Laboratorio de **C**ontaminación **L**umínica
LPL-USC
Light Pollution Lab

Short Report Series
LPL-USC-SRS/01
Date/version: May 5, 2015 / v01

Interobserver variability of hand-held SQM-L measurements

Salvador Bará[1,*], Raul Lima[2], Ángel R. Arós[3] and Lucía Giráldez[1]

[1] Universidade de Santiago de Compostela.
[2] Porto Polytechnic Institute.
[3] Universidade da Coruña.

Summary: Under stable luminance conditions the uncertainty of the brightness measurements obtained with hand-held SQM-L detectors arises from the combination of their intrinsic precision and the random pointing errors incurred by the observers. Based on the observations performed by 13 independent observers without previous training in SQM-L use, we got an estimate of 0.074 mag/arcsec^2 for the observer-induced uncertainty (standard deviation of the sample) under 20.83 mag/arcsec^2 skies.

INTRODUCTION

Unihedron^{TM} SQM-L devices are widely used to assess the night sky brightness at different sites. According to manufacturer specifications the absolute precision of each meter is believed to be ±10% (±0.10 mag/arcsec^2). The difference in the zero point between calibrated SQM-L is also rated at a ±10% (±0.10 mag/arcsec^2) level. There is however some lack of reliable data about the measurement uncertainty due to the interobserver variability in actual field conditions. Here we report on the results obtained during one observation night of the 2015 Winter campaign of measurement of the sky quality at the Galician Atlantic Islands Maritime-Terrestrial National Park (*Parque Nacional Marítimo-Terrestre das Ilas Atlánticas de Galicia*).

FIELD MEASUREMENTS

The zenithal sky brightness data were taken between the 23:00 and 24:00 h (CET) in the clear and moonless night of March 14 to 15, 2015, at the *Dique de Rodas* site located in *Illa do Faro*, belonging to the Cíes archipelago (42.224359°N,–8.905704°W). A group of thirteen young volunteers, with no previous experience using SQM-L devices, collaborated in this study. AA and LG coordinated this task. Each observer took three measurements of the sky brightness trying to point the SQM-L to the zenith. The all-sky luminance distribution at the islands has a noticeable gradient towards the East, due to the influence of the metropolitan area of Vigo and neighbouring towns, whereas the western horizon (Atlantic ocean) is free from stable light sources. Three SQM-L detectors were used (Serial No: 7909, 8144 and 8483). The detectors were randomly assigned to the observers. Each observer used a single detector to obtain the three measurements. The results are listed in Table 1 below. The recorded brightnesses were distributed in the range [20.64,21.00]

mag/arcsec^2, with overall average 20.83 mag/arcsec^2 and estimated standard deviation based on the sample close to 0.08 mag/arcsec^2. The standard deviations of the data acquired by individual observers spanned the range [0.00,0.10] mag/arcsec^2, with average 0.06 and median 0.07 mag/arcsec^2. The interobserver variability is just slightly higher than the typical value for individual observers.

LAB MEASUREMENTS

Since the field measurements were originally planned for another purposes and the serial number of the detector assigned to each observer was not recorded at that time, a separate run of measurements under controlled conditions was performed at the LPL of Universidade de Santiago de Compostela, Galicia, in April 2015, in order to assess the intrinsic variability of this detector set. To that end, the three SQM-L used in the field campaign were used again to measure the zenithal brightness of the lab ceiling, that was diffusely illuminated by light scattered at the walls from a stabilized current, NPL-traceable, spectral irradiance Bentham CL6-H quartz halogen lamp (Serial No 65175), with emission in the 200-3000 nm range and CCT 3296 K (nominal).

Ten measurements of the ceiling brightness were taken with each detector by two independent observers (RL and SB), with the detectors pointing vertically and precisely located at fixed points on a horizontal lab table. One of the observers recorded the brightness simultaneoulsy with the three detectors, located in contact with each other and thus pointing to potentially different patches of the lab ceiling. The other observer recorded the brightness sequentially, with one detector at a time, located always at the same position. The results are shown in Table 2. The intrinsic variability of each individual detector is small (the standard deviation based on the sample lies between 0.007 and 0.024 mag/arcsec^2, median 0.014). The results from observer 1 show higher intra- and interdetector variability, consistent with the use of different ceiling points at the center of the field of view in each measurement. Data from observer 2, using the very same detectors, show a more reproducible behavior, consistent with the use of a single zenith point for all measurements. In this last case the intradetector variability ranges from 0.007 to 0.013, whereas the absolute uncertainty (stdev) obtained by pooling all detector data is 0.028 mag/arcsec^2. This last value can be considered representative of the uncertainty of the pool of measurements made with this set of detectors, due to the relative bias and the intrinsic uncertainty of the detectors themselves, excluding extrinsic factors (zenithal pointing accuracy, short to medium term changes in the atmospheric brightness and so on).

DISCUSION

By assuming that the random pointing errors incurred in by the observers are essentially uncorrelated with the intrinsic detector variability, the corresponding uncertainties add quadratically. Hence the variance due to the observers' errors can be estimated by subtracting from the overall variance of the field measurements the intrinsic variance of the detector set. Taking σ_t^2=[0.079 mag/arcsec^2]^2 for the first variance and σ_i^2=[0.028 mag/arcsec^2]^2 for the second one (and assuming that these uncertainties are reasonably independent from the signal level), the uncertainty in the measurements due to the observers can be estimated as σ_o^2=sqrt[$\sigma_t^2 - \sigma_i^2$]=0.074 mag/arcsec^2 (standard deviation of the sample).

(*) Contact address: salva.bara@usc.es

Table 1: Zenithal sky brightness measurements obtained by thirteen observers at Dique de Rodas site.

Observer #	Measurements (mag/arcsec^2)			Average	Stdev
1	20.88	20.70	20.88	20.82	0.104
2	21.00	20.98	20.84	20.94	0.087
3	20.76	20.81	20.91	20.83	0.076
4	20.91	20.83	20.85	20.86	0.042
5	20.95	20.84	20.81	20.87	0.074
6	20.81	20.81	20.89	20.84	0.046
7	20.71	20.77	20.64	20.71	0.065
8	20.78	20.78	20.78	20.78	0
9	20.81	20.81	20.81	20.81	0
10	20.93	20.94	20.88	20.92	0.032
11	20.88	20.69	20.79	20.79	0.095
12	20.85	20.85	20.90	20.87	0.029
13	20.92	20.79	20.79	20.83	0.075
			All data pooled:	20.83	0.079

Table 2: Lab ceiling brightness measured by two observers under reproducible conditions.

	Observer 1 (different zenith points)			Observer 2 (single zenith point)		
Meas / SN	**7909**	**8144**	**8483**	**7909**	**8144**	**8483**
1	16.71	16.72	16.86	16.69	16.71	16.68
2	16.75	16.73	16.88	16.71	16.70	16.66
3	16.74	16.73	16.88	16.71	16.71	16.66
4	16.77	16.70	16.88	16.71	16.73	16.66
5	16.78	16.70	16.88	16.71	16.71	16.65
6	16.78	16.74	16.91	16.71	16.71	16.65
7	16.75	16.73	16.92	16.70	16.71	16.63
8	16.78	16.71	16.89	16.71	16.71	16.64
9	16.78	16.74	16.88	16.70	16.71	16.65
10	16.78	16.72	16.89	16.70	16.71	16.66
Average	16.76	16.72	16.89	16.71	16.71	16.65
Stdev	0.024	0.015	0.017	0.007	0.007	0.013

Observer #1, all data pooled		Observer #2, all data pooled	
Average	16.79	**Average**	16.69
Stdev	0.074	**Stdev**	0.028

***Disclaimer**: These data are believed to be correct but may still undergo different validation procedures and should not be considered definitive. Neither the authors nor the Universidade de Santiago de Compostela, Galicia can be held liable for the different uses or interpretations that the reader may make of these results.*