been found in the Nova; thus there are in our region 60 lines strong in \(\gamma\) Cygni and absent or weak in \(\alpha\) Cygni, and only 4 of these are found in the Nova. Adopting the step system of the Harvard notation, the spectrum of the Nova on 1912 March 15 between H\(\beta\) and H\(\delta\) might be described as \(\frac{3}{10}\) of the way from \(\alpha\) Cygni to \(\gamma\) Cygni, or briefly as \(a2y\). (The spectra of \(\alpha\) Cygni and \(\gamma\) Cygni are given in the \(R.H.P.\) as \(A2\) and \(F8p\) respectively.)

The elements represented by their enhanced spark lines are titanium (very strongly) and iron certainly; vanadium, scandium, and strontium most probably; and with much less certainty chromium and zirconium.

Radium, nitrogen, oxygen, silicon, and helium are not found in the spectrogram of March 15, either undisplaced or displaced along with the hydrogen, titanium, and iron.

With regard to the two bands so frequently identified with the helium lines at \(\lambda 4922\) and \(\lambda 5016\), the evidence points strongly to their being due to the enhanced iron lines at \(\lambda 4924, \lambda 5018\). They lie rather near the limit of good focus of the Cambridge plate, and the faint intensity makes measures on the edges of the absorption bands difficult; but the evidence from these measures and from the presence and absence of other lines in the Nova is in favour of the enhanced iron identification. This is supported by the comparison with \(\alpha\) Cygni, and by the persistence in later plates of the Nova of bright bands here and in the positions of other enhanced iron lines which are strong in \(\alpha\) Cygni. In this we agree with the views of Sir Norman Lockyer as to the sources of the corresponding lines in Nova Persei.

1913 March 10.


The recent experiments of Professor Fowler have demonstrated that, in important respects, hydrogen conforms in spectral behaviour with other elements. In particular, Rydberg's theoretical deduction of its Principal series has been confirmed in the laboratory. But that there is something peculiar in the hydrogen spectrum which distinguishes it from the known spectra of other substances, is at the same time shown by the discovery of a new ultra-violet series, tending to the same limit as the Principal series. The variable part of this new series is practically identical with that of the Sharp series found by Pickering.

No other element is at present known to show a second Principal series of this type, nor, in fact, of any type which tends to the same limit as the ordinary Principal series. That such series do not exist in other elements is not of course proved by their absence in terrestrial spectra—especially in view of the special conditions
under which the ordinary Principal series of hydrogen has been obtained after a long search in the laboratory.

But, on the other hand, these conditions, in Professor Fowler's experiments, have produced both the Principal series strongly at the same time, and the argument is suggested that other elements would, if they possessed two Principal series, show them simultaneously. If helium and parhelium possessed a second series, some of the lines would necessarily be in the visible spectrum, for their Principal series tend to the limits $\lambda = 3121\cdot8$, 2600 six—and, except for two lines in the infra-red, their spectra have been completely fitted into the more usual series.

Thus there is a strong possibility that the spectrum of hydrogen is exceptional, and it is instructive to examine the possibility of other series which it may show—leaving out of account the vacuum tube or secondary spectrum whose origin is still a matter of dispute. The accuracy of the Balmer formula

$$\lambda = \lambda_0 \frac{m^2}{m^2 - 4}$$

and of the formula for the Pickering lines

$$\lambda = \lambda_0 \frac{(m + \frac{1}{2})^2}{(m + \frac{1}{2})^2 - 4}$$

suggests the possibility of other lines given by

$$\lambda = \lambda_0 \frac{(m \pm \frac{1}{2})^2}{(m \pm \frac{1}{2})^2 - 4}$$

where $\lambda_0 = 3647$. If these lines have an existence, it is natural to expect them under conditions which produce the Pickering lines strongly. Of the various stars which show the Pickering lines, the class of Wolf-Rayet stars may be selected as the most favourable for this examination. Campbell has given a table of the centres of the Wolf-Rayet bands, from which the following is an extract, containing all those marked as strong.*

The intensities are in two divisions, denoted by (1) and (2), and the Pickering lines are very conspicuous:

<table>
<thead>
<tr>
<th>$\lambda$</th>
<th>Identification.</th>
<th>$\lambda$</th>
<th>Identification.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5877 (1)</td>
<td>$D_\alpha$, helium</td>
<td>4517 (1)</td>
<td>...</td>
</tr>
<tr>
<td>5813 (2)</td>
<td>...</td>
<td>4509 (2)</td>
<td>...</td>
</tr>
<tr>
<td>5093 (2)</td>
<td>...</td>
<td>4504 (1)</td>
<td>...</td>
</tr>
<tr>
<td>5593 (1)</td>
<td>...</td>
<td>4480 (1)</td>
<td>[4481] Nova Aurigae</td>
</tr>
<tr>
<td>5472 (1)</td>
<td>...</td>
<td>4473 (1)</td>
<td>Helium</td>
</tr>
<tr>
<td>5412 (2)</td>
<td>$H$ (Pickering)</td>
<td>4466 (1)</td>
<td>...</td>
</tr>
<tr>
<td>4862 (2)</td>
<td>$H\beta$</td>
<td>4442 (2)</td>
<td>[4445] Nova Aurigae</td>
</tr>
<tr>
<td>4688 (2)</td>
<td>$H$ (Rydberg)</td>
<td>4389 (1)</td>
<td>Helium</td>
</tr>
<tr>
<td>4652 (2)</td>
<td>Nova Persei</td>
<td>4341 (2)</td>
<td>$H_\alpha$</td>
</tr>
<tr>
<td>4636 (1)</td>
<td>...</td>
<td>4102 (2)</td>
<td>$H_\beta$</td>
</tr>
<tr>
<td>4626 (1)</td>
<td>[4629] Nova Aurigae</td>
<td>4063 (1)</td>
<td>[4067] Nova Aurigae</td>
</tr>
<tr>
<td>4541 (2)</td>
<td>$H$ (Pickering)</td>
<td>4023 (1)</td>
<td>Helium [4026]</td>
</tr>
</tbody>
</table>

The correspondences detected by Campbell with centres of strong
Nova bands are also indicated in the table, and also a strong cor-
respondence with a line in the later stages of Nova Persei.

Eight important lines remain which exhibit no certain relation
to any other type of spectrum, and which seem to be peculiar to
these stars.

Consider now the simple formula

$$\lambda = 3646 \frac{m^2}{m^2 - 9}$$

where $m = 5, 7$. This gives the lines $\lambda = 5696.5, 4466.3$, which are
coincident, within the experimental degree of error in the two
regions of the spectrum, with two of these eight lines. The degree
of possible error is found by an inspection of the measurements
of the hydrogen lines.

Accurate measurements of the Balmer series indicate that the
ture hydrogen limit is $\lambda_0 = 3647.14$, and the limit of the Pickering
series, derived from Professor Fowler's measurements, is $\lambda_0 = 3645.6$.
The values of Rydberg's constant $\mu$ in the Sharp series is not exactly $\frac{1}{2}$, but $0.4996$. We may expect similar small divergences
in the present case, especially since the observed lines can be in
error by a tenth metre. The lines $\lambda = 5693, 4466$ may be used to
determine the constants in a Rydberg formula, and there results

$$\lambda = 3646.59 \frac{(m+0.0036)^2}{(m+0.0036)^2 - 9},$$

with a limit even closer to Balmer's limit than that of the Sharp
series. A change of one-tenth metre in the first line makes a much
smaller value of $\mu$.

This formula gives no other lines falling in the observed range
of the Wolf-Rayet spectrum, except such as coincide with the more
usual hydrogen lines, so that the existence of the series cannot be
tested further. It is a special case of the two series

$$\lambda = \lambda_0 \frac{(m+\frac{1}{2})^2}{(m+\frac{1}{2})^2 - 4}, \quad \lambda = \lambda_0 \frac{(m-\frac{1}{2})^2}{(m-\frac{1}{2})^2 - 4},$$

where $m = 3$ in the first series, and $m = 5$ in the second, give the
two lines. The leading members of the first series

$$\lambda = 3646.5 \frac{(m+\frac{1}{2})^2}{(m+\frac{1}{2})^2 - 4}$$

are

$\lambda = 5695 \quad \lambda = 4633.8 \quad \lambda = 4243 \quad \lambda = 4050.6$, 

and the second of these is again very close to the observed centre
$\lambda = 4636$ of a bright band in the Wolf-Rayet stars—a band without
any identification at present.

But a more convincing argument for its origin from hydrogen is
found in an examination of the stars of types Oa, Ob, Oc in the
Harvard classification.* The bright lines in these stars are $\text{H}_\alpha$, $\text{H}_\beta$, $\text{H}_\gamma$, $\text{H}_\delta$, $\text{H}_\epsilon$, the Pickering lines $\text{H}_\gamma'$, $\text{H}_\delta'$, $\text{H}_\epsilon'$, and additional lines at $\lambda = 4633, 4688, 4472, 4059$. The third is weak, and due to helium. The second is the Rydberg line of hydrogen. These stars apparently, with the exception of a weak helium line, show mainly hydrogen, and it is a tempting hypothesis to suppose that $\lambda 4633$ and $\lambda 4059$ are due to hydrogen in an unusual condition.

The accuracy of determination of the Wolf-Rayet lines does not appear to preclude the identity of $\lambda 4636$ and $\lambda 4633$.

The leading members of the second series

$$\lambda = 3646 \cdot 5 \frac{(m - \frac{1}{3})^2}{(m - \frac{1}{3})^2 - 4}$$

are

$$\lambda = 4 \quad m = 5 \quad m = 6 \quad m = 7$$

$$\lambda = 5191 \quad \lambda = 4466 \quad \lambda = 4165 \cdot 6 \quad \lambda = 4007 \cdot 4$$

The first has not been found, and the second has been discussed. If a more extended investigation of the spectrum should reveal the first, the argument would be greatly strengthened.

All the lines included in

$$\lambda = \lambda_0 \frac{m^2}{m^2 - 9}, \quad \lambda = \lambda_0 \frac{m^2}{m^2 - 36}$$

where $m$ takes integral values, not forming part of the systems of Balmer and Pickering, have now been examined.

The intermediate series

$$\lambda = \lambda_0 \frac{m^2}{m^2 - 25},$$

where $\lambda = 3646 \cdot 5$, has, for its chief line in the visible spectrum, not included in other series, $\lambda = 4596$ corresponding to $m = 11$. This is also a Wolf-Rayet line of unknown origin, but of somewhat lower intensity than those given in the foregoing list.

It seems probable that all the lines

$$\lambda = \lambda_0 \frac{m^2}{m^2 - p^2},$$

where $m$ and $p$ take integral values, are included in the astrophysical spectrum of hydrogen. A more exhaustive study of the Wolf-Rayet spectrum from the experimental side is necessary, and especially a search for weaker lines, before this suggestion can be confirmed. But it supplies a very probable origin for the lines

$$\lambda \lambda 5693, 4466, 4634, 4596,$$

which are associated with unusual brightness of the Sharp series of hydrogen.

Total Eclipse of the Sun, 1912 October 10. Report on an Expedition to Passa Quatro, Minas Geraes, Brazil. By A. S. Eddington and C. Davidson.

(Communicated by the Astronomer Royal.)

An expedition to observe the total solar eclipse of 1912 October 10 having been sanctioned by the Admiralty, the Royal Observatory party proceeded to Passa Quatro, a village about 180 miles by railway from Rio de Janeiro.

The party were much indebted to the Brazilian Government for their hospitality and liberal assistance. The observers were entertained as the guests of the country during their stay; and free conveyance on the railways was provided for them and their instruments. They were also much indebted to Dr. Morize, Director of the Rio Observatory, for the arrangements made for their comfort, and for much general assistance.

Valuable assistance was rendered by Mr. J. J. Atkinson, who went with the expedition from England, and by Mr. O. Couto de Aguirre and Mr. Leslie Andrews, who joined them at Passa Quatro on October 3; they joined in all the work of the expedition, erection and adjustment of the instruments, etc.

Acknowledgments are also due to the Royal Mail Steam Packet Company, who conveyed the instruments and other baggage free of charge.

The party landed at Rio de Janeiro on September 16. Owing to various delays with the heavy baggage, Passa Quatro was not reached until September 22, and it was not possible to make a start with the preparation of the instruments until September 24. On that day brick piers were built by local workmen to carry the ceolostats and heliostat. Three huts, of light wooden frames covered with Willesden waterproof canvas, were taken out from Greenwich and erected. One of these contained the instruments fed by ceolostats; a second contained the spectrograph and heliostat, and was consequently placed with its length nearly at right angles to the first; the third was made tight-tight and formed a very satisfactory developing hut.

The charge of the instruments was distributed as follows:—
Thompson coronograph—Mr. Eddington.
Six-inch refractor with green colour filter—Mr. Aguirre.
Six-inch triplet with green colour filter—Mr. Andrews.
Spectrograph—Mr. Davidson, assisted by Mr. Atkinson.
M. Pierre Seux kindly volunteered to count seconds during totality.

Rehearsals were started on October 7, and repeated at frequent intervals during the next two days.

The weather during the three weeks preceding the eclipse was on the whole very favourable. Rain, however, set in at noon on the day before, and continued without intermission all through