

THE OBSERVATORY,

Madras, 5<sup>th</sup> August 1892

FROM

THE GOVERNMENT ASTRONOMER,

Madras.

TO

The Honble J. F. Price,  
Chief Secretary to Government,  
Cotacaimund.

SIR,

I have the honor to forward herewith my report on the observations made at Madras, Kodaitandal, and Kotagiri regarding the best site for a new Astronomical Observatory. I would suggest that it be read in connection with my two previous papers on the same subject - the "Report on observations made on the Palani Hills", dated 7<sup>th</sup> August 1883, and a letter to H.E. the Governor recorded in G.O. 4<sup>th</sup> March 1885, No. 572.

I have the honor to be,

Sir,

Your most obedt. servant,

C. Michie Smith,

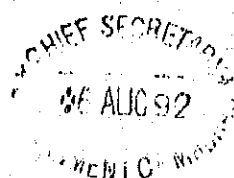
Govt. Astronomer

Enclosure (4)  
Photos sent  
Separately.

Public (1892) Department.

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From  
The Govt. Astronomer



Dated 5<sup>th</sup> } August 192  
Recd 6<sup>th</sup> }  
Ref 9<sup>th</sup>

Enclosure (4 photos sent by  
Govt. Astronomer)

Forwarding Report  
on the special observations made  
at Madras, Kodaikanal & Kota-  
giri with regard to their relative  
merits as sites for a new astro-  
nomical observatory.

Report on the relative merits of Kodaikanal,  
Kotagiri, and Madras as sites for an Astro-  
nomical Observatory.

In accordance with the proposals made in my  
letter, No. 21 dated 3<sup>rd</sup> February last, which were  
accepted in G.O. Public Dept., No. 92 of the 7<sup>th</sup>  
idem, I left Madras on February 18<sup>th</sup> for Kodai-  
kanal arriving there on the 20<sup>th</sup> idem. I returned  
to Madras on March 9<sup>th</sup> and left for Kotagiri  
on the 18<sup>th</sup> idem. I returned finally to Madras  
on April 5<sup>th</sup>.

2. Instruments. The chief instruments which  
I took with me were the following:-

- (1) The Smythian telescope of 3.7 inches aperture,  
with a portable stand and equatorial mounting  
by Cook and Sons.
- (2) A Pritchard's Wedge Photometer
- (3) A Spectroscope with a Rowland's grating of  
14,439 lines to the inch.
- (4) A Maclean's star spectroscope
- (5) A small direct vision spectroscope with cylin-  
drical lens
- (6) A Sextant with stand and artificial horizon for  
time determinations.
- (7) A sidereal chronometer.
- (8) A large Camera with portrait lens 6 inches in  
diameter 36 inches focus.
- (9) A half plate Camera
- (10) Aneroid barometer, rotating thermometers (we  
at

and dry bulb), and sun maximum thermometers.

To protect the instruments and those in charge of them I took with me a tent supplied from the Camp Equipage Depot.

3. Places from which Observations were made and weather. At Kodaikanal Mr. F. M. Gill very kindly placed at my disposal his house "Penn Craig" while Mr. Heimpel of Pondicherry allowed me to pitch my tent on the top of the hill rising behind "Bella Vista" which belongs to him. The situation of this hill, though good, is not so good as that of some of the peaks farther west, but I found that it was quite impracticable to carry on my observations from them without another tent while the close proximity of Mr. Heimpel's hill to Penn Craig made the work easy. The chief drawback was that the hill top, unlike those farther west was not entirely beyond the range of the mist formed by currents of moist air rising from the plains up the face of the Pambur cliff. On some nights the mist did not reach for more than a few yards beyond my tent and it was not unusual to have a thick wall of mist on one side and an almost clear sky on the other. So far as can be gathered from such meteorological statistics as are available there was an abnormal amount of mist and cloud at Kodaikanal during the time that I was there. My work during the earlier part of the night was frequently interrupted by mist and cloud

cloud. This was the more unfortunate because most of the objects which I had selected for observation should have been observed before midnight in order that the Madras, Kodaikanal, and Kolagiri observations might be made under as nearly as possible similar conditions as regards altitude. I found too that from 4 to 5 hours was as long a time as I could stand the cold on the exposed hill top during the night. There were, however, only two nights on which I was unable to get any observations and even on these nights the weather cleared up completely before morning. The comparatively large amount of cloud present seemed to be due in a large measure to the grass fires which were burning all the time I was at the station. That these fires do actually produce clouds was very clearly shown on one occasion when there was a fire on the flank of Perumal. The smoke rose in small quantities nearly vertically up to a certain point when it drifted along horizontally. To the windward of this the sky was almost clear but to the leeward there were dense clouds formed which evidently were due to moisture condensing about the dust particles. At the moment at which the accompanying photograph (see 1) was taken there was a slight wind blowing the smoke out of the vertical. On one night I had to stop observations on account of the dense clouds of smoke blowing over the hill top from a large fire beyond Shembaganur. Kodaikanal is always

subject

subject to these fires in the early part of the year but this year, I am informed, they were more numerous and continued later than usual.

A point of very great importance with regard to the climate of Kodakanal is that there is a strong tendency for the sky to clear after sunset and judging from my own experience during six visits to these hills there are very few nights even during the S.W. Monsoon, which remain cloudy throughout. This opinion was shared by the late Sir Vere Levinge who had made a careful study of the climate during many years. Another feature which sharply distinguishes the climate of Kodakanal from that of Kotagiri or of Madras is that the breaks in the sky between clouds are usually very clear. I do not mean that this is unknown at the other stations for it is a characteristic feature of anticyclonic weather but as a rule in Madras and, so far as my experience goes, at Kotagiri a cloudy night is a bad night for observation, whereas at Kodakanal excellent work can be done on nights when there is a considerable percentage of cloud.

The position of the telescope at Kodakanal was approximately

Lat.  $10^{\circ} 13' 30''$  N; Long  $5^{\circ} 10' 1''$  E: height above sea level 7,390 feet

At Kotagiri the only place where I could obtain a room was in the bungalow attached to Kotah Hall and for convenience the telescope was for the first part of

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of the time set up on the lawn in front of the house. Later on the telescope was taken to the top of One Tree Hill some 250 feet higher, to test whether or not the unsatisfactory results obtained were due to the position of the telescope. No difference, however, could be detected between the two stations. The position of the telescope at Kotah Hall may be taken as

Lat  $11^{\circ} 25'$  N; Long  $5^{\circ} 7' 39''$  E: height above sea level 6,100 feet

At Kotagiri I was even more unfortunate than at Kodakanal in respect to weather, for there were no less than 6 nights which were too cloudy to permit observations being made before midnight. On one of these nights I was able to get a few observations about 4 A. M. but was soon stopped by mist, and on another of them it cleared about 4.30 A. M. and I was able to observe till daybreak. Just as at Kodakanal the work was interfered with by the smoke from grass fires, so at Kotagiri the numerous fires lighted by the villagers for burning heaps of weeds produced a haze which on account of the stillness of the weather often hung about for a great part of the night. This smoke haze is to be expected at the hill stations during only a small part of the year and its prejudicial effect is probably not nearly so great as that of the dust haze which is present

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at Madras, more or less strongly developed, during a great part of the year.

At Madras the observations were made from the roof of the Observatory and were much interfered with by cloudy weather. The original intention was to make the complete series in the dark fortnight preceding the visit to Kodai-Kanal and the programme for observations was drawn up with a view to this. Cloudy weather almost completely stopped observations during that period and hence the greater part of the Madras observations had to be left over till the dark fortnight following the return from Hobagiri. During that period there were three very clear nights when a number of observations were made but thereafter hazy weather came on when it was useless to continue the work, so that the Madras comparative observations were far from complete. By the following dark fortnight most of the objects were too near the horizon to make the observations of any use. Had there been any difficulty in deciding on the relative merits of the three stations the incompleteness of the observations would have been a matter for serious regret but it seems to me that the matter is so clear that the observations actually made are abundant. To prevent misapprehension I ought to state that

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the cloudiness and haze which stopped the observations at Madras would not necessarily have stopped ordinary astronomical observations, but I thought it useless to make test observations when the atmospheric conditions were distinctly unfavourable.

#### 4. Observations.

The observations made may be classified as follows:-

- (a) Observations of the sun with special reference to spots and faculae and their spectra.
- (b) Observations of Venus and Saturn.
- (c) Observations of star clusters and nebulae.
- (d) Observations of double stars.
- (e) Observations of stellar spectra.
- (f) Measurements of apparent stellar magnitudes.
- (g) Photographs of star trails.

(a) Solar observations. The usual experience of observers at high altitudes is that the image of the sun is generally very unsteady, owing to the strong convection currents produced by the heat of the sun when it is above the horizon. At the Lick Observatory, for instance, it is, I believe, considered useless to employ on the sun a telescope of more than 6 inches aperture, and even with that aperture good views are obtained only early in the forenoon. At Kodai-Kanal this unsteadiness was found

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to be much less than I had expected for I usually got remarkably steady views of the sun's disc up to at least 10.30 or 11 A. M. while on several occasions I had good views in the afternoon. The feature that struck me most as regards the solar observations was the great clearness with which faculae were seen. I have never, even under the most favorable conditions, seen them with equal clearness at Kodak either with the same or with larger telescopes. Less difference, as might be expected, was noticed in the details of sunspots which were neither large nor numerous while I was at Kodak. With the grating spectroscope attached to the telescope the reversed prominence lines were seen very bright and steady and on one occasion I was able to get a view of a complete prominence by opening the slit ~~wide~~. I found however that the difficulty of keeping a given part of the limb exactly on the slit was so great that having seen one prominence I did not think it necessary to look for more. It was evident that with suitable appliances the prominences could be seen with great clearness. At Hatajiri the solar observations were much less satisfactory for the atmosphere usually became very unsteady about 9 A. M. and it was only on two or three occasions that

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I got satisfactory views later than that. Before that however some excellent views were obtained and both spots - which were then both large and numerous - and faculae were seen with much sharpness of detail. I made numerous micrometric measurements of spots and found that this could be done accurately with much greater ease and comfort than in Madras. As regards solar observations in general it seems certain that the best views got at the hill stations are much better than the best views got at Madras. Another point to be asked is that, especially in the hot weather, in Madras solar observations are carried on with great difficulty if not with actual danger to the health of the observer, whereas at a hill station, though the direct solar radiation may be more intense, the coolness of the air renders the work comparative-ly pleasant, as soon as the observer has once got thoroughly sunburned.

(b) Observations of Venus and of Saturn. Observations of Venus and of Saturn were made frequently at both hill stations and at various altitudes. Venus is a very severe test for both the telescope and the atmosphere. At Kodak the planet was usually too near the horizon when I began the night's work to get really good views of it but those that I did obtain were distinctly good under the circumstances while on the two or three occasions

occasions

occasions on which I observed it before or soon after sunset the views were excellent. At Khatagiri the views obtained near sunset were only fair and those obtained later were poor. Saturn is much easier than Venus and some excellent views of it were got at both stations, but at Kodakurall it was usually possible to employ with advantage a much higher power than at Khatagiri. At the former place a power of 360 emts usually he employed while at the latter 262 was generally too much. All the observations of Saturn were made at comparatively low altitudes at both places but the details of the markings on the planet shewed with great distinctness. I find in my Khatagiri notes the following entry after several nights of observations of Venus and Saturn "the definition is certainly better than in Madras but not so good as at Kodakurall".

(C) Star clusters and nebulae. For these I went systematically through a list taken from Chamber's Astronomy. Many of the selected objects were in no sense test objects but I believed that by examining a large number of different objects at each station I would get a better general idea of the relative qualities of each station than I would have got by confining my attention to test objects. The general conclusion arrived at was that for clusters there was a slight, and for

for faint nebulae a marked advantage of both hill stations over Madras, while as regards the relative merits of the two hill stations Kodakurall was distinctly better than Khatagiri. A few special cases may be mentioned. In the great Orion nebula the nebula round 734 Bond was a conspicuous object and the bright wisps of light that curve upwards round 1004 Bond was easily traced so far as it is shown in Bond's drawing. This was not the case at either of the other stations. I had no map of the nebula with me with which to make comparison but the impression left was that the nebula extended in several directions very much farther than I had ever seen it before. The nebula about

$\eta$  Argus is so far south that even a slight change in latitude makes a sensible change in its visibility still the very great differences between it as seen from the three stations cannot be entirely accounted for by this. The view of it from Kodakurall, especially on one night, was incomparably finer than any view I had previously had of it. The cluster about

$\kappa$  Crucis is an easy object and I used it simply as a test for colours. In Madras the colours of the many coloured stars in the cluster are well seen only on specially fine nights.

right. At Kodakanal the colours showed with great brilliancy. At Kotalpuri they were well seen with a power of 70 but with higher powers were distinctly poor. The crab nebula in Taurus stood a power of 134 at Kodakanal and showed much detail, at Kotalpuri I could not use a power of more than 100, with which it was 'fair' and at Madras it was usually a 'poor' object. The nebula M 94 was "seen but not clearly resolved" at both of the hill stations, while at Madras it was "very hazy" though the night was specially fine. The nebulae 49 M + 88 M in Virgo were both "well seen" at Kodakanal, they were "faint" and "very faint" at Kotalpuri, they were <sup>not</sup> found at Madras on the only occasion on which I was able to search for them. 85 M was "seen fairly well" at Kodakanal and was "very faint" at Kotalpuri, H 2102 (Hydra) was "seen but faint" at Kodakanal and was "very well seen" at Kotalpuri. H 2008 (Sextans) was "seen" and "well seen" at Kodakanal and Kotalpuri and "not found" at Madras.

(d) Double stars. The observations of double stars were made under very unfavourable conditions, especially at Kodakanal where the telescope placed on the top of the hill was fully exposed to the wind from all sides. The best observing nights were those on which

there

there was a pretty strong wind and I found that with even a moderate wind the light stand which I had for the telescope was not sufficiently steady to permit of the use of high powers, and that even with low powers it was difficult to distinguish between simple elongation and actual division of close double stars. At Kotalpuri there was much less wind and the observations were more satisfactory. The general result of the observations, so far as they go, is that little difference could be observed between Kodakanal and Kotalpuri but that the additional light and steadiness of the air at the hill stations as compared with Madras was very striking.

(e) Stellar spectra. Most of the observations on these were, for convenience, made with the Alaskan stellar spectroscope. The general conclusion arrived at was that both the hill stations were superior to Madras and that, so far as the observations went, Kodakanal was superior to Kotalpuri, but in fairness to the latter station it must be said that the nights on which the observations were made were by no means ideally fine. The spectra as seen at Kodakanal were remarkable both for their brightness and, what is of much more importance, their steadiness. The curious and very trying flickering which

which

which is so strongly marked at Madras was almost entirely absent. The etalon spectrocope is not fitted with any arrangement by which the position of the lines can be measured but had I had a spectrocope fitted with measuring apparatus it would have been easy to measure the positions of many lines with great accuracy. It seems to me that some of the chief difficulties in connection with the accurate measurements of stellar spectra would be avoided in an Observatory at Kodaikanal.

(f) Measurements of apparent stellar magnitudes.

The measurements of stellar magnitudes were made with a Pritchard's wedge photometer. To use this instrument effectively the light from the star must be made to pass through a very small aperture before it falls on the wedge of neutral-tinted glass by which it is extinguished. When the photometer is attached to a telescope with a fixed stand and clockwork this can be managed without difficulty but with a light portable stand which is never in perfect adjustment and with no clockwork or slow motion in declination it is far from easy to keep the star in exactly the right position. To simplify the observations as much as possible I

I observed only stars which were comparatively near the poles. Consequently the stars were always at a low altitude and hence the results are not only less uniform but give a much less favorable comparison than would be given by stars near the zenith. Each set of measurements consisted of not less than 5 readings of the wedge. The observations were made with various apertures but all were reduced to the reading for full aperture. The middle time of each set of observations was noted and the altitude of the star at that time was calculated. The following are the chief results:-

| Star                     | Madras       |             |               | Kodaikanal   |             |               | Kotagiri     |             |               | Remarks                                   |
|--------------------------|--------------|-------------|---------------|--------------|-------------|---------------|--------------|-------------|---------------|-------------------------------------------|
|                          | Mean Reading | No. of sets | Mean Altitude | Mean Reading | No. of sets | Mean Altitude | Mean Reading | No. of sets | Mean Altitude |                                           |
| $\alpha$ Ursae Majoris   | 5.98         | 6           | 36-36'        | 6.24         | 2           | 32-39'        | 6.26         | 2           | 37-2'         |                                           |
| $\beta$ Ursae Majoris    | 5.93         | 5           | 39-11         | 5.58         | 1           | 44-36         | 6.31         | 1           | 41-33         | * Object glass probably covered with dew. |
| $\delta$ Ursae Majoris   | 5.28         | 6           | 39-24         | 5.71         | 4           | 38-33         | 5.69         | 2           | 35-24         |                                           |
| Polaris                  | 5.47         | 3           | 12-20         | 5.88         | 7           | 9-14          | 5.62         | 2           | 10-42         |                                           |
| $\epsilon$ Argus         | -            | -           | -             | 6.20         | 2           | 19-10         | 6.04         | 1           | 18-51         |                                           |
| $\delta$ Argus           | 5.98         | 1           | 11-52         | 6.23         | 2           | 23-51         | 6.38         | 1           | 23-55         |                                           |
| $\kappa$ Argus           | 5.85         | 2           | 11-42         | 6.12         | 2           | 24-27         | 6.03         | 1           | 24-2          |                                           |
| $\gamma$ Ursae Majoris   | 5.04         | 1           | -             | 5.89         | 7           | 41-24         | -            | -           | -             |                                           |
| $\epsilon$ Ursae Majoris | -            | -           | -             | 6.42         | 2           | 17-27         | -            | -           | -             |                                           |
| $\epsilon$ Argus         | 5.54         | 1           | 9-29          | -            | -           | -             | 5.84         | 1           | 17-35         |                                           |

These observations were made only on nights on which the stars appeared. Quite clear and the sky near them free from clouds. Most of the Madras observations were made on specially clear nights. The observations would have been much more numerous and complete had they not been interfered with by cloudy nights but even as they

they stand they are sufficient to show a marked superiority of the two hill stations over Madras though not to distinguish between the two hill stations themselves. The scale difference for one star magnitude is very nearly 0.50 inches and the mean reading for Madras is about 0.34 inches less than for Kodaikanal. In other words to obtain the same amount of light from any star at Madras as at Kodaikanal the area of the object glass would have to be increased by one half. This I believe is really an underestimate. It is probably nearly the truth for stars with in  $30^\circ$  to  $40^\circ$  of the horizon but at great altitudes the difference would be greater.

(9) Photographs of star trails. As the Observatory is not provided with any photographic apparatus I got the loan from Mr. H. St. Linn, C.S., of a large camera fitted with a portrait lens of 6 inches diameter and 36 inches focal length. The lens was an excellent one for the purpose but the camera was a very unwieldy one of solid mahogany which required two men to lift it and I had no time to replace it with a more convenient one. Hence I found it impossible to take photographs at a greater altitude than about  $30^\circ$  while it was very difficult to point the camera to the exact part of the sky which was desired. At Kodaikanal I was much troubled by dew on the lens - a difficulty which would

not

not be felt in a regular observatory. By far the most striking photograph was one obtained at Madras on April 25<sup>th</sup>. The camera was directed so that Polaris fell near the upper right hand corner of the plate and the plate was exposed for about two hours with an interruption of ten minutes. The plates used was Wratten and Wainwright's "instantaneous." The negative shows the following stars: - [See photo. No. 2.]

R. P. L. 93, 79, 92, 128 (24 Ursae Minoris), 125 (8 Ursae Minoris)  <sup>$\alpha$  Serpentis, R. D. 88° 51'</sup> 100, 108, 89, 72, 99, and four or five others which I have not identified. That is all stars down to the 8<sup>th</sup> magnitude and a few fainter ones are shown. With reference to this it should be pointed out that on the 24<sup>th</sup> there was a rainfall of 0.69 inches the first heavy rain this year and the night of the 25<sup>th</sup> was brilliantly clear, the stars shining as they never do here except after heavy rain. The night was windy but by placing the camera inside the large dome it was possible to shelter it completely. In the Kodaikanal plates of the same region the smallest star visible is one of the 6<sup>th</sup> magnitude but it must be remembered that the altitude of the pole at that station is nearly  $3^\circ$  less than at Madras and that on none of the nights when I was there had there been enough of rain to clear the air, while the grass fires caused a heavy haze to hang round the northern horizon.

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I may add that there are few nights in Madras on which a photograph shows any stars of less than the 5<sup>th</sup> magnitude while on many nights even Polaris is invisible. The Kodagiri plate showed only Polaris and  $\delta$  Urs. Min. (4.5) clearly with a faint trace of R. P. L. 99.

A photograph taken in Madras on April 25<sup>th</sup> - also a very clear night - of a portion of Argus shows: - [See photo No. 3]

$\gamma$  Argus,  $\kappa$  Carinae,  $\kappa$  Argus,  $\iota$  Argus,  $\epsilon$  Carinae,  $\alpha$  Carinae,  $\zeta_1$  &  $\zeta_2$  Carinae,  $\eta$  Velorum,  $\theta$  Carinae,  $\phi$  Carinae,  $\delta$  Argus,  $\alpha$  Ursa,  $\nu$  Ursa ( $\gamma$  mag),  $\theta$  Argus,  $\lambda$  Carinae,  $\epsilon$  Argus. It is worth noting that while, in this plate,  $\zeta_1$  Carinae is strongly marked  $\zeta_2$  is hardly visible though Stone gives them both as of the same magnitude. The magnitude of  $\alpha$  Carinae also appears to be greater than is given in Stone. A negative taken at Kodaikanal did not cover exactly the same area but in the part that overlapped the negative showed all the stars shown in the Madras negative except

$\zeta$  Carinae. This plate was one of the earliest taken and was evidently underdeveloped. A negative of the same region taken at Kodagiri was very poor showing only the brighter stars.

Negatives of the Southern Cross were taken both at Madras and at Kodaikanal. The former taken on April 27<sup>th</sup> - also a clear night though not quite equal to the two preceding nights - showed only  $\alpha, \beta, \gamma, \delta$  Crucis. The latter showed also Stone 7119

(6.5 mag),  $\lambda$  Crucis, Stone 7055, Stone 5244 ( $\gamma$ ),  $\chi$  Crucis [See photo No. 4]

and

and  $\epsilon$  Crucis. Here again the photographic magnitudes do not agree with the visual magnitudes of Stone's Catalogue, especially in the case of  $\gamma$  which is given of the 2<sup>nd</sup> magnitude while  $\delta$  is of the 3<sup>rd</sup>. Yet  $\gamma$  is much fainter than  $\delta$  in the Kodaikanal plate while it does not appear at all on the Madras plate.

The general conclusion to be drawn from these and some other photographs is that there are a few exceptionally fine nights in Madras when the atmosphere near the horizon is fully as clear as that of Kodaikanal on ordinary nights, but that even on such nights the atmosphere at higher altitudes is distinctly less clear than it is at corresponding altitudes at Kodaikanal. This conclusion was confirmed by observations of faint nebulae made on the same nights as those on which the photographs were taken. As regards Kodagiri the results are too incomplete to be conclusive but so far as they go they are very unfavourable to that place.

5. General conclusions. The general results at which I have arrived from these observations as regards the relative merits of Kodaikanal and Kodagiri as a site for an observatory is that Kodaikanal is by far the better situation of the two. Whether or not this has been absolutely proved by the observations detailed above depends to a certain extent on the further consideration of

of

of whether the atmospheric conditions at the time when I was observing were fairly characteristic of the Kotagiri climate. Personally I have not the least doubt that the conclusion is the correct one, for the general impression of the superiority of Kodakanal very strongly forced itself upon me while I was observing at Kotagiri and I can affirm without hesitation that the best night while I was at Kotagiri was inferior to the worst observing night at Kodakanal. Having already expressed an opinion in favor of Kodakanal I took particular care that full justice was done to Kotagiri and took every possible opportunity of getting the most favorable observations. The inferiority was particularly marked in the solar observations and in the observations of the finer details of nebulae.

The explanation of the difference between the two stations is not difficult to find. In the first place Kodakanal is nearly 1000 feet higher than Kotagiri which is in itself a considerable advantage. In the second place the formation of the hills about Kotagiri is much less favorable than the formation about Kodakanal. Kotagiri itself lies in a basin surrounded by hills rising to a greater height on all sides and

and during the day the temperature of this basin rises considerably above that of the surrounding hills. Consequently convection currents of a very irregular kind are set up in the air producing a condition very prejudicial to accurate astronomical observations. These convection currents are found on all hills but their strength and duration depend on the configuration of the ground. Where the hill top is freely exposed the ascending currents die away before or soon after sunset and are in due course succeeded by downward currents which bring in the clear air from above and so produce the conditions most favorable for observations. On the other hand, with a large sheltered basin, as at Kotagiri, temperature falls slowly and the unfavorable conditions may continue far into the night. At Kodakanal there is a large plateau rising in the centre and the best site for an Observatory lies well away both from the precipitous edges of the plateau and from the hollow in which the lake lies. This situation seems to me to be exactly what would be chosen on general principles as the site of an observatory. It may be suggested that a similar position might be found near Kotagiri on the surrounding hills. This is a point to which I paid considerable attention. Doubtless I have tested

on a previous occasion in the month of January  
of but with most unfavourable results, and any  
situation further west would probably be even  
of worse, while towards the east I have been unable  
to find any position which was sufficiently  
removed from the edge of the plateau on the one  
of hand and from the Kodaïar basin on the other hand.

The question of the relative merits of Kodaï-  
Ranal and Madras is a much more difficult  
one. It is probable that the meteorological  
observations now being carried on will show  
that there is more cloud during the year at  
Kodaikanal than at Madras and there can  
be no doubt that at Madras there is a large  
number of nights on which ordinary astrono-  
mical observations can be made well enough,  
and a small number of really first class  
nights. On the other hand, it is perfectly  
clear that the 'seeing' on a good night at  
Kodaikanal is much better than on a good  
night in Madras, and my former observa-  
tions have shown that even during the  
S.W. Monsoon there are few nights during  
which good observations cannot be made.

During part of the N.E. Monsoon the nights  
seem to be very cloudy but I know of no ob-  
servatory where there is not a portion of  
the year during which few observations  
can

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can be made. The question as to whether or not the  
greater clearness of the unclouded atmosphere outweighs  
other disadvantages cannot be fully discussed till the  
meteorological observations have been completed, but I  
may point out at present that a very important factor  
in the discussion is the kind of work which the obser-  
vatory is to undertake. If the work is, as heretofore,  
to continue exclusively on the lines of the older astronomy,  
I doubt if the gain would be worth the cost, but if an  
attempt is to be made to enter upon the newer branches  
of research which have been taken up elsewhere  
I feel confident that the gain would be very great.  
Two subjects, for instance, which could be taken up  
with great advantage would be spectroscopic exami-  
nation of the stars for motion along the line of  
sight and physical observations of the planets. In  
both of these researches the remarkable clearness  
and transparency of the air at Kodaikanal would  
be an enormous advantage and I believe that some  
good work could be done on a dozen clear nights  
there than on fifty clear nights at Madras. Solar  
observations could be carried on with at least  
equal success and with much greater comfort  
to the observer. The sunshine recorder slips from  
February 19<sup>th</sup> to June 30<sup>th</sup> show that out of  
these 166 days the sun could have been photo-  
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C. Nicolson Smith  
Offg Govt. Astronomer

5<sup>th</sup> Aug 1892.

Note. The photographic prints accompanying this do not show nearly all the stars shown in the negatives but they give some indication of the sharpness of the photographs.

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GOVERNMENT OF MADRAS.

PUBLIC DEPARTMENT.

READ—the following paper :—

From C. MICHIE SMITH, Esq., Officiating Government Astronomer, to the Chief Secretary to Government, dated Madras, 5th August 1892, No. 95.

I have the honour to forward herewith my report on the observations made at Madras, Kodaikānal and Kōtagiri regarding the best site for a new Astronomical Observatory. I would suggest that it be read in connection with my two previous papers on the same subject—the "Report on observations made on the Palni Hills," dated 7th August 1883, and a letter to His Excellency the Governor recorded in G.O., dated 7th March 1885, No. 572.

ENCLOSURE.

REPORT on the relative merits of Kodaikānal, Kōtagiri and Madras as sites for an Astronomical Observatory.

In accordance with the proposals made in my letter, No. 21, dated 3rd February last, which were accepted in G.O., Public Department, No. 92, of the 9th idem, I left Madras on February 18th for Kodaikānal, arriving there on the 20th idem. I returned to Madras on March 9th and left for Kōtagiri on the 18th idem. I returned finally to Madras on April 5th.

2. *Instruments.*—The chief instruments which I took with me were the following :—

- (1) The Smythian telescope of 8.7 inches aperture, with a portable stand and equatorial mounting by Cook and Sons.
- (2) A Pritchard's wedge photometer.
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- (8) A large camera with portrait lens 6 inches in diameter, 36 inches focus.
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- (10) Aneroid barometer, rotating thermometers (wet and dry bulb) and sun maximum thermometer.

To protect the instruments and those in charge of them I took with me a tent supplied from the Camp Equipage Depot.

3. *Places from which Observations were made and Weather.*—At Kodaikānal Mr. F. N. Gill very kindly placed at my disposal his house "Penn Craig," while Mr. Heimpel, of Dindigul, allowed me to pitch my tent on the top of the hill rising behind "Bella Vista," which belongs to him. The situation of this hill, though good, is not

so good as that of some of the peaks farther west, but I found that it was quite impracticable to carry on my observations from them without another tent, while the close proximity of Mr. Heimpel's hill to Penn Craig made the work easy. The chief drawback was that the hill-top, unlike those further west, was not entirely beyond the range of the mist formed by currents of moist air rising from the plains up the face of the Pambar cliff. On some nights the mist did not reach for more than a few yards beyond my tent and it was not unusual to have a thick wall of mist on one side and an almost clear sky on the other. So far as can be gathered from such meteorological statistics as are available, there was an abnormal amount of mist and cloud at Kodaikānal during the time that I was there. My work during the earlier part of the night was frequently interrupted by mist and cloud. This was the more unfortunate because most of the objects which I had selected for observation should have been observed before midnight, in order that the Madras, Kodaikānal and Kōtagiri observations might be made under as nearly as possible similar conditions as regards altitude. I found, too, that from 4 to 5 hours was as long a time as I could stand the cold on the exposed hill-top during the night. There were, however, only two nights on which I was unable to get any observations and even on these nights the weather cleared up completely before morning. The comparatively large amount of cloud present seemed to be due in a large measure to the grass fires which were burning all the time I was at the station. That these fires do actually produce clouds was very clearly shown on one occasion when there was a fire on the flank of Perumal. The smoke rose in small quantities nearly vertically up to a certain point, when it drifted along horizontally. To the windward of this the sky was almost clear, but to the leeward there were dense clouds formed which evidently were due to moisture condensing about the dust particles. At the moment at which the accompanying photograph (No. 1) was taken there was a slight wind blowing the smoke out of the vertical. On one night I had to stop observations on account of the dense clouds of smoke blowing over the hill-top from a large fire beyond Shembaganur. Kodaikānal is always subject to these fires in the early part of the year, but this year, I am informed, they were more numerous and continued later than usual. A point of very great importance with regard to the climate of Kodaikānal is that there is a strong tendency for the sky to clear after sunset, and judging from my own experience during six visits to these hills there are very few nights, even during the south-west monsoon, which remain cloudy throughout. This opinion was shared by the late Sir Vere Levinge, who had made a careful study of the climate during many years. Another feature which sharply distinguishes the climate of Kodaikānal from that of Kōtagiri or of Madras is that the breaks in the sky between clouds are usually very clear. I do not mean that this is unknown at the other stations, for it is a characteristic feature of anti-cyclonic weather; but as a rule in Madras and, so far as my experience goes, at Kōtagiri, a cloudy night is a bad night for observation, whereas at Kodaikānal excellent work can be done on nights when there is a considerable percentage of cloud. The position of the telescope at Kodaikānal was approximately—Lat.,  $10^{\circ} 13' 30''$  N.: Long.,  $57^{\circ} 10' 15''$  E.: height above sea-level, 7,390 feet. At Kōtagiri the only place where I could obtain a room was in the bungalow attached to Kotah Hall and for convenience the telescope was, for the first part of the time, set up on the lawn in front of the house. Later on the telescope was taken to the top of One Tree Hill, some 250 feet higher, to test whether or not the unsatisfactory results obtained were due to the position of the telescope. No difference, however, could be detected between the two stations. The position of the telescope at Kotah Hall may be taken as—Lat.,  $11^{\circ} 25'$  N.: Long.,  $57^{\circ} 13' 39''$  E.: height above sea-level, 6,195 feet. At Kōtagiri I was even more unfortunate than at Kodaikānal in respect to weather, for there were no less than 6 nights which were too cloudy to permit observations being made before midnight. On one of these nights I was able to get a few observations about 4 A.M., but was soon stopped by mist, and on another of them it cleared about 4-30 A.M., and I was able to observe till daybreak. Just as at Kodaikānal the work was interfered with by the smoke from grass fires, so at Kōtagiri the numerous fires lighted by the villagers for burning heaps of weeds produced a haze which, on account of the stillness of the weather, often hung about for a great part of the night. This smoke-haze is to be expected at the hill stations during only a small part of the year and its prejudicial

effect is probably not nearly so great as that of the dust-haze which is present at Madras, more or less strongly developed, during a great part of the year.

At Madras the observations were made from the roof of the Observatory and were much interfered with by cloudy weather. The original intention was to make the complete series in the dark fortnight preceding the visit to Kodaikānal and the programme for observations was drawn up with a view to this. Cloudy weather almost completely stopped observations during that period, and hence the greater part of the Madras observations had to be left over till the dark fortnight following the return from Kōtagiri. During that period there were three very clear nights when a number of observations were made, but thereafter hazy weather came on when it was useless to continue the work, so that the Madras comparative observations were far from complete. By the following dark fortnight most of the objects were too near the horizon to make the observations of any use. Had there been any difficulty in deciding on the relative merits of the three stations, the incompleteness of the observations would have been a matter for serious regret, but it seems to me that the matter is so clear that the observations actually made are abundant. To prevent misapprehension I ought to state that the cloudiness and haze which stopped the observations at Madras would not necessarily have stopped ordinary astronomical observations, but I thought it useless to make test observations when the atmospheric conditions were distinctly unfavorable.

4. *Observations.*—The observations made may be classified as follows:—

- (a) Observations of the sun with special reference to spots and faculae and their spectra.
- (b) Observations of Venus and Saturn.
- (c) " star-clusters and nebulae.
- (d) " double stars.
- (e) " stellar spectra.
- (f) Measurements of apparent stellar magnitudes.
- (g) Photographs of star trails.

(a) *Solar Observations.*—The usual experience of observers at high altitudes is that the image of the sun is generally very unsteady owing to the strong convection currents produced by the heat of the sun when it is above the horizon. At the Lick Observatory, for instance, it is, I believe, considered useless to employ on the sun a telescope of more than 6 inches aperture, and even with that aperture good views are obtained only early in the forenoon. At Kodaikānal this unsteadiness was found to be much less than I had expected, for I usually got remarkably steady views of the sun's disc up to at least 10-30 or 11 A.M., while on several occasions I had good views in the afternoon. The feature that struck me most as regards the solar observations was the great clearness with which faculae were seen. I have never, even under the most favorable conditions, seen them with equal clearness at Madras either with the same or with larger telescopes. Less difference, as might be expected, was noticed in the details of sun spots, which were neither large nor numerous while I was at Kodaikānal. With the grating spectroscope attached to the telescope the reversed prominence lines were seen very bright and steady, and on one occasion I was able to get a view of a complete prominence by opening the slit wide. I found, however, that the difficulty of keeping a given part of the limb exactly on the slit was so great that, having seen one prominence, I did not think it necessary to look for more. It was evident that with suitable appliances the prominences could be seen with great clearness. At Kōtagiri the solar observations were much less satisfactory, for the atmosphere usually became very unsteady about 9 A.M., and it was only on two or three occasions that I got satisfactory views later than that. Before that hour some excellent views were obtained, and both spots—which were then not large and numerous—and faculae were seen with much sharpness of detail. I made numerous micrometric measurements of spots and found that this could be done accurately with much greater ease and comfort than in Madras. As regards solar observations in general, it seems certain that the best views got at the hill stations are much better than the best views got at Madras. Another point to be noted is that, especially in the hot weather, in Madras

solar observations are carried on with great difficulty if not with actual danger to the health of the observer, whereas at a hill station, though the direct solar radiation may be more intense, the coolness of the air renders the work comparatively pleasant, as soon as the observer has once got thoroughly sunburned.

(b) *Observations of Venus and of Saturn.*—Observations of Venus and of Saturn were made frequently at both hill stations and at various altitudes. Venus is a very severe test for both the telescope and the atmosphere. At Kodaikānal this planet was usually too near the horizon when I began the night's work to get really good views of it, but those that I did obtain were distinctly good under the circumstances, while on the two or three occasions on which I observed it before or soon after sunset the views were excellent. At Kōtagiri the views obtained near sunset were only fair, and those obtained later were poor. Saturn is much easier than Venus and some excellent views of it were got at both stations, but at Kodaikānal it was usually possible to employ with advantage a much higher power than at Kōtagiri. At the former place a power of 360 could usually be employed, while at the latter 262 was generally too much. All the observations of Saturn were made at comparatively low altitudes at both places, but the details of the markings on the planets showed with great distinctness. I find in my Kōtagiri notes the following entry after several nights of observations of Venus and Saturn: "The definition is certainly better than in Madras but not so good as at Kodaikānal."

(c) *Star Clusters and Nebulae.*—For these I went systematically through a list taken from Chambers' Astronomy. Many of the selected objects were in no sense test objects, but I believed that by examining a large number of different objects at each station I would get a better general idea of the relative qualities of each station than I would have got by confining my attention to test objects. The general conclusion arrived at was that for clusters there was a slight, and for faint nebulae a marked advantage of both hill stations over Madras, while as regards the relative merits of the two hill stations, Kodaikānal was distinctly better than Kōtagiri. A few special cases may be mentioned. In the great Orion nebula the nebula round 734 Bond was a conspicuous object and the bright wisp of light that curves upwards round 1004 Bond was easily traced as far as it is shown in Bond's drawing. This was not the case at either of the other stations. I had no map of the nebula with me with which to make comparison, but the impression left was that the nebula extended in several directions very much further than I had ever seen it before. The nebula about  $\eta$  Argus is so far south that even a slight change in latitude makes a sensible change in its visibility; still, the very great differences between it as seen from the three stations cannot be entirely accounted for by this. The view of it from Kodaikānal, especially on one night, was incomparably finer than any view I had previously had of it. The cluster about  $\kappa$  Crucis is an easy object and I used it simply as a test for colours. In Madras, the colours of the many coloured stars in the cluster are well seen only on specially fine nights. At Kodaikānal, the colours showed with great brilliancy. At Kōtagiri, they were well seen with a power of 70, but with higher powers were distinctly poor. The Crab nebula in Taurus stood a power of 134 at Kodaikānal and showed much detail; at Kōtagiri I could not use a power of more than 100, with which it was "fair" and at Madras it was usually a "poor" object. The nebula M 94 was "seen but not clearly resolved" at both of the hill stations, while at Madras it was "very hazy" though the night was specially fine. The nebulae 49 M and 88 M in Virgo were both "well seen" at Kodaikānal, they were "faint" and "very faint" at Kōtagiri, they were not found at Madras on the only occasion on which I was able to search for them. 85 M was "seen fairly well" at Kodaikānal and was "very faint" at Kōtagiri. H 2102 (Hydra) was "seen, but faint" at Kodaikānal and was "very well seen" at Kōtagiri. H 2008 (Sextans) was "seen" and "well seen" at Kodaikānal and Kōtagiri and "not found" at Madras.

(d) *Double Stars.*—The observations of double stars were made under very unfavorable conditions, especially at Kodaikānal, where the telescope placed on the top of the hill was fully exposed to the wind from all sides. The best observing nights were those on which there was a pretty strong wind, and I found that with

even a moderate wind the light stand which I had for the telescope was not sufficiently steady to permit of the use of high powers, and that even with low powers it was difficult to distinguish between simple elongation and actual division of close double stars. At Kōtagiri there was much less wind and the observations were more satisfactory. The general result of the observations, so far as they go, is that little difference could be observed between Kodaikānal and Kōtagiri, but that the additional light and steadiness of the air at the hill stations as compared with Madras was very striking.

(e) *Stellar Spectra.*—Most of the observations on these were, for convenience, made with the Maclean stellar spectroscope. The general conclusion arrived at was that both the hill stations were superior to Madras, and that, so far as the observations went, Kodaikānal was superior to Kōtagiri, but in fairness to the latter station it must be said that the nights on which the observations were made were by no means ideally fine. The spectra as seen at Kodaikānal were remarkable both for their brightness and, what is of much more importance, their steadiness. The curious and very trying flickering which is so strongly marked at Madras was almost entirely absent. The Maclean spectroscope is not fitted with any arrangement by which the position of the lines can be measured, but had I had a spectroscope fitted with measuring apparatus it would have been easy to measure the positions of many lines with great accuracy. It seems to me that some of the chief difficulties in connection with the accurate measurements of stellar spectra would be avoided in an Observatory at Kodaikānal.

(f) *Measurements of Apparent Stellar Magnitudes.*—The measurements of stellar magnitudes were made with a Pritchard's wedge photometer. To use this instrument effectively the light from the star must be made to pass through a very small aperture before it falls on the wedge of neutral-tinted glass by which it is extinguished. When the photometer is attached to a telescope with a fixed stand and clockwork, this can be managed without difficulty, but with a light portable stand which is never in perfect adjustment and with no clockwork or slow motion in declination it is far from easy to keep the star in exactly the right position. To simplify the observations as much as possible I observed only stars which were comparatively near the poles. Consequently, the stars were always at a low altitude, and hence the results are not only less uniform but give a much less favorable comparison than would be given by stars near the zenith. Each set of measurements consisted of not less than 5 readings of the wedge. The observations were made with various apertures, but all were reduced to the reading for full aperture. The middle time of each set of observations was noted and the altitude of the star at that time was calculated. The following are the chief results:—

| Star.                    | Madras.       |              |                | Kodaikānal.   |              |                | Kōtagiri.     |              |                |
|--------------------------|---------------|--------------|----------------|---------------|--------------|----------------|---------------|--------------|----------------|
|                          | Mean reading. | No. of sets. | Mean altitude. | Mean reading. | No. of sets. | Mean altitude. | Mean reading. | No. of sets. | Mean altitude. |
| $\alpha$ Ursae Majoris   | 6.08          | 6            | 38° 36'        | 6.24          | 2            | 32° 39'        | 6.26          | 2            | 37° 2'         |
| $\beta$ Ursae Majoris    | 6.03          | 6            | 39° 11'        | 6.68*         | 1            | 41° 30'        | 6.31          | 1            | 41° 33'        |
| $\delta$ Ursae Majoris   | 6.28          | 6            | 39° 24'        | 6.71          | 4            | 38° 33'        | 6.69          | 2            | 38° 27'        |
| Polaris                  | 6.47          | 3            | 12° 20'        | 6.88          | 7            | 9° 14'         | 6.62          | 2            | 10° 42'        |
| $\epsilon$ Argus         | 6.08          | 1            | 11° 52'        | 6.20          | 2            | 19° 10'        | 6.04          | 1            | 18° 51'        |
| $\beta$ Argus            | 6.85          | 2            | 11° 42'        | 6.23          | 2            | 23° 51'        | 6.38          | 1            | 23° 55'        |
| $\gamma$ Ursae Majoris   | 6.04          | 1            | ...            | 6.12          | 2            | 24° 27'        | 6.03          | 1            | 24° 2'         |
| $\epsilon$ Ursae Majoris | ...           | ...          | ...            | 6.89          | 1            | 41° 24'        | ...           | ...          | ...            |
| $\delta$ Argus           | 6.64          | 1            | 9° 29'         | 6.42          | 2            | 17° 27'        | ...           | ...          | ...            |
|                          |               |              |                |               |              |                | 6.84          | 1            | 19° 35'        |

\* Object glass probably covered with dew.

These observations were made only on nights on which the stars appeared quite clear and the sky near them free from clouds. Most of the Madras observations were made on specially clear nights. The observations would have been much more numerous and complete had they not been interfered with by cloudy nights, but even as they stand they are sufficient to show a marked superiority of the two hill stations over Madras, though not to distinguish between the two hill stations themselves. The

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5. *General Conclusions.*—The general results at which I have arrived from these observations as regards the relative merits of Kodaikānal and Kōtagiri as a site for an Observatory is that Kodaikānal is by far the better situation of the two. Whether or not this has been absolutely proved by the observations detailed above depends to a certain extent on the further consideration of whether the atmospheric conditions at the time when I was observing were fairly characteristic of the Kōtagiri climate. Personally, I have not the least doubt that the conclusion is the correct one, for the general impression of the superiority of Kodaikānal very strongly forced itself upon me while I was observing at Kōtagiri, and I can affirm without hesitation that the best night while I was at Kōtagiri was inferior to the worst observing night at Kodaikānal. Having already expressed an opinion in favour of Kodaikānal, I took particular care that full justice was done to Kōtagiri and took every possible opportunity of getting the most favorable observations. The inferiority was particularly marked in the solar observations and in the observations of the finer details of nebulae.

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important factor in the discussion is the kind of work which the Observatory is to undertake. If the work is, as heretofore, to continue exclusively on the lines of the older astronomy, I doubt if the gain would be worth the cost, but if an attempt is to be made to enter upon the newer paths of research which have been taken up elsewhere, I feel confident that the gain would be very great. Two subjects, for instance, which could be taken up with great advantage would be spectroscopic examination of the stars for motion along the line of sight and physical observations of the planets. In both of these researches the remarkable steadiness and transparency of the air at Kodaikānal would be an enormous advantage, and I believe that more good work could be done on a dozen clear nights there than on fifty clear nights at Madras. Solar observations could be carried on with at least equal success and with much greater comfort to the observer. The sunshine-recorder slips from February 19th to June 30th show that out of these 166 days the sun could have been photographed on 162 days—a very high record. In Madras photographs could probably have been got on 164 days, but on several of these the photographs would certainly have been poor. If the Kodaikānal observations for the rest of the year show anything like an equally good record, there should be no difficulty in determining the future location of the photo-heliograph.

In coming to a final conclusion on the locality of the Observatory it seems to me that it would be a mistake to leave out of the discussion the original proposal to make the Hill Observatory a branch of the Madras Observatory for special work. If this were done, the transit circle would remain in position in the Madras Meridian which is, theoretically at least, the meridian from which all Indian longitudes are measured. Within the last few weeks my work on the meridian circle observations has shown that certain questions will arise in the preparation of the final Madras star catalogue which can be satisfactorily decided only by further observations with the same instrument in the same position. So far as can be judged at present, these observations will have to be extended over several years, and they cannot be begun with advantage till the work on the catalogue is further advanced. It would evidently be a great mistake to remove the transit circle till all questions arising out of former observations with it are finally settled. Another advantage which would arise from the retention of the Madras Observatory would be that most of the Native assistants engaged in computations, time observations, &c., could remain in Madras—a plan which would save expense and increase efficiency; for few natives can stand hill climates for long, especially in the cold weather. Nor does it seem likely that the total expense of the Observatory would be increased by accepting this proposal if the present intention of having two European Astronomers is carried into effect. There would be a considerable saving in initial cost of buildings while the difference between the hill pay and the Madras pay of the assistants would more than cover the extra establishment required.

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Offg. Government Astronomer.

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To the windward of this the sky was almost clear, but to the leeward there were dense clouds formed which evidently were due to moisture condensing about the dust particles. At the moment at which the accompanying photograph (No. 1) was taken there was a slight wind blowing the smoke out of the vertical. On one night I had to stop observations on account of the dense clouds of smoke blowing over the hill-top from a large fire beyond Shembaganur. Kodaikānal is always subject to these fires in the early part of the year, but this year, I am informed, they were more numerous and continued later than usual. A point of very great importance with regard to the climate of Kodaikānal is that there is a strong tendency for the sky to clear after sunset, and judging from my own experience during six visits to these hills there are very few nights, even during the south-west monsoon, which remain cloudy throughout. This opinion was shared by the late Sir Vere Lvinge, who had made a careful study of the climate during many years. Another feature which sharply distinguishes the climate of Kodaikānal from that of Kōtagiri or of Madras is that the breaks in the sky between clouds are usually very clear. I do not mean that this is unknown at the other stations, for it is a characteristic feature of anticyclonic weather; but as a rule in Madras and, so far as my experience goes, at Kōtagiri, a cloudy night is a bad night for observation, whereas at Kodaikānal excellent work can be done on nights when there is a considerable percentage of cloud. The position of the telescope at Kodaikānal was approximately—Lat.,  $10^{\circ} 13' 30''$  N.; Long.,  $5^{\text{h}} 10^{\text{m}} 1^{\text{s}}$  E.; height above sea-level, 7,390 feet. At Kōtagiri the only place where I could obtain a room was in the bungalow attached to Kotah Hall, and for convenience the telescope was, for the first part of the time, set up on the lawn in front of the house. Later on the telescope was taken to the top of One Tree Hill, some 250 feet higher, to test whether or not the unsatisfactory results obtained were due to the position of the telescope. No difference, however, could be detected between the two stations. The position of the telescope at Kotah Hall may be taken as—Lat.,  $11^{\circ} 25' \text{N.}$ ; Long.,  $5^{\text{h}} 7^{\text{m}} 39^{\text{s}}$  E.; height above sea-level, 6,250 feet. At Kōtagiri I was even more unfortunate than at Kodaikānal in respect to weather, for there were no less than 6 nights which were too cloudy to permit observations being made before midnight. On one of these nights I was able to get a few observations about 4 A.M., but was soon stopped by mist, and on another of them it cleared about 4-30 A.M., and I was able to observe till daybreak. Just as at Kodaikānal the work was interfered with by the smoke from grass fires, so at Kōtagiri the numerous fires lighted by the villagers for burning heaps of weeds produced a haze which, on account of the stillness of the weather, often hung about for a great part of the night. This smoke-haze is to be expected at the hill stations during only a small part of the year and its prejudicial

effect is probably not nearly so great as that of the dust-haze which is present at Madras, more or less strongly developed, during a great part of the year.

At Madras the observations were made from the roof of the Observatory and were much interfered with by cloudy weather. The original intention was to make the complete series in the dark fortnight preceding the visit to Kodaikānal and the programme for observations was drawn up with a view to this. Cloudy weather almost completely stopped observations during that period, and hence the greater part of the Madras observations had to be left over till the dark fortnight following the return from Kōtagiri. During that period there were three very clear nights when a number of observations were made, but thereafter hazy weather came on when it was useless to continue the work, so that the Madras comparative observations were far from complete. By the following dark fortnight most of the objects were too near the horizon to make the observations of any use. Had there been any difficulty in deciding on the relative merits of the three stations, the incompleteness of the observations would have been a matter for serious regret, but it seems to me that the matter is so clear that the observations actually made are abundant. To prevent misapprehension I ought to state that the cloudiness and haze which stopped the observations at Madras would not necessarily have stopped ordinary astronomical observations, but I thought it useless to make test observations when the atmospheric conditions were distinctly unfavorable.

4. *Observations.*—The observations made may be classified as follows:—

- (a) Observations of the sun with special reference to spots and faculæ and their spectra.
- (b) Observations of Venus and Saturn.
- (c) " star-clusters and nebulæ.
- (d) " double stars.
- (e) " stellar spectra.
- (f) Measurements of apparent stellar magnitudes.
- (g) Photographs of star trails.

(a) *Solar Observations.*—The usual experience of observers at high altitudes is that the image of the sun is generally very unsteady owing to the strong convection currents produced by the heat of the sun when it is above the horizon. At the Lick Observatory, for instance, it is, I believe, considered useless to employ on the sun a telescope of more than 6 inches aperture, and even with that aperture good views are obtained only early in the forenoon. At Kodaikānal this unsteadiness was found to be much less than I had expected, for I usually got remarkably steady views of the sun's disc up to at least 10-30 or 11 A.M., while on several occasions I had good views in the afternoon. The feature that struck me most as regards the solar observations was the great clearness with which faculæ were seen. I have never, even under the most favorable conditions, seen them with equal clearness at Madras either with the same or with larger telescopes. Less difference, as might be expected, was noticed in the details of sun spots, which were neither large nor numerous while I was at Kodaikānal. With the grating spectroscope attached to the telescope the reversed prominence lines were seen very bright and steady, and on one occasion I was able to get a view of a complete prominence by opening the slit wide. I found, however, that the difficulty of keeping a given part of the limb exactly on the slit was so great that, having seen one prominence, I did not think it necessary to look for more. It was evident that with suitable appliances the prominences could be seen with great clearness. At Kōtagiri the solar observations were much less satisfactory, for the atmosphere usually became very unsteady about 9 A.M., and it was only on two or three occasions that I got satisfactory views later than that. Before that hour some excellent views were obtained, and both spots—which were then large and numerous—and faculæ were seen with much sharpness of detail. I made numerous micrometric measurements of spots and found that this could be done accurately with much greater ease and comfort than in Madras. As regards solar observations in general, it seems certain that the best views got at the hill stations are much better than the best views got at Madras. Another point to be noted is that, especially in the hot weather, in Madras

solar observations are carried on with great difficulty if not with actual danger to the health of the observer, whereas at a hill station, though the direct solar radiation may be more intense, the coolness of the air renders the work comparatively pleasant as soon as the observer has once got thoroughly sunburned.

(b) *Observations of Venus and of Saturn.*—Observations of Venus and of Saturn were made frequently at both hill stations and at various altitudes. Venus is a very severe test for both the telescope and the atmosphere. At Kodaikānal this planet was usually too near the horizon when I began the night's work to get really good views of it, but those that I did obtain were distinctly good under the circumstances, while on the two or three occasions on which I observed it before or soon after sunset the views were excellent. At Kótagiri the views obtained near sunset were only fair, and those obtained later were poor. Saturn is much easier than Venus and some excellent views of it were got at both stations, but at Kodaikānal it was usually possible to employ with advantage a much higher power than at Kótagiri. At the former place a power of 360 could usually be employed, while at the latter 262 was generally too much. All the observations of Saturn were made at comparatively low altitudes at both places, but the details of the markings on the planets showed with great distinctness. I find in my Kótagiri notes the following entry after several nights of observations of Venus and Saturn: "The definition is certainly better than in Madras but not so good as at Kodaikānal."

(c) *Star Clusters and Nebulae.*—For these I went systematically through a list taken from Chambers' Astronomy. Many of the selected objects were in no sense test objects, but I believed that by examining a large number of different objects at each station I would get a better general idea of the relative qualities of each station than I would have got by confining my attention to test objects. The general conclusion arrived at was that for clusters there was a slight, and for faint nebulae a marked advantage of both hill stations over Madras, while as regards the relative merits of the two hill stations Kodaikānal was distinctly better than Kótagiri. A few special cases may be mentioned. In the great Orion nebula the nebula round 734 Bond was a conspicuous object and the bright wisp of light that curves upwards round 1004 Bond was easily traced as far as it is shown in Bond's drawing. This was not the case at either of the other stations. I had no map of the nebula with me with which to make comparison, but the impression left was that the nebula extended in several directions very much further than I had ever seen it before. The nebula about  $\eta$  Argus is so far south that even a slight change in latitude makes a sensible change in its visibility; still, the very great differences between it as seen from the three stations cannot be entirely accounted for by this. The view of it from Kodaikānal, especially on one night, was incomparably finer than any view I had previously had of it. The cluster about  $\kappa$  Crucis is an easy object and I used it simply as a test for colours. In Madras, the colours of the many coloured stars in the cluster are well seen only on specially fine nights. At Kodaikānal, the colours showed with great brilliancy. At Kótagiri, they were well seen with a power of 70, but with higher powers were distinctly poor. The Crab nebula in Taurus stood a power of 134 at Kodaikānal and showed much detail; at Kótagiri I could not use a power of more than 100, with which it was "fair"; and at Madras it was usually a "poor" object. The nebula M 94 was "seen but not clearly resolved" at both of the hill stations, while at Madras it was "very hazy" though the night was specially fine. The nebulae 49 M and 88 M in Virgo were both "well seen" at Kodaikānal, they were "faint" and "very faint" at Kótagiri, they were not found at Madras on the only occasion on which I was able to search for them. 85 M was "seen fairly well" at Kodaikānal and was "very faint" at Kótagiri. H 2102 (Hydra) was "seen, but faint" at Kodaikānal and was "very well seen" at Kótagiri. H 2008 (Sextans) was "seen" and "well seen" at Kodaikānal and Kótagiri and "not found" at Madras.

(d) *Double Stars.*—The observations of double stars were made under very unfavorable conditions, especially at Kodaikānal, where the telescope placed on the top of the hill was fully exposed to the wind from all sides. The best observing nights were those on which there was a pretty strong wind, and I found that with

even a moderate wind the light stand which I had for the telescope was not sufficiently steady to permit of the use of high powers, and that even with low powers it was difficult to distinguish between simple elongation and actual division of close double stars. At Kótagiri there was much less wind and the observations were more satisfactory. The general result of the observations, so far as they go, is that little difference could be observed between Kodaikānal and Kótagiri, but that the additional light and steadiness of the air at the hill stations as compared with Madras was very striking.

(e) *Stellar Spectra.*—Most of the observations on these were, for convenience, made with the Maclean star spectroscope. The general conclusion arrived at was that both the hill stations were superior to Madras, and that, so far as the observations went, Kodaikānal was superior to Kótagiri, but in fairness to the latter station it must be said that the nights on which the observations were made were by no means ideally fine. The spectra as seen at Kodaikānal were remarkable both for their brightness and, what is of much more importance, their steadiness. The curious and very trying flickering which is so strongly marked at Madras was almost entirely absent. The Maclean spectroscope is not fitted with any arrangement by which the position of the lines can be measured, but had I had a spectroscope fitted with measuring apparatus it would have been easy to measure the positions of many lines with great accuracy. It seems to me that some of the chief difficulties in connection with the accurate measurement of stellar spectra would be avoided in an Observatory at Kodaikānal.

(f) *Measurements of apparent Stellar Magnitudes.*—The measurements of stellar magnitudes were made with a Pritchard's wedge photometer. To use this instrument effectively the light from the star must be made to pass through a very small aperture before it falls on the wedge of neutral-tinted glass by which it is extinguished. When the photometer is attached to a telescope with a fixed stand and clockwork this can be managed without difficulty, but with a light portable stand which is never in perfect adjustment and with no clockwork or slow motion in declination it is far from easy to keep the star in exactly the right position. To simplify the observations as much as possible I observed only stars which were comparatively near the poles. Consequently, the stars were always at a low altitude, and hence the results are not only less uniform but give a much less favorable comparison than would be given by stars near the zenith. Each set of measurements consisted of not less than 5 readings of the wedge. The observations were made with various apertures, but all were reduced to the readings for full aperture. The middle time of each set of observations was noted and the altitude of the star at that time was calculated. The following are the chief results:—

| Star.                    | Madras.       |              |                | Kodaikānal.   |              |                | Kótagiri.     |              |                |
|--------------------------|---------------|--------------|----------------|---------------|--------------|----------------|---------------|--------------|----------------|
|                          | Mean Reading. | No. of sets. | Mean Altitude. | Mean Reading. | No. of sets. | Mean Altitude. | Mean Reading. | No. of sets. | Mean Altitude. |
| $\alpha$ Ursae Majoris   | 5.98          | 0            | 36° 30'        | 6.24          | 2            | 32° 39'        | 6.26          | 2            | 37° 2'         |
| $\beta$ Ursae Majoris    | 5.93          | 5            | 39° 11'        | 5.68*         | 1            | 41° 36'        | 6.31          | 1            | 41° 33'        |
| $\delta$ Ursae Majoris   | 5.28          | 6            | 39° 24'        | 5.71          | 4            | 38° 33'        | 5.69          | 2            | 35° 27'        |
| Polaris                  | 5.47          | 3            | 12° 20'        | 5.88          | 7            | 9° 14'         | 5.62          | 2            | 10° 42'        |
| $\epsilon$ Argus         | ..            | ..           | ..             | 0.20          | 2            | 19° 10'        | 6.04          | 1            | 18° 51'        |
| $\delta$ Argus           | 5.98          | 1            | 11° 52'        | 6.23          | 2            | 23° 51'        | 6.38          | 1            | 23° 55'        |
| $\kappa$ Argus           | 5.85          | 2            | 11° 42'        | 6.12          | 2            | 24° 27'        | 6.03          | 1            | 24° 2'         |
| $\gamma$ Ursae Majoris   | 5.04          | 1            | ..             | 5.89          | 1            | 41° 24'        | ..            | ..           | ..             |
| $\epsilon$ Ursae Majoris | ..            | ..           | ..             | 6.42          | 2            | 17° 27'        | ..            | ..           | ..             |
| $\iota$ Argus            | 5.54          | 1            | 9° 29'         | ..            | ..           | ..             | 5.84          | 1            | 19° 36'        |

\* Object glass probably covered with dew.

These observations were made only on nights on which the stars appeared quite clear and the sky near them free from clouds. Most of the Madras observations were made on specially clear nights. The observations would have been much more numerous and complete had they not been interfered with by cloudy nights, but even as they stand they are sufficient to show a marked superiority of the two hill stations over Madras, though not to distinguish between the two hill stations themselves. The

scale difference for one star magnitude is very nearly 0.50 inches and the mean reading for Madras is about 0.34 inches less than for Kodaikānal. In other words, to obtain the same amount of light from any star at Madras as at Kodaikānal, the area of the object glass would have to be increased by one-half. This, I believe, is really an under-estimate. It is probably nearly the truth for stars within  $30^\circ$  to  $40^\circ$  of the horizon, but at great altitudes the difference would be greater.

(g) *Photographs of Star Trails.*—As the Observatory is not provided with any photographic apparatus, I got the loan from Mr. H. A. Sim, C.S., of a large camera fitted with a portrait lens of 6 inches diameter and 36 inches focal length. The lens was an excellent one for the purpose but the camera was a very unwieldy one of solid mahogany which required two men to lift it and I had no time to replace it with a more convenient one. Hence I found it impossible to take photographs at a greater altitude than about  $30^\circ$  while it was very difficult to point the camera to the exact part of the sky which was desired. At Kodaikānal I was much troubled by dew on the lens—a difficulty which would not be felt in a regular observatory. By far the most striking photograph was one obtained at Madras on April 25th. The camera was directed so that *Polaris* fell near the upper right-hand corner of the plate, and the plate was exposed for about two hours with an interruption of ten minutes. The

See photo. No. 2.

plate used was Wratten and Wainwright's "instantaneous." The negative shows the following stars:—R.P.L. 93, 79, 92, 128 (24 Ursæ Minoris), 125 (8 Ursæ Minoris), 100, 108, 89, 72, 99,  $\alpha$  Serpentis, B.D. 85° 512 and four or five others which I have not identified. That is, all stars down to the 8th magnitude and a few fainter ones are shown. With reference to this it should be pointed out that on the 24th there was a rainfall of 0.69 inches—the first heavy rain this year—and the night of the 25th was brilliantly clear, the stars shining as they never do here except after heavy rain. The night was windy, but by placing the camera inside the large dome it was possible to shelter it completely. In the Kodaikānal plates of the same region, the smallest star visible is one of the 6th magnitude; but it must be remembered that the altitude of the pole at that station is nearly  $3^\circ$  less than at Madras, and that on none of the nights when I was there had there been enough of rain to clear the air, while the grass fires caused a heavy haze to hang round the northern horizon. I may add that there are few nights in Madras on which a photograph shows any stars of less than the 5th magnitude, while on many nights even *Polaris* is invisible. The Kōtagiri plate showed only *Polaris* and  $\delta$  Ursæ Minoris (4.5) clearly with a faint trace of R.P.L. 99.

A photograph taken in Madras on April 25th—also a very clear night—of a portion of Argus shows:— $\phi$  Argūs,  $h$  Carinæ,  $\kappa$  Argūs,  $i$  Argūs,  $i$  Carinæ,  $a$  Carinæ,  $b_1$  and  $b_2$  Carinæ,  $h$  Velorum,  $c$  Carinæ,

See photo. No. 3.

$f$  Carinæ,  $\delta$  Argūs, anon. Velorum (7th mag.)  $\sigma$  Argūs,  $d$  Carinæ, and  $e$  Argūs. It is worth noting that while, in this plate,  $b_1$  Carinæ is strongly marked,  $b_2$  is hardly visible, though Stone gives them both as of the same magnitude. The magnitude of  $a$  Carinæ also appears to be greater than is given in Stone. A negative taken at Kodaikānal did not cover exactly the same area, but in the part that overlapped the negative showed all the stars shown in the Madras negative except  $b$  Carinæ. This plate was one of the earliest taken and was evidently under-developed. A negative of the same region taken at Kōtagiri was very poor, showing only the brighter stars. Negatives of the Southern Cross were taken both at Madras and at Kodaikānal. The former taken on 27th April—also a clear night, though not quite equal to the two preceding nights—

See photo. No. 4.

showed only  $\alpha$   $\beta$  &  $\delta$  Crucis. The latter showed also Stone 7119 (6.5 mag.),  $\lambda$  Crucis, Stone 7055, Stone 5241 (7),  $\gamma$  Crucis, and  $\zeta$  Crucis. Here again the photographic magnitudes do not agree with the visual magnitudes of Stone's catalogue, especially in the case of  $\gamma$  which is given of the 2nd magnitude while  $\delta$  is of the 3rd, yet  $\gamma$  is much fainter than  $\delta$  in the Kodaikānal plate while it does not appear at all on the Madras plate. The general conclusion to be drawn from these and some other photographs is that there are a few exceptionally fine nights in Madras when the atmosphere near the horizon is fully as clear as that

of Kodaikānal on ordinary nights, but that even on such nights the atmosphere at higher altitudes is distinctly less clear than it is at corresponding altitudes at Kodaikānal. This conclusion was confirmed by observations of faint nebulae made on the same nights as those on which the photographs were taken. As regards Kōtagiri the results are too incomplete to be conclusive, but so far as they go they are very unfavorable to that place.

5. *General Conclusions.*—The general results at which I have arrived from these observations as regards the relative merits of Kodaikānal and Kōtagiri as a site for an Observatory is that Kodaikānal is by far the better situation of the two. Whether or not this has been absolutely proved by the observations detailed above depends to a certain extent on the further consideration of whether the atmospheric conditions at the time when I was observing were fairly characteristic of the Kōtagiri climate. Personally, I have not the least doubt that the conclusion is the correct one, for the general impression of the superiority of Kodaikānal very strongly forced itself upon me while I was observing at Kōtagiri, and I can affirm without hesitation that the best night while I was at Kōtagiri was inferior to the worst observing night at Kodaikānal. Having already expressed an opinion in favour of Kodaikānal I took particular care that full justice was done to Kōtagiri and took every possible opportunity of getting the most favorable observations. The inferiority was particularly marked in the solar observations and in the observations of the finer details of nebulae.

The explanation of the difference between the two stations is not difficult to find. In the first place, Kodaikānal is nearly 1,000 feet higher than Kōtagiri, which is in itself a considerable advantage. In the second place, the formation of the hills about Kōtagiri is much less favorable than the formation about Kodaikānal. Kōtagiri itself lies in a basin surrounded by hills rising to a greater height on all sides and during the day the temperature of this basin rises considerably above that of the surrounding hills. Consequently, convection currents of an irregular kind are set up in the air producing a condition very prejudicial to accurate astronomical observations. These convection currents are found on all hills, but their strength and duration depend on the configuration of the ground. Where the hill-top is freely exposed, the ascending currents die away before or soon after sunset and are in due course succeeded by downward currents which bring in the clear air from above and so produce the conditions most favorable for observations. On the other hand, with a large sheltered basin, as at Kōtagiri, temperature falls slowly and the unfavorable conditions may continue far into the night. At Kodaikānal there is a large plateau rising in the centre, and the best site for an observatory lies well away both from the precipitous edges of the plateau and from the hollow in which the lake lies. This situation seems to me to be exactly what would be chosen on general principles as the site of an observatory. It may be suggested that a similar position might be found near Kōtagiri on the surrounding hills. This is a point to which I paid considerable attention. Dodabotta I have tested on a previous occasion in the month of January, but with most unfavorable results, and any situation further west would probably be even worse, while towards the east I have been unable to find any position which was sufficiently removed from the edge of the plateau on the one hand and from the Kōtagiri basin on the other hand.

The question of the relative merits of Kodaikānal and Madras is a much more difficult one. It is probable that the meteorological observations now being carried on will show that there is more cloud during the year at Kodaikānal than at Madras, and there can be no doubt that at Madras there is a large number of nights on which ordinary astronomical observations can be made well enough, and a small number of really first-class observing nights. On the other hand, it is perfectly clear that the "seeing" on a good night at Kodaikānal is much better than on a good night in Madras, and my former observations have shown that, even during the south-west monsoon, there are few nights during which good observations cannot be made. During part of the north-east monsoon the nights seem to be very cloudy, but I know of no observatory where there is not a portion of the year during which few observations can be made. The question as to whether or not the greater clearness of the unclouded atmosphere outweighs other disadvantages cannot be fully discussed till the meteorological observations have been completed, but I may point out at present that a

very important factor in the discussion is the kind of work which the observatory is to undertake. If the work is, as heretofore, to continue exclusively on the lines of the older astronomy I doubt if the gain would be worth the cost, but if an attempt is to be made to enter upon the newer paths of research which have been taken up elsewhere I feel confident that the gain would be very great. Two subjects, for instance, which could be taken up with great advantage would be spectroscopic examination of the stars for motion along the line of sight and physical observations of the planets. In both of these researches the remarkable steadiness and transparency of the air at Kodaikānal would be an enormous advantage, and I believe that more good work could be done on a dozen clear nights there than on fifty clear nights at Madras. Solar observations could be carried on with at least equal success and with much greater comfort to the observer. The sunshine-recorder slips from February 19th to June 30th show that out of these 166 days the sun could have been photographed on 162 days—a very high record. In Madras photographs could probably have been got on 164 days, but on several of these the photographs would certainly have been poor. If the Kodaikānal observations for the rest of the year show anything like an equally good record, there should be no difficulty in determining the future location of the photo-heliograph.

In coming to a final conclusion on the locality of the observatory it seems to me that it would be a mistake to leave out of the discussion the original proposal to make the Hill Observatory a branch of the Madras Observatory for special work. If this were done, the transit circle would remain in position in the Madras Meridian which is, theoretically at least, the meridian from which all Indian longitudes are measured. Within the last few weeks my work on the meridian circle observations has shown that certain questions will arise in the preparation of the final Madras star catalogue which can be satisfactorily decided only by further observations with the same instrument in the same position. So far as can be judged at present, these observations will have to be extended over several years, and they cannot be begun with advantage till the work on the catalogue is further advanced. It would evidently be a great mistake to remove the transit circle till all questions arising out of former observations with it are finally settled. Another advantage which would arise from the retention of the Madras Observatory would be that most of the Native assistants engaged in computations, time observations, &c., could remain in Madras—a plan which would save expense and increase efficiency; for few natives can stand hill climates for long, especially in the cold weather. Nor does it seem likely that the total expense of the observatory would be increased by accepting this proposal if the present intention of having two European Astronomers is carried into effect. There would be a considerable saving in initial cost of buildings while the difference between the hill pay and the Madras pay of the assistants would more than cover the extra establishment required.

5th August 1892.

(Signed) C. MICHIE SMITH,  
Offg. Government Astronomer.

NOTE.—The photographic prints accompanying this do not show nearly all the stars shown in the negatives, but they give some indication of the sharpness of the photographs.

(Intld.) C. M. S.

NOTE FOR THE CHIEF SECRETARY.

Public Department.

C. No. 2677.

ORDER: -16<sup>th</sup> Sept 1892. No. 648.

The Government of India

will be addressed.

LETTER: - No. 649.

The Secretary to the Govt. of India,

Rev. & Agri. Dept.

With reference to my letter dated 30<sup>th</sup> December last No. 1051, and your telegram of the 7th January, regarding comparative solar and other observations at Madras, Kodaikanal and Kotagiri, I am directed to forward a full report on the subject by the Offg. Govt. Astronomer.

2. Copies of the papers to which Mr. Michie Smith refers in his covering letter are annexed.

This was detained L-50th in the photo from Madras and I thought that it was brought back to the House.

Note  
Send the photographs to the G. of I.

Note.  
The proof is not accurate, but Mr. Michie Smith is correcting a copy.

Left 57 copies  
30/9/92  
Sent 30/9/92  
15 Sep  
12/8

I send this current and file to you as I think you will like to deal with it. In any case the report will have to be put into type. The photos are inside the bamboo which accompanies.

J.D.B.  
9/10/11

Print & send me two proofs, please. I will keep the photographs.

Official Memo.

The proof is returned with corrections. It is of great importance that these corrections should be made accurately & as the Greek letters are naturally puzzling to the printers it would be well if I saw another proof. I will be in Madras on Tuesday morning, the 30th inst.

C. Michie Smith  
Offg Govt Astronomer  
26.8.92

Pubd 648 49-16-9-92

*Astronomical obs.  
: Serua haw*

*PS*

*San. Sec. Henry Stokes  
HCS 2*

16TH SEPTEMBER 1892, No. 648, PUBLIC.

GOVERNMENT OF MADRAS.

PUBLIC DEPARTMENT.

READ—the following paper :—

From C. MICHIE SMITH, Esq., Officiating Government Astronomer, to the Chief Secretary to Government, dated Madras, 5th August 1892, No. 95.

I have the honour to forward herewith my report on the observations made at Madras, Kodaikānal, and Kōtagiri regarding the best site for a new Astronomical Observatory. I would suggest that it be read in connection with my two previous papers on the same subject—the "Report on Observations made on the Palni Hills," dated 7th August 1883, and a letter to His Excellency the Governor recorded in G.O., dated 7th March 1885, No. 572.

ENCLOSURE.

REPORT on the relative Merits of Kodaikānal, Kōtagiri, and Madras as Sites for an Astronomical Observatory.

In accordance with the proposals made in my letter, No. 21, dated 3rd February last, which were accepted in G.O., Public Department, No. 92, of the 9th idem, I left Madras on February 18th for Kodaikānal, arriving there on the 20th idem. I returned to Madras on March 9th and left for Kōtagiri on the 18th idem. I returned finally to Madras on April 5th.

2. *Instruments.*—The chief instruments which I took with me were the following :—

- (1) The Smythian telescope of 3.7 inches aperture, with a portable stand and equatorial mounting by Cook and Sons.
- (2) A Pritchard's wedge photometer.
- (3) A spectroscope with a Rowland's grating of 14,439 lines to the inch.
- (4) A Maclean's star spectroscope.
- (5) A small direct-vision spectroscope with cylindrical lens.
- (6) A sextant with stand and artificial horizon for time determinations.
- (7) A sidereal chronometer.
- (8) A large camera with portrait lens 6 inches in diameter, 36 inches focus.
- (9) A half-plate camera.
- (10) Aneroid barometer, rotating thermometers (wet and dry bulb), and sun maximum thermometer.

To protect the instruments and those in charge of them I took with me a tent supplied from the Camp Equipage Depot.

3. *Places from which Observations were made and Weather.*—At Kodaikānal Mr. F. N. Gill very kindly placed at my disposal his house "Penn Craig," while Mr. Heimpel, of Dindigul, allowed me to pitch my tent on the top of the hill rising behind "Bella Vista," which belongs to him. The situation of this hill, though good, is not so good as that of some of the peaks farther west, but I found that it was quite

solar observations are carried on with great difficulty if not with actual danger to the health of the observer, whereas at a hill station, though the direct solar radiation may be more intense, the coolness of the air renders the work comparatively pleasant as soon as the observer has once got thoroughly sunburned.

(b) *Observations of Venus and of Saturn.*—Observations of Venus and of Saturn were made frequently at both hill stations and at various altitudes. Venus is a very severe test for both the telescope and the atmosphere. At Kodaikānal this planet was usually too near the horizon when I began the night's work to get really good views of it, but those that I did obtain were distinctly good under the circumstances, while on the two or three occasions on which I observed it before or soon after sunset the views were excellent. At Kōtagiri the views obtained near sunset were only fair, and those obtained later were poor. Saturn is much easier than Venus and some excellent views of it were got at both stations, but at Kodaikānal it was usually possible to employ with advantage a much higher power than at Kōtagiri. At the former place a power of 360 could usually be employed, while at the latter 262 was generally too much. All the observations of Saturn were made at comparatively low altitudes at both places, but the details of the markings on the planets showed with great distinctness. I find in my Kōtagiri notes the following entry after several nights of observations of Venus and Saturn: "The definition is certainly better than in Madras but not so good as at Kodaikānal."

(c) *Star Clusters and Nebulae.*—For these I went systematically through a list taken from Chambers' Astronomy. Many of the selected objects were in no sense test objects, but I believed that by examining a large number of different objects at each station I would get a better general idea of the relative qualities of each station than I would have got by confining my attention to test objects. The general conclusion arrived at was that for clusters there was a slight, and for faint nebulae a marked advantage of both hill stations over Madras, while as regards the relative merits of the two hill stations Kodaikānal was distinctly better than Kōtagiri. A few special cases may be mentioned. In the great Orion nebula the nebula round 734 Bond was a conspicuous object and the bright wisp of light that curves upwards round 1004 Bond was easily traced as far as it is shown in Bond's drawing. This was not the case at either of the other stations. I had no map of the nebula with me with which to make comparison, but the impression left was that the nebula extended in several directions very much further than I had ever seen it before. The nebula about  $\eta$  Argūs is so far south that even a slight change in latitude makes a sensible change in its visibility; still, the very great differences between it as seen from the three stations cannot be entirely accounted for by this. The view of it from Kodaikānal, especially on one night, was incomparably finer than any view I had previously had of it. The cluster about  $\alpha$  Crucis is an easy object and I used it simply as a test for colours. In Madras, the colours of the many coloured stars in the cluster are well seen only on specially fine nights. At Kodaikānal, the colours showed with great brilliancy. At Kōtagiri, they were well seen with a power of 70, but with higher powers were distinctly poor. The Crab nebula in Taurus stood a power of 134 at Kodaikānal and showed much detail; at Kōtagiri I could not use a power of more than 100, with which it was "fair"; and at Madras it was usually a "poor" object. The nebula M 94 was "seen but not clearly resolved" at both of the hill stations, while at Madras it was "very hazy" though the night was specially fine. The nebulae 49 M and 88 M in Virgo were both "well seen" at Kodaikānal, they were "faint" and "very faint" at Kōtagiri, they were not found at Madras on the only occasion on which I was able to search for them. 85 M was "seen fairly well" at Kodaikānal and was "very faint" at Kōtagiri. H 2102 (Hydra) was "seen, but faint" at Kodaikānal and was "very well seen" at Kōtagiri. H 2008 (Sextans) was "seen" and "well seen" at Kodaikānal and Kōtagiri and "not found" at Madras.

(d) *Double Stars.*—The observations of double stars were made under very unfavorable conditions, especially at Kodaikānal, where the telescope placed on the top of the hill was fully exposed to the wind from all sides. The best observing nights were those on which there was a pretty strong wind, and I found that with

even a moderate wind the light stand which I had for the telescope was not sufficiently steady to permit of the use of high powers, and that even with low powers it was difficult to distinguish between simple elongation and actual division of close double stars. At Kōtagiri there was much less wind and the observations were more satisfactory. The general result of the observations, so far as they go, is that little difference could be observed between Kodaikānal and Kōtagiri, but that the additional light and steadiness of the air at the hill stations as compared with Madras was very striking.

(e) *Stellar Spectra.*—Most of the observations on these were, for convenience, made with the Maclean star spectroscope. The general conclusion arrived at was that both the hill stations were superior to Madras, and that, so far as the observations went, Kodaikānal was superior to Kōtagiri, but in fairness to the latter station it must be said that the nights on which the observations were made were by no means ideally fine. The spectra as seen at Kodaikānal were remarkable both for their brightness and, what is of much more importance, their steadiness. The curious and very trying flickering which is so strongly marked at Madras was almost entirely absent. The Maclean spectroscope is not fitted with any arrangement by which the position of the lines can be measured, but had I had a spectroscope fitted with measuring apparatus it would have been easy to measure the positions of many lines with great accuracy. It seems to me that some of the chief difficulties in connection with the accurate measurement of stellar spectra would be avoided in an Observatory at Kodaikānal.

(f) *Measurements of apparent Stellar Magnitudes.*—The measurements of stellar magnitudes were made with a Pritchard's wedge photometer. To use this instrument effectively the light from the star must be made to pass through a very small aperture before it falls on the wedge of neutral-tinted glass by which it is extinguished. When the photometer is attached to a telescope with a fixed stand and clockwork this can be managed without difficulty, but with a light portable stand which is never in perfect adjustment and with no clockwork or slow motion in declination it is far from easy to keep the star in exactly the right position. To simplify the observations as much as possible I observed only stars which were comparatively near the poles. Consequently, the stars were always at a low altitude, and hence the results are not only less uniform but give a much less favorable comparison than would be given by stars near the zenith. Each set of measurements consisted of not less than 5 readings of the wedge. The observations were made with various apertures, but all were reduced to the readings for full aperture. The middle time of each set of observations was noted and the altitude of the star at that time was calculated. The following are the chief results:—

| Star.                   | Madras.       |              |                | Kodaikānal.   |              |                | Kōtagiri.     |              |                |
|-------------------------|---------------|--------------|----------------|---------------|--------------|----------------|---------------|--------------|----------------|
|                         | Mean Reading. | No. of sets. | Mean Altitude. | Mean Reading. | No. of sets. | Mean Altitude. | Mean Reading. | No. of sets. | Mean Altitude. |
| $\alpha$ Ursæ Majoris   | 5.98          | 6            | 36° 36'        | 5.24          | 2            | 32° 39'        | 6.26          | 2            | 37° 2'         |
| $\beta$ Ursæ Majoris    | 5.93          | 5            | 39° 11'        | 5.68          | 1            | 41° 36'        | 6.31          | 1            | 41° 33'        |
| $\delta$ Ursæ Majoris   | 5.28          | 6            | 39° 24'        | 5.71          | 4            | 38° 33'        | 6.09          | 2            | 35° 27'        |
| Polaris                 | 5.47          | 3            | 12° 20'        | 5.68          | 7            | 9° 14'         | 6.62          | 2            | 10° 42'        |
| $\epsilon$ Argus        | ..            | ..           | ..             | 6.20          | 2            | 19° 10'        | 6.04          | 1            | 18° 51'        |
| $\delta$ Argus          | 5.98          | 1            | 11° 52'        | 6.23          | 2            | 23° 51'        | 6.38          | 1            | 23° 55'        |
| $\kappa$ Argus          | 6.85          | 2            | 11° 42'        | 6.12          | 2            | 24° 27'        | 6.03          | 1            | 24° 2'         |
| $\gamma$ Ursæ Majoris   | 5.04          | 1            | ..             | 5.80          | 1            | 41° 24'        | ..            | ..           | ..             |
| $\epsilon$ Ursæ Majoris | ..            | ..           | ..             | 6.42          | 2            | 17° 27'        | ..            | ..           | ..             |
| $\lambda$ Argus         | 5.54          | 1            | 9° 20'         | ..            | ..           | ..             | 5.84          | 1            | 19° 35'        |

\* Object glass probably covered with dew.

These observations were made only on nights on which the stars appeared quite clear and the sky near them free from clouds. Most of the Madras observations were made on specially clear nights. The observations would have been much more numerous and complete had they not been interfered with by cloudy nights, but even as they stand they are sufficient to show a marked superiority of the two hill stations over Madras, though not to distinguish between the two hill stations themselves. The

scale difference for one star magnitude is very nearly 0.50 inches and the mean reading for Madras is about 0.34 inches less than for Kodaikānal. In other words, to obtain the same amount of light from any star at Madras as at Kodaikānal, the area of the object glass would have to be increased by one-half. This, I believe, is really an under-estimate. It is probably nearly the truth for stars within 30° to 40° of the horizon, but at great altitudes the difference would be greater.

(g) *Photographs of Star Trails*.—As the Observatory is not provided with any photographic apparatus, I got the loan from Mr. H. A. Sim, C.S., of a large camera fitted with a portrait lens of 6 inches diameter and 36 inches focal length. The lens was an excellent one for the purpose but the camera was a very unwieldy one of solid mahogany which required two men to lift it and I had no time to replace it with a more convenient one. Hence I found it impossible to take photographs at a greater altitude than about 30° while it was very difficult to point the camera to the exact part of the sky which was desired. At Kodaikānal I was much troubled by dew on the lens—a difficulty which would not be felt in a regular observatory. By far the most striking photograph was one obtained at Madras on April 25th. The camera was directed so that *Polaris* fell near the upper right-hand corner of the plate, and the plate was exposed for about two hours with an interruption of ten minutes. The

See photo. No. 2.

plate used was Wratten and Wainwright's "instantaneous." The negative shows the following stars:—R.P.L. 93, 79, 92, 128 (24 *Ursæ Minoris*), 125 (8 *Ursæ Minoris*), 100, 108, 89, 72, 99,  $\alpha$  *Serpentis*, B.D. 83° 512 and four or five others which I have not identified. That is, all stars down to the 8th magnitude and a few fainter ones are shown. With reference to this it should be pointed out that on the 24th there was a rainfall of 0.69 inches—the first heavy rain this year—and the night of the 25th was brilliantly clear, the stars shining as they never do here except after heavy rain. The night was windy, but by placing the camera inside the large dome it was possible to shelter it completely. In the Kodaikānal plates of the same region, the smallest star visible is one of the 6th magnitude; but it must be remembered that the altitude of the pole at that station is nearly 3° less than at Madras, and that on none of the nights when I was there had there been enough of rain to clear the air, while the gross fogs caused a heavy haze to hang round the northern horizon. I may add that there are few nights in Madras on which a photograph shows any stars of less than the 5th magnitude, while on many nights even *Polaris* is invisible. The Kōtagiri plate showed only *Polaris* and  $\delta$  *Ursæ Minoris* (4.5) clearly with a faint trace of R.P.L. 99.

A photograph taken in Madras on April 25th—also a very clear night—of a portion of Argus shows:— $\phi$  Argus,  $h$  Carinae,  $\kappa$  Argus,  $i$  Argus,  $z$  Carinae,  $a$  Carinae,  $b_1$  and  $b_2$  Carinae,  $\pi$  Velorum,  $c$  Carinae,  $f$  Carinae,  $\delta$  Argus, anon. Velorum (7th mag.)  $\circ$  Argus,  $d$  Carinae, and  $e$  Argus. It is worth noting that while, in this plate,  $b_1$  Carinae is strongly marked,  $b_2$  is hardly visible, though Stone gives them both as of the same magnitude. The magnitude of  $a$  Carinae also appears to be greater than is given in Stone. A negative taken at Kodaikānal did not cover exactly the same area, but in the part that overlapped the negative showed all the stars shown in the Madras negative except  $b$  Carinae. This plate was one of the earliest taken and was evidently under-developed. A negative of the same region taken at Kōtagiri was very poor, showing only the brighter stars. Negatives of the Southern Cross were taken both at Madras and at Kodaikānal. The former taken on 27th April—also a clear night, though not quite equal to the two preceding nights—

See photo. No. 3.

showed only  $\alpha$   $\beta$  &  $\delta$  Crucis. The latter showed also Stone 7119 (6.5 mag.),  $\lambda$  Crucis, Stone 7055, Stone 5241 (7),  $\gamma$  Crucis, and  $\zeta$  Crucis. Here again the photographic magnitudes do not agree with the visual magnitudes of Stone's catalogue, especially in the case of  $\gamma$  which is given of the 2nd magnitude while  $\delta$  is of the 3rd, yet  $\gamma$  is much fainter than  $\delta$  in the Kodaikānal plate while it does not appear at all on the Madras plate. The general conclusion to be drawn from these and some other photographs is that there are a few exceptionally fine nights in Madras when the atmosphere near the horizon is fully as clear as that

See photo. No. 4.

of Kodaikānal on ordinary nights, but that even on such nights the atmosphere at higher altitudes is distinctly less clear than it is at corresponding altitudes at Kodaikānal. This conclusion was confirmed by observations of faint nebulae made on the same nights as those on which the photographs were taken. As regards Kōtagiri the results are too incomplete to be conclusive, but so far as they go they are very unfavorable to that place.

of Kodaikānal on ordinary nights, but that even on such nights the atmosphere at higher altitudes is distinctly less clear than it is at corresponding altitudes at Kodaikānal. This conclusion was confirmed by observations of faint nebulae made on the same nights as those on which the photographs were taken. As regards Kōtagiri the results are too incomplete to be conclusive, but so far as they go they are very unfavorable to that place.

5. *General Conclusions*.—The general results at which I have arrived from these observations as regards the relative merits of Kodaikānal and Kōtagiri as a site for an Observatory is that Kodaikānal is by far the better situation of the two. Whether or not this has been absolutely proved by the observations detailed above depends to a certain extent on the further consideration of whether the atmospheric conditions at the time when I was observing were fairly characteristic of the Kōtagiri climate. Personally, I have not the least doubt that the conclusion is the correct one, for the general impression of the superiority of Kodaikānal very strongly forced itself upon me while I was observing at Kōtagiri, and I can affirm without hesitation that the best night while I was at Kōtagiri was inferior to the worst observing night at Kodaikānal. Having already expressed an opinion in favour of Kodaikānal I took particular care that full justice was done to Kōtagiri and took every possible opportunity of getting the most favorable observations. The inferiority was particularly marked in the solar observations and in the observations of the finer details of nebulae.

The explanation of the difference between the two stations is not difficult to find. In the first place, Kodaikānal is nearly 1,000 feet higher than Kōtagiri, which is in itself a considerable advantage. In the second place, the formation of the hills about Kōtagiri is much less favorable than the formation about Kodaikānal. Kōtagiri itself lies in a basin surrounded by hills rising to a greater height on all sides and during the day the temperature of this basin rises considerably above that of the surrounding hills. Consequently, convection currents of an irregular kind are set up in the air producing a condition very prejudicial to accurate astronomical observations. These convection currents are found on all hills, but their strength and duration depend on the configuration of the ground. Where the hill-top is freely exposed, the ascending currents die away before or soon after sunset and are in due course succeeded by downward currents which bring in the clear air from above and so produce the conditions most favorable for observations. On the other hand, with a large sheltered basin, as at Kōtagiri, temperature falls slowly and the unfavorable conditions may continue far into the night. At Kodaikānal there is a large plateau rising in the centre, and the best site for an observatory lies well away both from the precipitous edges of the plateau and from the hollow in which the lake lies. This situation seems to me to be exactly what would be chosen on general principles as the site of an observatory. It may be suggested that a similar position might be found near Kōtagiri on the surrounding hills. This is a point to which I paid considerable attention. Dodabetta I have tested on a previous occasion in the month of January, but with most unfavorable results, and any situation further west would probably be even worse, while towards the east I have been unable to find any position which was sufficiently removed from the edge of the plateau on the one hand and from the Kōtagiri basin on the other hand.

The question of the relative merits of Kodaikānal and Madras is a much more difficult one. It is probable that the meteorological observations now being carried on will show that there is more cloud during the year at Kodaikānal than at Madras, and there can be no doubt that at Madras there is a large number of nights on which ordinary astronomical observations can be made well enough, and a small number of really first-class observing nights. On the other hand, it is perfectly clear that the "seeing" on a good night at Kodaikānal is much better than on a good night in Madras, and my former observations have shown that, even during the south-west monsoon, there are few nights during which good observations cannot be made. During part of the north-east monsoon the nights seem to be very cloudy, but I know of no observatory where there is not a portion of the year during which few observations can be made. The question as to whether or not the greater clearness of the unclouded atmosphere outweighs other disadvantages cannot be fully discussed till the meteorological observations have been completed, but I may point out at present that a

very important factor in the discussion is the kind of work which the observatory is to undertake. If the work is, as heretofore, to continue exclusively on the lines of the older astronomy I doubt if the gain would be worth the cost, but if an attempt is to be made to enter upon the newer paths of research which have been taken up elsewhere I feel confident that the gain would be very great. Two subjects, for instance, which could be taken up with great advantage would be spectroscopic examination of the stars for motion along the line of sight and physical observations of the planets. In both of these researches the remarkable steadiness and transparency of the air at Kodaikānal would be an enormous advantage, and I believe that more good work could be done on a dozen clear nights there than on fifty clear nights at Madras. Solar observations could be carried on with at least equal success and with much greater comfort to the observer. The sunshine-recorder slips from February 19th to June 30th show that out of these 166 days the sun could have been photographed on 162 days—a very high record. In Madras photographs could probably have been got on 164 days, but on several of these the photographs would certainly have been poor. If the Kodaikānal observations for the rest of the year show anything like an equally good record, there should be no difficulty in determining the future location of the photoheliograph.

In coming to a final conclusion on the locality of the observatory it seems to me that it would be a mistake to leave out of the discussion the original proposal to make the Hill Observatory a branch of the Madras Observatory for special work. If this were done, the transit circle would remain in position in the Madras Meridian which is, theoretically at least, the meridian from which all Indian longitudes are measured. Within the last few weeks my work on the meridian circle observations has shown that certain questions will arise in the preparation of the final Madras star catalogue which can be satisfactorily decided only by further observations with the same instrument in the same position. So far as can be judged at present, these observations will have to be extended over several years, and they cannot be begun with advantage till the work on the catalogue is further advanced. It would evidently be a great mistake to remove the transit circle till all questions arising out of former observations with it are finally settled. Another advantage which would arise from the retention of the Madras Observatory would be that most of the Native assistants engaged in computations, time observations, &c., could remain in Madras—a plan which would save expense and increase efficiency; for few natives can stand hill climates for long, especially in the cold weather. Nor does it seem likely that the total expense of the observatory would be increased by accepting this proposal if the present intention of having two European Astronomers is carried into effect. There would be a considerable saving in initial cost of buildings while the difference between the hill pay and the Madras pay of the assistants would more than cover the extra establishment required.

(Signed) C. MICHIE SMITH,  
*Offg. Government Astronomer.*

5th August 1892.

NOTE.—The photographic prints accompanying this do not show nearly all the stars shown in the negatives, but they give some indication of the sharpness of the photographs.

(Intld.) C. M. S.

ORDER—dated 16th September 1892, No. 648, Public.

The Government of India will be addressed.

(True Extract.)

J. F. PRICE,  
*Chief Secretary.*

To the Government Astronomer.

Exd. J. Moses.

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G.O., 16th Sept. 1892, No. 648.

SEPTEMBER.

Astronomical Observatory.

Directing that the report by the Officiating Government Astronomer on the relative merits of Madras, Kodaikānal and Kōtagiri as sites for an — be forwarded to the Government of India.

16TH SEPTEMBER 1892, No. 649, PUBLIC.

PUBLIC DEPARTMENT.

LETTER—from

THE CHIEF SECRETARY TO THE GOVERNMENT OF  
FORT ST. GEORGE,

To

THE SECRETARY TO THE GOVERNMENT OF INDIA,  
REVENUE AND AGRICULTURAL DEPARTMENT.

SIR,

With reference to my letter, dated 30th December last, No. 1051, and your telegram of the 7th January regarding comparative solar and other observations at Madras, Kodaikānal and Kōtagiri, I am directed to forward a full report on the subject by the Officiating Government Astronomer.

2. Copies of the papers to which Mr. Michie Smith refers in his covering letter are annexed.

I have the honour to be,

Sir,

Your most obedient servant,

OOTACAMUND,  
16th September 1892.

J. F. PRICE,  
Chief Secretary.

Exd. J. Moses.

1892.  
PUBLIC DEPARTMENT.

From the Government of  
Fort St. George.

Issued

Recd.

Encl.

Letter, 16th Sept. 1892, No. 649.

SEPTEMBER.

**Astronomical Observatory.**

Forwarding a report by the Officiating Government Astronomer on the relative merits of Madras, Kodaikānal and Kōtagiri as sites for an

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