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Are SQM-L measurements polarization dependent?

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Summary: We report on a series of SQM-L measurements made using linearly polarized light. The SQM readings suggest that there is no noticeable polarization dependence.

INTRODUCTION

Several observers informed that slightly different SQM-L zenithal brightness readings can be obtained depending on the azimuthal orientation of the device. Since the light scattered by the atmosphere generally has some degree of polarization, depending on the relative position of the source, the observation direction, the light spectrum, and the atmospheric molecular and aerosol constituents, we wanted to check whether the measurements made with these devices show any intrinsic dependence on the polarization of the incoming light. Although the SQM detectors do not purposely include any polarizing optical element, some polarization dependent effects could potentially arise from the presence of anisotropic materials (e.g. some kinds of plastics) producing differential Fresnel losses in the orthogonal vibration components of the incoming field.

EXPERIMENTAL SETUP

To that end, a SQM-L detector (S/N 3840) was tightly tied to a vertical holder attached to a XY displacement platform formed by an orthogonal pair of Newport M-TSX-1D linear translation stages (Fig 1). The XY assembly was mounted onto a Newport M-PRC-3 precision rotation stage. The linear stages allow an accurate alignment of the center of the detector pupil with the center of rotation of this setup. A research-grade absorption linear polarizer was located over the detector pupil, close enough as to avoid the entrance of stray light but leaving sufficient room as to allow the detector to rotate freely under the polarizer. The orientation of the polarizer was kept constant during all measurements. Rotating the detector instead of the polarizer prevented any effect related to the possible degree of polarization of the incident light. Moreover, it replicates the field conditions more closely.

The effective extended light source was the lab ceiling, diffusely illuminated by the light scattered at the walls from a stabilized current, NPL-traceable, spectral irradiance Bentham CL6-H quartz halogen lamp (S/N 65175), with emission in the 200-3000 nm range and CCT 3296 K (nominal). According to the manufacturer's specifications, the total expanded uncertainty of the

absolute spectral irradiance calibration is estimated not to exceed ± 2.3% over the wavelength range 400 nm to 700 nm, rising to ± 2.5% at 804 nm and to ± 3.4% at 296 nm (level of confidence about 95%). Since absorption polarizers generaly lose efficiency at long wavelengths, an additional bandpass filter (Astronomik IR blocking 002381) was located over the polarizer in order to limit the spectrum of the incident light to the range 370-680 nm.

Lab lights other than the Bentham lamp were shut off, and the SQM-L readings were recorded rotating the detector around its optical axis in steps of 10º. Three 0-360º measurement runs were made sequentially: one with the SQM without polarizer and IR filter, another with both, and the final one with IR filter but no polarizer.

RESULTS

The readings obtained with the SQM in these three measurement rounds (in mag/arcsec^2), listed in columns 2-4 of Table 1, are displayed in Figure 2. Figure 3 shows the behavior of the differences between the magnitudes recorded with and without polarizer for each angular position, using their average value as a baseline. The L_{IR_LP}/L_{IR} SQM-luminance ratio, defined as 10^[–0.4·(SQM_IR_LP - SQM_IR)] is listed in column 5 of that table, and displayed in Figure 4.

DISCUSSION

Polarization-related effects that could be relevant for SQM measurements shall show a two- or four-fold symmetric pattern across the range [0,360º] of rotation angles, with periods of 180º or 90º. That is, the corresponding magnitude or SQM-luminance plots shall have either two or four regularly spaced maxima (and minima) across an entire rotation of the detector around its optical axis. The results obtained here do not show such expected behavior.

An overall dependence of the SQM readings with the rotation angle is apparent in the three datasets plotted in Figure 2. Polarization effects should reveal themselves in the differences between the readings with and without polarizer (Figure 3) or in the ratio of the associated SQM-luminances (Figure 4), but the slight oscillation present in both does not show the expected multiple periodicity.

It is interesting to note that this slight oscillation is already present in the "SQM alone" measurements (blue dots in Figure 2), and has a similar overall shape in all three measurement runs, with the minimum located at about 120-150º and the maximum at about 300-330º. This common pattern of oscillation seems to have a different origin, unrelated to polarization effects. Since angular misalignments of the optical axis of the SQM with respect to the rotation axis of the M-PRC-3 mount can be reasonably discarded in this case, and any residual lateral shift of the SQM pupil center with repect to the rotation center has been carefully minimized, such 360º-periodic oscillation could be due to a slightly nonsymmetric SQM field-of-view in combination with a non-symmetric distribution of the ceiling luminance around the center of the SQM field.

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Table 1: SQM-L data

Angle	SQM	SQM_IR_LP	SQM_IR	L_{IR+LP}/L_{IR}
0	16.99	18.83	17.59	0.319154
10	17.00	18.83	17.57	0.313329
20	17.02	18.81	17.55	0.313329
30	17.01	18.81	17.56	0.316228
40	17.01	18.82	17.56	0.313329
50	16.99	18.81	17.54	0.310456
60	16.99	18.80	17.54	0.313329
70	16.98	18.78	17.51	0.310456
80	16.97	18.76	17.51	0.316228
90	16.97	18.76	17.51	0.316228
100	16.96	18.78	17.51	0.310456
110	16.96	18.76	17.46	0.301995
120	16.94	18.75	17.45	0.301995
130	16.95	18.78	17.45	0.293765
140	16.94	18.75	17.44	0.299226
150	16.94	18.76	17.45	0.299226
160	16.94	18.78	17.44	0.291072
170	16.94	18.77	17.47	0.301995
180	16.94	18.77	17.48	0.304789
190	16.93	18.78	17.48	0.301995
200	16.95	18.78	17.49	0.304789
210	16.96	18.81	17.47	0.291072
220	16.99	18.80	17.47	0.293765
230	16.98	18.79	17.53	0.313329
240	17.00	18.80	17.53	0.310456
250	16.98	18.84	17.55	0.304789
260	16.98	18.81	17.56	0.316228
270	16.99	18.81	17.57	0.319154
280	17.00	18.81	17.58	0.322107
290	17.01	18.81	17.60	0.328095
300	17.00	18.83	17.60	0.322107
310	17.00	18.82	17.60	0.325087
320	17.00	18.83	17.60	0.322107
330	17.00	18.82	17.57	0.316228
340	17.00	18.83	17.56	0.310456
350	16.99	18.85	17.56	0.304789
360	16.99	18.83	17.55	0.307610

Angle: Rotation angle of the SQM around its optical axis (degrees)

SQM: Measurements obtained with the SQM-L (mag/arcsec^2)

SQM_IR_LP: Idem with the SQM fitted with IR filter and linear polarizer

SQM_IR: Idem with the SQM fitted with IR filter but no linear polarizer

L_{IR_LP}/L_{IR}: Ratio of SQM-Luminances: 10^[−0.4·(SQM_IR_LP − SQM_IR)]

Figure 1. (Left) SQM-L on a rotation stage with linear displacement platforms. The polarizer and the IR blocking filter are located just above the detector. (Right) Polarizer and IR blocking filter.

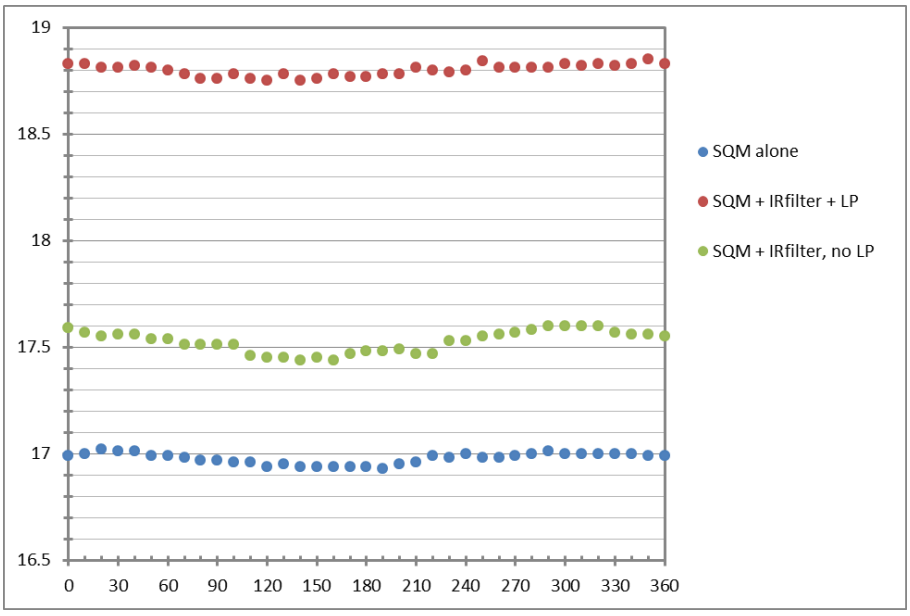

Figure 2. Brightness readings (mag/arcsec^2) obtained in the three sequential measurement runs. See text for details.

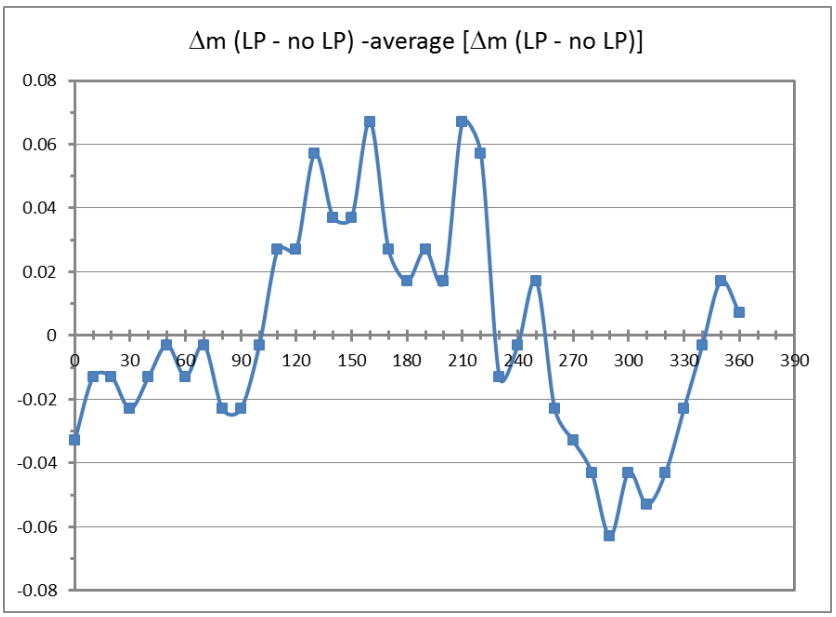

Figure 3. Differences between individual SQM_IR_LP and SQM_IR readings, centered at the average value.

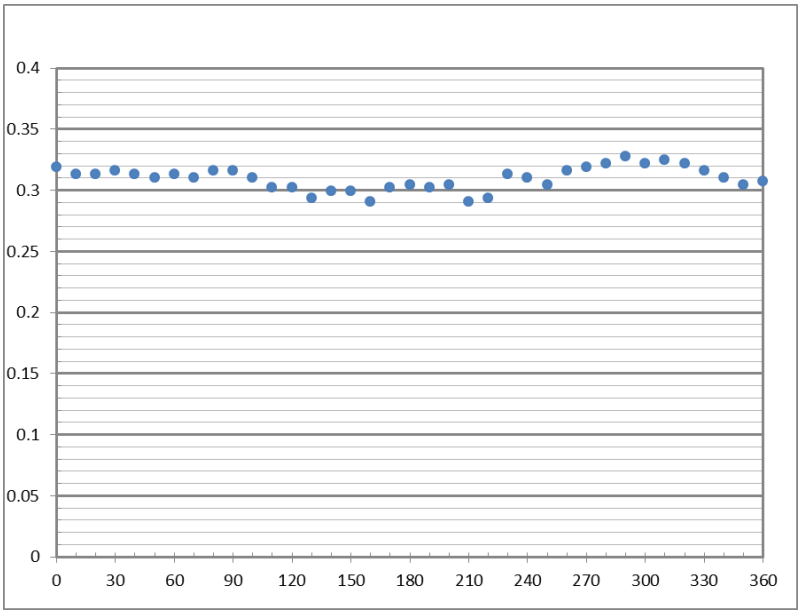

Figure 4. The L_{IR_LP}/L_{IR} SQM-Luminance ratio vs. the rotation angle in degrees.

***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.*