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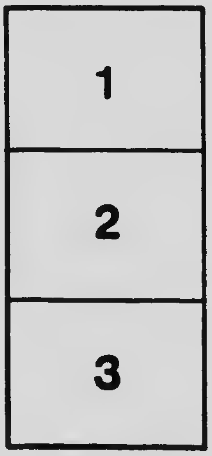
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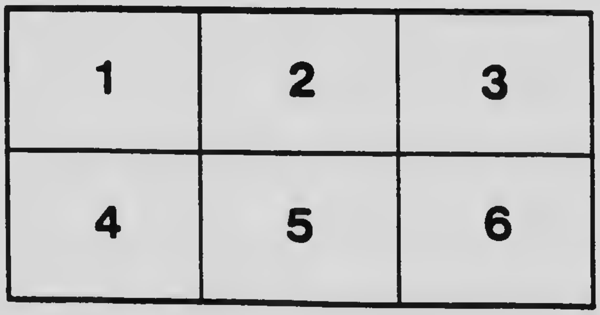
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THE SPECTRUM OF *MIRA CETI*

BY

J. S. PLASKETT

TORONTO
1907

SPECTRUM OF *o* CETI (MIRA).

PHOTOGRAPHED BY J. S. PLASKETT, AT THE DOMINION OBSERVATORY,

OTTAWA, 1906, DEC. 1st, 14h, 32m, G.M.T

LENGTH 3/4, WIDTH 60 TIMES THE ORIGINAL.

THE SPECTRUM OF *MIRA CETI.*

By J. S. Plaskett.

WITH FRONTISPIECE PLATE.

THE spectrum of *o Ceti* has been photographed at the Dominion Observatory 18 times on 11 nights during the months of December, 1906, and January, 1907. The number of observing nights during these two months has been very limited, the weather having been unusually cloudy, and no more spectra of this interesting variable could be obtained.

The spectrograph at present in use is an adapted Brashear Universal Spectro... ...ng collimator and camera lenses of 1¼ inches apert... inches focus, and a train of three dense flint prisms ... *Hγ* about 1·64, giving a linear dispersion at *Hγ* of ... ...n met...s per millimeter, with a resolving power of 40,000. A spectrum about 55 mms. long is obtained, of which, however, owing to curvature of field of the triplet camera lens, only about 15 mms. in the centre is in the best focus. The balance of the spectrum becomes more and more diffuse towards the ends of its range, which extends between λ3950 and λ5100. The extreme limits measured for radial velocities lie between λ4200 and λ4584, but it is possible to obtain fairly accurate values of the wave lengths, within one tenth of a tenth-metre, between *Hβ* and *Hδ*.

The spectrum of *Mira*, observed at this maximum, differs in some essential particulars from previously recorded observations.

The star has been much brighter than for several previous maxima and it is natural enough, if we consider its variability to be due to changes in its internal condition, to expect a change in its spectrum. These changes appear both in the absorption and the emission spectrum, and will be treated in greater detail later on.

Probably the most striking change is in the character of *Hβ*, which had been previously recorded as either dark, or as only faintly bright. Sidgreaves (*M.N.* LVIII., p. 344) did not consider he had certainly seen $H\beta$ bright. Miss. Maury (H.C.O. *Annals* XXVIII., p. 47) saw it bright on some Harvard plates. Campbell (*Astrophysical Journal* IX., p. 1) could not see it visually, while Stebbins, (*Ibid* XVIII., p. 341) in his exhaustive paper, was successful in recording both it and $H\epsilon$ on some plates, but with much less relative intensity than at this maximum. In every spectrum made here, even those with only two minutes exposure, $H\beta$ is distinctly and certainly bright, and there is not the slightest doubt of its emissive character. No trace whatever has been seen of $H\epsilon$ on any of our plates and it is apparently not present. It also had never been seen bright until Stebbins recorded it.

A number of comparative exposures from one minute to twenty minutes were made to determine, among other things, the relative intensity of the emission and absorption spectra. As an estimate from these plates,—no attempt was made to accurately determine intensities,—I would say that the bright $H\beta$ had an intensity about 15 times that of the continuous spectrum in that region, *H* about 25 times and $H\delta$ at least 50 times. These estimates apply to the plates of January 23 and 26, when the star was considerably past maximum. In December no comparative tests were made, but the ratio would not be very much different, so far as can be judged, from the over-exposed emission lines.

Before discussing the character of the spectrum it will be preferable to give the record of observations and the measures of the wave-lengths of the lines and bands obtained from the most suitably exposed spectrum, No. 486. Although 486, 515 and 521 are the best of the plates, the first eight are all measurable, and of these 486 and 515 have been reduced for the wave lengths of the absorption lines and bands, and for the determination of the radial velocity. All the plates, with the exception of 575 to 578, in which the camera was accidentally not in good focus, have been measured for the velocities due to the $H\gamma$ emission, and they show, as will be seen, fair agreement with one another and with Professor Campbell's previously determined values. The velocities obtained from the absorption part of the spectrum in the two plates measured agreed so closely with one another, and at the same time were nearly the same as Professor Campbell's and Mr. Stebbins' values, that it was not thought necessary to measure more plates.

RECORD OF OBSERVATIONS.

PLATE NO.	DATE	G. M. T.	EXP.	PRISM TEMP.	SEEING	OBSERVER	REMARKS
	Dec. 11	14 20	18 m.	3·5	Good	H	Absorption spectrum underexposed
480	" 18	14 32	19 m.	1·6	"	H	Good spectrum.
493	" 19	14 50	20 m.	7·4	Fair	P	Underexposed.
515	" 27	15 55	30 m.	+ 2·1	Poor	P	Fair spectrum
521	Jan. 9	13 45	30 m.	12·8	Fair	P	Good spectrum.
534	" 15	14 35	40 m.	− 12·8	Poor	H	Underexposed.
555	" 18	14 30	60 m.	− 8·0	Poor	P	"
563	" 21	13 55	20 m.	− 12·3	Good	P	"
566	" 22	15 16	05 m.	8·9	Fair	H	For emission lines only
575	" 23	13 43	20 m.	− 18·8	"	P	For emission lines.
576	" 23	14 07	10 m.	18·8	"	P	" " "
577	" 23	14 17	05 m.	− 18·8	"	P	" " "
578	" 23	14 23	02 m.	− 18·8	"	P	" " "
579	" 26	12 15	20 m.	− 10·0	Good	P	" " "
580	" 26	12 32	10 m.	− 10·0	"	P	" " "
581	" 26	12 41	05 m.	− 9·9	"	P	" " "
582	" 26	12 46	02 m.	− 9·8	"	P	" " "
583	" 26	12 50	01 m.	− 9·8	"	P	" " "

In the above measures, the wave lengths of the star lines are determined in the usual way, from the linear positions of the star and comparison lines on the plate, by Hartmann's interpolation formula. The displacement of the lines in tenth-metres due to the motion of the star is known, when the velocity is known from the formula

$$\delta\lambda = \frac{v\lambda}{299{,}860}.$$

The velocity is obtained from the mean of the velocities due to 25 lines near the middle of the plate, which had been identified as far as possible with known terrestrial or solar wave lengths. This velocity, on being transferred back into displacement by the . ~ve formula, gives the correction to be applied to the measured wave-lengths of the absorption lines, emission lines, and bands at the ends of the plate, to reduce them to normal wave lengths.

o CETI, No. 486.

1906, Dec. 18. Observed by W. E. Harper.

G.M.T., $14^h\ 32^m$. Measured by J. S. Plaskett.

MEASURED WAVE LENGTH	NORMAL WAVE LENGTH	DISPLACE-MENT	VELOCITY	REMARKS
4955·520	4·04			Red Edge of Bright Band
4862·877	1·527	1·350	[+82·75]	Hβ Emission
4848·048	7·55			R. Edge of Band
4806·639	5·24			Line near edge of band
4805·866	4·46			R. Edge of Band
4763·309	1·91			Mn Line near edge of band
4762·766	1·36			R. Edge of Band
4657·795	6·39			Ti Cr
4627·889	6·49			Cr Mn Line at R. Edge of Band
4608·688	7·28			Sr 7·51 Line at V. Edge of Band
4595·652	4·27			V 4·30
4585·917	4·53			Fe Line at R. Edge of Band
4581·841	0·46			V Cr 0·59, 0·23
4578·749	7·356	1·393	+91·10	V
4537·372	5·965	1·407	93·00	Ti Cr
4528·020	7·400	1·430	94·66	Ti
4524·335	2·974	1·361	90·23	Ti
4510·608	8·198	1·500	99·45	Ti
4472·804				Ti
4463·437				Fe Mn V
4454·795	3·505	1·200	80·76	Ti Mn
4436·630	5·439	1·191	80·49	Ca Ca
4428·730	7·420	1·310	88·68	Ti Fe
4406·211	4·951	1·260	85·80	Fe
4402·065	0·738	1·327	90·37	V
4396·746	5·286	1·460	99·42	Ti V
4386·213	4·873	1·340	91·05	V
4385·070	3·720	1·356	92·88	Fe

o Ceti, No. 486, (*Continued*)

MEASURED WAVE LENGTH	NORMAL WAVE LENGTH	DISPLACEMENT	VELOCITY	REMARKS
4380·616	9·396	1·220	+ 83·57	V
4369·560	8·26			Ti Fe
4354·312	3·038	1·274	87·78	Fe V
4345·977	4·597	1·380	95·22	Ti Cr
4341·734	0·634	1·100	[75·00]	Hγ Emission Line
4334·204	2·988	1·216	84·02	V
4331·409	0·189	1·220	84·30	V
4316·224	5·018			Ti Fe
4307·438	6·078	1·360	94·65	Ti
4297·334	5·914	1·420	96·84	Ti Cr
4292·800	1·50			Ti Fe
4276·252	4·922	1·330	93·10	Cr Ti
4259·747	8·477	1·270	89·28	Fe
4248·296	6·996	1·300	91·78	Y
4234·618	3·36			Fe Emission
4231·277	0·00			Fe 9·93
4230·768	9·51			Fe Emission ?
4228·131	6·904	1·227	86·99	Ca
4208·190	6·862	1·328	94·68	Fe
4180·090	8·84			V Ce Emission ?
4180·937	9·68			V 9·54
4179·009	7·82			Fe 7·70
4175·473	4·22			Fe 4·09
4174·826	3·58			Ti Fe Emission ?
4167·096	5·84			Ce Cr Fe Emission
4139·778	8·53			V Ce Mo Emission
4135·897	4·49			Fe V 4·49, 4·59
4120·807	9·56			Fe V Ce Mo Emission ?
4104·185	2·95			Mn Emission ?
4103·030	2·000	1·030	[+75·29]	Hδ Emission

Mean of Absorption Lines + 90·43

$\epsilon = + 5{\cdot}2$	V_a	− 24·20
$\epsilon_0 = \pm 1{\cdot}0$	V_d	− 0·09
	Curvature correction	− 0·50
	Radial velocity =	+ 65·6

o CETI, No. 515.

1906, Dec. 27.
G.M.T., 15^h 55^m.

Observed by J. S. Plaskett.
Measured by W. E. Harper.

MEASURED WAVE LENGTH	NORMAL WAVE LENGTH	DISPLACEMENT	VELOCITY	REMARKS
4572·705	1·275	1·430	+93·66	Mg
4550·222	8·938	1·284	85·27	Ti
4546·234	4·845	1·389	91·70	Cr Ti
4541·976	0·776	1·200	79·32	Cr
4537·385	5·965	1·420	94·00	Ti Cr
4528·780	7·490	1·290	85·40	Ti
4524·360	2·974	1·386	91·96	Ti
4497·975	6·57			Ti Mn Cr
4490·902	9·60			Cr
4463·517	2·21			Fe Mn
4461·557	0·20			V Mn
4459·016	7·656	1·360	91·39	Ti V Mn
4454·885	3·505	1·380	92·87	Ti Mn
4439·396	8·006	1·390	93·82	V
4428·780	7·420	1·360	92·07	Ti Fe
4427·351	6·201	1·350	91·39	Ti
4406·331	4·951	1·380	93·82	Fe
4402·076	0·738	1·338	91·18	V
4396·696	5·286	1·410	95·88	Ti V
4380·806	9·396	1·410	96·58	V
4369·560	8·071	1·489	102·06	Fe
4354·348	3·038	1·310	90·00	Fe V
4353·316	2·006	1·310	90·00	Cr Mg
4341·784	0·634	1·150	[79·35]	Hγ Emission
4334·308	2·988	1·320	91·10	V
4320·247	8·817	1·430	99·24	Ca Mn
4307·558	6·078	1·480	103·00	Ti
4302·203	0·945	1·258	87·68	Ti
4297·244	5·914	1·330	92·83	Cr Ti
4290·617	9·237	1·380	+96·32	Ti

Mean of Absorption Lines + 92·48

ϵ = ± 4·7	V_a	− 26·45
ϵ_o = ± 0·9	V_d	− 0·22
	Curvature correction	− 0·50
	Radial velocity =	+ 65·3

In the tables above, of plates 486 and 515, the first column contains the wave lengths computed from the linear measures by Hartmann's formula. The second column contains the normal wave-lengths determined, in the cases where there are no entries in the two succeeding columns, by the process outlined above, and in the other cases where the lines have been identified, by taking the corresponding wave-lengths from Rowland's table.

These identifications have been made as consistently as possible, using only those elements which it was considered probable from the similarity of *o Ceti* to third type stars, would be present in the star. The third column contains the displacement of the line in tenth-metres from its normal position due to motion, and is obtained by subtraction of the second column from the first. The fourth column contains the velocity corresponding to this displacement, obtained by multiplying by 299,860 λ.

Let us consider in the first place the radial velocity of *o Ceti* as determined from the displacements of the absorption and emission lines. The mean velocity from the absorption lines in No. 486 is + 90·43 kms. per second, which, on applying the correction for the orbital and diurnal movement of the earth, and for the curvature of the spectral lines, reduces to 65·61 kms. per sec., recession, compared with the sun. For plate 515 the velocity is + 65·3 kms., in good agreement with the first. Professor Campbell*, from his determinations in 1897 and 1898, obtained a mean velocity of + 62·3 kms., and Stebbins in 1902, of 66 kms. This shows that the motion of the star is constant, as the variation between the Lick and Ottawa determinations can readily be accounted for by the uncertainty in the identification of the lines, and in the intensity to be assigned to them in the blends, in a star so different from the sun in its absorption. Campbell's value of the velocity is probably more nearly the true one on account of the greater dispersion and resolving power of the Mills spectrograph, which admits of the resolution of lines much closer together than is possible with the Ottawa instrument.

The errors in identification and blending are plainly shown by the very high mean error $\epsilon = \pm 5{\cdot}2$ of the determination

* *Astrophysical Journal*, IX., p. 31.

from a single line. In the case of stars like *β Geminorum* and *α Boötis*, where their similarity to the Sun allows of satisfactory identifications and blends, the mean error is only one third of the above, while the mean error of setting on the lines of *o Ceti* which are of good quality for measurement, is not materially greater than with solar stars. It is evident, therefore, from the satisfactory agreement of the velocities obtained at two epochs nine years apart, that the star's velocity, so far as it is determined from displacements of the absorption lines, is constant, and, as Professor Campbell has already said, its variability is probably not dependent upon or connected with any orbital motion.

A comparison of the displacements of the bright hydrogen lines on the two plates already measured, and their corresponding velocities, with the mean velocity from the absorption lines, shows that the former is about 15 kms. smaller, that, if the displacement could be explained by velocity changes only, the emissive layer is lagging behind the absorptive layer at the rate of 15 kms. per sec. It is of course more likely that the difference is due to some unknown condition in the atmosphere of the star which may displace the spectral lines. To obtain all the information possible in regard to the character and displacement of the hydrogen emission lines, a number of plates were made with varying exposure, from 1 minute to 20 minutes, and these were carefully compared with one another and with the previously exposed more intense plates to determine the form of the emission lines. No trace could be found of Campbell's triple formation in any of the plates, although the earlier ones, when the star was near maximum, were not suitably exposed to exhibit such an effect. The lines were, however, in the majority of the plates, unsymmetrically broadened with respect to the actual centre of intensity determined from the tips of the emission lines. These tips were nearer to the violet side of the bands, showing that the radiation was not symmetrical, and this asymmetry became more evident, the more intense became the line. This is indicated in two ways in the table of the velocities due to the bright hydrogen lines, first by the actual measure of the positions of the red edge of the tips, and of the violet edge of the bright $H\gamma$ lines, and second, by the smaller velocities given by the short exposure, less intense plates, as compared with the plates exposed for the absorption spectrum, in which the emission lines were much over-exposed.

RADIAL VELOCITIES, *o CETI.*

From $H\gamma$ Emission line.—Reduced to the Sun.

NO. OF PLATE	EXPOSURE TIME	OBSERVER	RED EDGE OF $H\gamma$ TO TIPS REVS.	TIPS OF $H\gamma$ TO VIOLET EDGE REVS.	RAD. VEL.	REMARKS
452	18 min.	H	·086	·073	+ 48·5	
486	19 "	H	·099	·083	51·1	
493	20 "	P	·088	·076	46·7	
515	30 "	P	·083	·056	52·2	
521	30 "	P	·091	·078	48·8	
534	40 "	H	·075	·070	51·1	
555	60 "	P	·102	·046	37·9	Abnormal? (Poor night and change of temp.)
563	20 "	P	.067	·068	43·0	
569	05 "	H			44·0	
579	20 "	P	·057	·055	45·4	
580	10 "	P	·057	·038	46·8	
581	05 "	P	·046	·047	44·3	
582	02 "	P			45·7	
583	01 "	P			40·1	

Mean of 14 plates = + 46·1

Mean of plates exposed for absorption spectrum = + 48·0

" " " " " emission spectrum only = + 44·2

These measures show a fair agreement among themselves, but this accordance is considerably increased when they are divided into two sets—of the strongly and moderately exposed plates,—and when plate No. 555 is omitted. It is abnormal in the marked asymmetry of the bright line, as shown by the measure in columns 4 and 5, and its low velocity may be due to the long exposure on a poor night, where an instrumental displacement might have occurred through change of temperature.

The mean of the first six, exposed for the absorption spectrum, is 49·9, and the mean of the last seven, exposed for the emission spectrum, is 44·2. This difference may be due to two causes, either an actual change in the position of the centre of intensity of the bright $H\gamma$, or an apparent change due an unsymmetrical broadening of the line on the plate, caused by the over exposure of a bright line whose curve of intensity is not similar on each side of the centre. In the case of the first six plates, in which the emission lines are over exposed, the velocity obtained is greater, indicating that the setting of the microscope wire had been further to the red than in the case of the last seven. Mr. Harper, to whom I am indebted for the measurement of these plates, tells me that in each case he set the wire as nearly as possible on the centre of the broad black line and no attention was paid to the tips. This would indicate that the emission line was slightly asymmetric towards the red, thus shifting the setting towards the red with increased exposure, and the displacement is not likely due to an actual change in the position of $H\gamma$ itself.

There is a remarkable agreement between the mean velocity 44·2 kms. obtained from the last 7 plates, and the mean velocity 44·4 kms. found by Prof. Campbell from 6 plates made by him in November 1898, when, as he says, the lines appeared nearly monochromatic, with a faint broadening or companion to the red side, practically of the same character as observed here. This would tend to show that the conditions in the star under which the bright $H\gamma$ lines are produced, tend to repeat themselves at different maxima, so far, at any rate, as the displacement is concerned, although the relative intensity of the different members of the H series is widely different.

No trace can be found, however, in these spectra of the bright Fe lines at 4308·081 and 4376·107, recorded by Profs. Campbell and Stebbins, but there are no fewer than 8 lines between $H\delta$ and λ 4235 which have every appearance of emission lines. They stand out as isolated narrow bright lines in a fairly uniform strip of absorption spectrum, with an intensity at least twice as great as the back ground of spectrum in which they lie, and are even shown prominently in the widened reproduction of plate 486. It seems hardly possible that they can be narrow strips of continuous spectrum left unabsorbed, as their width is generally less than half a tenth-metre. It may be said on the contrary, however, that they have not been identified with any one element, and that the nearest identifications, are of elements which have the most pronounced lines in the absorption spectrum There is an exception to this statement in the case of four of the lines which fall reasonably close to four lines in the spectrum of Cerium.

The wave-lengths, and the nearest metallic lines are as follows :—

BRIGHT LINES IN THE SPECTRUM OF *o CETI.*

NORMAL W.-L.	NEAREST METALLIC LINES.		
* 4233·36	4233·76 Fe,	4233·33 Mn Fe	
4229·51	4229·61 Fe,	4229·87 V	
4178·84	4178·54 V,	4179·45 Ce	
4173·58	4173·71 Ti,	4174·00 Fe,	4173·20 Fe
* 4165·84	4165·78 Ce,	4165·71 Cr,	4165·60 Fe
* 4138·53	4138·27 V,	4138·51 Ce,	4138·70 Mo
4119·56	4119·62 V,	4119·99 Ce,	4119·77 Mo, 4119·55 Fe
4102·95	4103·14 Mn		

The three lines marked with a star (*), are those which appear the most sharply defined and separated from the absorption spectrum, and which seem to be almost certainly emissive in character.

The normal wave-lengths, were obtained from the measured wave-lengths by subtracting the displacement equivalent to the velocity of the absorption lines. If the mean value of the velocity due to the bright *H* lines were applied to the normal wave lengths above given, they would be increased by 0·25 tenth metres. Owing to the distance from the centre of the spectrum and the consequent poor focus, the wave-lengths above given may be uncertain to the extent of one tenth of a tenth-metre, possibly more although the identifications of the absorption lines measured in that region agree to the same limit with the values in Rowland's table. It seems, therefore, impossible to certainly identify any of these lines with the metallic emission lines, though their appearance and their isolated positions in the general absorption in that region scarcely admit of any other interpretation of their character than the emissive one. A further evidence in this regard is their appearance in some of the other early spectra, in which the exposure was insufficient to show any but the faintest trace of absorption spectrum in the given region. Stebbins, in his paper found only one of the above lines as bright, λ 4233·36, but did not attempt any identification. He also finds λ 4178·84 as apparently bright, but considers it to be only a bright place between two absorption lines. He gives no record of the other lines registered as bright here, and evidently they were not visible in his spectra. Professor Campbell, in his observations says there is good reason to believe in a bright line at λ 4102·8, evidently the same as the one observed here at λ 4102·95. He also mentions one or two more as probably present on the violet side of *Hδ*, but no such lines can be seen in our spectra.

The absorption spectrum of *o Ceti* is of the banded type, Secchi's third, Miss Maury's XX., and has scarcely any recognizable similarity to the solar type. It is considerably different from *α Orionis* and even further advanced than *Herculis*. Its character is well shown by the identifications in the tables of measures of plates 486 and 515. The only absorbing elements present in the strong and best defined lines, those which were measured, are Ti, V, Fe, Mn, Cr, Ca also is present, and a stray *Mg* line appears in No. 515, which is undoubtedly the same line seen as distinctly bright by Stebbins. The first specified are those which are most strongly affected in the spectra of sun spots, and which, as Professor Hale and Mr. Adams have shown,* are much intensified in the spectrum of Arcturus and still more so in *α Orionis* as compared with their intensity in the sun. Apparently, they are even more prominent in *o Ceti* than in *α Orionis* as our measures have disclosed no other elements

* *Contributions of the Solar Observatory*, Nos. 8 and 12.

as certainly present in its spectrum. Stebbins doubts the presence of *Ti*, but the number of positive identifications in Nos. 486 and 515, and its analogy with the other sun spot elements. seem to offer conclusive evidence in its favor.

As the spectrum does not extend much below λ 5000, only the bands in the blue-green are shown, but they are distinctly marked, sharply limited towards the red if considered as bright bands. They are brighter than the neighboring bands, and fade off gradually towards the violet. There is one exception to this last statement however, the band beginning at λ 4626·0, which is of quite uniform intensity and sharply limited toward the violet at λ 4607·3. As the measures of plate 486 show, when the band was very distinctly and sharply limited, its edge was measured, and generally also the centre of intensity of the absorption line to the red side of the edge, but where not very sharply limited the absorption line at the red edge was measured. Taking these measures and estimating the distance of the edges from the measured positions, we get the following approximate wave lengths :—

4954·0	Red Edge of Band
4847·5	" " " "
4804·5	" " " "
4761·4	" " " "
4626·2	" " " "
4607·6	Violet Edge of above band
4584·2	Red Edge of Band

These measures are only given to the nearest tenth of a tenth-metre, as, owing to the poor focus in this region, they are not trustworthy beyond that limit.

The spectrum of *o Ceti* is very interesting, and will well repay a more extended study than has yet been given to it. Sufficient has been learned about it, however, to say that it is not necessarily identical at successive maxima, and this is very well shown by the behaviour of the $H\beta$ and $H\epsilon$ lines. It may be considered as well established now that it has a constant velocity of recession with respect to the sun of about

64 kms. per second and that the velocity determined from the bright hydrogen lines is some 15 kms. per second less. This difference of velocity is probably not real, the corresponding shift of the bright lines being produced by some other cause such as abnormal conditions of pressure, temperature, or electrical state in the atmosphere of the star.

The difference in the spectrum of *o Ceti* as observed here and at previous maxima may be summarized as follows:—

1. Absorption Spectrum.

Titanium, whose presence has been considered doubtful by Stebbins, is now very prominent as at least one fourth of the identifications of the prominent absorption lines measured in the two spectra appear to be due to this element.

The magnesium line at λ 4571, which was undoubtedly bright in 1902, is now, quite as undoubtedly represented by an absorption line, which was measured in plate 515, and gives a velocity displacement in close agreement with the mean.

The bands seem to end towards the violet at λ 4584, as in none of the negatives obtained here could any banded appearance be recognized below that limit. This is also clearly shown in the reproduction. The position of the bands in the blue green, however, agrees with Stebbins' values.

2. Emission Spectra.

Hβ which at previous maxima had either been invisible or faint, is now of a decidedly emissive character, apparently over half as intense as *Hγ*.

Hε recorded by Stebbins as bright in 1902, but previously invisible, cannot be seen in any plate made here.

There is no trace of the triple character of *Hγ* and *Hδ* observed by Campbell, but no plates were made here at as early a date in the period as those obtained by him. *Hβ*, *Hγ*, *Hδ* are slightly asymmetric, more intense to the red side of the true emission line, similar to the later plates obtained by Campbell.

No evidence, whatever, can be seen of the bright iron λ 4308 and λ 4376, observed by Campbell and Stebbins. The magnesium λ 4571 observed as distinctly bright by Stebbins is now represented by an absorption line. The bright lines λ 4202, λ 4216 and λ 4373, observed bright by Stebbins are not now present.

Eight other bright lines are present in some of the negatives obtained here at λ 4233·4, λ 4229·5, λ 4178·8, λ 4173·6, λ 4165·8, λ 4138·5, λ 4119·6 and λ 4102·9. Of these the first and last have been seen bright by Stebbins and Campbell, respectively, and the third Stebbins considers as a bright space between absorption lines. There is no doubt in my mind that the first, fifth and sixth are emissive, but of the others I do not feel so certain.

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