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Night sky brightness monitoring

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Abstract. There are several ways to measure the brightness of the night sky, making it possible to evaluate light pollution levels at a given site. The objective of this work is to present some sky brightness measuring methods for quantitative monitoring of light pollution and use them to elaborate hands-on scholar activities material. We conducted observations at the Observatório Abrahão de Moraes (Valinhos-SP) during the year of 2022 for testing such methods, which resulted in a characterization of the observatory sky for the monitored period. Sky britghness values (SB) were found for the photometric Johnson B (16.82 ± 0.30 mag/arcsec^2) and V filters (16.49 ± 0.48 mag/arcsec^2), indicating that the sky at the observatory is highly light polluted, equal to big cities inner regions.

Resumo. Existem diversas formas de medir o brilho do céu noturno, possibilitando avaliar os níveis de poluição luminosa em um determinado local. O objetivo deste trabalho é apresentar alguns métodos de medição do brilho do céu noturno para monitoramento quantitativo da poluição luminosa e utilizá-los para elaborar material prático de atividades escolares. Realizamos observações no Observatório Abrahão de Moraes (Valinhos-SP) durante o ano de 2022 para testar tais métodos, o que resultou em uma caracterização do céu do observatório para o período monitorado. Valores de brilho do céu (SB) foram encontrados para os filtros fotométricos Johnson B (16,82 ± 0,30 mag/arcsec^2) e V (16,49 ± 0,48 mag/arcsec^2), indicando o céu do observatório como altamente poluído pela luz, similar a regiões centrais de grandes cidades.

Keywords. Light pollution – Teaching of Astronomy – Techniques: photometric – Site testing

1. Introduction

One of the main forms of light pollution is skyglow, which consists of the diffuse light in the atmosphere, causing excessive brightness in the sky, therefore harming astronomical observations. In urban and suburban areas, light by artificial origins usually dominates over natural factors contributing to the total brightness of the night sky. By measuring its intensity and comparing to the expected value for a clear night at a non-polluted sky in the same moon phase, the difference between values implies how much artificial originated britghness is affecting the sky in that area.

We investigated two methods for measuring the night sky britghness: classical astronomy photometry and the *"Dark Sky Meter"* (DSM) application, for *IOS*, in order to elaborate hands on activities for studying light pollution. The choice for this methods were to conduct a characterization of OAM light pollution regime and to ensure that the activities proposed can be conducted at schools and other places for science dissemination, even if a *in situ* or remote observation with a telescope is not possible.

With the activity, we hope to provide material that can be used for introducing light pollution topics for high school and university students, stimulating their critic analysis towards how it affects their context of everyday life, while also performing the data acquisition and analysis to gain pratical experience. Not only, but the activity can also be used in observational astronomy undergraduate classes for introduction to photometry.

2. Methodology

For the photometric acquisition, we used the Argus telescope, a Schmidt-Cassegrain type from *Celestron* with a 28 cm aperture and ST7-XE CCD camera installed. Argus can be accessed remotely through the "Telescópios na Escola" project, but our observations were made *in situ* to compare with the DSM measures. The application, using the *Iphone* camera, works as a panchromatic detector, being easy to obtain night sky britghness values with it, but its spectral response, accuracy and precision requires further analysis to determine how reliable its measurements are.

The standart results used as reference for evaluating light pollution levels at a site are based on the Johnson V and B band measurements (21,5 mag/arcsec^2 approximately), so a calibration procedure was adopted to establish comparison between the application and photometry values. Measurements were made with the two apparatus at the same spot and close to the same time. By doing this, we have a way to evaluate the application results, as both methods measure the brightness of the sky at the zenith. This procedure allowed us to study sky brightness evolution through the hours of the night, calculating the averages for each date. In total, 15 observation missions (from April to October 2022) were conducted at OAM. This set of missions represents enough data to also evaluate the evolution of sky brightness on a monthly scale.

The images were processed using absolute photometry, then reduced by the instrumental parameters of the equipment and the observation conditions. To obtain these parameters, standart photometric stars were observed, determining instrumental magnitudes (m_{inst}) both in the B and V filters for them at different airmasses (χ). This process allows to calculate the photometric zeropoint (ZP) and the extinction coefficient (k) by adjusting a line when correlating the data as $m_{inst} \propto \chi$. While ZP is the linear coefficient found plus the catalogue magnitude of the standart star, k is the angular coefficient obtained. Mean values between the chosen stars of both parameters were taken on a new moon night and adopted for calculating all night sky britghness data. Also, the software used for photometry were *ImageJ*, *SalsaJ* and *DS9*.

For each filter, sky brightness is given in magnitudes per squared arcsecond ($mag/arcsec^2$). Its determination starts by calculating the mean instrumental magnitude of the sky mea-

Table 1. Mean calibration values determined for the night of 30/06/2022.

ZP (V filter) mag	k (V filter) mag/airmass	ZP (B filter) mag	k (Bfilter) mag/airmass
19.18 ± 0.16	0.18 ± 0.08	18.87 ± 0.09	0.27 ± 0.08

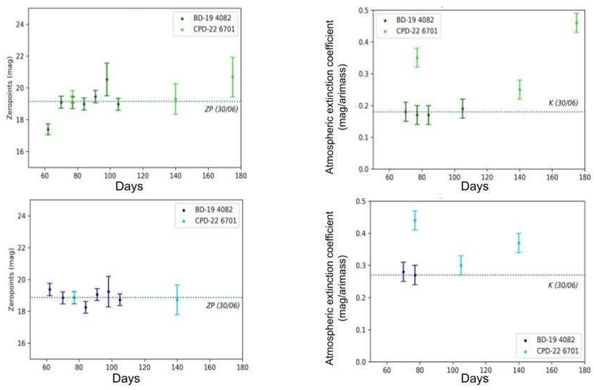

Figure 1. Evolution of calibration parameters (zeropoint and atmospheric extinction coefficient) for the Johnson's V band (top) and B band (bottom).

sured in a surface area of 1 arcsec^2, then fitting it to the calibrated magnitude scale using the instrumental parameters. By doing this, night sky brightness (SB) may be defined as a function of the sky intensity counts (I_{sky}) in an angular area of $1 arcsecc^2$, the image exposure time (t), the airmass at the pointed target (χ), the detector scale (p), the coefficients *zeropoint* (ZP) and atmospheric extinction (k), as:

$$SB = 2,5log(\frac{p^2 t}{I_{sky}}) + ZP + k\chi. \quad (1)$$

3. Results

The night selected for the determination of the parameters used in SB values was June 30th, since it was a new moon night right in the middle of the period monitored, and the only one with in that moon phase with a clear sky. In Table 1 we present the values found.

To maintain some control and check the stability of the instrumental parameters used all over the monitored period, ZP and k were also determined in other nights of non-ideal observation conditions just so it could be compared to the reference values. In Figure 1 we present the evolution of ZP and k among the missions for both V and B filters.

In Figure 2 we present the sky britghness values measured on the night of best observation conditions, (30/06/2022), the same used for determining the parameters. Comparing photometric values with the DSM values, we notice a gap indicating the sky is about 2.5 mag/arcsec^2 darker when measured with the app on that date.

In Figure 3 we present the sky britghness mean values for each mission date, also comparing photometric and the application results. The same gap of darker values for the app (2.5 mag/arcsec^2) can be systematically observed, indicating that there is, indeed, an offset that corrects DSM data to Johson's V band, as the cell phone is not sensible enough to reach the precision of a telescope with a CCD camera.

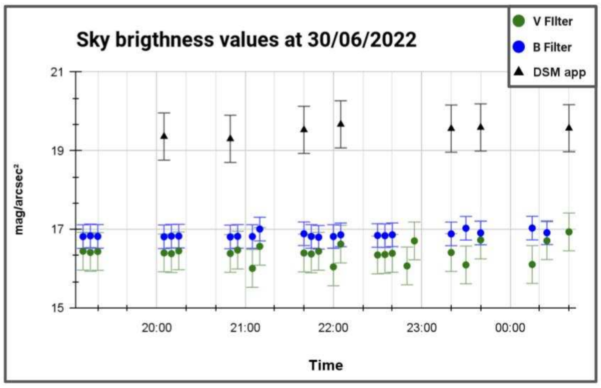

Figure 2. Night sky brightness values measured in 30/06/2022 (new moon).

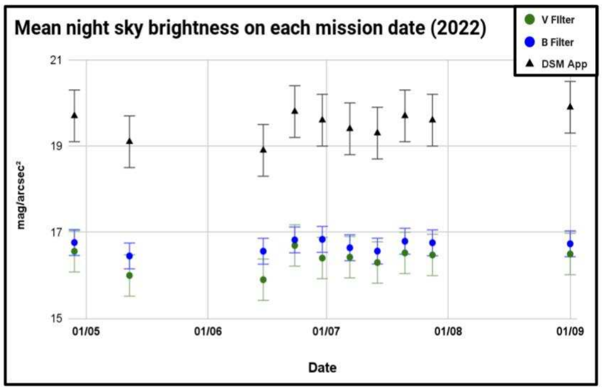

Figure 3. Mean night sky brightness values on each mission date for the V filter, B filter and DSM app.

4. Conclusion

From the 15 missions, only in ten of them data were successfully acquired because of weather conditions, which mainly harmed observations during the last three months of the study (see Fig. 3). Through the period monitored, the OAM showed zenital night sky brightness values consistent with those measured in big cities with high contamination of light pollution.

The DSM app was consistent in its own scale to evaluate night sky brightness variations. However, it is roughly compatible with V or B bands from the UBV Johnson photometric system, showing fainter magnitudes with 2.5 mag offset.

We elaborated a script to conduct similar activities, both locally at an observatory or remotely through the "Telescópios na Escola" project, allowing students to measure night sky brightness with the same Argus telescope used by us. We also addressed experiments with the DSM app for light pollution teaching and outreach, in order to promote awareness and discussions about its impacts where the usage of astronomic apparatus is neither viable or recommended.

References

Hänel, A. & Posch, T. & Ribas, S., 2018, JQSRT, 205, 278-290.