

Magnitude...?

Jan Hollan

1998-09-01

Among several “obtrusive medieval features” in astronomy there is one, which is simple to solve, but difficult to obey the chosen solution. I mean the ridiculous way of indicating, how bright the stars are. For two thousand years the stars had been just sorted into several classes. Only recently, in the 19th century, this procedure was somehow defined and refined. So, we have not just stars of *first brightness class*, *second brightness class*, etc., but we can use decimal numbers as well. However, we do it rather silly.

The problem is not that we would not get accurate results. Similarly, as in case of positions of celestial bodies, we only keep secret, what we really mean. What do our numbers mean. This secrecy is useless, and I am sure that it is harmful. No wonder that we are misidentified with astrologists. What we miss to be taken for physicists?

In the astronomical photometry just a little. The information, how bright a star is must be expressed by a value of a physical quantity. And to this quantity, some unit of measurement should belong. For historic reasons, this unit is called *magnitude*. But to prevent confusion, the quantity itself must have another name. We propose to use the term *faintness* when referring to this physical quantity. (English linguists may replace it by a more suitable word.) To be able to define the quantity easily, we need one more quantity, *brightness* (its unit being lumen per square meter). Then it is sufficient to give brightness corresponding to the faintness of zero magnitudes (approximately to that of the star Vega), and to define that stars which are five magnitudes fainter (i.e., with faintness of five magnitudes) are hundred times fainter (i.e., their brightness is just 0.01 of the brightness of Vega). Difference of 2.5 mag means the ratio of brightnesses of 10, stars 7.5 mag faint illuminate us thousand times less than Vega. Faintness is a dimensionless and a logarithmic quantity. Some quantities in acoustics are of similar type, what is not strange: they also try to match the rules of human perception.

Nowadays photometry is seldom based on human vision. Therefore many similar quantities have been used, each applying to some filter used for observation of visible and invisible radiation from the universe. Transmissivity curve of one of them (of the V filter) is similar to the sensitivity curve of human eye (hence V for Visual). Almost all faintnesses are defined in such a way that Vega is approximately zero magnitudes faint (for setting the base level more accurately, a set of stars is used). There is just one notable exception, a “filter-less” *bolometric faintness*¹ (encom-

passing the whole electromagnetic spectrum), where Vega has some -0.3 mag. Thanks to this convention one needs not much care of which filter has been used indeed when reading popular texts. If e.g. the text reads that “the minor planet was of *fifteenth brightness class*”, i.e., that its faintness was approximately fifteen magnitudes, one understands that it was some one million times fainter than Vega, or than a fixed star of zero-th brightness class (fifteen is three times five, and the third power of one hundred is one million).

It is a bit queer language, but it is not vague. Unfortunately, it becomes vague in common texts. Words *brightness class*, *brightness*, *faintness* and *magnitude* have been arbitrarily interchanged. The last one is sometimes used not for a unit, but for a quantity. Moreover, it has been often combined with an ordinal numeral. However, an ordinal numeral suits just to the ancient way of sorting into brightness classes.

The most substantial terminological problems of this kind occur naturally in some Romanic languages. Those brightness classes have been traditionally called “magnitudes”, i.e., sizes, and it has been well understood in these languages. Unfortunately, the same situation has developed in English. Other languages can avoid confusing name of the unit for the name of the class simply by using their own word for “size”. “Magnitude” is foreign word for them, and is not felt as a synonym for size. E.g., in German, the brightness class is called *Größe*, in Czech it is *velikost*. Both these languages have one more advantage over English: they have a standard (maybe felt a bit obsolete, but all the more traditional) name for the faintness. In German it is *Sterngröße*, in Czech *hvězdná velikost*. Or is it a disadvantage? Faintness rises, when the star gets fainter, and everybody would expect it to do so. It is far from being the case for *Sterngröße*.

I insist that *magnitude* should never be used as a name of the quantity. Using it as a synonym for a brightness class should be mostly avoided. If one does not like saying “a star of the third brightness class”, one can say “the star has three magnitudes” or “the star is some 3 mag” instead.

Most astronomers are vulnerable to use confusing language when speaking about stellar photometry, as they have been educated that way. It takes some time to get rid of it, even if one tries hard. Even me, an author of this proposal of transparent terminology, lasted years, to adhere to it completely and to avoid most mistakes.

¹Bolometric faintness is the first quantity in astronomical “photometry” (radiometry, in fact), which can be attached to SI without problems. A star which is 10 parsecs distant has bolometric faintness 0 magnitudes, when it is an isotropic source of radiant flux of $3.055 \cdot 10^{28}$ W. This value proposed by Roger Cayrel has been adopted at the assembly of the International Astronomical Union in 1997[4]. However, the quantity is called magnitude, and it has no unit in the resolution from 1997.

Why?

Maybe you have your own system for speaking about how bright the stars are, and you believe it to be coherent. I doubt you are able to keep it coherent indeed, if it differs substantially from the above-mentioned one. It is really difficult to do without four terms: the one for the linear quantity (which we call brightness), the others for the dimensionless logarithmic quantity (we call it faintness), for its unit (we call it magnitude) and finally for the ancient way of speaking about stars (if its using cannot be avoided, we call it brightness class).

Even four distinct terms are not entirely satisfactory, as there are more linear quantities differing in their dimensions: the old one is photometric (based on *luminous intensity* as a basic SI[3] quantity and on *candela* as its unit)², and all the new ones are energetic (having nothing to do with candelas and lumens, but based just on length, mass and time, and expressed in *watts per square metre*)³

The most common habit is that there is no unit at all. Magnitude is used then as a denomination of the quantity. Having no unit poses large stylistic problems, and it is difficult to express small differences of the discussed quantity. In my proposal, the star can brighten by three millimagnitudes, 3 mmag. Try to examine your texts, whether the word *magnitude* does not mean sometimes a unit, in spite the author trying to avoid that. If you find such phrases (what I consider probable), it will be the same situation as measuring length in “lengths” (not horse lengths, just in lengths). Let’s have an example from a magnificent textbook *An Introduction to Modern Astrophysics*[2]:

Using sensitive instruments called **photometers**, astronomers can measure the apparent magnitude of an object with an accuracy of ± 0.01 magnitude, and *differences* in magnitudes with an accuracy of ± 0.002 magnitude.

In spite of the book being quite clear and rigorous as far as pure physics of the universe is concerned, here the vague astronomical heritage took over. Isn’t magnitude a unit in the quoted sentence? If not, do the authors really mean that accuracy is one per cent of “the quantity named magnitude”? For a star “of magnitude 1” the uncertainty would be then 0.01 (of no unit), for a star “of magnitude 10” it would be 0.1, and for a star “of magnitude 0” it would be none at all! No, they use the same word both for the quantity and for its unit (and for the ancient brightness class as well, elsewhere).

Another system is using *brightness* as a name for the quantity that I call *faintness*. Definition of that quantity becomes then more difficult. But the main defect of such a system is the silly behaviour of the quantity: when the star grows brighter, its “brightness” goes smaller.

If you know some other terminology which remains always coherent and is not confusing, I would be obliged to you if you get in touch with me.

References

- [1] More information from the author is currently available only in Czech. See <http://astro.sci.muni.cz/pub/hollan/a-papers/>
- [2] Carrol, B. W., Ostlie, D. A.: *An Introduction to Modern Astrophysics*. Addison-Wesley Publ. Comp, Inc., 1996. ISBN 0-201-54730-9. <http://astrophysics.weber.edu>
- [3] See, e.g., <http://physics.nist.gov/cuu/> or <http://www.bipm.fr>.
- [4] Andersen, J. (ed.): *Transactions of the IAU, vol. XXIIIB, Proceedings of the 23rd General Assembly*, p. 141 and 181. Kluwer Academic Press, 1999. ISBN 0-7923-5588-1.

The author thanks to his colleague Jindřich Šilhán for much improving the language of the paper.

Jan Hollan,



N. Copernicus Observatory and Planetarium
Kraví hora 2
616 00 Brno
Czech Republic

tel. +420 (5) 43 23 90 96

41 32 12 87

e-mail: hollan@ped.muni.cz

²It may be not quite clear whether photopic (daytime) or scotopic (dark-adapted) vision and units are more appropriate.

³Astronomers often misuse word *luminosity* for (radiant) output of a star. However, the word *luminosity* suggests to be a short for *luminous intensity* (in Czech, e.g., its translation *svítivost* is indeed the only name for luminous intensity). Confusion with a basic quantity of the SI is then easily possible. All the worse, electromagnetic radiation of stars is not just light, what *luminosity* suggests. It is so easy and clear to say simply *output* when one means radiant flux from a given astronomical object.

The worst term used by astronomers is, however, “surface brightness”. The quantity that they understand by it is *brightness per solid angle*, which is the same as *luminance* or rather *radiance* through a given filter. It should be measured in candelas per square metre, or in watts per steradian and square metre. If one wishes to express it in a logarithmic way, it is quite correct to say, e.g., that “one square second of this nebula is 20 mag faint”. One can table faintness of a given solid angle in a list of astronomical objects to express their luminances indirectly. But no sound quantity can possibly have a unit of “magnitude per square second”.

Two simple programmes, which convert logarithmic and linear photometric and radiometric quantities, are available at <http://astro.sci.muni.cz/pub/hollan/programmes/photometry>.