Kodaikanal Observatory.

BULLETIN No. XLII.

REPORT ON THE CONDITIONS FOR ASTRONOMICAL WORK IN KASHMIR.

It has been the universal experience at all mountain observatories, and perhaps to a less extent at observatories situated near sea-level, that the best time of day for steadiness of seeing for the sun is during the first few hours after sunrise, when the atmosphere is cool and calm. Later in the day the definition becomes so bad from unequal heating of the air and local ascending currents of heated air that all photographic work is usually suspended, and it is very rarely possible to follow up the interesting changes that may be going on in sunspots or in prominences from hour to hour. Spectroscopic and spectrographic work, which is now of supreme importance in the study of the sun is even more seriously hindered by these adverse conditions.

During a visit to the Valley of Kashmir in August and in October 1913 the observing conditions for solar work were found to be extraordinarily good. Contrary to all previous experience in other localities, the definition of the sun was found to be of the best quality throughout the day and on all the days that observations were made, there being apparently no marked variations depending on the height of the sun above the horizon, nor upon the type of weather prevailing. From the first hour after sunrise to the last before sunset photographic and spectrographic work of the highest excellence would have been possible. The higher valleys were visited in September, ascending to about 12,000 feet, but the definition was found to be not so good as in the main Valley.

It may here be explained that the Valley of Kashmir is a nearly level plain extending for about 80 miles in a north-west and south-east direction, with many smaller side-valleys opening into it from the surrounding mountains. It is about 15 to 20 miles in width and is completely enclosed by high mountains The Pir Panjal chain of peaks on the south-west side rises to 15,000 feet above sea-level, whilst the mountains on the north and north-east side exceed 20,000 feet in some cases. In spring and early summer a complete ring of snow-covered peaks is visible from the centre of the valley. The plain is elevated above sea-level 5,200 feet at Srinagar. The alluvial soil is highly cultivated, and there are numerous water-ways and irrigation channels as well as the broad and placid Jhelum river flowing through it. The plain appears to have been the bed of a lake, and there are still large masses of water near the north-west end, such as Wular Lake and the Dal and Anchar lakes. Owing to the protection afforded by the surrounding mountains the air within the valley is extraordinarily tranquil, and high winds are very exceptional.

Observations made with a telescope or field-glass of terrestrial objects such as distant mountain peaks indicated by the remarkable clearness of vision the unusual tranquillity of the air, and small objects from 50 to 100 miles distant could be examined with a powerful astronomical telescope with very little interference from atmospheric tremors. The observations of the sun appeared to show that the Valley of Kashmir might offer very exceptional opportunities for solar research, if the conditions found in August and October were fairly representative of the whole year.

With a view to testing the conditions during other months of the year, and also to make more critical observations with larger instruments, an expedition to Kashmir was sanctioned by Government in April 1914, and the result of the work done during this expedition is the subject of this Report.

Before starting for Kashmir, the following scheme of operations was arranged :—

(1) A series of photographs of the sun was to be taken at Kodaikanal during March and April with a 3-inch photoheliograph specially arranged for the work. The instrument was then to be transported to Kashmir, and a second series of photographs taken under identical instrumental conditions. The definition of the photographs obtained would give a good comparison of the average "seeing" at the two stations.

(2) Critical observations of the definition of the sun were to be made with a 4½-inch visual telescope at different hours of the day and on as many days as possible while in Kashmir.

(3) Sunspot spectra and prominences were to be observed with a grating spectroscope, whenever possible, in order to see how such observations would compare with those habitually made at Kodaikanal.

(4) It was planned to test the definition of stars and planets with the 4½-inch telescope.

(5) It was considered desirable to spend part of the time in touring in the Kashmir Valley and neighbouring hills, to discover the limits of the good conditions which prevail, and to test the influence of different local conditions on the seeing.

Instrumental Outfit.—The principal instruments taken to Kashmir include the following :—

(1) A 3-inch photoheliograph constructed for the work at Kodaikanal.
(2) A polar heliostat adapted for use with the photoheliograph.
(3) A 4½-inch equatorial telescope by Grubb, kindly loaned by Dr. Walker.
(4) A grating spectroscope for use with the 4½-inch telescope.
(5) A 3-inch portable telescope.

Itinerary.

The personnel of the expedition consisted of the writer, Mrs. Evershed, and one servant. Mrs. Evershed had had considerable experience of the kind of work in New Zealand, where she had become expert in estimating the quality of the seeing by projecting the sun's image on a screen. Endeavours were made to secure the services of a photographic assistant in Srinagar, but no one qualified for the work could be obtained.

The expedition reached Srinagar on May 3, and observations of the sun were begun with the portable telescope on May 4. The heavier instruments were not received until May 7. While making the necessary arrangements in Srinagar we received valuable help from the Assistant-Resident, Major James, from Rai Bahadur Dr. Mitra, Home Minister for Kashmir, from the Governor of the State, who provided us with a general order to all officials of the districts to be visited to render every assistance, and from the Motamid Durbar. Dr. Arthur Neve of the Mission Hospital, Srinagar, also gave valuable advice.

A doonga was hired, and all instruments and stores put aboard, and on May 11 we started on a prospecting tour up the River Jhelum as far as Islamabad, observing the sun from the river bank at various localities. A very convenient site for a temporary Observatory was found about 10 miles out from Srinagar near the village of Pampur. This was a small grass-covered hillock about 100 yards from the river bank, rising some 20 feet above the general level of the plain. On this, most conveniently arranged for our work, were some foundations of an abandoned building with stone walls about 3 feet high, and plenty of building materials lying near. A very small amount of masonry work was needed to adapt these walls for mounting the polar heliostat, which had to be raised above the ground about 7 feet in order to reflect the sun downwards at the correct angle.

The photoheliograph was fixed on a heavy plank built into the wall, and a 10 by 10 feet tent was pitched over it. A small dark room was built adjoining the tent for developing plates, etc. Another tent was pitched near and adapted for use as an Observatory, the 4½-inch telescope being mounted inside. By unlacing a portion of the tent the tube of the telescope could be directed to the sun through the opening, and observations made inside the tent. The most satisfactory method was to project a large image of the sun from 2 to 3 feet diameter on to a white screen placed in the semi-darkness of the tent. Spectroscopic observations could also be made in the tent. The views of the solar surface obtained in this way were very remarkable. Minute spots or pores which were estimated at ½″ to 1″ of arc in diameter could be clearly seen and the rapid changes studied from hour to hour, whilst sunspots of any considerable size were magnificent objects.

The telescope was erected on May 18, and detailed visual work was started on that day. A continuous record of the state of the seeing had however been made from May 4 with the 3-inch portable telescope. The photoheliograph was in operation on May 22, and numerous photographs were obtained with it until June 3. On that day the camera and plate holder were dismounted and modified in such a way that they could be attached to the 4½-inch telescope, in order to obtain photographs of portions of the solar disc, including sunspots, on a very much larger scale than was possible with the photoheliograph. The performance of the 4½-inch telescope on the sun was so good that it appeared worth while to attempt photography with this telescope notwithstanding the fact that the colour-correction of the object-glass was for the visual rays. The photographs with this instrument would be comparable with those taken on the same days at Kodaikanal with the 6-inch photo-visual telescope, although the theoretical resolving power is less in proportion to the diameter of its object glass.

To adapt the visual telescope for photography, the component lenses of the object-glass were separated about 3 mm. to achromatize the rays more perfectly between G and F of the spectrum. It was then necessary to limit the light affecting the photographic plate to the spectral region between G and F, that is to cut out the whole of the violet and ultra-violet, which would not be perfectly focussed. This was accomplished by the use of two coloured absorbing screens of optically worked glass, a deep green and a yellow. An ordinary eye-piece of considerable power was used to project a large image on the plate, which was placed in a whole-plate slide attached to the end of the camera-box which fitted to the draw-tube of the telescope. A Kodak exposing shutter taken from a pocket camera was attached inside the camera-box and immediately behind the eye-piece; this was set to give the shortest exposure or 1/100 of a second. The rubber tube of the pneumatic release passed through a hole in the camera-box so that the bulb was accessible from outside. The small finder telescope attached to the equatorial was used to project an image of the sun on a marked screen in order to determine exactly when the sunspot to be photographed was central in the camera. It was a matter of no small difficulty with a telescope unprovided with clock driving to hit off the exact moment for making the exposure and at the same time avoid disturbances due to the wind shaking the telescope.

With this apparatus, notwithstanding the difficulties of manipulation, a very good series of photographs was obtained of a fine spot-group visible between June 7 and 21, using Imperial "Lantern" plates.

On June 20, having obtained a satisfactory series of visual and photographic observations, both of the day and night definition, the Observatory camp was placed in charge of the official chowkidhar of the village of Tengan, and we started on a tour to various localities to test the influence of local conditions on the definition of the sun. During this tour observations with the 3-inch portable telescope were made at a large number of stations in the valley and in the mountains, the route chosen being from Awantipur on the Jhelum river to Traal, and thence over the Bugmar pass to the Lidar valley, ascending this to an altitude of 11,000 feet at Zojpal. Returning from the high elevations, the Jhelum river was reached again at Bijbihara and the journey continued by river to near Awantipur and thence by two marches across the valley to the foothills of the Pir Panjal range near Romu. These last marches gave us an opportunity of testing the definition in the midst of vast stretches of wet rice cultivation, and also on low hills of about 200 feet elevation above the general level of the valley. From Romu the plain was re-crossed diagonally back to Pampur, the observing camp being reached on July 8. After a few further observations with the 4½-inch telescope the whole equipment was packed and transferred to the doonga, and the expedition reached Srinagar on July 13.

After arranging for the transport of the heavy baggage to Rawalpindi, a further set of observations was made with the 3-inch telescope across the level plain to the north-west of Srinagar and up the hills to Gulmarg. Here a stay of two days was made and the Assistant Resident and the Home Minister were again visited. On this visit to Gulmarg we were accompanied by Professor Chowla of the Government College, Lahore, who was on a holiday tour in Kashmir and who kindly assisted us in many ways.

The programme of work being completed, we started on July 19 on the return journey to Kodaikanal. Madras was reached on July 25, and a few days were spent in inspecting the observatory, Kodaikanal being reached on July 30.

Observations with the 3-inch portable telescope were continued after arrival for some weeks in order to estimate the solar definition by the same method as had been adopted in Kashmir.

RESULTS.

It may be stated at once that the remarkably favourable conditions discovered in 1913 in August and October have been found to be maintained also during the months of May, June and July, and there is no reason to doubt that the remaining months of the year, especially September and November, will also prove favourable. Owing to the prevalence of cloud during the winter, observations in December, January and February would be limited in number, although in all probability exceedingly good in quality.

The quality of the seeing was estimated by adopting a rough scale of five figures, in which 1 denotes very bad definition, 2 bad, 3 fairly good, 4 good, and 5 so perfect that no tremors can be perceived in the 8-inch solar image projected on the screen attached to the portable telescope. Seeing 1 and 2 would be useless for photographic work, except of the roughest kind for determining approximate spot positions. It was found in practice that fractions between the units could be discriminated and a scale of 10 units would perhaps have been more convenient.

During the 61 days spent in the valley of Kashmir, 204 estimates of the seeing were made, and the mean of all is 3·9. The observations were made at all hours of the day, and dividing them into three periods, morning, midday, and evening, the following interesting result is obtained.

Between 6 A.M and 11 A.M. average seeing	3·8
„ 11 A.M. and 3 P.M. „	4·2
„ 3 P.M. and 6-30 P.M. „	3·9

The better quality of seeing at midday or a little after noon had often been noticed when working with the 4½-inch telescope, and it appeared as if the best definition, often classed as 5 when estimating with the smaller telescope, occurred between 2 and 3 P.M. As the morning observations were more numerous than those taken at midday or in the afternoon, the general mean is lower than it would have been had the observations been evenly distributed through the day.

Another remarkable feature is the constancy of the good seeing from day to day. This is in marked contrast to our experience at Kodaikanal, where the variations are erratic and often occur without any apparent change in the type of weather prevailing.

In the Kashmir Valley the worst seeing recorded was 2, and this occurred on only three days: one of these was an observation made during a temporary break on a very wet day; another was near sunset at 6-30 P.M. On the third occasion the day was fine, with seeing estimated at 2 during the morning, improving to 3 in the afternoon This was the only fine day on which the seeing was not altogether satisfactory: on all fine days it ranged from 3 to 5 according to the time of day, and also to some extent according to the locality, for it was found that the very finest seeing was obtained when the telescope was located near large areas of wet cultivation, as near the entrance to the Lidar valley or near Romu, or on some small islands on the Dal lakes near Srinagar.

These islands were visited on June 13, and from the Sona Lankh in the Bod Dal the seeing was estimated as from 4½ to 5 continuously between 11 A.M. and 3 P.M. From this island the water surface is practically continuous for about 3½ miles to the south or south-east, and there are many water channels and marshes to the south-west. No doubt this fact contributed to the good seeing, because of the absence of disturbances in the lower strata of the air by contact with the sun-heated soil or rock surface.

It was found that no particular advantage was gained by ascending the low flat-topped hills called karewahs that stretch out into the plain from either side of the valley. The definition here seemed slightly less good than on the level plain among the rice fields. On the Takht-i-Suleiman hill, which rises a thousand feet above the plain, the best seeing was estimated at 4½ and the worst at 3 during a morning, and there appeared to be a tendency toward poorer seeing as the sun rose higher in the sky, as seems to be always the case on mountain tops.

In the Lidar Valley, which opens out on the main valley on its north-east side, 46 observations of [illegible] definition were made. In the lower and wide part of this valley at about 6,000 feet above sea-level the [illegible] was practically the same as in the main valley. here also there is much wet cultivation, and the

country is intersected with irrigation channels. At higher elevations up to 11,000 feet at Zojpal the valley becomes very much narrower, with steep rocky sides and much snow on the higher slopes. Here the seeing was decidedly less good, although the average for all the observations taken in the Lidar Valley is as high as 3·4.

At Gulmarg at an elevation of 8,800 feet in the Pir Panjal range on the south-west side of the main valley, observations were much impeded by cloud, but in the clear hours the definition was found to be distinctly inferior to that in the valley. The general result of our experience at high elevations in the mountain ranges on either side of the main valley tends to show that, while the conditions are good over the whole region traversed, local air currents set up in the high valleys among steep inclines with more or less bare rock surfaces injure the quality of the solar definition to a marked degree; and in addition to this there is a much greater tendency to cloud and mist among the hills than in the level plain. At night the definition of stars was generally exceedingly good at the higher elevations, but was not so constantly good as appeared to be the case in the valley.

The night definition of stars, etc., was studied at Pampur and at other places in the main Kashmir Valley. With the 3-inch telescope it appeared to be perfect when the star's zenith distance did not exceed 60° on all occasions but one. With the 4½-inch equatorial telescope star-images were usually perfect at zenith distances up to 50° or 60°, the diffraction pattern appearing like an engraving and sliding with an absolutely uniform movement across the field of view (the telescope was not provided with clock driving for following the diurnal movement). A very slight undulation was on some nights perceptible, and at low elevations below 20° altitude slow and regular undulations were always visible. The definition of the planet Jupiter was nevertheless very fine when only about 10° to 15° above the horizon, the undulations being of such a nature as not to interfere very seriously with the visibility of fine details on his surface. These slow undulations were also always present when observing the sun during the first hour after rising or the last hour before setting.

As regards the cloudiness in the main valley, our observations at Pampur, Srinagar, and other places show that 50 out of the 61 days spent in the valley were clear sunny days, 7 were partially clear, and 4 completely overcast. Since the partially fine days were available for photographing for at least one hour in each day, there were 57 days, or 93 per cent. of the days in which excellent photographs could be obtained. Twenty-five of the 50 fine days were practically without cloud from sunrise to sunset. As a rule the sky was beautifully clear and of a deep blue colour, but there was a tendency to the formation of high cirrus clouds towards afternoon; also on two occasions in June observations were very much impeded by thick dust haze from the Punjab. This latter was the worst type of weather experienced from an astronomical point of view, but it was fortunately of short duration.

Comparison of Results at Kodaikanal and in Kashmir.

At Kodaikanal the seeing was estimated with the same telescope and by the same method as was used in Kashmir, immediately after returning to head-quarters. There was a great deal of interruption from cloud owing to the prevalence of the south-west monsoon, and the seeing varied a good deal from day to day, ranging from 1 to 3, the mean for the month during the hour between 7-30 and 8-30 A.M. being 2·1. In the middle of the day on two occasions when it was possible to see the sun it was no better than 1. It must be remembered that the six months May to October inclusive are generally unfavourable at Kodaikanal, July and August being the worst months when good definition is unusual even at 8 A.M. During the other half of the year it would be better, and might be estimated at 3 to 4 at 8 A.M., rarely reaching 5 After 8-30 A.M. the definition falls off rapidly, so that the mean for the whole day, even at the best season of the year, would not exceed 2.

So far as is possible therefore to estimate numerically the definition at the two stations, it may be stated approximately that the mean seeing at Kodaikanal for the whole year would hardly reach 2, whilst that in Kashmir Valley would probably slightly exceed 3·9 The number of days when the seeing ranged between 4 and 5 would be very much larger in Kashmir than in Kodaikanal.

The photographs of the sun's disc obtained with the 3-inch photoheliograph at Pampur at different hours of the day are all good and show the sun's limb sharply defined, whilst most of the Kodaikanal plates

show the limb poorly defined. Only one of this series appears equal to a Kashmir plate. The average definition for March and April in Kodaikanal is therefore not nearly equal to the average for May in Kashmir, although March and April are favourable months in Kodaikanal, and the best hour for photographing was chosen.

The series of photographs of sunspots obtained during June with the 4½-inch telescope at Pampur, was compared with the series obtained on the same dates at Kodaikanal with the 6-inch photo-visual telescope. Although the Kodaikanal plates are mostly of good quality not often excelled even during the most favourable months of the year, they do not bear comparison with the Kashmir plates taken with improvised apparatus under considerable difficulties and a smaller optical power. The Kodaikanal plates of course were taken during the most favourable hour of the day, whilst the Kashmir plates were taken at any time the sun happened to be visible; and those taken in the morning, near midday, or in the evening, are all equally good.

The photographic work therefore entirely confirms the visual and indicates the enormous possibilities of progress in the study of solar physics which an observing station established in Kashmir Valley would present.

The spectroscopic observations in Kashmir, as was anticipated, were entirely satisfactory. In sunspot spectra the clear definition of umbra and penumbra, showing radial motion effects, and in the prominences the marvellous detail visible, impressed one with the splendid possibilities for photographic work.

As regards the cloudiness at the two stations, the sunshine records show that the mean annual number of hours of bright sun is practically the same at Kodaikanal and at Srinagar, viz., about 2028 hours. The distribution throughout the year is however different, for at Kodaikanal the winter months are the clearest, and in Srinagar those months are the cloudiest. But in estimating the relative suitability for solar work account must be taken of the fact established by the observations at both stations that at Kodaikanal not more than one hour in six of bright sunshine is available for photography or for detailed spectroscopic study, whilst in Kashmir at least 5 hours out of 6 would be available—a very conservative estimate would give four times the opportunity for work in Kashmir as compared with Kodaikanal, and in addition the quality of the material which could be secured at all times in Kashmir would be equal to the very best that Kodaikanal can produce on occasions when the definition is really good. One of the greatest difficulties experienced in Kodaikanal is the constant interruption of critical photographic work, due either to clouds which tend to cover the sky after 10 A.M., or if clear to bad definition. This involves wastage of photographic plates, as a considerable proportion of those taken have to be rejected from faults entirely outside the control of the observer. In recent years the work at the Observatory has become much more exacting in its requirements, and in order to obtain spectrographic records for measurement and study a complicated series of operations has to be performed, and the large expenditure of time involved is often wasted when, as so frequently happens, the operations are interrupted in the middle by adverse atmospheric conditions.

General Conclusions.

The comparison of Kodaikanal with Kashmir brings out forcibly the disadvantages of a mountain station, especially as regards definition. Hitherto it has been considered by astronomers that the poor midday definition was inevitable and unavoidable, but careful observations made by me both in Kashmir and New Zealand has proved that this is by no means the case; and if one may judge by published spectroheliograms even the low-level observatories of Meudon and Yerkes are able to secure far better midday photographs than Mount Wilson or Kodaikanal. With regard to Mount Wilson and Meudon M. Deslandres remarks :—

"L'Observatoire du Mont Wilson, situé sur une crête élevée, doit souffrir des grands courants de convection que la chaleur solaire développe dans les vallées voisines; et, en fait, les images solaires n'y sont bonnes que le matin et le soir. A l'Observatoire Lick, où les conditions locales sont les mêmes, les images solaires sont considérées comme mauvaises. Pendant la nuit, d'autre part, au Mont Wilson comme à Lick, les images stellaires sont magnifiques et remarquablement calmes.

"L'Observatoire de Meudon, situé sur un petit plateau, a des images bonnes surtout le soir, et aussi parfois pendant la journée, le ciel étant clair ou plutôt légèrement brumeux."*

At Kodaikanal there is a very obvious daily convection current, rising from the southern and eastern slopes of the mountains and evidently due to the strong heating of these slopes and precipices by the morning sun. Although the Observatory is situated some two or three miles from the declivity it does not escape from the bad effects of this current of hot air; for not only is definition ruined soon after 8 A.M., but also masses of cloud are continually forming and dissolving and re-forming in the immediate vicinity of the sun, which renders photographic work extremely difficult after 10 A.M., even if possible at all. This condensation occurs at all times of the year, even in the dry season.

Perhaps the chief advantage of a high-level observatory is the freedom from dust haze, and certainly the air of Kodaikanal is remarkably clear; but as regards practical solar work the advantage of this is somewhat illusory, and at Kodaikanal it is nullified by the prevalence at all times of the year of high thin cirrus clouds, which have a strong tendency to form immediately over the mountain mass, leaving the sky over the plains quite clear. The diffusive and white sky due to this condensation at a great height is of course inimical to most spectographic work, although it is not necessarily injurious to definition.

Long experience of solar research work has convinced me that the main factor which should be considered in selecting a site for a solar observatory is the character of the seeing. All other considerations are of minor importance. Mountain tops have certainly proved a great disappointment, and the reason for this is now clear; it is equally clear that far better conditions exist in some localities. Probably an observatory near sea-level and on the sea-coast would experience better average seeing than one situated on a mountain. There is a uniformity of temperature conditions over the sea, and an absence of convection currents, which is extremely favourable to good definition. Sir John Herschel observing the sun at the Cape of Good Hope, says:—

"What is not a little remarkable, in the hottest *days*, looking *northwards* over the burning tract intervening between Feldhausen and Table, or Saldanha Bay, the most admirable and tranquil definition of the solar spots, and other phenomena of the sun's disc, is by no means unfrequent. In such cases, I presume the strongly heated stratum of air incumbent on the surface of the soil, is swept off by the south-east wind blowing from False to Table Bay, before it ascends high enough to interfere with the visual ray."†

My experience in New Zealand and at Perth in Western Australia shows that in calm weather with a sea-breeze blowing, almost perfect definition may be observed at midday near the sea, however hot the air may be, and it was for this reason I selected a site for the Cawthron observatory on the low hills near the coast at Nelson. Many more imposing sites on the mountains inland were tried, but the definition at high elevations, although better than at Kodaikanal, was found to be far less good than near sea-level; and there can be no doubt from the general purity and blueness of the skies at Nelson that work of the very highest excellence could be carried out at the site chosen.

In India a solar observatory near sea-level would not be practicable, on account of the great heat, which would make the work extremely difficult and trying, except perhaps in the so-called "cold weather" season; but in Kashmir there is the very unique advantage of a temperate climate and considerable elevation above sea-level combined with the extraordinary atmospheric tranquillity in the enclosed valley.

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* Annales de L'Observatoire d'Astronomie Physique de Paris. Tome IV, p. 43.

† Cape Observations, Introduction, par. XIX.

KODAIKANAL,
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