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NOTES ON THE SPECTRUM OF NOVA AQUILÆ NO. 3

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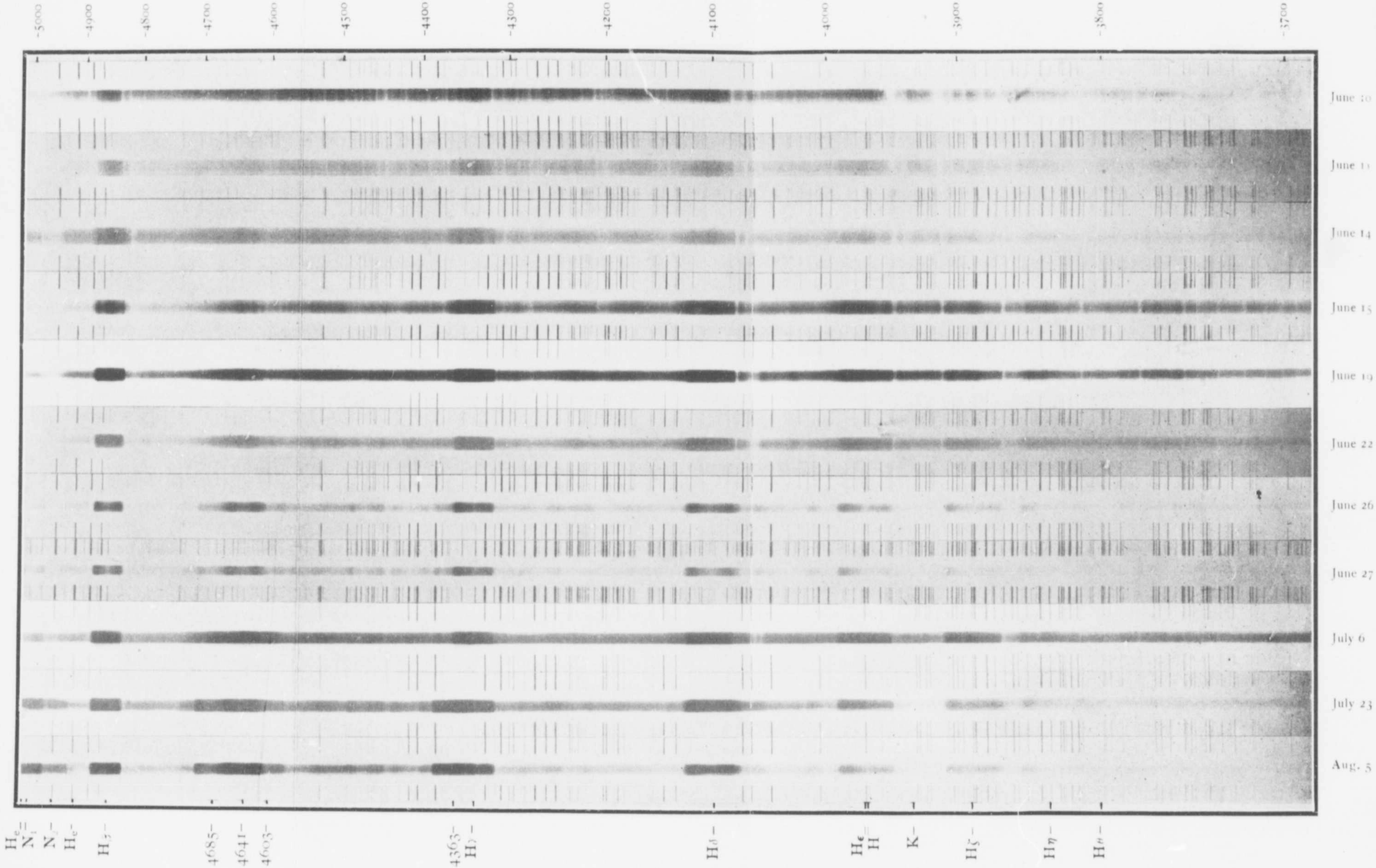
PLATE XI.



SPECTRA OF NOVA AQUILÆ

Taken at the Dominion Astrophysical Observatory, Victoria, B.C.

June 10

June 11

June 14

June 15

June 19

June 22

June 26

June 27

July 6

July 23

Aug. 5

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By J. S. Plaskett

SIXTY spectra of the Nova have been obtained here with the spectrograph used with a single prism giving linear dispersion at H_γ of 35 A. per mm. The measurable region extends from H_β well into the ultra-violet so that 19 of the hydrogen series were measured on one plate.

The spectrum has apparently followed fairly closely the usual developments taking place in novæ but has shown some rather singular features. The first spectrum obtained here on June 10 showed numerous rather broad and diffuse metallic and hydrogen absorption lines and also hydrogen emission, though the latter was not marked. The metallic absorption first became narrower and gradually disappeared, and hydrogen emission and absorption increased. Metallic lines disappeared about June 17, hydrogen absorption, doubled on June 15, became most marked on June 19, when 19 of the H series were measured, and then became fainter, disappearing on June 27 as emission became stronger. Hydrogen absorption in approximately the same position reappeared on July 1, disappeared on July 11, reappeared for a day or two on July 15 and absorption, at this displacement from normal, has not since appeared.

The spectrum indicated a change towards the nebular stage about June 20 when λ5007, λ4685, λ4363 began to show. On July 11 the nebular stage was strongly marked and since, up to August 5, not much change in relative intensity of nebulium and hydrogen lines has occurred.

There have been numerous and sometimes sudden changes in the relative intensity of emission and continuous spectrum, which will probably prove to be coincident with changes in apparent magnitude, although I have not at hand any photometric measures, and, at the date of writing, August 5, the light from the star is apparently almost entirely emissive in character.

The most curious features about the spectrum however, are the behavior of the absorption lines especially hydrogen, the displaced enhanced metallic lines, and calcium.

Hydrogen, as in all novæ, is probably the most striking feature of the spectrum, and although the emission has hitherto not been as complex as in previous novæ, the behavior of the absorption lines has been exeeedingly interesting. The emission bands, weak at first, have been abruptly ended at the violet side in many spectra, the dates of appearance and disappearance being given above, by strong, generally sharply defined and moderately narrow lines at distances proportional to the wavelength and increasing at $H\gamma$ from about 20·5 A. on June 10 to 25·4 on June 24. No hydrogen absorption was visible again until July 1 when very narrow lines, doubled from July 2 to July 6 appear at 24·2 A. and 25·8 A. respectively to the violet of the normal positions at $H\gamma$ and correspondingly displaced at $H\delta$, $H\epsilon$, and $H\zeta$. These absorption lines are not present on July 11 and 12 but reappear as single lines on July 16 at 24·2 A. to violet. This series has not since appeared although there are some absorption lines within the emission bands on some of the later plates but displaced by very much smaller amounts and not forming a continuous series as the ones just described. From June 10 to June 15 inclusive a second hydrogen absorption about 33 A. to the violet at $H\gamma$ appeared, diffuse at first, narrowing and sharpening down till June 15 when it was measured from $H\beta$ to $H\mu$. No traces of this second absorption are present in the spectrum of June 17 or later.

As announced in a telegram to Professor Pickering, the measured positions of these lines agree with computed positions by Balmer's formula, changing the constant from 3646·13 to 3625·78 for the first, and 3618·4 for the second component on June 15. The residuals between computed and measured positions for 15 of the broader and 7 of the narrower components average 0·15 A. and if 5 rather discrepant ones are omitted, the average residual is only 0·06 A., a remarkably close agreement. The constants determining the positions of the principal violet absorption series, which is practically 3629·0 on June 10, 3625·8 on June 15, diminishes to 3624·8 on June 24 and then jumps suddenly to 3625·8 when the closely doubled lines appear, and remains practically constant so long as the absorption series is present. On June 19 no less than nineteen consecutive *H* lines, beginning at $H\beta$, were measured and three more were visible. The average deviation of the computed positions, Balmer constant 3624·99, of the middle thirteen of these lines from the observed was only 0·07 A., and of nine only 0·04 A., showing that they are undoubtedly due to hydrogen, displaced by some unknown and identical cause from their normal positions.

The displacement of many enhanced metallic lines which was discovered by Messrs. Adams and Joy, of Mt. Wilson and announced as 23 A. at λ4500 has been fully confirmed in the spectra obtained here between June 10 and June 15. The positions of some 65 metallic lines identified chiefly as due to *Ti, Fe, Cr, Sr, Sc, V* have been measured on these plates, and it has been shown beyond doubt that the displacements are also proportional to the wave-length, are exactly the same as those of the hydrogen absorption and increase from spectrum to spectrum in exactly the same way. These displacements must evidently all be due to the same cause but what the cause is cannot be determined. Although the displacements follow the same law as if they were velocity shifts, it seems to me very unlikely that such enormous velocities as 1400 km. per sec. on June 10 increasing to 1750 on June 24 could be present. A further evidence that it can not be due to velocity is given by the second narrow absorption series of seven lines, also unmistakably due to hydrogen, whose shifts would correspond to a velocity of 2300 km. on June 15 ; that is to say the absorbing hydrogen would have two different velocities 1675 and 2300 km. per sec. at the same time.

When these displacements so exactly follow the Balmer law for hydrogen, and are of the same amount for the enhanced lines and also for calcium as will be seen below, it seems more likely that they are due to some physical cause acting in the same manner on the molecules of all these elements — what the action is can only be speculated on — than to velocity.

Perhaps the most remarkable behavior of the gases is shown by the *H* and *K* lines of calcium which take three forms:—

(1) Emission, not very strongly shown, but undoubtedly present in some spectra and of similar width and position to the hydrogen emission.

(2) Displaced absorption lines, that of *K* showing always when the displaced hydrogen absorption shows and to exactly the same amount and that of *H* generally clearly separated from the H_ϵ absorption, by which it differs in wave-length by about 2 A.

(3) Very narrow and sharp lines *H* and *K* nearly in their normal position and present in most of the spectra, even when the hydrogen and other calcium absorption did not show. These lines are very accurately measurable and are apparently constant in position. They show some indications of a small cyclic change in velocity but this is so close to the probable error of measurement that it can not be regarded as by any means established. The mean value of the velocity obtained from these *H* and *K* lines on 17 plates reduced to the sun is $19{\cdot}7 \pm 0{\cdot}4$ km. per sec. Considering the velocity as constant, the probable error of a plate as determined by the measure of these two lines is 1·7 km. per sec. The early plates gave a velocity of about 17 km., which increased to 23 in about 10 days, dropped to 19 and increased again to 23, but although the lines agree very well and can be accurately measured, the difference is not sufficient with low dispersion to definitely indicate variation in velocity and we may state that this absorbing calcium is moving towards the sun at about 20 km. per sec.

It seems hardly reasonable to believe that the emissive calcium vapor, that giving the displaced lines whose position changes in a week from 20 A. to nearly 25 A. to the violet of the normal position, and that giving the narrow sharp lines, constant in position and with a velocity towards the sun of 20 km. per sec.

can be directly connected with the same body. The behavior of these stationary *H* and *K* lines is similar to that observed in numerous early type binaries where the large velocity variation given by the diffuse hydrogen and helium lines is not shared in by the sharp *H* and *K* lines. The conditions here would even more certainly seem to indicate that the light from the star is shining through a layer of relatively cooler calcium vapor which is undisturbed by the tremendous cataclysms occurring in the star. The calcium line 4226·9 has been measured on 5 or 6 plates between June 18 and June 26 and gives a velocity about 15 km. per sec. more positive than the *H* and *K* lines but it is not so sharp nor persistent as they are.

There are a number of other singular features about the spectrum which may be just mentioned. A line whose measured position is about λ4210 appears coincidently with the displaced hydrogen and the true wave-length is probably hence about λ4233 and is probably due to what Lockyer calls proto-iron. Similarly there appears to be an emission band corresponding to the proto-carbon at λ4267. Another curious feature is a pair of very broad diffuse lines to the violet of H_β which appear and disappear and reappear again in a startling manner. The wave-length of the one decreases from λ4065 to λ4060 and of the other from λ4060 to λ4054. Their centres are about 6 A. apart and they occasionally merge into one very broad absorption band. No reasonable identifications for these lines have been found.

From measures of broad emission bands on several sprectra and comparison with the several hydrogen bands whose normal wave-lengths are known, the wave-length of some of the nova and nebular bands have been fairly well determined. For example N_1 5006·9; N_2 4959·4; 4685·4; 4641·0; 4605·2; 4471·5; 4415·0; 4363·4, etc., but these measures can probably be improved by following the star closely and catching it when the emission is well defined. It is proposed to obtain spectra at frequent intervals as long as the star can be followed here and this note is preliminary to a fuller discussion of the spectrum when complete data have been obtained.

The accompanying reproduction (Plate XI.) of a number of spectra of the nova on different dates shows clearly the great changes taking place in the spectrum as it developes from the absorption line type to the nova type with strong hydrogen, 4641, and helium emission and the gradual appearance and increase of intensity of the nebular emission, particularly N_1 5007, 4685 and 4363.

The hydrogen absorption series is also well shown on a number of these spectra, normal and displaced *H* and *K*, and also the broad pair of lines to the violet of $H\delta$. These spectra are reproduced in the negative form which seems to me more suitable than the positive, especially to those accustomed to examine spectrum negatives. The scale of enlargement over the original negatives is 6·54 times.

DESCRIPTION OF SPECTRA

It is interesting to note the development of the spectra in this series, and a few notes may help to point out the most striking features.

On June 10, the spectrum is mostly absorption with displaced metallic and hydrogen lines with emission relatively weak at $H\beta$, $H\gamma$, $H\delta$, $H\epsilon$.

On June 11, the metallic lines are narrower and sharper and emission relatively stronger.

On June 14, only a few metallic absorption lines are left, the hydrogen emission is still stronger and helium emission bands at 5017 and 4923 are quite prominent. The nova band at 4641 is also beginning to appear.

On June 15 there are still a few metallic lines, including the stationary *H* and *K* of calcium which are present in the majority of the spectra, but the feature of this spectrum is the much strengthened hydrogen and nova emission and the long broad and narrow displaced hydrogen series.

On June 19, the narrow hydrogen absorption has disappeared, the broad is sharper and extends almost to the theoretical limit and there is a great further strengthening of the emission. In these two last spectra particularly, the displaced *H* and *K* are well shown, *H* and H_ϵ being well separated. The helium emission to the red of H_β is also prominent.

Except an increase in the relative intensity of emission as compared with continuous spectrum, there is not much change on June 22, but on June 25 it is practically entirely emission with neither continuous spectrum nor absorption lines. In this spectrum the nebular stage begins to show by emission at 4685 and 4363 and N_1 5007.

On June 27 the change is carried further still, there being neither lines nor continuous spectrum.

On July 6, there is again both continuous spectrum, the displaced hydrogen and calcium absorption and the broad absorption pair at 4060, 4054 of which traces are seen in some of the earlier spectra especially June 19, though further to the red.

On July 23, it is again mostly emission with no absorption lines and the nebular spectrum is now much stronger. N_1, N_2, 4685 and 4363 are getting nearly as strong as 4641 and the hydrogen emission, and this change is carried still further on the plate of August 5 where the nebular lines are relatively still more strong.

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