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Importance of Estimating Extinction Coefficients in Stellar Photometry

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Abstract: **In this article, we discuss the importance of estimating the extinction coefficients for different pass-band filters in the stellar photometry. As the stellar brightness measured by ground based telescopes is reduced due to the scattering and absorption by the atmosphere of the Earth, the extinction correction is required to overcome such attenuation in the stellar brightness. Because of this fact, we also describe the procedure of determining the extinction coefficients for B and V pass-band filters using the CCD images of the Landolt's standard stars field PG2331+055, which are provided by the Skinakas Observatory. Since the extinction coefficients are estimated by the slope of the graph between the airmass and instrumental magnitudes of a standard star marked as 'A' in the field PG2331+055, the stellar magnitudes are calculated by performing the aperture photometry on this standard star 'A' whose CCD images were observed in the same night over a wide range of airmass. It is found here that the effect of atmospheric extinction is less in V-filter than in B-filter.**

Keywords: **Atmospheric coefficients – methods: observations and data analysis – technique: CCD photometry.**

1. INTRODUCTION

As light from a celestial object passes through a certain amount of optical path length through the earth's atmosphere to reach the observer, the light is attenuated by scattering and absorption. This optical path length is known as airmass and this reduction of the intensity of radiation is called atmospheric extinction. For precise photometric observation, extinction measurement must be made with great precaution and each data point should be corrected for extinction [1]. Precise atmospheric extinction determinations are needed not only for stellar photometry but also for any sort of photometry, spectroscopy, spectrophotometry and imaging whenever accurate, absolute and well-calibrated photometric measurements are required for the derivation of physical parameters in the studies of galaxies, nebulae, planets, and so forth [2]. In addition to this, it is worth mentioning here that even on a clear night and in good weather condition, the extinction coefficients are found to be variable. The most probable cause of extinction variation throughout the night could be settling of dust particles, shrinking or swelling of the aerosols due to water vapour content variations and/or exchange of different airmass over the observing sites [3, 4]. This suggests that the extinction coefficients must be estimated for the several standard stars which are available in a particular night sky during different courses of time.

2. EXTINCTION COEFFICIENTS AND AIRMASS

The atmospheric extinction depends on the wavelength of the light, the filters being used in the observatory. At the effective wavelength λ, the ground observed instrumental magnitude m is related to the extra-atmosphere instrumental magnitude m_0 by Bouger's law

$$m = m_0 + K_\lambda X \qquad \text{……………..} (1)$$

where K_λ is the extinction coefficient(measured in mag/airmass) at a particular wavelength λ and X is the airmass, which is related to the zenith angle Z by the relation $X = sec\ Z$ [5]. As the airmass is function of zenith angle Z, the variation of airmass with the zenith angle is shown in Fig. 1. The airmass is having minimum value at the overhead, where Z is equal to zero, whereas its value increases as one looks at stars closer to the horizon and reaches to maximum at the equator. From eq. (1), it is clear that the extinction corrected stellar magnitude can be obtained by subtracting $K_\lambda X$ from the instrumental magnitude m.

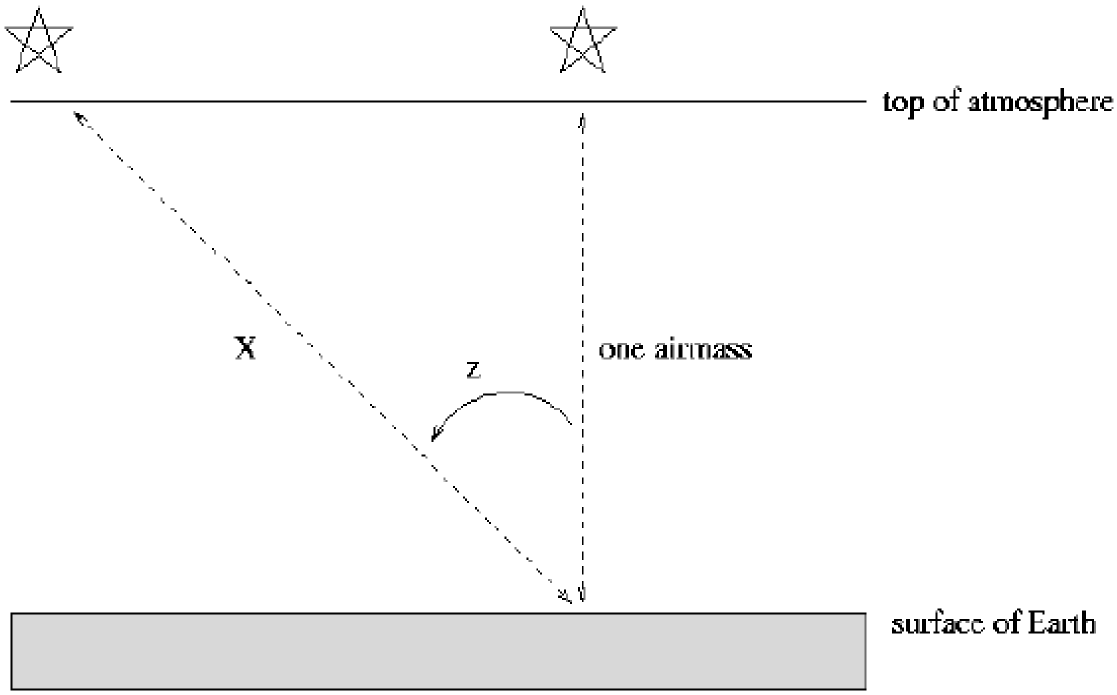

Fig. 1: Change of Airmass with the Distance from the Zenith

The value of the airmass can be calculated by the following equation

$$sec\ Z = [sin\ (LAT)*sin\ (DEC) + cos\ (LAT)*cos\ (DEC)*cos\ (HA)]^{-1} \qquad \ldots\ldots\ldots\ldots(2)$$

where *LAT* is the observer's latitude while *DEC* and *HA* are the star's declination and hour angle, respectively [6].

3. REQUIRED OBSERVATIONS AND DATA REDUCTIONS

In order to calculate the extinction coefficients, multiple observations of a standard star at the different time in a night is required by the ground based telescope with the CCD and B, V, R, and I pass-band filters as the backend instruments. As far as the standard stars are concerned, one can choose any one of the Landolt's standard stars fields such as PG2331+055. In addition to this, one need to have calibration frames such as the bias, dark and flat-field frames, which are required for the preprocessing of CCD images of the standard stars to get the clean images using the task within the image reduction and analysis facility (IRAF) [7, 8]. Since eq. (1) suggests that the extinction coefficients are estimated by the slope of the graph between the airmass and instrumental magnitudes of a standard star, the aperture photometry is required to perform on the CCD images of the standard star in B, V, R, and I pass-band filters to calculate its instrumental magnitudes at different time using the 'phot' task within the IRAF.

4. DEDUCTION OF EXTINCTION COEFFICIENTS USING LANDOT'S SATNDARD STAR FIELD

In order to calculate the values of the extinction coefficients, we have taken the Landolt's standard star field PG2331+055 which is shown in Fig. 2. The CCD images of this standard star field observed in B and V pass-band filters on August 20, 2005 were provided by the Skinakas observatory. The standard star field includes two standard stars marked by 'A' and 'B'. To determine the values of the extinction coefficients in B and V pass-band filters, the CCD observations of the standard star 'A' were taken throughout the whole night at different values of airmass. The range of the airmass for which the above mentioned CCD observations in B and V pass-band filters were carried out is listed in Table 1. The instrumental magnitudes of the standard star 'A' for B and V pass-band filters are calculated by the process of aperture photometry as discussed in the previous Section 3. The calculated values of the instrumental magnitude of the standard star 'A' for B and V pass-band filters at the different values of airmass are listed in Table 1. In order to estimate the values of the extinction coefficients in B and V pass-band filters, the plots between the instrumental magnitude and airmass are made for B filter (left panel of Fig. 3) and V filter (right panel of Fig. 3). The slope of these plots gives the values of the extinction coefficients which are found to be K_B = 0.30538 and K_V = 0.2049 for B and V pass-band filters, respectively.

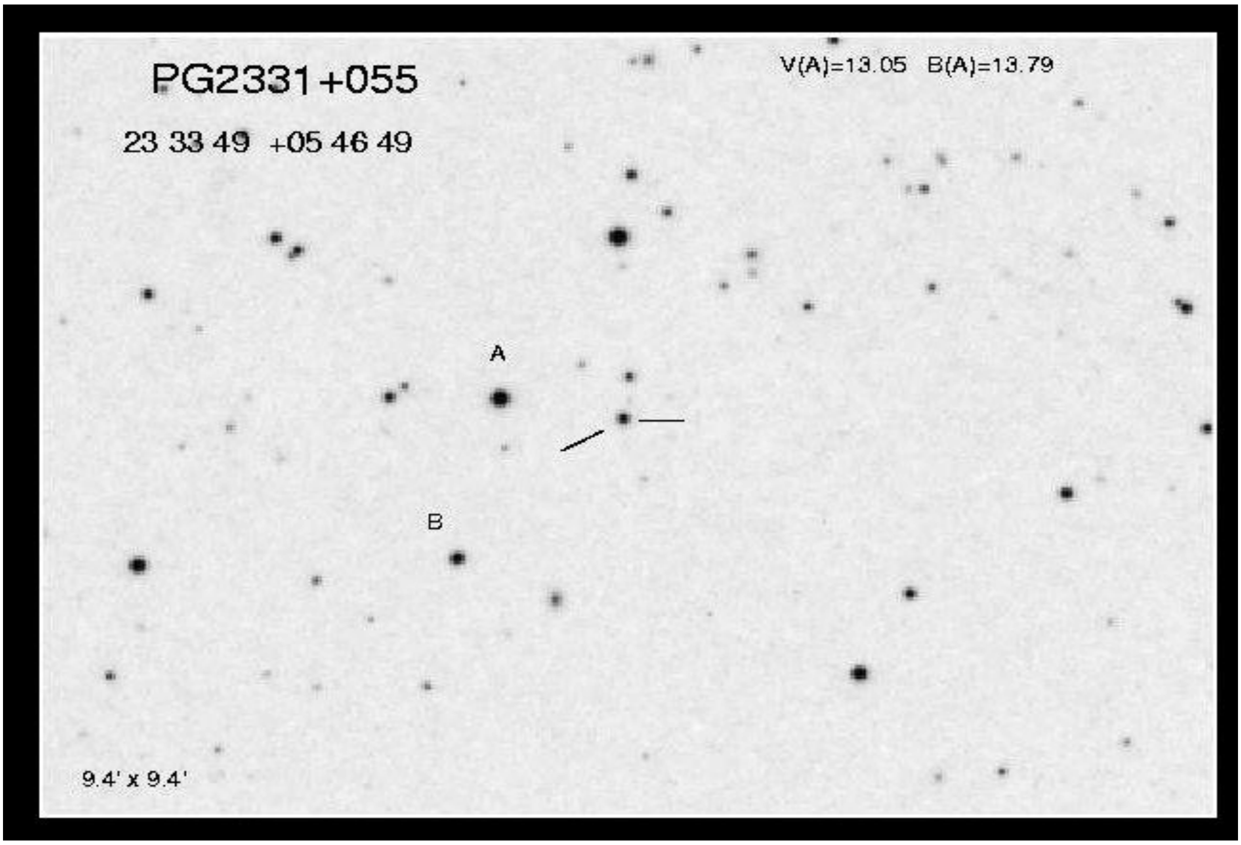

Fig. 2: Standard Star Field PG2331+055 [9]

Table 1: Airmass and Instrumental Magnitude in B and V Pass-band Filters

B filter			V filter		
Airmass (X)	Magnitude (m_B)	Extinction Coefficient (K_B)	Airmass (X)	Magnitude (m_V)	Extinction Coefficient (K_V)
1.9435	11.27	0.30538	1.893	11.40	0.2049
1.6775	11.18		1.641	11.34	
1.223	11.05		1.214	11.27	
1.1485	11.02		1.149	11.25	
1.0635	11.00		1.0815	11.22	

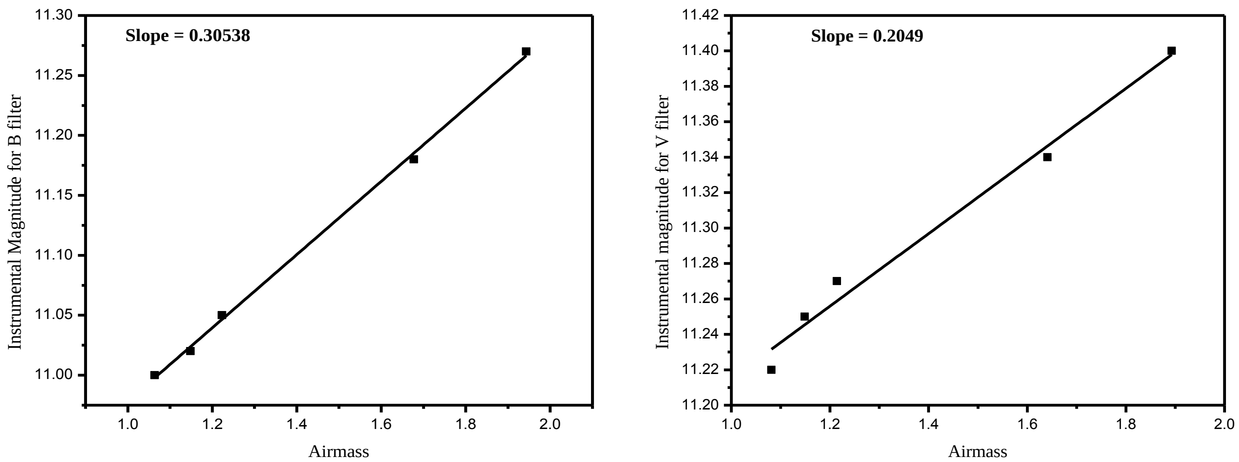

Fig. 3: Left panel shows the plots between the airmass and instrumental magnitudes in B filter, whereas the right panel represents that in V filter.

5. CONCLUDING REMARKS

We conclude here that the extinction correction is worth to be done so that the attenuation of stellar brightness by the Earth's atmosphere could be avoided. It is therefore necessary to point out here that during the course of observations of target stars using any ground-based astronomical observatories, the determination of extinction coefficients in the utilized pass-band filters is requisite. Moreover, the extinction coefficients are found to be colour dependent, since they are having lesser values in higher wavelength (V-filter) than in lower wavelength (B-filter) that can be justified by our calculated extinction coefficients $K_B = 0.30538$ and $K_V = 0.2049$. This also suggests that if one needs the high precession CCD photometry such as in the case of extra-solar planetary systems, instead of B and V pass-band filters, the CCD observations should be done in R pass-band filter.

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