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Calibration of SQM-L photometers for the NixNox project

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Abstract

Twelve SQM-L night sky photometers have been tested and analyzed to determine their internal precision and differences in response. These photometers will be used by amateur astronomers around Spain, under the supervision of the Sociedad Española de Astronomía (SEA), to locate and characterize sites with dark skies well suited to perform astronomical observations (NixNox Project). A simple experimental setup has been built to obtain zero offsets for each photometer in order to correct all the observations.

1. Introduction

The Spanish Astronomical Society (SEA, Sociedad Española de Astronomía) has acquired 12 SQM-L photometer units (http://www.unihedron.com/projects/sqm-l) for the NixNox Project (http://www.sea-astronomia.es/). These photometers will be borrowed by associations of amateur astronomers around Spain to characterize sites with dark skies and easy access suited to perform astronomical observations by the astronomers. SEA will call public attention to these locations to preserve them from Light pollution and to promote the observations of the starry skies by the common people.

According to the manufacturer the internal precision is around 0,1 mag/arcsec^2 [1] and differences in zero point between units are expected to be also around ~0,1 mag/arcsec^2. Thus, these values should be taken into account when comparing measurements reported from different observers using their own photometers.

Since our twelve units have been purchased and shipped together, we have a good opportunity to test them at the laboratory before using them in the field. Knowing their internal precision and differences in zero point, the collected values of night sky

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[1] The astronomical unit to measure surface brightness is mag/arcsec^2 (magnitudes per square second of arc), which is equal to the apparent magnitude of the flux emitted by one square arcsecond of the object. For night sky brightness measurements, a value of 21 mag/arcsec^2 means a brightnes similar to that of a 21st magnitude star spread over 1 square arcsec.

brightness could be transformed into a common reference frame.

We intend neither to test the linearity of the detector, which has been assumed perfect during our study, nor to obtain the absolute calibration by comparing with convencional astronomical photometry and standard lamps. These studies, which are out of the scope of this project, and those related with the spectral and angular response, will be carried out later[2].

2. Design of the tests and instrumental setup

First of all, each photometer has been labelled so they could be identified unambiguously. A running number has been assigned when the units were extracted from the postal parcel in a random way. The following table shows this name along with the serial number (which can be obtained by pressing and holding the button a second time after the measurement).

SEA Code / Serial Number			
#01 / _2.175698	#02 / _2.175705	#03 / _2.175714	#04 / _2.175697
#05 / _2.175695	#06 / _2.175691	#07 / _2.175710	#08 / _2.175699
#09 / _2.175692	#10 / _2.175693	#11 / _2.175690	#12 / _2.175708

To obtain internal precision and zero-point differences we have designed a strategy, which is based in a repeated measurement with the different units under the same illumination conditions. The laboratory setup is very simple: a stable light source illuminates the SQM through a yellow filter, which acts also as a diffuser (see figure 1). There is no other optical part except a light tight box, made in black lightweight cardboard, which holds all the pieces together and ensure that the photometer are placed always in the same position and orientation. A blue LED is used as light source and the electrical voltage and intensity are controlled with a stabilized power supply. The yellow filter and blue LED were used because they were available when the setup was built. An additional potentiometer circuit is used to regulate the intensity of the light source so that values similar to those of dark unpolluted skies could be reached with this system. Much effort was put in the control of stray light, for which the measuring box was sealed with black tape, a cover was designed and attached to the rear of the box, and any internal leakage of light was also sealed with tape. It is mandatory that the photometers were tested in the same conditions. This is why the box has been built with a design and size which ensures that the distance and orientation to the diffuser are always the same, and the measuring photometer is tightly hold in place.

[2] A very exhaustive test of the SQM to be used for night sky brightness can be found in "*Night Sky Photometry with Sky Quality Meter*" by P. Cinzano (2005) (http://www.unihedron.com/projects/darksky/sqmreport_v1p4.pdf).

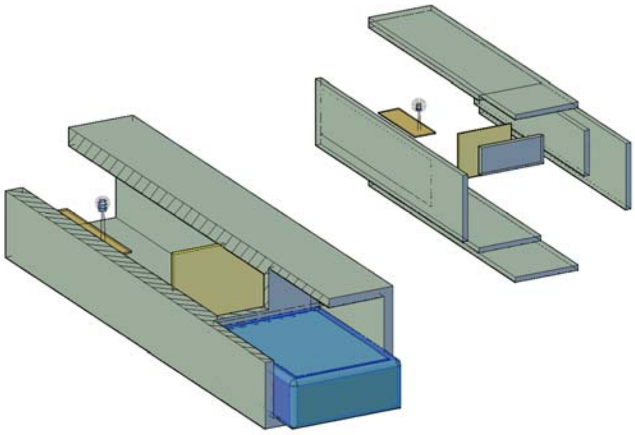

Figure 1. Schematic drawing of the box used to perform the measurements. On the left, a section allows observing the interior of the box and the position of the SQM during a measurement. On the right the box is shown exploded into its components.

Figure 2. Instrumental setup. The box has two open sides, and is similar to a tube. The filter and diffuser are inside and thus not visible in this image. (Left) Stabilized power supply and light source. (Right) View of the other side of the box, with one photometer in position. Although the pictures were made in ambient light, we measure in darkness to avoid stray light.

The SQM is powered by a 9V battery. The photometer contains a voltage regulator to power the sensor, microcontroller and other components. The effects of temperature on the microcontroller oscillator are removed by the electronics.

3. Experiment protocol

The first photometer that was taken out of the postal parcel has been labelled SEA#01 and it was considered the reference or master photometer.

A low level brightness similar to that of the dark sky has been selected to perform the tests. The repeated measurements correspond to values around 18 mag/arcsec^2. Assuming that the detector has a linear behaviour, differences in the results when using a brighter source are not expected.

Initial tests with the master photometer showed that, with a series of just 20 repeated continuous measurements with the same photometer, we were able to reach precisions of a few hundredths of magnitude per square arcsecond. The following experiments were then performed as repeated series of 20 measurements with the master and 3 more photometers. To minimize differences, the photometers were used consecutively without interruption, and in a sequential way (1-2-3-4-1...). Being the master one of the 4 photometers additional tests of the stability of the light source could be performed. To get rid of this posible unstableness, the measurements may be referred to the level measured by the master photometer, or (thanks to the sequential protocol) to an average flux of the four for each run.

Data were recorded along with the data and time of each series and the room temperature although the photometers were all the time inside the optical lab, which is temperature controlled.

4. Results

Within a period of nine days we took measurement series, almost daily, of photometers 1, 2, 3, and 4. By that time, SQM#1 had been used in several preliminary tests, while the rest were barely used. We noted that in the first measuring series SQM#1 had much lower dispersion than the others (0.02 mag/arcsec^2, compared to around 0.1 mag/arcsec^2). Secondly, we noted that the dispersion of SQM#2-4 improved as days passed by and more measurements were carried out. After the period of one week, the precision of all the photometers had matched that of SQM#1. We also observed that the differences of zero point between photometers are stable to a few hundredths of magnitude. Figure 3 shows this sequence of measurements, where the commented results can be observed.

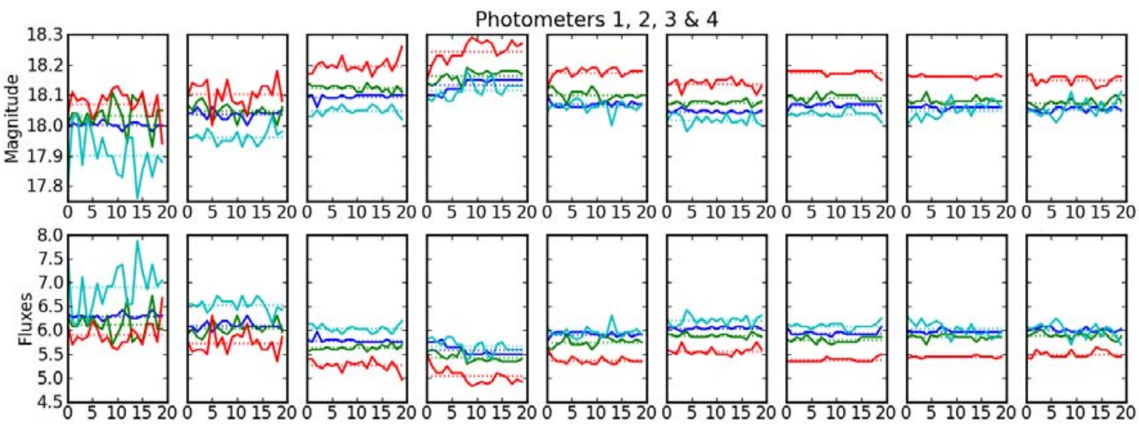

Figure 3: sequence of measurements for the photometers 1, 2, 3, and 4, along several days. The upper panels show the direct measurement of the SQM, while in the lower

panels this has been transformed to a flux in arbitrary units. Every panel shows a series of 20 measurements, with different colours standing for different detectors. The blue line represents the data from SQM#1.

In order to check that the commented above was a real instrumental effect, and not a by-product of our improved experimental protocol, we selected another three new photometers, to repeat the test together with the reference one. As expected, the dispersion of the newly used photometers was much higher than that of the SQM#1, which had been extensively used before. This can be appreciated in Figure 4.

The taking of experimental data had then to be interrupted for two weeks, due to urgent requirements of the work at the lab. During this period the light source was turned off and unplugged, and the photometers were not used at any moment. After resuming the taking of data we observed that the dispersion had increased notably, including that of the reference SQM. In some measuring series of those days we could observe also some variation of the light source (as correlated variations in the measurements of the different photometers), so this was removed by relating the data to an average flux of the measurements for the four photometers in one run (1-5-6-7; one complete series is composed of 20 runs). The effect of increased dispersion, and again decreasing with use, can be observed in the data corrected for light source variation, as well as the stability of the needed zero-point correction.

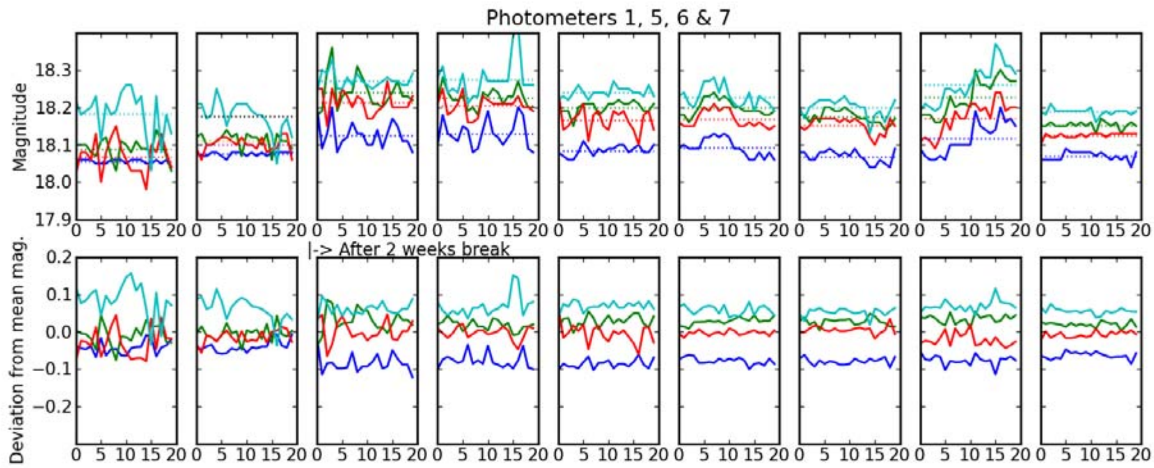

Figure 4: sequence of measurements for the photometers 1, 5, 6, and 7, along several days. The upper panels are similar to Figure 3. In the lower panels we plot instead the corresponding deviation from a mean magnitude, calculated from an average flux for each run (measuring 1-5-6-7). This removes possible source variations. Between the second and third column of panels there is a time gap of 2 weeks. The blue line represents the data from SQM#1, and the other colours stand each one for one photometer.

5. Discussion and conclusions

We have found that the dispersion in the measurements, and thus the expected precision, changes with the use of a SQM unit. In several days of daily use (just 15 minutes a day) a stable low dispersion of a few hundredths of magnitudes is achieved. However, a resting period of a couple of weeks may worsen the measuring dispersion of the units. A better behaviour is again recovered after some days of use.

We have also proven that differences in zero-point do exist and can be measured, and that they seem to be stable up to a few hundredths of magnitude.

In some measuring series with the second group of photometers we have observed some variations of the light source. These have been removed relating the measurements to an average flux for each run. However, this procedure cannot remove the possible variations of a characteristic time of less than a few seconds (the time required for measuring one run of the four photometers). This may contaminate the result of increased dispersion after a rest period, while the other conclusions are fairly robust.

The choice of a blue LED for the illuminating source, and a yellow filter as a diffuser may have been inappropriate to ensure a highly stable illumination. The LED can change the wavelength of its peak emission with temperature, than can then be further modulated by the filter. We are planning now to replicate the results with a different experimental layout, although we believe that this would not affect our conclusions regarding the change in the measuring dispersion.

Acknowledgements

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