WATER-VAPOR IN SUN-SPOTS

By WALTER M. MITCHELL

There has been considerable discussion in recent years regarding the presence of water-vapor in sun-spots, but as yet no satisfactory conclusions have been reached. The difference of opinion is of course due to the varying observational data recorded by the different observers. Just why the observations for this particular portion of the sun-spot spectrum should vary so greatly is hard to understand; possibly the variety of instruments used in making the observations is a contributing cause.

Recent investigations have shown that some of the characteristics of the sun-spot spectrum appear to be caused by the absorption of various oxides and hydrides existing in a state of vapor in the sun-spot region, and as these compounds apparently are low-temperature products it is thought possible that water-vapor may also exist in these regions on account of the reduced temperature. Unfortunately the present state of our knowledge regarding the actual physical conditions in the sun-spot or in the levels above is so deficient, that it is doubtful if we can state, with any approximation to the truth, whether or not the conditions are favorable for the existence of water-vapor.

Since the solution of the question from theoretical considerations is at present impossible, our only remaining method of investigation is the spectroscope, and, as past experience has shown, the results of this method are not very convincing.

The various observations of the widened lines in this region of the spectrum (λ 5860–λ 6000) are widely discordant. However, the lines resolve themselves pretty clearly into two classes:

1. Lines which have been recorded by nearly all observers, and are surely affected.

2. Doubtful lines, identified as due to water-vapor but not recorded by all observers.

Most of the lines of the first class are identified with those of known elements, principally iron and titanium; a few have been regarded as water-vapor lines. The question immediately arises whether the latter are really water-vapor lines or faint solar lines, unidentified as yet, but coincident or approximately so with the water-

vapor lines. The latter view has always been held by the writer. Instruments of low resolving power are not capable of separating the components of close doubles, and the widened line is erroneously identified as due to water-vapor, while the solar component of the pair is the one affected. One instance is the titanium and water-vapor lines at λ 5938.04 and λ 5938.27: most observers record the latter line as the one affected. Other instances are the pairs at λ 5918.7 and λ 5941.8 in which the titanium line of each pair is the one affected, as can easily be verified with an instrument of sufficient resolving power. These instances show the insecurity of conclusions regarding the identity of the line, based upon observations made with low-power instruments.

The lines of the second class are more numerous. On comparing the various observations of these lines one is struck by their very great discordance.[1] Hardly two observers ever record the same lines; frequently, however, the observations are grouped about a certain wave-length, indicating that there must be some line or shading at that point, but its nature is so indefinite that it is impossible to fix the position with any certainty. In other cases there is no agreement whatever.

From the discordance of the observations one is led to the conclusion that the selection of water-vapor lines intensified changed with the different spots observed; this is not in agreement with the general behavior of spot lines, and may be considered as evidence that the widening of the water-vapor lines observed is due to some other cause than sun-spot absorption.

It is unquestionably a difficult matter in the case of a faint line, only feebly intensified, to decide whether the intensification is really due to the spot or is a subjective effect caused by the darker background of the umbral spectrum. That something of this sort takes place, and that numerous lines have been recorded as intensified when in reality they were unaffected, has long been the opinion of the writer. This effect seems to be increased with instruments of low power, for various observers have remarked upon this change

[1] It may be remarked that the system of recording the intensity of spot lines devised by Fowler is not very satisfactory for the water-vapor lines, for inasmuch as these lines "change with the weather" we have no standard of intensity to use in comparison with their intensity as recorded in the spot spectrum.

in the appearance of the widened lines when using different instruments. Hence the disagreement of the observations may be partly due to this.

The writer is not prepared to state that he has ever been certain that he saw the water-vapor lines affected. Sometimes they have been slightly darkened, but the appearance was so different from that of the real spot lines, even if equally faint, that he hesitates in stating that they were affected.

Observations recently made by the writer with a powerful spectroscope (to be described in a later paper) seem to indicate that the false intensification is more pronounced when the water-vapor lines are prominent in the solar spectrum, i. e., when the proportion of water vapor in the earth's atmosphere is greater. This may partly explain the differences between the different observations. It has also been noticed that the number of water-vapor lines apparently darkened increases with the darkness of the umbral spectrum, irrespective of whether it be a more or less strongly absorbing spot that is under observation.

Cortie states (*The Observatory*, **32**, 102, 1909) that the observations recorded in the *Astrophysical Journal* for December 1908 were made under such atmospheric conditions that water-vapor lines of intensity ooo (on Rowland's scale) were visible. Evershed's observations, which have been compared with Cortie's, were made when lines marked o were invisible. Cortie records many more water-vapor lines affected than does Evershed; this agrees with the writer's observations noted above. Cortie remarks that for a satisfactory comparison with his, observations should be made under similar atmospheric conditions. With this the writer does not agree at all. It is obviously the worst possible time to look for spot lines when the solar spectrum is crowded with water-vapor lines of terrestrial origin. In order to eliminate any effects of water-vapor in the earth's atmosphere, and to render the spot spectrum as "unadulterated" as possible, observations should be made when the sun is at the highest altitude and the atmosphere is most free from water-vapor. Then only will the true sun-spot spectrum be visible, disencumbered from the spurious widenings of telluric lines.

It has occurred to the writer that the most satisfactory method of determining whether the widening of any line is real and due to solar action, or is merely a subjective effect, is by means of the sun's rota-

tion. If the widening of the line is due to solar action, its wave-length will vary with the position of the spot on the sun's disk. Measurements can perhaps be made most advantageously from neighboring lines known to be of solar origin. The difference of wave-length between the spot and solar line will remain constant no matter what may be the position of the spot on the sun's disk. The question of varying velocities due to possible differences of level might affect the results somewhat, but this effect would be very small. If, however, the difference in wave-length of the two lines varied, that is, if the wave-length of the line under investigation were constant, it would seem to indicate that the intensification of the line was not the result of solar action.

With the instruments used by the writer at Haverford and formerly at Princeton displacements due to the sun's rotation should easily be seen; at least the lines should appear unsymmetrical. But as no such phenomena have ever been observed in the water-vapor lines, one concludes that the intensification cannot be due to solar sources.

It may be noted that Hale remarks (*Astrophysical Journal*, **28**, 322, 1908) that the water-vapor lines show no evidences of circular polarization in the sun-spot spectrum; whence it is probable that they are unaffected by sun-spot absorption.

In conclusion the following points are to be brought out:

1. Our knowledge of the physical conditions prevailing in sun-spot regions is too deficient to permit deductions of any value to be made from it.

2. Lines in the sun-spot spectrum identified as water-vapor lines may be metallic lines as yet unidentified, similarity of wave-length leading to the erroneous identification.

3. The slight intensifications of faint lines may not be real, but only subjective effects, instrumental and otherwise, and until we are certain that the lines are really affected, evidence derived from them cannot be regarded as worthy of consideration.

4. The existence of water-vapor in sun-spots may be possible, for we know nothing to the contrary, but in the opinion of the writer there is no evidence of its presence.

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