The intensities are again those of Watson,* which are not in close agreement with those of Merton and Barratt † in all cases. The latter are more in accord with the arrangement suggested. We notice that lines beyond \( \lambda 6000 \) not belonging to the Fulcher bands come into the scheme.

It should also be added that the lines in these two groupings I. and II., and (a) and (b)—which naturally have certain members in common, as forming parts of a series arrangement—appear to be the lines most characteristically unaffected by the presence of helium. This fact alone suggests that they are related, and agrees with the observations of Frost,‡ and some later plates taken by Merton and Nicholson, but not published.

Our general conclusion is that the lines of the secondary spectrum of hydrogen are of two main classes. Those which show no Zeeman effect are band-lines of wide separation, of molecular origin. Those which show the effect belong to a series spectrum of some complexity, of a type nearer to that of neon than to that of helium, and quite possibly of an atomic origin and with some degree of representation in celestial spectra.

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On a Method for deducing approximately the Focal Lengths and Magnifying Powers of Early Telescopes. By S. B. Gaythorpe.

Of the early telescopes little is known. Very few of those primitive instruments have been preserved, and contemporary accounts record little more than the magnifying power, with here and there a rough estimate of the radii of curvature of the lenses. If, however, a telescope has been applied to the observation of the sun by projection, and measurements are available, it will nearly always be possible to deduce approximately the magnifying power, and sometimes also the focal lengths of the lenses.

In the present paper it is proposed to develop this method of inquiry, and illustrate it by application to a telescope of the Galilean type, used (1640–41) by William Gascoigne, the inventor of the micrometer.

If \( \beta \) denote the linear semi-diameter of an object, and \( \beta' \) that of the final image formed by a system of two lenses, then it can be shown that

\[
\beta' = \frac{\beta x' y'}{xy'}
\]

where \( x, y \) are the distances of the object and the final image from the outer principal points of the first and second lenses respectively, and \( x', y' \) the foci conjugate to those respective distances, measured from the inner principal points in the usual way. The distance, \( c \), between the two lenses will accordingly be \( x' + y' \).

Now, in the case of the sun, $x'$ becomes the principal focal length, $f'$, of the first lens, or object-glass, while $\beta/x$ is the tangent of the sun's apparent semi-diameter, $a$. Hence

$$\beta' = \frac{fy \tan a}{y'} \quad \text{.} \quad \text{(ii)}$$

Further, it can be shown that if $f'$ denote the principal focal length of the second, or eye-, lens,

$$\frac{1}{f'} = \frac{1}{y'} + \frac{1}{y} \quad \text{.} \quad \text{(iii)}$$

Hence, if both lenses are collective, as in the Keplerian telescope, $y'$, and therefore $\beta'$, are both positive, and the final image is erect; but if the second lens is dispersive, as in the Galilean telescope, $f'$, $y'$, and $\beta'$ are all negative, and the image is inverted.

If the diameter of the solar image and its distance from the eye-lens are known, as also the distance between the two lenses, their principal focal lengths can be found from equations (ii) and (iii) and the relation $c=x'+y'$, as follows:

$$y'\beta' = \beta'c - \beta'f = fy \tan a \quad ; \quad \text{hence} \quad f(\beta'+y \tan a) = \beta'c, \quad \text{or}$$

$$f = \frac{c}{1+y \tan a} \quad \frac{1}{\beta'} \quad \text{.} \quad \text{(iv)}$$

In the case of the Keplerian telescope, the denominator is greater, and in the case of the Galilean, less than unity. Hence, in the former, the focal length of the object-glass is less, while, in the latter, it is greater than the distance between the lenses.

Lastly,

$$y' = c - f = \frac{fy \tan a}{\beta'} \quad \text{.} \quad \text{(v)}$$

and

$$f' = \frac{yy'}{y+y'} \quad \text{.} \quad \text{(vi)}$$

When the data are insufficient for a solution of the above equations, an approximate value of the magnifying power may still be found. Substituting for $y'$ in equation (ii) its equivalent $\frac{f'y}{y-f}$ we have

$$\beta' = \frac{fy - ff'}{f'} \tan a \quad ; \quad \text{But} \quad f/f' \quad \text{is the magnifying power,} \quad m. \quad \text{Hence}$$

$$\beta' = (mf - f) \tan a \quad \text{.} \quad \text{(vii)}$$

In the case of the Galilean telescope, $m$, being the ratio of a positive and a negative quantity, must be regarded as negative; and so not only is the image inverted, as we have already seen, but also for an equal distance, $y$, from the eye-lens, its semi-diameter is larger by $2f \tan a$ than that of the corresponding image formed by a Keplerian telescope.
with lenses of the same focal lengths, and consequently of equal magnifying power. As, in addition to the larger image, the total length of the combination is shorter in the case of the former by nearly twice the focal length of the eye-lens, it is evident that in the early days of the telescope, and for the purpose under consideration, the Galilean type possessed advantages over the Keplerian, other than the superior distinctness of the image mentioned by Professor Grant (Hist. of Phys. Astronomy, p. 525).

In his second letter to Oughtred, not dated, but probably written in 1641 February, printed in Rigaud's Corresp. of Sci. Men, 1, 35-59, Gascoigne gives the following measurements of two "London best sale glasses," which he used as a Galilean telescope:—

**Object-glass (plano-convex).**

| Diameter  | 1·2 inches |
| Thickness | 0·105 "    |
| Radius of Curvature | 25·8 |
| Refractive Index | sin 2° 5' 52"/sin 1° 19' 56". |

This makes $\mu = 1·5744$, whence $f = r/\mu - 1 = 44·91$ inches.

**Eye-lens (plano-concave).**

| Diameter  | 0·75 inches |
| Thickness | 0·055 "    |
| Radius of curvature | 2·17 " |
| Refractive Index (first determination) | sin 15°·40/sin 9°·95. |
| " (second) | sin 15°·2449/sin 9°·8047. |

The first of these values gives $\mu = 1·5369$, and the second, 1·5441. The mean is 1·5405, whence $f'' = -4·915$ inches, and $m = f/f'' = 11·19$.

The same letter also contains the following measurements of the semi-diameter of the solar image, its distance from the concave surface of the eye-lens, and the distance apart of the two lenses, in three observations, dated 1640 October 31, December 18, and 1640-41 January 20, O.S.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1</td>
<td>6·00</td>
<td>110·21</td>
<td>40·91</td>
<td>15 12.3</td>
</tr>
<tr>
<td>2</td>
<td>2·50</td>
<td>43·07</td>
<td>40·97</td>
<td>16 17·8</td>
</tr>
<tr>
<td>3</td>
<td>6·00</td>
<td>109·46</td>
<td>40·85</td>
<td>16 14·7</td>
</tr>
</tbody>
</table>

The figures in the last column have been computed for the given dates from the Nautical Almanac value of the sun's mean apparent semi-diameter and approximate values of the orbital elements. It would, however, have been sufficient to take the figures directly from the Nautical Almanac for the dates most nearly corresponding to those of the observations.

It should be mentioned that the lenses were so arranged that their
plane surfaces were directed towards the object. As the distances in
the last column but one were measured from the convex surface of
the object-glass to the plane surface of the eye-lens, they require to
be increased by 0.036, or the thickness of the latter divided by its
refractive index.

This adjustment having been made, a solution of the equations
gives the following results:—

<table>
<thead>
<tr>
<th>Obs.</th>
<th>(f) (inches)</th>
<th>(f') (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>44.83</td>
<td>-4.02</td>
</tr>
<tr>
<td>2</td>
<td>44.65</td>
<td>3.98</td>
</tr>
<tr>
<td>3</td>
<td>44.74</td>
<td>4.00</td>
</tr>
</tbody>
</table>

The mean values are \(f=44.74\) and \(f'=-4.00\), whence \(m=11.185\).
The refractive indices corresponding to these values of \(f\) and \(f'\), and the
radii of curvature already given, are 1.5767 and 1.5425 for the object-
glass and eye-lens respectively, differing from Gascoigne’s independent
determinations by quantities of the order of 0.002.

As a further illustration of the method, let us take the telescope
specified by Flamsteed in his first communication to the Royal
Society, dated 1669 November 24 (Rigaud’s Corresp. of Sci. Men
2, 80), where he advises the observers of solar eclipses “to cast
the species of the sun through a telescope of at least two feet, free
from spots and colours, on an extended paper placed at least six
feet behind the eye-glass, or so far as that his species may appear
at least six inches over. . . .”

There is nothing to show whether the telescope was to be of the
Keplerian or Galilean type. We have, therefore, \(\beta'=+3\) or \(-3\), \(y=72\),
and \(a\) (mean) 16' 1".8. Taking an approximate value for \(f\), we find
from equation (vii) that the magnifying power would be about 9.2 for
a Keplerian and 8.6 for a Galilean telescope. Further, we find that
\(f\) would be between 21 and 22 in the case of the former, and about
27 in the case of the latter. As with a focal length of only 21 or 22 a
power as high as 9 seems unlikely, it is probable that the telescope
Flamsteed had in mind was of the Galilean type. On this assumption,
taking \(c=24\), we obtain as the foci of the two lenses 27.0 and -3.15
respectively, and 8.57 as the magnifying power.


The photometric observations of Nova which follow are in con-
tinuation of those made and published in previous years, the same
comparison stars having been used in each case. Nearly all the obser-
vations were made with powers of 120 or 280 on the 6-inch Wray
refractor.

Nova Cassiopeiae (1572).

The field of this Nova was examined on 11 nights during the
year, but no changes were noted in the magnitudes of the small stars