic Observatory in Johannesburg. Thus came into existence the South African Astronomical Observatory. Initially it was financed jointly for a decade by both South Africa and Britain, sharing on a 2:1 basis.

To make the new institution viable for modern research, a pollution-free site at Sutherland in the Karoo, away from areas of dense population, was established. The most useful existing telescopes were moved there and were joined in 1976 by the 1.9-m Radcliffe instrument. Previously the latter had been operated by a private foundation but it was also now suffering from degraded urban skies and its trustees agreed to sell it to the South African Astronomical Observatory.

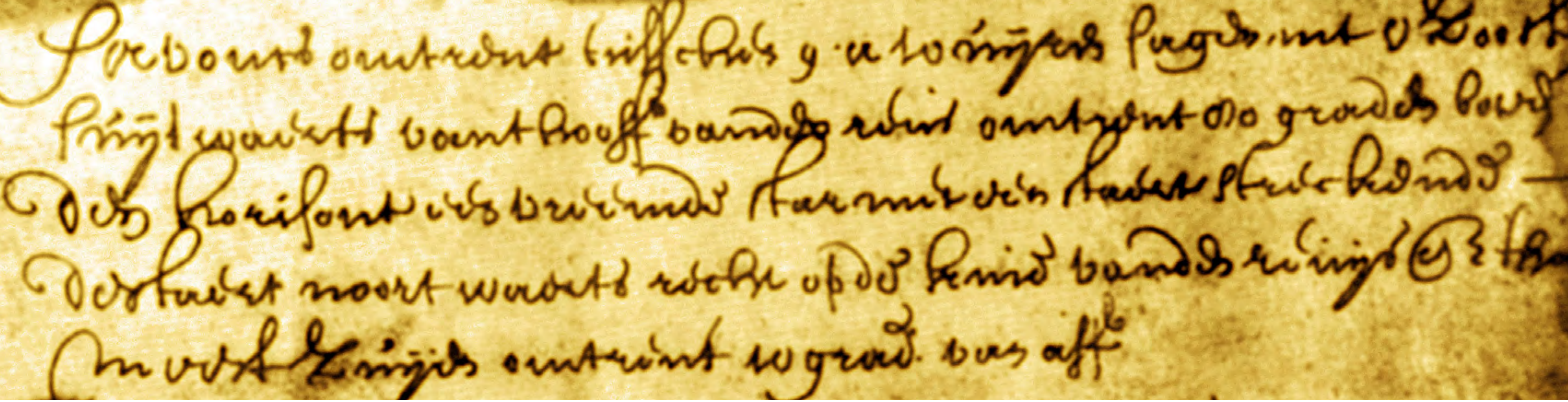
Observing activities in Cape Town gradually declined in favour of the much superior Sutherland site and today the Royal Observatory campus is the place where the astronomers have their offices and data reduction facilities. New measuring instruments for the telescopes are designed and built here. Its central location and convenient parking make it a natural meeting place for the astronomical community.

Many new telescopes have been built at Sutherland in the 21st century, particularly to take advantage of modern detectors and computer techniques for continuously monitoring the sky in ways that were impossible before.

In 2005 the Southern African Large Telescope, a specialised spectroscopic instrument, was opened at Sutherland. It has the largest light-collecting area of any telescope so far constructed. It is owned by an international consortium consisting of astronomers from several countries and managed by the SAAO. The South African astronomical community has a one-third share.

The original aim of the Royal Observatory, the astronomy of position, is now most successfully pursued from earth satellites, away from the complications introduced by the earth's atmosphere. Today, astrophysicists study the properties of distant objects through their spectra and their light variations. In addition, wavelengths outside those of ordinary light have become accessible and many studies incorporate gamma-ray, X-ray, infrared and radio data obtained from space probes and specialized telescopes.

SALT – the Southern African Large Telescope



On December 17, 1652, eight months after landing in Table Bay, Commander Jan van Riebeeck observed a bright comet. His journal entry, reproduced above, reads: "At night about 9 or 10 o'clock saw to the East South East, southward from the head of the giant, about 80 degrees above the horizon a strange star with a tail; the tail extending northwards right on the knees of the giant and the head mostly to the South about 10 degrees away." The 'giant' is the constellation of Orion.

Early Astronomy at the Cape

The early colonists were people used to being at sea for months at a time and so were very conscious of the sky above them. Only a few months after the colony had been founded in 1652 van Riebeeck noted a bright comet in the constellation Orion. The first European observations of this comet were made by Hevelius of Danzig a few days later.

His successor, Zacharias Wagenaar, had a telescope and observed the comet of 1664 – the same one that Daniel Defoe believed had brought the great plague to London. He however claimed that it was a sign sent from heaven to warn the colonists not to skip church and go drinking in the woods on the Sabbath!

Other comets came and went but the first serious astronomer to work at the Cape was a French Jesuit priest, Guy Tachard. He was on a royal mission to the government of Thailand and stopped for a few days in Cape Town in 1685 to try to find the longitude using the moons of Jupiter.

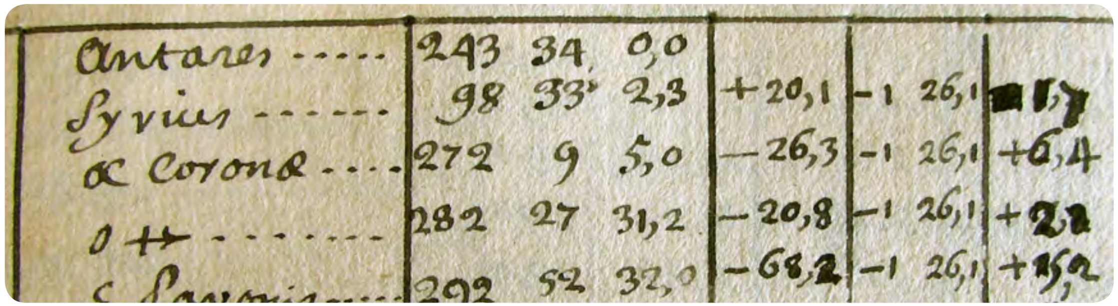
A more serious effort was made by Peter Kolb who was sent from Berlin in 1705 to make measurements of the Moon simultaneously with others being made in Europe, so that its distance

A fanciful rendering of Tachard's observatory in the Fort at Cape Town.

could be found by triangulation. This project seems to have failed and Kolb was later accused of spending his time in drinking, smoking and gossiping. His journals have never been critically examined so it is difficult to know how justly he acquired his bad reputation. He certainly annoyed some of the Dutch East India Company officials by meddling in politics.

It was really the arrival of Nicolas-Louis de La Caille in 1751 during the governorship of Ryk Tulbagh that put Cape astronomy on the map. He was one of the greatest astronomers of his time, and was a member of the French Royal Academy of Sciences and a professor at the Mazarin College of the University of Paris. He realized how poorly the southern celestial hemisphere had been explored and managed to raise funding for a substantial expedition to the Cape. He brought with him the latest and most sophisticated instruments for measuring star positions and set up a small observatory on the foreshore of Cape Town, quite close to the present-day Waterkant Street. Here he laboured every night for a year to map 10,000 stars and also make observations of solar system objects and nebulae.

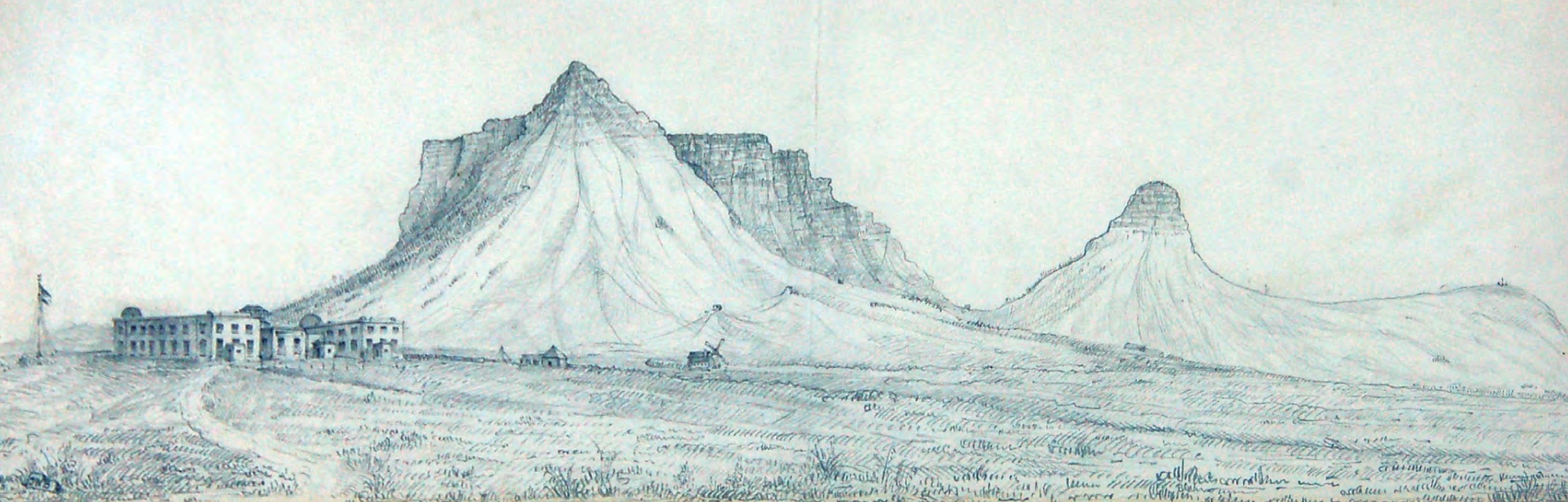
In his second year at the Cape La Caille decided to measure the radius of the earth. A few years before his visit he and other astronomers in the north had found that it was flattened towards the north pole and he decided to check whether it was similar in the south. To his surprise, he found that it was, and even more so than in the south, leading to the conclusion that the earth is slightly pear-shaped! This conclusion was later found to be wrong.



Antares	243 34 0,0			
Syrius	98 33 2,3	+20,1	-1 26,1	[illegible]
α Coronæ	272 9 5,0	-26,3	-1 26,1	+6,4
[illegible]	282 27 31,2	-20,8	-1 26,1	[illegible]
[illegible]	292 52 32,0	-68,2	-1 26,1	[illegible]

A portion of one of La Caille's notebooks in which he recorded stellar positions.

Nicolas-Louis de La Caille, the first important astronomer to work in South Africa.



The Story of the Royal Observatory

The Cape had become one of Britain's colonies in 1814 and was the obvious place from their point of view to establish a southern hemisphere observatory. Its good weather, the fact that it was on the main trade route to the East and was relatively easy to access from Europe (a mere 10 weeks or so of sailing time) made it an ideal choice. In addition, it had been the site of a very successful observatory operated by La Caille.

H M Astronomers

Fearon Fallows	1820 – 1831
Thomas Henderson	1831 – 1833
Sir Thomas Maclear	1833 – 1870
Edward James Stone	1870 – 1879
Sir David Gill	1879 – 1907
Sydney Samuel Hough	1907 – 1923
Harold Spencer Jones	1923 – 1933
John Jackson	1933 – 1950
Richard Hugh Stoy	1950 – 1968

Officer in Charge

George Alfred Harding	1969 – 1971

Foundation and the first HM Astronomer

The first His Majesty's Astronomer (HMA) was Rev Fearon Fallows, a Cambridge-educated mathematician. He was not really a man of action and had many problems in getting the building constructed thanks to the rough contractors he had to deal with.

Though the decision to establish the Observatory had been taken in 1820 and plans had been drawn up ahead of time for its building by the naval architect John Rennie, it took several years for the project to get going. Firstly, a suitable site had to be chosen. The requirement was for a hilltop that could be seen from ships in Table Bay and was free from the dust that blew everywhere before the era of tarred roads. No harbour then existed in Cape Town and vessels had to anchor out in the Bay. After looking at the Tygerberg and a few other places, the present low hill – a mere 6m above sea level – was felt to be the best choice, even though it was surrounded by unhealthy swamps and not very accessible in winter.

The land was duly bought, a contractor was appointed and the building slowly took shape. Word came that a boat loaded with teak had just arrived at the Cape and its cargo was quickly bought up before others came to hear of it. This wood, which is very resistant to weathering, was used to make the windows, shutters and floors of the new building. Much of it is still in place and in excellent condition.

The building was completed with difficulty thanks to the truculent and unhelpful local officials. A detachment of soldiers had to guard the site and the building materials. Much of the effort fell onto the shoulders of the first HM Astronomer. Nevertheless, the main instruments had been installed and adjusted by 1828. In the meantime, he had had to work from a temporary observatory in the town.

Unfortunately a there was a budget cutback right in the middle of the work. As a result, there was insufficient money for the "finishing touches" such as toilets and fences.

The only image – a silhouette – that we have of Rev Fearon Fallows.

Since it was controlled and paid for by the Royal Navy Hydrographer's office, the astronomical staff were appointed for the most part from the United Kingdom. Following the tradition of the Royal Greenwich Observatory, the director was always a graduate and he had to be familiar with mathematics at a sophisticated level. The standard of education at the Cape was then far too low to provide such people. For a long time after its foundation, the personnel consisted of a HM Astronomer and two Assistants, with most of the thinking and planning left to the top man. Even in England it was hard to find well-educated people with the necessary experience let alone someone who was willing to live so far away and under comparatively primitive conditions.

The conditions at the Royal Observatory just after he completion of the Main Building were downright insanitary and the health of Rev Fallows soon deteriorated. He died in 1831 of scarlet fever and was buried in the grounds of the institution he had created. It is said that his will contained an instruction that he was to be buried very deep to avoid the attentions of grave robbers. This was a problem in England at the time where corpses were needed for dissection by medical students. The ground is so rocky at the Observatory that it is doubtful if this was in fact carried out.

Here is a description of conditions at the time, though written a decade or so later:

> *"The outhouses, offices etc. were never completed, or even begun: the supply of money was suddenly cut off, as was said by reason of a change of Ministry; & there the Obs^y, the H building, was left, by itself, finished within itself to admiration, but only a part of the original design; the dirty, black flea-y servants were never intended to go into the beautiful rooms of the wings so exquisitely fitted up; there was to have been a range of low buildings just below the crest of the hill for them, & for the workshops, carpenters, & instrument makers, & for horses and carts so necessary in so isolated a situation. The ground too was to have been in some little degree smoothed & enclosed, & a road to the Obs^y was to have been made in connection with Cape Town. Thus the Obs^y building appeared accidentally dropped from the clouds in a rough wilderness, without any sort of enclosure, & and in a manner in the middle of a high way, for when the marsh below was very full of water in the winter, the wagons & cattle used to come over the hill, grazing the corner of the building. There was no road to Cape Town, other than by wading through the river, & crossing a piece of marshy land."*

In spite of numerous complaints to higher authorities, matters were not rectified.

Thomas Henderson and the nearest star

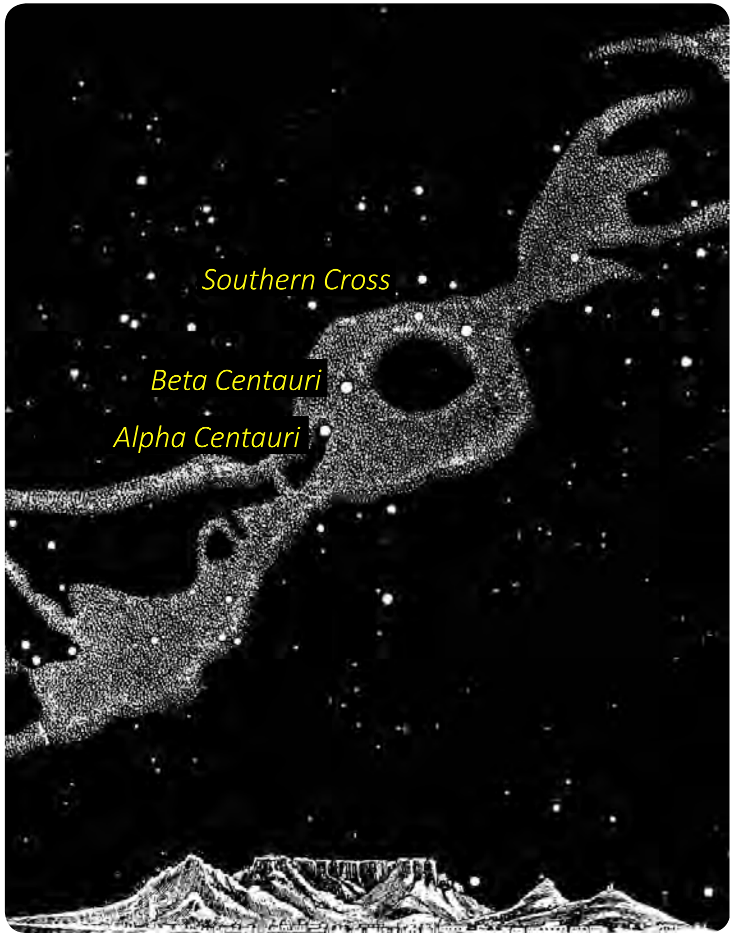
The second HM Astronomer (1831–1833), Thomas Henderson, a Scot, only stayed for a bit over a year. He was a fussy and precise person and could not stand the primitive life at the Observatory, which was still in its unfinished condition. Yet during this single year he made an enormous number of measurements. In these he was assisted by Lieutenant William Meadows who was appointed just before the death of Fallows.

In hindsight, the greatest achievement of the early days in the Royal Observatory was the first measurement of the distance to a star.

Ever since Copernicus taught that the earth revolves around the Sun people had wondered why the nearby stars did not seem to move against the more distant background, that is why they did not show *parallax*. Much serious effort went into this question over the centuries and there were several over-optimistic claims to have detected it. None of these could be substantiated and several reputations were damaged as a consequence. The problem, as it turned out, was that the early instruments were simply not accurate enough to detect the effect, which we now know to be a very small one.

Enormous progress in the development of divided circles was made towards the end of the eighteenth century and these were the technological key to the solution of the problem. The instruments that were provided for the new Royal Observatory were state-of-the-art in 1820. For the first time, sufficient accuracy was available to make the measurement, but nobody was to know this until it had actually been done. In addition, there was new mathematical understanding as to how multiple observations with small probable errors could be combined in order to derive more accurate results.

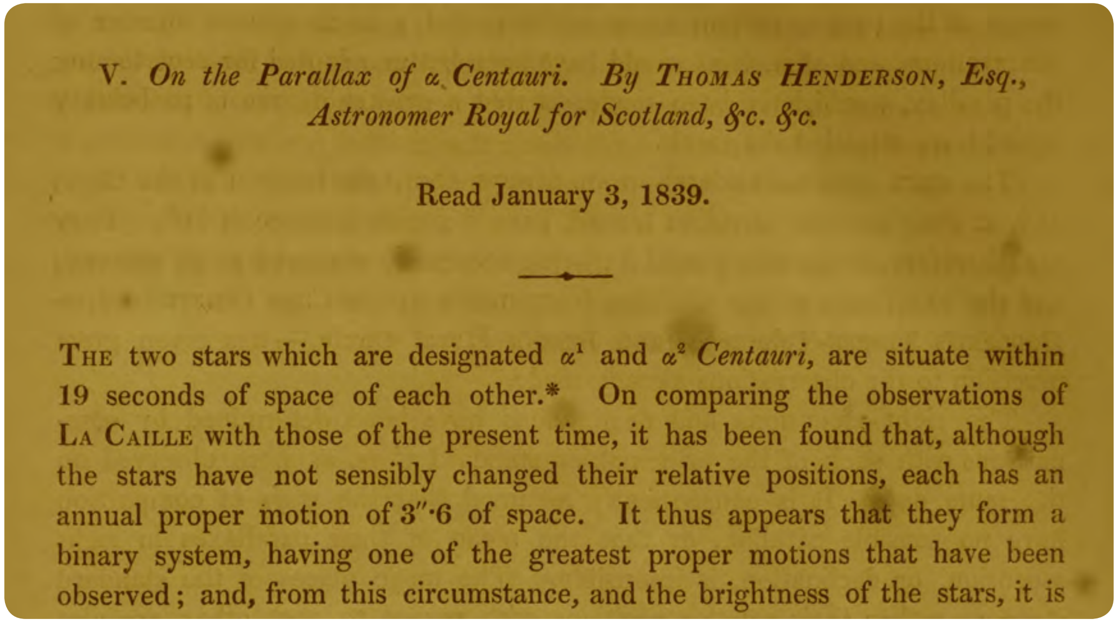
Henderson was tipped off by Manuel Johnson, a young astronomer working for the British East India Company at an observatory on the island of St Helena, that one of the brightest objects in the sky, the double star Alpha Centauri (one of the pointers to the Southern Cross)



The sky over Cape Town, looking South, as envisaged by a 19th century artist. The Pointers to the Southern Cross, Alpha and Beta Centauri, are shown together with the Cross itself. The Coal Sack, a dark nebula, lies in between, blotting out part of the Milky Way.

seemed to have changed its position over the seventy years or so since it was last measured by La Caille. This was indeed a surprise because at that time only a small number of stars were known to move. It suggested that Alpha Centauri must be nearby. The effect can be understood in terms of looking out of a window – a nearby bird may pass quickly by but a much faster aeroplane, though further away, can take several minutes. Such a change of position is known as *proper motion* in astronomy.

Henderson and his assistant William Meadows made a point of measuring the position of Alpha Centauri against presumed background stars when the earth was at places six months apart on its orbit around the Sun, to get as long a baseline as possible in order to see if the distance to Alpha could be measured by trigonometry. In spite of finding a measurable parallax, Henderson lacked confidence in his measurements, which were extremely delicate, and was afraid to publish in case something was wrong with them. He sat on his data for several years and lost priority to the German astronomer F W Bessel of Königsberg in East Prussia who had measured a northern star, 51 Cygni, in the meantime.



V. *On the Parallax of α Centauri.* *By* THOMAS HENDERSON, *Esq., Astronomer Royal for Scotland, &c. &c.*

Read January 3, 1839.

THE two stars which are designated α^1 and α^2 *Centauri*, are situate within 19 seconds of space of each other.* On comparing the observations of LA CAILLE with those of the present time, it has been found that, although the stars have not sensibly changed their relative positions, each has an annual proper motion of 3″·6 of space. It thus appears that they form a binary system, having one of the greatest proper motions that have been observed; and, from this circumstance, and the brightness of the stars, it is

Henderson's report to the Royal Astronomical Society describing his observations of Alpha Centauri that led to a measure of its parallax.

Bessel published his result in October 1838. Nevertheless, when Henderson's became known in January 1839 he and the Royal Observatory were given considerable recognition. Alpha Centauri remained the nearest star known until well into the 20th century, when R T A Innes, then in Johannesburg, discovered Proxima Centauri not far away from it.

By May 1833 Henderson had had enough. He suddenly resigned and immediately sailed for England. He made it perfectly clear to the Admiralty that he had found the conditions at the Observatory completely intolerable and his letters probably made them realize that there would have to be improvements if they ever expected to appoint another HM Astronomer.

The remainder of Henderson's life was somewhat happier. His work at the Cape was recognized as being of great value and he received proper recognition for the star catalogues he had published. He was soon appointed Astronomer Royal for Scotland and got married in 1836. Unfortunately, his wife died in 1842 after their only child was born and he died himself in 1844. In the last part of his life he was friendly with F W Bessel, the person who had scooped him in the discovery of stellar parallax and they are known to have taken a holiday together in the Highlands of Scotland.

Thomas Maclear, Third HMA (1833 – 1870)

Henderson's successor, Thomas Maclear (1794 – 1879), afterwards knighted, was born in Ireland. He was originally a country doctor whose involvement in astronomy was that of a serious amateur. He was a tough and dynamic person who knew how to handle officialdom. Though well aware of the poor conditions at the Cape he jumped at the opportunity to become a professional astronomer. The numerous complaints that the Admiralty had received and the precipitate resignation of Henderson undoubtedly helped Maclear in his efforts to get the situation put right. Nevertheless he had to use some of his own money to get fences, toilets and stables erected.

Maclear arrived in 1834 and stayed as HM Astronomer until 1870. With him he brought Thomas Bowler as a manservant and general assistant but soon dismissed him for insolent behavior towards Mrs Maclear. Bowler afterwards made a living as an art teacher and later became one of the most famous painters at the Cape. His work is highly valued today. Meadows, the Chief Assistant that Maclear had inherited, did not last long either. Maclear declared that he and his wife were "the most melancholic, discontented, croaking helpless couple I ever met with". In 1834 the couple headed back to England and never returned.

As a replacement for Meadows, Maclear chose the sixteen-year old Charles Piazzi Smyth, a precocious youngster from a highly talented

Thomas Maclear as a young man.

family. Piazzi was extremely inventive during his time at the Observatory from 1835 to 1845. Among other things, using his own money, he invented an air conditioner, set up a windmill system to pump water to make a garden on the previously barren Observatory hill and became the pioneer of photography in South Africa.

During Maclear's lengthy period as HM Astronomer (1833 – 1870) a magnetic observatory, consisting of several buildings, was built on the site. Almost no trace of these remains although they appear in some of Smyth's early photographs. An anemometer building called the "Wind Tower" survived until the mid-20th century after conversion to use as a telescope dome.

One of Maclear's main tasks was to verify La Caille's claim of almost a century before of the alleged pear shape of the earth. With the latest equipment, his two young assistants and a detachment of military personnel, he repeated La Caille's procedure over several years with great care. He extended the survey over a longer range in latitude. He found that in fact La Caille's geodetic measurements had been extremely accurate but that the plumb lines used in measuring the latitude had been deflected by the gravitational attraction of the mountains at each end of

Piazzi Smyth: Pioneer of Photography in South Africa

Piazzi used the process called "Calotype", the first positive-negative system, developed and patented by Fox-Talbot in 1841. By the following year Smyth had succeeded in making use of the new process. His earliest remaining photographs date from about 1843 and include a number of pictures taken at the Royal Observatory. They are photos of the Main Building, a group of surveyors working at the back, a picture of his new garden and a portrait of William Mann (the Second Assistant Astronomer, appointed in 1839). This latter image (adjacent) is the first photographic portrait made in South Africa.

Cartoon of Maclear in the Squib, dated 1870. As the principal weather expert in Cape Town he was regarded as responsible for the bad weather that forced postponement of the opening of the Albert Dock.

his survey. Maclear took over twenty years to prepare his report. The earth turned out to be similar in the Northern and Southern hemispheres!

Maclear, thanks to his long tenure, had a finger in almost every scientific and cultural pie in the Cape Colony. He was one of its best-known citizens. The Observatory was relied on for all kinds of scientific advice. For example, the official standard weights and measures were deposited there. He was even expected to make weather forecasts.

When he was forced to retire he stayed at the Cape. Like Fallows but unlike all his successors he was buried on the grounds.

The Standard Weights and Measures box in the Observatory Library. Its former contents are said to be in the Iziko South African Museum.

Visit of JFW Herschel to the Cape (1834–1838)

Maclear's time at the Cape was greatly enlivened scientifically by the presence of Sir John Frederick William Herschel (1792–1871), the son of William Frederick Herschel. He was already famous for his work on double stars and had been one of the first presidents of the Royal Astronomical Society. Herschel's aim in coming to the Cape was to make a catalogue of the southern skies to complement that of the northern made by him and his father. His purpose was quite different from that of the Royal Observatory in that he wished to observe double stars and nebulous objects, these being of scientific rather than practical interest.

Herschel bought an estate called Feldhausen that covered much of present-day Claremont and on this he erected a large reflecting telescope. He worked closely with Maclear, who provided necessary information on the positions of stars for reference purposes, and in various ways helped to raise the profile of the Royal Observatory and overcome the administrative obstacles that had bedeviled the work of Fallows and Henderson.

(top) John Herschel in old age. (bottom) The Royal Observatory as sketched by John Herschel in 1837. An early Time Ball is seen to the left in this picture.

Edward Stone, Fourth HMA (1870–1879)

Maclear's follower, Stone (1831–1897), had been Chief Assistant at the Royal Greenwich Observatory and was more of a theoretician than the kind of tough-minded practical astronomer that was needed at the Cape. After Maclear's long tenure, the Observatory was seriously run down and the publication of results had been neglected. Stone managed to get the data reductions up-to-date but left the Observatory in a very poor state.

In 1876 however, a photo-heliograph for taking photographs of the Sun was installed. Photography was only possible for relatively bright objects. This was probably an instrument left over from the Transit of Venus expedition of 1874. It was mounted in a polygonal wooden dome. However, it saw little use until the twentieth century, when it was used to photograph the Sun twice daily. The glass photographic plates were sent to Greenwich for archiving and analysis.

David Gill, Fifth HMA (1879–1907)

David Gill (1843–1914) was the most famous astronomer to work at the Royal Observatory. He started life as a watchmaker, inheriting his father's business in Aberdeen, Scotland. He studied at Marischal College, Aberdeen, where he came under the influence of the great theoretical physicist James Clerk Maxwell. However, he was forced to join the family business, spending three years in Switzerland and elsewhere learning watchmaking. As a result he became very knowledgeable concerning instrumental matters, something that helped him greatly in later life. However, his interest in astronomy had already been stimulated and he had set up a private observatory in King's College Aberdeen.

Sir David Gill (knighted 1900) at the height of his fame.

In 1871 he became a professional astronomer for James Ludovic Lindsay, later Earl of Crawford, who had decided to set up a modern observatory on his estate, Dun Echt. In helping Lindsay to choose the necessary instruments, Gill visited most of the leading telescope makers of Europe and became and expert on instrumentation. He led expeditions to Mauritius for the Transit of Venus in 1874 and later, after he had left Dun Echt, to the island of Ascension. These activities made him quite famous and he was consulted frequently on instrumental matters by other astronomers.

His main achievements in photography and instrumentation are dealt with in detail in later chapters. In addition to the subjects mentioned, Gill was very active in measuring the earth–Sun distance (the so-called "Astronomical Unit"), of fundamental importance to the measurement of all astronomical distances. His value was accepted as the most accurate for many years.

Outside astronomy he was heavily involved in geodetic surveying and was trusted by both sides to define the boundary of what is now Namibia. He was a well-known figure in Cape Town: the First President of the Owl Club and a founder member of the Royal Cape Golf Club. He retired to London for his last few years and enjoyed basking in his fame.

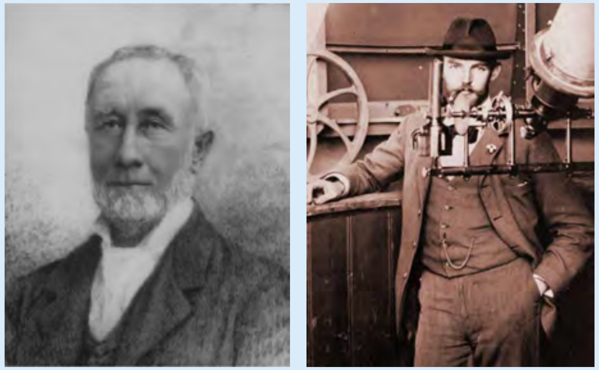
Research atmosphere in Gill's time

The Royal Observatory was at its most famous during Gill's directorship. He received quite a few visits from overseas astronomers such as von Auwers (Germany) and Newcomb (USA).

Frank McClean was a leading British amateur astronomer who was invited by Gill to spend some time at the Cape. Using the Astrographic telescope with his privately-owned prism over the lens, he discovered the presence of oxygen in stars. He admired Gill so much that he offered the Observatory a new telescope – the one now known as the McClean (see p 24).

Willem de Sitter, a young Dutch astronomer, visited the Royal Observatory for two years (1897–1899) just after obtaining his doctorate, to obtain observational experience. He was later famous for showing that Einstein's field equations for general relativity had a solution that allowed for an expanding universe.

John Franklin-Adams was another British amateur astronomer and friend of Gill's. He was responsible for the first photographic atlas that covered the entire sky. The southern part was commenced at the Royal Observatory and completed in Johannesburg. His telescope still exists today near Broederstroom in Gauteng, on a property belonging to the Tshwane University of Technology.



(left) Frank McClean, the donor of the McClean telescope and the discoverer of oxygen in stars. (right) Willem de Sitter with a Zöllner photometer (an early instrument for measuring the brightnesses of stars) attached to the 6-inch telescope then in the Wind Tower.

Twentieth century

Sketch of J K E Halm, Chief Assistant from 1907 to 1927. By "MAC" – Herbert Wood MacKinney of the Cape Times, 19 September 1908.

As previously mentioned, by the early twentieth century, scientific interest had shifted away from the astronomy of position towards astrophysics.

J K E Halm, the Chief Assistant from 1907 to 1927, was the first real astrophysicist to be appointed and as such one of the few people interested in modern developments, such as the growing understanding of our galaxy, the Milky Way, and the eventual discovery that our solar system is well away from its centre. Halm studied streaming motions amongst the stars, now known to be a manifestation of the rotation of the Milky Way. Using the results of the Cape photographic surveys, he discovered a third stream in addition to two found previously by Kapteyn. One of his interesting ideas was that stars must be behaving like the molecules of a gas because the fastest moving ones were usually less massive that the slower ones. In this he was unfortunately quite wrong but his work stimulated Eddington and others to seek the true explanation.

His most important contribution to the understanding of how stars evolve was his discovery that their masses and luminosities (power output in watts) are in most cases related. Other important results due to Halm include a measurement of how much blue light is absorbed by interstellar dust particles compared to visible (essentially green) light. He made the first measurement of the ratio of selective to total absorption, as it is technically known, and estimated the amount of absorption due to dust between the stars. He also studied reciprocity failure, i.e. the non-linear reaction of photographic plates to different levels of light intensity.

In January 1897 Gill appointed an amateur astronomer who had tried since he had been a teenager to obtain a job in astronomy. R T A Innes had led a somewhat bohemian existence in the liquor trade and had become well-known as an observer in Australia. At first his official job was as a Clerical Assistant, "counting bars of soap" as he told his friends. One of his astronomical tasks was to investigate known stars that had been noted by Kapteyn as not registered in the Cape Photographic Durchmusterung. One of these he found to have such high proper motion that it was quite some distance from where it was first spotted. Unfortunately for him it came to be known as Kapteyn's star and not Innes' star!

When the Transvaal Meteorological Department was founded in 1903 Innes was recommended by Gill to become its first director. This establishment afterwards became the

Transvaal, then the Union and finally the Republic Observatory. Innes was to discover there a faint star near Alpha Centauri that is moving in a similar way to Alpha. He made a crude measurement of its distance by visual means and concluded (on the flimsiest of evidence) that it is the closest star, naming it “Proxima Centauri”. It was extraordinarily difficult to prove that he had in fact been right. At the Royal Observatory a Dutch volunteer, J G E G Voûte, using a much better technique, showed that Innes’s evidence was in fact too weak to make such a statement. When Spencer Jones was HM Astronomer, he turned over the 24-inch McClean telescope to questions of distance but he too could not confirm Innes’s result. To cut a long story short, it was only when the results of the Hipparcos satellite became available after the end of the century that it was proved beyond doubt to be the nearest star!

A photograph of the male members of the Observatory staff and overseas visitors taken in 1914. Front row (at centre) S S Hough (6th HMA), to his left, F W Dyson (Astronomer Royal of England), on his other side A S Eddington (Cambridge). Behind Hough is J K E Halm (with pipe), to right of Halm, J Lunt. J Voûte is 3rd from left in the back row. The black man sitting on the ground was a Krooman from West Africa.

R T A Innes shortly after his arrival at the Royal Observatory, with his three sons. His wife had fallen seriously ill and was left behind in Australia. He arrived in Cape Town with another lady whose image has been cut off on the right! Later his wife recovered and joined him in South Africa.
Gill, with Innes in mind, once stated “The great double star observer is born, not made.”

The Buildings of the Royal Observatory

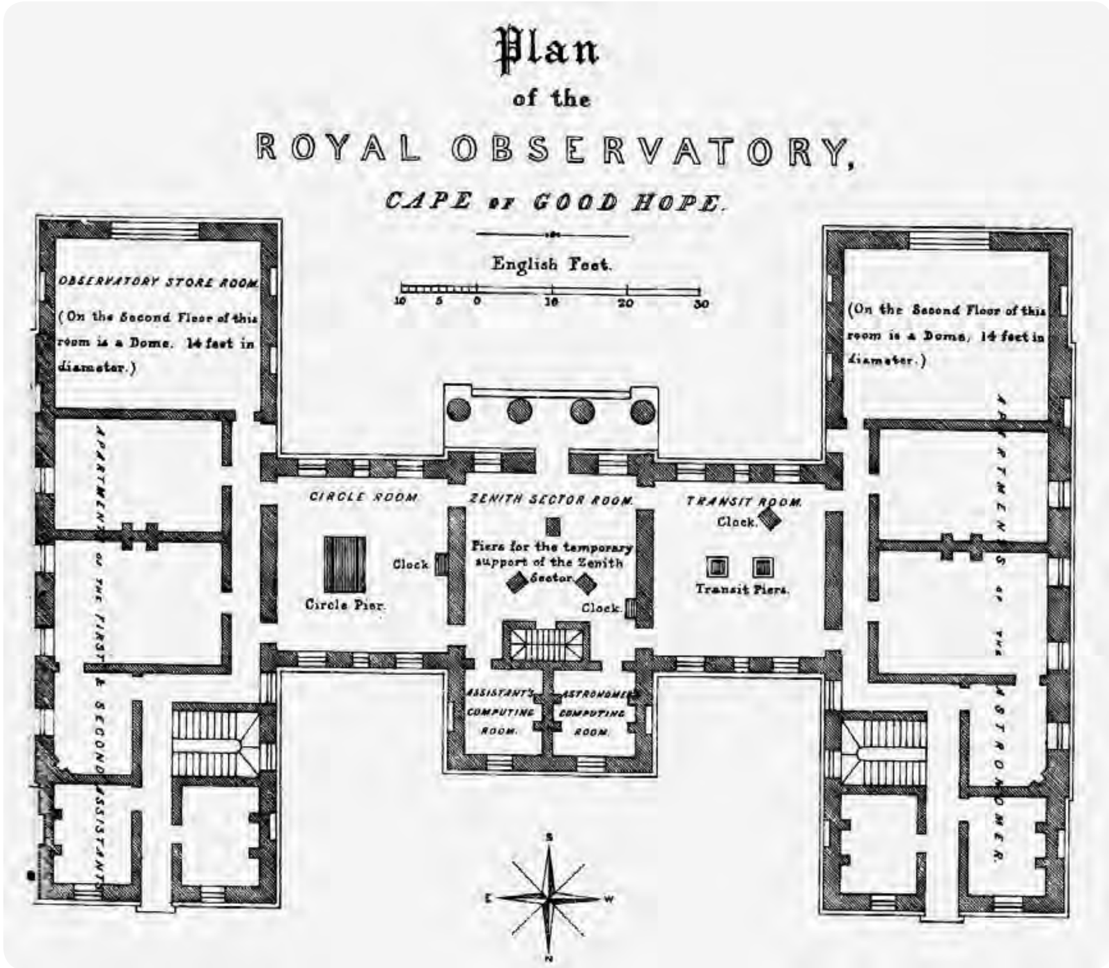
Though it is located close to the centre of Cape Town, the Observatory is an oasis of calm in the busy inner suburbs. It lies at the confluence of the Liesbeeck and Black Rivers, in the Two Rivers Urban Park, with wetlands on two sides.

Going up the curved road from the gate one approaches the classical Doric pillars of the Main Building, one of only a few surviving examples of Greek Revival architecture at the Cape.

Scattered over the grounds are many nineteenth-century domes, houses and other buildings, including that of the picturesque McClean or Victoria telescope. Yet time has not stood still here as elsewhere and in the 20^{th} century many other structures appeared as a result of the site's continuous development and use. There are about 100 structures of one kind or another on site.

Today the Royal Observatory campus, as the Headquarters of the South African Astronomical Observatory, is the main centre for astronomical research in South Africa. From it are administered the observing facilities at Sutherland in the Karoo, where most of the night-time work is now carried out, far from city lights and pollution.

The Main Building



Plan of the Main Building drawn around 1840.

This is the oldest building on site and architecturally the most important. Today it contains most of the astronomers' offices. It is in the "Greek Revival" style, fashionable in Europe and the United States of America and reflecting public interest in classical themes at the time. In Cape Town, the original St George's Cathedral of 1830 – 34 was also in this style but the only other remaining local example is St Andrew's Presbyterian Church (1827 – 28).

The portico with its four pillars is strictly Doric. Interestingly, these are not as solid as they appear, being made of brick clad with wood.

The accompanying figure shows a plan of the Main Building, drawn around 1840. Originally, only the central part was devoted to astronomical work. The walls are thick and constructed of rough stones. Small basements exist under the northern ends of each wing, presumably for food and wine stores. The west wing was a good-sized residence for HM Astronomer and the east wing was shared by the First and Second Assistants. Originally the living quarters were fitted out with marble fireplaces but few of these remain. The ceiling cornices have unusual plaster flower decorations in the corners. An unusual feature of the windows on the upper floors is that the sashes slide completely into the walls so that they can be opened fully for ventilation on hot summer days. All the windows have shutters on the inside for security. Bathrooms seem to have been an afterthought, not included on the original drawings. The floors, doors and window frames are all teak and almost all are original thanks to the natural durability of this type of wood.

On the roofs of the wings were originally two domes, intended for small instruments. However, no solid foundations had been provided for the instruments and the roof beams were far too bouncy and unsteady. The domes were leaky and were finally got rid of in 1883.

Only the central portion was used for the instruments. The wings were residences for the astronomers. The “Circle Room” was extended to the north in the 1850s to accommodate the Airy Transit Circle and the ceiling beams that are still visible reflect this.

The observing instruments were located in the central rooms of the H-shaped building. The whole structure was carefully orientated towards the main points of the compass since observations were only to be made along the meridian or north-south line.

The central room was never outfitted with the zenith telescope called for in the plan and the “lantern” designed for this was removed around 1950. Many other modifications have been made over the years to the building. The original residences in the wings have been converted to offices and some of the big rooms have been divided up and provided with extra windows. Even the toilets are additions to the original plan!

Shutters called “chases” extended from the south wall to the ceiling and across to the north wall of each observing room so that the instruments had clear views along the

(top) How the Main Building used to open up to allow the instruments an unobstructed view along the North-South line (meridian). The Airy Transit Circle can just be seen inside. (bottom) The Main Building soon after the arrival of Gill. Note the freshly planted grass runners.

meridian. These were closed up when the Main Building ceased to be used for observations, though vestiges of them can still be seen inside the building.

Today the central part of the main Building holds the library of SAAO. The book collections reflect the dynamism of the Observatory or lack of it under the different directors; it is particularly rich in later-nineteenth century material accumulated under David Gill.

In the special collections are many historical books. The collection of journals goes back to the first issues of many of them. With the advent of fast Internet most of the astronomical periodical literature is published on-line so that there is no longer a need for paper editions and, in the last few years, many of the historical journals have been digitized.

All the books listed in an inventory dated 1830 are still in the library. Many of the journal series are complete from the first numbers. They include that of the French Royal Academy of Sciences, from the 17th and 18th centuries. In the past, many observatories published their own results and the library contains a large collection of these.

Though many of the early archives were sent to the Royal Greenwich Observatory when the Royal Observatory (Cape) became the South African Observatory in 1972, a large number are still here, including many old photographs, drawings and prints, though poorly conserved for lack of funds.

(top) Colophon from the oldest book in the library, Claudius Ptolemy's Almagest, printed in Venice in 1515. This is the first printed edition. (bottom) The central room of the Main Building. This part of the library is devoted to modern books.

The McClean Dome & Victoria Telescope

Conspicuous because of its large size, the McClean dome contains the Victoria Telescope, the largest on site. The building was designed by the famous imperial architect Herbert Baker, many of whose structures still exist in South Africa today.

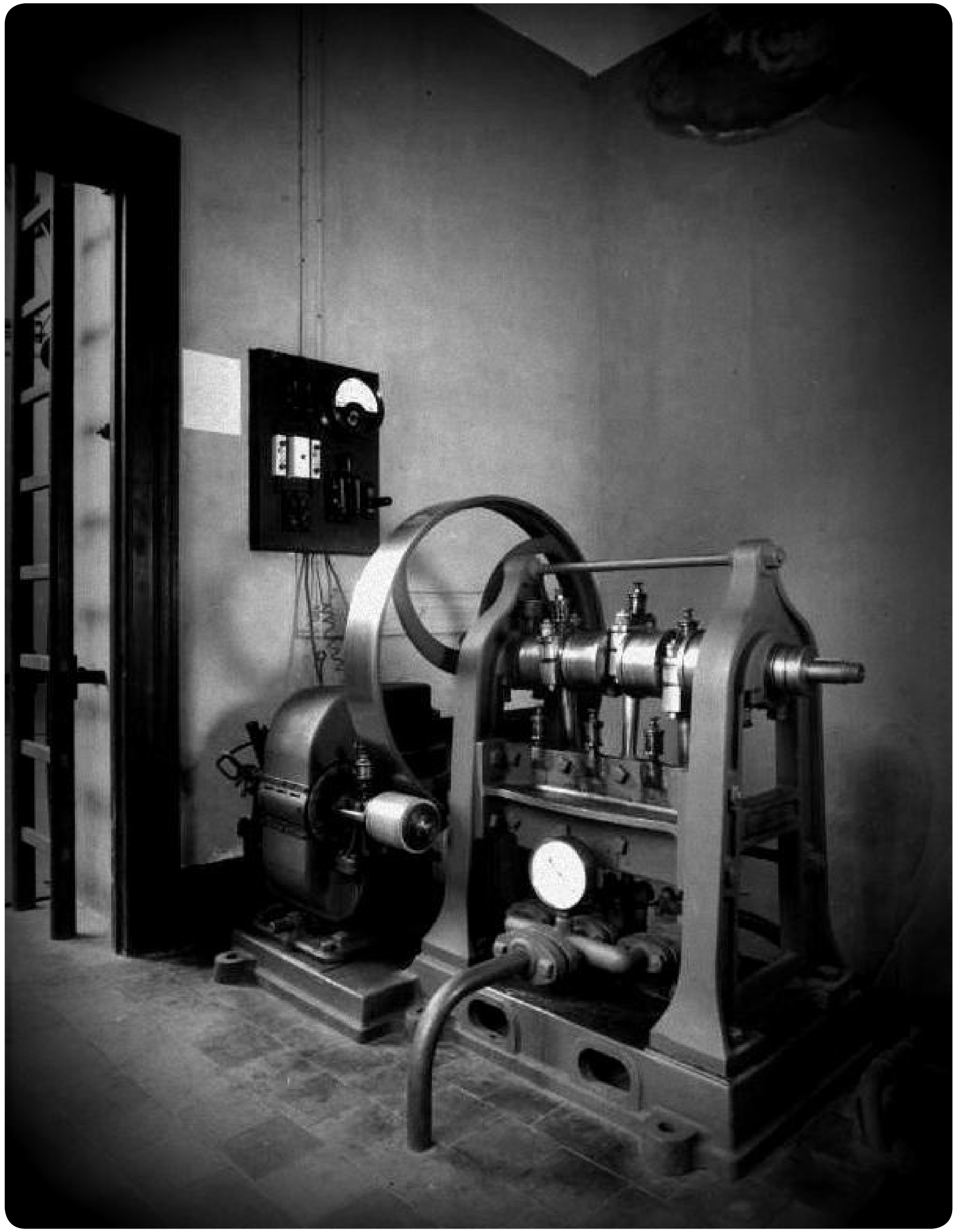
The McClean telescope has an interesting origin. David Gill had always wanted a large telescope with which to do astrophysics. He had tried to tap Cecil Rhodes for funds without success. However, a long-term British visitor, the retired engineer Frank McClean, greatly admired Gill's work and offered to pay for a suitable instrument, if the Admiralty would accept it.

Needless to say, Gill made sure that they did so. Contracts were placed with Grubb of Dublin for the telescope and T. Cooke & Sons of York for the 36-foot (11-m) dome. Herbert Baker was asked to design the building. A state-of-the-art three-prism spectrograph was constructed by the Cambridge Instrument Company. A Scottish firm supplied the machinery for the rising floor and the necessary hydraulic equipment.

The Victoria Telescope in the McClean.

Building: 1896 – present
Telescope:
Victoria (1899 – present)

Used for: Double star discoveries & measurements (Innes), discovery of europium in stars (Lunt), earth – Sun distance determination via spectroscopy, early spectra of the supergiant star Eta Carinae (Gill), detailed monitoring of Nova Pictoris 1926 (Spencer Jones), measurements of stellar distances, radial velocities & proper motions.



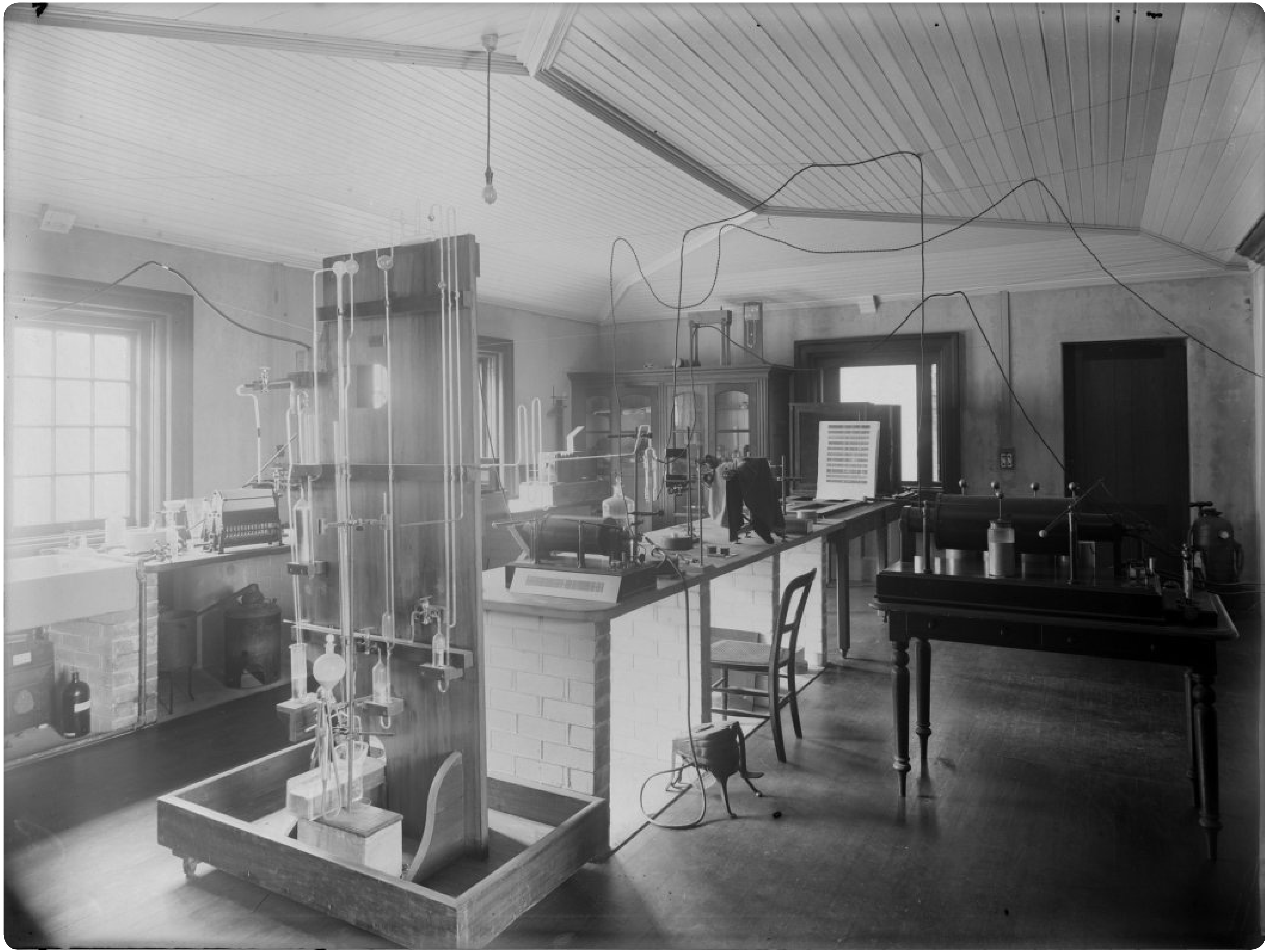
Original 3-cylinder hydraulic pump used in connection with the rising floor. This was originally driven by a DC electric motor (on view). The motor ran off lead-acid batteries in the Battery House (see p 29).

The Victoria Telescope actually consists of three separate telescopes. The largest is a “photographic” refractor of 24 inches (61-cm), designed for optimal performance in the blue region of the spectrum. This was because the photographic plates of those days were sensitive only to blue light. The next is a visual refractor of 18 inches (46 cm), designed for use by the human eye. The smallest is a guide refractor of 8 inches (20 cm). All have the same focal length of 6.9 m, twice that of the slightly older Astrographic Telescope.

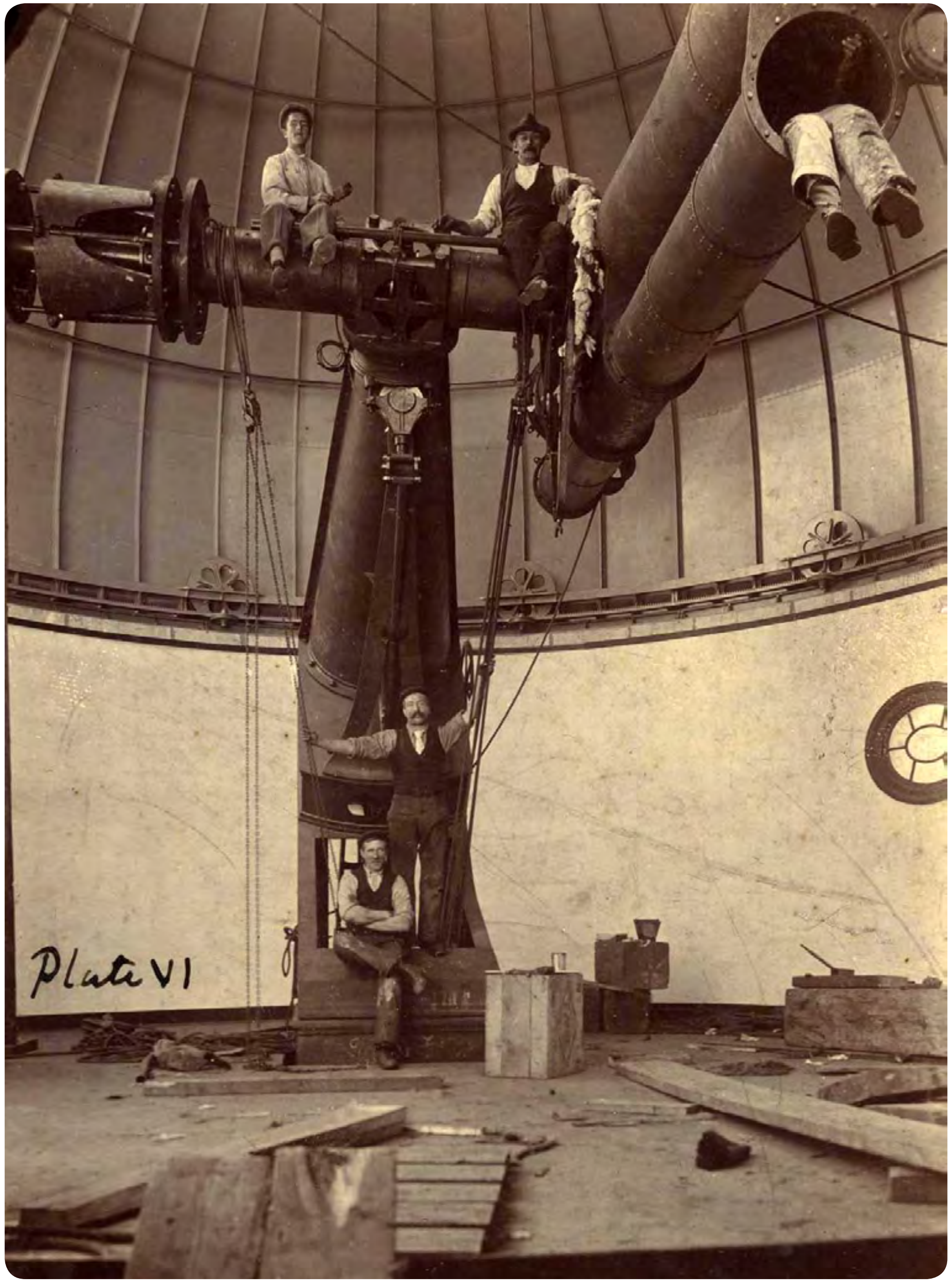
For the first 25 years or so, the telescope was used with the spectrograph and many publications resulted. However, after 1926, it was mainly used for finding the distances to the nearby stars by taking photographic plates at six-month intervals, to use the earth’s orbit as a baseline for triangulation.

It ceased to be used on a regular basis around 1980 but is still kept in working order, mainly for visitors’ nights. When sky conditions are suitable, the dome is usually opened and it is possible to look at the Moon or a planet in the 18-inch telescope.

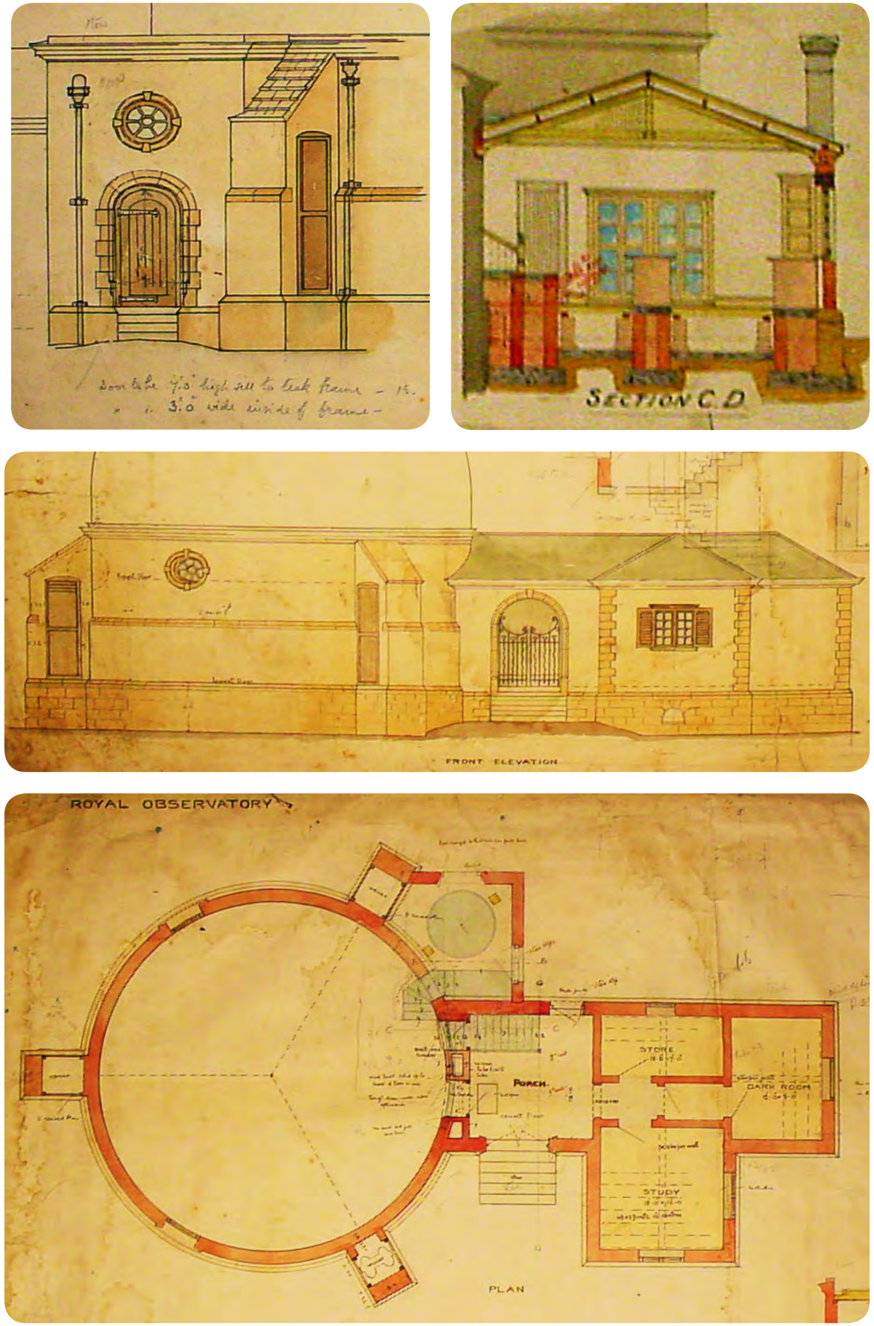
A visit to this telescope and the adjoining Astronomical Museum (see p 70) is a must for any visitor to the Observatory. A ride on the hydraulic rising floor has excited generations of children and is something to be remembered even if everything else gets forgotten!



The McClean Laboratory around 1900. Here the spectra of earthly materials were examined for comparison with those of stars and planets.The apparatus in the foreground is an early high-vacuum pump. This was the first spectroscopic laboratory in South Africa.

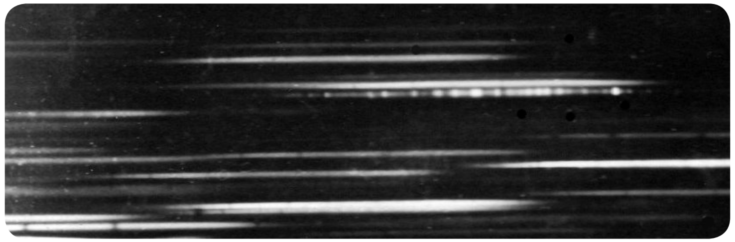


Workmen posing on the partly-completed Victoria Telescope.



Details from the original plans for the McClean.

This telescope was fitted with many accessories. One of them was an "objective prism", the largest ever made at the time, which fitted over the 24-inch lens and spread each star image out into a spectrum. Here it is seen folded away from the lens. The objective prism was used mainly during the first few years of this telescope.



One of the spectra taken with the objective prism in 1901 is of the unstable supergiant star Eta Carinae. It is the object with many bright lines in its spectrum.

Young visitors looking through the 18-inch visual telescope of the McClean during an open night. Such visits often form part of educational tours of the Observatory.

The Battery House (1896 Building) next to the McClean, contained lead-acid batteries that were charged during the day by a steam-powered generator.

The Photoheliograph / 7-inch Dome

In 1849 Maclear erected a 7-inch Merz refractor (see p 40) inside a wooden dome of 14 feet diameter that rotates on cannon balls. The building is still standing today and is the oldest dome on site. During Stone's period as HMA the original flimsy Merz mount was replaced by the Troughton and Simms one that is still there.

In 1875 Stone acquired a 4-inch Dallmeyer photoheliograph, an instrument for photographing the Sun, and installed it in a polygonal wooden dome with its own darkroom, near the Magnetic Observatory. The photoheliograph was built to a design by the noted amateur astronomer and pioneer of solar photography, the printer Warren de la Rue.

Initially the Sun was photographed regularly but in 1885 the programme was discontinued and the telescope dismounted. It was sent to England in 1909 for refurbishment and on its return was mounted on the Astrographic. Between 1910 and 1929 two photographs of the Sun were taken on every clear day.

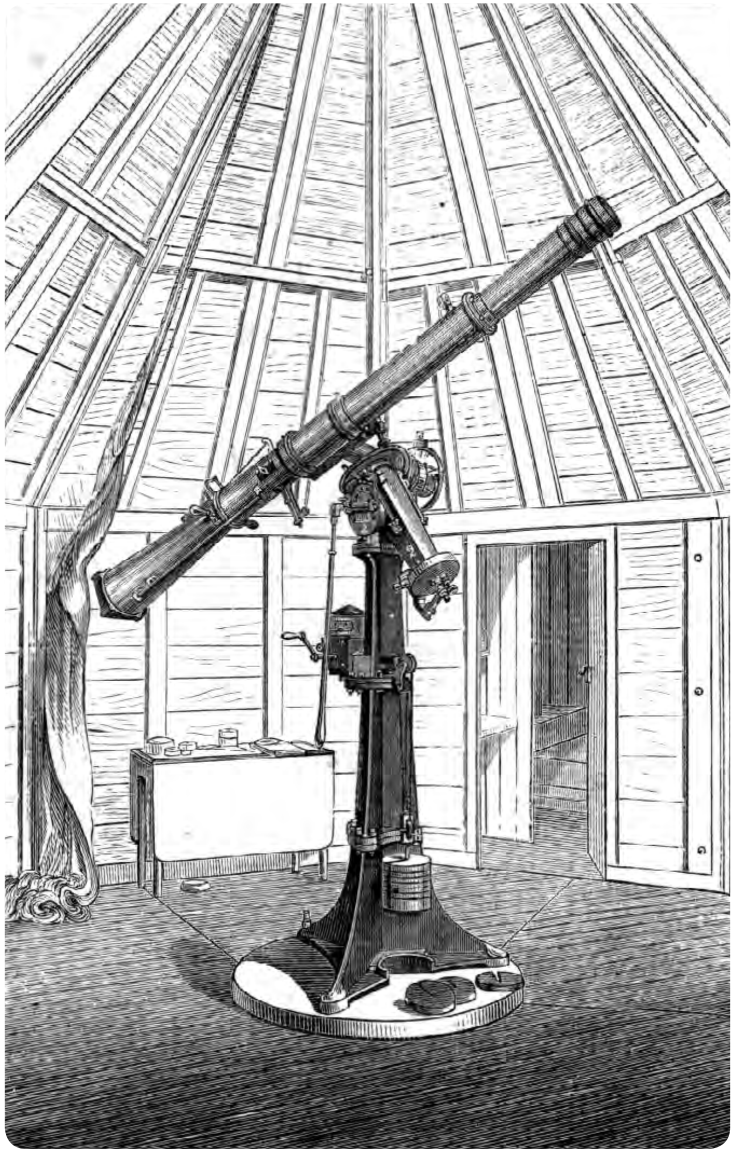
The photo-heliograph in the dome of 1849.

Building: 1847 – present
Telescopes: 7-inch Merz refractor (1849 – 1929)
4-inch Photoheliograph (1929 – present)

Used for: Regular photographs of the Sun and sunspots.

In June 1929 the photoheliograph was moved to its present location in the 7-inch Dome on the Troughton and Simms mount. The programme of daily solar photographs resumed and continued until the late 1970s. These solar images were forwarded to the Royal Greenwich Observatory where they were used in the compilation of the Sunspot index.

(top) This chronograph, adapted from a Morse code recorder, is located in the photo-heliograph dome. It was probably intended for occultation timings. It or a similar one was used with the Airy Transit Circle for timing transits. Time signals are recorded on a paper tape that was drawn through the machine continuously. (above) Picture taken early in the 20th century that shows the 7-inch Dome on the right and the Time Ball on the left. Devil's Peak is in the background. The small battery house nearby has since been demolished. The 7-inch telescope was used to observe the Transit of Venus of 6 December 1882 and again (for fun) that of 2004.

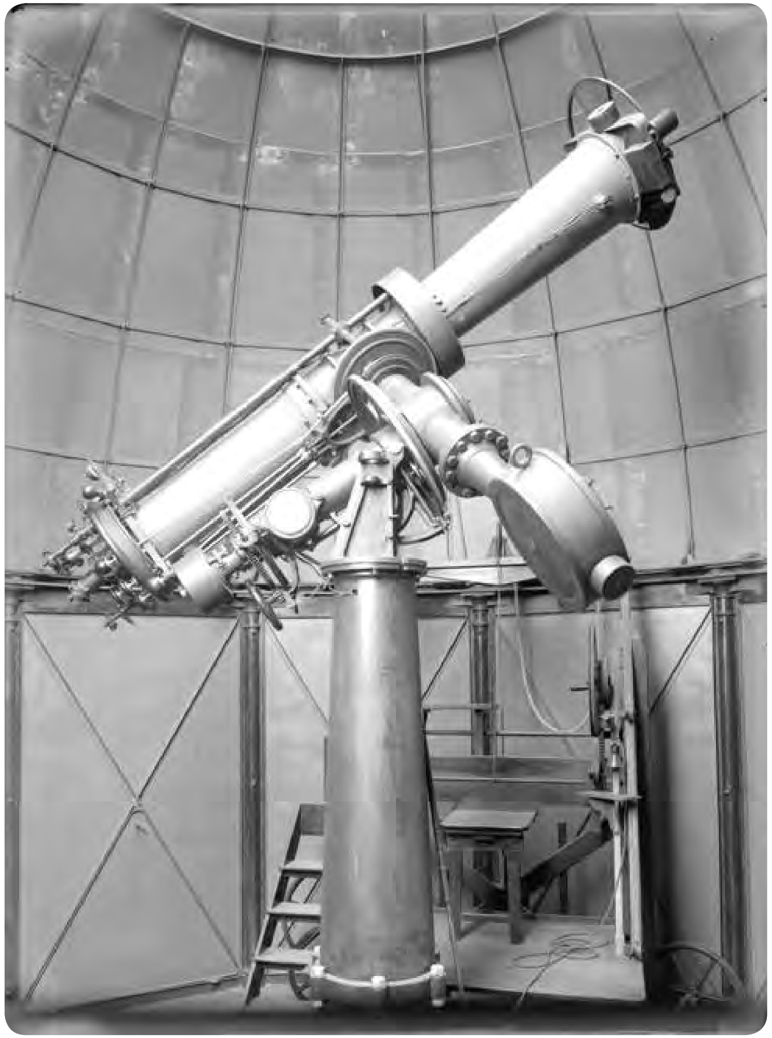


The photo-heliograph as originally installed around 1876 in a polygonal wooden building. The instrument still exists but the building was removed in the early 20th century. The mount was also used for some early efforts to photograph the corona of the Sun around 1885 with a special instrument designed by Sir William Huggins.

The 18-inch / Heliometer Dome

Gill made his name originally by his skill on the heliometer. Despite its name this instrument had nothing to do with the Sun but was rather a split-lens telescope designed for measuring small angles with great accuracy. Before photography came along it was the best instrument for measuring stellar parallaxes. Gill used his privately-owned instrument at first, but he very soon ordered the latest model for the Cape Observatory from the Repsold firm in Hamburg. To house it he designed a special building (the framework of which was constructed by Howard Grubb of Dublin) with wooden louvres to shield it from the heat of the Sun. After sunset, metal doors behind the louvres were opened to let the cool evening air flow through. In this way the steadiest possible air conditions were achieved.

Most of the southern star distances known before 1900 came from observations made by Gill and his collaborators with this instrument. It was succeeded by photographic methods



The Repsold 7-inch heliometer in 1933.

Building: c.1887 – present
Telescopes: 7-inch heliometer (1887 – 1933), 7-inch Merz by itself (1933 – 1955), 18-inch Cox-Hargreaves + 7-inch Merz as guider (1955 – present)

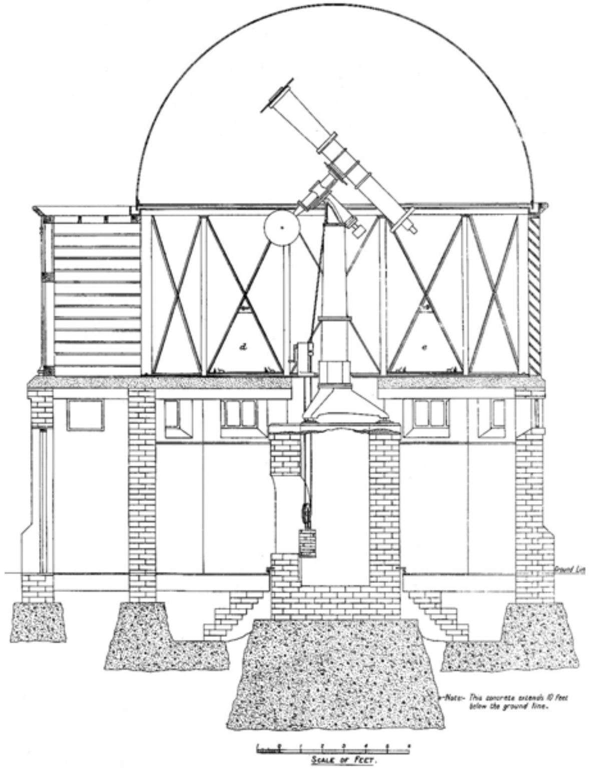
Used for: [heliometer] Precise distances of stars including α Cen (Gill, Elkin), earth – Sun distance via Mars and minor planets (Gill). [18-inch] Precision UBVRI and Hβ photometry of stars (Cousins), discovery of Gamma Doradus-type variable stars (Cousins), JHKL infrared photometry (Glass), co-discovery of rings of Uranus (Churms).

towards the end of the century and these in turn have given way to satellites.

This fine precision instrument was eventually decommissioned around 1933 and placed in storage. Unfortunately, it was stolen by metal thieves shortly before the creation of the Astronomical Museum in 1987. Most of the original mounting and observing carriage are still in place.

The 18-inch was acquired during a period of great austerity, not long after the Second World War. It was built by Cox and Hargreaves to a simple two-mirror Cassegrain design called a Dall-Kirkham. The original stand and drive gears of the Repsold Heliometer were retained and the tube of the 7-inch Merz telescope of 1849 was mounted to use as a guide telescope.

Attached to this telescope for most of its active years were photoelectric photometers designed by A W J Cousins. The electronics that went with them were improved from time to time as solid-state electronics replaced the earlier valves.



Cross-section of the Heliometer building c. 1887.

The 18-inch telescope on the former heliometer mount. A W J Cousins, the main user of this telescope, is seen on the observing platform, with his chart recorder in the background. The adjustable platform is an adaptation of the original Repsold observing chair.

The Astrographic Telescope

In 1887 an international conference was held under Admiral Mouchez, the Director of Paris Observatory, in collaboration with Gill with the aim of producing a comprehensive catalogue of the sky. Each participating observatory around the world was assigned a particular strip of sky in declination to study and each had to equip itself with a standard telescope. Gill collaborated with Grubb of Dublin in designing the instruments to be used in the British Empire and the Henry brothers of Paris constructed most of the others. These were known as "Astrographic" Telescopes and the whole project was called the "Carte du Ciel" (map of the sky).

The Astrographic telescopes were all designed to the same optical specifications. They were 13-inch (33-cm) refractors. Their two-element lenses were specially designed for astronomical photography in blue light (the only light that the early photographic plates were sensitive to). Their focal length is 3.43-m so that the scale of the images on the plates is 60 arcsec per mm.

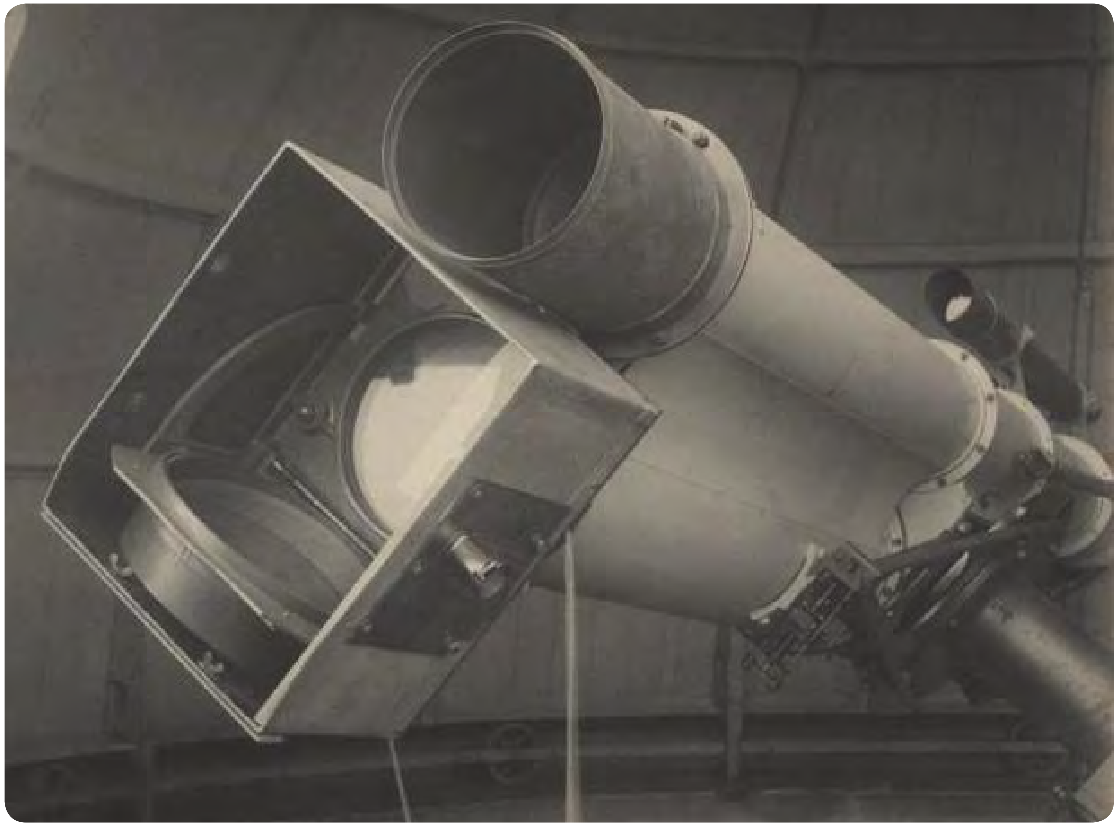
The Astrographic Telescope photographed around 1900.

Building: 1890 – present
Telescopes:
13-inch Astrographic (1890 – 1995)
16-inch Parkes (1995 – present)

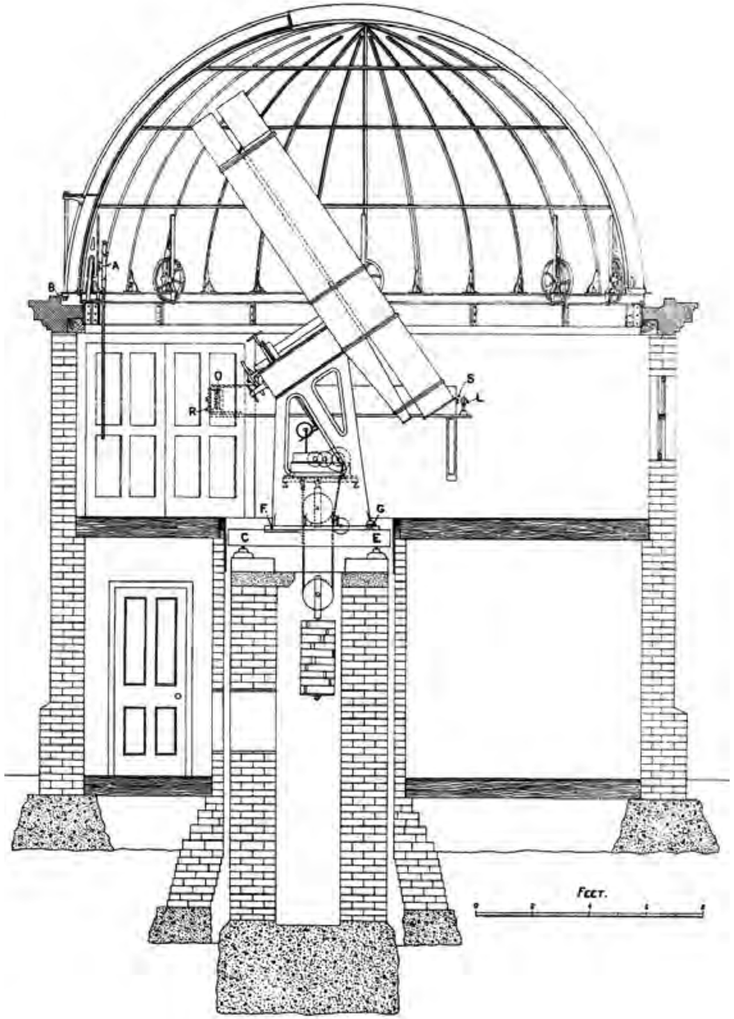
Used for: Photography of the Cape Zone of the International Carte du Ciel project, discovery of oxygen in stars using objective prism spectra (Frank McClean), first distance measurement by photographic parallax of Proxima Centauri (Voûte), accurate photometry using the Fabry photographic and photoelectric methods.

The part of the sky assigned to the Cape, called the Cape Astrographic Zone (CAZ), covered declinations between –40° and –52°. The measurement of about half a million stars and the follow-up from photographs taken 25 years later to give proper motions for the 40 000 brightest stars took up much of the effort of the Observatory for about 44 years, until 1936.

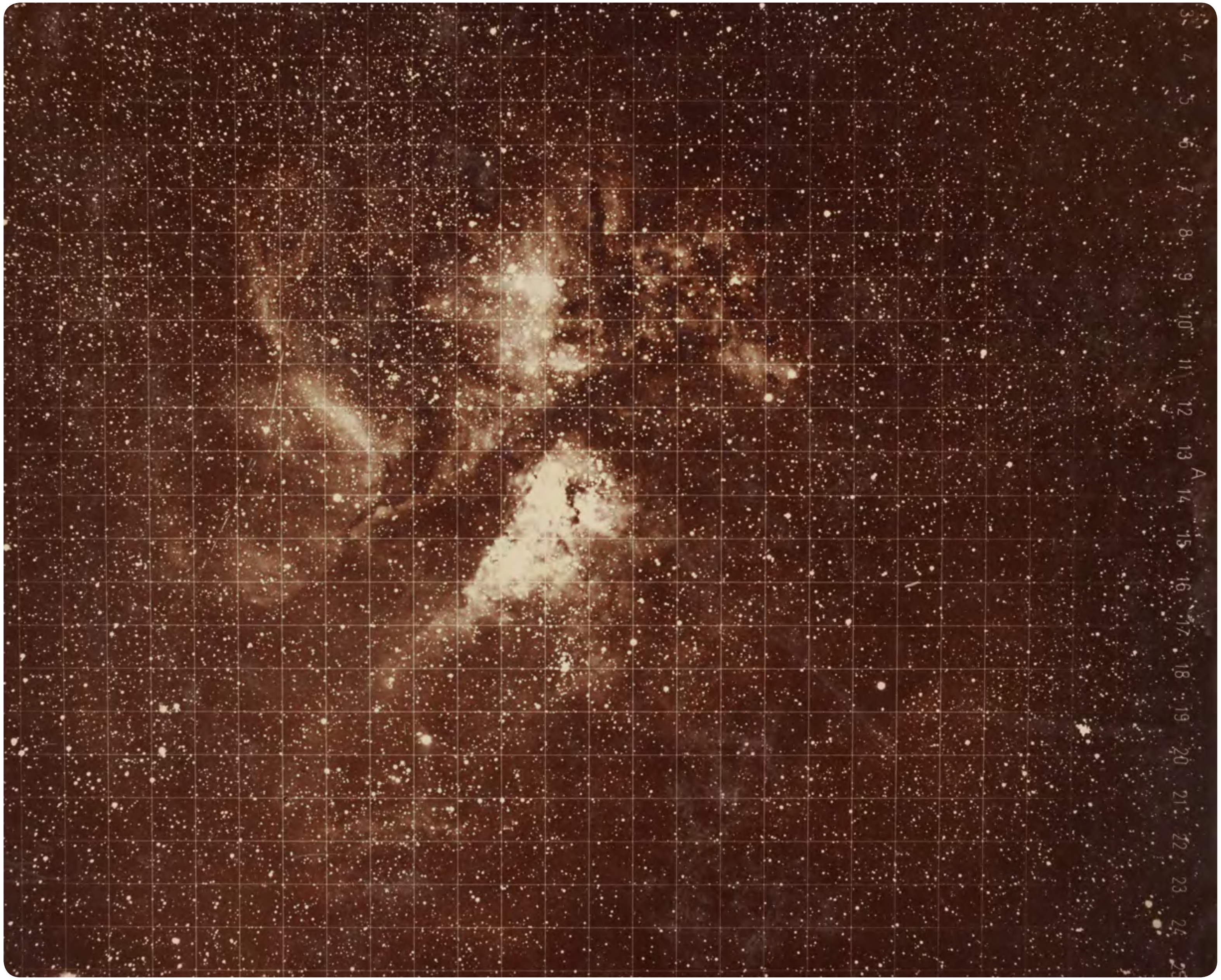
The Astrographic telescope, though built by Grubb of Dublin, was largely designed by Gill. Each photographic plate might have to be exposed for many hours and so it was necessary to add a guide telescope. The mounting of the telescope had to be very robust to avoid any shaking and the polar axis was driven by a massive weight-driven clockwork motor. An ingenious mechanism synchronized the motion to the Observatory clock system.



The top end of the Astrographic with McClean's objective prism ready to be folded over the lens (1897). With this system, he discovered the presence of oxygen in stars.



Cross-section of the Astrographic building. Note the heavy drive weight within the pier.

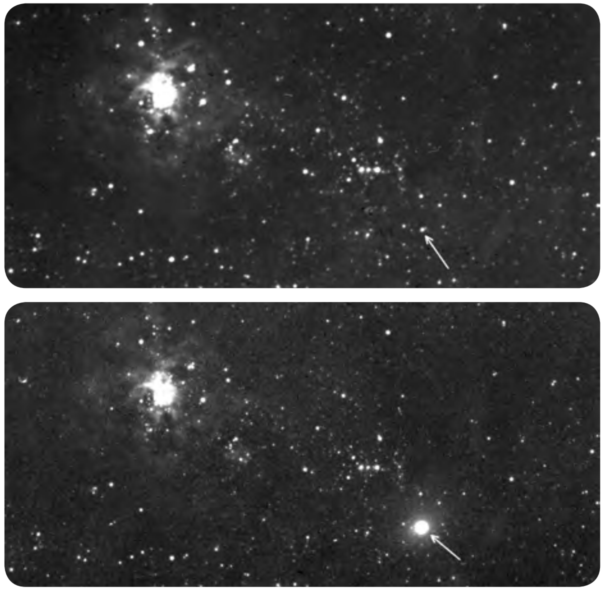


Twelve hour exposure of the Eta Carinae Nebula, taken in March 1892. This would have been achieved by making exposures on successive nights without disturbing the plate. The grid imposed on the image was believed to help in obtaining precise stellar positions but was later discontinued.

The telescope is still in the dome but lying on the observing floor where it was put when a 16-inch Parkes Newtonian telescope replaced it on the mount in 1995.

In 1897 Frank McClean, the donor of the McClean telescope, visited the Royal Observatory at Gill's invitation. He mounted a 20° prism of 12 inches diameter in front of the main objective and with this took photographic spectra of all southern stars brighter than magnitude 3.5. In the course of this work he discovered that the element oxygen is present in certain types of stars.

Another interesting application of this telescope was to the measurement of parallaxes by J G E G Voûte around 1915 – 1917. Voûte was a Dutch visitor at the Observatory for several years. Unlike previous observers, who worked with the Heliometer, he made use of photography. One of the objects he studied was the high proper motion star near Alpha Centauri found by R T A Innes of the Union Observatory in 1915. He determined that it was, within the errors, at the same distance as Alpha. Just afterwards Innes asserted, on the slimmest of evidence, that his star was in fact closer and gave it the name of "Proxima". By a fluke, Innes was right and Proxima remains to this day the nearest star known. At the time it was also the faintest star known in terms of its absolute luminosity (i.e. wattage).



Photographs taken with the Astrographic of the region in the Large Magellanic Cloud containing the Tarantula Nebula and Supernova 1987A (before and after). This was the brightest supernova in centuries.

The Astrophotographic Congress

As the Cape Photographic Durchmusterung progressed, research in photographic cataloguing took the astronomical world by storm. In Paris Observatory, the Henry brothers succeeded in developing a much superior form of lens, specially suited to astronomical photography. This led to the "Astrographic Project" or Carte du Ciel.

Exposures for the Cape Astrographic Zone (CAZ) started in 1892 and the whole area was re-photographed 25 years later to get proper motions for a large sample of stars.

The plates taken at the Royal Observatory each night were stored in light-tight boxes and developed the next morning. They were measured on machines with microscopes and precision screws. The raw x-y coordinates of each star had to be converted into standard Right Ascensions and Declinations using tables, hand calculators and later by early-model electronic computers.

The last of the massive positional programmes was conducted using the "Multiple Refractor Mount", a set of telescopes acquired in 1964 and mounted above where the computer department is located today. The main telescope had a modern four-component lens of 8 inches diameter that gave much superior definition than the old two-component photographic lenses. The plates produced for this programme were measured using computer-controlled scanning machines which were faster and more accurate than the older methods. This telescope was moved to Sutherland in the early 1970s but has since been decommissioned.

Gill's Reversible Transit Circle

Gill had a lifelong interest in obtaining accurate star positions. Early in his stay at the Royal Observatory he realized that the Airy Transit Circle of 1855 was thoroughly obsolete. Airy, an autocratic character, had been the Astronomer Royal at Greenwich for 46 years (1835 – 1881) and it was only with great trepidation that anything to do with him could be criticized.

Gill designed a completely new type of Transit Circle whose features were copied in many later instruments. Thermal stability was one of the most important considerations and the building he designed incorporated a double skin with ventilation features that prevented the inside of the building from heating up during the heat of the day. The cast iron piers of the instrument were filled with water because of its high specific heat. The construction was carried out by Troughton and Simms and the building was by Thomas Cooke and Sons. It was ready for use in 1905. Mechanical stability was ensured by going deep for the foundations and making sure that ground

An observer at work with the RTC c.1960.

Building: 1905 – present
Telescope: 6-inch transit circle (1905 – present)

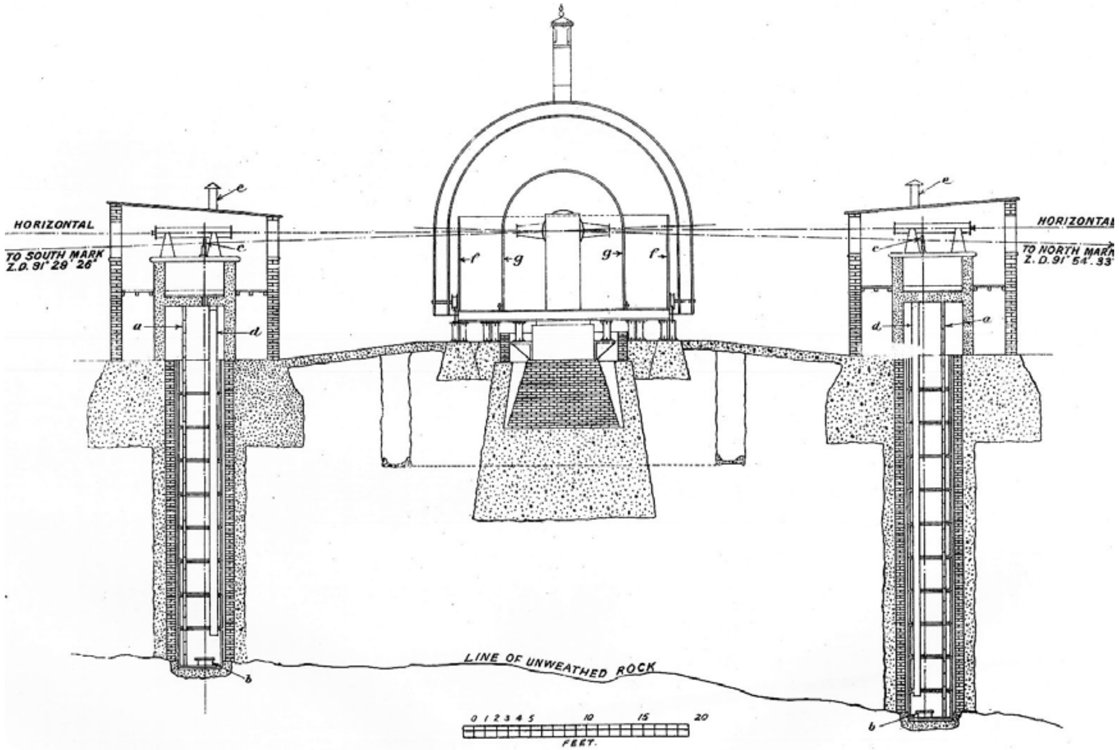
Used for: Determining fundamental star positions.

water level changes did not tip the building significantly – remember that sub-arcsecond precision was aimed for.

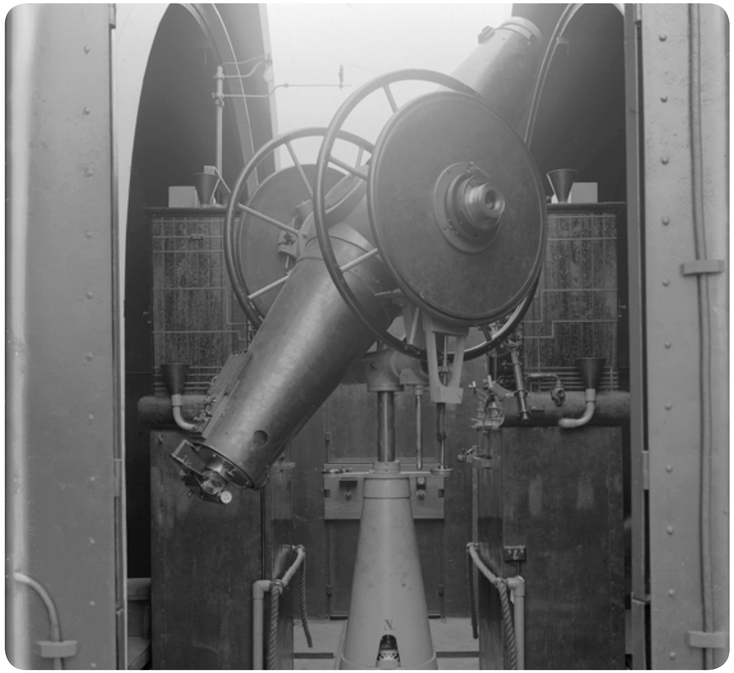
The whole instrument could be lifted off its bearings and turned east-west. It was calibrated from the external "mark houses" and "collimator houses".

This instrument remained in use into the 1970s and was considerably automated over the years to make the reductions of the data simpler.

The building has suffered from lack of care and maintenance and is today in poor condition.



The building housing Gill's Reversible Transit Circle. It was designed for extreme thermal and positional stability. The foundations were surrounded by special drains to minimize the effect of ground water and the collimator houses at its side were anchored to the bedrock. The building had a double skin with the space carefully ventilated to protect the instrument against the Sun's heat.



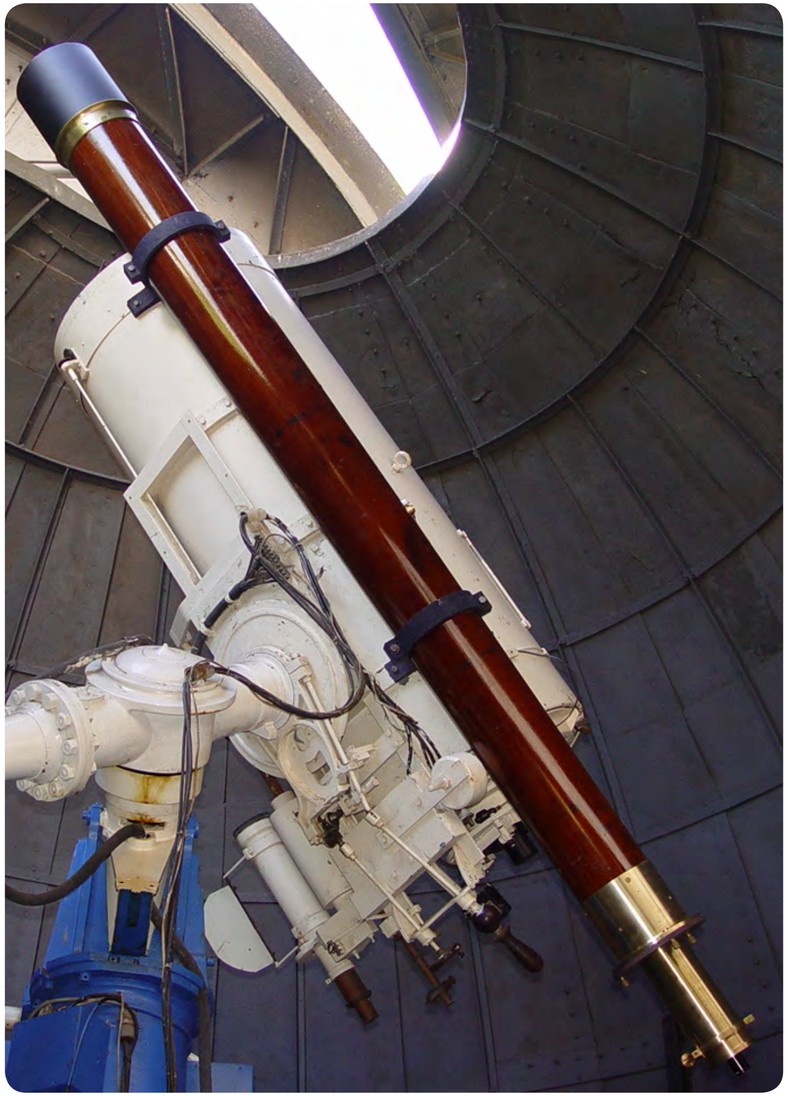
(top) The Gill Reversible Transit Circle, a masterpiece of instrumental design. This photograph dates from about 50 years ago when the instrument was in full use. It is seen with the building opened for observing. All measurements were made when the stars were on the meridian. (below) A photograph from the 1900s showing the instrument being reversed.

The 7-inch Equatorial

In 1849 Maclear mounted a 7-inch equatorial refractor by Merz of Munich in what is today the Photoheliograph Dome (p 30). This was the only sizable general-purpose telescope at the Observatory for many years, allowing for the possibiity of looking at objects all over the sky and not just along the meridian. During Stone's period as HMA the original flimsy Merz mount was replaced by the Troughton and Simms one that is still there.

The 7-inch was used for many programmes, especially during the Gill period. It was was used by R T A Innes to look for stars of high proper motion (ie foreground that had moved relative to the background). He discovered with it a star that had been observed before but was found by Kapteyn to be missing from the CPD (p 53). It was subsequently rather unjustly named after the latter.

In 1933 the Merz refractor ended up replacing the Repsold heliometer on its mount (p 32) and, when in 1955 the 18-inch reflector was installed, it became the latter's guide telescope.



The restored 7-inch mounted as a guider for the 18-inch.

Telescope: 7-inch Merz refractor (1849 – present)

Used for: Occultations (Finlay), discovery of double stars (Innes), double star observations (Voûte), revision of the CPD (Innes), Transit of Venus 2004 (Glass).

The 6-inch Telescope

The 6-inch Grubb refractor.

The 6-inch telescope was built by Howard Grubb of Dublin in 1882 and was installed in a building known as the "Wind Tower" (see p 54). It was purchased with the Transit of Venus of 1882 in mind. With it were made the first scientific observations of the Great Comet of 1882 by William Finlay, its discoverer. To it was attached the Ross lens with which the first scientific photographic observations of a comet were made in 1882. It was also used for the discovery of Comet Finlay 1886e.

The telescope tube was removed temporarily and the mount used for the definitive CPD camera (see p 53) during 1889 – 1890.

During Willem de Sitter's visit of 1897 – 1899 it was used with a Zöllner photometer, an early instrument for measuring the brightness of stars.

Its original Grubb clockwork motor, now in the Astronomical Museum, has been replaced by an electric one. The telescope has been used in more recent times for observations by amateur astronomers, particularly R P de Kock, and for public open nights.

Building: 1935 – present
Telescopes:
6-inch Grubb (1935 – present)

Used for: First scientific observations of the Great Comet of 1882 (Finlay), Transit of Venus (1882), first scientific photographic observations of a comet (1882), discovery of Comet Finlay 1886e, mount used for definitive CPD camera (1889 – 1890), Zöllner photometry of stars (de Sitter).

The Kinetheodolite Dome

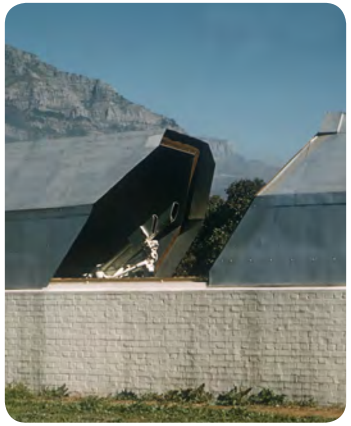
This small dome originally contained an Askania Kinetheodolite liberated from Peenemunde after the Second World War and placed at the Royal Observatory in 1967 to track satellites. It was owned by the Royal Aircraft Establishment, Farnborough, and operated independently of the Royal Observatory by them. It was eventually returned and the dome is now empty.

Observers with the kinetheodolite.

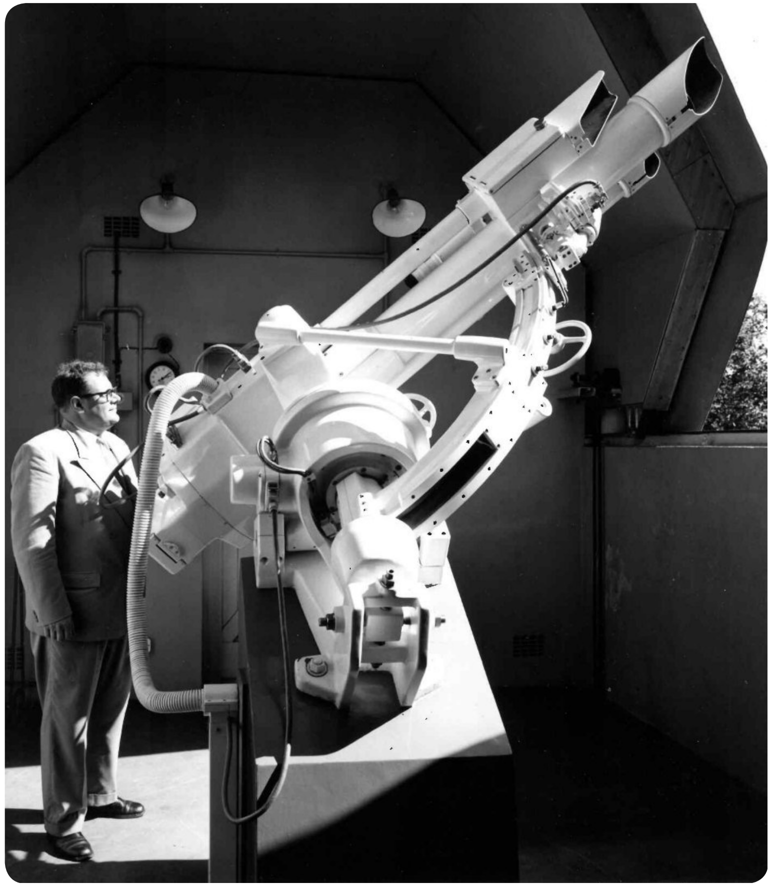
Building: 1967 – present
Instrument: 1967 – 1981

Used for: Tracking artificial satellites.

The Lyot Coronagraph



The Lyot Coronagraph was installed for the International Geophysical Year 1957 – 1958. This form of coronagraph was invented by the French astronomer Bernard Lyot in 1939. Previously the corona of the Sun could only be studied during eclipses because it was overwhelmed by the brilliance of the photosphere. This instrument contained specialized optics to suppress most of the light of the Sun's disc, coupled with a very narrow-band filter at the wavelength of the red hydrogen line Hα.



Joe Churms with the Coronograph.

Early attempts to construct a coronagraph, such as that of Huggins (see p 31), were unsuccessful, principally because narrow-band filters could not be made.

The Lyot was designed to take photographs on film of the Sun's corona every minute. It formed part of a worldwide flare patrol network. The films were sent to the University of London Observatory for analysis.

The control system of the Coronagraph utilized large numbers of electronic valves and relays and is no longer in working order. It has been out of action since the late 1970s.

The unusual shape of the housing is due to the fact that it only has to track the Sun and does not need to view the whole sky.

Building: 1957 – present
Telescope: 1957 – present

Used for: Narrow-band photographic monitoring of solar activity.

The 40-inch Elizabeth Telescope

This telescope, no longer in Cape Town, was acquired in 1964 to be used for photoelectric photometry. It was made by Grubb, Parsons in Newcastle upon Tyne, the successors to the original Grubb company that constructed three of the older telescopes of the Royal Observatory. The dome was a second-hand one, originally used at the Royal Greenwich Observatory to house the 36-inch Yapp reflector.

The telescope was an f/20 Cassegrain with a prime focus camera that could be used with a large corrector plate over its front to give a much larger field than a classical Cassegrain. However, this configuration was rarely if ever used in practice.

The building contained a 40-inch aluminizing plant designed by DS Evans, Chief Assistant at the time. When the Sutherland station was constructed in 1971–72, the telescope and aluminizing laboratory were moved there. Subsequently a replacement secondary was constructed to make it f/16. This was designed for a focal plane much further back than the original one in order to accommodate long auxiliary instruments.

The site of this telescope in Cape Town was in the area now occupied by the Technical Building.

The 40-inch reflector building in Cape Town, demolished c.1986.

Building: 1964–1986
Telescope: 40-inch Elizabeth (1964–1971)

Used for: Photometry

The 30-inch Steavenson

The Steavenson as it appeared in the 1960s.

This building was intended to house a 30-inch reflector donated to the Royal Greenwich Observatory in about 1960 by W H Steavenson. However, it proved unsuitable for professional use. A programme of reconstruction begun in the Royal Observatory workshops was abandoned around 1971 in favour of projects for the new Sutherland observatory and the parts were sent back to the Royal Greenwich Observatory. The reconstructed telescope was eventually installed in Spain where it is now at the Science Park in Granada. The domeless building was used as an electronics laboratory for several years and, following the construction of the Technical Building in 1986, now houses part of the Observatory's archives.

Telescope: 30-inch Steavenson (1962 – 1972)

Used for: Intended for performing photometry.

Moonwatch Pillars

The Moonwatch project was for tracking the first artificial satellites. From 1957 to 1968 a group of up to 100 amateur astronomers operated a number of small telescopes for monitoring them. The need arose because the initial orbits of the satellites were uncertain and more formal means of tracking were not yet available. Each of 20 or more telescopes pointed at a different declination band so that any satellite crossing the meridian could be timed and have its apparent declination measured.

Pillars used: 1957 – 1968

Used for: Tracking the first artificial satellites.

The Work of the Royal Observatory

In the early years the night-time work consisted of visually measuring the places of stars and planets using transit instruments and the mural circle. Daytimes were occupied in "reducing" the data to forms suitable for publication. Firstly, calibration corrections had to be applied to allow for the mechanical imperfections of the instruments. Then followed allowances for the bending of rays by the earth's atmosphere (refraction). Afterwards the movements of the earth's axis in space (precession, nutation) had to be accounted for and finally compensation for the aberration caused by the finite speed of light had to be applied. These required many calculations for each star.

The main output of the Observatory at first was time information and positional catalogues of celestial objects. From Gill's directorship onwards research papers began to be published.

In the late 19th and early 20th century many observations were made by photography on glass plates. To derive positions, these had to be measured using special precision machines and the numbers had to be converted by much the same series of processes described above to standard coordinates. From the middle of the 20th century onwards various types of calculating machines and early electronic computers came into use, greatly expediting this work.

Longitude and Time

The preoccupation with time all had to do with the problem of finding a ship's position at sea. It was easy enough to find the latitude by measuring the height of the Sun above the horizon at midday or else of the stars at night but finding the longitude was impossible unless one knew the time at longitude zero. It had to be obtained by comparing when a star passed overhead according to local time with when it passed overhead at longitude zero (such as at Greenwich). Every hour of difference represents 15 degrees of longitude.

Long sea voyages then took months. The only way of keeping accurate time over long intervals was the pendulum clock but this could not be made to function on a rolling and pitching ship. The development of marine chronometers around 1760 solved the problem in principle but these were very expensive and not completely reliable. It took until 1826 for chronometers to become standard issue in the Royal Navy! Even the very best ones had to be checked against standard time as often as possible.

Getting the longitude of a fixed location such as the Cape was a little easier because it was possible to observe the moons of Jupiter through a telescope (not possible from a moving ship). They eclipsed each other on a regular basis and so the time could be looked up in tables.

The Royal Observatory used a combination of star observations with state-of-the-art pendulum clocks to provide a time service for ships in Table Bay.

The actual form that the time signals took changed over the years. One of the earliest (1833) was a flare pistol that was fired from the roof of the Observatory at a certain moment. A signalman with a telescope then dropped a time ball near Table Bay. The latter consisted of a large basketwork ball covered in painted canvas that could be raised to the top of a mast and dropped at a precisely designated time.

(top) Nineteenth-century nautical chronometer. Vessels often carried three or more of these precision clocks in case one of them went wrong. They were mounted in gimbals so as to stay level as a ship pitched and rolled.
(bottom) Signalling pistol used by Maclear (c.1833) to convey precise time to ships moored in Table Bay. Now in the Astronomical Museum.

(left) The last of the Royal Observatory's time balls, dismantled around 1935. This one was located just behind the stables of the Main Building. (right) A repeating time ball controlled by an electrical signal from the Observatory was set up in the harbour in 1894 and is still there. Although the mechanism has been reconstructed, the Waterfront authorities are not prepared to hand-raise the ball each day for dropping.

In 1836 a time ball was erected in the Observatory grounds. This was easily seen from Table Bay and was let fall each day at a certain time. In 1861 signals were sent by telegraph line to Simonstown and some other ports to operate semaphore signals and in 1883 the time ball that still stands was erected at the Cape Town Waterfront. At a certain time, the ball was released from the top of the mast and ships' captains in the harbor could set their chronometers by it.

A noonday gun had been fired each day from the beginning of the British occupation of the Cape in 1806. How it was checked in the early days we do not know, but it could not have been very precise. However, since

The "Noonday Gun" on Signal Hill being fired. It takes about 25 seconds for the sound to reach the Observatory because of the finite speed of sound (about 333m/s).

1864 a gun on Signal Hill has been fired electrically at noon each day from the Observatory. Visitors can nowadays witness the firing of the antique cannon by driving up Bloem Street from Buitengracht Street and following the Noon Gun signs – at the right time, of course!

By around 1876 it was possible to use the telegraph to establish the longitude relative to the Greenwich Meridian of the main Cape instrument with a precision of better than a tenth of a second of time. The next major improvement was with radio time signals in the 20th century, when an accuracy of about 1/100 of a second was possible (the remaining uncertainty was due to the changing height of the earth's ionosphere by which radio signals are reflected).

The dependence of ships on visual time signals was removed by about 1930 because of the general availability of radio receivers and the Observatory time ball was then scrapped. However, the Royal Observatory continued to supply time to the Post Office and other institutions. A number of nations established radio stations that emitted time signals every second.

The timekeeping within the Observatory itself was done by means of special clocks called "Regulators". They usually had mercury-filled pendulums for temperature compensation. Each clock had its own notebook so that its drift could be calibrated carefully and adjustments made when necessary. A fine example by Hardy, dating from before 1820, is to be seen in the Observatory library. These clocks had small 24-hour hands, large minute hands and small second hands. They had a loud tick so that the astronomer could count them without taking his eye off the star he was measuring.

The Observatory had clocks that told Mean Time, based on the Sun, and Sidereal Time, based on the stars. They differ by about four minutes per day because of the revolution of the earth around the Sun.

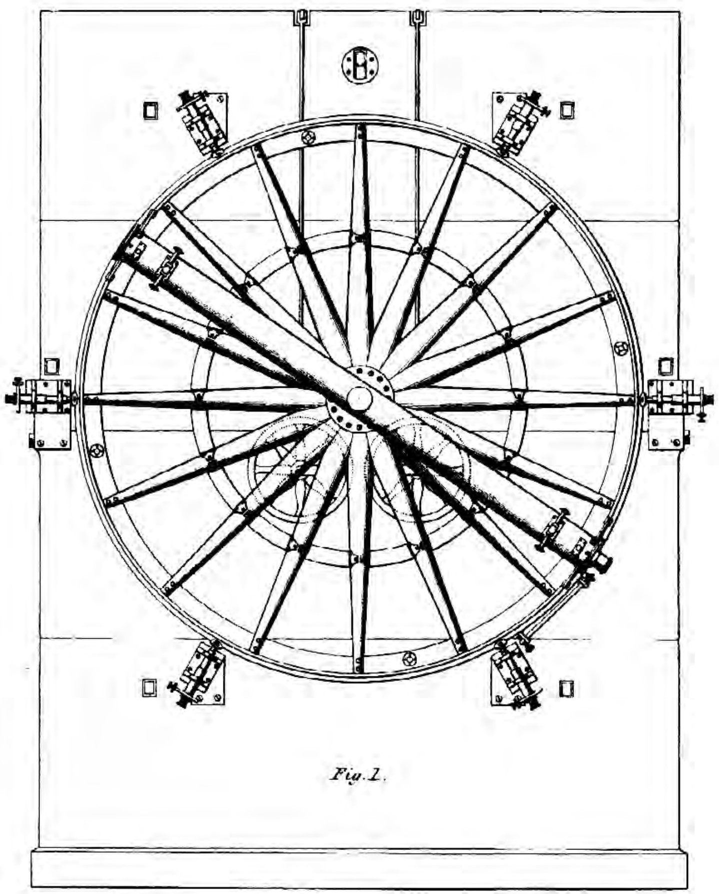
The coming of the telegraph required that the country adopted a uniform time system and the Observatory provided this, in the form of local mean time. However, the railway system needed to have a uniform

One of the regulator clocks that were used to keep time since the start of the Royal Observatory. This one, by Molyneux of London, was made around 1820. The big hand told the minute and the small hands the hours and seconds. The pendulum terminated in a glass cylinder filled with mercury for thermal compensation. Such clocks could keep time to about one second per day and had to be checked regularly against the stars.

national time and this was set at 1½ hours before Greenwich Mean Time from 1892 until 1903, after which the present time of 2 hours before Greenwich was adopted over the whole of South Africa. Somewhat later on, the Observatory supplied time to the SA telephone service to calibrate its speaking clock. This was done in exchange for free mail service!

In the 1960s the Observatory had its own electronic crystal clocks that were calibrated from the atomic clocks at the Republic Observatory in Johannesburg by means of their radio station ZUO. In this way, an accuracy of a few thousandths of a second could be maintained.

Since the advent of the GPS (Global Positioning System) satellites the Observatory time systems in Cape Town and Sutherland have been calibrated from their atomic clocks and can be checked at the microsecond level, though this degree of precision is required only occasionally.



Mural circle by Troughton, similar to that at the Cape. It was made to swing exactly on the meridian (north-south line) and was used to measure a star's declination.

The Positions of the Stars

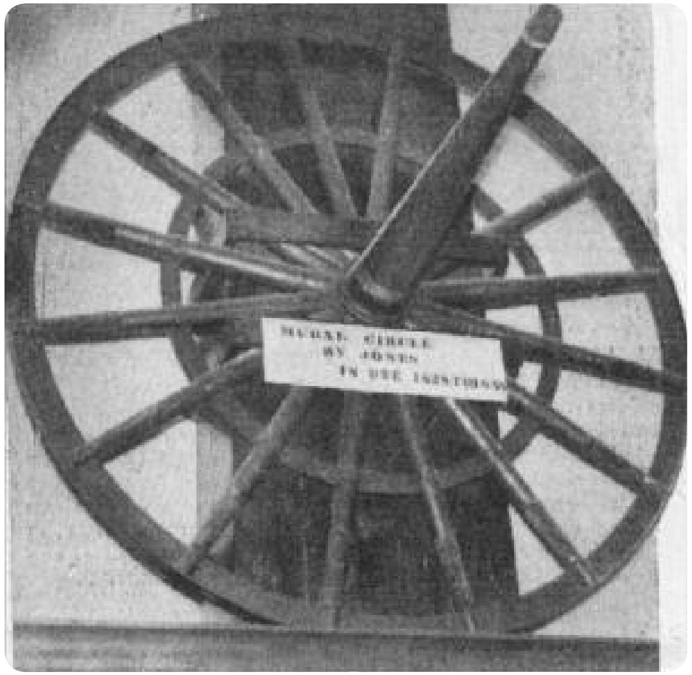
Finding the positions of the stars was the main reason for the existence of the Royal Observatory. This was the main aim of astronomy since ancient times and the increasing precision with which this could be done was for centuries almost synonymous with the history of the subject until about a century ago. Just after the Renaissance, instrument making started to improve dramatically. The development of Newtonian gravitational theory in the seventeenth century led to an understanding of the earth's movements and in the eighteenth century the movements of the earth's axis itself became better understood.

By about 1800 the positions of stars and planets could be measured to about one second of arc, or in lay terms about one part in 1.3 million of a circle of 360 degrees, several times better than was possible fifty years before in La Caille's time. The instruments that were installed during the 1820s at the Royal Observatory could do about four times better than this if observations were repeated and combined. This was in part made possible by new mathematical understanding of errors and statistics. In fact, the science of statistics owes a great deal to astronomers.

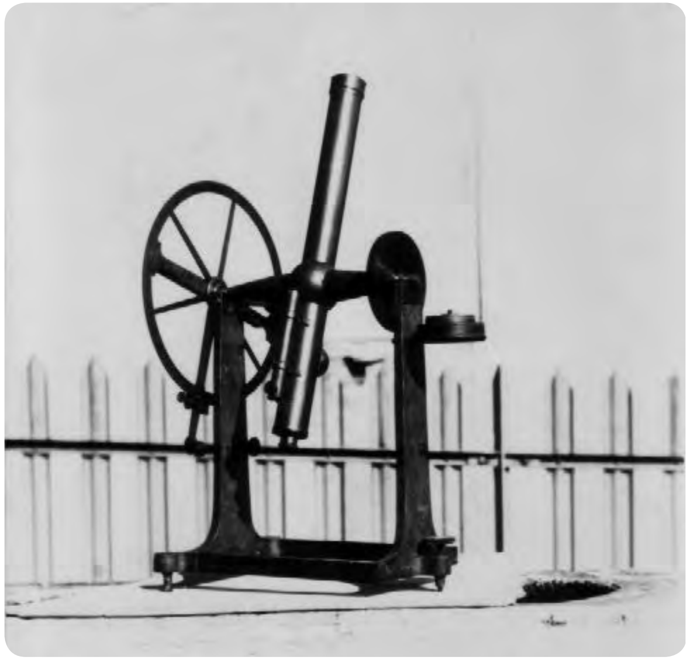
The two main instruments installed in the Observatory when it opened were a Mural circle and a Transit. The Mural circle was a large calibrated circle carrying a telescope and mounted on a small wall accurately aligned North-South. It was used to measure the distance of a star from the celestial equator as it passed from east to west across the meridian of the Observatory.

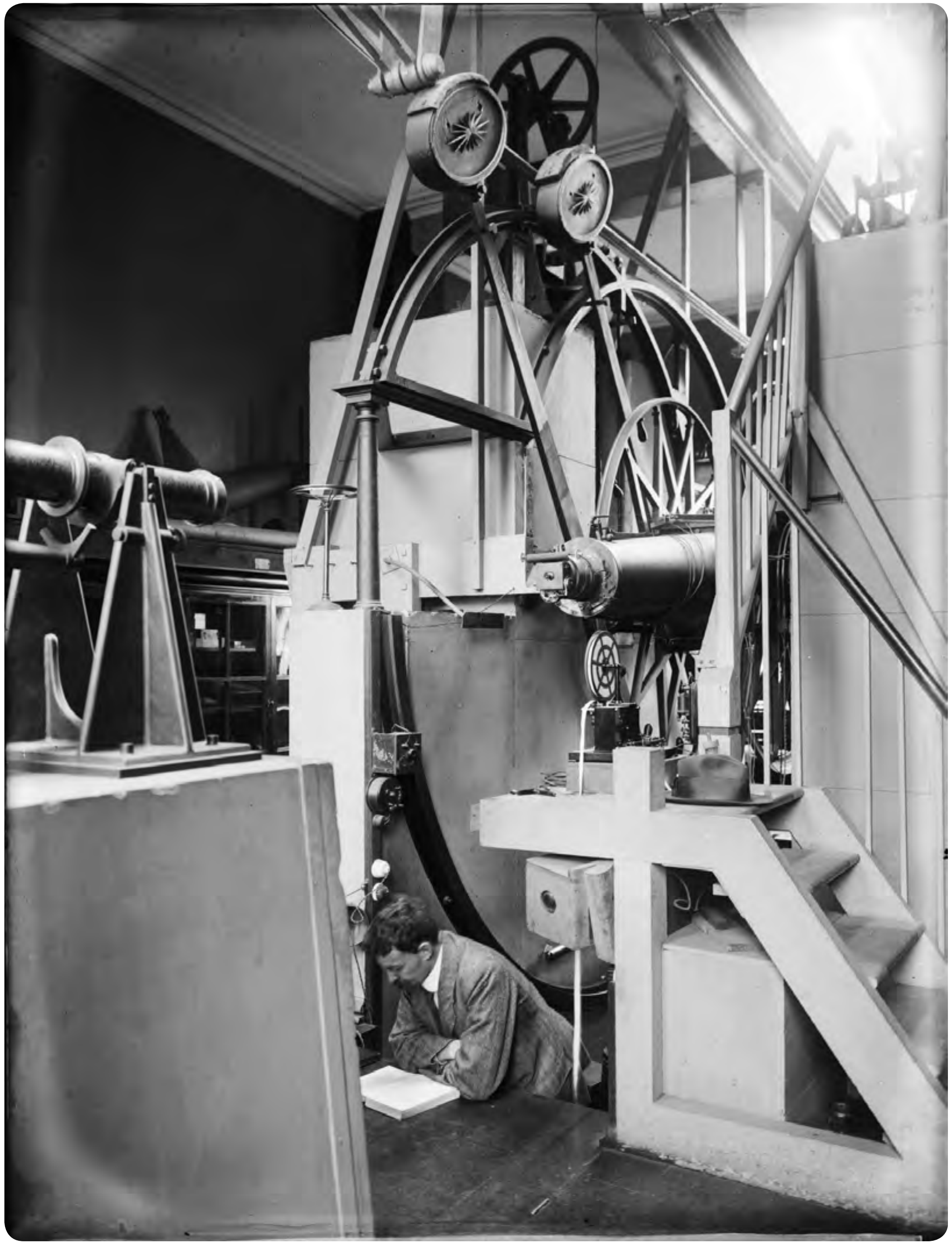
The circle was read by six microscopes spaced at 60 degree intervals around it. The microscope readings could be averaged to reduce errors in the calibration of the circle, off-centring of the axis and other effects. The observer had to prepare for the observation by setting the circle to the approximate place of the star and then wait for it to go from east to west across his eyepiece. He then adjusted the circle so that the star moved precisely along a crosswire. Afterwards he read the position of the circle through the six microscopes.

The other main instrument was the Meridian Transit. This was a telescope that swung in the North-South direction between two piers. Its purpose was to note the time at which a star crossed the meridian. The observer noted when the star passed the crosswire by listening to the ticks of the nearby regulator clock. Each person had his own reaction time and this could be calibrated so that a time could be measured to about a tenth of a second.



(top) Relic of a mural circle installed around 1840 and kept in service until 1857. Unfortunately it was scrapped around 1950. (left) An astronomer using a meridian transit telescope similar to that of the Royal Observatory. The telescope swung along the meridian and was used to time the precise moment at which a star passed the meridian due to the earth's rotation. This gave its right ascension, similar to geographic longitude. Note the regulator clock standing nearby so that the observer could hear and count its ticks. (right) A portable transit instrument used by Fallows before the Observatory was completed.





For each star whose position was to be determined a measurement had to be made with each of the two telescopes. The measurements were usually repeated several times and the final results were used to form the basis of star catalogues – the chief output of the Observatory.

In 1855 a new instrument called a Transit Circle, a copy of one at the Royal Greenwich Observatory which still exists, replaced the Mural Circle and the Transit telescope. The designer of this was Sir G B Airy, the imperious Astronomer Royal at Greenwich.

It was now possible to observe both coordinates of a star simultaneously. It was improved somewhat later by the addition of a chronograph, a pen device that enabled the observer to record the moment of transit by pressing a button. A mark was then made on a paper tape that also recorded time impulses from one of the Observatory's clocks. This took away some of the uncertainty associated with the individual observer.

This instrument remained in place until about 1950. The lens and eye-end of this telescope are preserved in the Astronomical Museum. A chronograph of the type shown in the photograph still exists in the Photo-heliograph Dome.

(left) The Airy Transit Circle that stood in the Main Building of the Royal Observatory from 1855 to 1950. With this instrument both coordinates of a star's position could be read simultaneously. The elaborate counterweight system was used to relieve the weight on the precision bearings. The north wall of the Transit Room had to be moved outwards in order to accommodate this telescope.

Astronomical Photography

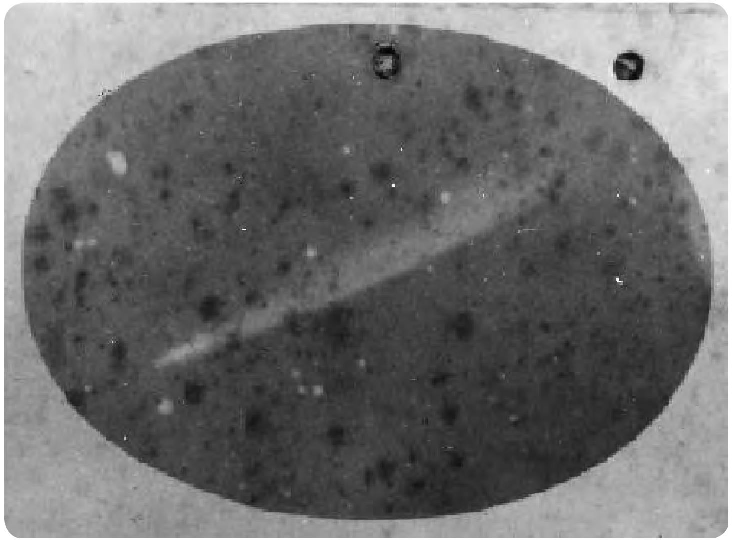
The Royal Observatory was a pioneer of astronomical photography. Though astronomical photography had been tried before, it involved wet chemicals and was very insensitive, making it unsuitable for use with telescopes. During the 1870s a new process was introduced, called "dry plate" photography and by 1879 it was available commercially. This was the background against which photography was introduced to serious astronomy.

In 1882 a comet was noticed by W.H. Finlay, then First Assistant, as he walked home in the early morning. This later became so bright that it could be seen even in the day. But what changed everything was that it could be photographed.

Gill was surprised to receive a letter from a Mr Simpson of Aberdeen in the Cape Colony, with a picture of the comet. In the background were some images of stars. He immediately realized that a new and ideal method for making star catalogues had appeared. Instead of the laborious process of observing individual stars one-by-one, photography could be used to obtain images of a large field of stars at once. The glass plate negatives offered a permanent record that could be checked at any time and was not dependent on the eye of any individual astronomer.

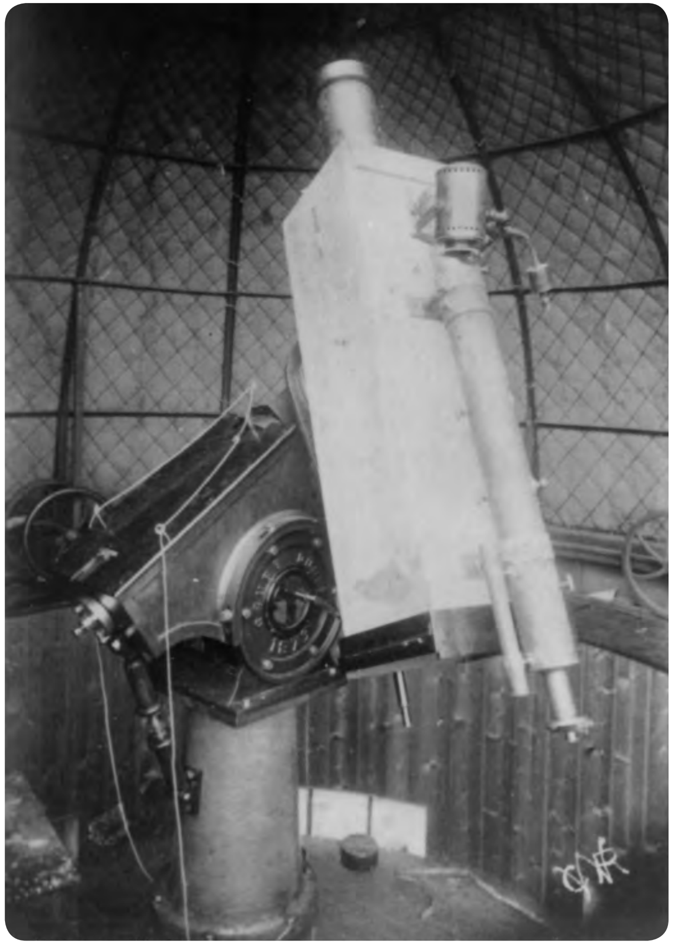
Gill realized that to take long exposures it would be necessary to follow the sky as the earth rotated. He resolved to make some experiments and borrowed a camera with a portrait lens from a local photographer, Mr E H Allis of Mowbray. He strapped this camera onto the side of the 6-inch telescope and tried some long exposures. They were everything he had hoped for and he lost no time in sending prints to his colleagues in Europe (Gill later purchased the lens from Allis and it can be seen in the Astronomical Museum).

Next he set about cataloguing the southern stars. In the north, a catalogue called the Bonner Durchmusterung containing 324 198 stars had been completed in 1863 using the traditional visual methods



(top) This photographic print by Mr Simpson, a photographer in Aberdeen, Cape, called Gill's attention to the possibility of mapping the stars by photography. The spectacular comet of 1882 is seen with stars in the background (the dark spots are mildew on the print).
(bottom) Gill's photograph of the comet taken with a portrait lens borrowed from a local photographer, Mr E H Allis of Mowbray.

and enormous effort. Gill's plan was to do the same for the southern hemisphere using the new photographic technique. He applied for money to carry out his project, the Cape Photographic Durchmusterung, but was thwarted by intrigues on the part of the Astronomer Royal in England, who had become jealous of him. He decided, with the agreement of his wife, that he would devote half of his own salary to the project, which "cost him a great many domestic economies".



(left) The CPD Telescope was the first photographic survey telescope, designed by Gill. At the top was a 15-cm Dallmeyer portrait lens and at the bottom of the square wooden tube was a photographic plateholder. The small telescope in front was used for visual guiding. The lens is in the Astronomical Museum. (right) The "Wind Tower", a building constructed in 1841 that once served as an anemometer. The dome was installed by Gill. Inside can be seen the CPD telescope. This pretty building served various purposes until it was demolished around 1966 on account of its poor condition.

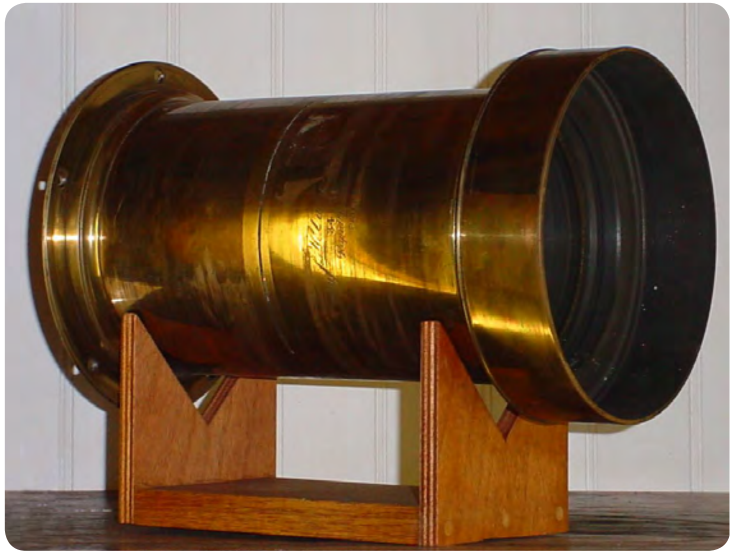
To carry out the work, he needed a wide-angle lens that did not distort the images. Lens theory was then quite primitive and the most suitable one that gave good images over a large angular field was the "Rapid Rectilinear" invented and manufactured by JH Dallmeyer of London. He obtained one of six inches (15cm) diameter that he mounted on the end of a long wooden tube. A holder for glass plates was attached at the other end. Mounted beside his photographic tube was a long-focus refracting telescope used as a guider because the primitive clockwork of the telescope was not accurate enough to track the stars exactly.

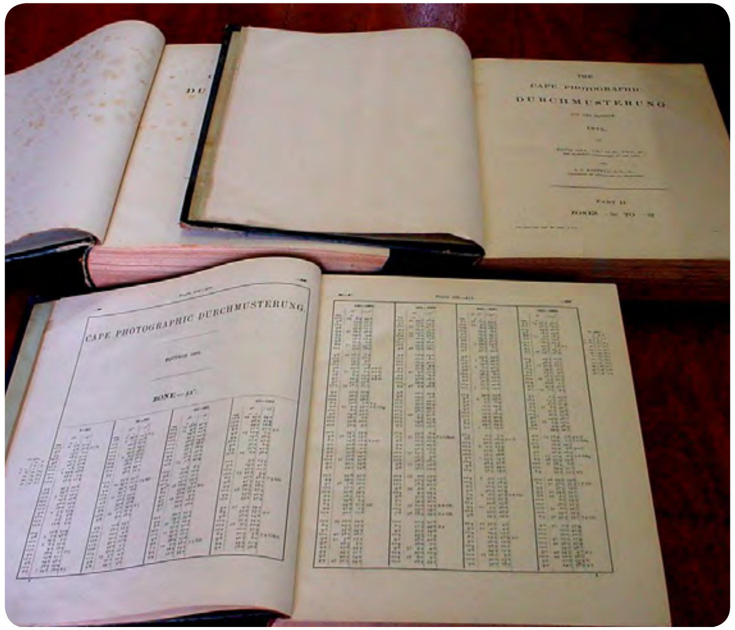
It was one thing to make thousands of photographs of the sky but quite another to measure all the plates and "reduce" the data into sky coordinates. Gill was fortunate to have made the acquaintance of an energetic Dutch astronomer, Jacobus Kapteyn (1851-1922) of Groningen, who undertook to organize all the measuring work.

The resulting three volumes, known as the Cape Photographic Durchmusterung, which contained 454 875 stars south of –19°, was published in 1895 – 1900. Every one of these stars was measured off the plates by hand and eye. Kapteyn used a special measuring machine of his own design that can be seen today in the Boerhaave Museum in Leyden.

In the hands of Kapteyn and others, and with repeats, the CPD was used to study the movements of stars in the sky. The "star streams" discovered by Kapteyn were among the first clues that led to the discovery of the Milky Way as a galaxy and to understanding our place within it.

The measurements of the many photographic plates taken each night and the "reduction" of the measurements to standard astronomical coordinates was necessarily a very tedious and time-consuming process. For this reason, a large staff of people called variously "computers", "supernumerary computers" and "lady computers" were employed to carry out the necessary computations. Many of these people stayed for only short periods because of the tedium of the work.





(top) The 6-inch Dallmeyer "Portrait Lens" that Gill used to make his first sky survey. (bottom) The three volumes of the Cape Photographic Durchmusterung, the first star catalogue produced by photography.

Photometer developed by A W J Cousins and built at the Royal Observatory. It was used for precision photometry of southern bright stars, mainly on the 18-inch telescope.

Photometry

The work of the Observatory for the first half of the century concentrated on repeating the photographic catalogues from the end of the 19th century, mainly with the idea of finding the proper motions of the brighter stars, but also their magnitudes (apparent brightnesses) and their spectral types.

During its last few decades, the area in which the Royal Observatory made the greatest mark was in photometry: the measurement of magnitudes. After the Second World War this became one of the main areas of interest. It might be thought that photographic plates would have revealed accurate enough magnitudes, but they are good only to about 10%, and even then over a limited range. The conventional technique was to relate the size of the image to the brightness of a star – thanks to the characteristics of photographic material the image was larger for brighter stars, but not in a very direct way.

The Royal Observatory pioneered an unconventional way of measuring magnitudes by photography that involved de-focusing the images and measuring their photographic density by means of a device called a microdensitometer. This “Fabry Method” gave a modest increase in accuracy but was very tedious to use. The future Nobel prizewinner, Allen Cormack, worked on this programme as a summer student in 1944 under R H Stoy, then Chief Assistant.

It may be asked why the magnitudes (brightnesses) of stars are such an issue. They are of central importance to measuring distances in astronomy. Certain stars have closely predictable wattages and if we can measure how bright they appear we can tell how far away they are, using the well-known inverse square law of optics. In fact, our entire knowledge of the size of the universe ultimately depends on the measurements of star brightnesses.

Alan Cousins

In 1947 Alan William James Cousins, a distinguished South African amateur astronomer with a long record of publications, was hired by the Royal Observatory to participate in its photometric programmes.

Around 1950 the Observatory was visited by the American astronomers J B Irwin, A N Cox and I R King who brought with them more sophisticated new photometers for measuring magnitudes. These made use of photomultiplier tubes, a new type of light detector that had been developed during the Second World War. The essential feature of these tubes is that unlike photographic plates they respond very exactly (linearly) to the light that falls on them. Cousins then developed equipment, such as high-voltage power supplies and electrometers (devices for measuring very feeble currents) for use with these tubes that eventually made the Royal Observatory the centre for precision photometry in the southern hemisphere.

Much of his success was due to the highly systematic way in which he set about his work, eliminating every kind of influence that could impinge on its accuracy. He was to be found observing every usable night until his 90th year with the 18-inch telescope.

It is rather remarkable that some of his most famous work was done after his retirement in 1972. He developed a UBVRI (Ultraviolet, Blue, Visible, Red and Infrared) photometric system that was widely recognised and used. In retirement he even discovered a new class of variable stars called after the type-star, Gamma Doradus. Cousins's record of publication extended over 77 years, from his first paper as an amateur to his last one (with JAR Caldwell) in 2001. This record has not been equaled.

Cousins the young astronomer.

Deterioration of the site

The Salt River railway yards were such a source of air pollution in the days of steam trains that precision measurements were impossible when the wind was blowing from their direction. But until the last few years, the southeaster wind that blew across the Cape Flats brought clean air that was ideal for observing. Only in the last few years have developments of the city made the air too dirty when the winds are blowing from this direction also.

By the 1960s, light pollution also became a problem. When the sky is too bright due to city lighting it becomes impossible to observe faint objects. Much city lighting is very wasteful in the sense that it shines upwards instead of downwards where it is needed.

Ever since the Observatory was founded the steadiness of the air has been a problem. In the early nineteenth century it had not yet been realized that certain high-altitude sites offer much better conditions for observing fine detail in the sky than typical places in Europe or indeed in Cape Town. A clear sky is not the only requirement for astronomy; the sky must also be dark, the air must be clean and there should be little atmospheric turbulence.

In the 1960s, the observatories in South Africa together with the European Southern Observatory embarked on a "site testing" programme with the idea of finding a suitable site in the countryside where conditions were as near to ideal as possible. Measurements included percentage of clear nights and seeing quality (the steadiness of the atmosphere). This resulted eventually in the selection of Sutherland as a suitable location, partly because it offered reasonably good weather in all seasons.

Site testing at Sutherland in the late 1960s.
(left) Constructing the temporary observatory.
(right) J Churms inspecting the double-beam telescope for monitoring the seeing quality.

Latter days of the Royal Observatory

Gill's follower as His Majesty's Astronomer was Sydney Hough (1907 – 1923). He had been First Assistant before and did not introduce any revolutionary changes. His successor was Harold Spencer Jones (1923 – 1933) from the Royal Observatory, Greenwich who rejuvenated some of the traditional programmes. His most important projects were a spectroscopic programme on Nova Pic 1925 (with Lunt) and work on the earth – Sun distance using the minor planet Eros.

The next HM Astronomer (1933 – 1950) was John Jackson, formerly Chief Assistant at Royal Greenwich Observatory, a rather dour Scot who concentrated on the grinding routine of parallax observations. The number of accurate parallaxes was then still quite small and he added considerably to them. Of course, today, this type of work is almost completely the domain of specialized satellites.

The Chief Assistant from 1935 to 1950 was R H Stoy, a former student of Eddington's who had also had experience in the famous Lick Observatory in California. Although he too was bogged down by the inherited routine programmes of the Observatory, he became interested in developing photometry, for which the establishment became justly famous.

On becoming HM Astronomer, he introduced the first reflecting telescope, the 18-inch reflector, which enabled ultraviolet observations to be made for the first time (the glass of a refractor does not transmit at this wavelength) and this was used most successfully by Cousins. He also obtained funds for the new 40-inch (1-m) telescope which was installed in 1964 and still exists, though moved in 1972 to Sutherland. Stoy was also conscious, perhaps as a result of his California experience, of the need to find a better observing site away from the city lights and air pollution. He, with D S Evans, commenced a programme of site-testing in the Karoo in 1967 (see previous page). Stoy became an honorary professor of astronomy at the University of Cape Town in 1958, which can be regarded as the beginning of that department. Numerous students were given the opportunity of observing during the long vacations.

In 1960 the Royal Observatory Cape became in effect the southern division of the Royal Greenwich Observatory of the UK. In 1965 the Science Research Council of the UK took over the running of the Royal observatories from the Royal Navy. From being a small, almost negligible, item on the naval budget the observatories thereafter had to compete for funds with British academic institutions and became subject to increasing criticism, which eventually proved fatal to their existence.

J W Jackson, the penultimate HM Astronomer

R H Stoy, the last HM Astronomer.

The people of the Royal Observatory

The number of astronomers was always quite small. The astronomical staff consisted of HM Astronomer and two to five assistants. At first there were no calculating machines to help with the heavy burden of data reduction. A small army of clerks and lady and gentleman computers were always busy with this task. In fact, astronomy was one of the biggest users of mathematical and computational power and some of the pioneers of statistics such as Bessel and Gauss were drawn from its ranks. One of the Royal Observatory astronomers, William Mann, even "moonlighted" as a statistician for a local insurance company.

In the 19th century there were usually a few white labourers and artisans for maintenance work on the instruments. As time went on, formal workshops were set up for instrument building and electronics.

Of the early black staff relatively little is known. Gill obtained the services of two or three Kroomen (seafaring men from the West African coast near the present-day Ghana and Côte d'Ivoire) from the Naval Dockyard in Simonstown. These acted as messengers and groundsmen and wore sailors' outfits. By the end of the Royal Observatory about ten or twelve South African blacks and coloureds were on the staff.

(left) The Observatory staff in 1897. David Gill is second from the right. First from the right is Willem de Sitter, 3rd from the left is Robert Innes and 5th from the left is SS Hough, later HMA. The ladies were presumably computers.
(right, clockwise from top-left) Lady computer at adding machine, Measuring a plate, Instrument Workshop, Listening to wireless time signals.

Birth of the South African Astronomical Observatory (SAAO)

In the late 1960s the Royal Observatory had been transferred from the Royal Navy to the UK Science Research Council (SRC). Partly as a result of political pressure and partly as a result of the increasing disenchantment of the British astronomical community with the traditional astronomy of position, the SRC decided to close down the Royal Observatory. This led to a loss of morale. The last HM Astronomer, R H Stoy, left in November 1968 for a position at the Royal Observatory, Edinburgh.

However, the South African Council for Scientific and Industrial Research (CSIR) forged an agreement with the SRC to form a new organization to pursue astronomy in South Africa, financed for a limited time two-thirds from South Africa and a third from the UK. The personnel expenses were taken over by the new organization and a new observatory was to be constructed at Sutherland in the semi-desert Karoo region, near where the seeing tests had been carried out.

The SAAO came into existence formally on 1 January 1972. The Royal Observatory, Cape of Good Hope and the Republic Observatory (formerly the Union Observatory and before that the Transvaal Observatory) were combined and a new field station was already under construction at Sutherland.

The relatively new 40-inch (1.0-m) telescope of the Royal Observatory (built in 1964) and the 20-inch (0.5-m) telescope (1968) from Johannesburg were moved to Sutherland. Observations started at Sutherland in mid-1972 and the official opening took place in April 1973, attended by Mr B J Vorster, Prime Minister of South Africa and Mrs M Thatcher, UK Minister of Education and Science.

Sir Richard Woolley, who had just retired as Director of the Royal Greenwich Observatory, was appointed director of the new institution. As most of the former Royal Observatory staff continued in place, they continued to carry out its traditional activities, especially in photography with the Astrographic and McClean telescopes, daily photography of the Sun with the Photoheliograph and the Lyot camera and fundamental measurements of stellar positions using the Gill Reversible Transit Circle. However, these activities were gradually phased out over the next decade or so. Precision stellar photometry of bright stars by Cousins carried on until he became about 90 years old. His work was continued for a number of years in the better climate of Sutherland.

A number of new staff members were appointed, for the most part research astrophysicists. They worked as individuals rather than as cogs in a massive data production machine. Most of them were researchers who had either just received their doctorates or were studying part-time towards them. A few were on secondment from the Royal Greenwich Observatory. They typically defined their own research programmes and received telescope time at Sutherland with which to carry them out. Their output was measured in terms of the number of refereed research papers that they published in the academic journals.

In 1975 the Radcliffe Observatory, a private British foundation, was closed and several of its staff astronomers accepted positions with the SAAO. In 1974 a new 30-inch (0.75-m) telescope had been acquired and in 1976 the 74-inch (1.9-m) telescope was bought from the Radcliffe Foundation and moved from Pretoria to Sutherland. Built originally in 1938, this telescope had to be considerably updated and it became the main instrument for the study of faint objects. In 1988 the SAAO became an institute of the Foundation for Research Development. This is now the National Research Foundation.

SAAO Directors

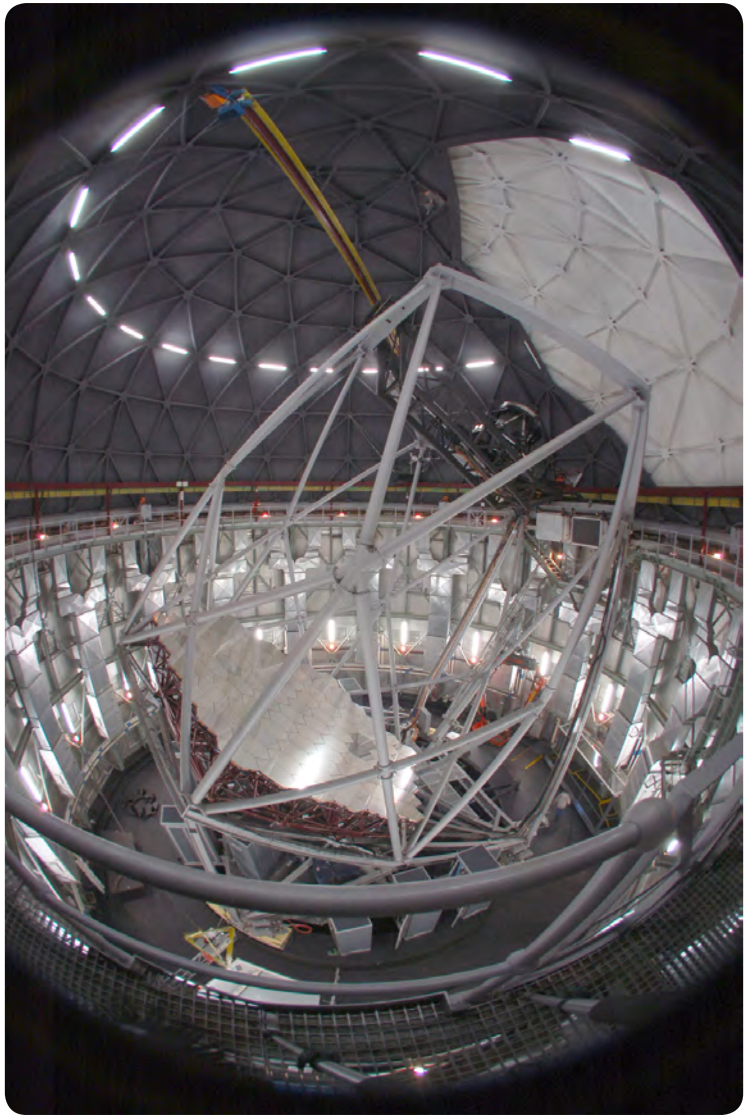
Sir Richard van der Riet Woolley	1972 – 1977
Michael William Feast	1977 – 1992
Robert Stewart (Bob) Stobie	1992 – 2002
Patricia Ann Whitelock*	2002 – 2003
Peter Martinez*	2003 – 2004
P A (Phil) Charles	2004 – 2011
Patricia Ann Whitelock	2012
T B (Ted) Williams	2013 – 2017
P S M (Petri) Väisänen	2018 – present

**Acting Director*

Southern African Large Telescope (SALT)

In 1987, at the request of the SAAO board, I S Glass put forward a proposal to construct a large telescope at Sutherland. This was presented to the Advisory Board of SAAO but no action was taken until R S Stobie was appointed Director with a mandate to look into this possibility. Although a considerable effort was put into costing out a 3.5-m altazimuth telescope this project went nowhere.

Around 1999 however, an offer was made to copy the Hobby-Eberly telescope in Texas, a special-purpose spectroscopic telescope that offered a large collecting area at much less cost than a general purpose instrument. This proposal was eventually financed to the tune of R 50 million by the Department of Arts, Science and Technology. The new telescope – SALT, the Southern African Large Telescope – has a main mirror with a diameter of about 11m. A number of foreign countries and individual institutions contributed to this project, of which South Africa now owns about a third. A separate entity was set up to manage SALT and the SAAO was contracted to take care of its administration. The original design of the Hobby-Eberly telescope was improved in various ways and construction was completed in 2005, though serious teething trouble delayed its full use until 2010. President Thabo Mbeki of South Africa did the official opening on 10 November 2005.



New Wavelength Regions in Astronomy

The immense changes in physics and electronics during the 20th century have broadened the scope of astronomy. Radio signals coming from space were identified by Karl Jansky in 1935 but his work was ignored by mainstream astronomers. Only towards 1950 did interest pick up.

South Africa owes its main radio telescope to NASA who erected a 26-m diameter dish for satellite tracking purposes in 1961 at Hartebeesthoek. In 1975 it was handed over to the CSIR and was re-equipped for use as a radio astronomy telescope. It has since been used for many astrophysical and geodetical research projects. Subsequently, the Karoo Array Telescope (KAT, with seven antennas) has been constructed and at the time of writing MeerKAT (eventually to have 64 antennas) is under construction. South Africa will be the site for most of the Square Kilometre Array (SKA), an international project.

I S Glass brought infrared technology to the SAAO in 1972. Until about ten years before, detectors were extremely insensitive and only a few bright objects had been investigated. The instrumentation required was quite complex and alien to traditional astronomers. In the following decades SAAO became a leading observatory in the field of measuring the heat radiation from stars and galaxies.

South African physicists, mainly at the University of Potchefstroom (now Northwest), had been interested in cosmic rays, or energetic charged particles that reach the earth from space. Because they were charged, they could be deflected by magnetic fields, so that their place of origin was impossible to make out. However, following the discovery of high-energy gamma rays which, unlike light, are not deflected by magnetic fields, South Africa became a partner in an international gamma-ray telescope located in Namibia.

Technical Building

In 1986 a large “Technical Building” was completed towards the northern end of the property. This included today the instrument workshop (formerly in the building that is now the Auditorium), the electronics department, the drawing office, the optical laboratories and the Cape Town offices of the SALT telescope.

Conservation and Heritage

Conservation of the Royal Observatory site, its buildings, telescopes, museum-worthy items and intangible heritage has become a concern since this is not the primary aim of the South African Astronomical Observatory or its parent organization, the National Research Foundation.

With the need to support the modern observatory at Sutherland and the gradual cessation of night-time work in Cape Town less effort has been available for ongoing maintenance of the Royal Observatory site. The staff that formerly looked after the buildings and grounds has gradually been whittled down. Most repair and maintenance jobs now have to be out-sourced. The condition of the some of the buildings and telescopes has deteriorated, particularly those not in frequent use. Many of the exteriors have however been painted and otherwise maintained as funding has allowed. A particular problem is that the servicing of the hydraulic rising floor of the McClean telescope, always a favourite with visitors of all ages, needs to be carried out frequently. Invasion of the domes by bees and starlings has also been a problem.

In recent years, various staff members and others have worked towards preserving the heritage of the Royal Observatory. A group known as "Friends of the Cape Town Observatory" has encouraged maintenance and endeavoured to keep up interest. Mary Stobie and Anne Charles, the wives of former directors, have contributed greatly, as have many others.

Natural History of the Site

The site is to some extent isolated from its urban surroundings by the two rivers, the Liesbeek and the Black. To the north and east are wetlands that form a sanctuary for bird life. Near its northern boundary is a bird hide that overlooks the vlei area. In winter, flamingos, geese, ducks and many other birds can be seen.

During the last few years funds were made available to commission an important study of the site, resulting in the *Observatory Landscape Framework*, by Liesl van der Walt and Nicole Strong. This was intended as a tool to inform and guide its future development and conservation. In essence the study sought to find a balance between the functioning of ecological processes, conservation of valuable historical elements and the contemporary needs of people who use the site as a workplace, home and educational facility.

A tree inventory was compiled as part of this study, indicating that there are more than 116 species of trees and shrubs on site. Many of these are exotics such as pine and eucalyptus, planted as fast growers, to provide shade and windbreaks. Some are today regarded as invaders, but others such as the stone pine are suitable for re-planting. There are, however, parts of the grounds that retain their original vegetation.

This study was complemented by a report written by Penny Mustart, giving the botanical history of the site and the needs of certain areas specifically worthy of conservation.

Bird hide at the north end of site, overlooking seasonal wetlands. This was erected by the Two Rivers Urban Park (TRUP) in 2008.

The site supports many wild flowers but is especially known for the Moraea aristata, a member of the Iris family, that flowers around mid- to late-August. This is the last area where these bulbs occur in their original habitat. Porcupines also inhabit the area and are known to dig up the bulbs.

Each year the grassy area containing the rare Moraea aristata plants, which flower around the end of August, is left unmown until the seeds have had time to germinate.

Planting of a wind break along the southern border using *Tarchonanthus camphoratus* (camphor bush) has been very successful. Also, along the side of the Liesbeek canal a number of *Carissa macrocarpa* (num-num), a prickly bush, have been planted to discourage intruders. In addition, indigenous trees have been planted at various locations, including some yellowoods that act as memorials to particular people.

The gardens at present are maintained at a very basic level. Many of the old paths are overgrown with grass and the picturesque brick gullies are in a poor state or have been cheaply repaired by covering with cement. Though a consultant horticulturalist works one day a week, more effort both at a supervisory level and on the ground is needed to make them more presentable.

The site was noted in the past for the extraordinary number of snakes that abounded there, though today they are only rarely seen. On one day during the construction of the Main Building as many as 90 were killed. Mammals such as mongoose, porcupine, skink, bats and squirrels are still found. The endangered Western Leopard Toad *Bufo pantherinus* is well-known on the site, which is approximately their northern limit. In addition there are a number of frogs – the Cape River Frog, the Clicking Stream Frog, Cape Rain Frog and Cape platanna.

Heritage Status

The Royal Observatory site has not until now been declared a National Heritage Site (or, under the former regime, a Historical Monument), largely due to the fear that this might limit changes that become necessary for its efficient functioning as a living institution. In spite of this, the buildings older than 60 years are already protected by law, at least in principle.

Various interested parties have engaged with the South African Heritage Resources Agency (SAHRA) in the hope that they will declare the Observatory a National Heritage Site, in order to protect it from land grabbing, leading to undesirable development. SAHRA has already given the site Grade I status.

In 2011, the heritage architects Nicolas Baumann and Sarah Winter were engaged to produce a report for use towards a declaration. They surveyed 99 structures of various kinds on site and produced a report indicating that 43 of these are worthy of protection. Buildings classified by them as Grade I are the Main Building and the McClean Telescope and Laboratory.

Heritage Objects

At the Observatory are preserved large numbers of "heritage objects" in addition to the telescopic equipment and other items mentioned earlier in this book

Many of the smaller instruments and historical items are on display in the Astronomical Museum attached to the McClean telescope (see p 70). However some of the larger measuring machines and historical regulator clocks are too big to display there. In the library there are celestial and terrestrial globes and some antique furniture such as Maclear's office chair. In the former transit room are two antique Fortin-type barometers and in the former mural circle room are prints and portraits of former astronomers including a fine portrait of Gill by GM Winkles (see p 16), an artist who practiced in Cape Town.

On site, though not often on display, are some pictures by T W Bowler, the artist who came to the Cape to work at the Royal Observatory. There are also many landscape and mountaintop

The endangered Western Leopard Toad.

drawings made in the 1840s by Piazzi Smyth during expeditions to perform geodetic surveys. A number of architectural plans are still in existence.

There is a large collection of photographs from the mid-nineteenth century onwards, covering the construction of the Observatory's buildings, astronomical objects, famous astronomers and observatories from around the world.

Most of the archival material of the Royal Observatory was sent to the Royal Greenwich Observatory in 1971. However, a considerable number of bound volumes of letters and other documents from the Gill and later periods are still present. To these have been added correspondence from the SAAO period. Unfortunately some of the early volumes were improperly stored and were damaged by flood waters, probably in the 1960s.

Riefler regulator clock from 1910 with electrical remontoire movement. Clocks of this kind were among the most accurate mechanical clocks ever built. This one was used at the Transvaal/Union/ Republic Observatory.

The Astronomical Museum

In such an old institution as the Observatory there was inevitably a large amount of disused equipment scattered all through the around 60 structures on the property. Many items were in poor condition or were covered in dust. Some antique items had been sold off or had found their way into peoples' private collections. Various instruments thought to be safely stored turned out to have been stolen by a thief on the staff. Some of us therefore felt it was necessary to gather together as much as possible of what remained.

During the 1970s and 1980s the spectroscopic laboratory attached to the McClean telescope was used as a laboratory for the preparation and testing of infrared equipment. However, when the Technical Building was completed in 1986 the old laboratory was no longer needed. Permission was obtained to turn it into a museum and, using minimal funds, the original glass-fronted cabinets were provided with illumination. The cabinets are devoted to particular themes. One of these is computing.

Computing (see Cabinet no. 2) has always been an essential part of astronomy. Over the years, many people with job titles such as "Established Computers" and "Lady Computers" were employed. They usually did not stay very long because the work was so boring, but a job at the Royal Observatory was considered very respectable and the hours were quite short! In the early days, Crelle's multiplication tables were essential. The advent of mechanical calculators simplified some of the tasks and eventually digital computers arrived. At first the data had to be fed into them using punched paper tape and punched cards.

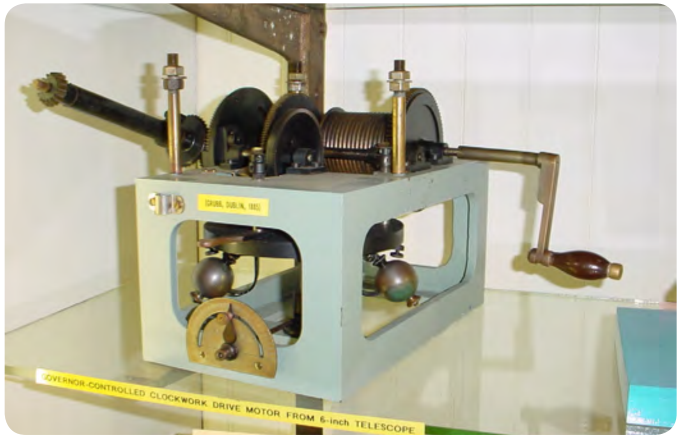
In Cabinet no. 3 is some of the equipment used for picking up the faint signals from the stars. The photomultiplier was for many years the main device for photometry – the measurement of the light intensity – but it could measure only one point in the sky at a time. Later on, image tubes such as the Spectracon and television camera tubes such as the SEC Vidicon allowed many “pixels” or points in an image to be measured at once. These devices have now been superseded by the “Charge-Coupled Device” or CCD.

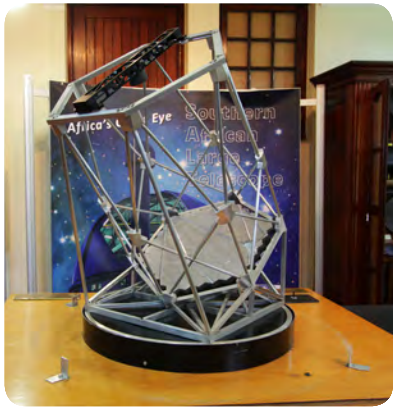
Early photographic equipment is displayed in Cabinet no. 4, including the lens borrowed by Gill from Mr Allis to make his first images of the Comet of 1882 (see p 53) and the Dallmeyer portrait lens used to make the Cape Photographic Durchmusterung (p 55).

Relics of the early days such as the signal pistol used by Maclear to convey time information to ships moored in Table Bay are on display in Cabinet no. 5. In the same cabinet are lenses from the early telescopes and parts of the Airy Transit Circle.

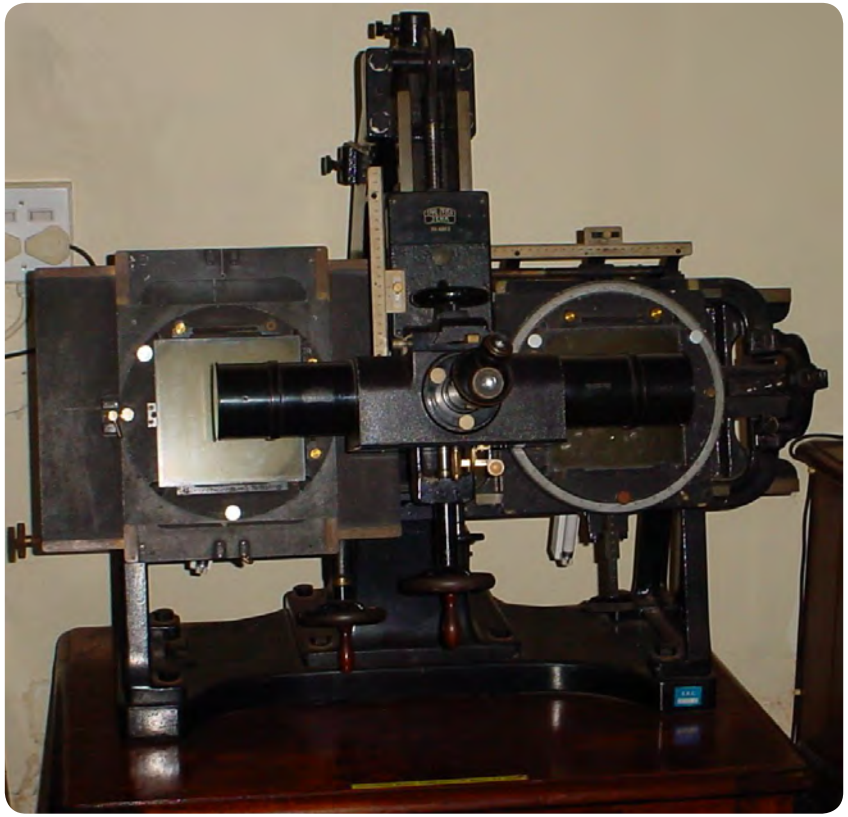
In Cabinet no. 6 some later equipment developed at the Observatory in the twentieth century for measuring the brightnesses of stars in both the visible and infrared regions are also to be seen, as well as old laboratory equipment.

Two small alt-azimuth telescopes can also be seen. The first is a “Repeating Transit” by the Dollond Company of London and used in the early days of the Observatory. The second is a “Universal Instrument” by Carl Bamberg of Berlin, dating from around 1900 and borrowed from the Imperial Observatory in St Petersburg. It was used at the Union/ Republic Observatory for many years in connection with the national time service.





Some items from the Astronomical Museum.
(top row) Mirror made by William Herschel, lens from Airy Transit Circle, original motor of 6-inch telescope. (middle row) Model of 74-inch telescope, model of SALT, material from Koue Bokkeveld Meteorite. (bottom row) Dollond Repeating Transit, card punch, Nova minicomputer front panel.



More Museum items:
(top row) Zeiss blink microscope, objective prism used with McClean telescope, end-window photomultiplier tube. (bottom row) Circular slide rule, original D.C. motor used with hydraulic rising floor of McClean dome, eyepiece end of Airy transit circle.

History of the Built Environment

Before Colonial times, the Observatory site was probably summer pasture used by the indigenous Khoisan for their cattle. Soon after the arrival of the Dutch, the area between the Black and Liesbeek rivers lay on the boundary of their settlement and a defensive palisade fence ran through the future site of the Observatory.

The land for the Royal Observatory was acquired in four separate transactions. The large area marked “FREEHOLD” on the 1888 map (see next page) is the original erf obtained by Fallows in 1824 and the large area marked “QUITRENT” was added in 1827. The smaller pieces, which lie in the floodplain, were purchased in 1840 and 1843, probably to improve access.

The Main Building was begun in 1825 and finished in 1828. The stables and some outbuildings date from 1836. Otherwise, only a few temporary structures appear on early maps and pictures. Until the installation of a windmill-driven water pump (see front cover picture) by Piazzi Smyth in 1836 the hilltop was rather barren.

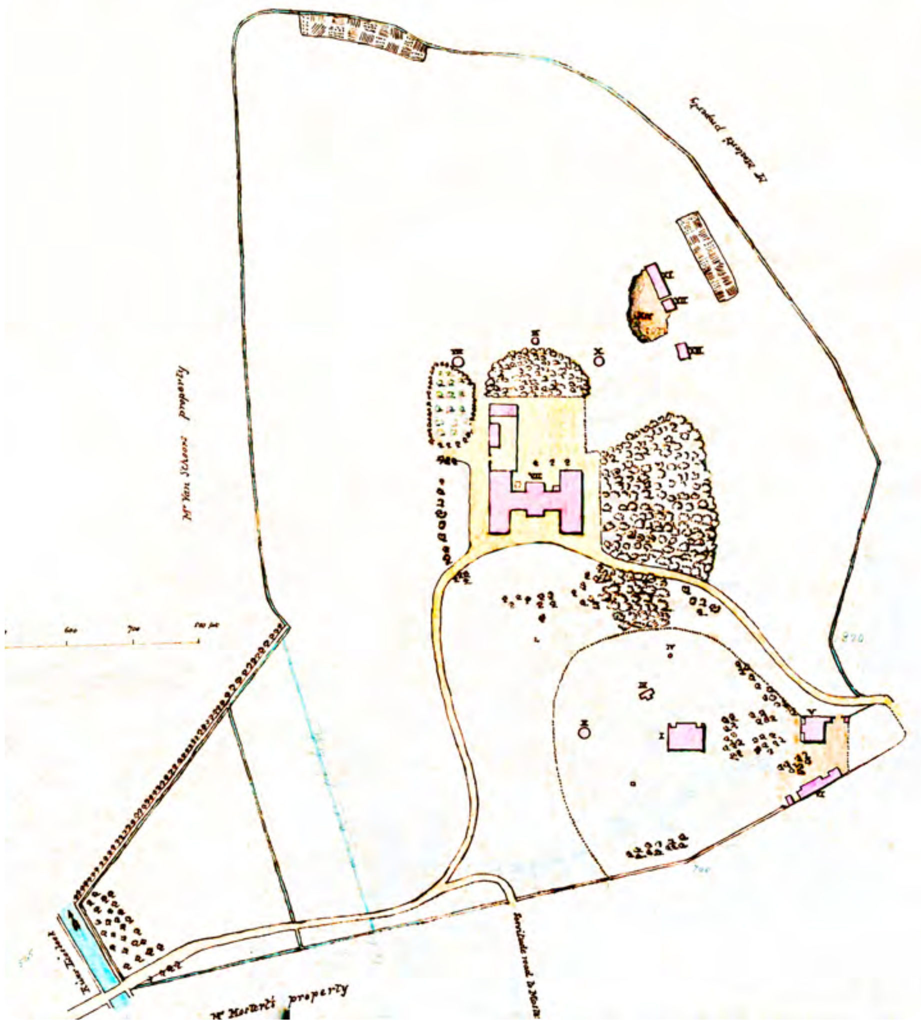
Aerial photos from the 1950s (top) to today (bottom).

In 1841 a Magnetic Observatory was erected in the SE corner of the site. As shown on the 1850 map, it was fenced in and comprised several buildings. One of these is part of the residence that still exists today in the SW corner and another (the “Intensity House”) was probably incorporated into Quarters 6 (Jacaranda House) around 1865. The main Magnetic building, no longer extant, was made of massive wooden beams fixed together with non-ferrous nails and lined inside, to create a suitably stable environment. It had dimensions of 14.6-m × 8.5-m. Another building was the “Wind Tower”, a cylindrical edifice that at first contained a form of anemometer and was perhaps named after the Tower of Winds in Athens. It afterwards supported a telescope dome until demolished in 1966.

The 1850 map also shows small buildings to the NE of the Main Building, used as storerooms and a carpenter’s workshop. Like other low-lying parts of the site, this area is subject to occasional flooding. The buildings here survived until the Technical Building was constructed in 1986.

When David Gill became HM Astronomer in 1879 he initiated a period of rapid expansion. Many of the structures seen today, such as the Astrographic and McClean telescopes as well as most of the residences date from his time. The Observatory had one of the earliest electrical generating plants in the country, situated in the first workshop building shown on the 1888 map near point “B”.

In the 20th century the main addition was the Technical Building (1986). The largest telescope on site, the 40-inch of 1964, was moved to Sutherland in 1971 and its dome was demolished. Other significant buildings are the Administration block, dating from 1930, and the Auditorium, a former workshop, from World War II. The latter was originally constructed as a repair centre for military optical instruments during the War. Around 1960 the Liesbeek river was diverted from its original course into a canal that runs along the western boundary of the Observatory.



(left) The 1850 map shows two domes (the western one is the Photoheliograph) and two time-balls north of the main building as well as the Magnetic Observatory to the south-east. (right) The 1888 map shows the start of the rapid development that occurred under the Gill regime. Most of the buildings still exist (see map on p 80).

Glossary

Magnitude: The brightness of celestial objects is measured in magnitudes. The brightest star, Sirius, has magnitude –1.4 and the faintest ones that are visble have magnitude about +6. Though magnitudes were at first subjective estimates they were later made quantitative. A difference of 5 magnitudes corresponds to a factor of 100 in brightness.

Zenith: The point in the sky directly above any place.

Meridian: The meridian of a place is a line in the sky running from north to south and passing through the zenith.

Parallax: This is the angular amount by which a nearby star seems to move compared to the more distant background when viewed from the two ends of a baseline equal to the radius of the earth's orbit around the Sun. From it the distance of the star may be found. The largest known proper motion is that of the nearest star, Proxima Centauri, at 0.769 seconds of arc, corresponding to a distance of 4.243 light-years.

Proper Motion: The proper motion of a nearby star is its annual apparent motion against the distant stars. The largest known proper motion is that of Barnard's star with 10.3 seconds of arc per year.

Sidereal Time: Ordinary Solar time is based on the earth's rotation beneath the Sun but Sidereal or Star Time is based on its rotation beneath the stars. Because the earth also revolves around the Sun, the Sidereal day is about 4 minutes shorter than a Solar day.

Star Positions: Star positions are given as numbers resembling terrestrial longitudes and latitudes. The ***Right Ascension*** is the Sidereal Time at which the star crosses the meridian and the *Declination* is the angular distance of the star from the celestial equator towards the pole (negative when southwards).

Angular Measure: A circle is divided into 360 degrees; a degree is divided into 60 minutes of arc and a minute is divided into 60 seconds of arc. Thus one second of arc is one part in 1.296 million of a complete circle.

Spectrum: When light is split up in great detail according to its wavelengths, for example by a prism, it forms a spectrum of colours. The colours are sometimes crossed by dark or bright lines and these reveal what chemical substances are in the source of the light. Their exact wavelengths reveal the velocity with which the source is approaching or receding. The temperature of a star can be deduced from its spectrum.

Further Reading

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Historical Section web pages of the Astronomical Society of Southern Africa http://assa.saao.ac.za/sections/history/

Acknowledgments

- The author wants to thank Auke Slotegraaf for laying out the book and many suggestions concerning material to be included.
- Those who contributed photographs.
- Samantha Bennett (Librarian SAAO).
- Computer Dept Staff (SAAO).
- All those who have helped preserve or restore artifacts.
- Those who have studied the history of the RO.

Visiting the South African Astronomical Observatory

The South African Astronomical Observatory (SAAO) is a national facility for optical and infrared astronomy and forms part of the National Research Foundation. The SAAO headquarters in Observatory, Cape Town, is open for night-time visits on the second Saturday of each month at 20:00. Day tours for large groups are conducted by prior arrangement only (tel: 021 460-0025). GPS: 18° 28′ 39.0″ E, 33° 56′ 03.5″ S.

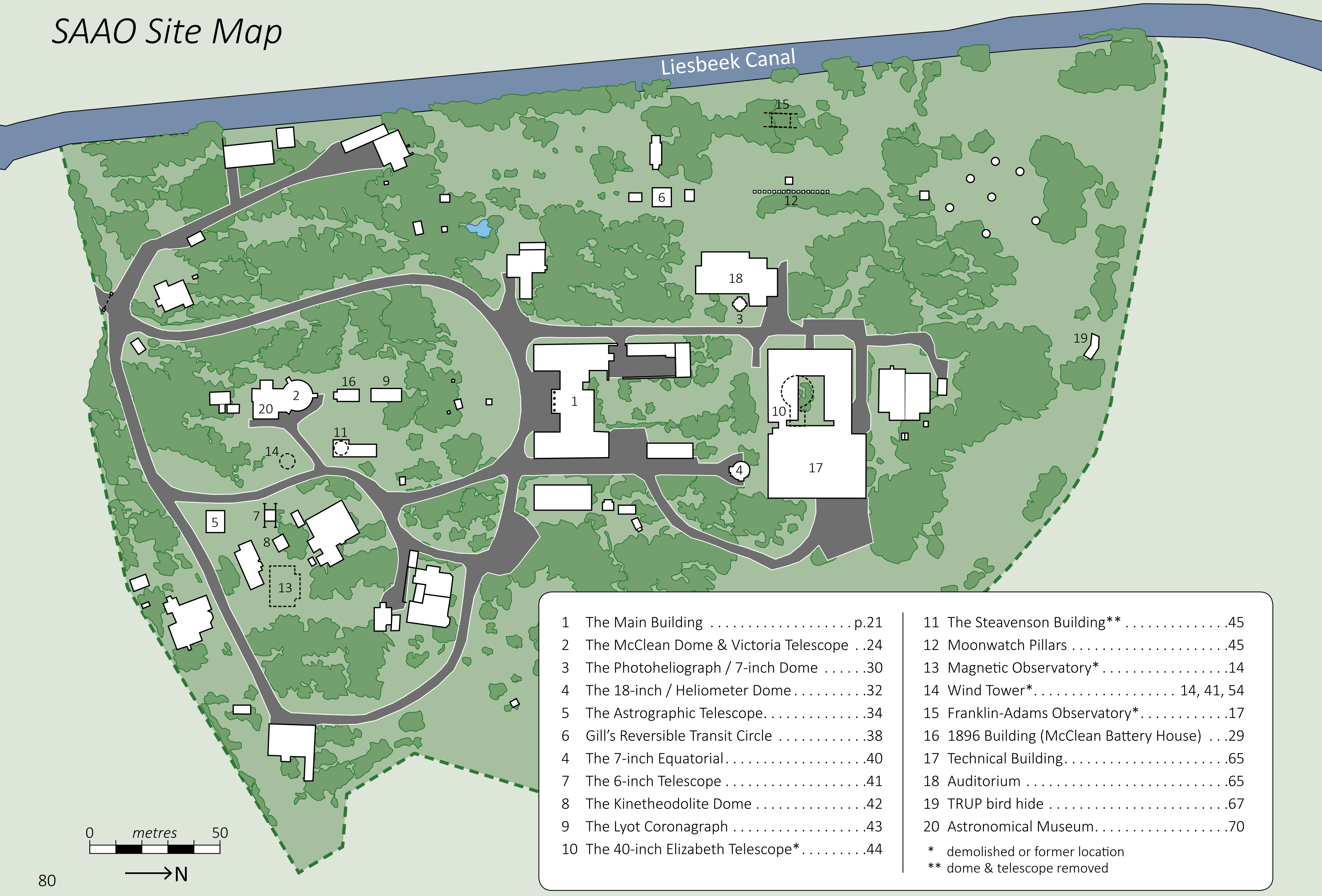
Image Credits

Front cover: *Illustrated London News* 21 March 1857.
2 Drawing by T W Bowler: SAAO.
3 Calotype of Observatory by C P Smyth: Museum of the History of Science, Oxford. Note: Edges trimmed.
4 Flagpole: SAAO.
5 SALT: Paul Kruger, Cape Town.
6 D McIntyre, *Comets in the Old Cape Records*, Cape Times Ltd, 1949.
6 G Tachard, *Relation of the Voyage to Siam*, Robinson & Churchil, London, 1688.
7 La Caille notebook: A892 Abbé Nicolas-Louis de La Caille, Historical Papers Research Archive, University of the Witwatersrand.
7 La Caille portrait by A- L le Jeuneux: Paris Observatory. Photo: ISG.
8 Drawing by T W Bowler: SAAO.
9 Fallows silhouette: SAAO.
11 E Dunkin, *The Midnight Sky*, Religious Tract Society, London, 1869.
12 T Henderson, *Mems Roy Astr Soc*, 11, 61, 1840.
13 Maclear painting: Courtesy Prof Brian Warner.
14 Calotype of William Mann by C P Smyth: Reproduced by permission of the Royal Society of Edinburgh, from the RSE's Piazzi Smyth Bequest, held on deposit at the Royal Observatory Edinburgh.
14 Maclear cartoon: *The Squib* (Cape Town) Vol. 3, No. 55, 1870.
14 Weights and Measures box: AS.
15 Sir J Herschel: P Dudgeon, SAAO.
15 Sketch by J Herschel: SAAO.
16 Gill Portrait by G M Winkles: SAAO.
17 F McClean: SAAO.
17 W de Sitter: Source unknown.
18 Halm sketch: *Cape Times* 19 September 1908 (SAAO).
19 R T A Innes: SAAO.
20 Aerial view of Main Building: Janus Brink, SAAO.
21 RO plan by C P Smyth: *Mems Roy Astr Soc*, 19, 1, 1851.
22 Chase: SAAO.
22 ca 1880 photo of Main Building: SAAO.
23 Colophon from *Almagest*: Photo ISG.
23 Library: Peter Robinson, George.
24 McClean at night: Richard Sessions, Cape Town.
24 Victoria (McClean) telescope: Peter Robinson, George.
25 McClean building: AS.
26 Hydraulic pump: SAAO.
27 McClean laboratory: SAAO.
28 McClean construction: SAAO.
28 Architectural drawings (3): SAAO, Photo ISG.
29 McClean objective prism: SAAO.
29 McClean objective prism spectrum: Photo (print) ISG.
29 McClean Battery House (1896 Bldg): ISG.
29 Young visitors: SAAO.
30 Photoheliograph/7-inch dome: ISG.
30 Photoheliograph: ISG.
31 Chronograph: ISG.
31 Photoheliograph dome etc: SAAO.
31 Photoheliograph: G Forbes, *Transit of Venus*, Macmillan 1874.
32 18-in dome: ISG.
32 Heliometer: SAAO.
33 Heliometer building cross-section: Gill (1913).
33 Cousins at 18-inch telescope: David Laney.
34 Astrographic Building: ISG.
34 Astrographic: SAAO.
35 Astrographic with McClean's prism: SAAO.
35 Astrographic sectional drawing: Gill (1913).

36 Carina nebula 12 hour exp: SAAO.
37 SN1987A (before): SAAO.
37 SN1987A (after): Joseph Churms, SAAO.
38 RTC: ISG.
38 RTC with observer: SAAO.
39 RTC sectional drawing: Gill (1913).
39 RTC Building: Peter Smits collection (via WPK).
39 RTC being reversed: SAAO.
40 18-inch/7 inch: WPK.
40 18-inch dome: ISG.
41 6-inch telescope: ISG.
41 6-inch building thumbnail: ISG.
42 Kinetheodolite dome: ISG.
42 Kinetheodolite with observers: SAAO.
43 Lyot: SAAO.
43 Lyot open: SAAO.
44 40-inch thumbnail: SAAO.
44 40-inch dome: SAAO.
45 Steavenson 1960s: Greg Roberts, Pinelands.
45 Steavenson/Archives Bldg: ISG.
45 Moonwatch pillars: ISG.
46 Gill at desk with Agnes Clerke opposite: SAAO.
47 Chronometer: ISG.
47 Pistol: ISG.
48 RO Time Ball: SAAO.
48 (centre) Photo: J Forshaw (Wikimedia).
48 Noonday gun: SAAO.
49 Molyneux clock: ISG.
50 Mural Circle: W Pearson, *Introduction to Practical Astronomy*, Longmans et al 1824 – 9.
51 Relic of Mural Circle: SAAO.
51 Transit: SAAO.
51 Transit observer: W H Smyth, *Speculum Hartwellianum*, London, 1860.
52 Airy Transit: SAAO.
53 Simpson comet image: W Simpson, in SAAO.
52 Comet image: Gill, in SAAO.
54 CPD camera: C Ray Woods, in SAAO.
54 Wind Tower: SAAO.
55 CPD lens: ISG.
55 CPD volumes: ISG.
56 Cousins photometer: ISG.
57 A W J Cousins: SAAO.
58 (2) site testing: SAAO.
59 Jackson, Stoy: SAAO.
60 Staff group 1897: SAAO.
61 Four photos various activities: SAAO.
62 SAAO Sutherland: SAAO.
64 SALT: Lisa Crause, SAAO.
65 Technical Building: ISG.
66 Aerial image: Janus Brink, SAAO.
67 Bird hide: ISG.
68 *Moraea aristata*: Ann Charles.
69 Leopard Toads: Phil Charles.
70 Riefler clock: AS.
72 Museum: 9 Photos ISG.
73 Museum: 5 Photos ISG.
74 B/W Aerial photos: SAAO; colour Janus Brink.
75 Maps (2): SAAO.
80 General Map: drawn AS.
Back cover: Google Earth (Digital Globe).
Thumbnail maps in main body: drawn AS.

AS = A Slotegraaf
ISG = I S Glass
WPK = W P Koorts
SAAO = South African Astronomical Observatory

SAAO Site Map



* demolished or former location
** dome & telescope removed

This book draws attention to a unique institution that has been part of Cape Town's heritage for nearly two centuries. The former Royal Observatory, now the headquarters of the South African Astronomical Observatory, has been the scene of several important advances in astronomy and deserves to be treasured not only for this reason but also because it is a unique architectural complex.

The large collection of instruments and historic images of the Observatory has been drawn upon to present a pictorial history from its foundation in 1820 up to the present day. Emphasis has been placed on the remarkable work done there and on the extraordinary astronomers who carried it out.

IAN GLASS was born in Ireland and educated at Trinity College Dublin and the Massachusetts Institute of Technology. He has lived in Cape Town since 1971 and has worked for most of his career at the South African Astronomical Observatory, specializing in the infrared. He is the author of several other books – *Victorian Telescope Makers, the Lives and Letters of Thomas and Howard Grubb* (1997), *Handbook of Infrared Astronomy* (1999), *Revolutionaries of the Cosmos – the Astro-Physicists* (2006), *Proxima, the Nearest Star Other than the Sun* (2008) and *Nicolas-Louis de La Caille, Astronomer and Geodesist* (2013).

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