THE APPROACHING TOTAL ECLIPSE OF THE SUN.[1]

IV.

THE programme of work to be attempted in the Indian eclipse of next year, referred to in the last article, carries me back very vividly to the eclipse of 1871, also observed in India. The shadow path of the eclipse of that year also cut the west coast of India, but at a much more southerly point than Viziadurg. The coast station was then Baikal, and from this point the shadow swept over the land in a south-east direction, as shown in the accompanying map (Fig. 13).

The retrospect is very encouraging, for one is reminded of the enormous advance in our knowledge of the sun since that time; and more than this, we have now the supreme advantage that eye observations have been almost entirely superseded by permanent photographic records. The accompanying view (Fig. 14) of my observatory at Baikal in 1871 will show that eye observations of the spectra alone were attempted.

It must also be remembered that none of the laboratory experiments, referred to in the last article, had then been made.

Now it was to try to understand such hard solar facts as those referred to in the last article, facts since observed carefully in all their detail, month after month and year after year, that much of my early experimental work was undertaken.

[1] Continued from page 321.

By 1872 the influence of quantity or density had been made out; when experiments were made at one temperature the spectrum got simpler as the quantity was reduced, so that the spectrum was finally reduced to its longest line.[1]

I am glad to see that Sir William Huggins, who appears to be ignorant of my quarter-of-a-century-old work, has quite recently arrived independently at the same conclusions.

Next came the influence of temperature. This was a much more difficult problem to tackle, for the reason that enormous changes in the spectrum of each chemical substance were brought about by changing the temperature conditions; but finally the association of certain lines with certain temperatures was accepted by everybody, though as to the *why* there were and are contending schools of opinion.

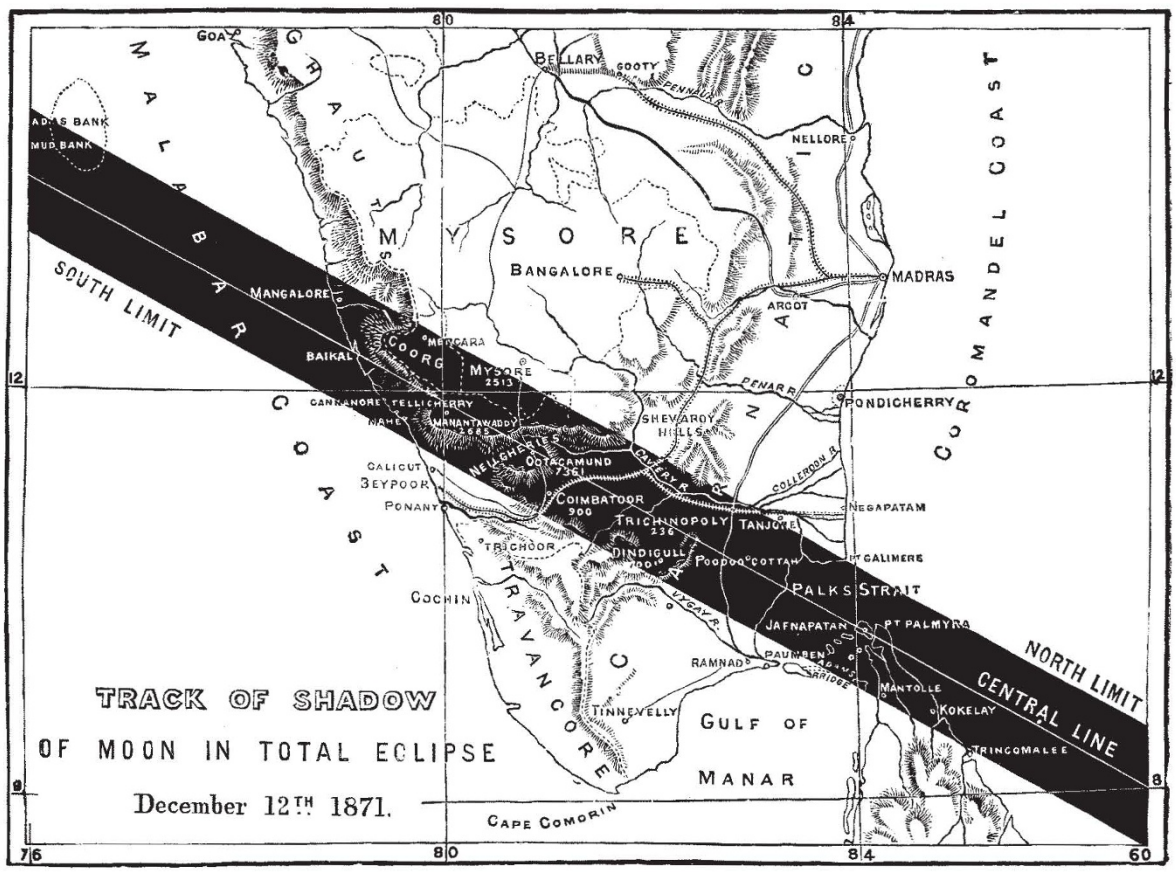

FIG. 13.

In connection with certain stellar problems awaiting solution, I have recently been compelled to return to this question, and I have used a more powerful current and larger jar-surface than that I formerly employed; and, further, the recent work carries the results into the photographic region. The result is important, since the old results have been confirmed and extended. To deal with the case of iron, seven additional lines in the spectrum have been found to have their brightness enhanced at the highest temperature.

These, as well as the two previously observed, are shown in the following table, which also indicates the behaviour

[1] *Phil. Trans.*, 1873, pp. 253 and 639.

of the lines under different conditions, as observed by Kayser and Runge (K. and R.) and myself (L.) in the arc, and by Thalèn (T.) and myself in sparks :—

Lines of Iron which are enhanced in Spark.

Wave-length.	Intensity in flame.	Intensity in arc (K. and R). Max. = 10.	Length in arc (L). Max. = 10.	Intensity in spark (T). Max. = 10.	Intensity in hot spark (L). Max. = 10.
4233·3	—	1	—	—	4
4508·5	—	1	—	—	4
4515·5	—	1	—	—	4
4520·4	—	1	—	—	2
4522·8	—	1	3	—	4
4549·6	—	4	5	—	6
4584·0	—	2	4	—	7
4924·1	—	1	3	6	6
5018·6	—	4	—	—	6

hottest stars are shown in the diagram on p. 368, and for the sake of comparison, the behaviour of a group of three lines, which are among the most marked at lower temperatures, is also indicated. In addition, the diagram shows the inversion in intensities of the spark and arc lines in the spectrum of a relatively cool star—such as α Orionis (Fig. 16).

The facts illustrated by the diagram indicate that the enhanced lines may be absent from the spectrum of a star, either on account of too low or too high a temperature. In the case of low temperature, however, iron is represented among the lines in the spectrum, but at the highest temperature all visible indications of its presence seem to have vanished.

This result affords a valuable confirmation of my view, that the arc spectrum of the metallic elements is produced by molecules of different complexities, and it also indicates that the temperature of the hottest stars is sufficient to produce simplifications beyond those which have so far been produced in our laboratories.

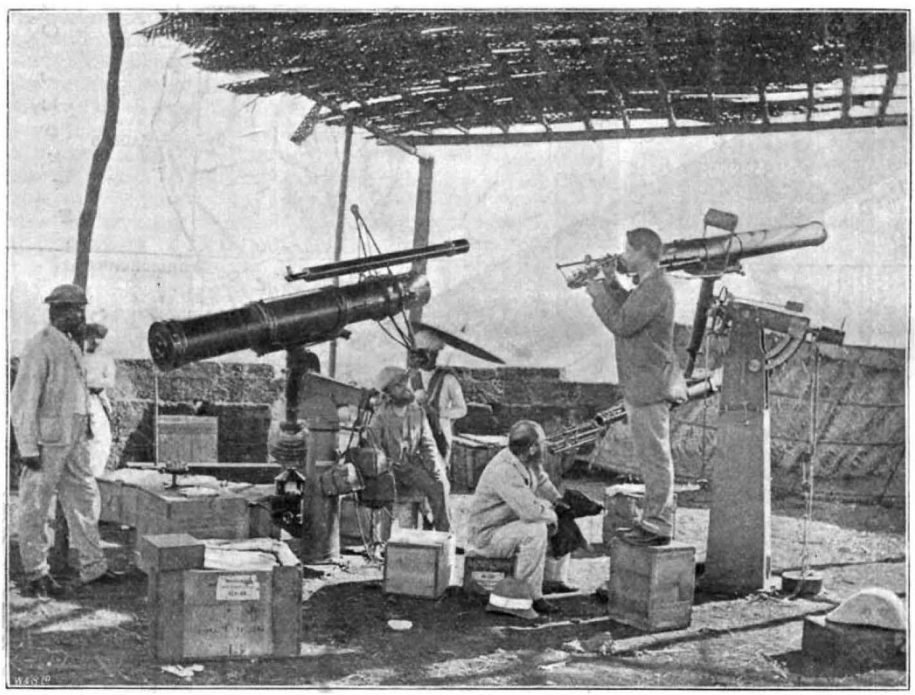

FIG. 14.—The spectroscope observatory at Baikal in 1871.

Combining this with former results, we seem justified in concluding that, in a space heated to the temperature of the hottest spark, and shielded from a lower temperature, these lines would constitute the spectrum of iron.

To enforce what I have previously written concerning the value of the solar work in relation to the study of the physics and chemistry of the stars, it is worth while to consider for a moment the behaviour of these lines of iron which are found to brighten as the temperature is increased and which play such an important part in the chromosphere spectrum, in stellar spectra (Fig. 15).

Defining the hottest stars as those in which the ultra-violet spectrum is most extended, it is known that absorption is indicated by few lines only. In these stars iron is practically represented by the enhanced lines alone; those which build up, for the most part, the arc spectrum are almost or entirely absent.

The intensities of the enhanced lines in some of the

We may say broadly that the stars Bellatrix, α Cygni, and Arcturus represent three very different stages of star life from the point of view we are considering.

In Bellatrix the metallic lines, both enhanced and cool, are almost entirely absent. In α Cygni we get the enhanced metallic lines alone; in Arcturus they are generally absent; this statement is true for the sun, the spectrum of which is almost identical with that of Arcturus.

Now it has been found from the study of the photographs of the chromosphere obtained in 1893 and 1896, that among the bright lines recorded the enhanced lines hold a most important place. I have already given copies of two of the photographs obtained in 1893. I can now add untouched copies of an enlargement of one of the photographs obtained in 1896, which has quite recently been published by the Royal Society. The photograph was obtained by Mr. Shackleton, attached

to Sir George Baden Powell's expedition to Novaya Zemlya (Figs. 17, 18).

So far as the work has gone, the comparison of the enhanced lines with the spectrum of the chromosphere reveals several facts of importance. In the case of iron, I have already pointed out (*Roy. Soc. Proc.*, vol. lx. p. 475) that the enhanced lines were all present in the chromosphere during the eclipse of 1896, and most of them in that of 1893, their intensities being greater than those of the corresponding Fraunhofer lines. Many of the characteristic arc lines of iron also appear in the chromosphere, but the presence of the enhanced lines with such great intensities indicates that at least in some parts of the chromosphere the temperature of the iron vapour is considerably higher than that of the iron vapour which is most effective in producing the Fraunhofer lines. A

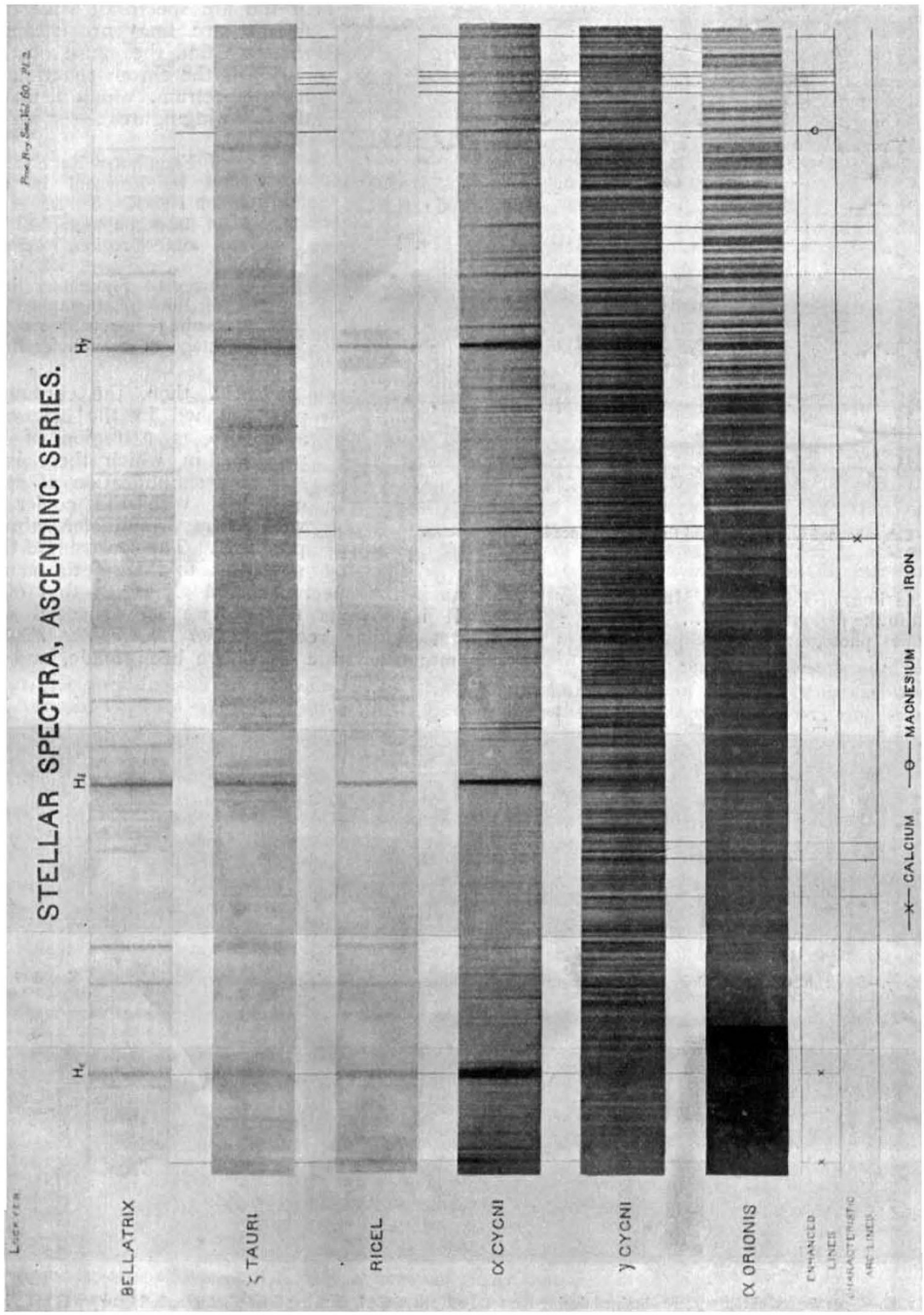

FIG. 15.—Map showing cool and enhanced lines of iron, and their behaviour in stellar spectra.

similar result is obtained when other substances are considered. The special importance of the enhanced lines in the chromosphere is shown by the following figures relating to substances which have been most completely studied.

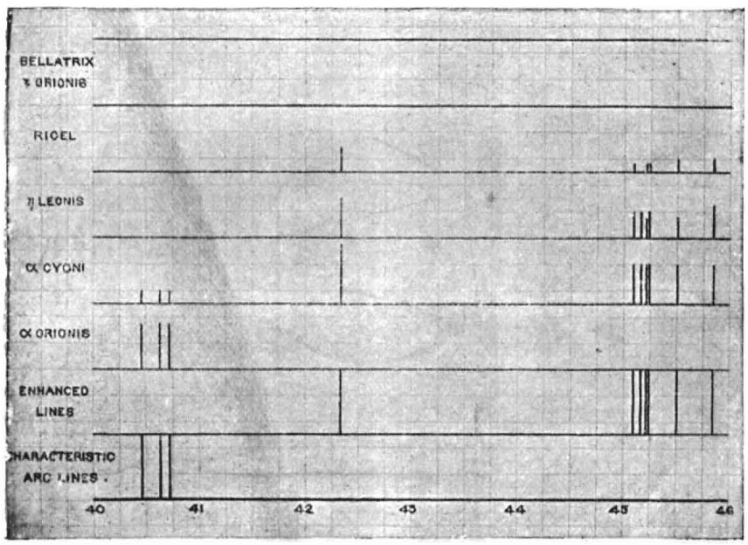

FIG. 16.—The enhanced lines of iron and their appearance in stellar spectra.

No. of enhanced lines of Fe, Mg, Ca, Mn, Ni, Ti, so far tabulated in the region F to K	63
No. of these lines photographed in eclipse of 1893 in the same region	28
Percentage of enhanced lines of Fe, &c., in eclipse of 1893	44
No. of enhanced lines photographed in eclipse of 1896	41
Percentage of enhanced lines of Fe, &c., in eclipse of 1896	65

These numbers show that the chromospheric spectrum is largely composed of enhanced metallic lines in addition to the lines of hydrogen and helium.

In the Fraunhofer spectrum enhanced lines may be regarded as wanting, for in the case of iron and magnesium, at least, they only appear with the feeble intensities which they have in the arc spectrum, while the characteristic arc lines are strong. Here, then, we find the cause of the dissimilarity of the chromospheric and Fraunhofer spectrum, which is indicated by the following figures :—

No. of Fraunhofer lines tabulated by Rowland in the region F to K	5694
No. of lines photographed in the same region, eclipse 1893	164
Percentage of Fraunhofer lines	3
No. of lines photographed in the same region, eclipse 1896	464
Percentage of Fraunhofer lines	8

Clearly, then, the chromosphere as photographed in the eclipses of 1893 and 1896, is a region of high temperature, in which there is a corresponding simplification of spectrum as compared with the cooler region in which the Fraunhofer absorption is produced. The spectrum of the chromosphere is to that of the sun generally as is the spectrum of *a* Cygni to that of Arcturus. It is obvious that if we can succeed in 1898 to get similar records *with double the dispersion*, an immense stride will have been made, and hence the programme for the coming eclipse to which I have drawn attention.

NORMAN LOCKYER.

(*To be continued.*)

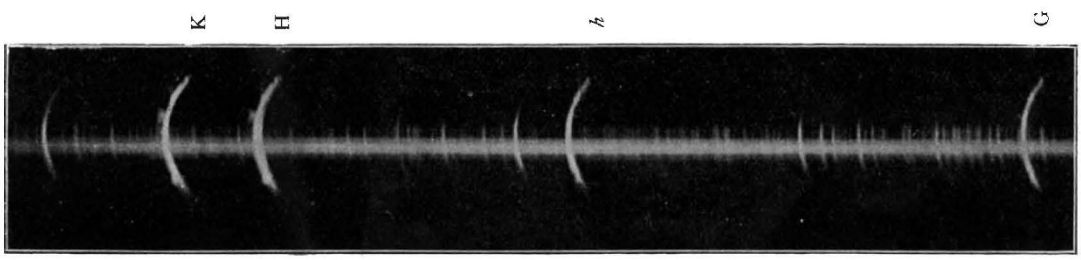

FIG. 17.—Spectrum of chromosphere obtained during the total eclipse of 1896, showing lines photographed between K and G.

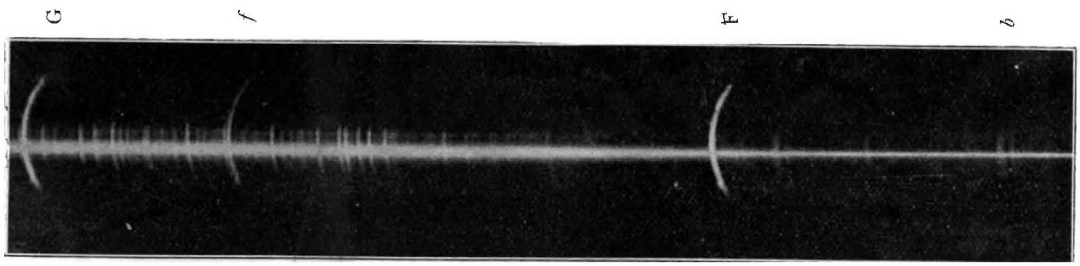

FIG. 18.—Spectrum of chromosphere obtained during the total eclipse of 1896, showing lines photographed between G and *b*.