

**John Evershed and Solar Physics
at the
Kodaikanal Observatory**



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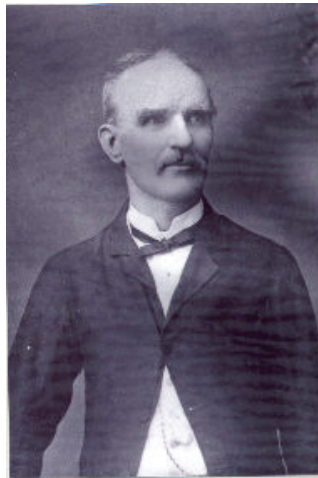


Painting of the Kodaikanal Observatory by an unknown artist (1908)

Historical Background

More than two hundred and twenty years ago, when the East India Company had foot-holds in India only at Bengal, Madras and the Northern Circars, an observatory was started in Madras by the Company “for promoting the knowledge of astronomy, geography and navigation in India”. The observatory grew in the 19th century to be one of the principal institutions devoted to work on the fundamental positions of stars, and until the commencement of activity by the British at the Cape Observatory in South Africa, the Madras Observatory continued to be a principal source of stellar positions for most of the southern hemisphere stars. John Goldingham (1796 - 1805, 1812 - 1830), T. G. Taylor (1830 - 1848), W. S. Jacob (1849 - 1858) and Norman R. Pogson (1861 - 1891) were the successive Government Astronomers who directed the activities in Madras. Under Taylor’s direction, in 1843, after 13 years of painstaking work with a transit instrument and a mural quadrant, a catalogue of 11,000 southern stars was produced by the Madras Observatory, eliciting praise from the then Astronomer Royal Sir George Airy, who called it the ‘greatest catalogue of modern times’.

Norman Pogson, a distinguished stellar and planetary astronomer, whose name is associated with the modern definition of the magnitude scale, was appointed the Government Astronomer of the Madras Observatory in 1861.

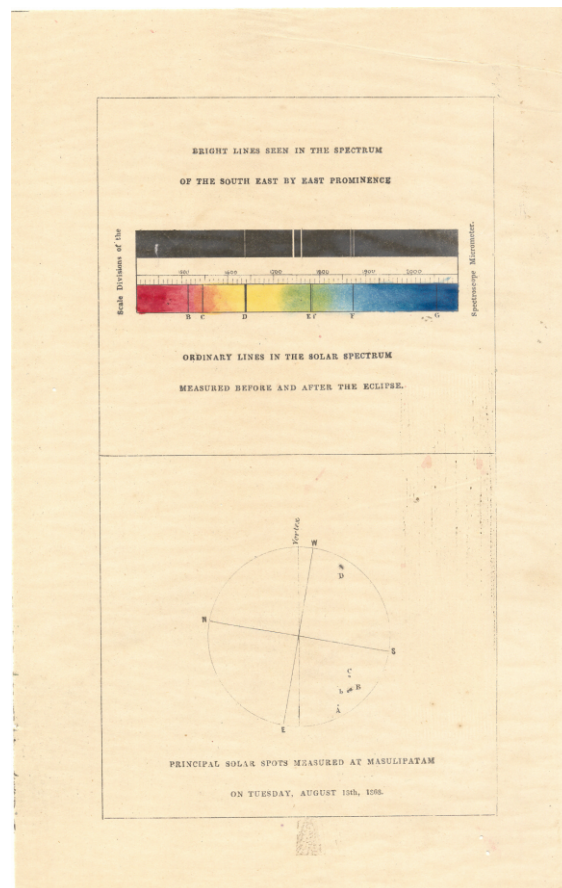


Norman Pogson

The observatory had recently acquired a transit circle by Troughton and Simms which was mounted and ready for use in 1862. Pogson, who had considerable experience with transit instruments in England, put this instrument to good use. With the help of his Indian assistants, Pogson measured accurate positions of about 50,000 stars for the next 25 years. He was burdened with much routine work on magnetic and meteorological observations. Due to scarcity of time available to himself, a lack of trained staff to help him with the reduction of data, and his own pre-occupation with astronomical observations with an 8-inch Cooke equatorial, which he used to study variable stars and also, discover asteroids, Pogson failed to publish the vast body of observations collected at the observatory until 1887, when the first of the three annual catalogues

of individual results and mean positions of each star came out. He managed to publish two more volumes complete with observations taken up to 1870 but most of the results remained unpublished at his premature death in June 1891.

Apart from his own accomplishments in astronomy, Pogson's years in Madras are remembered for another important reason — two total eclipses and one annular eclipse of the Sun were visible from India during the period, to all three of which Pogson led teams from his observatory taking an active part in the events. The first one of these, a total eclipse on August 18, 1868, excited an enormous interest amongst European astronomers and preparations for its observation were made in England and France for many months preceding the event. Teams of professional astronomers from both countries arrived in India and established their camps at Guntoor, on the central line of the eclipse. The Madras Observatory astronomers had their camp at Masulipatam and Vunpurthy further east. This eclipse is of great historical significance as it was the first time when spectroscopes were used during an eclipse event. A new line close to the D₁ line of sodium and to the left of it was seen in the spectrum of the chromosphere. Pogson's hand drawing of the line is shown in the figure below.



The discrepancy in the wavelength of this line with the sodium line was confirmed by Norman Lockyer who could not ascribe it to any known terrestrial element. Helium was discovered. During the same eclipse, observations of the hydrogen Balmer lines in the spectra of the prominences established their gaseous nature.

Historically, the eclipse of 1868 marks the beginning of solar physics. Janssen and Lockyer made effective use of the spectrograph to show that 'red prominences could at any time be examined, without waiting for an eclipse at all'. During the annular eclipse of June 6, 1872, which was visible from Madras, Pogson found the bright chromospheric spectrum flash out for a short duration on the formation and again at the breaking up of the annulus. This is the first observation on record of viewing the flash spectrum at an annular eclipse.

Pogson was much criticised in England because of the slow rate of publication of the work done at Madras. There were questions raised in London as early as 1867 whether the Madras Observatory should be continued at all. The concerned authorities in England had felt that rather than accumulating new observations, the Madras Observatory should concentrate more on publication of the data already obtained. In May 1882, Pogson had proposed a 20-inch telescope to augment the needs of his observatory and had suggested that it could be located at a hill station in South India to engage in the photography and spectrography of the Sun and the stars. The proposal had received active support both in India and Britain and the search for a suitable location in the southern highlands of India was authorised. The task devolved on Michie Smith, Professor of Physics in the Christian College, Madras and a good friend of Pogson, who had arrived in India in 1877. Michie Smith undertook a survey of the Palni and Nilgiri Hills in 1883 to 1885, his observations covering the twin requirements of transparency and steadiness of image during both day and night. But the Astronomer Royal sitting in England dithered on a final decision in clearing the project since he felt 'saddling Pogson with additional work connected with the new large equatorial, when he has accumulated large arrears in observations, would not be desirable'.

In 1879, a Committee was appointed by the British Government, consisting of some leading astronomers in the country, to consider and advise on the methods of carrying on observations in solar physics. One of the tasks of the Committee, which came to be known as the Solar Physics Committee (hereafter, SPC), was to reduce the solar photographs taken daily since 1878 in Dehra Dun with a photoheliograph. The British Government in India had supported the work in the belief that a study of the Sun would help in the prediction of the monsoons, their success and failure, the latter often leading to famines that caused such a havoc. SPC also suggested to the Government of India 'that photographs of the Sun should be taken frequently in order that India might assist towards securing a permanent record of the number and magnitude of the sun's spots and other changes in the solar surface'. At a later date they added that special spectroscopic observations should also be taken in India, in order to collect evidence which will probably throw light on the constitution of the Sun.

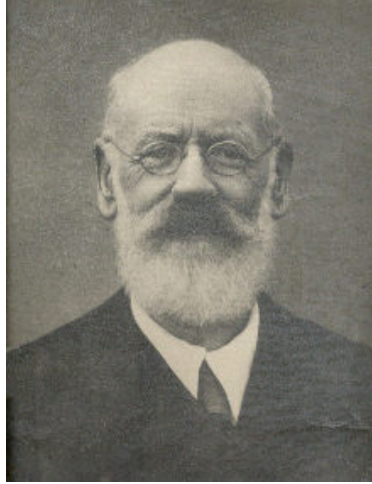
In 1885, the Royal Society, London, constituted the Indian Observatories Committee comprised of the Astronomer Royal, and a few Fellows of the Royal and Royal Astronomical Societies.

The Committee was entrusted with the task of coordinating the work of Madras and Bombay Observatories and of advising the Secretary of State for India pertaining to the administration of these observatories. The suggestions of SPC regarding regular observations of the Sun and the thinking of the Indian Observatories Committee on the future orientation of activities of the Madras Observatory converged to pave the way for the creation of a new observatory in the hills of South India. After the death of Norman Pogson on June 23, 1891, a series of initiatives were taken that eventually led to the establishment of the Solar Physics Observatory in Kodaikanal, a change in the administrative control of the observatories and the relegation of the Madras Observatory to a secondary status. It took about nine years to effect this transition.

Establishment of a Solar Observatory in Kodaikanal

In October 1891, John Eliot, the Meteorological Reporter to the Government of India wrote to the Government of Madras about a rethinking of the status of the Madras Observatory by the Secretary of State, Government of India, on the advice of the Astronomer Royal. They felt it was desirable that, in place of the Madras Observatory, a large Astronomical Observatory should be maintained in India, the work at which should, as defined by the Astronomer Royal in a letter, dated April 14, 1883, consist of (a) astronomical work proper, including the determination of accurate positions of the Sun, certain fundamental stars, the moon and planets, and (b) astronomical physics, more especially, daily observation of the solar prominences and other solar phenomena with the spectroscope, and daily photography of the Sun. Eliot suggested that the work on the Sun as recommended by SPC should get high priority and there was a need to relocate the observatory to a suitable hill-station, where the climate was nicer and more conducive to work. He further suggested that changes and additions of the European staff would be required for the observatory to carry out both solar physics and other astronomical work and changes in the control and inspection of the observatory would be necessary to ensure its working in the way desired by the Secretary of State and the Observatories Committee in England.

A serious effort was then made to find a suitable location for an observatory. The northern hill-stations were discredited right at the outset for one reason or the other. The regions chosen for further exploration were Kotagiri in the Nilgiris and Kodaikanal in the Palnis. On Pogson's death, Mr Michie Smith took over as the Officiating Government Astronomer. His substantive post was still that of Professor at the Christian College, Madras and the authorities of the College had permitted him to retain a lien on the professorship. The Government of Madras directed Michie Smith to conduct the site survey at Kodaikanal and Kotagiri. Small temporary observatories were established at the two places to record temperatures, cloud cover at night and other observations and the amount of sunshine. The Government of Madras was instructed by the Government of India to request Smith to arrange for special observations to test the clearness of the atmosphere at night.



Michie Smith

In August 1892, Michie Smith submitted to the Government of Madras a detailed report on the relative merits of Kodaikanal, Kotagiri and Madras as sites for an astronomical observatory. He had based the report on extensive observations of (i) the Sun, its faculae, spots and their spectra, (ii) Venus and Saturn, (iii) star clusters and nebulae, (iv) double stars, and (v) measurements of apparent magnitudes of stars and (vi) photographs of star trails. The steadiness of the image of the Sun was also studied. On all counts, Kodaikanal appeared to be the best of the three sites. It also had the advantage of altitude, the spot chosen there by Smith was more than a 1000 ft higher than the highest spot in Kotagiri.

The report was considered by the SPC in July 1892 and by the Indian Observatories Committee under the Chairmanship of Lord Kelvin in October of the same year. SPC suggested that if funds were not available for equipping a complete new observatory with two branches, the furtherance of solar physics in India would be the greater benefit to science. Continuity of the photographic registration of the sunspots in India had to be maintained as it was only with the Indian cooperation the then nearly complete record had been secured. Both the committees endorsed the appointment of Michie Smith on a more permanent basis to superintend the work at the new observatory. It was also said that the magnetical and meteorological observations could continue at Madras, which would become a branch observatory with a Superintendent and a small staff. It was asserted that with these changes, the Southern India Astronomical Observatory would become the only Government Astronomical and Solar Physics Observatory in India. It would therefore be a national and not a provincial institution. The committees felt it was essential that the control of the new institution should go to the Imperial Government.

In a gazette notification dated November 21, 1893, it was stated that Kodaikanal afforded the most suitable site for the proposed Solar Physics Observatory. The Meteorological Reporter suggested

that the consideration of the question of the permanent site of the Astronomical Observatory be deferred for some five years. In 1894, Michie Smith's position as the Government Astronomer became permanent.

With the official sanction and notification, actual planning of the observatory started. Michie Smith was allowed additional duty leave to spend time in England, from May 17 to October 9, 1895, to enable him to discuss with the astronomers in Europe many issues pertaining to the setting up of the observatory. On July 17, 1895, Michie Smith laid before the Indian Observatories Committee his plans for the proposed Kodaikanal Observatory and the equipment. The Committee strongly recommended the acquiring of a solar spectroscope. The other major equipment, already collected in Madras from various sources, that had to be shifted to Kodaikanal, consisted of a photoheliograph, a spectrograph, a 6-inch Cooke Equatorial, a transit telescope and chronograph, and a 6-inch Lerebour and Secretan equatorial.

In October 1895, the foundation stone of the new observatory was laid by the Governor of Madras. By the end of 1896 plans and estimates of the new establishment were completed and sanctioned. In July 1897 Michie Smith visited Kodaikanal and laid out a North-South line for the observatory building. The building work was slow to begin with but picked up later. When the large spectrograph — a polar siderostat with an 11-inch mirror, a 6-inch lens of 40-foot focal length and a concave grating mounted on Rowland's plan, was received in 1897, it had to be temporarily housed in the library building.

On January 22, 1898 there was another total solar eclipse at Sahdol, in the princely state of Rewa. The Secretary of State invited the Astronomer Royal and Sir Norman Lockyer to visit and also report on the various Indian observatories. The Astronomer Royal, W. H. M. Christie, visited Madras early in February (1898) on his way home from his eclipse camp at Sahdol. Mr Christie spent two days at the Observatory and carefully went into all questions concerning the equipment and the work that was being carried on. He then visited Kodaikanal and discussed the plans of the new buildings. Various changes which would improve the buildings were suggested and were at once adopted. Sir Norman Lockyer visited Madras but not Kodaikanal and expressed his dissenting views on the planned buildings in Kodaikanal. On his return to England, Lockyer represented to the Secretary of State for India that the buildings were too costly and too permanent, while the structures in his own South Kensington Observatory were temporary and cheaper, although his observatory was the most powerful solar observatory in the world. The Secretary of State ordered stoppage of all work at Kodaikanal until the matter was sorted out with the Astronomer Royal.

Whether Lockyer's protest was forwarded to the Indian Observatories Committee is not known, but the result was a delay from June to October end, after which the buildings were allowed to go on. Books and instruments were transferred from Madras to Kodaikanal and sent up the ghat in the dry weather before end of March 1899. 1000 coolie loads reached Kodaikanal. No damage was detected. Michie Smith took up residence in Kodaikanal by end February (1899) as it was necessary for him to be there to advise the engineer in charge of the buildings regarding details of the work and to take charge of the instruments on their arrival.

Officially, the observatory started work on April 1, 1899. After the work of construction was largely completed (December 1901), additional measures were taken to protect the Observatory from very strong winds. Progress was made in planting oak and pine trees and laying out grounds, although it was known that many years would elapse before these would take their full effect in modifying the strength of the winds to which the Observatory was exposed.

In 1902 a Calcium-K spectroheliograph was ordered from Cambridge Scientific Instrument Company. It arrived in Kodaikanal in 1904. The spectroheliograph consisted of a 12-inch triple achromatic lens of 20-ft focal length fed by a Foucault siderostat incorporating an 18-inch aperture plane silver-on-glass mirror, fitted with differential electric motors for fine adjustments in R.A. and Dec. The design of the instrument was as specified by George Ellery Hale (the discoverer of the spectroheliograph), in which the image of the Sun and the camera remain stationary while the collimating lens, the camera lens, the prisms and slits are carried on a rigid frame which moves at right angles to the optical axis. This was the instrument that John Evershed put to effective use after his arrival in Kodaikanal in 1907.

John Evershed joined on January 21, 1907 as Chief Assistant to the Director. Michie Smith went on combined privilege leave and furlough for nine months from April 1. Naturally, Evershed took charge of the observatory as soon as he arrived. This was his first professional appointment as an astronomer.



John Evershed (1864 - 1956)

John Evershed was born at Gomshall in Surrey on February 26, 1864. He is a descendant of the ancient family of Evereshavedes in Surrey who can be traced back to before the Norman Conquest (1066 A.D.). They were yeoman farmers and Evershed's grandfather, John Evershed, was the last of the branch to carry on an unbroken family tradition as yeoman farmers in Surrey for over 600 years. Evershed's mother's side of the family was in Portsmouth where his maternal great grandfather had a shop selling nautical almanacs and charts. He was well known to Lord Nelson.

Evershed's interest in astronomy began rather early. When he was only 11, there was a partial eclipse of the Sun, visible from Surrey, and boy Evershed ran almost all the way from Gomshall to Shere to watch the eclipse in a telescope belonging to a doctor. Even before that when he was six, his imagination was spurred by a picture of German shells falling in the streets of Paris in 1868, during which Janssen, the French astronomer, escaped by balloon from the besieged city to watch the total eclipse of the Sun. It was during this eclipse Janssen had discovered the H-alpha line in a solar prominence and soon after obtained pictures of the same outside of an eclipse. This was the beginning of the daily spectroscopic observations of prominences without waiting for an eclipse, an activity to which Evershed had a lot to contribute when he grew up.

Evershed was educated at a preparatory school at Brighton where Neville Chamberlain was a fellow schoolmate of his. He then went to a school at Croydon. In 1877, at the age of 13, he constructed a telescope with some odd lenses and watched Mars, which was near opposition then, with the telescope but through a plate glass window as he was told that the night-air was harmful for children.

Evershed's eldest brother, Sydney Evershed, was a student at the School of Mines in London and was good with his hands. Evershed's early training in building instruments and at workshop practice were received from his brother. He built his first spectroscope with a tiny prism of 1 cm aperture given to him by Sydney and a pair of lenses from a disused opera glass. He was able to see the Fraunhofer spectrum of the Sun quite satisfactorily, even the fine structure of the sodium lines, but the instrument was hopeless for viewing prominence spectra. Those were the initial years of solar physics when spectroscopy and spectrography were being extensively used for the study of all features of the Sun. Evershed was deeply influenced by the publications of Sir Norman Lockyer in *Nature* which he read with great interest. He built a spectroscope in the same design as Lockyer's with a train of prisms and with this attached to a 3-inch telescope he obtained beautiful views of the prominences. Thus began Evershed's long quest into the nature of the prominences which continued for many years, well into his Kodaikanal days. Perhaps due to his brother's influence, Evershed was trained as a chemical engineer and took up jobs as an industrial chemist in various manufacturing

concerns. Outside of his work, he was an avid amateur astronomer and viewing the Sun and solar prominences was his real passion.

A parallel strain in Evershed's life was his interest in natural history. His brother was responsible for his introduction to active scientific circles. He brought Raphael Medola, a Fellow of the Royal Society, to the Evershed home. Medola became a friend of the family and brought with him scientific news whenever he visited. Through Medola Evershed was able to attend the Friday meetings of the Royal Institution. On one occasion, Medola took young John Evershed to the Royal Society, where he met Charles Darwin. Medola also introduced him to Alfred Wallace. As he says 'My interest in evolution and in natural history was thereby greatly stimulated'. This interest led to his becoming a fine collector of Lepidoptera, both Indian and British. He became extremely proficient in photographing butterflies in colour.

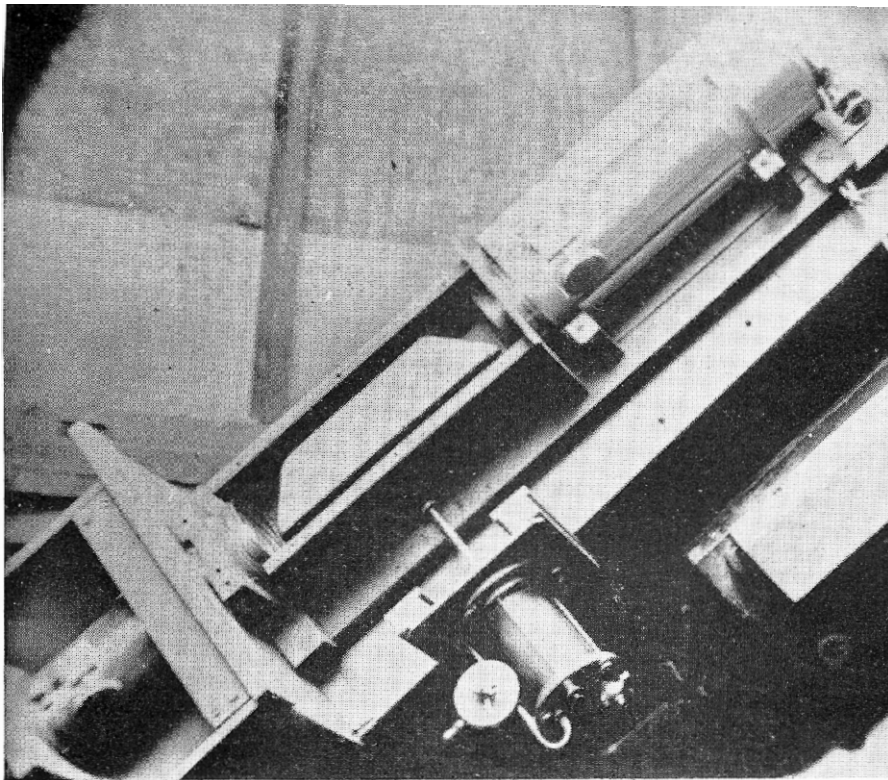
Evershed was, until his appointment in Kodaikanal, an amateur astronomer par excellence. In his workplace, he was involved in analysing oils and other products. He had access to equipment with which he performed some experiments on radiation from heated gases. In the 1890s, when Evershed was already studying the solar radiation for some time, it was generally believed that elements could not be changed to their gaseous state by heat alone. It was thought that to produce the characteristic line spectra of gaseous elements, some electrical or chemical stimulation was needed. The same was thought to be true of the Sun! Evershed was induced by some great spectroscopists including Pringsheim and Paschen to perform experiments on heated gases and study their radiation pattern. As he says 'I was able to show that coloured vapours of iodine and bromine heated to the temperature of red heat glowed with a continuous spectrum, at the same time giving a discontinuous absorption spectrum by transmitted light. ... I was able to show that vapourised sodium could be made to emit its characteristic D radiation by heat alone under conditions where there could be no action other than heat.'

In 1890, Evershed set up a private observatory in Kenley, Surrey, and with the spectroscope, he had designed, and his 3-inch telescope he started a long series of observations of prominences and recorded their distribution in heliographic latitude and their variation with the cycle of sunspots. Between 1890 and 1905, Evershed recorded some 13,458 prominences. In 1890, he became a founder member of the British Astronomical Association and he was the Director of the Section on Solar Spectroscopy between 1893 and 1899.

The 1890s were exciting years for Solar Physics. In the spring of 1891, George Ellery Hale invented the spectroheliograph. Like Evershed he had set up his own Kenwood Physical Observatory in the backyard of his house in Chicago, where he had a self-made 12-inch telescope. Using the spectroheliograph and this telescope, he was soon able to see the reversals in the Ca II H and K lines. Evershed had his own way of photographing prominences in the H_β line of hydrogen. With this technique of monochromatic photography, he was getting solar images showing the brilliant flocculi around sunspots. When he learnt about Hale's new machine, he abandoned the

idea of working in the hydrogen line and transferred his attention to the Ca II K line. Through some correspondence in the journal *Knowledge*, Evershed got to know Arthur Cowper Ranyard, a barrister by profession but with a deep interest in astronomy, who was the editor of *Knowledge*. Ranyard was an FRAS and knew Hale personally. When Hale visited England in 1894, Ranyard introduced Evershed to Hale. This was the beginning of a long friendship between the two pioneer solar astronomers of the time, which lasted till Hale's death in 1938.

Ranyard died in 1894 and left Evershed with his 18-inch reflector and a small spectroheliograph. Evershed found problems with Ranyard's machine which produced curved spectral lines and gave distorted images of the Sun. He put the 18-inch telescope at Kenley, and designed a spectroheliograph on his own using large direct vision prisms which gave straight spectral lines and undistorted solar images.



Evershed's spectroheliograph at Kenley

Evershed's boss, in the company he was working, was interested in science and Evershed was granted leave to join solar eclipse expeditions. His first visit to India was in connection with the eclipse of January 22, 1898. He was in the company of W. H. M. Christie, the Astronomer Royal, H. H. Turner, the Savilian Professor of Astronomy at Oxford, Sir Norman Lockyer among others. He obtained excellent flash spectra and caught the emission continuum at the head of the Balmer series extending to the ultraviolet end of the plate. He realised this was the counterpart of the continuous absorption spectrum seen by William Huggins in stars with strong hydrogen absorption lines. At a later solar eclipse in Algeria in 1900, he repeated the same experiment and again saw the continuum emission. His results definitively proved that the flash spectrum and the Fraunhofer spectrum were of the same origin, the flash spectrum representing the higher and more diffused portion of the gases which by their absorption gave the Fraunhofer dark line spectrum. At all eclipses, Evershed carried his own home-made instruments -- prismatic spectroscopes with a long focal length camera, where only the optical parts were procured from specialised manufacturers. These prismatic spectroscopes consisting of two or more prisms are often referred to as Evershed Spectroscopes.

The results of Evershed's eclipse expeditions attracted the attention of the great stellar spectroscopist Sir William Huggins who was then the President of the Royal Society. Evershed and Huggins had an interesting correspondence in this matter. Later it was Huggins who recommended the appointment of Evershed to the position of the chief assistant to Michie Smith in the observatory in Kodaikanal.

In the original recommendation for setting up an Imperial Astronomical Observatory in the hills of Southern India, the Government had indicated that the observatory would be headed by an Astronomer to be appointed by the Indian Observatories Committee in England while the Solar Physics Section would be headed by a Superintendent, either appointed by the Solar Physics Committee and the Observatories Committee, or Mr Michie Smith, the then Government Astronomer, could be appointed to the position. Smith was deemed to have the requisite qualification and experience to run the Solar Observatory, while his suitability to head the Imperial Observatory was somewhat in doubt. It was agreed that the staff of the new observatory should consist of two Europeans and a group of Indian assistants. When the idea of establishing an Imperial Observatory was temporarily abandoned, and it was decided that the Solar Physics Observatory was the one to be immediately established in Kodaikanal, Michie Smith became the natural choice for its directorship. The European assistant to him was not immediately appointed.

The principal thrust of the work at Kodaikanal was to be solar spectroscopy. There were three existing spectroscopes none of which appeared suitable for obtaining spectra of prominences and sunspots with good efficiency. In 1903, it was decided to build a spectroscope and one of the existing ones (a large six-prism instrument with a collimator and a telescope of 17-inches focus) was dismantled and two lenses from it were mounted with an existing diffraction grating to rig up an instrument which was then used with the 6-inch Lerebour and Secretan equatorial to obtain spectra of the solar features. A three-prism Evershed spectroscope was ordered from Hilger Co.

during the same year and this went into operation in November 1904. It gave excellent spectra of sunspots and prominences. Also in 1904, the Cambridge Spectroheliograph arrived in Kodaikanal. Naturally there was a great need of having a person who would direct the spectroscopic work. Michie Smith visited Hale at Mt Wilson in early 1904 and discussed in detail the kind of work Kodaikanal should undertake. Hale was also keen on developing an international network on solar research and he was particular that the work with spectroheliographs, at Catania and Yerkes Observatories, his own at Mt Wilson, yet to be commissioned, and the newly acquired one at Kodaikanal, was done in a coordinated fashion. He was already in correspondence with Evershed and was coaxing him to join this proposed network, since Evershed had his own spectroheliograph and was producing Ca II K spectroheliograms on a regular basis. Hale narrated in detail his conversations with Michie Smith in a letter to Evershed on February 2, 1904. Evershed was quick to respond saying that he felt a cooperation in spectroscopic and spectrographic methods of observation rather than the other older methods of photographic work would indeed be of great help to the community. He called himself 'an irresponsible amateur' who was not afraid to be part of any professional network.

Evershed in Kodaikanal

In 1904, the Government of India sanctioned the appointment of an European Assistant to the Director, Michie Smith. John Evershed was clearly the most eminent choice for the position. According to Evershed, Sir William Huggins greatly influenced the decision of the Government of India in making Evershed the offer, which also had the support of Gilbert Walker, the Director-General of Observatories in India. In a letter to Hale dated December 3, 1904, Evershed said that he had been offered an appointment in Kodaikanal and it would take him six months to decide. He was a bit depressed at the prospect of having to close down his private observatory in Kenley. He probably had in mind a personal matter, that of his marriage, before he could definitely take a final decision. He was preparing for the journey to India in 1906. On the advice of Professor Turner of Oxford, he decided to go to India not by the regular route but by the longer Trans-Atlantic/Trans-Pacific one via America and Japan. Turner gave Evershed introductions to the leading American astronomers of the day, Pickering in Harvard, Frost at Yerkes and Barnard and Campbell at Lick. Turner also arranged for his visits to Harvard and Princeton, and to these observatories and arranged for the India Office to sanction these visits. Evershed's main aim, of course, was to spend a month with Hale at Mt Wilson.

At the eclipse expedition of August 9, 1896 in Norway, Evershed had first met Mary Ackworth Orr, a young and sprightly amateur astronomer and a member of the British Astronomical Association. Mary was also interested in Dante Alighieri and was to write a book titled 'Dante and the Early Astronomers' in 1914. In 1906 September John and Mary got married. In a letter to Hale on June 28, 1906, Evershed had told him about his plan to visit America on his way to India. He also wrote that before leaving England he was to be married to 'Mary A Orr' who would accompany him to America. On September 22, 1906, the Eversheds left England by the Anchor Liner Columbia reaching New York end of September. The couple travelled to Williams Bay, Wisconsin, where the

Yerkes Observatory is situated. Edwin Frost, the Director hosted them for a week. They arrived in Pasadena on October 18 planning to spend several weeks with Hale. However, owing to some miscommunication Hale was away at the time and was not returning to Mt. Wilson until the end of November. But the couple had a wonderful and scientifically fruitful time organised by Hale's main solar collaborator Ellerman. Evershed was deeply impressed by the instruments, the method of work and Hale's organisation of the observatory. On January 21, 1907 the Eversheds reached Kodaikanal.



Evershed Hall — this building was ready for occupation in December 1907

Evershed got his hands dirty as soon as he arrived in Kodaikanal. The Cambridge Spectroheliograph had been put into operation in 1905. The building where it was housed was faulty with a leaky roof and a new roof had to be constructed. There was also some problem with the setting of the second slit at the correct wavelength. So, although spectroheliograms were obtained in 1905 and 1906, the instrument did not perform to its full potential. It was left to Evershed to bring the instrument to its fine working order. By then a new moving roof was in place in the spectroheliograph building with an addition of ruberoid sheets to prevent leaks. A new collimator slit was fitted and Evershed solved the problem with the camera slit, giving it greater stability and incorporating a new device to facilitate the setting of the slit at any desired wavelength. He also started working on an auxiliary spectroheliograph to obtain pictures of the Sun in H-alpha.

When Comet Daniel showed up in the sky, Evershed used his eclipse prisms (he had brought them with him to India) and made a prismatic camera fitted to the 6-inch Cooke equatorial to obtain spectra of the comet. He identified the CN bands in both the nucleus and the tail of the comet. When Halley's Comet appeared in 1910, Kodaikanal geared up to observe the object both photographically and spectroscopically. Between April 19 and May 16, 1910 when the comet was most amenable to observations in the early dawn, Evershed was able to obtain spectra which showed the CN bands and the C, Swan bands in the head, while the tail showed bands due to CO. He was ably assisted in the observations by his wife Mary.



Halley's Comet taken in Kodaikanal in 1910

However, Evershed's chief work in the initial years in Kodaikanal was on the spectra of sunspots. He used the high dispersion spectrographs at the observatory to systematically study the spectra of

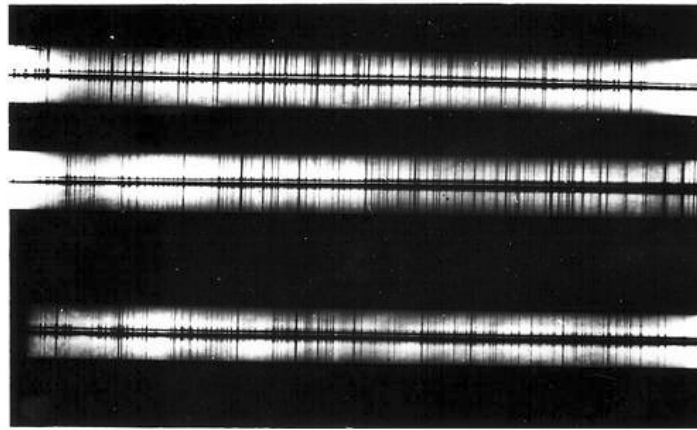
spots whenever the weather was favourable. He noted that the sunspot spectra were constant in character and consisted mainly of intensified Fraunhofer lines. The general absorption was continuous and was similar to the continuous absorption seen in the limb of the Sun. The pressure in the spot regions seemed to be slightly less than in the reversing layer of the photosphere. In 1909, Evershed made another 'very powerful spectrograph', one he called Spectrograph III. This had a parabolic silver-on-glass mirror which formed the solar image on the slit plate and he used an excellent 6-inch plane grating by Michelson, which the observatory had, as the dispersing element. He employed this instrument to solely concentrate on the spectra of sunspots.



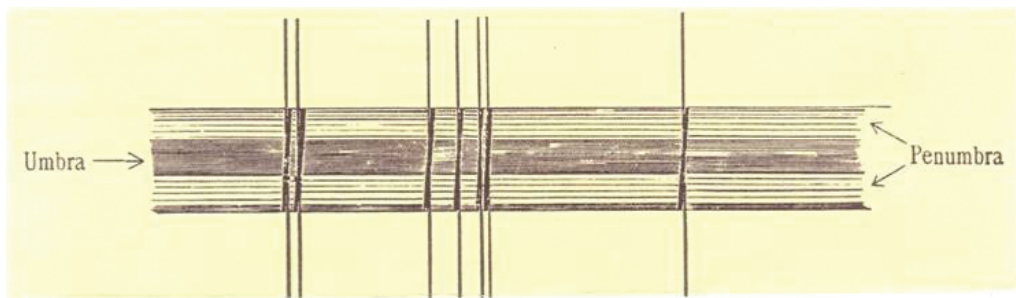
Evershed at work with the spectroheliograph at Kodaikanal

In the early morning of January 5, 1909, on a day when the atmosphere was exceptionally steady and the sky transparency was excellent after some heavy thunderstorm activity, Evershed found two large spots and obtained their spectra. As he says, 'the spectra revealed a curious twist in the lines crossing the spots which I at once thought must indicate a rotation of gases, as required by Hale's recent discovery of strong magnetic field in spots, but it soon turned out from spectra taken with the slit placed at different angles across a spot that the displacement of the lines, if attributed to motion, could only be due to a radial accelerating motion outward from the centre of the umbra. Later photographs of the Calcium H and K lines and the H-alpha line revealed a contrary or inward motion at the higher levels represented by these lines.' This was the first time line displacements in the penumbral region were seen indicating an outward radial flow of gases in the spots. None of the

previous spectroscopic studies had revealed the dynamics of the flow of gases in the spots. Two days later, Evershed obtained more spectra which confirmed the discovery.



Solar Spectra recorded by Evershed, Jan 5, 1909 at Kodaikanal



The line sketch of the spectra obtained by Evershed shows the shift of the absorption line in the penumbra around the sunspot.

Earlier studies had concentrated on spots near the central meridian of the Sun. Evershed was the first to observe spots at various positions, up to 50 degrees, on either side of the central meridian. He found that the line displacements were more pronounced in the penumbral regions of the spots which are closer to the limb of the Sun. This established that the flow of the gases was radially outward parallel to the surface of the Sun. In a letter to Hale on February 1, 1909, Evershed described his remarkable discovery and said 'I have found that there is a Doppler shift of all the lines in all spot spectra. I made a special study of it having obtained more than one hundred and fifty spectra representing seven northern spots and four southern.' The complete results were published in the Kodaikanal Observatory Bulletins of 1909 and the inverse flow seen in the strong lines in a paper in *MNRAS* in 1910.

Hale responded soon congratulating Evershed for the discovery and stated that because of the pressure of their magnetic field work, they were unable to investigate the dynamics of gases in sunspots.

The general problem of an unexplained redshift of spectral lines seen at the limb of the Sun with respect to the same lines seen from the centre had occupied the thoughts of all major observers at the time. This was first brought out by Halm at the Cape Observatory in 1907. The Mt Wilson astronomers, who investigated the phenomenon in great detail, came to the conclusion that the shift was due to the differences in pressure in the two regions — disk centre and the limb. Evershed too was trying to understand the nature and cause of this shift. His observations however indicated complexity. His work further showed that the pressure interpretation was incorrect, as some of the lines supposed to be most affected by pressure were actually shifted to the violet. Evershed had developed very accurate methods of measuring extremely small line shifts and much of the spectroscopic work in Kodaikanal was concerned with the measurements of these minute shifts.

It turns out that the astronomers of the time had no idea of the actual value of pressure in the various layers of the solar atmosphere. A commonly accepted notion was that the pressure was several times Earth's atmospheric pressure. It was also thought for some time that the weak lines formed at lower pressures than did the strong lines. Only after the appearance of Meghnad Saha's work on thermal ionization and its great success in establishing a quantitative effective temperature scale of stars, spectroscopists were able to calculate the actual pressure from spectral diagnostics and it turned out that the pressure in the solar atmosphere was only about a tenth of that in the Earth's atmosphere. The solution to the problem of redshifts came from an altogether different quarter. Albert Einstein had calculated the gravitational redshift of spectral lines in his general theory of relativity. As his theory gained credibility, particularly after the solar eclipse expedition by Eddington in 1919 that gave an accurate measure of the bending of a light beam in the gravitational field of the Sun, the effect of gravitational redshift on the spectral lines in the Sun became a major target of study. Towards the end of his stay at Kodaikanal, Evershed made a comparative study of plates taken in 1914, 1921, 1922 and 1923 and found that for the weaker lines which are supposed to form deep down in the atmosphere, the results of the redshifts were in agreement with Einstein's theory. However, there was an unexplained extra redshift detected in limb spectra whose origin was not known.

In January 1911, Michie Smith retired and Evershed became the Director of the Kodaikanal Observatory. Dr T Royds joined as the new Assistant Director. In the same year Evershed put into operation a second spectroheliograph as an auxiliary to the Cambridge instrument utilising its perfect movement and using a grating and special arrangements for getting photographs of the solar disk in H_{α} . As red-sensitive plates became available, he started obtaining daily spectroheliograms in H_{α} along with the same in the Ca II K line. Several spectacular eruptions were recorded in some of which the speed of recession of the flying fragments was measured.

The study of prominences had continued uninterrupted into the Kodaikanal days. Mary too developed an interest in the prominences after moving to Kodaikanal. In 1913, she published a paper in which she analysed observations of prominences associated with sunspots made between 1908 and 1910. The number of prominences recorded at Kodaikanal during the years 1904-1914 numbered nearly 60,000 and these, supplemented by the earlier Evershed collection at Kenley, formed the subject of an exhaustive study and was jointly published by Mary and John Evershed as a Memoir of the Kodaikanal Observatory in 1917.

In 1913, the Eversheds visited Kashmir on three months' leave and found the observing conditions in the Kashmir Valley excellent for solar work. As Evershed wrote later, 'The Valley of Kashmir is a level plain containing a river and much wet cultivation of rice. It is 5,000 ft above sea level and is completely surrounded by high mountains. Under these conditions the solar definition is extremely good at all times of the day, and unlike most high level stations it is best near noon and in hot summer weather.' He established a temporary observatory near Srinagar in 1915-16 obtaining very high-quality photographs of prominences and sunspots. This experience of Evershed was later extended to various localities including one on an ocean liner in tropical waters. The view that the best solar definition is found in low level plains near the sea or on small islands surrounded by extensive sheets of water grew out of these experiences.

In 1915, Evershed was elected a Fellow of the Royal Society and he was awarded the Gold Medal of the Royal Astronomical Society in 1918. At the latter award the President of RAS, Major P. A. MacMahon, gave a full account of Evershed's work up to that time giving maximum prominence to the discovery of the radial motion in sunspots. The other contributions that he highlighted were (i) prominence observations, (ii) spectra of sunspots in general, (iii) investigations into the reversing layer, (iv) the minute displacements of lines at all parts of the solar disk, (v) eclipse and cometary observations, and (vi) the invention and perfection of instruments of observation and measurement. Major MacMahon compared Evershed with Sir William Huggins saying '*There is much in our medallist's career which is a reminder of the scientific life of William Huggins. They come from the same English neighbourhood, and began as amateurs of the best kind. They both possess the same kind of scientific aptitude.*'

John Evershed retired in 1923 and left Kodaikanal for England. As the Eversheds went down the ghat road, a tiger darted across their path, the only time in 16 years in India that they saw a tiger. They returned to Surrey, where Evershed established his own observatory in Ewhurst near Guildford and continued with his solar observations for well over another thirty years. He made liquid-filled prisms which revealed great possibilities for high dispersion work. He obtained Zeeman spectra of sunspots using these prisms as dispersers. He and Mary continued to take part in solar eclipse expeditions and also attended meetings of the IAU every three years. Mary died in 1949 at the age of 83 and John Evershed in 1956 at the age of 92. The years of Evershed's directorship are considered to be the golden period of the Kodaikanal Observatory.

The Scientific Impact of Evershed Effect

As we look back at the spectroscopic detection, through Doppler shifts, of gas motions in the penumbral photospheric layers of sunspots in 1909 by John Evershed at the Kodaikanal Solar Observatory, in the light of the subsequently developed subject of magnetohydrodynamics (MHD) and the vastly improved observational capabilities, it clearly stands out as the earliest successful observation of velocity fields due to a complex magnetohydrodynamical phenomenon in action in a celestial setting. The most remarkable aspect of Evershed's work has been his ingenuity, given the limited resources and sensitivities of the instrument that he used, in providing accurate interpretations of his observations that the gas motions in sunspot penumbrae were indeed radial outflows parallel to the solar surface. This dominant dynamical phenomenon, as Evershed discovered, still remains so in our modern observations with vastly improved spectral and spatial resolutions, though additional components involving vertical and wave motions are seen to take place. And, we still have not fully understood the basic cause of this phenomenon.

The immediate scientific impact of Evershed's discovery pertained to another momentous event in astrophysics, viz. the detection of magnetic field in sunspots by George Ellery Hale a year earlier in 1908 at the Mt. Wilson Observatory. This was the first ever discovery of an extraterrestrial magnetic field, and was motivated by the prevailing speculations at that time that sunspots were giant vortices and that all rotating heavenly bodies harboured magnetic field. Hale considered his detection of magnetic field in sunspots, in turn, as an indication of swirling flow of ionized gas, which could have generated the magnetic field locally. However, Evershed himself pointed out in his discovery paper in 1909 that his observations of radial outflow of gas made the circular flow hypothesis untenable. It was not until the early 1930's that the local generation of magnetic field due to axisymmetric motions was shown to be impossible by Cowling through theoretical calculations, and in particular, he suggested sunspots as pre-existing tubes of magnetic flux breaking through the surface.

The two beautiful discoveries by Hale and Evershed having surfaced early in the exciting era of applications of spectroscopic techniques to study the Sun, the immediate follow-up research on Evershed effect, naturally, was through intense observational examinations, most notably at Mt. Wilson Observatory. More observational programmes followed gradually all over the world, and in general, observational studies have gone on almost continuously over the past century. However, theoretical attempts to explain the physical causes and understand the origin of this effect have gone through several calm periods, and we are currently in a period of revived attention mostly fuelled by our increased numerical computational capabilities to simulate MHD processes.

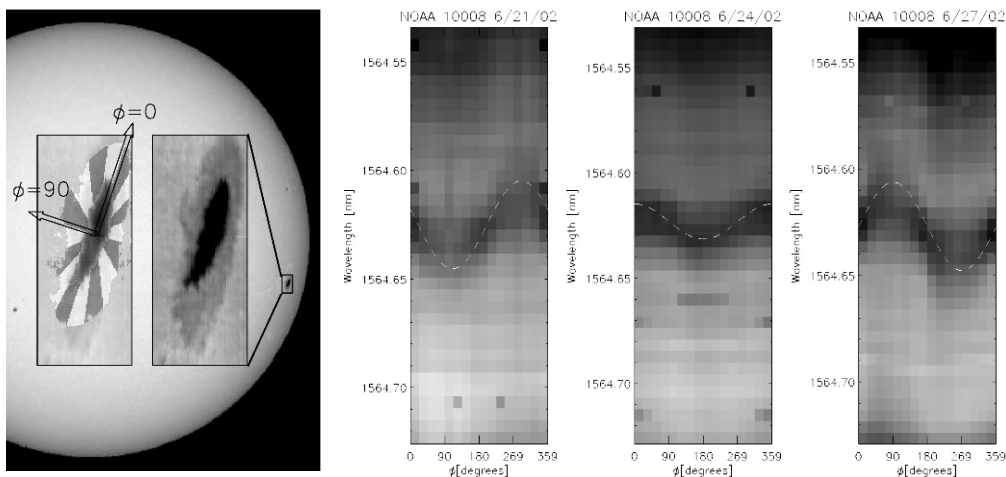
Observational Research:

Evershed's initial estimates of flow speeds were of the order of 2 km/s, and he found increasing speed as distance increases from the spot centre, and no tangential components for flow velocity.

His later results, using chromospheric lines, indicated a radial inflow of gas at these heights; and he measured small tangential components in photospheric velocity, but considered them unreliable because they were irregular.

Detailed observational programmes started in Mt.Wilson (St.John 1913) and across several countries in Europe, most notably - at Arcetri in Italy (G. Abetti 1929), at Oxford using the Oxford Solar Telescope (Kinman 1952), in France and in the Soviet Union in the early 1960's, and at Oslo Solar Observatory during the mid 1960's. All these observational studies essentially confirmed the results of Evershed, added more details on the spatial variation of flow over the penumbra, established the filamentary structure of the flow, and tentatively identified the magnetic and flow field associations.

Considerable improvements in spatial and spectral resolutions emerged in the late sixties, and with that came the identification that Evershed flow is concentrated into dark penumbral filaments (Beckers 1968) and where the magnetic field is more horizontal (Beckers and Schroter 1969).



A modern observation of Evershed effect: radial outflows. Observed by Penn et al. (2003 ApJL, 590, L119) using CN absorption line at 1564.6 nm.

Starting from the 1990's, high resolution observations, from various groups all over the world, have served to spatially resolve the flow and magnetic structures which have the following dominant properties: the flow occurs mainly in the dark penumbral filaments where the field is more nearly horizontal than the average, the inner penumbral heads of horizontal flow structures have concentrated but bright upflows, which feed the horizontal flows.

The deeper connections between fine-scale magnetic fields and the Evershed flow fields have always been the motivating factor to go for higher spatial and spectral resolutions, which have

proved to be essential in understanding this dynamical phenomenon. Most notable modern observational studies have come from the Lockheed and the National Solar Observatory (Rimmele et al) groups in USA, the Spanish group at Canary Islands, the Swedish Solar Telescope group, the German Vacuum Tower Telescope group, the Dutch Open Telescope group and the space missions SOHO/MDI and Hinode.

Theoretical Research:

Even though a dominant role for the magnetic field in the thermal and dynamical structures of a sunspot was envisaged early on (Biermann 1941, Cowling 1935, 1953, Alfvén 1943), at the time when the work of Hannes Alfvén on Alfvén waves gave shape to the science of magnetohydrodynamics, theoretical interpretations of the Evershed flow started relatively late in 1955 when Sweet found an origin in convectively driven motions. Since then, there have been various magneto-convective processes proposed and they form a large body of research on sunspot related problems. In fact it forms one of the two major theories to explain the physical causes of Evershed flows, the other being the siphon flow proposal by Meyer and Schmidt in 1968 and its detailed exploration by Thomas, Montesinos et al. over a period of time up to the present.

There have been several different theories based on magneto-convective mechanisms to explain the Evershed flow, most notable ones being: (i) a linear theory of convective rolls in horizontal magnetic field proposed by Danielson (1961) and its non-linear modification by Galloway (1975) to drive a radial outflow, (ii) Busse's (1987) theory of three dimensional convection in inclined magnetic field, where Reynolds stresses drive an Evershed flow, and (iii) interchange convection of Jahn and Schmidt (1994) and Schlichenmaier et al (1998) where a dynamical evolution of thin flux tube produces the Evershed flow. Currently, a new magneto-convective picture of Evershed flows has emerged based on 2D and 3D MHD simulations (Heineman et al. 2007, Scharmer and Spruit 2006, Scharmer et al. 2008, Rempel et al. 2008) where the convective interactions between an upward hot plume and magnetic field produce all the necessary ingredients to drive a horizontal Evershed flow as observed. The siphon flow models of Montesinos and Thomas (1997) have the attractive feature that they can consistently explain both the normal (outward) and the reverse (inward) Evershed flows at the photospheric and chromospheric layers, respectively.

A complete and fully consistent picture of Evershed flows, with ability to match all the observed features is yet to be realised, even a 100 years after its discovery. It is likely that more delicate and detailed picture of Evershed flows would emerge from the very high spatial and spectral resolution spectropolarimetric observations planned in the near future. It is equally likely that the fast developing computational resources and algorithms could get complex enough to reproduce well the observations.

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Kodaikanal Observatory: 1923 – 1960

Following John Evershed's retirement in 1923, activity in solar physics continued unabated at Kodaikanal and work progressed along the lines of the early years of the century. The successive Directors at the Observatory were T. Royds (1923-1937), A. L. Narayan (1937-1946) and A. K. Das (1946-1960). The scientific highlights of this era were (a) discovery of oxygen lines in emission in the chromosphere without the aid of an eclipse, (b) centre to limb variations of hydrogen lines and their use to study the solar atmosphere, and (c) detailed study of the properties of the filaments, seen in H_{α} . Significant progress was made on the instrumentation front during this period; the new ionospheric and geomagnetic laboratory was set up in the mid-fifties and a major solar facility, the solar tunnel telescope was commissioned in 1960.

Eclipse expeditions:

Royds led the Observatory's expeditions to the eclipses in 1929 to Siam and in 1936 to Japan. While the totality at Siam was lost to clouds, in Japan, Royds used one of the largest ever spectrographs to record the spectra and he was the only observer to get any results. Royds carried out measurement of lines at the extreme limb of the Sun. The 1952 totality in Iraq and the 1955 one in Sri Lanka were again lost to cloudy skies.

The Saha Committee:

A committee appointed by the Government of India, with Meghnad Saha as the Chairman, examined in 1945 a plan for the development of astronomical research and teaching at the existing observatories and the universities. One of the main recommendations of this committee was aimed at improving the facilities for solar observations, especially during the first five year plan. It was proposed to make available a solar tower telescope, a coronagraph, and a laboratory for solar terrestrial studies in Kodaikanal. Most of these were implemented by 1960.

Ionospheric and geomagnetic laboratory:

Another post-independence development carried out at Kodaikanal was the setting up of a magnetic and ionospheric laboratory in order to study the reaction of the earth's ionosphere and magnetic field to transient solar events. Two aspects of Kodaikanal greatly stimulated much of the research carried out subsequently in this area. The first one was the ready and immediate availability of information on solar happenings observed optically or by radio techniques with the Kodaikanal telescopes. Few places in the world have available the facility of an ionospheric laboratory and a solar station in close proximity. The advantages in quick experimentation and

inference have been substantial. The second feature is Kodaikanal's location very close to the geomagnetic equator; hence several aspects of the ionosphere, so vital in radio communication can be studied in Kodaikanal with much advantage.

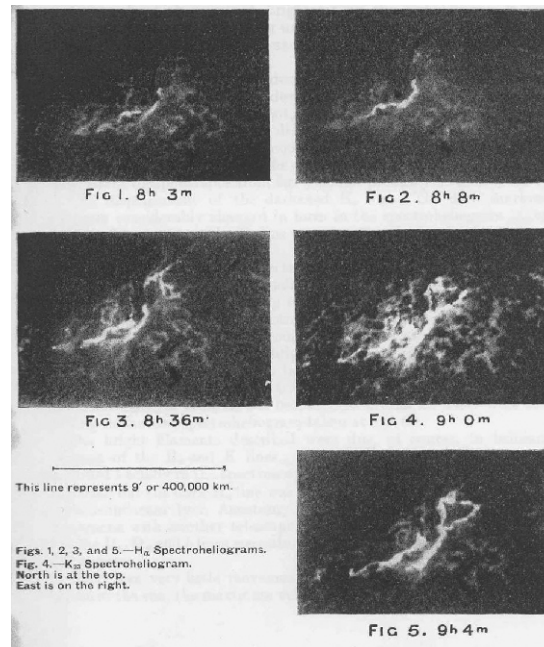
The laboratory went into operation around 1955, just before the International Geophysical Year. There have been numerous studies of the properties of the ionosphere over low equatorial latitudes which have improved our understanding of the phenomena governing radio propagation and its dependence on the solar radiation characteristics. Interestingly, the laboratory once recorded the geomagnetic effects of a stellar x-ray source.

Solar instrumentation:

A Hale spectrohelioscope for visual observations of the Sun was received as a gift from the Mount Wilson Observatory during 1933-34, for participation in a systematic watch of the Sun by international cooperation. The H_{α} line in the first order of the grating was used for visual observations of prominences, dark markings, and for solar flare patrol. A line shifter device was soon added for visual estimation of the Doppler shifts. This instrument was in regular use for the next sixty years. Transient activity first noticed with this instrument was followed up with fast sequences using the main spectroheliographs and also to alert the ionospheric and geomagnetic laboratory on campus.

The tunnel telescope by Grubb Parsons, purchased in 1958 and commissioned in 1960, consists of a 60 cm diameter two mirror coelostat, mounted on a 11 m high tower, that directs light via a flat mirror to a 38 cm aperture, f/90 achromat which forms a 34 cm diameter solar image at the focal plane. A Littrow-type spectrograph with an inverse dispersion of 9 mm/Å in the fifth order of its grating, and a spectroheliograph capable of giving pictures in a chosen line became available for use. These have continued to be, for nearly half a century now, the country's main facility for high spectral resolution observations of the Sun.

The Kodaikanal Observatory continued its programmes of cooperation with the Greenwich, Cambridge, Meudon, and the Mt. Wilson observatories, especially with regard to exchange of observations for missing days. The Observatory was responsible for communicating to the IAU material for publication of H_{α} flocculi and dark markings, for most part of the above period. The spectrohelioscope observations were sent regularly as inputs for the quarterly bulletins of the IAU on solar activity. Beginning 1949 May, the Observatory started sending regular coded messages on solar activity for the benefit of the Meteorological Department, geophysicists, and radio specialists in the country and abroad. The Observatory continued to regularly publish the Kodaikanal Observatory Bulletins and also the half-yearly bulletins of solar statistics.

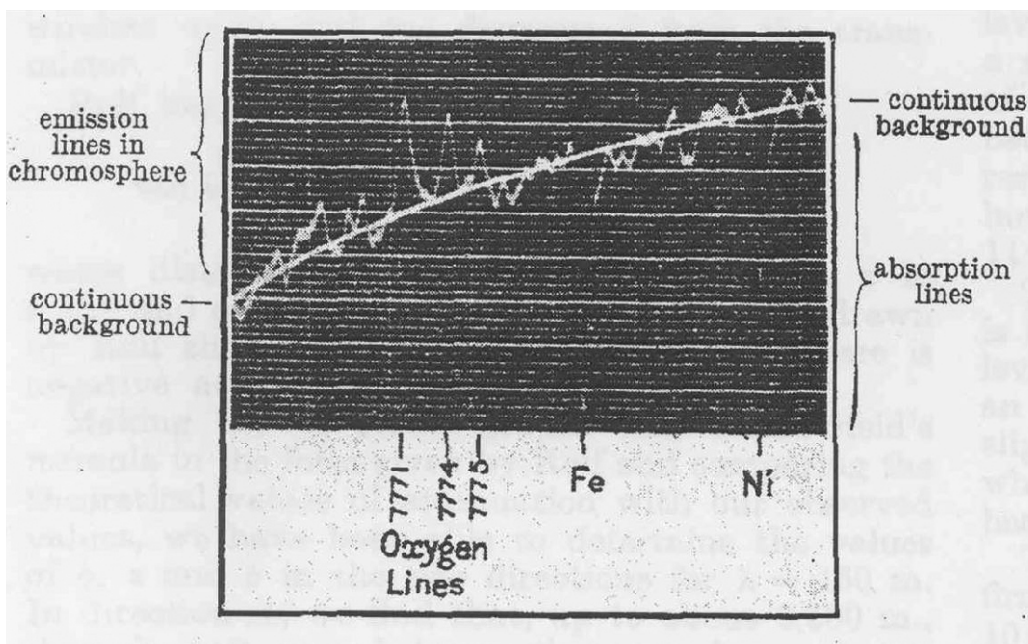


Royds' flare of Feb 22, 1926. One of the largest ever at Kodaikanal that covered two large sunspot groups.

Scientific highlights:

- Royds carried out laboratory studies of spectra with a view to investigating the cause of observed displacements of solar lines with reference to lines in the spectra of terrestrial sources. Royds and Narayan later observed the centre to limb variations of several strong solar lines.
- Royds succeeded in photographing, outside an eclipse, the infrared triplet of oxygen at 7771, 7774, and 7775 Å as emission lines in the chromosphere. These lines are normally observed as absorption lines in the Fraunhofer spectrum.
- Rao et al (1949) observed H_{α} , H_{β} , D, and several other lines near simultaneously during the maximum phase of a solar flare. They argued that the observed line broadenings were mostly due to Doppler effect and were not assignable either to the Zeeman effect or to the Stark effect.
- Narayan and co-workers studied several atoms, ions, and molecules in the laboratory and looked for their signatures in the solar spectrum. They established the presence of P_2 and studied CN spectral lines in the Sun.

- Das and Ramanathan observed the distribution of radiation flux across sunspots in the continuum and narrow band windows of the H and K lines. They demonstrated that certain sunspots show the presence of bright rings and that they are especially more intense in the wavelength of K_2 .
- Statistical studies of solar features, such as sunspots, prominences, and filaments and their periodicities, longitudinal and latitudinal distributions, migration patterns, changes in orientations, and rates of occurrences were carried out.



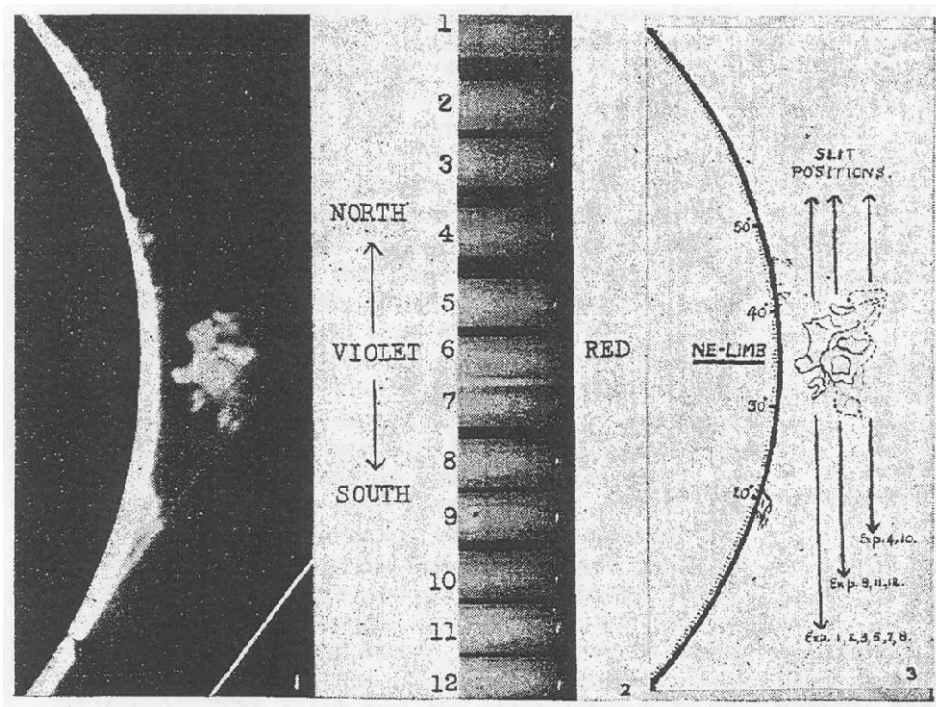
Oxygen emission lines in chromosphere without the aid of an eclipse. Royds used a straight slit tangential to the Sun's limb to record the triplet. Figure above shows microphotometer scan of the spectrum obtained.

Transient phenomena:

- Flare patrol and follow up observations were carried out routinely at the Observatory. All efforts were made to not miss particularly strong events.
- In 1926, Royds obtained extensive spectroheliogram coverage of an exceptionally strong and widespread flare (which was known at Kodaikanal as Royds' flare). The observations were later used for various studies.

- In 1949, Das and Raja Rao observed a 3+ flare followed by a great magnetic storm starting 40 hours later but lasting over two days. Peculiarities of the storm were studied in detail.
- In 1953, Das and Sethumadhavan recorded observations of an apparently quiescent prominence, not visibly associated with any sunspot, grow into a dramatic eruptive event. Spectra of the dramatic event were recorded and the associated radio noise bursts were also observed.

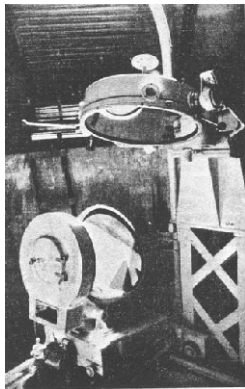
M. K. Vainu Bappu arrived in Kodaikanal Observatory in 1960 and by the end of 1962, he put into operation the newly installed solar instruments, especially the solar tunnel telescope. While solar observations continued with these facilities, new horizons were opening up in the area of night time astronomy.



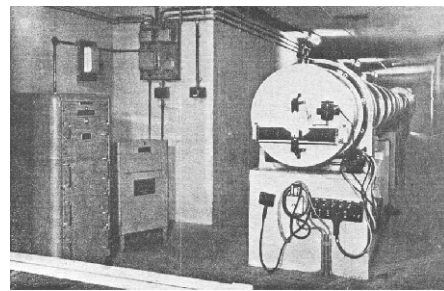
An apparently quiet prominence suddenly grew to twice its height and erupted. H_{α} spectra were obtained and Doppler shifts measured. Associated radio noise bursts were also studied.

Solar Physics Research at Kodaikanal from 1960 onwards.

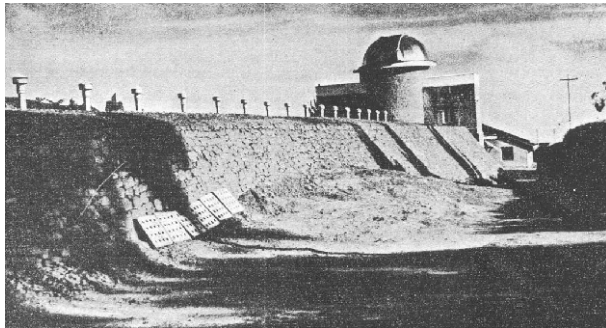
Renewed vigour and productivity characterised solar research in Kodaikanal under the leadership of Vainu Bappu. The solar tower telescope was in regular operation in 1962, and by 1965 it had a spectrograph and a Babcock type magnetograph. There were three spectroheliographs housed in the building adjacent to the solar tower. The photoheliograph of 20 cm diameter was also in operation.



60 cm (24 inch) two mirror coelostat by Grubb Parsons



Main spectrograph of Littrow type and high dispersion



**Solar Tunnel Telescope
(commissioned in 1960)**

With the above facilities, the observational programmes and research that materialised during the period 1960 - 1985 fell into five broad scientific categories: Solar Velocity Fields, Solar Magnetic Fields, Chromospheric Features and Dynamics, Coronal Studies, and Solar Terrestrial Relationship studies.

Solar Velocity Fields:

Arvind Bhatnagar undertook a detailed study of the Evershed effect based on observations in Zeeman insensitive lines of Ni I and Fe I. He measured sizeable tangential velocities in the sunspot penumbrae, with a maximum value of about 0.6 km/sec, and studied in detail the line asymmetries,

which were first observed by Evershed in 1916. Bhatnagar also performed correlative studies of continuum brightness and equivalent widths and found that darker regions of the penumbra show larger equivalent widths while an opposite correlation was found for the brighter regions. This was one of the earliest identification of flow and brightness associations that have now been well studied by high spectral and spatial resolution observations.

Studies on solar 5-minute oscillations were undertaken by K. R. Sivaraman during 1966 - 1972, culminating in a Ph.D. thesis. A comprehensive study of various properties of the solar velocity and intensity oscillations was done, and though it fell short of bringing out the resolved $k-\omega$ diagnostic spectrum and thus the resonant-cavity nature of solar interior for acoustic waves, this work was among the early observational studies of solar oscillations. Temperature and velocity fields in the temperature-minimum region and the low chromosphere were studied using photoelectrically determined profiles of molecular lines of CN and C₂ by Nirupama Subrahmanyam in 1965.

Studies of solar rotation, by means of sunspot observations and estimation of their anchor depths in the convection zone, have formed a major research activity in more recent years and have been carried out by K. R. Sivaraman and S. S. Gupta in collaboration with Robert F. Howard from the National Solar Observatory, Tucson, USA.

The white light images recorded at Kodaikanal, from early 1900's, have been used in a number of studies including solar surface and internal rotation, evolution of large scale bipolar regions, solar diameter, solar activity cycle dependent zonal velocity bands, optical flares, correlations between rotation of bipolar sunspots and flares.

Solar Magnetic Fields:

Regular observations of strong magnetic fields in sunspots began in 1963. Measurements were made by means of the compound quarter-wave-plate technique and using the 6303 Å line with a major objective of evaluating the spatial distribution of longitudinal magnetic field. A longitudinal magnetograph of the Babcock type was designed and brought into use by J. C. Bhattacharyya in 1965. It operated at a chopping frequency of 50 cycles/sec and was in use for the study of weak longitudinal magnetic fields on the solar surface. Weak field in polar regions and elsewhere was also studied by Bhattacharyya.

Chromospheric Features and Dynamics:

Exhaustive studies of Ca II K line spectra were carried out during 1969 - 1976 by Bappu and Sivaraman. The analyses and results included: role of Ca II K line as a reliable diagnostic of chromospheric activity, the solar cycle variation of Ca II K line emission profiles of integrated sunlight, association between photospheric magnetic structures and Ca II K structures and their use in inferring the morphological evolution of photospheric structures, and the implications of the above for other stars. Variation of the luminosity of the Sun as star in Ca II K line was studied by

K. R. Sivaraman, Jagdev Singh, S. P. Bagare, and S. S. Gupta in the mid-eighties. During this same period, Jagdev Singh and others carried out a detailed study of active region contributions to Ca II K line luminosity variations over a solar cycle. Intensity fluctuations in H α line due to chromospheric mottling were studied by M. K. V. Bappu in 1964. J. Singh and M. K. V. Bappu studied the supergranular network size and its variation with solar cycle. Bappu also carried out detailed observations of prominences and calcium flocculus in the early sixties. K. R. Sivaraman and V. I. Makarov observed filament migrations, and poleward migration of magnetic structures, meridional motions and polarity reversals at the poles.

Coronal Studies:

M. K. V. Bappu, J. C. Bhattacharyya, and K. R. Sivaraman saw H α and Ca II K lines during the solar eclipse of 1970. Important coronal studies, most notably on coronal wave dynamics, were carried out over several eclipse expeditions starting from 1983 to date. The recent eclipse expeditions have achieved high spatial resolution narrow band photometry of coronal structures to investigate the nature of waves. Studies of intensity oscillation in the coronal green line and red emission line have also been carried out.

Solar Terrestrial Relationships:

Several studies relating to the ionosphere over Kodaikanal and the electrojet have been carried out in the early sixties. Notable among them are the variation over a solar cycle of ionic densities at different levels of the equatorial ionosphere, and the spatial, seasonal, and solar cycle variations in the lunar semi-diurnal oscillations in the ionospheric F-region. An analysis of magnetic crochets associated with relativistic flares was done in 1964 and the amplitude characteristics of geomagnetic sudden commencements with energetic proton events were studied.

Current Observational Facilities and Programmes at Kodaikanal Solar Observatory:

The Ca II K, H α images and spectroheliograms are continuing to be obtained at Kodaikanal for studies of the chromospheric network, solar cycle variations of the background flux in K, and synoptic observations of solar activity. Digitisation of Kodaikanal data is one major new project: a new digitiser using better CCD camera and uniform light source have been fabricated to digitise the solar images with higher resolution (spatial resolution 1 arc sec, limiting resolution of the images) and with very high photometric accuracy.

A new spectropolarimeter, indigenously designed and built, has been installed and being used at Kodaikanal for the study of active regions on the Sun. A new system to obtain K-line images of the Sun using a K-line filter has been installed. These K-filtergrams are recorded onto a 1K x 1K CCD. The system has been operational since 1996-97.



John and Mary Evershed photographed in Kashmir (1913)

In
This Building
ON
JANUARY 5, 1909
JOHN EVERSHED
MADE THE DISCOVERY OF
THE PHENOMENON OF RADIAL MOTION
IN SUNSPOTS, THAT IS NOW TERMED
THE
EVERSHED EFFECT.



**The building where Evershed discovered the effect named after him.
The 'Solar Tunnel Telescope' which came up later can be seen in the background.**