terms of the u's and v's. From this equation is deduced the addition-theorem for the functions.

In §§ 25 and 26 is given the discussion of a particular case of the above, viz., that in which the functions are of the order 2, the fifteen functions being the quotients of all but one of the double theta-functions by that one. The addition-theorem in these functions has already formed the subject of a paper by Cayley in Crelle, t. lxxxviii (1878), p. 74.

IV. "Note on the Recent and Coming Total Solar Eclipses." By J. NORMAN LOCKYER, F.R.S. Received November 17, 1882.

The following note has been drawn up in anticipation of the detailed accounts of the work done by me in Egypt on the eclipsed sun of 1882, May 17, which I am preparing to lay before the Royal Society, because as the next total eclipse occurs next May, there is no time to be lost if any attempt is to be made to secure observations, and I am of opinion that such observations are most important.

I have prefaced the statement of the work done by a reference to the considerations which led me to undertake it, and I have added a scheme of observations which, in the present state of our knowledge is, I think, most likely to produce results of value.

1. In order to understand the recent change of front in solar research which has followed the introduction of the view of the possible dissociation of elementary bodies at solar temperatures, and suggested the later laboratory, and especially the later eclipse observations with which we are now chiefly concerned, we must first consider what facts we may expect on the two hypotheses. In this way we can see which hypothesis fits the facts best, and whether there are any inquiries possible during eclipses of a nature to throw light on the question.

2. On the old hypothesis the construction of the solar atmosphere was imaged as follows:—

(1.) We have terrestrial elements in the sun's atmosphere.

(2.) They thin out in the order of vapour density, all being represented in the lower strata, since the solar atmosphere at the lower levels is incompetent to dissociate them.

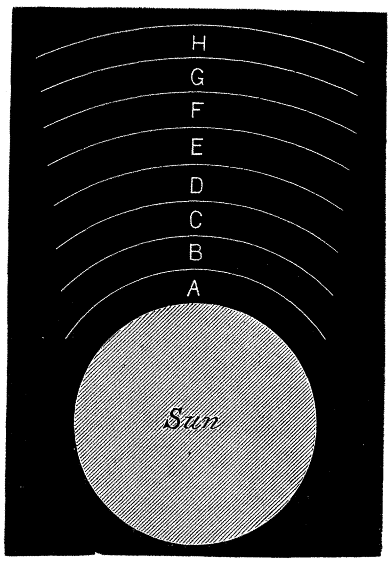
(3.) In the lower strata we have especially those of higher atomic weight, all together forming a so-called "reversing layer" by which chiefly the Fraunhofer spectrum is produced.

3. The new hypothesis necessitates a radical change in the above views. According to it the three main statements made in paragraph 2 require to be changed as follows:—

(1.) If the terrestrial elements exist at all in the sun's atmosphere they are in process of ultimate formation in the cooler parts of it.

(2.) The sun's atmosphere is not composed of strata which thin out, all substances being represented at the bottom; but of true strata like the skins of an onion, each different in composition from the one either above or below. Thus, taking the sun in a state of quiescence and dealing only with a *section*, we shall have (as shown in fig. 1) C say containing neither D nor B, and B containing neither A nor C.

FIG. 1.

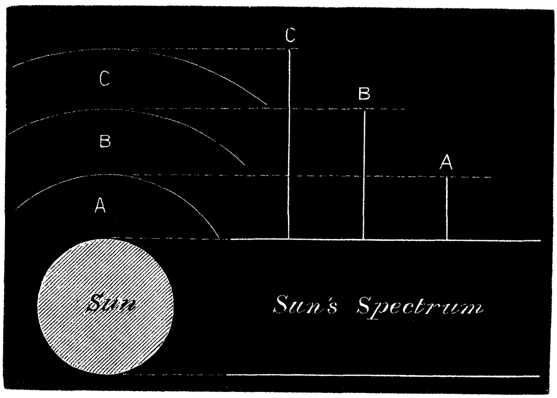


(3.) In the lower strata we have not elementary substances of high atomic weight, *but those constituents of all the elementary bodies which can resist the greater heat of these regions.*

4. The conditions under which we observe the phenomena of the sun's atmosphere have not, as a rule, been sufficiently borne in mind, and it is quite possible that the notion of the strata thinning out has, to a certain extent, been based more upon the actual phenomena than upon reasoning upon the phenomena.

5. Take three concentric envelopes of the sun's atmosphere, A, B, C (fig. 2), so that C extends to the base of A, and B also to the base of A, that is, in both cases to the photosphere. Then, whether we deal with the sphere or with a section of it, the lengths of the lines in the spectrum of the strata C, B, A will give the heights to which the strata extend from the sun, and show where B and A respectively thin out. As the material is by hypothesis continuous down to the

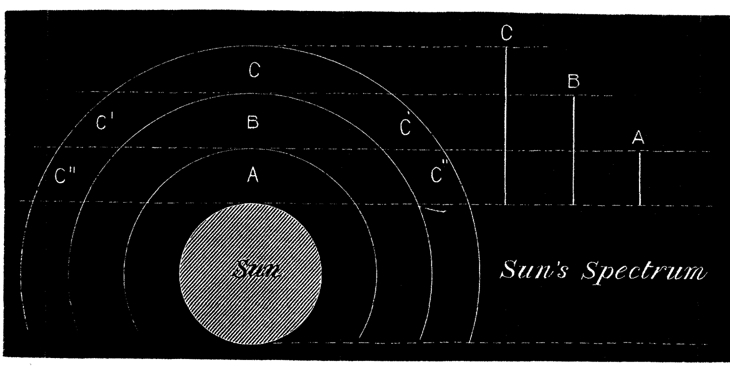
FIG. 2.



sun, the lines will be continuous down to the spectrum of the sun seen below as shown.

6. Now take three concentric envelopes, A, B, C (fig. 3), so that only A rests on the photosphere, B rests on A, and C on B. The

FIG. 3.



phenomena will *in the main* be the same as in the former case, *i.e.*, the line C will still appear to rest on the spectrum of the photosphere, for it will be fed, so to speak, from C′ and C″, though absent along the line CBA at B and A. So also with B.

7. Thus much having been premised with regard to the observations as conditioned by the fact that we are observing a sphere, we can now proceed to note *how the two hypotheses deal with the facts.*

Old Hypothesis.	*New Hypothesis.*
1. The spectrum of each element as seen in our laboratories should be exactly represented in the solar spectrum.	The spectra should *not* resemble each other.

FACT.—There is a very wide difference between the spectra.

2. Motion in the iron vapour, *e.g.*, in a spot or a prominence, should be indicated by the contortion of all the iron lines equally.

Motion should be unequally indicated, because the lines are due to divers constituents which exist in different strata according as they can resist the higher temperatures of the interior regions.

FACT.—The indications show both rest and motion.

3. The spectrum of iron in a prominence should be the same as the spectrum of iron in a sun-spot.

The spectrum of iron in a prominence should be vastly different from the spectrum of iron in a sun-spot, because a spot is cooler than a prominence.

FACT.—The spectra are as dissimilar as those of any two elements.

4. The spectra of spots and prominences should not vary with the sun-spot period.

The spectra should vary, because the sun is hotter at maximum.

FACT.—They do vary.

5. The spectrum of the base of the solar atmosphere should most resemble the ordinary Fraunhofer spectrum.

The spectrum of the base should least resemble the Fraunhofer spectrum, because at the base we only get those molecules which can resist the highest temperatures.

FACT.—As a rule the lines seen at the base are either faint Fraunhofer lines, or are entirely absent from the ordinary spectrum of the sun.

6. *Quâ* the same element the lines widest in spots should always be the same.

Quâ the same element the lines widest in spots should vary enormously, because the absorbing material is likely to originate in and to be carried to different depths.

FACT.—There is immense variation.

7. The spectra of prominences should consist of lines familiar to us in our laboratories, because solar and terrestrial elements are the same.

The spectra of prominences should be in most cases unfamiliar, because prominences represent outpourings from a body hot enough to prevent the coming together of the atoms of which our chemical elements are composed.

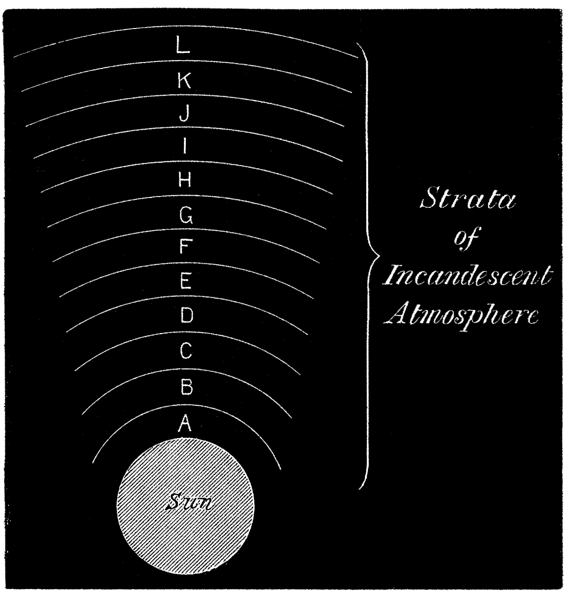
FACT.—When we leave H, Mg, Ca, and Na, most of the lines are either of unknown origin or are feeble lines in the spectra of known elements.

8. From the above sketch, hasty though it be, it is I think easy to gather that the new view includes the facts much better than the old one, and in truth demands phenomena, and simply and sufficiently explains them, which were stumbling blocks and paradoxes on the old one.

This being so, then, it is permissible to consider it further.

9. Let us first suppose, to take the simplest case, that the sun when cold will be a solid mass of one pure element, *i.e.*, that the evolution brought about by reduction of temperatures shall be along one line only. Let us take iron as the final product. Then the sun's atmosphere on the new theory *quâ* this one element may be represented as follows :—

FIG. 4.



Assume strata A—L. Then—

(1.) The Fraunhofer spectrum will integrate for us the absorption of all strata from A to L.

(2.) The darkest lines of the Fraunhofer spectrum will be those absorbed nearest the outside of the atmosphere.

(3.) We shall rarely, if ever, see the darkest lines affected in spots and prominences.

(4.) The germs of iron are distributed among the various strata according to their heat-resisting properties, the most complex at L, the least complex at A.

(5.) Whatever process of evolution be imagined, as the temperature runs down from A to L, whether A, 2A, 4A; or A+B, 2[2(A+B)], or X+Y+Z, the formed material or final product is the work of the successive associations rendered possible by the gradually lowering temperature of the successive strata, and can therefore only exist at L.

10. Now at this point a very important consideration comes in. It was stated (in 6) while discussing the conditions of observation, that whether we were dealing with strata of substances extending down to the sun or limited to certain heights, the spectral lines would always appear to rest on the solar spectrum, and that the phenomena would *in the main* be the same.

11. This, however, is true in the main only, there must be a difference, and this supplies us with a test between the rival hypotheses of the greatest stringency. The stratum B, being further removed from the photosphere than the stratum A, will be cooler, its lines therefore will be dimmer, and the lines of C will be dimmer than the lines of B, and so on. So if we could really observe the strata, *the longer a line is, i.e.*, the greater the height at which the stratum which gives rise to it lies, *the dimmer the line will be.*

12. Now our best chance of making such an observation as this is during a total eclipse. We do not see the lines ordinarily in consequence of the illumination of our air. As during an eclipse before totality the intensity of this illumination is rapidly diminishing, the lines first visible should be short and bright, and should remain short while the new lines which become visible as the darkness increases should be of gradually increasing length, so that the spectrum should become richer in the way indicated in fig. 5.

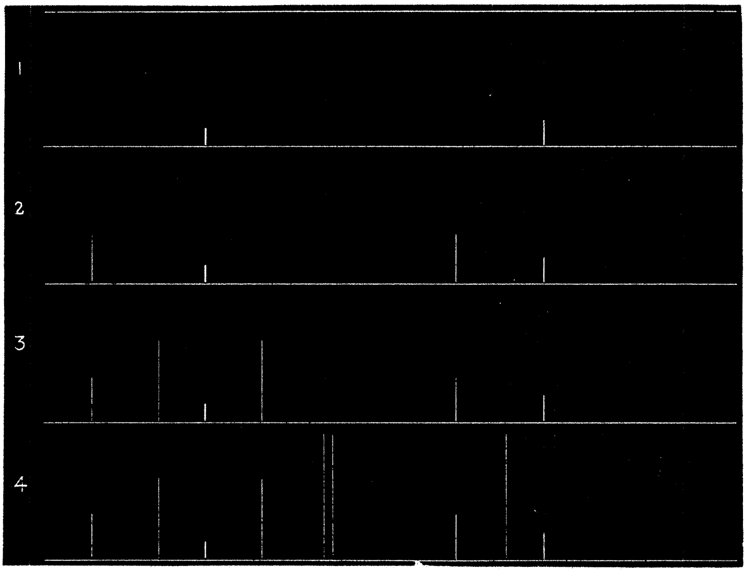
13. Further, the lines in 1 should be lines seen in prominences, and not in spots, and relatively brighter in the spark than in the arc, while the longer lines added in 2 and 3 should be lines affected in spots, and *not* in prominences.

14. All these phenomena were predicted for the Egyptian eclipse a year before its occurrence, and were verified to the letter for the lines of iron over a purposely limited region.

15. The actual observations of the iron lines made at Sohag are shown in the accompanying map, and these actual observations are contrasted with the lines thickened in spots, the lines observed in the prominences by Tacchini, those intensified on passing from the arc to the spark. The Fraunhofer lines are also given according to Ångström and Vogel, and the iron spectrum of the arc and spark according to Ångström and Thalén. The observations during the eclipse were made 7 minutes, 3 minutes, and 2 minutes before

totality as the air was gradually darkened, by which darkening successive veils, as it were, were lifted so that the more delicate phenomena could be successively seen.

FIG. 5.

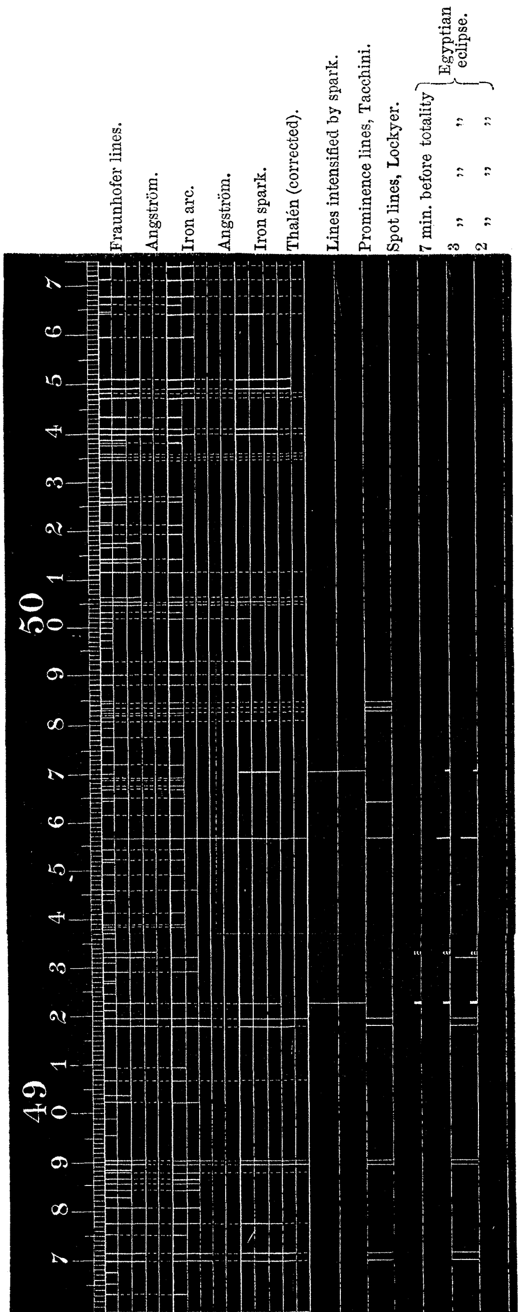


16. We begin with one short and brilliant line constantly seen in prominences, never seen in spots. Next, another line appears, also short and brilliant, constantly seen in prominences, and now, for the first time, a longer and thinner line appears, occasionally noted as widened in spots, while last of all we get very long, very delicate relatively, two lines constantly seen widened in spots, and another line not seen in the spark and never yet recorded as widened in the spots.

17. The procession from the hot to the colder is apparent, and the simplicity of the spectrum as opposed to the Fraunhofer spectrum even yet, is eloquent of the gradual approximation which would be still possible if the darkness could be greater and our attack more complete.

18. It will be noted over what an excessively small range the observations extend. We want similar observations over a wider range during future eclipses, and to do this work properly many observers armed with similar instruments must divide the whole or part of the solar spectrum amongst them, preferably that part between F and D, which has been most closely watched in prominences and spots by Tacchini and myself.

FIG. 6.



The Ba line at λ 4933·4 is a line seen thirty times by Young at the maximum spot period, and not recorded by Tacchini at the minimum. The lower longer iron line not seen till five minutes afterwards is a Te line λ 4932·5

19. I next pass to another point on which an observation was made in Egypt.

20. In fig. 4 we considered the sun's atmosphere, taking the simplest case, that of one element; when the sun cools it will be a very complex mass chemically. If the laws of evolution hold we need not expect that this will largely increase the complexity of the hottest layers A and B, but higher up, say at H—L, the complexity of chemical forms produced by evolution along the fittest lines will be very considerable.

21. These strata H—L may be taken to represent the corona. Its spectrum, therefore, should not be a continuous one, but should consist of an integration of all the radiations and absorptions of these excessively complex layers.

22. The spectrum of the corona as I saw it in Egypt exactly answered to this description. Instead of the gradual smooth toning seen, say in the spectrum of the limelight, there were maxima and minima producing an appearance of ribbed structure, the lines of hydrogen and 1474 being, of course, over all. This observation, however, requires confirmation, for the look I had at the corona spectrum was instantaneous only.

23. This observation should certainly be repeated during future eclipses with the proper instrumental conditions, *i.e.*, small, intensely bright image on narrow slit and spectroscope of small dispersion. I believe that, under these conditions, photographs could readily be obtained with the new plates.

24. Now an eclipse occurs next May at a critical time of the sun's activity, for, so far as we can see, we shall be nearly at sun-spot maximum, and I hold that it will be a disgrace to our nineteenth century science if efficient steps are not taken by those who are regarded as the leaders of science in this and other civilised countries to secure adequate observations.

25. So far I have only referred to those special observations undertaken this year to discriminate between two rival hypotheses, but both hypotheses may be wrong in many points, so that we must not limit ourselves to such observations, but collect facts over the whole field, as has always been the custom in eclipse expeditions.

26. In my opinion the following scheme shows the observations which, in the present state of our knowledge, it is *most desirable* to secure. The scheme, I am aware, is by no means exhaustive. I give the observations in the order of importance I attach to them, having regard to the present position of solar theory and the conditions of eclipse observations.

(1.) 6-inch equatorial of long focus, perfect clockwork, spectroscope with dispersion of at least five prisms of 60°.

Clamp point of disappearance of sun at base of normal slit, and

record phenomena observed from ten minutes before totality to actual totality.

a. Order in which lines appear.

b. Brightness and length when first visible.

The spectrum from λ 4800 to λ 5900 should be distributed among at least five observers.

Repeat observations after totality on point of reappearance.

(2.) 6-inch photographic lens of four feet focus, perfect clock, same dispersion as above.

Clamp point of disappearance of sun on centre of tangential slit and record phenomena observed from ten minutes before totality to actual totality.

a. Order in which lines appear.

b. Brightness and length when first visible.

Repeat observations after totality on point of reappearance. Same part of spectrum, same distribution as in (1).

(3.) 6-inch photographic lens as in (2).

Photographic phenomena before and after totality on slowly ascending or descending or rotating plate, taking care to expose only narrow strip of plate.

(4.) Ditto. Spectroscope of small dispersion, long slit.

Photograph spectrum of corona during totality on both sides of dark moon.

(5.) Prismatic camera. 6-inch photo. lens as in (2), but with grating.

Use first order spectrum on one side and second order on the other.

Commence two minutes before totality. Continue till two minutes after totality on gradually ascending or descending or rotating plate.

(6.) 6-inch photo. lens as in (2), mounted on alt-azimuth. Fine slit. One prism of 60°. To observe spectrum of corona.

(7.) Photographs of corona of short, medium, and very long exposure to determine form and true solar limit of apparent corona due to the illumination of our air, using for the latter purpose the photographic intensity of the image of the moon.

I am aware that because Solar Physics is a new subject, and one so entirely in the domain of pure science, the above scheme may appear ridiculous to many, for if carried out in its completeness its cost would perhaps amount to the sixtieth part of the sum expended on the Transit of Venus in 1874. I have, however, felt myself bound to put it forward as an ideal scheme and one which, if several civilised Governments do each a little, concerted action may help us in part to realise. I am informed that the French and Italian Governments are already making preparations for observations, and my desire is that we may be represented on an occasion which, having regard to the duty which is incumbent upon us to secure observations for the use of those who come after us, is one of high importance.

FIG. 1.

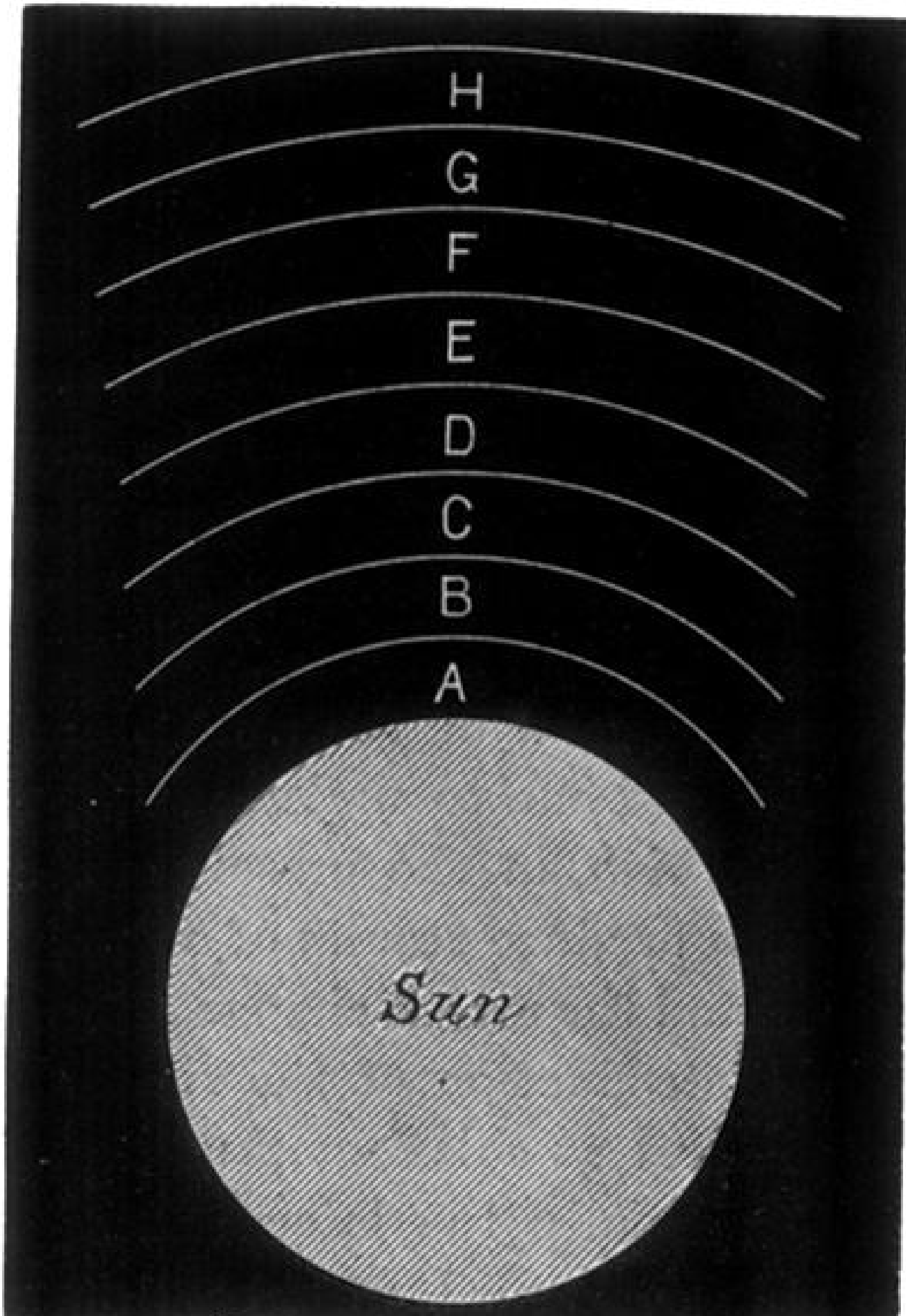


FIG. 2.

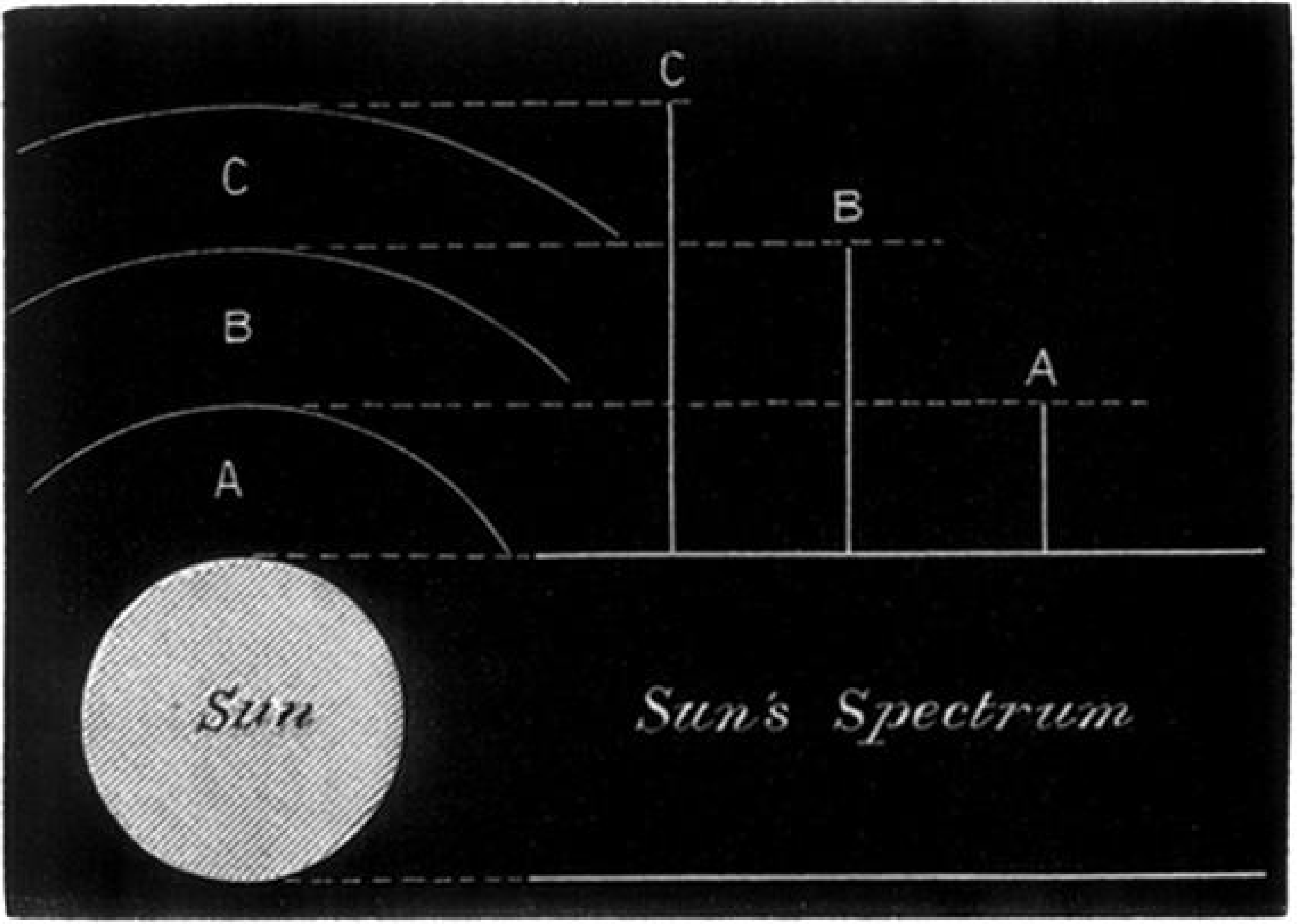


Fig. 3.

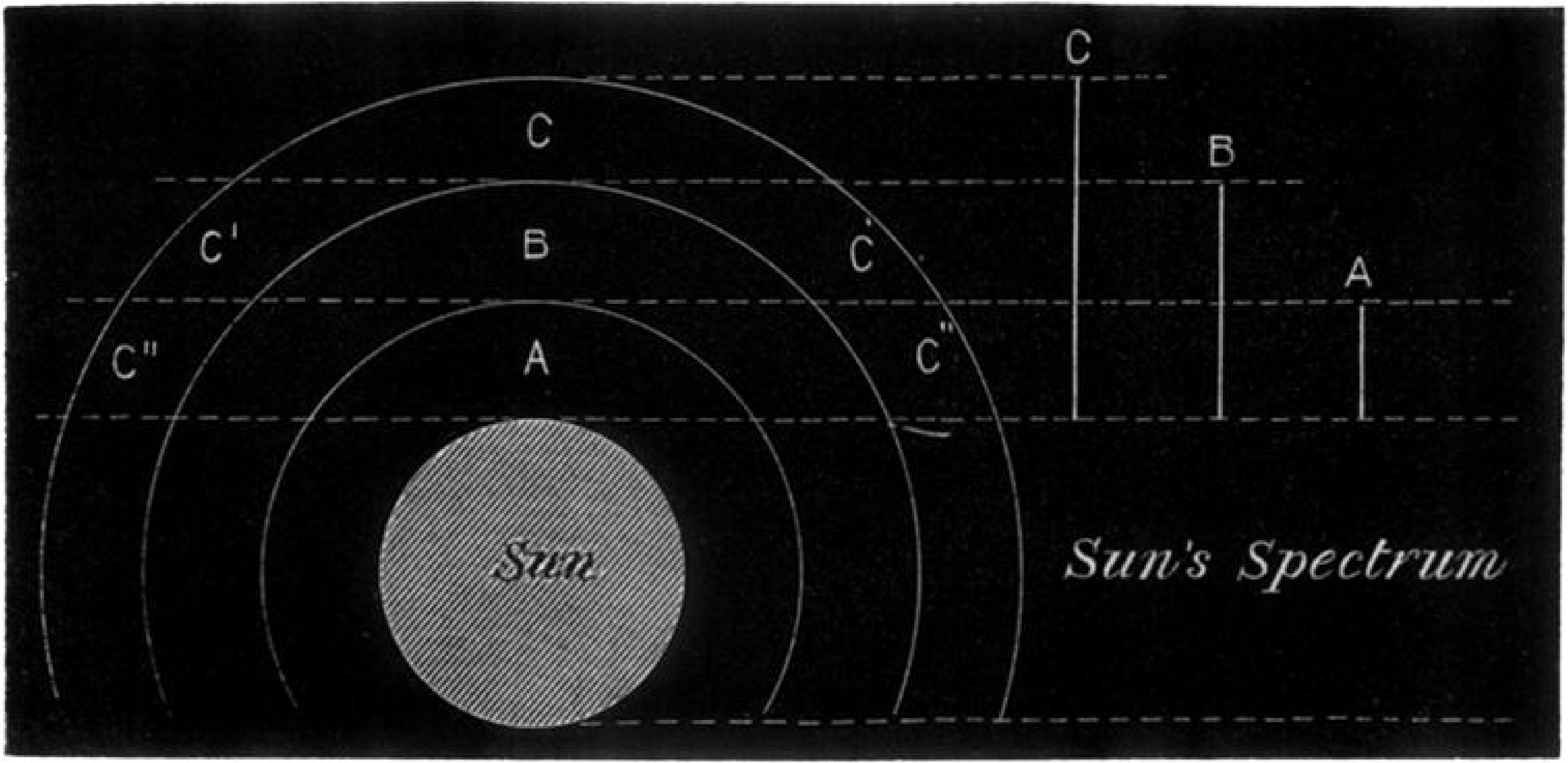


FIG. 4.

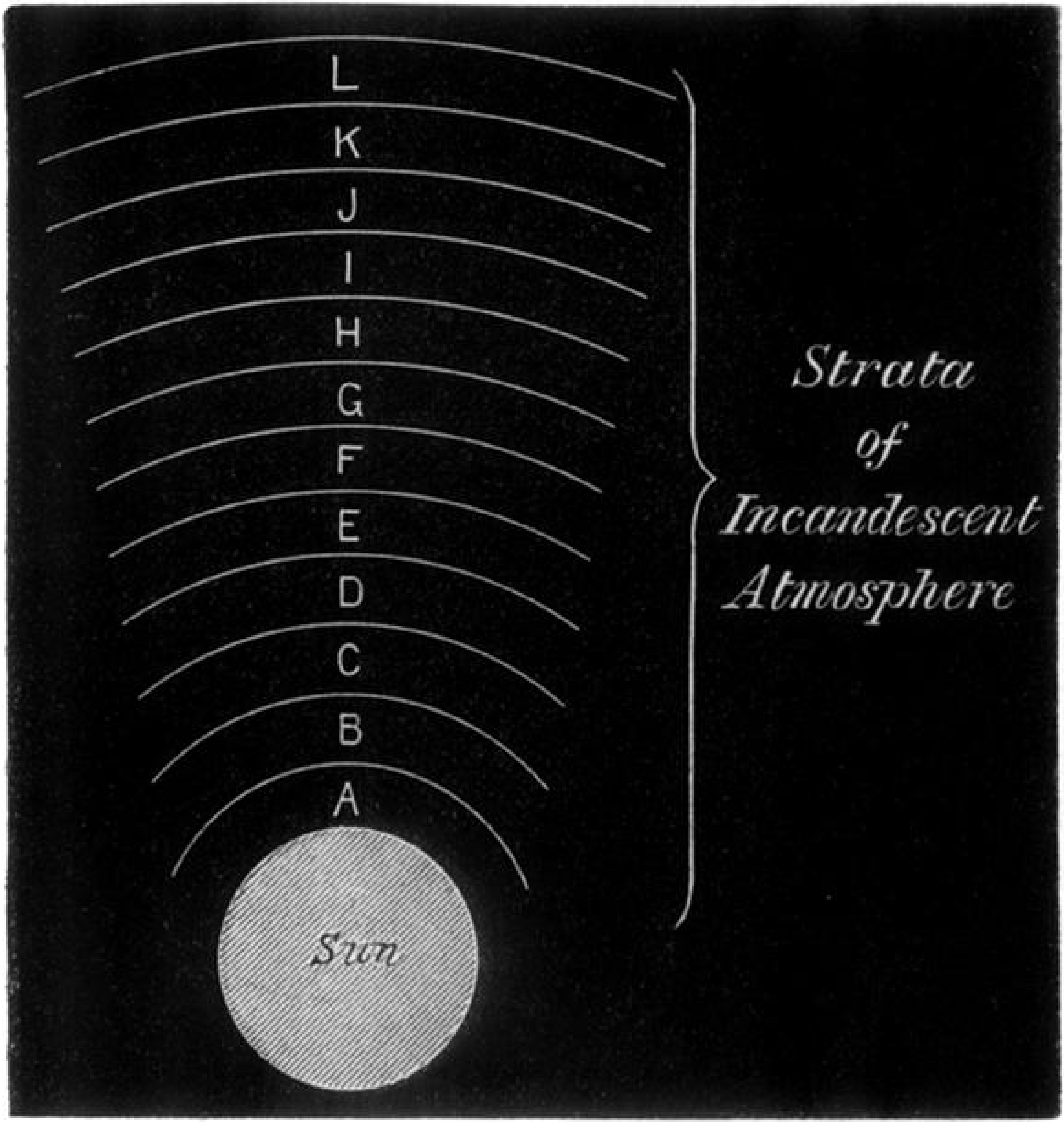


Fig. 5.

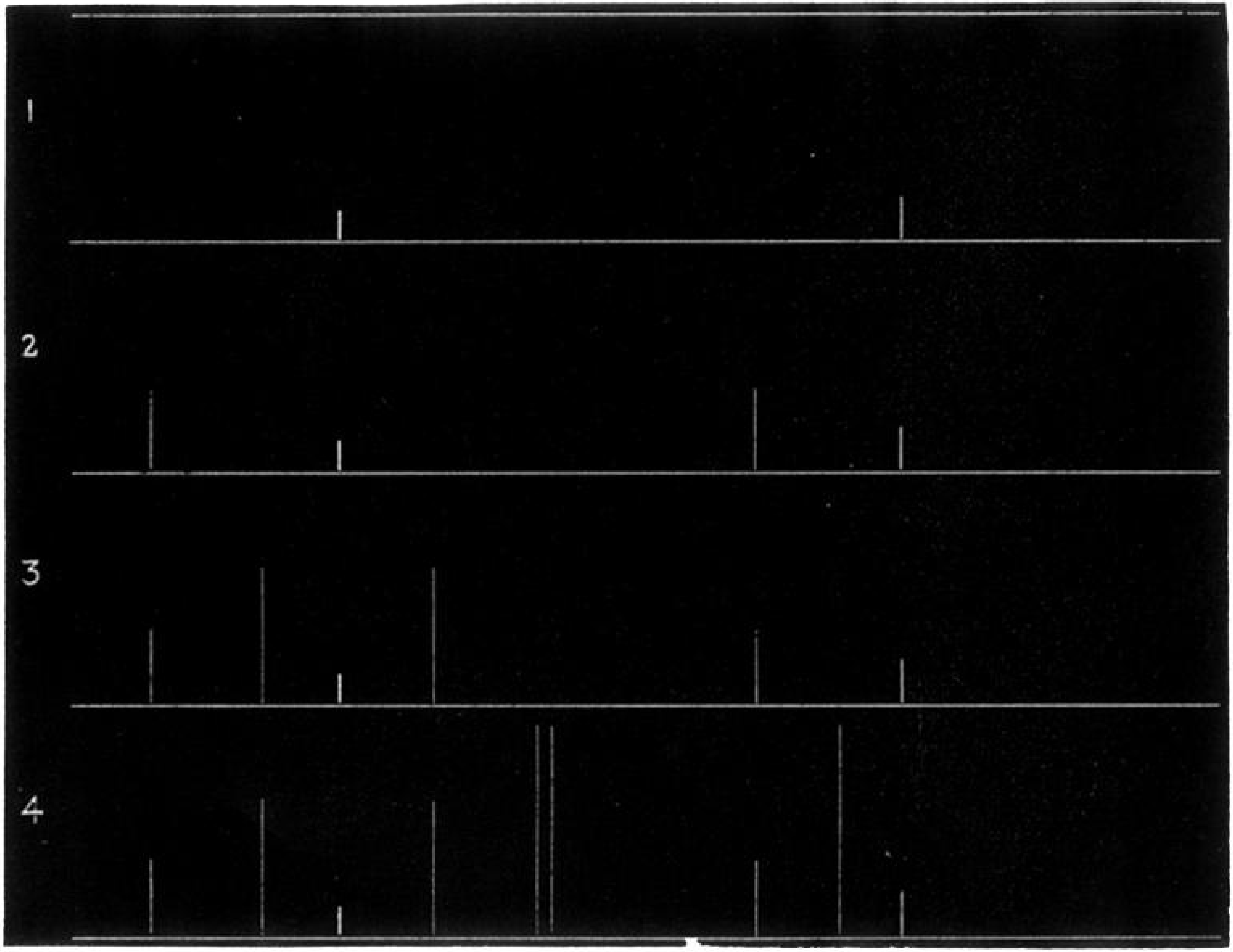
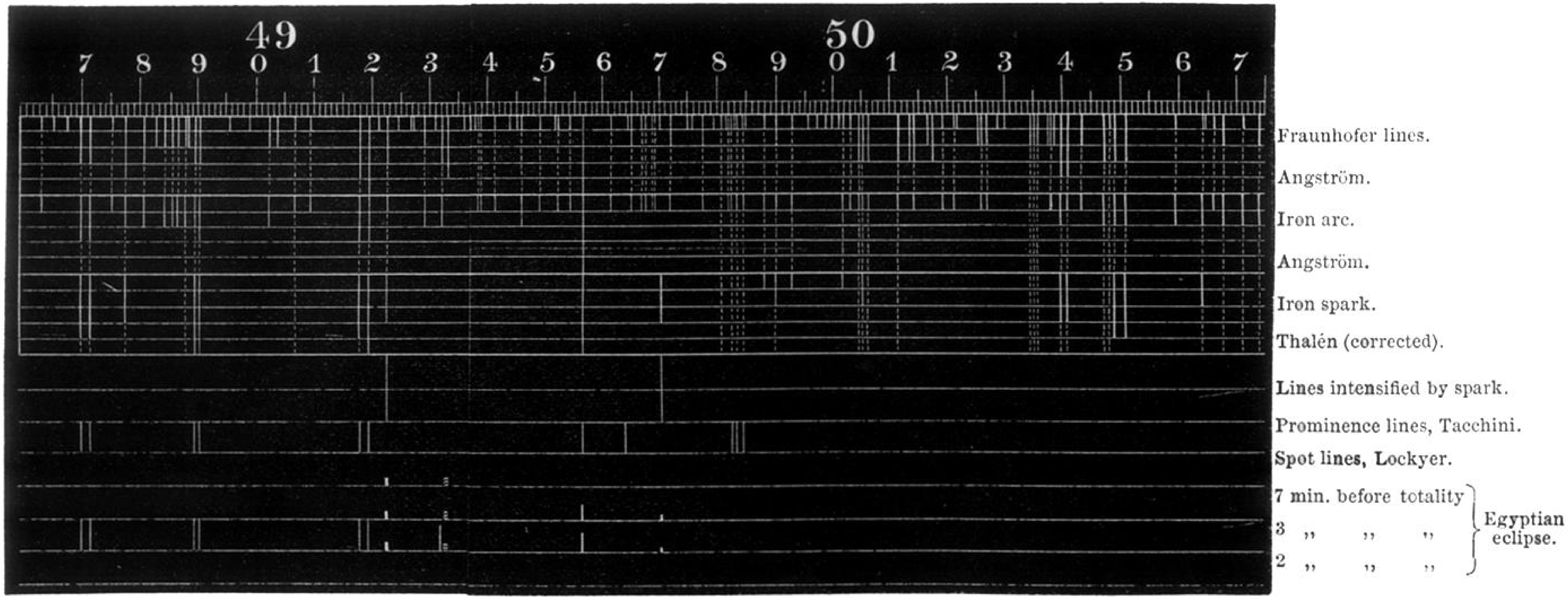


Fig. 6.



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