

THE INTRODUCTION OF ABSOLUTE MAGNITUDE (1902-1922)

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Abstract: The absolute magnitude of a star, this being the apparent magnitude that a star would have if it was moved to a distance of 10 parsecs from the observer, is a ubiquitous concept and is commonly used by today's astronomers to represent the luminosity of a star. This short paper traces the history of the expression 'absolute magnitude' from the time of its introduction in 1902 by its originator J.C. Kapteyn, up to the ratification of its acceptance by the International Astronomical Union at its first meeting in 1922.

Key words: stellar luminosity, parallax, absolute magnitude, H-R diagram

1 INTRODUCTION

As soon as astronomers could measure both the brightness of a star and its distance, they could then calculate the star's total energy output. As with all physical quantities this had to be expressed as a number. In the MKS (Metre Kilogram Second) system the energy output of the Sun, the solar luminosity L_{\odot} , could be quoted as 3.827×10^{26} W. But this number is very large and one of the golden rules when it comes to quoting physical and astronomical quantities is that the units that are used should give the quantity as a handy number, usually somewhere between 1 and 1,000. So why not choose the solar luminosity itself, as a unit. Well the snag here is that stars have luminosities that typically range from about $0.001 L_{\odot}$ to $30,000 L_{\odot}$, so, like the MKS energy output, this is not very 'handy' either. The answer was to move to a quantity that was logarithmic. The *absolute magnitude* was ideal. This is the apparent magnitude a star would have if it were seen from a distance of 10 parsecs. Stars typically have absolute visual magnitudes that range from about -6.5 , for the most luminous supergiants, to $+12$ for the feeblest main sequence stars of M5 spectral class (although it must be pointed out that the full extent of this range was not known at the time of the introduction of the absolute magnitude). The Sun has an absolute visual magnitude of 4.82 (see Cox, 2000). Absolute magnitudes are thus numerically extremely 'handy'.

The history of astronomy often produces intriguing questions. Three have fascinated me for many years, and these concern the afore-mentioned absolute magnitude:

- Who introduced the concept and when?
- Who decided that the reference distance should be 10 pc?
- When was this commonly accepted?

These questions are answered in this short paper.

Let us start with the modern definition. The absolute magnitude, M , of a star is equal to the apparent magnitude, m , that the star would have if it were placed at a distance, d , equal to 10 pc, from the Earth-bound observer, and thus had a parallax, π , of 0.1 seconds of arc. We can thus write

$$M = m + 5 - 5 \log d, \text{ or} \quad (1)$$

$$M = m + 5 + 5 \log \pi. \quad (2)$$

The 'apparent magnitude' system, in which the brightness of a star was expressed as an 'importance', appears in the *Almagest* or *Syntaxis*, an astronomical treatise written in Alexandria by Claudius Ptolemy around AD 145 (see, for example, Graßhoff, 1990; Hutchins, 1952; Toomer, 1984). Many historians of science think that both the star catalogue in the *Almagest*, and its associated magnitude (brightness) system, were probably first produced by Hipparchus, the famous Greek astronomer and mathematician, in around 134 BC, and not by Ptolemy some 280 years later. For those wishing to enter the debate I refer them, for example, to Evans (1987), Graßhoff (1990), Newton (1982) and Rawlins (1982).

Hipparchus was observing the sky from the Greek island of Rhodes, at latitude 36° N. Supposedly encouraged by the appearance of a nova in the constellation of Scorpius, he decided to produce a new catalogue of stars. Not only did he list the positional coordinates of each of 1,028 stars (1,025 plus three duplicates), grouped into 48 constellations (12 zodiacal, 21 in the northern sky and 15 in the southern sky), but he also is thought to have introduced a grading system representing the relative 'importance' of each of his catalogued stars. This started at 1 for the brightest fifteen stars visible in 'his' sky, and increased, in unit steps, to 6, the latter grade containing all those stars that were barely visible to the naked eye. According to François Arago (1854: 333), Hipparchus/Ptolemy recorded 15 stars as being of first magnitude stars, 45 second, 208 third, 474 fourth, 217 fifth and 49 sixth, plus 9 obscure and 5 nebulous.

The logarithmic relationship between apparent magnitude and stellar brightness was first placed on a firm footing by the Oxford astronomer, Norman R. Pogson (1856). He suggested that a scale of apparent magnitudes should be introduced such that a star of magnitude m was *exactly* $10^{2/5}$ brighter than one of magnitude $(m + 1)$. Hints as to the logarithmic nature of the relationship between brightness and magnitude had been made well before the time of the formalisation by Pogson. Among others, Halley (1720) and Herschel (1829) mention it (see Hearnshaw, 1996: 76). Pogson tacitly assumed that the human eye and brain responded to light such that the sensation was proportional to the logarithm of the stimulus, a relationship that was formalised by G.T. Fechner (1858, 1860). Logarithms were much in vogue in the seven-

teenth, eighteenth and nineteenth centuries having facilitated numerical calculations greatly since their invention by Baron Napier of Merchistoun in 1614 (see Bell, 1945). Pogson's ideas became generally accepted among the astronomical community when Pickering et al. (1887) used them as the photometric basis of the work at the Harvard College Observatory and Müller adopted them for the Potsdamer Durchmusterung (see Müller, 1897: 446). Jones (1968) notes, however, that they were only universally accepted after 1905.

Returning to Equations 1 and 2, it can be seen that any thoughts about absolute magnitude only become realistic when a reasonable number of stellar distances are known. Historically the astronomer's concept of the cosmos changed drastically with the general acceptance (about the middle of the seventeenth century) of the heliocentric model put forward by Nicolaus Copernicus (1473–1543) in *De revolutionibus Orbium Coelestium* (see, for example, Hutchins, 1952: 510-838). The previous paradigm, that stars were all the same distance from Earth, was replaced by the realisation that the visible world of the fixed stars was immeasurably large (see Koyré, 1957) and that differing distances as well as differing luminosities affected stellar brightness.

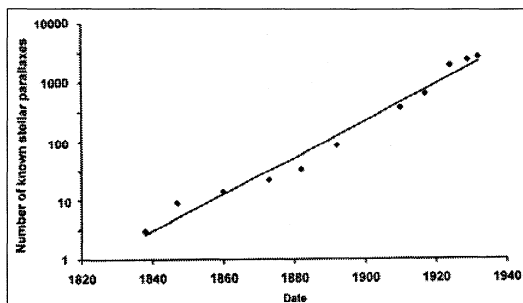


Figure 1: The rate of development of the astronomical knowledge of stellar distance is shown by plotting the way in which the number of stars with reasonably accurate parallaxes (shown logarithmically) varies as a function of date. These data have been taken from Lundmark (1932).

The orbiting Earth presented astronomers with a possible trigonometric mechanism for measuring the distance to stars. In six months our planet moves to a place that is two astronomical units (300,000,000 km) on the other side of the Solar System. Nearby stars thus change their celestial position with respect to more distant stars, and a measurement of this parallactic shift (plus knowledge of the astronomical unit) gives the distances. Astronomers had, however, to wait from 1543 to 1838 before their instruments became sufficiently sensitive to enable this parallactic angle to become measurable.

October 1838 saw the first announcement of a measured parallax. This was for the 5.2 magnitude star 61 Cygni, a so-called 'flying star' with a huge proper motion of 5,260 sec arc per millennium. Friedrich Wilhelm Bessel had been observing this star using the Königsberg Observatory's 6.25-inch Fraunhofer heliometer. Nearly simultaneously Thomas Henderson (1839), working in South Africa, reported the parallax of α Centauri, another 'flying star'. Other parallaxes were reported in steady succession over the next fifty

years, and Charles Young (1895), in his famous *Text Book of General Astronomy*, was able to publish a list of 28 known stellar parallaxes (stellar distances were given in light-years).

The stars on this list were fairly eclectic. They had been selected because they were thought to be close to Earth and thus to have large and easily-measurable parallaxes. The two main selection criteria were a large proper motion, and a large brightness (the latter making the stars easily discernible using the visual telescopes of the day). The resulting 28 parallaxes ranged from $0.187''$ to $0.054''$, this being equivalent to a distance range of 5.4 to 18.5 pc. The median parallax of the group was $0.176''$ ($d = 5.7$ pc), and 64% of the group lay in the range $0.12 < \pi < 0.28''$ ($3.6 < d < 8.3$ pc). As to brightness, the median apparent magnitude was 4.5 and the range was $1 < m < 9$. The data showed no obvious relationship between parallax and apparent magnitude.

The way in which the number of known stellar distances varied as a function of date is shown in Figure 1, these data coming from Young (1895) and Lundmark (1932). The fact that this number was increasing by a factor of ten about every 32 ± 2 years clearly had an influence on the date around which absolute magnitude-spectral type diagrams could be drawn for stars in general.

Many of the parallax results presented at the end of the nineteenth century were of dubious quality and the errors in individual values were large. It was only in the first decade of the twentieth century that accuracy improved, mainly due to the endeavours of the American astronomers H.N. Russell (1905) and F. Schlesinger (1904), and the Cambridge astronomer A.R. Hinks (1906). Only then did astronomers start to become very interested in the importance of the fact that stellar luminosity varied drastically from one star to another. Crommelin (1893) selected 14 stars which had been estimated to be within 4 pc of the Sun, and recorded that their luminosities varied from $83 L_{\odot}$ to $0.01 L_{\odot}$. Interestingly he did not comment on this difference. By the first decade of the twentieth century the interest in stellar luminosity had blossomed, and the possible units of measurement became of great interest too.

Agnes Clerke (1905: 383) listed 70 stellar parallaxes, these ranging from $0.75''$ to $0.015''$ (1.3 to 67 pc). The median parallax was $0.11''$ ($d = 9.1$ pc) and 64% of the group lay in the range $0.04 < \pi < 0.26''$, ($3.9 < d < 25$ pc). The stars had a very similar brightness range to the Young's set (1895: 536). Their median apparent magnitude was 4.5, the range being $-1.6 < m < 9.0$. (64% of the group lay in the range $1.15 < m < 7.5$).

Parallax measurement at that time was far from easy. Eddington (1914: 40) noted:

... for a parallax-determination of the highest order of accuracy, the probable error is usually about $0''.01$. Thus the position of a star in space is subject to a comparatively large uncertainty, unless its parallax amounts to at least a tenth of a second of arc.

At the time Eddington was clearly thinking in terms of certain standard stellar distances. He was also trying

to estimate the actual spatial densities of stars in the local region of the Galaxy. Realising that the stellar tally became less and less complete as their distance increases, he chose 5 pc as a standard distance and recorded (1914: 41) that there were 19 known stars closer to the Sun than 5 pc.²

Eddington (1914: 47) also recorded that there were 27 known stars with distances between 5 and 10 pc. The use of 5 pc and 10 pc as significant 'celestial boundaries' clearly echoed the previous use of 'standard distances' at the time when 'absolute magnitude' was first introduced. Interestingly, Eddington did not use the term 'absolute magnitude' in his 1914 book, *Stellar Movements and the Structure of the Universe*. As a measure of energy output he listed stellar luminosities as a ratio of the solar luminosity.

Eddington realised that both the numbers given for the star counts, i.e. 19, and 27, were very much lower limits. When it came to the 19 stars closer than 5 pc he noted that none had a luminosity less than 0.006 (i.e. 1/200) that of the Sun. He was convinced (quite correctly) that "... numerous fainter stars exist." (Eddington, 1914: 42). Also, the volume of the 5 to 10 pc region is seven times greater than the volume of the sphere of 5 pc radius. So if measurements were being made to the same luminosity limit in both regions the outer region should contain 133 stars, not 27.

By the second decade of the twentieth century, parallax studies had become more formalised, mainly due to both the efforts of the northern European astronomers J.C. Kapteyn and H.A. Weersma at the University of Groningen (see Kapteyn and Weersma, 1910) and the English Astronomer Royal, F.W. Dyson (see Dyson, 1909).

The use of the standard distance of 10 parsec, a distance that is now used to define absolute magnitudes, must clearly post-date the introduction of the parallax units of stellar distance, as opposed to the light year. According to Waterfield (1938: 133), the name of the major 'parallax unit', the parsec, is simply a portmanteau word (parallax of one arc second), this word being introduced by the Oxford Savilian Professor of Astronomy, Herbert Hall Turner (1861-1930). Eddington (1914) was apparently fairly quick off the mark. The 'parsec' as a new basic stellar distance unit (i.e. the distance of a star at which the radius of the Earth's orbit subtends one second of arc) was first mentioned (according to the *Oxford English Dictionary*) in 1913 by the then English Astronomer Royal, Frank Watson Dyson (1868-1939). Quoting from Dyson (1913: 342):

There is need for a name for this unit of distance. Mr Charlier³ has suggested Siriometer, but if the violence to the Greek language can be overlooked, the word *Astron* might be adopted. Professor Turner suggests *Parsec*, which may be taken as an abbreviated form of "a distance corresponding to a parallax of one second."

Early astronomical distance terminology was also discussed by Lundmark. He noted (1932: 430) that

... the light-year is the one most used. The parsec is also comparatively much used and would be more so also if it were not for its awful name.

Other stellar distance units were mentioned by Lundmark (1932), these being the Herschel (66,890

au), Siriusweite (1,031,324 au), and the metron and Sternweite (both, like the parsec, 206,265 au).

2 ABSOLUTE MAGNITUDE AND THE HERTZSPRUNG AND RUSSELL DIAGRAMS

Today the most easily encountered early uses of the concept of stellar absolute magnitude is in two historic and extremely famous graphs, these being the 1911 'Hertzsprung' diagram and the slightly later 1913 'Russell' diagram.

A redrafted version of the original 'Hertzsprung' diagram is reproduced as Figure 2, taken from his first illustrated paper on the relationship between stellar luminosity and surface temperature (see Hertzsprung, 1911, and also, for example, Struve and Zebergs, 1962). Notice, in passing, that figures and graphs in research papers were much less common in those days than they are today. Hertzsprung's previous two papers on stellar physical characteristics (see Hertzsprung, 1905; 1907) were without diagrams. In these papers Hertzsprung was investigating the characteristics of the stars in the Hyades open cluster. As all the Hyades stars are approximately the same distance away from the Earth-bound observer (a distance now known to be about 46 pc) there is a constant difference between their apparent magnitudes and absolute magnitudes (this being $m - M = 3.3$). If Hertzsprung were one of today's university students he would have lost marks for not labelling the axes of his graph, and I have taken the liberty of adding these.

In Figure 2, the ordinate is colour index, i.e. the apparent photographic magnitude of the star minus the apparent visual magnitude. Hertzsprung used the Draper Catalogue G-band magnitude for the former (this being obtained using photographic telescopes equipped with objective prisms and blue filters isolating the 0.4215 - 0.4325 μ region around the CH line; see Hearnshaw, 1986: 372) and the Harvard Photometry for the later (see, for example, Pickering (1913) and Hearnshaw, 1996: 91). Approximately main-sequence stars of spectral class A0, F0, G0, K0 and M0 have colour indices of -0.05, +0.3, +0.6, +0.8 and +1.4. For comparison with a modern Hertzsprung-Russell diagram, Figure 2 needs to be rotated clockwise through 90°.

The upper abscissa is the stellar apparent photographic magnitude. The full dots represent stars that, at the time, were thought to be members of the Hyades, and the open circles are stars in the same region of the sky, so some of these are Hyades members and some are not. Hertzsprung's brightest star in Figure 2, $m_{pg} = 4.2$ mag, is probably θ^2 Tau ($m_V = 3.4$).

The lower abscissa in Figure 2 is the first known visual representation of the absolute magnitude. As a 'standard distance', Hertzsprung has used a standard parallax of 1 arcsec (a distance later known as 1 pc). His absolute magnitudes have values that are thus five less than the ones used today, with the today's accepted 'standard distance' of 10 pc.

Hertzsprung (1911) also produced a similar diagram for about 62 stars in the Pleiades, but as this diagram had no absolute magnitude numbers on its abscissa axis it is of less importance in the context of this paper. The Pleiades was investigated in a very similar way by Rosenberg (1911).

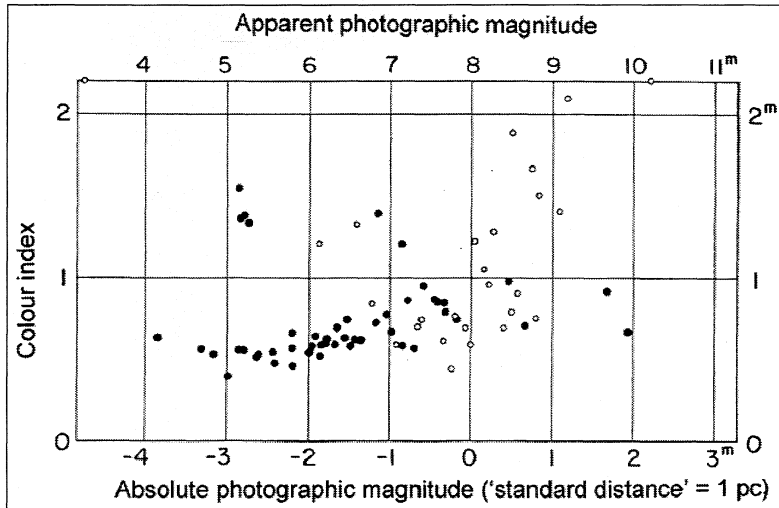


Figure 2: This redrafted original 1911 'Hertzsprung' diagram has been taken from his first illustrated paper on the relationship between stellar surface colour and luminosity. The full dots represent stars that, at the time, were thought to be members of the Hyades open cluster, and the open circles are stars in the same region of the sky. As all the Hyades cluster stars are assumed to be the same distance away from the observer, there is a constant numerical difference between apparent magnitude and absolute magnitude.

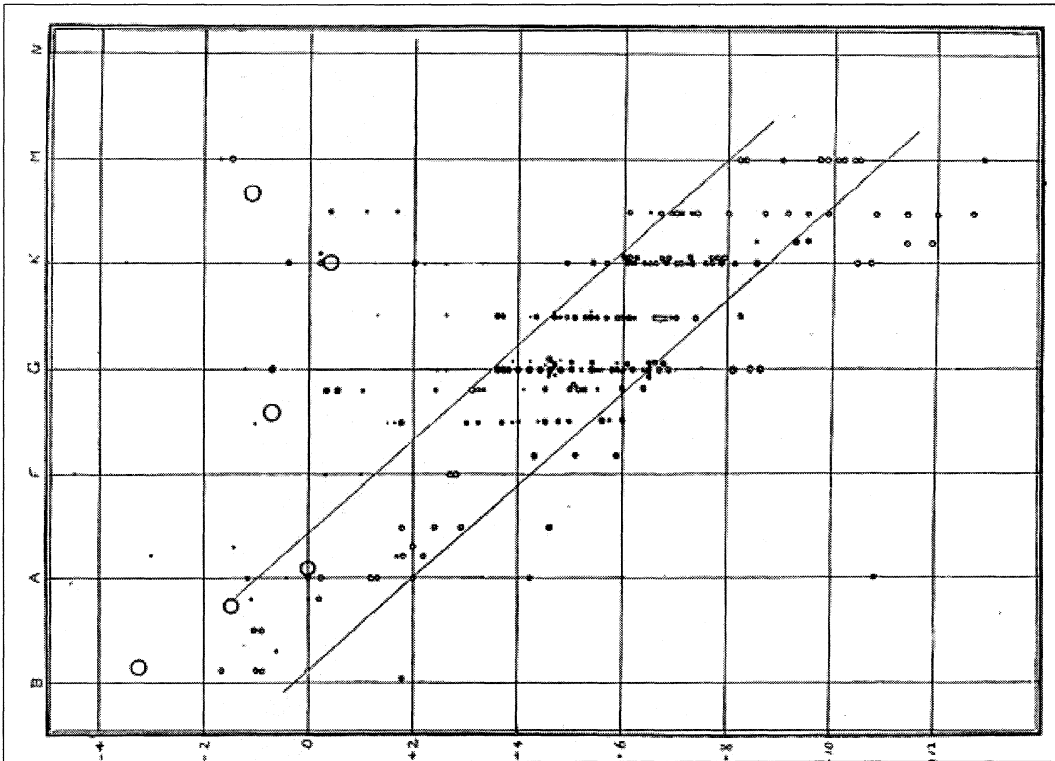


Figure 3: The original 'Russell' diagram (see Russell, 1914a and 1914b). The abscissa shows seven stellar spectral types and the ordinate is the absolute magnitude ("according to Kapteyn's definition", with a standard distance of 10 pc, corresponding to a parallax of 0.1"), the range being $-5 < M < 14$. Four types of data points have been used for the 220 stars represented. The filled circles are for stars which have had their parallaxes measured at least twice. Small filled circles indicate an absolute magnitude error of greater than ± 1.0 , and the large filled circles are for stars with an absolute magnitude error of less than ± 1.0 . The small open circles are for stars with single parallax determinations. The large open circles at the top of the diagram represent mean values for collections of stars (about 120 altogether) with small proper motions and parallaxes which hardly exceed their probable errors.

The two diagonal lines delineate the main sequence of 'dwarf' stars. The lone point in the bottom left portion of the diagram was regarded at the time as being very strange (the observation of its spectrum was hindered by the proximity of a bright primary). This star, Omicron Eridani B, was later found to be a white dwarf.

Finally, note that the original version of this diagram has been rotated through ninety degrees so that it has the same orientation as the 'Hertzsprung' diagram in Figure 2, above.

The original 'Russell' diagram, Figure 3, first saw the light of day in the spring of 1913, in London, at the 13 June meeting of the Royal Astronomical Society. The Princeton University astronomer, Henry Norris Russell (1877-1957), was giving a lecture on "*Giant and Dwarf Stars*" during a short stop-over on his journey, with a small group of American astronomers, to the summer meeting of the International Solar Union, in Bonn, Germany. The slide that Russell showed illustrated the physical characteristics of some 220 stars with known parallaxes. This graph, to quote Russell (1913: 324), plotted "... the relation between the spectral types of the stars and their real brightness."

Russell's RAS lecture was subsequently published twice as a research paper (see Russell, 1914a and 1914b), in *Nature* and *Popular Astronomy*, both papers being identical. Fortunately in the written version Russell had changed the expression 'real brightness' into the much more acceptable (and longer lasting) 'absolute magnitude'. In these papers the 'Russell' diagram was plotted as a figure in which

... the spectral class appears as the horizontal coordinate, while the vertical one is the absolute magnitude, according to Kapteyn's definition, - that is, the visual magnitude which each star would appear to have if it should be brought up to a standard distance corresponding to a parallax of 0".1

Russell had no idea at the time he drew this historic and iconic diagram, that Hertzsprung had essentially 'pipped him to the post' three years previously. In passing, David Leverington (1995: 131) notes that Russell's graph was first given its present appellation 'Hertzsprung-Russell diagram' in a paper by Ström-gren (1933), this being the written version of a lecture Ström-gren gave at a meeting of the Astronomische Gesellschaft in Göttingen.⁴ Actually the laurels for the appellation introduction should go to the Swiss-American astronomer, Robert Julius Trumpler (1886-1956) who, like Hertzsprung, was interested in the colour-magnitude diagrams of open clusters. Writing about the Wild Duck cluster in Scutum (M11) Trumpler (1924: 13) referred to the "... well known Russell diagram of giant and dwarf stars ...". A year later Trumpler (1925) reviewed the brightness and spectral characteristics of 52 clusters. In his 1925 paper he rather arbitrarily and alternatively used the expressions 'magnitude-spectral class diagram' and 'Hertzsprung-Russell diagram'. Trumpler (1925: 311) never gave any indication that he was pioneering the use of the later title.

The expression 'Hertzsprung-Russell diagram' entered into common usage after Chandrasekhar (1939) published his book, *An Introduction to Stellar Structure*. For more details about the history of the Hertzsprung-Russell diagram refer to DeVorkin (1977; 1978; 1984), Gingerich (1982) Nielsen (1963) and Sitterly (1970).

3 J.C. KAPTEYN AND ABSOLUTE MAGNITUDE

The Kapteyn mentioned above by Russell was the famous Dutch astronomer Jacobus Cornelius Kapteyn (1851-1922) who, after studying mathematics and physics at the University of Utrecht had become the Professor of Astronomy and Theoretical Mechanics at the University of Groningen (see Hertzsprung-Kapteyn, 1993). He remained at Groningen until

his retirement in 1921. Kapteyn was interested in the proper motion of stars and their distribution in the vicinity of the Sun. To help in this investigation, Kapteyn and H.A. Weersma (1910) published a list of stellar parallax determinations. Much care was taken with error evaluation and the assessment of the accuracy of the different values obtained by different observers. It was clear that this list was one of the major foundation stones of the subsequent work by H.N. Russell. Each star was catalogued according to the normal characteristics, such as name, position, spectral type, apparent magnitude, proper motion and so on. What is important in the context of the present paper is the fact that the final two columns of the catalogue table (columns seventeen and eighteen) contained the stellar absolute magnitude and luminosity. To quote Kapteyn and Weersma (1910):

The seventeenth column gives the absolute magnitude (= apparent magnitude at a distance corresponding to parallax 0".1), the eighteenth gives the luminosities (unit = luminosity of the sun). These quantities have been computed by means of the formulae (see Gron. Publ. 11, page 12):

$$\begin{aligned} \text{Abs. mag} &= \text{appar. mag} + 5 + 5 \log \pi \\ \text{Log Lum.} &= 0.200 - 0.4 \text{ app. mag} - 2 \log \pi \end{aligned}$$

These quantities have not been computed in the case, that the parallax is + 0".030 or smaller. It is considered that no reliable values can be obtained in these cases.

It is clear that Kapteyn found the absolute magnitude a very interesting and useful concept. In 1910 he discussed the fact that stars of different spectral classes have different values of average absolute magnitude (Kapteyn, 1910). This, needless to say, is the basis of the main sequence of the early Russell H-R diagram where it can be seen that, for example, stars of spectral class B0, A0, F0, G0, K0 and M0 have average absolute magnitudes of about -2.0, 0.0, 2.8, 5.2, 6.8 and 10.2 respectively.

But let us go back to the earlier paper mentioned in the Kapteyn quotation, i.e. *Publications of the Astronomical Laboratory at Groningen*, No. 11. In this 1902 paper, (i.e. Kapteyn, 1902), we find the very first definition of the term absolute magnitude. Kapteyn introduces the concept in terms of stellar luminosity, and adopts as the unit of luminosity the total luminosity of the Sun. Equation (11) in Kapteyn (1902) is

$$\text{Log } L = 0.2000 - 0.4 m - 2 \log \pi, \quad (3)$$

where L is the stellar luminosity of a star of apparent magnitude m and parallax π . Kapteyn (1902: 12) writes

We further define the *absolute magnitude* (M) of a star, of which the parallax is π and the distance r , as the apparent magnitude which that star would have if it was transferred to a distance from the sun corresponding to a parallax of 0.1". It is easily seen that

$$M = m - 5 \log r + 5 = m + 5 \log \pi + 5 = 5.5 - 2.5 \log L \text{ [his Equation 12]}$$

For the Sun, $L = 1$; the formula thus gives for the absolute magnitude of the Sun $M = 5.5$, in accordance with what has been said above.

So the 'father and founder' of the absolute magnitude system is the great Dutch astronomer Jacobus

Cornelius Kapteyn, and the concept was first introduced in 1902.

4 CONCLUSIONS

Even though Kapteyn defined absolute magnitude for the first time, in 1902, and chose the standard parallax of 0".1 (i.e. a distance later referred to as 10 pc), its universal acceptance owes much to the work of Hertzsprung. To quote Waterfield (1938: 133):

The importance of the conception of the real or "absolute brightness" of stars was first urged by Professor Hertzsprung, the great Danish astronomer ... By absolute brightness we mean that brightness a star would have if placed at a certain standard distance from us.

Historically, the role of Hertzsprung has been somewhat confused. Some (e.g. Abbott, 1984: 72) have suggested that Hertzsprung actually pioneered the usage of absolute magnitude in 1905. This is not so, as Kapteyn preceded him by three years. Also, when Hertzsprung used absolute magnitudes he had a standard parallax of 1 sec arc, and not the 0.1 sec arc suggested by Kapteyn in 1902.

In the first two decades of the use of the term absolute magnitude, this being the period 1902–1922, the choice of standard distance was left to the individual. This clearly presented ample opportunity for confusion. Things were regularised in 1922 at the first meeting of the General Assembly of the International Astronomical Union in Rome. The Commission des Notations, des Unités et de l'Économie des Publications accepted an American suggestion: Quoting from Volume 1 of the *Transactions of the International Astronomical Union* (see Fowler, 1922: 23):

UNITÉS.

En ce qui concerne les unités on pourrait adopter les propositions du comité américain (Report on the organisation of the International Astronomical Union, *Proceedings of the National Academy of Sciences*, 6, 1920, p. 360 ...

(b) *Magnitude absolue*. Magnitude d'une étoile, ramenée à la distance de 10 parsecs. (Fowler, 1922: 23).

By 1922 the word parsec was in common usage, and everyone had adopted the same standard distance for the absolute magnitude.

5 NOTES

1. Russell worked with Hinks as a Carnegie Institution funded research assistant when he was at King's College, Cambridge, during 1902–1905 (see DeVorkin, 2000: 54).

2. Moving to the present, on 1 July 2005, Henry et al. (2005) recorded that there were 48 stellar systems inside a sphere of radius 5 pc. Five were triple stars, 11 were doubles and 32 were single stars, making 69 stars in all.

3. The Swedish astronomer, Carl Vilhelm Ludvig Charlier (1862–1934) was the Director of the Lund Observatory.

4. Note, however, that in a rather Germanic fashion Strömgren hyphenates the whole expression trying to make Hertzsprung-Russell-diagram one word.

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