URANOMETRIA NOVA EXONIENSIS: A PHOTOMETRIC DETERMINATION OF THE MAGNITUDES OF ALL STARS VISIBLE TO THE NAKED EYE FROM THE POLE TO TEN DEGREES SOUTH OF THE EQUATOR

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A PHOTOMETRIC DETERMINATION

OF THE

MAGNITUDES OF ALL STARS VISIBLE TO THE NAKED EYE
FROM THE POLE TO TEN DEGREES SOUTH OF
THE EQUATOR

BY

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INTRODUCTION.

General Historical Survey of Astrometry.

In the present volume is condensed the record of three years' labour on the Photometry of the stars visible to ordinary and unaided eyes, from the North Pole, to about ten degrees South of the Equator. Estimations of the relative brightness of these stars have been made from time to time by various astronomers, but by none more successfully than by the illustrious Argelander, who gave the results of his survey in the *Uranometria Nova*, published at Berlin in 1843. It may not be too much to say of these estimations that, taken as a whole, and viewed as estimations made without the aid of graduated instruments, they are not likely to be surpassed in point of precision; yet it is not any disparagement of their intrinsic value to add, that the requirements and progress of modern astronomy demand greater exactitude than that which Argelander's work justly claims, and a precision exceeding any that can be expected from observations made with the unaided eye.

In the place of these estimations, I now propose to substitute instrumental measures, made at the University Observatory in Oxford, with the aid of a Photometer devised for the purpose by myself, and in which a long and varied experience warrants me in placing a high degree of confidence.

From time immemorial, reaching probably even far beyond the Homeric epoch, the configuration of the stars in the heavens served, mainly through their risings and settings, as a rough calendar for the regulation of the dates of civil and religious proceedings, and for the purposes of agriculture and navigation. There is a record that such configurations were depicted on a Celestial Globe, constructed by Eudoxus four centuries before the Christian Era; and there can be no doubt that some method was at the same time devised for the designation thereon of their relative brightness. A copy or modification of this ancient Globe, supported on the shoulders of a marble Atlas, was dug up from the ruins of Rome, and now furnishes one of the most interesting objects of antiquity in the Royal Museum at Naples, placed there by the munificence of Cardinal Farnese. It may be mentioned in passing that the configurations of the constellations on this Globe are substantially the same as those recognised at the present day.

But it is to Ptolemy, in his immortal work the Μεγάλη Συντάξις, or Almagest as it was termed by his Arabian translators, that we are indebted for a record, not only of the celestial co-ordinates of the stars visible in his day (cir. A.D. 150), at Alexandria, but also for a catalogue of their relative brightness, such as he had himself probably received from Hipparchus and his predecessors more remote. It is a remarkable instance, among many others, of the incisive intellect of the ancient Greeks, that they adopted not only an admirable nomenclature for stellar brightness, which has remained substantially unaltered to the present day, but one which even in its minuter sub-divisions has been but slightly improved by modern astronomers. It is still more remarkable that in this ancient and conventional nomenclature, they practically but unconsciously anticipated an important and fundamental law in Photometry, the first verbal expression of which was brought into prominence by Fechner at so recent a date as 1859[1].

These ancient astronomers, as is well known, divided the brightness of the stars, conceived by them under the thought of 'Magnitude' (Μέγεθος) into six classes. They assigned the 'first magnitude' to a small group of the brightest stars, and then proceeded step by step in successive groups to the sixth, which included all stars shining with the feeblest lustre admitting of appreciation by the naked eye. There was again in Ptolemy's catalogue a sub-division of each magnitude into three, an amount of precision which seems to have been subsequently abandoned for a long period by his successors. It was, however, a nomenclature resumed by Flamsteed and adopted by Argelander in his *Uranometria Nova*, and perhaps it is not too much to say that a finer or more delicate sub-division of stellar lights, than that denoted by the third of a magnitude, is not readily, and by direct means, ordinarily appreciable by the human eye.

These tabulated magnitudes of individual stars, recorded in the catalogues of Ptolemy, remained practically unimproved from his day to that of the elder Herschel at the close of the eighteenth century. Nevertheless the majority of those who flourished in the long line of eminent astronomers between these distant intervals, did make some few and feeble attempts to improve estimations, which they could not do otherwise than feel, were not more than provisional. Among these the most honourable place must be assigned to Abd-al-Rahman Al Sûfi, who, about the year 930, re-examined Ptolemy's work by a comparison with the heavens[2]. Tycho (cir. 1570) made no advance herein; the same remark applies also to Hevel (cir. 1680). It might have been expected that Bayer, when, in A.D. 1601, he bestowed on astronomers the memorable boon of a new nomenclature of the stars in their several constellations, through the application to them of the letters of the Greek alphabet, would have availed himself of the golden opportunity thus afforded him for a re-examination of the ancient

[1] Über ein psychophysisches Grundgesetz und dessen Beziehung zur Schätzung der Sterngrössen, von G. Th. Fechner. Leipzig, 1859.

[2] Description des Étoiles fixes, composée au milieu du dixième siècle de notre ère par l'astronome persan Abd-al-Rahman Al Sûfi, St. Pétersbourg, 1874; and Monthly Notices, vol. xlv, p. 417.

magnitudes. Unaccountably, Bayer allowed the opportunity to pass, and thereby laid himself open to the caustic remark of Delambre, as to the cheap rate at which he had acquired immortality.

Finally, Flamsteed (cir. 1689), the first astronomer who applied the telescope to systematic celestial measurements, re-introduced the sub-divisions of a magnitude into thirds, by means of the notation now in general use; but in other respects exhibited either negligence or unconcern in his estimations of relative stellar brightness. It was this disregard of precision on Flamsteed's part which mainly induced Sir William Herschel[1] to turn his own attention to the subject.

Penetrated with the importance of some record whereby obvious variations in the brightness of stars could be ascertained; important, not solely on the side of inevitable curiosity, but from the consideration that our own star, the Sun, might itself be variable in light and heat, William Herschel (cir. 1796) set himself to the task of forming that record, after his own manner and from his own resources. With this view, he did not propose to verify or improve Ptolemy's magnitudes, and still less those of Flamsteed, but he adopted a more practical expedient, leading, as he rightly thought, both to greater exactness and to greater utility in the direction of the variability intimated above. Accordingly, he divided a constellation into small groups of two, or three, or four stars of nearly equal brightness, and he then arranged the stars in these small groups in the order of their lustre. One star might in this way be found in more groups than one, and thus might furnish the means also of connecting several groups together. Beyond this, he attempted with much success to designate the degrees of the various differences in lustre, not by numerical sub-divisions of magnitude as had heretofore been the expedient, but by the introduction of symbols such as dots, commas, semicolons, &c., placed between the stars whose brightness was compared. For instance, in his nomenclature, a dot placed between two stars would indicate all but absolute equality in brightness, the second star however being, if anything, somewhat less bright than the star which preceded the dot. A comma between them would indicate a somewhat greater difference of brightness, and so on. It is due to the reputation of this great practical astronomer to state that, on a photometric examination of the small differences of light indicated by some of these symbols, there is a precision and a consistency generally observable, which excite admiration.

It was evidently no part of Sir William Herschel's intention to form, or even to lay the foundation for forming a systematic catalogue of the brightness of the stars; but, as already intimated, it was his intention to record the means of detecting any, the slightest, variation which might occur at future periods in any of the stars forming any one of his groups. These groups or short sequences are so numerous that they have not unnaturally induced some astronomers to attempt the deduction therefrom

[1] Philosophical Transactions, 1796, p. 166.

of a complete catalogue of brightness systematically and numerically arranged. Such an unavailing attempt has been made by the author of the present volume, and, could it be successful, the value as a record would be great indeed. But the groups are often so unconnected, the lacunæ are so numerous, and although the estimates of light between stars in the same group are for the most part unimpeachable, nevertheless these considerations render a complete catalogue of magnitudes, considered as Herschelian, unattainable. The danger consists in the liability of importing so much from the observations, whether photometric or otherwise, of other astronomers, as would (and, in fact, do) render the final result, not so much Herschel's unmixed production, as the reflection therein of other catalogues formed by these astronomers. It must be here repeated, that these remarks are not meant as the slightest disparagement of the illustrious astronomer's work, for in this matter nothing was probably less in his mind, than the formation of a systematic record of star magnitudes.

Sir John Herschel, however, during his busy life at the Cape of Good Hope (1835–1838) did, in his mind, propose to complete the Astrometry of the Heavens so far as was visible to the naked eye. His object appears to have been, through loyalty to his father's memory, and for the permanent advance of Sidereal Astronomy, to apply to the Southern Heavens that same sort of scrutiny on which the latter had so long laboured at Slough, with regard to the Northern. The process which he adopted was to divide the stars visible to the unaided eye, into many sets of long and interlacing sequences arranged in graduated lustre. These, when completed, he considered would furnish him with a systematic catalogue of magnitudes, possessing far greater accuracy than any that had heretofore existed. This plan, it will be observed, was generically different from that adopted by the elder Herschel, whose aim was confined to the comparison of stars divided into small sets of nearly equal brightness. While Sir John Herschel was engaged in this project, and in the midst of others of greater magnitude, he invented a photometer, by means of which he hoped to arrive instrumentally at the same sort of results which heretofore he and his predecessors had sought from estimations alone, though now with far greater precision. The implement he devised was of rude construction, such as could be arranged from the scanty resources of a distant colony, but it was, in principle, sufficient for his purpose. Roughly described, it consisted of a pole, a prism, a small lens of short focus, a few strings and a graduated tape. With these materials properly arranged, he could obtain, in the focus of the lens, a microscopic image of the moon, and this he could view in any direction, and at any measured distance from the eye, so that being brought into the same line of sight with any particular star, he could alter the distance of the tiny image, until it and the star appeared to be equally bright. In this way, the brightnesses of some sixty-nine stars were compared with that of α Centauri, and the results were tabulated. These relative light intensities, and the results of the sequence-observations were then expressed in magnitude, in such a way and on such a scale as

best to accord with the accepted magnitudes contained in the best catalogues then extant.

The details of the process, at once ingenious and complicated, can be mastered only by a reference to the original account given by the Author in *The Cape Observations*. Unfortunately the entire project was not completed. An interesting comparison of some of the results with those obtained by the Oxford Photometry will be found in Vol. XLVII of the *Mem. R. A. S.*, and more elaborate descriptions will be found in the *Photometric Researches at Harvard College* both by Mr. C. S. Peirce and by Professor Pickering.

About the same time that Sir John Herschel was engaged in his astronomical observations at the Cape of Good Hope, Argelander was at work at Bonn, on the similar work of Astrometry; but fortunately, with this difference, that he was able to complete it. In 1843 he published his *Uranometria Nova*, containing the estimated magnitudes of all the stars visible to the naked eye in central Europe. This, in fact, is the first successful attempt made by modern astronomers to arrange in an original and independent catalogue, the relative brightness of the stars, and it must ever remain a striking instance of what can be achieved by well-directed perseverance and accurate discernment. Argelander has not recorded the details of the method which he adopted to secure his results, nor is it possible to say by what means or mental impressions, he preserved a fair uniformity of scale, and a general conformity to the magnitudes recorded by his predecessors. It may be sufficient to say that some not inconsiderable variations of light-ratio do occur, depending on magnitude; but such variations are unavoidable, when the scale is the result of mental impressions, rather than an instrumental measure.

Argelander's work was soon followed by another of still greater magnitude and importance in which he, with the most able assistance of Drs. Schönfeld and Kreuger, has recorded the approximate celestial coordinates and the magnitudes of no fewer than 324,000 stars. In this case the magnitudes are such as they are estimated to be, when seen through the telescope, and not, as in the *Uranometria Nova*, observed with the eye alone. If there are found some slight variations both in the magnitude of individual stars, and in the light-ratios existing in the general estimate of the larger intervals, the cause is to be sought in the same sources of imperfection as those just referred to in the case of the *Uranometria Nova*.

More recently, the heavens have again been scrutinized by Heis, at Münster, who has re-examined Argelander's *Uranometria Nova* and has added a considerable number of stars of a fainter lustre; but many of these, it is not too much to say, are beyond the vision of ordinary eyes. Houzea, also by observations made during a residence for that purpose at Jamaica, has rendered good service to astronomy, by publishing the results of his own estimations. The same remark applies also to the astrometry of M. Flammarion at Paris. Dr. Gould has recently enriched the resources of astronomy by his astrometry of the southern heavens, with a degree of