

Calibration of the Stellar Magnitude Scale Prior to Pogson

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The most obvious thing we notice about the stars is that they have different brightnesses. Over two thousand years ago, the Greek astronomer Hipparchus (2nd Century B.C.) divided the stars that he could see into classes of brightness. His measurements were extended by Claudius Ptolemy in Alexandria in about A.D. 150. In their classification, the brightest stars were said to be of the first magnitude, somewhat fainter stars were of the second magnitude, and so on down to the six magnitude, which represented the faintest stars that could be seen with the naked eye.

The study of the relative brightness of stars—a branch of astronomy now generally known as STELLAR PHOTOMETRY—has also been carried on extensively during this century and has now been put on a scientific basis. The traditional classification of stars into magnitudes, according to their brightness, was almost wholly arbitrary, and decidedly uncertain. As soon as exact quantitative comparisons of stars of different brightness began to be carried out on a large scale, the need for a more precise system of classification became felt. John Herschel (1792—1871) in England was one of the pioneers in this direction; he suggested a scale capable of precise expression which would agree, roughly at any rate as far as naked-eye stars are concerned, with the current usages; while at the Cape of Good Hope he measured carefully the light of a large number of bright stars and classified them on this principle.

According to the scale now generally adopted, first suggested in 1856 by the English astronomer Norman Robert Pogson (1829—1891), the light of a star of any magnitude bears a fixed ratio (which is taken to be 2.512...) to that of a star of the next magnitude. The number is so chosen that a star of the first magnitude is 100 times brighter than one of the sixth magnitude, and thus the scale is quantitative. In other word, since there are five steps in magnitude, the difference between the first and the sixth magnitudes corresponds to a factor of 100 in brightness, and one magnitude difference corresponds to a factor of $(100)^{1/5} = 2.512...$. The magnitude scale has been extended to positive magnitudes larger than +6.0 to include faint stars and to negative magnitudes for very bright objects (the star Sirius is magnitude -1.4).

This is a short background history, widely known to us today, concerning the accurate calibration of the stellar magnitude scale by Norman Robert Pogson.

In the 18th Century approximately one century earlier than Pogson, however, another significant attempt to calibrate the stellar magnitude scale had already been carried out, this time by

a group of Royal astronomers in Korea, on the opposite side of the earth from Pogson's England. Their work was recorded in 1770 in the Dongkook Munheonbigo (東國文獻備考 象緯考 卷一) under the name of Tsedae-ron (體大論) as shown in Table I.

Table I. 體大論(增補文獻備考 卷一)

恒星大小分 六等,
 一等星 體大于地球六十有八倍,
 二等星 體大于地球二十八倍有奇,
 三等星 體大于地球近一十一倍,
 四等星 體大于地球四倍有半,
 五等星 體比地球得一又一十八分之一,
 六等星 體比地球得三分之一

The first impression we get when we glance at the records in Table I is that this is a statement about the size of stars of different magnitudes, because all stars of six different magnitudes are measured in reference to the earth as a unit. The largest star is the first magnitude star which is 68 times the size of the earth, while the smallest one is only one and a third times the earth.

Interpretation of the records in Table I in this way is wrong, however. We know that customarily in Korea a bright star is said to be a large star and a faint star a small star. The expression, LARGE or SMALL, does not mean the size of a star at all but the star's brightness. Therefore, the numbers given in Table I for the six different magnitudes represent solely the brightness of the stars.

Table II shows the numerical calculations. The first column of this table represents the magnitudes 1 through 6 and the second is the stellar brightness of each magnitude in terms of the earth as a unit. Therefore, these two columns are the records in Table I in modern form. The third and fourth columns are included in order to make a comparison with the Pogson values which result from his own formula,

$$m_i - m_{i+1} = -2.5 \log \frac{I_i}{I_{i+1}}.$$

Table II. Calibration of Stellar Magnitudes

Magnitude Scale i	Brightness (Earth=1) I_i	Ratio of Brightneses I_i/I_{i+1}	Magnitude Difference $\Delta m = m_i - m_{i+1}$	No. of Stars (星鏡) (1861)
1	68			16
2	28 ⁺	2.43	0.96	51
3	11 ⁻	2.55	1.01	159
4	4.5	2.44	0.97	349
5	2.06	(2.18)	(0.85)	(349)
6	1.33	(1.55)	(0.48)	(343)

$$I_1/I_6 = 51.19$$

$$1,267$$

Using the Korean source in the second column of Table II, the calculated ratios of the brightnesses between two stars of one magnitude difference are shown in the third column.

These values show an extreme accuracy for those stars up to fourth magnitude. The average value of this range (1 through 4) is 2.473, smaller than Pogson's by only 0.039. Since the conventional way for expressing stellar brightness is in terms of magnitude, the magnitude differences are calculated using the formula above with the values from the third column of Table II and are given in the fourth column of Table II. The average of the three magnitude differences for those stars of first through fourth magnitude is 0.98. If one allows for an observational error of ± 0.2 magnitude for the naked-eye estimation, the average value 0.98 is in perfect agreement with Pogson's. This is clear evidence which recognizes the excellency of the calibration work for stars of fourth magnitude and brighter by the Korean astronomers a century prior to Pogson.

Table III. Statistics of the Traditional Stars

Division	No. of Constellation (座)	No. of Stars Compiled	
		星 (1861)	中國百科全書 (1980)
紫 微 垣	38	163	163
天 市 垣	19	87	87
太 微 垣	20	78	78
東 方 七 舍	46	186	186
西 方 七 舍	54	297	300
南 方 七 舍	42	245	247
北 方 七 舍	65	408	408
sub-total	284	1,464	1,469
近 南 極 星	23	130	130
TOTAL	307	1,594	1,599

A significant departure of the ratios given in the third column of Table II from the value 2.512 is, however, clear for stars of fifth and sixth magnitudes. The brightness calibration by the Korean astronomers for these stars fainter than fourth magnitude is thus unreliable. A possible reason for this deficiency will be discussed using the information listed in Tables II and III.

Our interest in this early Korean calibration of the stellar magnitude scale can further be extended in the future.

Who made the calibration, and when?

What were the techniques applied and the instruments used?

Was there any work in China prior to that in Korea?