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ON THE HISTORY OF THE STELLAR MAGNITUDE SCALE

ANNEMARIE MAYER
1485 Ries Street
Barberton, OH 44203

Abstract

The paper reviews the development of the stellar magnitude scale from its origin in antiquity to its standardization during the second half of the 19th century.

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1. Introduction

There are at least two reasons why the development of the stellar magnitude scale may be of interest to the variable star observer, first, because of the observer's direct involvement with the scale through magnitude estimation, and second, because the earliest record of the comparative brightness of the stars was due to the sudden appearance and gradual fading of a previously unnoticed star, generally referred to in the literature as Hipparchus' new star.

2. Origin of the Stellar Magnitude Scale

Although there are some discrepancies in the astronomical literature regarding the origin of the scale, the Greek astronomer Hipparchus (ca. 190-125 B.C.) generally is considered to be the first one to have produced a star catalogue which indicated the positions and comparative brightness of several hundred naked-eye stars (Herschel 1861; Jones and Boyd 1971; Merrill 1938; Moulton 1935; Pannekoek 1969; Thomas 1953; Waterfield 1938; Weigert and Zimmermann 1975; Williams 1932). Hipparchus has been called "lover of truth" because of his emphasis on the accuracy of measurement (Williams 1932), and he is considered to be the founder of scientific observational astronomy because he relied on observation, not speculation (Weigert and Zimmermann 1975).

Hipparchus undertook the task of cataloguing the naked-eye stars following the appearance of a bright new star. According to J. Herschel, this star attracted Hipparchus' attention because it was so bright that it was visible during the daytime (Herschel 1861). But in the opinion of other authors, records do not permit deciding whether this star was a nova or some other type of variable star (Pannekoek 1969), or even a comet (Thomas 1953; Waterfield 1938). Tycho Brahe, following his discovery of a new star in 1572, stressed that Hipparchus had been the only one of the "founders" to have noticed the appearance of a new star in the celestial world, if Pliny's report of this event could be believed (Shapley and Howarth 1928).

In addition to differences of opinion among various authors regarding the nature of the star that inspired Hipparchus to make a star catalogue, there are also differences of opinion regarding the number of stars the catalogue contained and the number of brightness divisions established by Hipparchus as the earliest form of a stellar magnitude scale. There is no agreement on whether it was Hipparchus or Ptolemy (ca. A.D. 90-160) who first used the six-category scale of brightness. Unfortunately, Hipparchus' original catalogue is lost, and only fragments of his work have been transmitted. It is assumed, however, that Ptolemy's **Almagest** was greatly influenced by Hipparchus' work, and that the star catalogue contained in Ptolemy's book was a revised and extended version of Hipparchus' older catalogue (Moulton 1935; Weigert and Zimmermann 1975).

Ptolemy seems to have been the first one to use the word magnitude

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to indicate brightness, based on his assumption that brighter stars were of greater size (Pannekoek 1969).

The fact that the original scale had six brightness divisions was attributed by Jastrow to the limits set by Hipparchus' ability to make brightness discriminations; he thought that had Hipparchus possessed "a more delicate eye," the original scale might have contained twelve instead of six categories (Jastrow 1887, p. 115).

Baker (1978) proposed another interesting explanation for the six categories of the original scale. In his opinion, the choice of six categories was due to the influence on Greek astronomy of the Babylonian system of mathematics, which used six as a base.

3. Increase in Precision of Magnitude Determinations

Ptolemy had not recognized fractional magnitudes. To increase precision, he had used modifying terms for stars brighter or fainter than the average star of each magnitude (Campbell and Jacchia 1946; Pannekoek 1969; Waterfield 1938).

For approximately 16 centuries there were no improvements on Ptolemy's magnitude determinations, with the exception of the revision by Al-Sufi during the 10th century (Miczaika and Sinton 1961), and Ptolemy's magnitudes served as a basis for many succeeding catalogues (Waterfield 1938).

The use of telescopes at the beginning of the 17th century made the observation of fainter objects possible and required the extension of the magnitude scale. There was no device available for the exact determination of the comparative brightness of stars, and observers constructed their own versions of the magnitude scale based on Ptolemy's magnitudes. The result was that no astronomer used exactly the same scale as another (Jones and Boyd 1971; Waterfield 1938).

Toward the end of the 18th century, W. Herschel noticed that brightness sequences in constellations often deviated from the magnitudes assigned by Flamsteed, and also from the sequence of Greek letters assigned by Bayer (Pannekoek 1969). Herschel assumed that the stars had changed in brightness, but he recognized that the existing methods did not allow the determination of small changes in brightness with sufficient accuracy. Herschel then devised a system of signs, consisting of commas and dashes of varying length, to indicated small brightness differences between stars. His signs had denoted magnitude fractions, but his observations were largely left unreduced, until Pickering reduced them on his Harvard scale in 1884 (Jones and Boyd 1971).

At the beginning of the 19th century, the study of stellar variability gained importance and directed attention to the measurement of stellar brightness. At that time, the magnitude determinations of Ptolemy were still in general use, and the only way to determine stellar brightness was by visual estimate (Waterfield 1938).

During the first half of the 19th century, Argeländer started the systematic observation of variable stars, and more accurate determinations of stellar brightness required more subdivisions of each magnitude. Argeländer used magnitude fractions of one third in his **Uranometria Nova**, published in 1843, and magnitude fractions of one tenth in the **Bonner Durchmusterung**, published 1859-62 (Campbell and Jacchia 1946; Pannekoek 1969). This increased precision was made possible by Argeländer's introduction of the step method of magnitude estimation, which used numerical values to indicate small brightness differences instead of the commas and dashes used by Herschel. The use of decimals in magnitude determinations not only increased the precision of measurement, but changed the character of magnitudes from a class of ordinal number to a quantity of measure (Pannekoek 1969).

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4. Photometric Determinations of Stellar Brightness

During the 19th century, there was an increasing emphasis on measurement and quantification, not only in astronomy but in other sciences as well. In 1835, the German astronomer Steinheil proposed that stellar magnitudes indicated not differences but ratios of light intensity. Based on his own photometric determinations, he thought that the ratio between successive magnitudes was 2.83 (Pannekoek 1969). At approximately the same time, J. Herschel determined that the average star of Ptolemy's first magnitude was about 100 times as bright as the average star of sixth magnitude. By 1850, several observers had arrived at similar results by various photometric methods (Waterfield 1938). The brightness ratio of stars with one magnitude difference has been found to be close to 2.5 and approximately constant throughout the scale (Miczaika and Sinton 1961).

In 1854, the English astronomer Pogson suggested that a magnitude be defined as a brightness ratio of 2.512 between successive magnitudes. This suggestion was adopted in theory but decades passed before it could be adopted in practice because the available measurement techniques lacked a sufficient degree of precision.

In 1877, E. C. Pickering assumed the directorship of the Harvard College Observatory and decided shortly thereafter to make precise stellar photometry the first research objective of the observatory (Jones and Boyd 1971). Instruments that measured the comparative brightness of stars with a sufficient degree of accuracy had by then become available, and Pickering is considered to be the first astronomer who successfully used the photometer (Waterfield 1938).

During the early years of his directorship, Pickering standardized the stellar magnitude scale by accepting Pogson's ratio as magnitude scale by definition; he also set the zero point for the scale by arbitrarily designating the Pole Star to be magnitude 2.1 (Jones and Boyd 1971; Waterfield 1938).

In conclusion, the developement of the stellar magnitude scale from a crude category scale of perceived brightness to a scale of light intensity ratios (logarithmic) took from the 2nd century B.C. to the 19th century A.D. - a time period of over 2000 years.

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