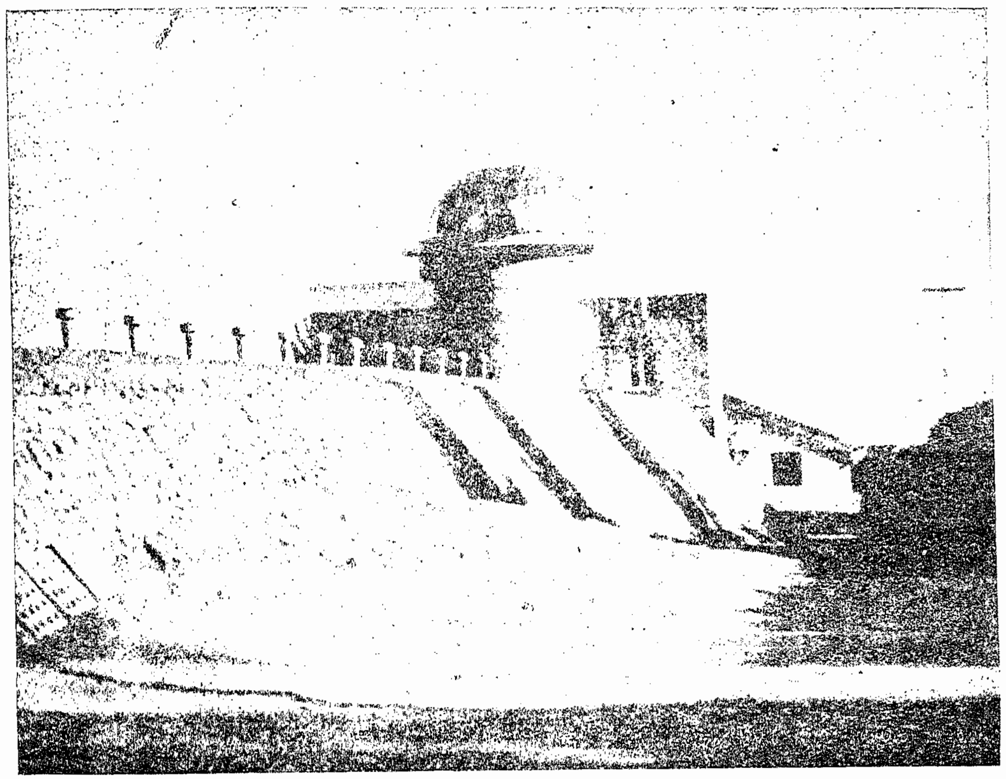
INDIA METEOROLOGICAL DEPARTMENT

MODERNISATION OF THE ASTROPHYSICAL OBSERVATORY KODAIKANAL

1960



General view of the Observatory

On the occasion of the
inauguration of
Solar Telescope, Coronagraph and Heliograph
in the Astrophysical Observatory, Kodaikanal
by
Dr. P. Subbarayan
Minister for Transport & Communications,
Government of India

MODERNISATION OF THE ASTROPHYSICAL OBSERVATORY, KODAIKANAL

I. Introduction

Before describing the steps taken in recent years to modernise the Kodaikanal Observatory it will not be out of place to give a brief survey of the history of this observatory. Although it is often called the "Kodaikanal Observatory", its history began at Madras in 1792, for it is the successor to the Astronomical Observatory established at Madras in that year by the East India Company "for promoting the knowledge of astronomy, geography and navigation in India." Thus, as an institution for the study of what may be called modern or telescopic astronomy, this observatory is to be regarded as one of the older observatories of the world. It is to be remarked that during much of the period when the old Madras Observatory was functioning as a live centre of astronomical research, astronomy meant almost exclusively *positional* astronomy. However, already towards the middle of the nineteenth century a new branch of astronomy was developing. This new development was in the direction of an enquiry into the physical constitution of astronomical bodies, although this did not imply any lessening of the astronomer's interest in the older branch of astronomy whose main concern was the study of the changes of position or motions of the astronomical bodies. This new interest in the physics of the astral objects brought about a most fruitful co-operation between the older 'star-gazing' astronomers and the physicists; the result was the modern science of astrophysics which offers an unlimited scope of study to the modern experimental and mathematical physicist as well as to the pure mathematician. Indeed it may be said today with sufficient justification that astrophysics, which began as a part of astronomy, now encompasses the whole of old astronomy.

II. The Madras Observatory and its shift to Kodaikanal

At about the time when the former astronomical observatory at Madras was nearing the completion of a century of fruitful work in positional astronomy, certain considerations—not strictly astronomical—made the then authorities lay greater emphasis on the study of a particular branch of astrophysics, namely solar physics, and it was decided to transfer the observatory to a high-level station which would be more suitable for such work than the sea-level city of Madras. So in 1895 the foundation stone of a Solar Physics Observatory was laid at Kodaikanal, and by 1898 the earliest work on solar physics began at this hill station at an elevation of 2,343 metres above mean sea level. The Government Astronomer (as he was then called) of the Madras Observatory shifted his headquarters to Kodaikanal with the new designation of Director, Kodaikanal and Madras Observatories. Very little of astronomical work other than that associated with the issuing of time-signal continued to be done at Madras after the head of the Kodaikanal and Madras Observatories took up residence at Kodaikanal, and in the course of the years even that little astronomical work was discontinued at Madras. No regular work on positional astronomy was undertaken at all at Kodaikanal, the main function of this observatory in those days being the study of the physics of the sun, although some general meteorological and seismic observations were also made as a daily routine.

III. Early instrumental equipment

The basic instrumental equipment for solar physics with which the observatory started work at Kodaikanal during the closing years of the nineteenth century was simple, but of excellent quality, and modern according to the prevailing standards. Within a very few years thereafter a spectroheliograph for observation in the violet K-line of the ionised calcium atom was acquired from the Cambridge Scientific Instrument Company of England. A few years later a new plane grating spectrograph and a second spectroheliograph for observation in the red H-alpha line of the Hydrogen atom were constructed in the observatory. From that time onwards, although some modifications and improvements were made to the available equipment and some instruments were also temporarily constructed for specific problems of research, the basic permanent equipment for solar research (except for the addition of a spectrohelioscope obtained as a gift from Dr. Hale of the Mt. Wilson Observatory) remained fundamentally the same up to about the middle of 1946 as it was at the end of World War I. However, through the leadership of the successive directors during the first half-century of its work at Kodaikanal, the observatory's reputation in the astronomical world as a first-rank centre of solar research had been established. But it is certain that these scientists, particularly the later ones, would have realised that the observatory's equipment was necessarily becoming obsolescent with the progress of time; but they must have felt pretty helpless in the face of the great difficulties about the availability of funds and the general lack of interest in scientific research on the part of the administrative authorities.

IV. Modernisation of instrumental equipment

Soon after the end of World War II, and particularly from 1947, the prospects appeared to be more encouraging for seriously attempting to modernise the equipment of the observatory and to expand the observatory's activities to all branches of astrophysics instead of confining them only to solar physics. The first efforts were directed towards developing a serviceable machine-shop at the observatory and towards the recruiting and training of young and capable mechanics for the local construction of astrophysical apparatus. These efforts were so successful that within a very few years it became possible to build locally at an almost insignificant cost quite a number of perfectly satisfactory instruments of solar research, such as high-dispersion spectrographs, coelostats, siderostats, photo-electric photometers using both ordinary photocells and electron-multipliers and a variety of other physical apparatus which made the daily routine work as well as investigational work of the observatory far quicker and more convenient than before. Without having to ask for large grants it became soon possible to build up so much apparatus for modern solar research that there was enough to keep a number of experimental research workers busy on a variety of solar problems at the same time, while in the olden days there was just about enough apparatus for only one active experimental worker. However, in spite of these developments in the scope of the observatory's research work there was need for other developments. For instance, it had been appreciated sometime earlier than 1946 that the Kodaikanal Observatory occupied a very special geographical position, which made it fairly unique in its research potential in certain branches of astrophysics. The observatory's location is only about 10° to the north of the geographical equator so that here it is possible to observe all the northern stars and a vast proportion of the southern stars as well. The observatory is situated barely 1/2 a degree to the north of the geomagnetic equator so that continuous observations of the ionosphere and of the geomagnetic field at this location are of the highest scientific importance. So in 1948 a fairly well-equipped magnetic observatory was attached to the Kodaikanal Observatory. The initial capital cost of this new development was small, because the buildings for the new magnetic observatory were already available, being the discarded buildings of the old magnetic observatory of the Survey of India disused since 1923; also the instruments of the old magnetic observatory could be repaired and brought into use to begin with. But soon thereafter modern instruments were added, so that it can now be claimed with justice that the Magnetic Division of the Kodaikanal Observatory is as well equipped as and has as much research potential as the best magnetic observatories anywhere. In 1951,—that is, within about three years of the starting of the new magnetic division, —an Ionospheric Division was added to the Kodaikanal Observatory. The equipment of the ionospheric laboratory is of the highest quality and of a very up-to-date type. There is an electronics laboratory attached to the ionospheric division; although it had a very modest beginning, it is now fairly well-equipped for the needs of the observatory. In fact, the electronics laboratory has been able to build a number of radio telescopes which have yielded interesting and useful results in connection with the study of radio waves emitted by the sun and certain "radio" stars. Thus the activities of the Kodaikanal Observatory have in recent years extended also into the latest branch of astronomy which is known as radio-astronomy. It is the observatory's aim to develop its radio-astronomical studies and to organise them into a new Division of Radio-astronomy. Plans for the establishment of this new division are well under way, and the construction of a special building for housing the Radio-astronomy Division is already well advanced. Three motor-generator sets for providing to the radio-astronomical and other electronic apparatus of the observatory a really steady electric supply have already been acquired; and Government of India has sanctioned the construction of a power-house at the observatory for housing these generators.

V. The Stellar Physics Division

During the last 12 or 13 years the authorities of the Kodaikanal Observatory have planned to make the fullest use of the advantages that result from the favourable climatic conditions, the rather unique geographical location and the high elevation of Kodaikanal. Apart from the various developments outlined above one of the most important projects of the observatory has been to organise a Division of Stellar Physics which will specialise in research connected with problems of stellar evolution, structure of the astronomical universe and so on. The Stellar Physics Division was started some years ago with a 20-inch reflecting telescope and an 8-inch refractor. Both these telescopes are old instruments, but of high quality; they are inheritances from the long-disused Takhtasinghji Observatory of Poona and from the old Madras Observatory, and have been rebuilt and adapted to the latitude of Kodaikanal. Several accessories have also been added to these telescopes during the last two or three years, so that their utilities in the spheres of work to which they are most suited have been enhanced. However, the aim of the Stellar Physics Division has also been to create facilities for research in fields accessible to really large telescopes. Plans were prepared many years ago for the acquisition of two large telescopes for Kodaikanal,—a 100-inch conventional reflector and another new type of 46/34-inch Schmidt-Cassegrain telescope. Unfortunately, such large instruments have to be acquired from abroad; they are quite expensive, and notwithstanding all serious efforts it has not yet been possible for Government to allot the funds required for these two major projects of development of the Kodaikanal Observatory. When these two projects are executed the Stellar Physics Division will be regarded as well-equipped for really modern researches in Stellar Physics. It is to be earnestly hoped that funds for these important projects will be available at least in India's Third Five-Year Plan.

VI. Need for an Optical Shop

From the preceding paragraphs it will be evident that during the last decade or more the modernisation of the Kodaikanal Observatory has gone on at a steady pace; and although as late as 1946 it was still appropriate to call it a Solar Physics Observatory, its activities during the last ten years have extended into every branch of astrophysics in the widest sense. Therefore, the only name that adequately describes the Kodaikanal Observatory in its present state of development is "The Astrophysical Observatory, Kodaikanal". Nevertheless, it must be admitted that the degree of development has not been the same in every branch of the observatory's activities. This non-uniformity is mainly, if not entirely, due to the non-availability of large capital grants for the modernisation and development of astronomical work. Those branches which require, for modern equipment, comparatively small capital outlay have developed faster, and even for such equipment it has been the observatory's constant aim to keep the costs down by building at least the mechanical parts of new instruments locally whenever possible without sacrificing quality or accuracy. Optical components of very high quality required for astronomical work are extremely expensive even if they are of comparatively small sizes. If the present optical workshop of the Kodaikanal Observatory is developed sufficiently for constructing even the comparatively small optical pieces with the required degree of precision the saving in cost will be very considerable. Most important astronomical institutions of the West have highly developed optical workshops. A rudimentary optical shop with a few basic tools was started at the Kodaikanal Observatory some time ago; the few optical components locally produced have been so encouraging that steps have been taken to develop the optical shop adequately. This way, in the course of some years, the observatory may hope to be independent in respect of its requirements of optical components for its smaller equipments; and when the country's heavy engineering industries are sufficiently developed—as they are bound to be in a very few years—it will be quite unnecessary for the observatory to acquire even the largest astronomical instruments from abroad. That will be a goal worth aiming at.

VII. The Solar Physics Division

The Solar Physics Division is at present the most highly developed branch of the observatory. This is of course natural, since this section had a start of almost half a century over the other divisions. Notwithstanding the very considerable modernisation of the equipment of the Solar Physics Division mentioned earlier in this report, the observatory had been lacking in some of the most modern tools of solar research. Among these the principal ones were: (1) a *Coronagraph;* (2) a *Monochromatic Heliograph;* and (3) a large *Solar Telescope combined with a powerful Spectrograph of exceptionally high dispersive and resolving powers.* These deficiencies have been eliminated only during the last few months through very considerable effort.

1. The *Coronagraph* (Figs. 1 and 2) is a special kind of telescope invented by the famous French astronomer, Bernard Lyot, for the study of the *inner* corona of the sun. Before Lyot's invention the solar corona could be studied only during the brief durations of total solar eclipses. In fact, during the last 85 years or so it has been possible to study the corona observationally only for a total time of 4 hours or less. The coronagraph,

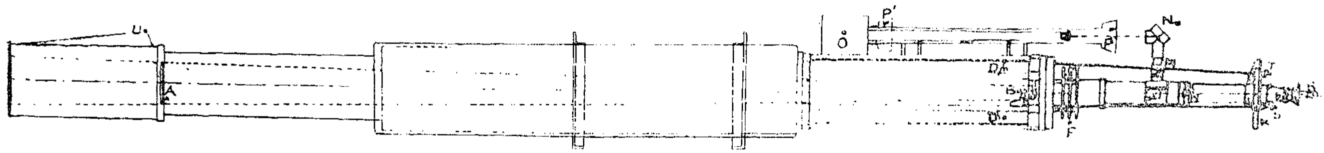


Fig. 1. Optical diagram of Kodaikanal Coronagraph

A—Principal objective; aperture 20 cm (8″), focal length 4 metres (15′), B—Reflecting plane surface, C—Metallic screen for occulting solar disc. D—Polished metal reflector, E—Field lens. F—Blackened discs for heat absorption, G—Plane mirror, H—Camera objective, K—Hand wheel, L—Camera, M—Condensing lens for focussing corona on spectrograph slit, N—Plane mirror, O—Two-prism spectrograph, P—One metre (40″) camera of spectrograph, P′—19 cm ($7\frac{1}{2}$″) camera of spectrograph, Q—Spectrograph slit, R—Eye piece, S—Control rod for rotation of coronagraph tube, T—Control rod for shutter in the sun shade, U—Sun shade

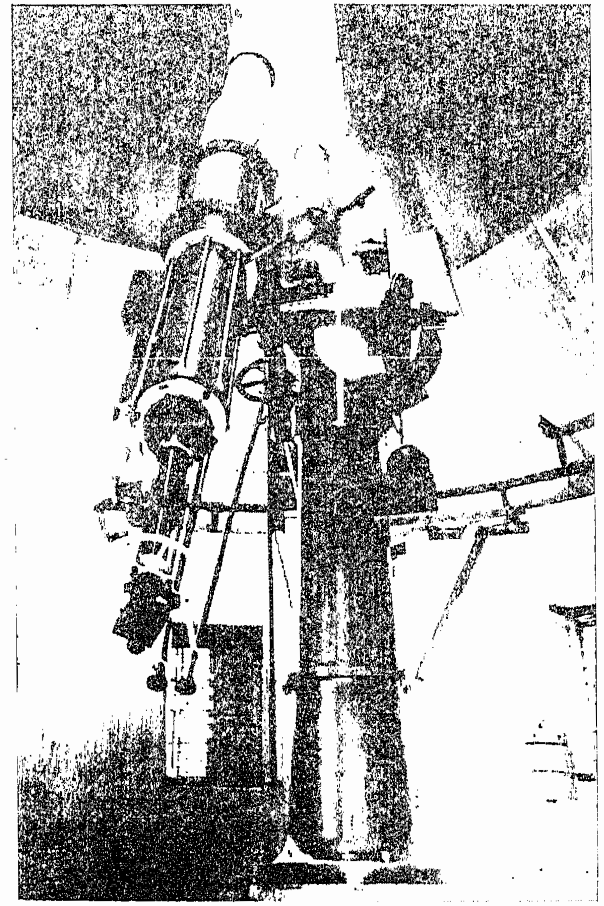


Fig. 2. Photograph of Kodaikanal Coronagraph (left) and Monochromatic Heliograph (right) as installed in their dome

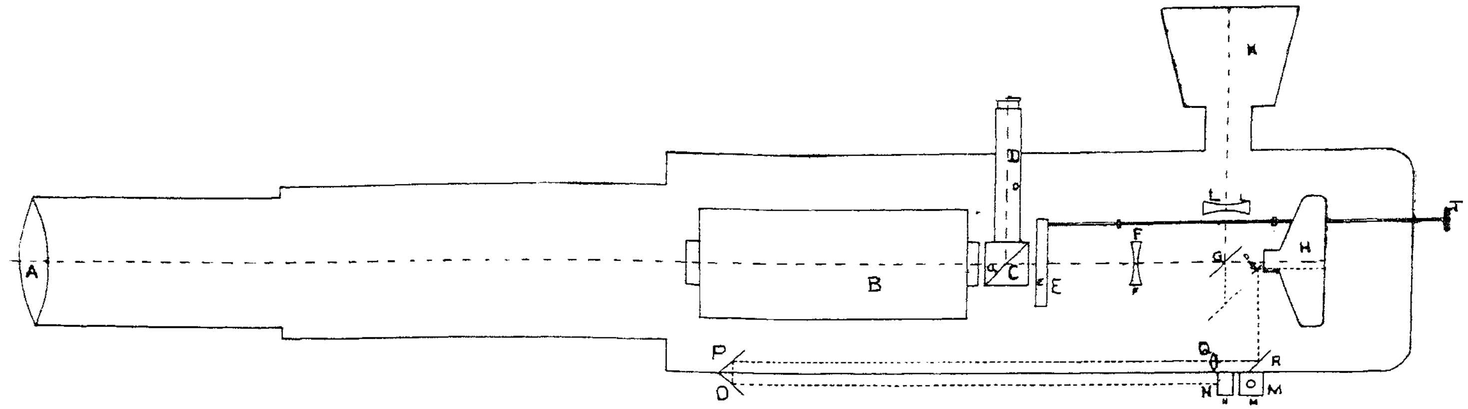


Fig. 3. Optical diagram of Monochromatic Heliograph as designed and constructed at Kodaikanal Observatory

A—Principal objective, B—Lyot's interfer polarising filter, C—Cube, D—Viewer, E—Metallic shutter, F—Diverging lens for keeping size of image constant throughout the year, G—Plane mirror, H—35 mm film camera, K—Quarter plate camera, L—Enlarging lens, M—Lamp, N—Frame containing watch and wedge, O, P, R, S—Plane mirrors, Q—Focussing lens, T—Handle operating shutter E and film camera shutter, U—Semi-reflecting surface if installed at a suitable observing station, makes it possible to observe the solar corona without a total eclipse; a conservative estimate of the possible time of coronal observation at a reasonably good station equipped with a Lyot Coronagraph would be 200 to 300 hours per year. The invention of the coronagraph is, therefore, a great astronomical advance. But it does not make eclipse expeditions unnecessary, for during the precious moments of a total solar eclipse one can undertake many kinds of observation other than what is possible with the coronagraph. It is not every optician who can make a really satisfactory object-glass for a coronagraph. The technique of making such a lens is very special, and the difficulties of realising near perfection in its performance increase enormously with the aperture of the objective. The best coronagraph objectives in existence are those made by the late Bernard Lyot and his associates who are busy astronomers and optical experts, not commercial instrument makers. It has, therefore, not been easy to have the coronagraph made by these scientists; even persuading them to undertake this work for Kodaikanal has involved a great deal of effort and personal influences and contacts. The coronagraph recently installed at Kodaikanal was built in Paris under the personal supervision of experts who were co-workers and associates of the late Bernard Lyot and is, therefore, expected to be of the finest possible quality. So far as coronagraphs go, it is a large instrument of 20-cm aperture. Kodaikanal Observatory has bought from France just the telescope without the equatorial mount and without accessories, such as spectrograph, photometer etc. The telescope has cost a little over a lakh of rupees, but the equatorial mount, which is an essential but very expensive part, has been improvised by adapting components of disused old instruments and the optical accessories have been designed and built in the observatory's machine-shop and laboratories with the help of optical components already available in the observatory. This procedure has saved the country more than a lakh of rupees.

2. The *Monochromatic Heliograph* (Figs. 2 and 3) installed at Kodaikanal is also an invention of the late Dr. Bernard Lyot of France and is intended for studying the chromosphere and connected solar phenomena. Its vital component is an interference polarising filter for isolating a part of the red H-alpha line of the hydrogen atom. Kodaikanal Observatory has bought from France (where the best filters of this kind have so far been built) just the filter, a suitable telescope objective and one or two small optical components at a total cost of about Rs. 31,000; the whole design and the construction of all mechanical parts for the complete heliograph have been done at the observatory. The monochromatic heliograph has been mounted on the same substantial equatorial stand which carries the coronagraph. The heliograph, if bought all complete from France, would have cost about Rs. 1,50,000. The actual procedure followed by the observatory has saved the country at least a lakh of rupees. The idea of mounting the coronagraph and the monochromatic heliograph on the same equatorial stand has also obviated the need for constructing two domes for the two instruments, thus making for a further saving of money. The common practice is to buy the pre-fabricated cupola from telescope-makers

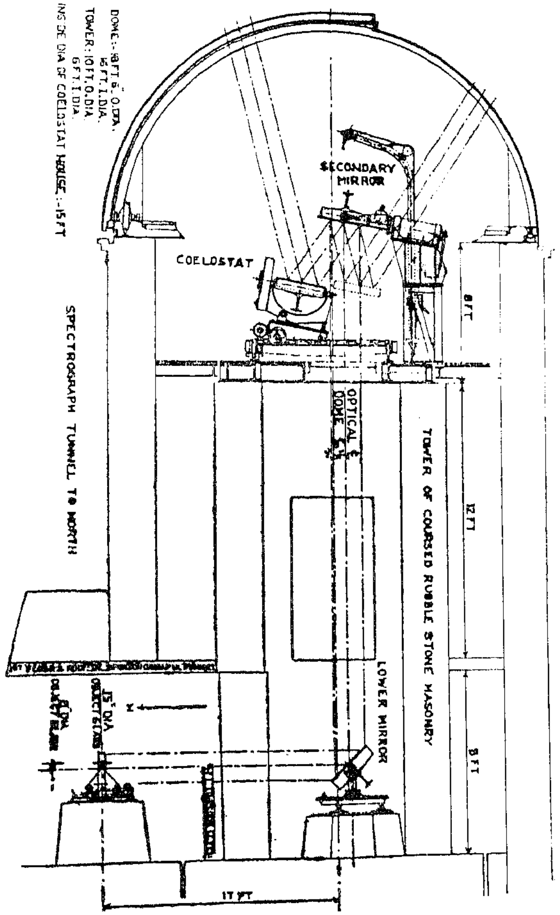


Fig. 4. Optical diagram of Grubb Solar Telescope of Kodaikanal Observatory

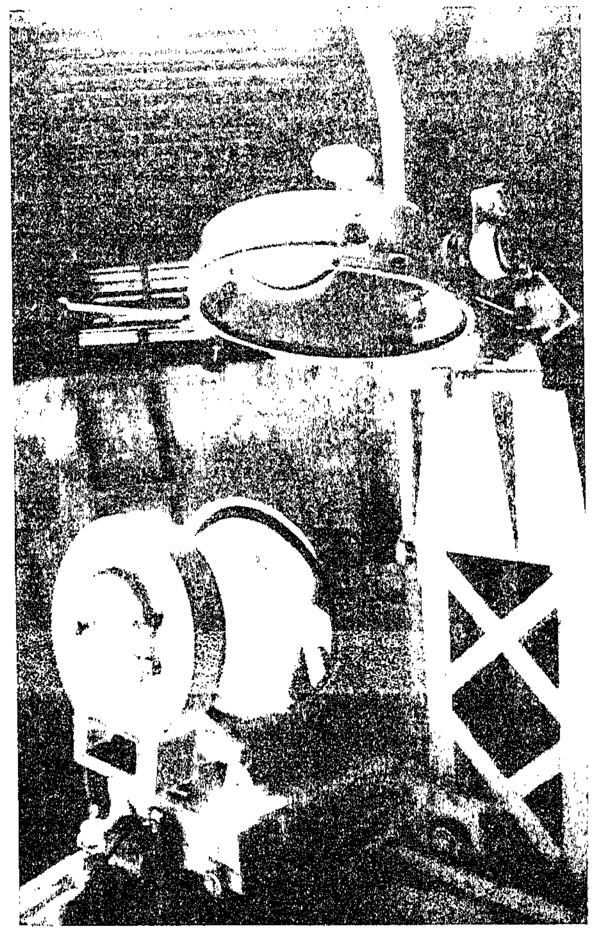


Fig. 5. Photograph of primary and secondary mirrors of Solar Telescope in dome at Kodaikanal

abroad. But at Kodaikanal Observatory all domes erected since 1947 have been completely designed at the observatory and constructed by Indian contractors and engineering concerns. This has been responsible for a very considerable saving in costs; but perhaps the much greater gain has been the gain in experience and self-confidence on the part of all persons concerned with the design and the construction of the instruments and their housings.

3. The large *Solar Telescope* (Figs. 4 and 5) erected at the Kodaikanal Observatory consists of a coelostat with three fused silica mirrors of fully 60-cm aperture and two telescope object-glasses of 37.5-cm and 20-cm apertures. The instrument is constructed in England by the famous firm of Sir Howard Grubb-Parsons according to the observatory's general specifications. The primary and secondary mirrors of the coelostat are mounted on a substantial, double-walled stone-masonry tower of 11-metre height above ground and are so arranged that a broad beam of sunlight can always be reflected vertically downwards; the third mirror of the coelostat (mounted on the floor of the tunnel) reflects the light (received from the other two mirrors on the top of the tower) horizontally into an underground tunnel of about 70-metre length. This long tunnel houses the telescope objectives and mirrors mounted on long horizontal steel rails and an exceptionally powerful *20-metre long Spectrograph* (Figs. 6—10) having both a reflectance grating and a system of prisms as its alternate dispersive organs. The optical pieces for the spectrograph were acquired from the best makers in England and the U.S.A.; this spectrograph is completely designed at the observatory and every one of its mechanical parts has been built either in the observatory's own machine-shop or in the workshops of engineering concerns in the country according to the exact specifications supplied by the observatory. The instrument incorporates every desirable feature useful for solar research : for instance, it has a plane reflection grating of over 20-cm long ruled (600 rulings/mm) surface and a set of $3\frac{1}{2}$ prisms of 15-cm aperture in autocollimating arrangement; the air can be pumped out of the spectrograph tube (which is about 20 metres long and 75 cm in diameter in its narrowest part and over $1\frac{1}{4}$ metres across where it is widest) so that internal turbulence can be reduced to a minimum; the slit, camera and all optical components can be rotated accurately round the axis joining the centre of the slit to the centre of the collimator-camera lens; the spectrograph, being housed in the underground tunnel, is maintained at a constant temperature with a high degree of accuracy. For work in some regions of the spectrum where absorption by the glass collimator-camera lens is a disadvantage, a 12-inch concave mirror (made by one of the officers in the observatory's optical workshop) of nearly 18-metre focal length can be easily mounted on the inner end of the focussing tube carrying the lens. The mirror then serves both for collimating the incident beam from the slit and for focussing the spectrum on the camera; in this arrangement a second plane reflectance grating appropriately mounted on inner side of the front disk (which carries,—on its outer side—, the slit, camera and other atttachments) becomes the dispersive organ. When the spectrograph is set in this

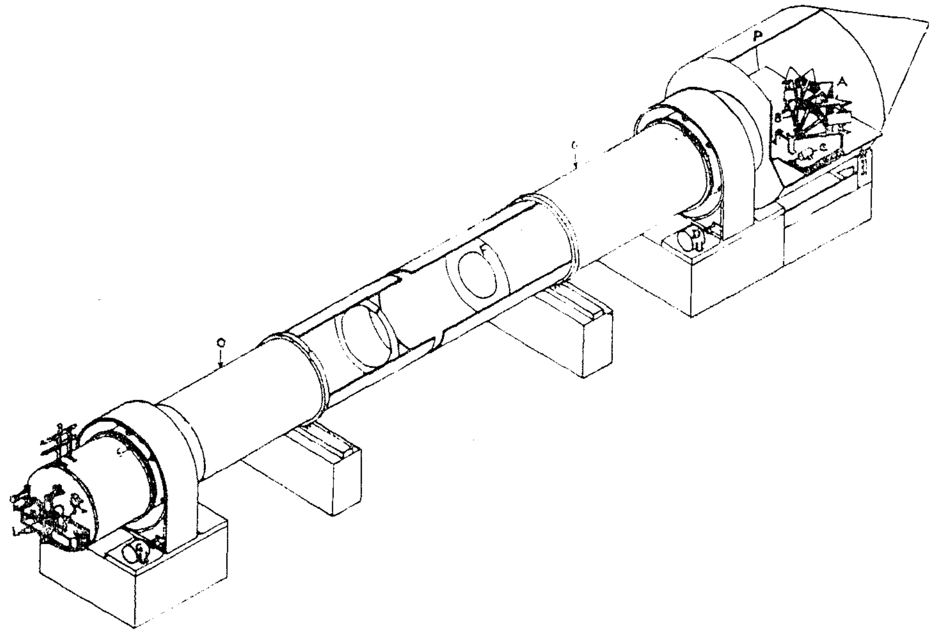


Fig. 6. Optical diagram of 20-metre Solar Spectrograph designed and constructed at Kodaikanal Observatory showing the prism system with electrically controlled minimum deviation link at the back end (right) and spectrohelioscope attachment on front (left)

A—Prisms (three equilateral prisms and one half prism), B—Minimum deviation link, C—Motor for moving the prisms, D—Motor for rotating optical parts at back end of spectrograph, E—Worm wheel, F—Diaphragms for eliminating stray light, G—Motor for rotating the front end of the spectrograph, H—Camera, K—Drums for winding the cloth shutter, L—Anderson prisms for spectroheliocope, M—Motor for rotating the Anderson prisms, N—Spectrograph slit, O—Steel tube of length 18 metres (60′) and diameter 73 cm (29″), P—Detachable steel tube, length 2.3 metres and diameter 1.2 metres for covering the back end of the spectrograph, Q—Telescopes for viewing the scales fixed at both ends of spectrograph

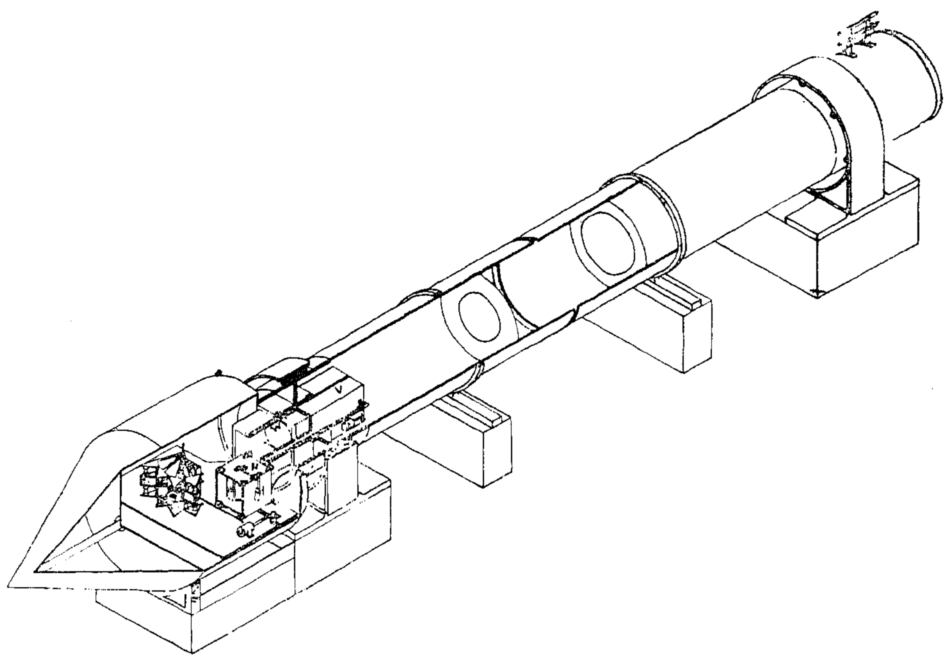


Fig. 7. Optical diagram of 20-metre Solar Spectrograph designed and constructed at Kodaikanal Observatory showing grating in electrically controlled mount and focussing tube carrying collimator-camera lens or concave mirror

R—Grating box on rollers. S—Grating. T—Motor for rotating the grating. U—Motor for moving the grating box in and out of position, V—Square tube carrying the lens W. W—Collimator-camera lens; aperture 20 cm (8″) and focal length 18 metres (60′). X—Motor for focussing lens W

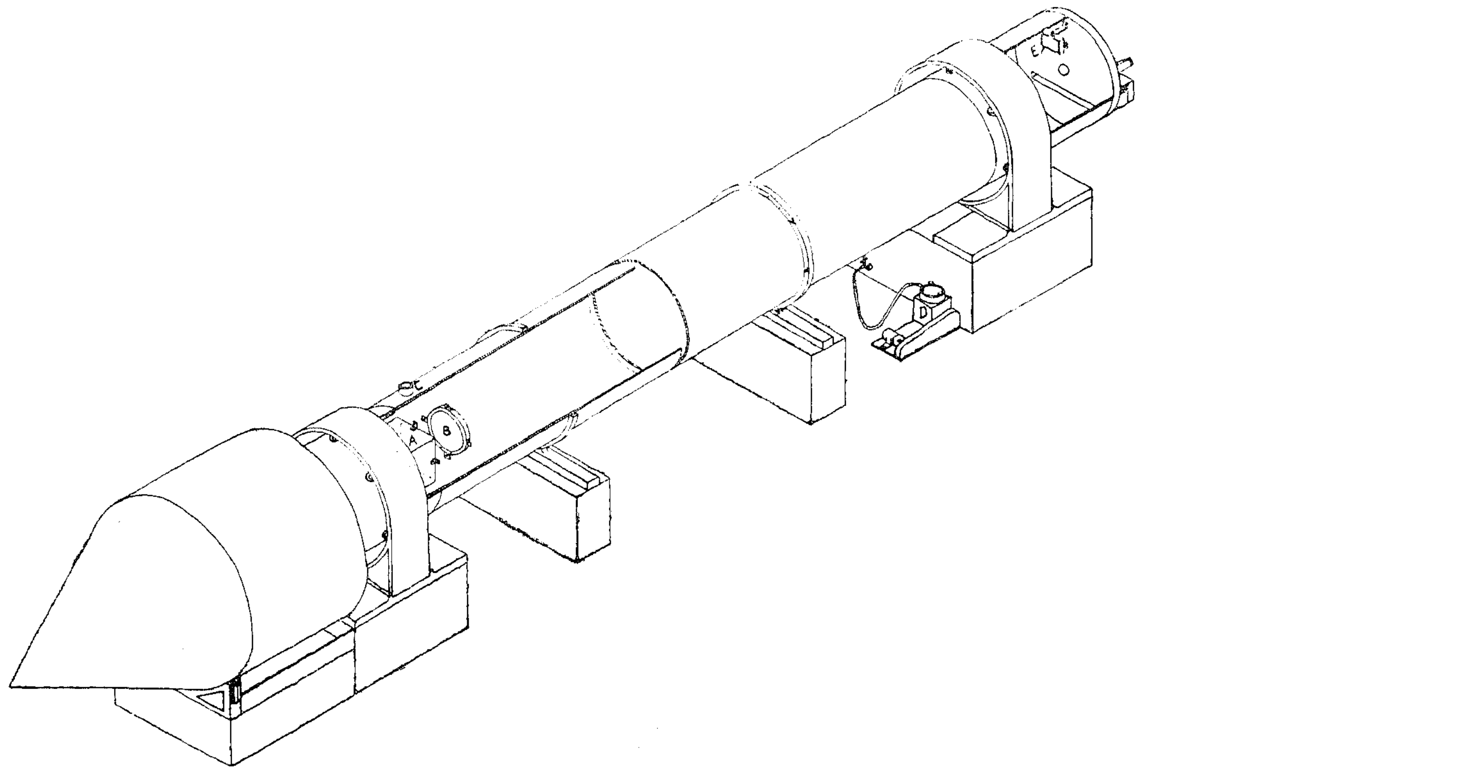


Fig. 8. Diagram of the 20-metre Solar Spectrograph with collimator-camera mirror and second plane grating mounted behind slit plate

A—Focussing tube, B—Detachable collimator-camera mirror at end of focussing tube, C—Airtight window, D—Vacuum pump, E—Plane grating

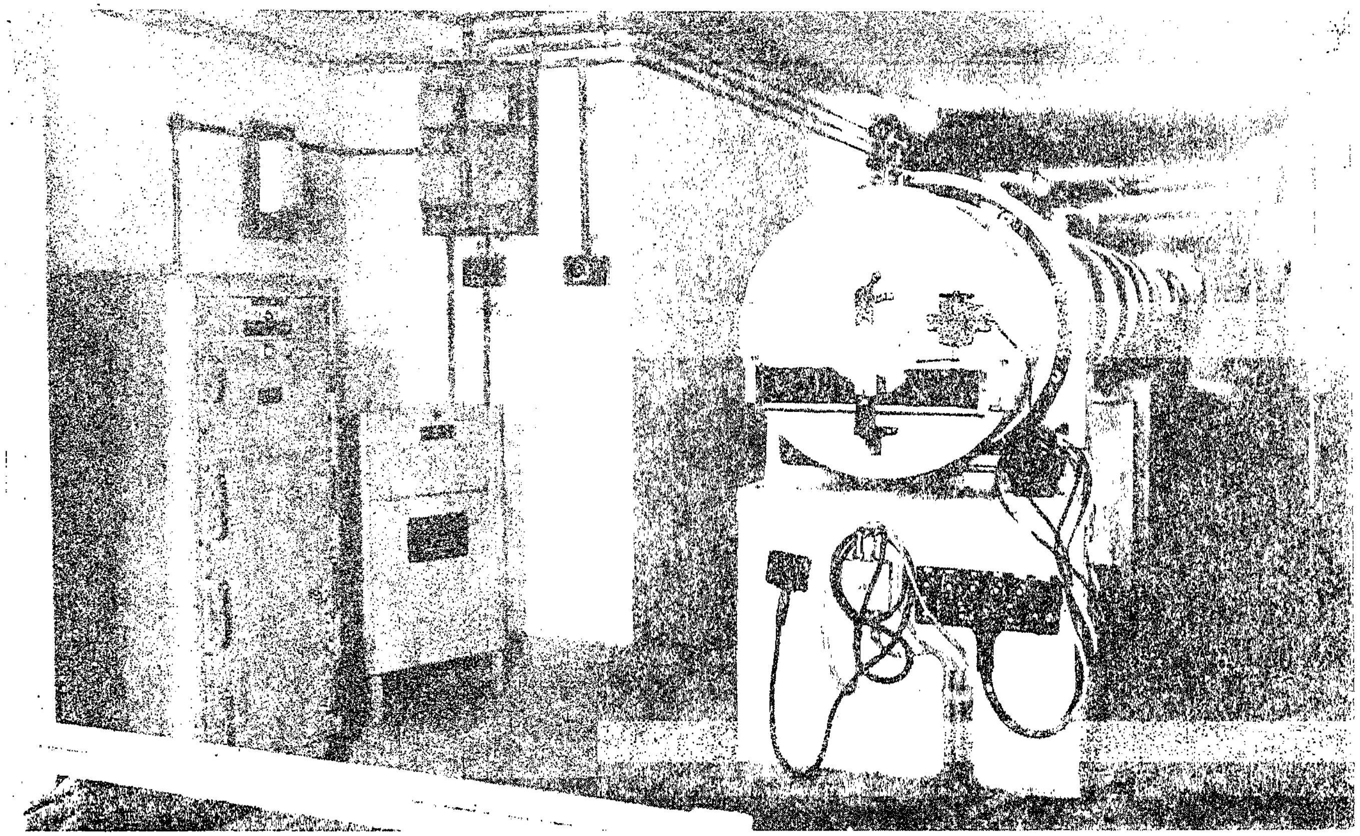


Fig. 9. Photograph of front end of 20-metre Spectrograph and the control units for Coelostat drive etc. as installed in the tunnel

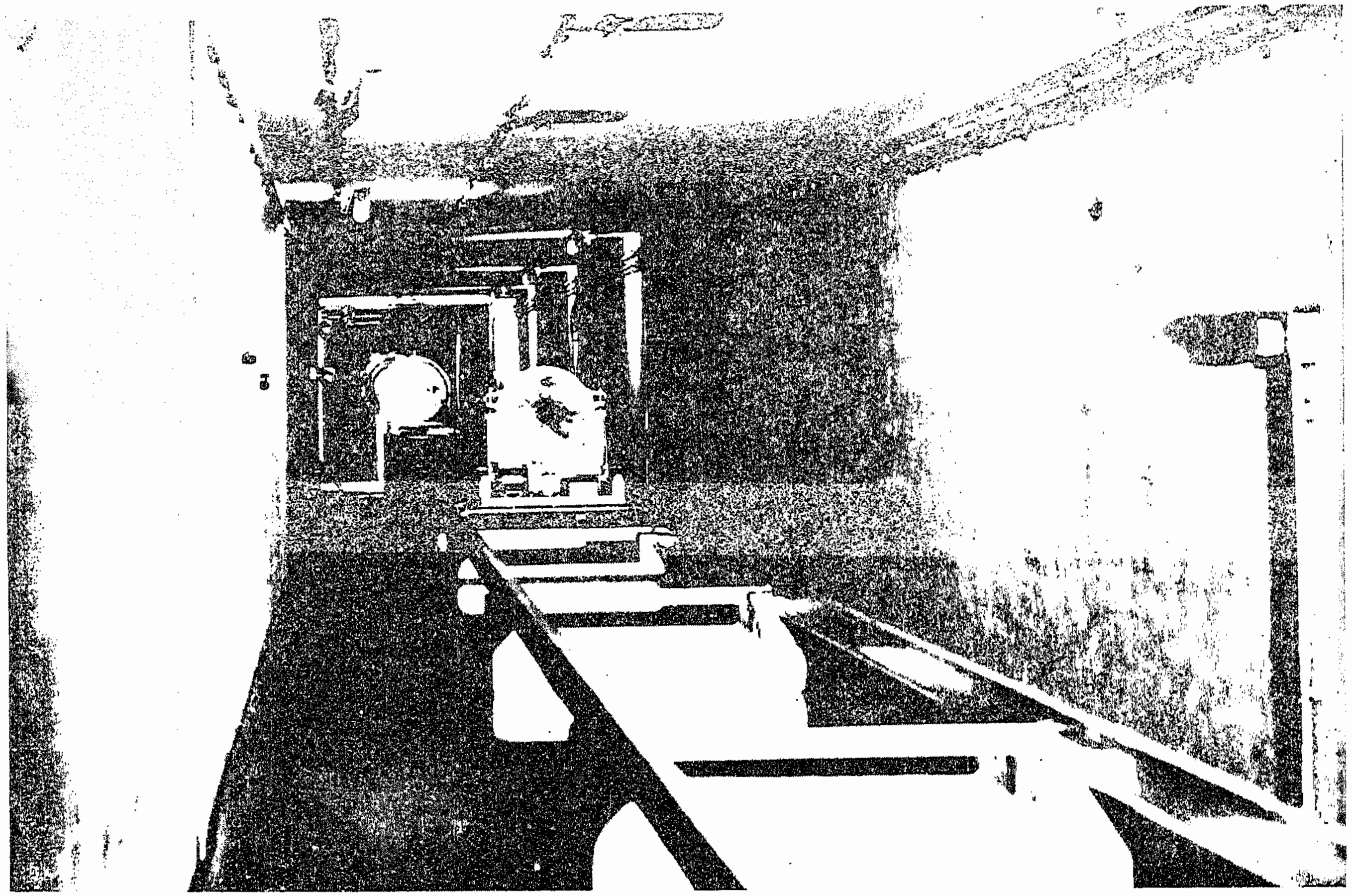


Fig. 10. Composite view of one telescope objective (on rails) and of spectrograph as installed in tunnel

particular manner the solar image projected on the slit is formed by a reflecting system (consisting of an 18-inch parabolic mirror combined with a 6-inch auxiliary hyperbolic mirror) which is also intended to be used whenever an image of variable size is required or better achromatism than what can be obtained with the doublet object-glasses is desirable. The spectrograph has also been provided with certain additional accessories permanently attached to the slit end which make it possible to convert the spectrograph into a spectroheliosope within a few seconds; this facilitates the positioning of chromospheric features not visible on the whitelight image projected on the slit plate.

VIII. Scope for future developments

It is believed that no more powerful solar installation than the one now built at Kodaikanal exists at present in any other astrophysical observatory; in point of versatility also it is perhaps quite exceptional. The installation has been so designed that further additions of accessories will be possible without any radical change of design. If the spectrographs were to be made by any reputed maker in Europe or America according to the observatory's specifications it would have cost between 3 and 4 lakhs of rupees at least; it has actually been built at a cost considerably less than one lakh of rupees. The whole installation including the telescope, the spectrograph and the building with rotating dome has been completed at a cost of about 6 lakhs of rupees. The building with the revolving cupola (Fig. 11) is also designed by the observatory, but its actual construction has been done through the Central Public Works Department. The double-walled coelostat tower is so designed that the third mirror, which is capable of rotation around a vertical axis, can send the sunlight in a direction making an angle of about 45° to the axis of the underground tunnel and into an underground laboratory consisting of three or four chambers. This underground laboratory is not available yet, but is included among the future plans of development of the observatory. In order to facilitate the construction of the underground laboratory without any risk of damage to the present solar installation a wide enough trench was dug on the eastern side at the time of the construction of the tower and tunnel and filled with rubble and earth. There is also, in the outer wall of the tower, a bricked-up opening on the east. When the underground laboratory is constructed in the future the light from the coelostat is planned to feed, through an appropriate image-forming system, a large concave grating with 90,000 rulings and of 9-metre radius of curvature installed in a Paschen or similar mount in one of the chambers. The large concave grating has already been acquired and it is hoped to execute this plan in the near future. There are very important solar problems which can be studied by this arrangement supplemented by certain accessories. The present intention also is that one of the chambers of the underground laboratory should be suitably arranged for housing an engine for ruling gratings. The ruling of precision gratings is admittedly a most delicate and difficult technique, but there seems to be no *prima*

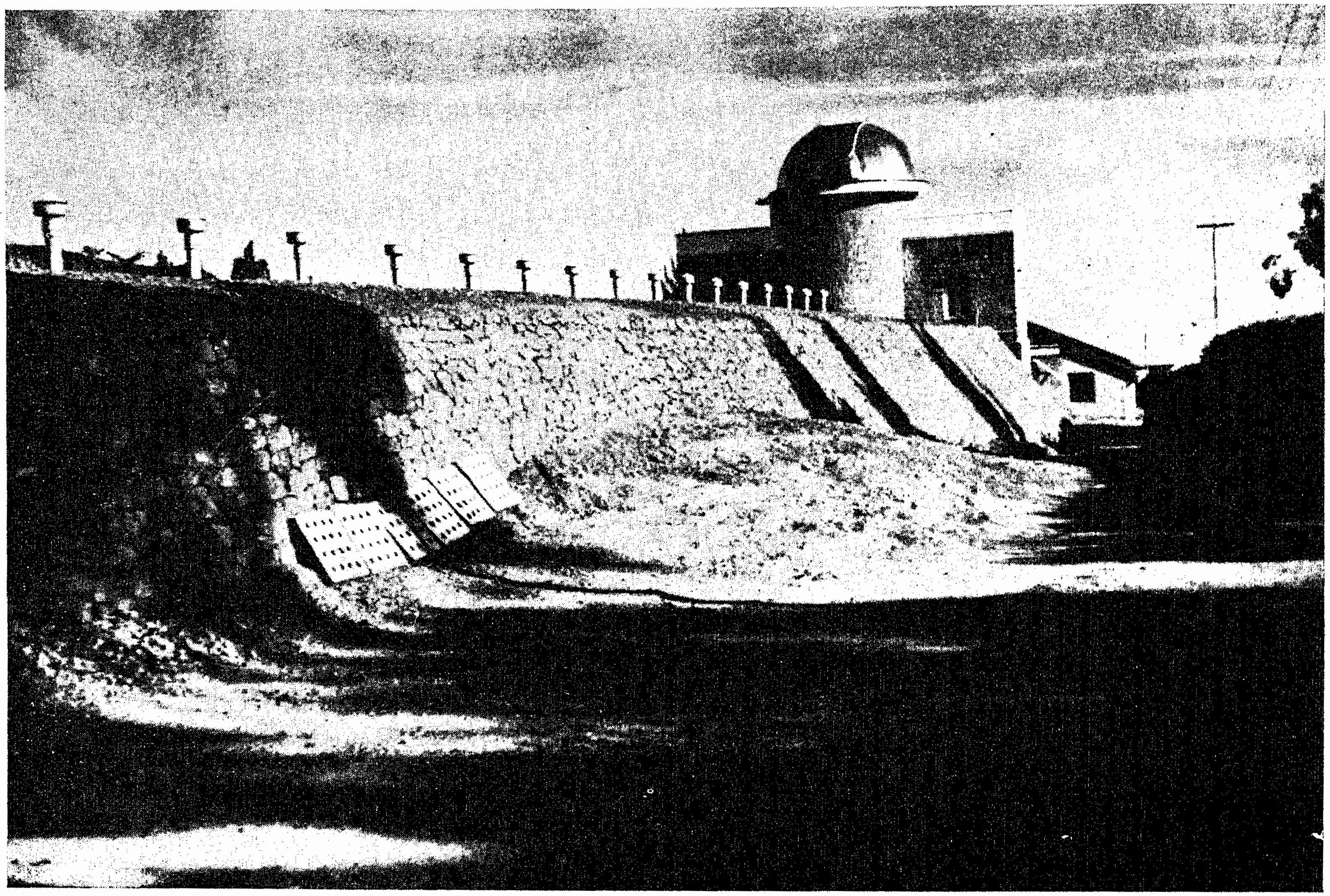


Fig. 11. View of tower for Solar Telescope and part of underground Spectrograph tunnel at Kodaikanal

facie reason for thinking that one should not even attempt it in this country.

IX. Conclusion

It is very common to have large and important astronomical instruments of foreign make erected at site by the manufacturers themselves. The Kodaikanal Observatory has done the installation of all new instruments acquired from abroad with no external help of any sort and at a considerable saving in expenditure. The gain in experience by the staff who have collaborated in this has been enormous and will surely be invaluable for the execution of future large astronomical projects of the country.

This article was prepared by Dr. A. K. Das, D.Sc. (Paris), F.R.A.S., F.N.I., who was connected with this Observatory as Assistant Director from September 1937, as Director from July 1946 and as Deputy Director General from March 1954 till his retirement in April 1960. He was responsible for all the improvements described in this article and was awarded PADMA SHRI in January 1960 in recognition of his services in the field of Astrophysics.