Report on Sky Quality Meter, version L

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ABSTRACT

Sky Quality Meter is a low cost and pocket size night sky brightness photometer, which allow a quick measurement of the night sky brightness. Cinzano (2005) tested and characterized this instrument, analyzed with synthetic photometry and laboratory measurements the relationship between the SQM photometrical system and the main systems used in light pollution studies, evaluated the conversion factors for typical spectra and computed the spectral mismatch correction factors when specific filters are added. Recently a narrow field of view version of this instrument, called SQM-L, was introduced. In this paper I present measurements of SQM-L field-of-view and a calibration check.

Subject headings: light pollution – night sky brightness – photometry – instruments – calibration

1. Introduction

Unihedron Sky Quality Meter (thereafter SQM) is a low cost and pocket size night sky brightness photometer, which allows an easy and quick quantification of the quality of the night sky at any place and time. Expecting that measurements taken with SQM be widely diffused, Cinzano (2005) tested and characterized the instrument in order to well understand how they relate to usual measurements. He tested the field of view, the linearity, the calibration and the spectral responsivity. He studied the effects of the instrumental response on the measurements of light pollution based on synthetic photometry and laboratory tests carried out with the equipments of the Light Pollution Photometry and Radiometry Laboratory (LPLAB). He also evaluated for typical spectra the conversion factors to photometric systems used in light pollution studies, like Johnsons (1953) B band, V band, CIE photopic and CIE scotopic responses. He finally checked the spectral mismatch correction factors when specific filters are added.

Recently a narrow field of view version of this instrument has been introduced, called SQM-L.

Fig. 1.— The aperture of the SQM-L.

In order to characterize this instrument, I present measurements of SQM-L field-of-view and a test of its calibration. They updates sec. 3 and some paragraphs of sec. 5 of Cinzano (2005).

I didn't checked the linearity and the spectral response of the SQM-L because the detector and the filter should be the same of the previous SQM,

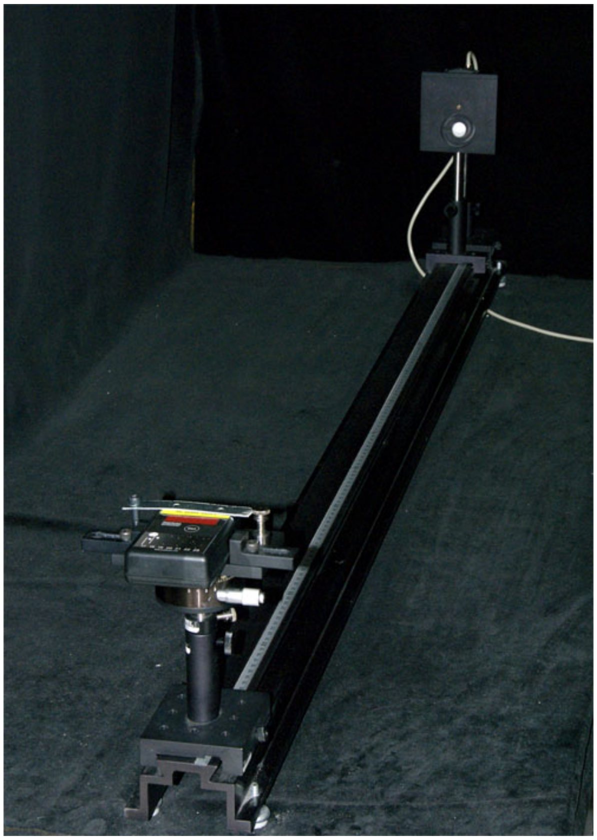

Fig. 2.— Measurement of the acceptance angle.

so the reader can refer to Cinzano (2005).

Relationship between SQM photometric band and V-band, the conversion factors between SQM response and V band response for most common source spectra and spectral mismatch correction factors between SQM response and the CIE photopic, CIE scotopic, V-band, B-band responses, when specific filters are added, are expected to be the same. The following sections of Cinzano (2005) should apply unchanged to the SQM-L: sec. 3 (Linearity), sec. 4 (Spectral response), sec. 5 (Relationship between SQM photometric band and V-band), included the conversion factors for the night sky spectrum in fig.20 but with the exclusion of the calibration test and the zero point of SQM calibration in figs. 15-18, which has been updated in sec. 3 of this paper, sec. 6 (Addition of filters for CIE photopic, CIE scotopic, V-band, B-band), sec.7 (Further notes on measurement comparison) and sec. 8 (Conclusions) with

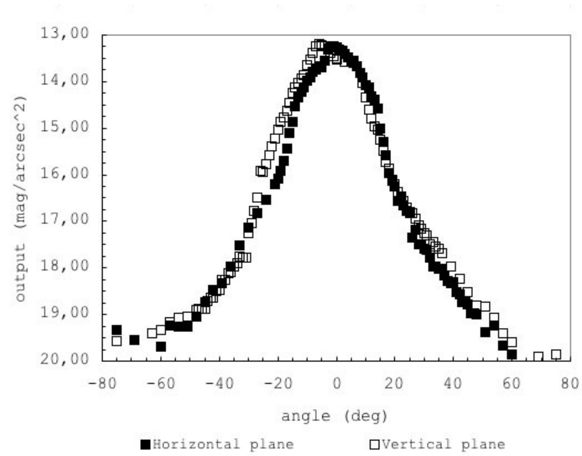

Fig. 3.— Angular response of SQM-L in magnitudes. Angles are positive downward and rightward.

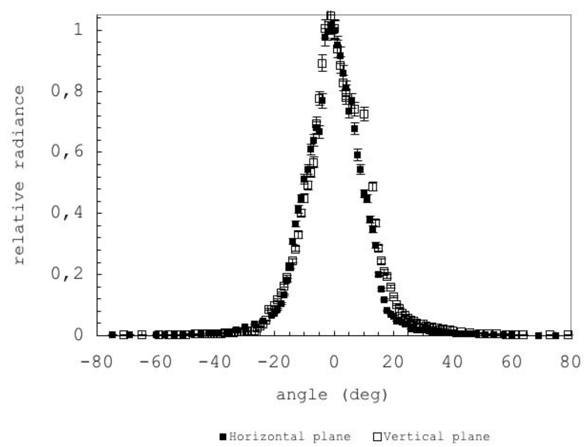

Fig. 4.— Angular response of SQM-L in a linear scale.

the exclusion of point (c).

2. Acceptance angle

I checked the acceptance angle of the SQM-L serial n.1885 mounting it, both in horizontal and vertical position, on a rotation table (accuracy 0.01 degrees) placed at 1.289 m from a circular aperture with diameter 3.2 mm in front of LPLAB Spectral Radiance Standard (lamp 7) powered by the LCRT-2000 radiometric power supply (radiance stability 1% at 550 nm)(Cinzano 2003c, e). The set up is shown in fig. 2. Room temperature was maintained at 25±1 C. Background light has

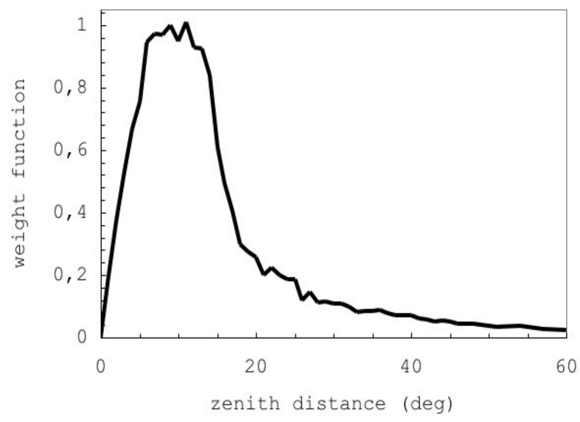

Fig. 5.— Weight of the radiance at each angle of incidence in the measured average radiance.

Fig. 6.— The Variable Low Light Level Calibration Standard. From left to right are visible the SQM-L and the reference detector, the Uniform Integrating Sphere, the aperture wheel and the standard lamp 7.

been subtracted.

The readings of the instrument at each angle are shown in fig. 3 in magnitude scale with arbitrary zero point. Open squares are data along the vertical plane, filled squares are data along the horizontal plane. Angles are positive below the middle plane and at right.

Fig. 4 shows the same readings in a linear scale normalized to its maximum. The Half Width Half Maximum (HWHM) is ∼10 degrees. The Full Width Half Maximum (FWHM) is then ∼20 degrees. A factor 10 attenuation of a point source is reached after ∼19 degrees from the center. An attenuation of 3 magnitudes is reached at ∼20 degrees from the center and 5 magnitudes at ∼40 degrees.

When comparing SQM-L zenith measurements with measurements taken with very narrow field photometers, like e.g. those applied to telescopes, it should be taken into account that night sky brightness is not constant with zenith distance. In particular, artificial night sky brightness in polluted areas usually grows with zenith distance with large gradients. The brightness measured pointing the SQM-L toward the zenith will be the weighted average of brightness at different zenith distances:

$$\overline{I} = \frac{\int_0^{2\pi}\int_0^{\pi/2} I(\theta,\phi)D(\theta)\sin\theta\, d\theta\, d\phi}{\int_0^{2\pi}\int_0^{\pi/2} D(\theta)\sin\theta\, d\theta\, d\phi}\ , \qquad (1)$$

where $\overline{I}$ is the measured average radiance, $D(\theta)$ is the angular response given in fig. 4 and $I(\theta,\phi)$ is the radiance of the night sky in the field of view of the SQM. Fig. 5 shows the weight function $D(\theta)\sin\theta$ for each angle of incidence θ. It is peaked between 5-15 degrees because going from 0 to $\pi/2$ the angular response decrease and the integration area grows. Given that the instrument collects a not negligible quantity of light down to a zenith distance of about 20 degrees, the measured brightness will be slightly greater (lower magnitude per square second of arc) than the punctual zenith brightness. However this integration effect for the SQM-L is very small in comparison with the SQM, which has a large field of view and reaches a factor 10 attenuation of a point source only after 55 degrees. A simulation made by Cinzano (2005) suggested a difference of -0.3 mag/arcsec^2 for the SQM whereas this difference is likely well under -0.1 mag/arcsec^2 for SQM-L.

Given that the response of the instrument is still of the order of $\sim 4\times10^{-3}$ at 60 degrees (6 magnitudes attenuation), users should be very careful to not include strong sources, like e.g. lighting fixtures, inside a field of 60-70 degrees without apply a shade to the instrument.

3. Calibration

In order to check the calibration, I compared a series of brightness measurements taken by three SQM-L with those taken by the IL1700 reference radiometer (accuracy of V band calibration ±4.9%, linearity 1%) over the LPLAB Low Light Level Calibration Standard with the spectral radiance standard lamp no. 7 powered by the LCRT-2000 radiometric power supply (radiance stability 1% at 550 nm). The source spectra is nearly Illuminant A. I taken measurements with 5 different radiances produced by an aperture wheel between the source and the integration sphere. The sphere has an exit port radius of 5 cm.

The following table shows a comparison between the IL1770 and three SQM-L (1885, 1882 and 1892). The SQM-L lenses were at a distance of 8,2 cm from the sphere's port.

aperture	IL1700	1885	1882	1892
1	14,41	14,38	14,16	14,38
2	11,58	11,64	11,50	11,68
3	9,82	9,87	9,72	9,90
4	9,19	9,21	9,06	9,25
5	7,99	8,01	7,83	8,05

This table allows to recognize that there are some differences in the calibration of these SQM-L and that the 1882 is likely quite out-of-calibration. However I was not able to obtain an accurate calibration of SQM-L because the measurements taken from the SQM-L depends on its distance from the sphere's port, as shown in the following table:

ap.	IL1700		SQM-L		
	3 cm	14 cm	3 cm	8,2 cm	14 cm
1	14,39	14,37	14,12	14,35	14,73
2	11,58	11,57	11,35	11,63	12,23
3	9,82	9,82	9,55	9,85	10,46
4	9,19	9,18	8,90	9,20	9,81
5	8,00	7,99	7,71	8,00	8,61

Likely this happen because at distances larger than 7 cm the apparent radius of the sphere's port (20 degrees at 6,8 cm) become smaller than the field-of-view and some light is missed, whereas at distances under 6 cm there are effects due to the small distance. It is very difficult to evaluate the correct distance in the range 6-8 cm and 1 cm uncertainty produces an uncertainty of about 0,1-0,2 mag. I do not have a sphere with larger exit port but I plan to check the calibration with some other method in future.

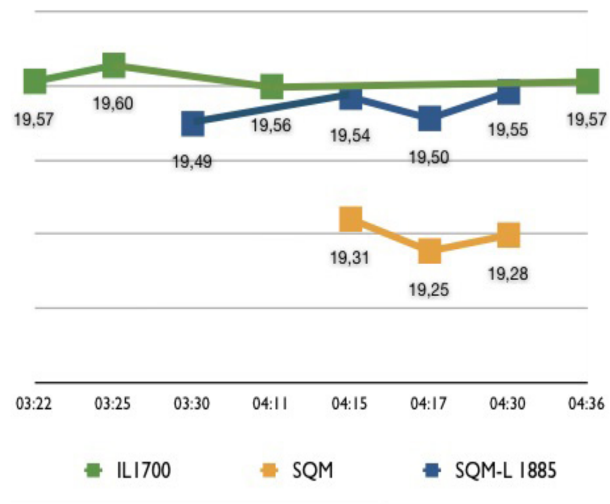

Fig. 7.— Zenith night sky brightness measurements taken by the SQM-L, SQM and the IL1700 reference radiometer.

In order to better check the calibration, I compared some measurements taken with the SQM-L 1885 and the IL1700 reference radiometer over the zenith night sky in a clean photometric night and at late time when brightness is known to be quite constant. Results are shown in figure 7. The agreement is good, given that it is difficult to point exactly the zenith with hand-carried instruments. The shift of the SQM is due to the averaging of the light of the entire sky.

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REFERENCES

Cinzano, P. 2003a, A laboratory for the photometry and radiometry of light pollution, poster, meeting IAU Comm. 50 Working Group "Light Pollution", XXV General Assembly, Sidney 25 June - 2 July 2003

Cinzano, P. 2003b, A laboratory for the photometry and radiometry of light pollution, Mem. Soc. Astron. It. Suppl., 3, 312-315

Cinzano, P. 2003c, The Laboratory of Photometry and Radiometry of Light Pollution (LPLAB), ISTIL Int. Rep. 7, Thiene, Italy, www.lplab.it

Cinzano, P. 2003d, Characterization of the Variable Low Light Level calibration Standard, ISTIL Int. Rep. 3, Thiene, Italy

Cinzano, P. 2003e, The ISTIL/LPLAB Irradiance and Radiance Standard, ISTIL Int. Rep. 6, Thiene, Italy

Cinzano P. 2005, Night Sky Photometry with Sky Quality Meter, ISTIL Int. Rep. n. 9, v.1.2, ISTIL, Thiene, Italy

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