Luminous variable stars with naked eye: data reduction including extinction

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Abstract
The observation of variable stars from urban contexts is hampered by city lights and field of view. Some bright stars like Betelgeuse and Antares are visible from the majority of cities, and during clear nights can be accurately estimated with the naked eye. The reference stars should be bright stars, not necessarily at the same altitude, including the atmospheric extinction in the data reduction. The software Stellarium 0.12.4 calculates well the standard atmospheric extinction with stars at least 10 degrees above the horizon. The accuracy of visual estimations is better than 0.1 magnitudes.

Introduction: variable stars for divulgating astronomy at MAST
During my visits at MAST, Museu de Astronomia in Rio de Janeiro, in December 2013 and February-April 2014 I started a project based on the observation with naked eye and binoculars with some variable stars. They were the Nova Centauri 2013 [1,4] Betelgeuse, Antares, Delta Scorpii with naked eye; Eta Carinae, V520 Car, V766 Cen and again Nova Cen 2013 in its fading phase with binoculars. The students who visit the Museum can continue alone the observations, without being limited by the possession of an instrument, and stimulated by a creative use of the computer. These naked-eye observations are promoted to make students independent from their teachers, as were the students of Gerbert when used his celestial spheres "*Gerbertus Suos liberaliter instruxit*" [3]. Using Stellarium software the students can prepare the observation, or doing an experiment design and perform data reduction, completing the two important steps of a scientific measurement.
Data of Betelgeuse and Antares are presented.

Stellarium 0.12.4 and online databases
Stellarium free software is routinely used to present to the public the observations with the historical and modern telescopes. Thanks to the great diffusion of personal computers, why do not use Stellarium for improving the data reduction of naked eye observations? The results obtained with Betelgeuse and Antares during these months are encouraging: it is possible to perceive their variability in a few weeks. The formative value of such an

experience is enormous, as the opportunity for students to use intelligently their computers for preparing and reducing their observations.
The data on stellar magnitudes available on 0.12.4 version are generally good for our purposes, but they are mainly refereed to Hipparcos/Tycho catalogue were the magnitude are slightly different (no more than 0.05/0.07 magnitudes) from Johnson system UBV. I recommend to check the reference stars on *Simbad*[43] database and to take into account the V magnitude as a reference. Stellarium shows the Hipparcos magnitude and the extincted one. We have to keep in our calculations only the amount of the extinction ΔV, easily obtainable from Stellarium 0.12.4 by clicking on the star. Also the comparison stars (or planets[44]) are extincted and this magnitude should be considered in the estimations, remembering to change the Hipparcos magnitude Hp to V by using the colors B-V and U-B: $V \sim Hp + \alpha1(B-V) + \alpha2(U-B) + \alpha3(B-V)^2 + \alpha4(B-V)^3 + \alpha5$ with α1=-0.2964; α2=0.0050; α3=0.1110; α4=0.0157 and α5=0.0072 [7].

Extinction and color: models and observations
For a fruitful measurement of the stellar magnitude it is recommended to select stars of the same color index; to observe stars high in the sky, possibly at the same altitude [4]. But the calculation of the extinction is rather confiable up to 10 degrees above the horizon; below 10 degrees the differential extinction occurring with different colors became significant, and specifical corrections should be taken into account. When a star is rising or setting it does not follow the law m(X) = m0 + k * X, were X=airmass and k=0.08, 0.1, 0.2, 0.4 or 0.6 respectively for I, R, V, B and U bands [5]: the humidity layers determine locally peculiar absorption conditions [6].
The loss of magnitudes should be modeled *ad hoc*, in order to understand the corresponding behavior of red stars like Aldebaran and Antares, but it is better to avoid observations below 10 degrees.

Results and remarks: Betelgeuse and Antares
The classical method of Argelander, is corrected for the extinction. As example Betelgeuse is at an altitude where the extinction is ΔV=0.30 and it appears of magnitude intermediate between Procyon (0.37+0.20) and Aldebaran (0.85+0.40); so x+0.30=½(0.57+1.25)=0.81; hence the unperturbed magnitude of Betelgeuse that day is x=0.51.

[43] http://simbad.u-strasbg.fr/simbad/
[44] Unlike previous versions of Stellarium, the 0.12.4 has reliable magnitudes for planets. It has been verified with naked eye Saturn estimation, and the ephemerides calculated by the Observatório Nacional of Rio de Janeiro [2].

Here the images of the two stars observed by the author with SGQ AAVSO code. Note the large spread of other visual observations of the AAVSO database (circular dots).

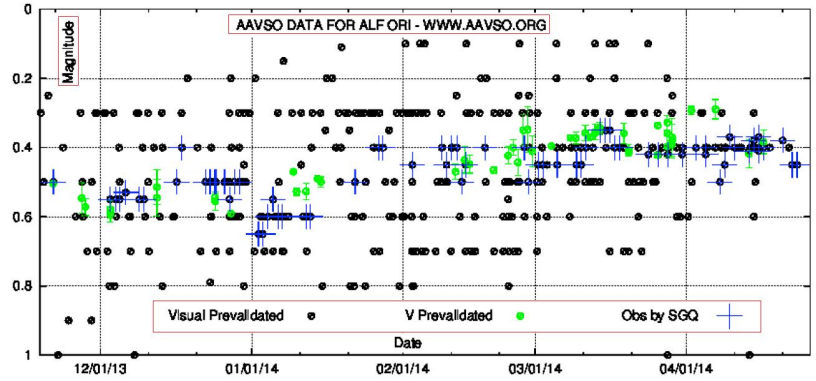

Fig. 1. Light Curve of α Orionis, Betelgeuse from December 2013 to April 2014; the crosses represent the observations here described, made by the author (SGQ code). Note the unreliable large scatter of other AAVSO data, ranging one whole magnitude.

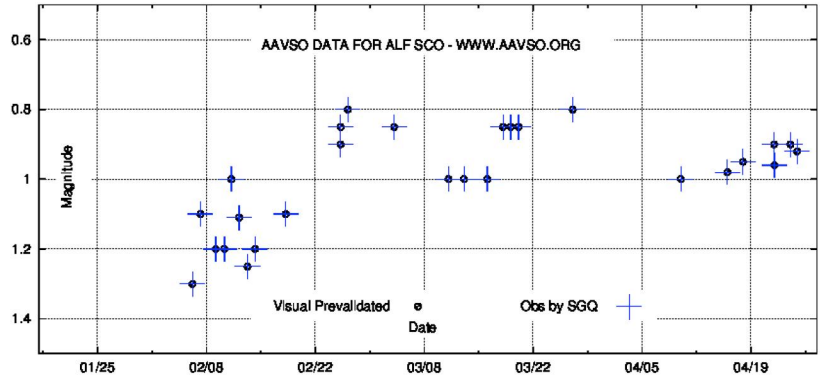

Fig. 2. Light Curve of α Scorpii, Antares, from February to April 2014. The star underwent variations of 0.2 magnitudes within 10 days. No other AAVSO observers contributed to the measurements of this red supergiant in this period of time. The cross is the default marker used in AAVSO website, and it suggests an errorbar, which is not the case in x axis. In the y axis the cross amplitude correspond with a very good, but reliable, errorbar of 0.05 magnitudes.

Conclusions

The reliability of visual observations is out of discussion, since the history of such astronomical field has been grounded on these observations. Especially when there are appropriate comparison stars, slightly brighter and fainter than the variable star in measurement, the data obtained are good and can have optimal accuracies, to the level of 0.01 magnitudes.[45]

Many observers are not enough accurate to estimate bright stars without close and appropriate comparison stars, as for Betelgeuse and Antares. A method of data reduction using Stellarium 0.12.4 atmospheric extinction has been described and tested, with good results.

The method is simple, suitable for students, beginning their observational carreer, suitable to be adopted in urban environments, were both light pollution and reduced fields of view hamper the observations.

The use of naked eye as measuring instrument is also very important for epistemological reasons. It is a common (and wrong) opinion that the eye is not suitable for accurate measurements. This is an heritage of positivism, were the eye, the five senses and the man without instruments were undressed by their capability of achieving the truth (and therefore the Truth with capital T), a capability never discussed at the time of Gerbert, or of St. Thomas Aquinus.

The eye is a wonderful instrument, which requires a calibration as the other instruments, and can attain a photometric accuracy of 1/100 of magnitude.

The observations with naked eye help students to be introduced in the world of Astronomy, put them in special relation with the Creation, stimulating the creativity either in observational methods (like defocusing stars to better compare their magnitudes) either in data reduction procedures, like setting the equation for unextincted magnitude of the variable stars, in a extended concept of differential photometry which make use also of distant comparison stars at different altitudes.

References

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