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BULLETIN No. CVII.

OXYGEN IN THE SUN'S CHROMOSPHERE*

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Abstract.—Photographs taken at the Kodaikanal Observatory show that oxygen is a normal constituent of the sun's chromosphere, and is probably in great abundance. The plate attached is a reproduction from one of the photographs obtained when the slit of the spectrograph was placed tangentially to the image of the sun's limb, and shows the infra-red triplet of oxygen at λλ 7771, 7774 and 7775 as emission lines in the sun's chromosphere. The greatest height reached by oxygen is apparently 3·5″ but this may be an underestimate. The significance of the presence of oxygen in the chromosphere for the theory of support of the chromosphere is discussed.

Oxygen was discovered in the sun by Runge and Paschen [1] who observed the infra-red triplet λλ 7771, 7774 and 7775 as absorption lines in the Fraunhofer spectrum, and it was conclusively proved by the Royal Observatory, Edinburgh [2] that these lines originated in the sun. It is also known[3] that the oxygen doublet λ 8446 is present in the Fraunhofer spectrum. These five lines are all the known lines in the sun's spectrum due to oxygen.

The author has now succeeded in photographing the oxygen triplet as emission lines in the chromosphere. The image of the sun's limb was thrown on the slit plate of the large spectrograph of this observatory with the slit tangential to the sun's limb which was as near as possible to the slit without admitting photospheric light into the spectrograph. The spectrum was photographed in the first order of a plane Rowland grating on Ilford infra-red sensitive plates.

The plate accompanying this bulletin illustrates the oxygen triplet in one of the photographs obtained of the chromospheric spectrum. Fig. B shows the oxygen triplet as bright lines, as compared with the ordinary solar spectrum in fig. A, where the oxygen lines are seen as absorption lines as is well known. The background of fig. B is due to the sky spectrum which consists of scattered light from the sun, and hence shows the usual continuous spectrum and absorption lines of the solar spectrum except where emission lines due to the sun's chromosphere are sufficiently strong to show brighter than the scattered sky spectrum. When the spectrograph slit is not close to the sun's limb, the oxygen triplet is seen in the sky spectrum as absorption lines, but when the sun's chromosphere impinges on the slit, the lines are reversed into bright lines as may be seen in fig B. In case these reversals may be difficult to see in the reproduction, microphotometric records of the photographs

*Since this bulletin was sent to press the author became aware of Curtis & Burns' paper in Publications of the Allegheny Observatory, VI, 95, 1925, on the infra-red flash and coronal spectra, eclipse of January 24th, 1925. Regarding the oxygen lines they say, "The oxygen triplet 7772, 7774 and 7775A appears as one broad line on our plates. It is very strong at low levels and weaker at higher levels, though faintly present in a high prominence." The discovery of the presence of oxygen in the chromosphere must therefore be credited to Curtis and Burns. So far as I am aware, the oxygen triplet in the flash spectrum has not been photographed in any subsequent eclipse, notwithstanding the great improvement in red sensitive plates.

[1] Runge and Paschen, A. J. 4. 317. 1896.

[2] Royal Observatory, Edinburgh, M. N. R. A. S. 73. 31. 1912.

[3] Mt. Wilson Revision of Rowland's Table, 1928.

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have been added Fig b is the microphotometric record across the right hand half of fig B, and fig a is the record across the same part of fig A In fig a, the oxygen lines due to the solar spectrum show as absorption lines (absorption is shown downwards from the continuous spectrum) exactly similar to the neighbouring iron and nickel lines, whereas in fig b the oxygen lines due to the chromosphere are shown as emission lines (i e, upwards from the continuous spectrum) in the direction opposite to the neighbouring iron and nickel absorption lines in the sky spectrum of figs b and B, and in the solar spectrum of figs a and A This shows that oxygen is present in the chromosphere but not iron and nickel The scale of the microphotometer records is arbitrary and has no photometric significance It should be mentioned that the graininess of the photographs has been subdued in obtaining the photometric records for the sake of clearness, but at a slight sacrifice of resolving power

The presence of the bright oxygen lines in the chromospheric spectrum seems to be a permanent feature of the chromosphere Evidence of the bright reversals was secured in the first photographs attempted and they have been photographed every day since the first attempt whenever the sky has been sufficiently clear Also, since the sun's image from the siderostat feeding the object glass rotates during the day, the spectrograph slit becomes tangential to the sun at different latitudes in the course of the day, but evidence of the reversal of the oxygen lines was secured always It is therefore clear that the reversals have not been seen once only at a favoured region of the sun's limb, but are a permanent feature of the whole chromosphere

The length of the reversed oxygen lines obtained with a straight slit tangential to the sun's limb is a measure of the height to which oxygen (as represented by this triplet) extends in the chromosphere The height deduced from the photograph reproduced in fig B is 3 5″ This is very likely an underestimate, since the limb of the sun was probably a little distance from the slit at its nearest point, in order to avoid the risk of photospheric light entering the spectrograph Under the best conditions of observation and in eclipse photographs it is to be expected that the oxygen lines will extend to greater heights than this.

One other point should be mentioned At the time of observation and at the position on the sun's limb at which the photograph reproduced in fig B was taken, there was no prominence at the sun's limb

Since the oxygen triplet at λ 7770 has a high excitation potential, it follows that if they are observed at all in the chromosphere, the number of atoms in the ground state must be large Russell has shown [1] that at solar temperatures the number of oxygen atoms in the ground state is of the order of 10^8 times those which can emit the triplet at λ 7770 Consequently we may conclude that oxygen is extremely abundant in the sun's chromosphere Russell has stated [1] that although there is some uncertainty regarding the proportions of non metals in the reversing layer of the sun, it would appear that the proportions of elements (by volume) in the reversing layer are H 91 per cent, He 3 per cent, O 3 per cent, all metals 1 5 per cent Since oxygen is therefore of great abundance in the reversing layer of the sun, it is not surprising that it is also to be found in the chromosphere, and by the same arguments as Russell's for the reversing layer, it follows that if the infra-red triplet of high excitation potential is seen at all, the abundance of oxygen in the chromosphere must be large

As is well known, Milne's theory of radiation pressure on the atoms of ionised calcium as the support of a chromosphere is the only theory which has even partially explained the phenomena of the sun's chromosphere It has successfully explained the great height reached by calcium in the chromosphere, the possibility of the formation of calcium prominences and the origin of the large velocities of ascent in eruptive calcium prominences It is also well known[2] that there are very serious objections to Milne's theory The strongest

[1] Russell, A J 70 11. 1929.

[2] Royds, Kodaikanal Observatory Bulletin No 95 287 1932 and others

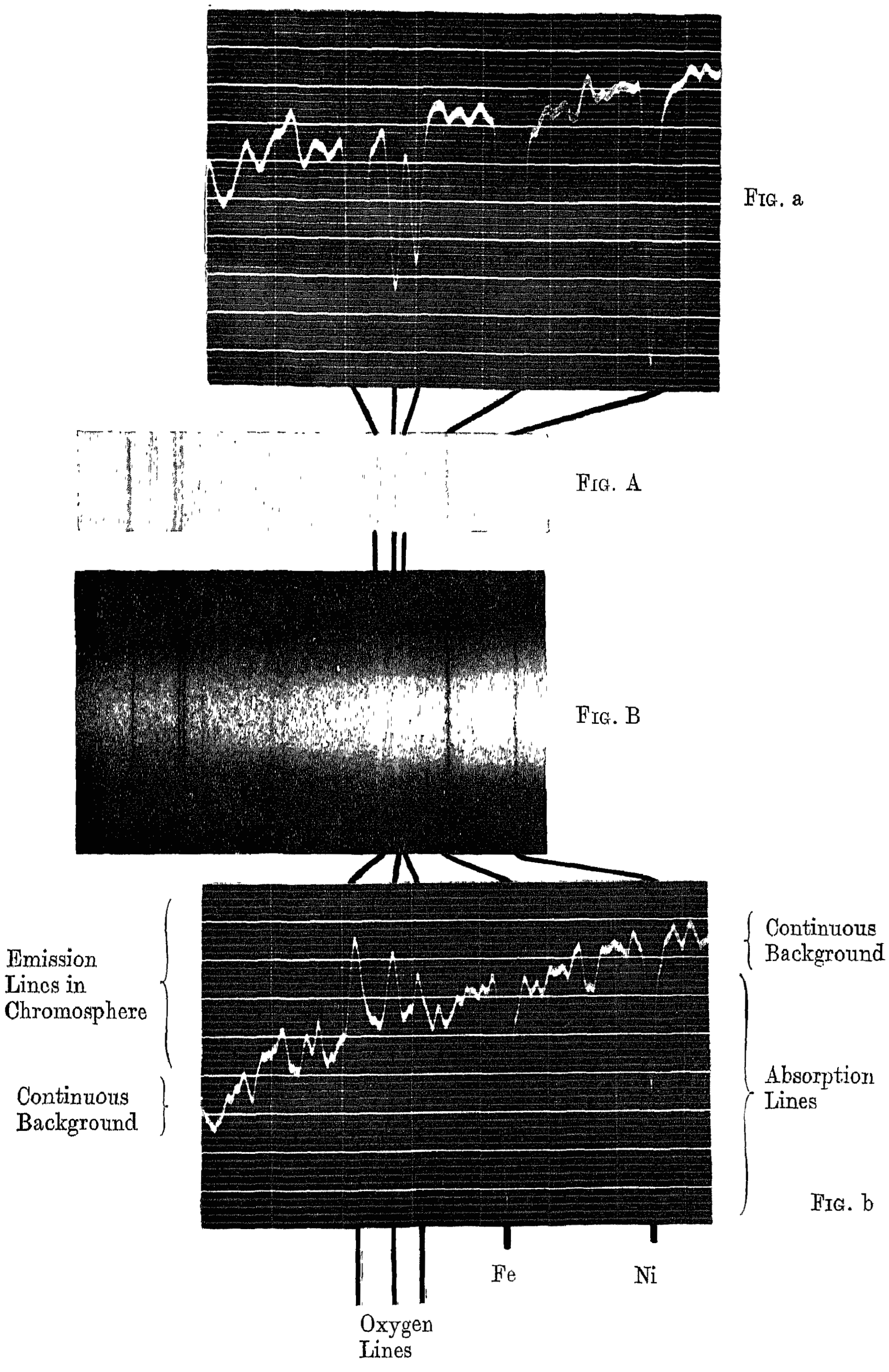

Fig. B shows bright Oxygen lines in Chromosphere.

Fig. A shows ordinary solar spectrum.

Fig. a and b are photometric records of A and B.

objection is that the chromosphere contains other elements which are present in far greater abundance than calcium. To the previously known presence of hydrogen and helium we have now the presence also of oxygen. All these three elements are present in great abundance, indeed they are, as mentioned above, the three most abundant elements in the sun. Yet the selective radiation pressure on all three is insignificant. It would seem therefore that mere abundance in the reversing layer is an important factor for the presence of an element in the chromosphere. Whatever may be the nature of the force which supports the sun's chromosphere containing H, He, O and Ca^+, it might be that the function of radiation pressure is to raise the calcium atoms to that high level where the chromospheric supporting force begins to be effective, rather than that the radiation pressure effective on ionised calcium alone is in some way enabled to drag with it into the chromosphere enormous quantities of H, He and O.

The presence of neutral potassium and rubidium in the chromosphere is not to be expected on account of their low ionisation potentials. The most favourable lines for detecting their presence are their resonance lines and it so happens that these lines lie near the oxygen triplet, so I have looked for them. I have not been able to detect any suspicion of bright lines of K at 7698, Rb at 7800, nor the subordinate lines Rb 7757 and 7619.

For the formation of the sun's image in this research, use has been made of a 15″ object glass loaned by the Nizamiah Observatory to whom I express my indebtedness.

KODAIKANAL OBSERVATORY,

29th August 1935.

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