1856MNRAS..17...12P



## *Magnitudes of Thirty-six of the Minor Planets for the First Day of each Month of the Year* 1857. By Norman Pogson, Esq., Assistant at the Radcliffe Observatory, Oxford.

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| No. | Planet. | M. | Jan. | Feb. | Mar. | Aprl. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | 1858. Jan. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ceres...... | 7·5 | 7·4 | 7·1 | 7·1 | 7·4 | 7·8 | 8·1 | 8·4 | 8·6 | 8·8 | 8·9 | 9·0 | 8·9 | 8·8 |
| 2 | Pallas...... | 7·9 | 6·8 | 6·7 | 6·8 | 7·1 | 7·6 | 8·0 | 8·4 | 8·7 | 9·0 | 9·1 | 9·2 | 9·2 | 9·1 |
| 3 | Juno ...... | 8·7 | 9·4 | 9·4 | 9·5 | 9·4 | 9·4 | 9·3 | 9·2 | 9·1 | 9·0 | 8·8 | 8·6 | 8·3 | 8·1 |
| 4 | Vesta...... | 6·4 | 7·0 | 7·3 | 7·6 | 8·0 | 8·2 | 8·4 | 8·5 | 8·5 | 8·4 | 8·3 | 8·1 | 7·8 | 7·5 |
| 5 | Astræa .... | 9·9 | 12·2 | 12·3 | 12·3 | 12·2 | 12·0 | 11·8 | 11·4 | 11·0 | 10·6 | 10·3 | 10·2 | 10·4 | 10·6 |
| 6 | Hebe ...... | 8·5 | 9·2 | 9·1 | 9·2 | 9·6 | 10·0 | 10·4 | 10·7 | 10·9 | 11·0 | 11·1 | 11·0 | 10·9 | 10·7 |
| 7 | Isis........ | 8·5 | 10·5 | 10·2 | 9·9 | 9·7 | 9·7 | 9·9 | 10·3 | 10·6 | 10·8 | 11·0 | 11·1 | 11·1 | 11·0 |
| 8 | Flora ...... | 8·7 | 10·4 | 10·4 | 10·4 | 10·3 | 10·2 | 10·1 | 9·9 | 9·7 | 9·5 | 9·3 | 8·9 | 8·6 | 8·4 |
| 9 | Metis...... | 8·7 | 10·5 | 10·6 | 10·5 | 10·5 | 10·3 | 10·1 | 9·9 | 9·5 | 9·1 | 8·7 | 8·2 | 7·9 | 8·0 |
| 10 | Hygeia .... | 9·8 | 11·1 | 11·3 | 11·4 | 11·4 | 11·4 | 11·3 | 11·1 | 10·9 | 10·6 | 10·3 | 10·3 | 10·4 | 10·7 |
| 11 | Parthenope . | 9·6 | 10·6 | 10·2 | 10·1 | 10·3 | 10·6 | 11·0 | 11·2 | 11·4 | 11·5 | 11·6 | 11·5 | 11·4 | 11·3 |
| 12 | Victoria .... | 9·8 | 11·2 | 10·9 | 10·5 | 10·1 | 9·6 | 9·1 | 8·7 | 8·4 | 8·4 | 8·9 | 9·5 | 10·1 | 10·6 |
| 13 | Egeria ..... | 9·7 | 11·4 | 11·2 | 11·0 | 10·7 | 10·3 | 10·1 | 10·2 | 10·4 | 10·8 | 11·1 | 11·4 | 11·6 | 11·7 |
| 14 | Irene ...... | 9·8 | 11·8 | 12·0 | 12·1 | 12·1 | 12·1 | 11·9 | 11·7 | 11·4 | 11·1 | 10·7 | 10·4 | 10·3 | 10·5 |
| 15 | Eunomia ... | 8·5 | 8·2 | 8·7 | 9·0 | 9·3 | 9·6 | 9·8 | 9·9 | 10·0 | 10·0 | 9·9 | 9·8 | 9·6 | 9·3 |
| 16 | Psyche..... | 10·0 | 10·7 | 10·5 | 10·5 | 10·7 | 11·1 | 11·4 | 11·7 | 11·9 | 12·0 | 12·0 | 12·0 | 11·9 | 11·7 |
| 17 | Thetis ..... | 9·9 | 11·3 | 11·3 | 11·3 | 11·2 | 11·0 | 10·8 | 10·5 | 10·2 | 10·0 | 10·0 | 10·3 | 10·7 | 11·2 |
| 18 | Melpomene . | 9·4 | 9·0 | 9·6 | 10·1 | 10·6 | 10·9 | 11·2 | 11·5 | 11·6 | 11·7 | 11·7 | 11·6 | 11·4 | 11·1 |
| 19 | Fortuna .... | 9·5 | 9·6 | 10·0 | 10·3 | 10·6 | 10·8 | 11·0 | 11·1 | 11·2 | 11·2 | 11·1 | 11·0 | 10·7 | 10·4 |
| 20 | Massilia.... | 9·2 | 9·1 | 9·5 | 9·8 | 10·1 | 10·3 | 10·4 | 10·6 | 10·7 | 10·7 | 10·7 | 10·6 | 10·5 | 10·3 |
| 21 | Lutetia .... | 10·5 | 10·9 | 11·4 | 11·8 | 12·2 | 12·5 | 12·7 | 12·8 | 12·9 | 12·9 | 12·8 | 12·6 | 12·3 | 12·0 |
| 22 | Calliope.... | 10·2 | 11·1 | 11·3 | 11·4 | 11·4 | 11·4 | 11·3 | 11·1 | 10·9 | 10·6 | 10·3 | 9·9 | 9·7 | 9·7 |
| 23 | Thalia ..... | 10·7 | 11·0 | 11·3 | 11·4 | 11·5 | 11·6 | 11·6 | 11·5 | 11·5 | 11·4 | 11·3 | 11·1 | 10·9 | 10·7 |
| 24 | Themis .... | 11·6 | 12·3 | 12·6 | 12·8 | 12·9 | 12·9 | 12·9 | 12·8 | 12·6 | 12·4 | 12·1 | 11·7 | 11·3 | 11·1 |
| 25 | Phocea..... | 10·7 | 12·0 | 11·6 | 11·1 | 10·6 | 10·0 | 9·5 | 9·2 | 9·2 | 9·5 | 9·9 | 10·4 | 10·9 | 11·3 |
| 26 | Proserpine.. | 10·8 | 11·3 | 10·9 | 10·6 | 10·6 | 10·9 | 11·2 | 11·5 | 11·8 | 12·0 | 12·1 | 12·2 | 12·2 | 12·1 |
| 27 | Euterpe.... | 10·2 | 11·7 | 11·8 | 11·8 | 11·8 | 11·7 | 11·6 | 11·4 | 11·2 | 11·0 | 10·8 | 10·4 | 10·1 | 9·7 |
| 28 | Bellona .... | 10·3 | 11·7 | 11·9 | 11·9 | 12·0 | 11·9 | 11·7 | 11·5 | 11·3 | 10·9 | 10·5 | 10·1 | 9·7 | 9·6 |
| 29 | Amphitrite . | 9·1 | 9·0 | 9·4 | 9·8 | 10·1 | 10·4 | 10·6 | 10·7 | 10·8 | 10·8 | 10·8 | 10·6 | 10·4 | 10·1 |
| 30 | Urania..... | 10·1 | 12·1 | 11·8 | 11·5 | 11·1 | 10·8 | 10·7 | 11·0 | 11·3 | 11·6 | 11·8 | 12·0 | 12·1 | 12·1 |
| 31 | Euphrosyne. | 11·3 | 12·6 | 12·4 | 12·1 | 11·9 | 11·8 | 12·0 | 12·3 | 12·6 | 12·9 | 13·2 | 13·3 | 13·4 | 13·4 |
| 32 | Pomona .... | 11·0 | 12·4 | 12·2 | 12·0 | 11·7 | 11·4 | 11·1 | 10·9 | 11·1 | 11·5 | 11·9 | 12·3 | 12·6 | 12·8 |
| 33 | Polyhymnia. | 11·2 | 13·2 | 12·9 | 12·7 | 12·7 | 12·8 | 13·1 | 13·3 | 13·4 | 13·5 | 13·5 | 13·4 | 13·3 | 13·0 |
| 34 | Circe ...... | 11·6 | 13·5 | 13·6 | 13·7 | 13·6 | 13·5 | 13·3 | 13·0 | 12·7 | 12·3 | 12·0 | 11·8 | 12·0 | 12·3 |
| 35 | Atalanta.... | 12·5 | 13·1 | 12·9 | 12·9 | 13·1 | 13·6 | 14·0 | 14·4 | 14·6 | 14·8 | 15·0 | 15·0 | 14·9 | 14·8 |
| 36 | Fides ...... | 10·8 | 11·0 | 10·7 | 10·7 | 11·0 | 11·4 | 11·9 | 12·3 | 12·6 | 12·8 | 12·9 | 13·0 | 13·0 | 12·9 |

The column headed M in the preceding table gives the mean opposition-magnitudes for the thirty-six minor planets, ephemerides of which have been published in the supplement to the *Nautical Almanac* for 1860; *i. e.* the magnitudes such planets would have, if when in opposition both they and the Earth were at mean distance from the sun. These numbers have, for the most part, been deduced from estimated magnitudes near opposition, reduced to mean distance; and when such could not be obtained from my own or other observations, the values given by Prof. Argelander and

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1856MNRAS..17...12P



Dr. Bruhns, in their papers on the subject, have been adopted. (*Astronomische Nachrichten*, Nos. 928 and 1047.) The other columns furnish the magnitudes of the planets for the first day of each month, calculated on the assumed ratio of the light of 2·512, *i. e.* that a star of any magnitude, as for instance the eighth, contains 2·512 times the light of the next less, or ninth magnitude. A comparison of the brightest predicted magnitude of any planet with the number in column M, will show whether such planet is favourably situated for observation in the year 1857 or not. Thus, for *Polyhymnia*, which comes in opposition about the middle of March, when a little past its aphelion passage, the brightest magnitude will be 12·7, or 1·5 magnitude fainter than if at mean distance; while for *Phocea*, which will be very favourably situated at its opposition in July, the sun being in apogee and *Phocea* in perihelion, the magnitude will be 1·5 brighter than at mean distance. It must, however, be remembered, that an error in the assumed value of M for any planet will cause a corresponding error in the ephemeris throughout the year, and at present these quantities are by no means satisfactorily determined, especially for the more recently discovered planets. But, perhaps, the greatest use of such an ephemeris will be on the occasion of the earliest observations after conjunction, when an approximate knowledge of the magnitude may save the annoyance of mistaking an adjacent star for the object sought, an accident of too common occurrence even to experienced observers. Six planets have been omitted for want of ephemerides: for one of these, *Daphne*, no elements have yet been computed. For the remaining five, the numbers M may be taken as follows:—*Leucothœa*, 12·5; *Leda*, 11·5; *Lœtitia*, 8·8; *Harmonia*, 8·5; and *Isis*, 10·3. Their magnitudes at any time may then be found by the formula,—

$$m = \mathrm{M} - 5 \log (a \,.\, \overline{a-1}) + 5 (\log r + \log \Delta).$$

The magnitude-ephemeris will also be a severe test of the truth of the adopted light ratio; for if that ratio be really the one employed by the majority of observers, the correction for any one planet will be the constant one due to the number in the column M; but if, on the contrary, the ratio should be false, the ephemeris will run wide of truth, especially as each planet approaches conjunction, but this I do not anticipate.

The considerations which led to the adoption of the light ratio here employed were as follows:—I had read with much interest the remarks made by the Rev. W. R. Dawes, in the *Monthly Notices*, vol. xi. pages 187–198, and intended to make use of his proposed ratio of 4, when the very different result of 2·43, obtained by Mr. Johnson from his heliometric equalisation experiments, as given in his appendix to vol. xii. of the *Radcliffe Observations*, on the 'Photometry of Stars,' threw uncertainty upon a matter I had regarded as settled. The subject being one of especial importance in the pursuits which had occupied most of my leisure hours, viz., chart-making and variable star-observing, I at once set to work with a little modification of the method of reduced apertures,

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1856MNRAS..17...12P

to see which result my own observations would yield the nearest approximation to. I must even confess to having entertained at starting a little bias in favour of the ratio given by Mr. Dawes. Instead of reducing stars to a *minimum visible*, their total extinction was preferred, as being more certain. Having found by trial the apertures with which certain stars of assumed magnitude were lost sight of, these measures were grouped together, and submitted to the formula,—

$$(M - m) \log R = 2 (\log A - \log a).$$

in which R is the required ratio; M, *m*, the magnitudes of stars as widely different as possible, and A, *a*, the respective apertures with which each star vanished. The assumed magnitudes were taken from the *Radcliffe Observations*, from the zones of Argelander and Bessel, and from the catalogues of Piazzi, Lalande, and Groombridge, so as to find the ratio of each observer separately. The ratios thus found were remarkably accordant: the mean of all, 2·4. This result, derived by a perfectly independent method, was an unexpected verification of Mr. Johnson's ratio of 2·43. (The decreasing ratio of 0·412 was given by Mr. Johnson, but I prefer using its reciprocal.) Shortly afterwards I learnt that Steinheil, of Munich, had deduced a ratio of 2·83, by experiments upon 26 stars between the 1st and 4th magnitudes. Prof. Stampfer found, from 132 stars between the 4th and 9·5 magnitudes, a ratio of 2·519. Finally, Argelander has endorsed this ratio with his high authority upon such matters, by adopting it as the basis of his formulæ for computing the magnitudes of the minor planets. It signifies little which of these ratios is adopted in dealing with the ranges of ordinary telescopes. I selected 2·512 for convenience of calculation, as the reciprocal of $\frac{1}{2}$ log R, a constant continually occurring in photometric formulæ, is in this case exactly 5. If then any observer will determine for himself the smallest of Argelander's magnitudes just discernible by fits, on a fine moonless night, with an aperture of one inch, and call this quantity L, or the limit of vision for one inch, the limit *l*, for any other aperture, will be given for the simple formula,—$l = L + 5 \times \log$ aperture.

Numerous comparisons, made with various telescopes and powers, at different seasons of the year, have furnished me with the value $L = 9{\cdot}2$ for my own sight, which is, I believe, a very average one, and therefore suitable for such a determination. As a verification of these results, Mr. Hind, who has extended Bessel's scale downwards in the construction of Mr. Bishop's Ecliptical Charts, has considered that with the South Villa equatoreal of 7 inches aperture, "a faint glimmering," to use his own words, was about a 13 or 13·14 magnitude. By the formula, we have for 7 inches, $l = 9{\cdot}2 + 5 \log 7 = 13{\cdot}4$ magnitude. Again, a 6th magnitude of Argelander is, *by trial*, my limit for an aperture of 0·23 inch. The formula gives for such an aperture, $l = 9{\cdot}2 + 5 \log 0{\cdot}23 = 6{\cdot}0$ magnitude.

It appears, then, that whatever they may have intended, nearly all the great catalogue-makers have involuntarily fallen into this ratio, or one so nearly the same as to be practically identical.

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1856MNRAS..17...12P



True, they have not all adopted precisely the same standard of brightness for any one magnitude, but if we take Argelander's 8th or 9th magnitudes and this ratio, all will be sufficiently close to fall considerably within the errors of estimation. Lalande's 6ths and 7ths are perhaps the most out; the rest present on the whole very fair agreement.

It remains to treat of those who have adopted a different ratio. Struve has divided the stars between the limits of naked-eye vision and of his 15-inch refractor into 6 magnitudes, *i. e.* he has made 12th magnitude the limit of vision for his instrument. The formula gives 15·1 magnitude for its limit. Mr. Dawes has adopted Struve's magnitudes, and therefore the same table will apply to both. Mr. Bond, with a similar telescope, has gone to the 20th magnitude, starting from Bessel's 9th magnitude. But according to the proportional apertures given for stars from the 9th to the 12th magnitudes on page liv. of the Introduction to the *Harvard Zone Observations*, he has not followed any fixed ratio in these four magnitudes, so all that can done is to tabulate for these, and simply interpolate between his 12ths and 20ths. For Sir John Herschel's estimates I must assume, as in Mr. Dawes' table, agreement with other authorities at the 6th magnitude, but that his 18th equals Struve's 12th (my 15·1 magnitude). Admiral Smyth in his *Cycle* took 16th magnitude as the limit for his aperture of 5·9 inches. The formula gives 13th magnitude, and supposing that his 8th magnitude was the point of departure from Piazzi, whose brighter magnitudes he professedly conformed to, we may interpolate the intermediate magnitudes.

The following table exhibits these equivalents in a collected form. The first, or standard column, contains Argelander's scale, extended to the lower magnitudes by the adopted ratio; the second, the apertures required by an average sight to reduce such stars to a limit of vision, and the remaining columns, the corresponding magnitudes of Struve, Bond, Herschel, and Smyth:—

| Standard Magnitudes. | Apertures in Inches. | Corresponding Magnitudes of | | | |
|---|---|---|---|---|---|
| | | Struve. | Bond. | Herschel. | Smyth. |
| 6 | 0·229 | 6·0 | 6·0 | 6·0 | 6·0 |
| 7 | 0·363 | 6·6 | 7·0 | 7·3 | 7·0 |
| 8 | 0·575 | 7·3 | 8·0 | 8·6 | 8·0 |
| 9 | 0·912 | 8·0 | 9·0 | 10·0 | 9·6 |
| 10 | 1·44 | 8·6 | 10·0 | 11·3 | 11·2 |
| 11 | 2·29 | 9·3 | 11·6 | 12·6 | 12·8 |
| 12 | 3·63 | 10·0 | 12·9 | 13·9 | 14·4 |
| 13 | 5·75 | 10·6 | 15·2 | 15·2 | 16·0 |
| 14 | 9·12 | 11·3 | 17·5 | 16·6 | |
| 15 | 14·4 | 11·9 | 19·8 | 17·9 | |

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