ART. XIV.—*A short Study upon the Atmosphere of β Lyræ ;*
by ORRAY T. SHERMAN.

A COMPARISON of the observations upon the spectra of those stars admitted to possess a spectrum comprising bright lines leads to the conclusion that, while persistent in place, the bright line is not persistent in intensity. That this is the case in the solar chromosphere, β Lyræ, γ Cassiopeiæ, R. Geminorum, γ and η Argus, the Wolf and Rayet stars, and through the courtesy of Dr. Konkoly we add η Ceti, may not be doubted. In the others also it seems probable. This peculiarity, now presented as a characteristic of the bright line in stellar spectra, affords a distinction between bright line light, bright background space, and any accidental disturbance the spectrum light may suffer.

Under its guidance the observation was extended to noting the relative places of every persistent or at times outflashing break in the spectrum light, and the single observation was replaced by a series as frequently as opportunity allowed. For greater intensity of bright line light, the sharply focussed star was made to replace the slit, the jaws being symmetrically opened, so that, while allowing the full disc to pass, any displacement soon caused a diminution of the stellar light. For reference spectra the jaws were reclosed. The cylindrical lens was removed. The observing telescope was of low power. For least intensity of background light, the highest dispersions practicable were employed. No foreign light was permitted, the telescope being set during the day so as to be swept upon the star. The record was automatically made. The routine of observation is as follows: For some time previous the observer's eye is kept in the dark. Seated at his telescope, he has then before him a faint, barely traceable line of light, beading or imbedded in which are a number of bright monochromatic stellar images. These points are brought so as to be bisected by the edge of the thick cross-bar which it is desirable to employ. The position is recorded and the observer proceeds to the next dot. In this way he has usually passed through the first, second and a portion of the third spectrum. At the end of the observation the position of the bright lines afforded by a salted alcohol flame or Plücker's tube are added. The slip is withdrawn. The relative position of the punctures are measured and the wave-length reduced by a proper formula. The record of the three spectra combined in one is then recorded as the result of the day's observation. The spectra in which the especial line has been observed forms a measure of its intensity. In combining one day's work with the others, those lines which lay nearest together have been referred to

the same line. No line has been admitted unless circumstances rendered its admission necessary. The mean of each horizontal line has then been taken as the approximate wave-length. Throughout the observation the observer has absolutely no definite knowledge of the identity of any especial dot. Nor is it possible for him, while at the telescope, to connect one day's work with another. Nor in tabulating is there any great chance for judgment.

These appearances seem worthy to be classed as bright lines, for (1) they are seen as well with prism as with grating; (2) their number increases as the dispersion increases; (3) they occur for periods together, and are absent for periods together; (4) they remain constant in position but vary in intensity; at times they are dazzling bright, and at times they are faded, scarcely noticeable; at times they remain a steady glare, at other times they sparkle in and out, are caught only in instants; (5) these variations are not dominated by the weather, they may be bright or dull under the most favorable circumstances, and dull or bright under the most unfavorable.

Our final list contains over a hundred and fifty positions; some appear so few times that independently they could not be claimed as bright lines. Although probably correct to within two in the fourth figure, yet they are useless for purposes of identification. The number of observations, however, places a means of discriminating at our disposal. If those lines, which are capable of being referred to a single substance, varied together, we may fairly consider that they belong to the same substance.

In this way we have identified *hydrogen*, presenting in addition to the four ordinary excitation lines to which we are accustomed, a large number, perhaps ninety, due to its low excitation spectra.

Oxygen presents eleven lines of its high excitation spectrum, and in addition the *glow of the negative pole* represented by sixteen lines.

Nitrogen presents probably eighteen lines of its high excitation spectrum, and in addition the *glow of the negative pole* represented by five lines.

Carbon presents five lines, generally occurring together.

Compounds of carbon and hydrogen present seven lines, generally occurring together. Oxygen and carbon in combination present eight lines generally occurring together. Nitrogen and carbon in combination are probably represented by the most intense line of the cyanogen spectrum, but from the scantiness of the data we are unable to speak with certainty.

Magnesium is represented by five lines generally occurring together, and yet the traces of magnesium burning in hydrogen are very faint.

The whole of this evidence, the low temperature of the hydrogen spectrum, the apparent ease with which the hydrocarbon* compound forms, the fact that during its formation there is an increase in the star's variable light without accompanying evidence of combustion and the spectra of the negative glow, presents us with the fact of an electric discharge in which hydrogen plays the part of the positive pole, and oxygen and nitrogen the parts of the negative pole. From evidence presented by the bright line† stars, noting that, roughly speaking, the high excitation hydrogen belongs to the brighter, the lower to the fainter stars, we are inclined to think this charge the residual of that produced by chemical action, perhaps simply dissociation taking place in the interior. We will not stop here to recall to the student of terrestrial and cosmical physics the evidence presented by comets, by the magnetic needle, by certain bands of the solar spectrum, by sun spots, by the zodiacal light perhaps, and many similar phenomena, not only of an electric charge upon the sun, but also of a cold atmosphere between it and our earth.

We have studied these spectra with regard to their appearance in time, and find evidence of a force especially evident in the nitrogen negative glow, in the magnesium and in the hydro-

Light curve of β Lyrae. Observation by Sawyer.

gen, whose laws our short series does not permit us to determine, but which is probably the cause effecting the disappearance of the hydrogen lines in 1874,‡ and their reappearance in 1883, and is perhaps similar to that causing the sun spots.

We have also studied the spectra with regard to the variation of the star's light, a single period of which derived from observations by Sawyer is represented in the adjoining cut. And we find in the spectra of hydrogen, oxygen and their carbon compounds a simultaneous variation. To any one acquainted with Berthelot's§ work, upon the action of mixtures of these gases under an electric spark, this will appear quite natural. The rise in the curve from primary minimum to primary maximum corresponds to a period of increasing oxygen,

* Ann. Chim. et Phys., III, lxvii. 67, 1863.

† The Astron. Jour., No. 4, vol. vii.

‡ Astronomische Nachrichten, No. 2581.

§ Comptes Rendus, t. lxviii. 1869.

of increasing hydro-carbon, and of an almost entire absence of carbonic acid. The downward slope to secondary minimum corresponds to a period abundant in carbonic acid, almost wanting in oxygen with variable evidences of hydro-carbon. The remaining portion of the curve corresponds to a period in which the evidences of hydro-carbon, oxygen, and carbonic acid are irregularly variable; as would be the case if the light waxed and waned by a series of undulations similar to those which Chandler* tells us are actually observed. The final slope corresponds to a period of decreasing carbonic acid, increasing hydro-carbon, increasing oxygen, preparing as it were for a conflagration at primary minimum, and such apparently takes place. It is of interest to remark that hydro-carbon probably formed a part of the spectra of both Nova Cygni and the star near χ , Orionis, but was only traceable near the star's maximum.

Recalling Lockyer's result in the study of the solar atmosphere, agreeing as it does with certain observations which we have quoted above, we may picture to ourselves the condition of the stellar atmosphere, and the action therein somewhat as follows: An outer layer of hydrogen positively electrified, an inner layer of oxygen negatively electrified, and between them a layer of carbon mingling on its edge with hydrogen. The electric spark passing through the mixture forms the hydro-carbon compound, whose molecular weight carries it into the oxygen region where combustion ensues with the formation of carbonic acid and aqueous vapor, both of which descending under the influence of their molecular weight are again dissociated by internal heat, and return to their original positions. Under the insight which this result gives we have found the spectrum of the nebulæ† referable to low excitation hydrogen, the spectra of the bright line stars referable to high excitations oxygen and hydrogen of higher or lower excitation according as the central star is of a high or low magnitude, and as far as the accuracy of the observations permits, τ Coronæ, Nova Andromedæ, Nova Cygni and the star near χ , Orionis itself a variable, likewise referable to the same spectra similarly conditioned. There is also reason for thinking that a similar atmosphere in similar physical conditions, lies between us and the sun, and it seems as if we might consider that from the faintest nebula to the most highly finished star we have but progressive stages of the phenomenon here presented. To observe, to differentiate, to classify, to interpret, presents a vast field of deep interest and high promise. This line of investigation, however, will appreciate both new work in the laboratory and new methods with the telescope. To prepare these is now our charge; later we hope, under some clearer sky, to reënter the field.

* Chandler. *Astronomical Journal*, vol. vii, No. 1. † *Ibid.*, vol. vii, No. 6.