LoNNe
ES1204
Loss of the Night Network

Report of the 2014 LoNNe Intercomparison Campaign

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Meeting participants

Organizers: Alejandro Sánchez de Miguel, Jaime Zamorano, Miguel Nievas, Carlos Tapia and Ainhoa Sánchez Penim
Participants: Salvador Bará, Brian Espey, Fabio Falchi, Christopher Kyba, Paolo Pescatori, Salvador Ribas, Philipp Staubmann, Günther Wuchterl

Report finalized on 31st of August, 2015.

Introduction

The 2014 LoNNe (Loss of the Night Network) intercomparison campaign is the second of four campaigns planned during EU COST Action ES1204. The goal of these campaigns is to understand systematic uncertainty inherent in observations of skyglow (light pollution). The first campaign took place in 2013 in Lastovo, Croatia. The third took place in Torniella and Florence, Italy (see Kyba et al. 2015a), and the final campaign is scheduled to take place in Montsec, Spain in 2016. An innovation of this year's campaign was to take measurements with many of the instruments at two sites: an urban location and a location far from artificial lights. This report summarizes the meeting, and also provides three recommendations for obtaining and analyzing handheld SQM observations.

The UCM group of Astronomical Instrumentation and Extragalactic Astronomy (GUAIX) hosted the meeting at the Physics building of Universidad Complutense de Madrid (UCM). A meeting room at Departamento de Astrofísica y CC. de la Atmósfera and the astronomical observatory

(Observatorio UCM) were prepared in advance. In particular, a tailor made station to set the SQM and other photometer devices was installed on the roof of the Physics building. The Laboratorio de Investigación Científica Avanzada (LICA) was used to test and characterize a number of devices and filters.

Sky observation locations

Observatorio UCM (Physics building rooftop): 40.45097N, 3.72629W (640 m)
Hotel "El Carrascal": 40.57476N, 5.03415W (1160 m)
Mountaintop position on July 19-20 "Puerto de Menga": 40.47561N, -5.01300W (1564 m)

Summary of activities undertaken night by night

Day of July 16

Participants arrived at airport.

Night of July 16-17

Some of the participants set up earlier than planned, mainly taking SQM measurements. The sky was clear. After setting up the instruments we went into the city to try to make measurements from a rooftop terrace. Unfortunately, due to the moonrise, it was only possible to take one SQM measurement, which was submitted to Globe at Night.

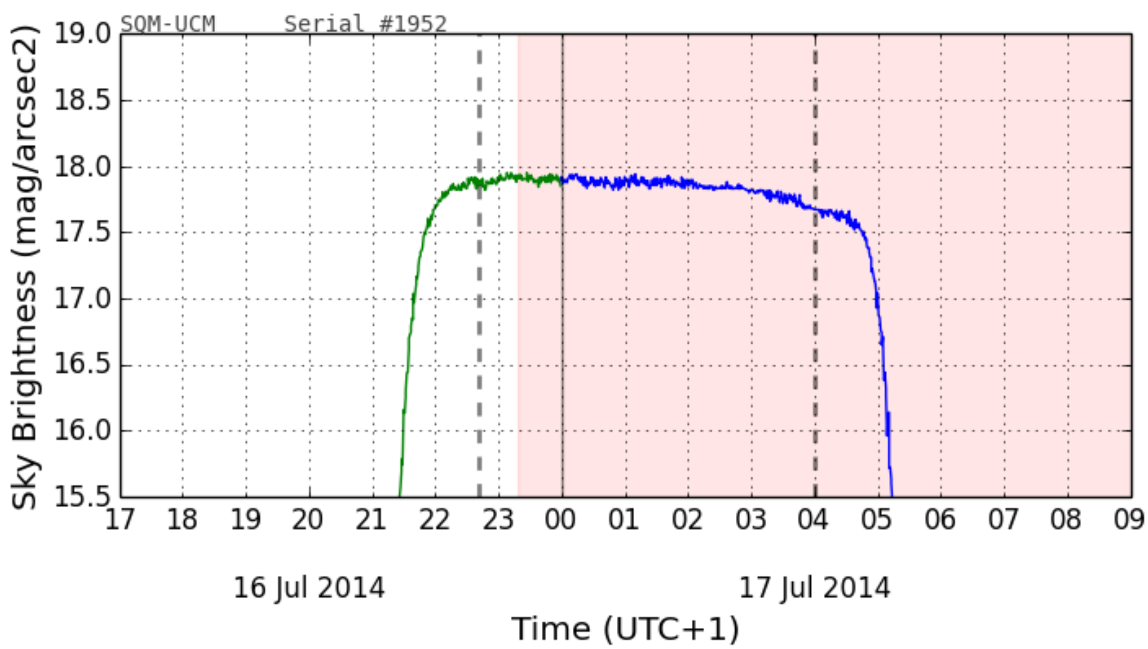

Figure 1: SQM record from Observatorio UCM. Pink shadow indicates Moon over the horizon

Day of July 17

The meeting was opened by Alejandro Sánchez de Miguel, who gave a talk about activities of the group at UCM. Participants had a tour of the labs, including the astronomical observatories.

Laboratory measurements were taken in the afternoon. These included:

- Measurement of the spectral response of the IYL Lightmeter at direct and glazing incidence.
- Spectral response of BG12, BG18 and GG495 filters.

Some SQM devices were opened to align the near infrared filter. The images in Figure 2 show photographs of the filters. It seems likely that if the filter were larger and more evenly cut, and installed with better optical coupling, that both internal reflections and unit-to-unit variation could be reduced.

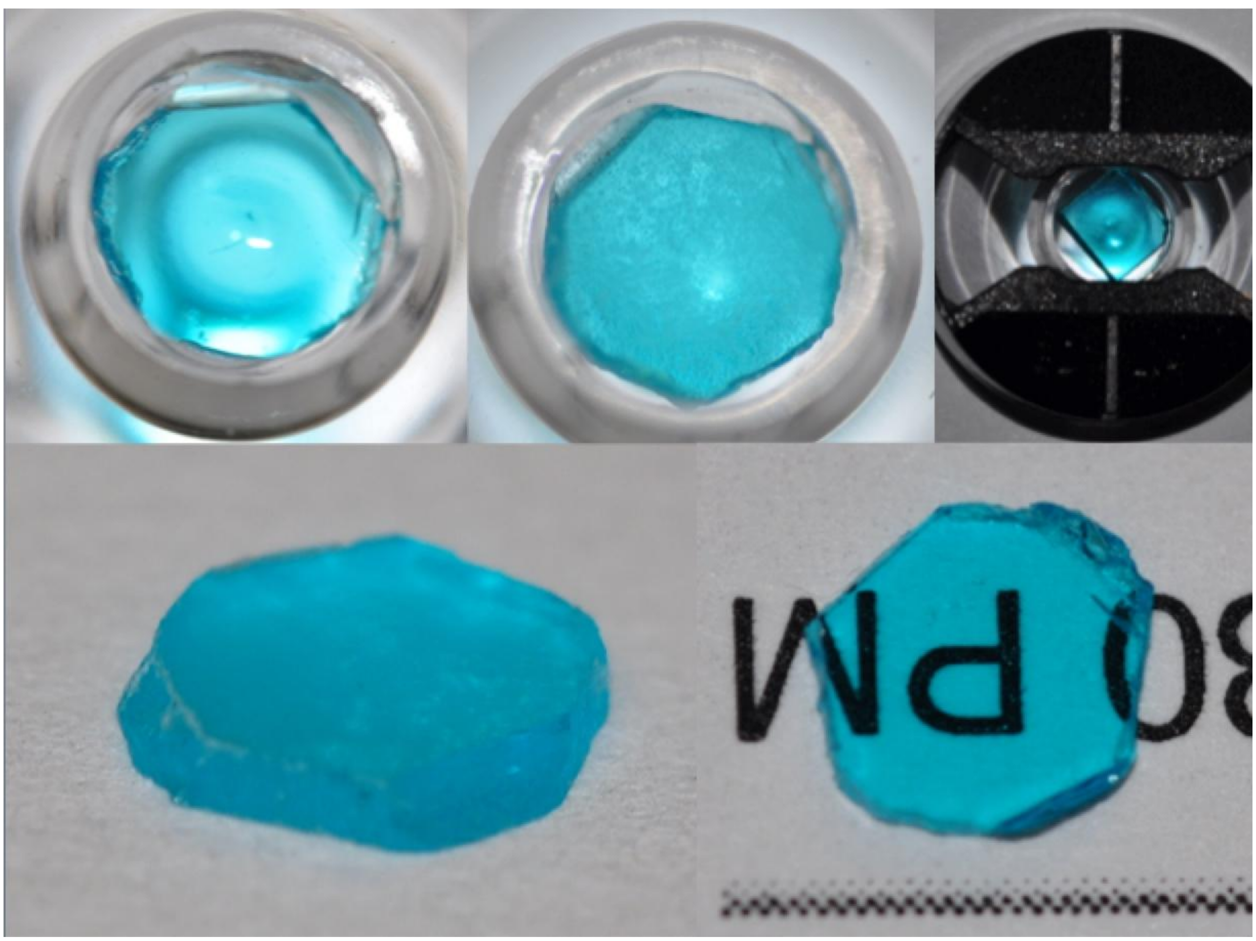

Figure 2: close up images of the SQM infrared filter. Photos by Carlos Eugenio Tapia Ayuga.

Figure 3: Carlos Tapia (UCM) explains the results of a SQM test at LICA-UCM optical workbench.

<u>Night of July 17-18</u>

After dinner, participants returned to the University to install instruments. Installation was completed before astronomical twilight ended around 21:40 UT. Thin, scattered clouds were present during twilight, and were observed to leave the sky and reppear in different moments of the night according to ASTMON data. The clouds were most prevalent from 1:30 UT until the morning twilight. This can be seen in the lightmeter data of figure 4. A nearby very bright light source (the Hippodrome) was lit until about 23:00-23:30 UT.

SQMs:
19 SQMs took data from the rooftop, including 4 SQM-LU-DL, 5 SQM-LU and 2 SQM-LE. Many of the SQMs were not able to fit in the measurement rail, because they were installed in the housing used for measurements while travelling.

Data was also taken by handheld SQM-L devices (6 units: #1892, #2164, #3204, #5855, #6386, #8037) and 1 SQM, (#3111) all of which were installed in a rail to ensure a fixed direction. Data taken with the SQM instruments between ~21:30 and 23:00 UT showed a zenith brightness of ~17.60 $mag_{SQM}/arcsec^2$. Relative to the mean values of all the instruments, the handheld SQM-L units showed a slightly non-uniform distribution around the mean. The expected SQM-L calibration accuracy is given as ~0.1 $mag_{SQM}/arcsec^2$ by the manufacturer. We do not see any obvious correlation between the offset from the mean and the device number (as a proxy for the age of the device / firmware). However we do note here that there is a good correlation between the relative offsets between the tested instruments derived from these data and those taken on the night of 18/19 July, (taken under skies of ~21.30 $mag_{SQM}/arcsec^2$), with the exception of measurements from SQM-L #5855.

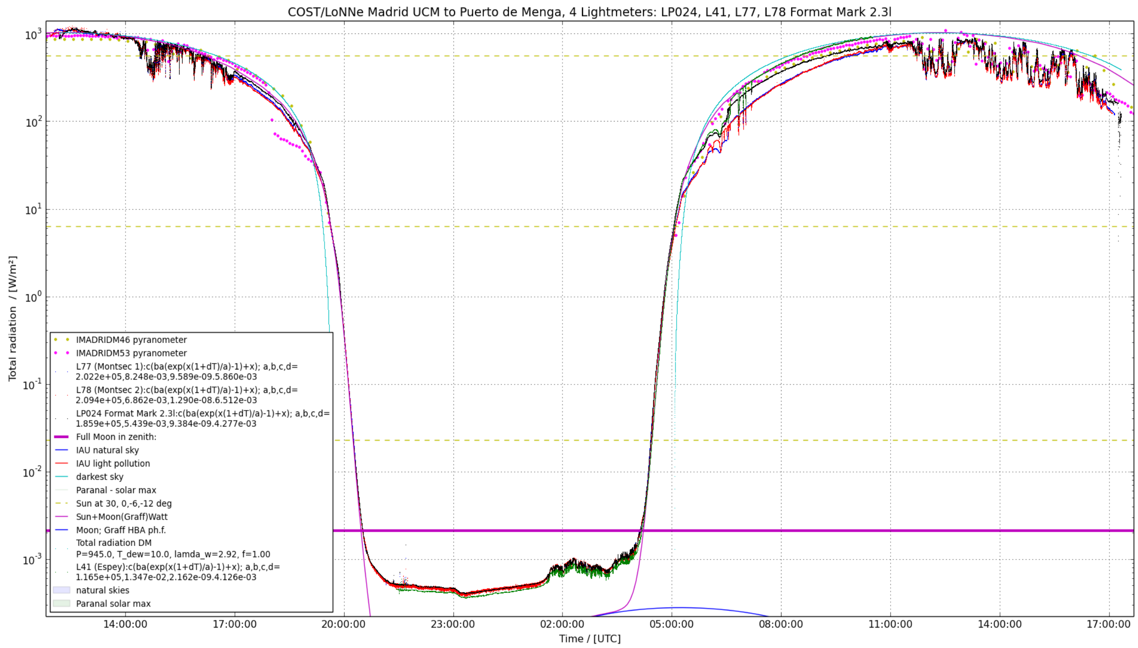

Figure 4: Detail of the lightmeters measurements. The drop at 23.00 UT was related to the Hippodrome switch off, and the increase of brightness at 1:30 UT is due to clouds.

Figure 5: An image of the rooftop of the UCM building showing the rail used for the SQM measurements: note that meters have been covered in aluminium foil to provide some protection from the sun. (Image provided by Fabio Falchi)

Table 1: Data for each of the tested meters displayed against the mean of the data for that testing session. Data for the night of 17/18 were taken between 21:30 - 23:00 UT with a mean zenithal sky value of 17.60 $mag_{SQM}/arcsec^2$. Data for the night of 18/19 July were taken in darker conditions with a zenithal sky brightness of 21.30 $mag_{SQM}/arcsec^2$ and are discussed further below.

Device #	Night 17/18	Night 18/19
1892	+0.15	+0.14
2164	-0.07	-0.15
3204	0.000	-0.06
5855	+0.15	-0.01
6386	+0.09	+0.07
8037	-0.004	Not tested

Data taken with the automated SQM instruments (SQM-LE, SQM-LU, SQM-DL) are shown graphically below. For one instrument (SQM-LU #1118) for which data was taken on a 1 second timescale, oscillations in the readings are visible at the ~0.1 $mag_{SQM}/arcsec^2$ level around ~21:30 UT, but the instrumental offset of one meter relative to another is relatively stable, although offsets of +/-0.15 $mag_{SQM}/arcsec^2$ from the median are seen. In normal operation the meters are operated with a protective cover above the SQM units and an additional correction of ~0.12 $mag_{SQM}/arcsec^2$ needs to be subtracted to account for absorption by the glass window.

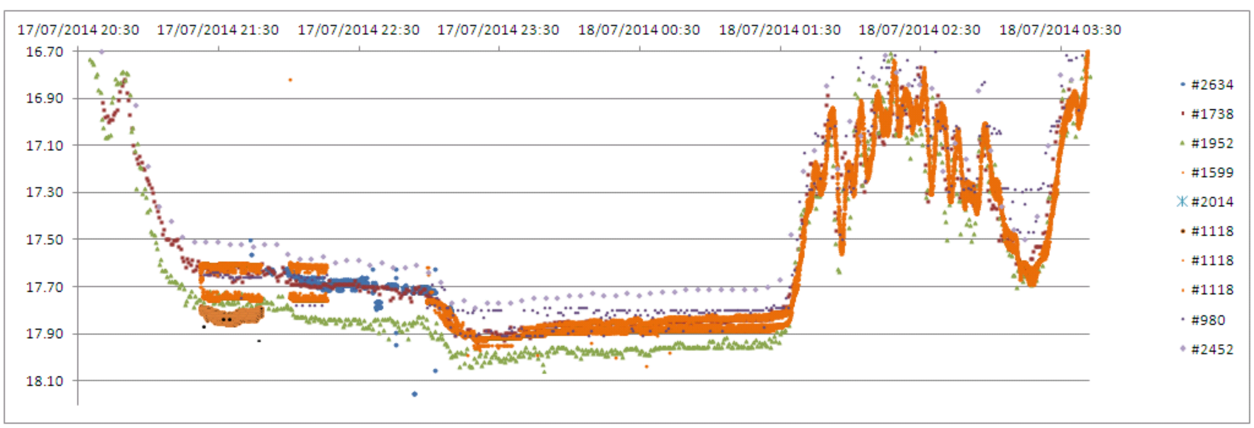

Figure 6: Measurements taken with the automated SQM instruments on the night of 17/18 July from the roof of the UCM building, with the x-axis given in terms of UT time, and the vertical scale in terms of $mag_{SQM}/arcsec^2$, with larger values indicating darker skies. The instrument readings were relatively stable (with small offsets between instruments) until the appearance of clouds in the early morning. Occasional outliers are due to blocking of the line-of-sight of the instrument.

Lightmeters:
4 Lightmeters took data (L41 Espey, L77 & L78 Ribas, LP024 Wuchterl)
The lightmeters were calibrated fitting data with natural clear-sky light model and can be controlled using the pyranometer data provided by weather stations of Madrid, as can be seen in Figure 16 of this document.

Apps:
Alejandro Sánchez used Dark Sky Meter
Loss of the Night app was used by Günther Wuchterl, Fabio Falchi and Chris Kyba (x2).

Cameras:
Two Astmon devices took data, the fixed unit at Observatorio UCM (AstMon-UCM) and the traveling unit of Montsec. Both instruments working with B, V and R filters.
Philip Staubmann ran a Canon (manual photos)
Sánchez de Miguel Nikon D3 with fisheye Sigma 8mm (continuously)
Espey Nikon D300 with Nikkor 20mm f/2.8 AF lens and Zeikos 0.18x fisheye adapter (manual)
Sánchez de Miguel Nikon DF with Sigma 24mm f/1.8 DG lens and Hama pro class 77mm linear polarization filter (manual)
Bará and Zamorano: Watec 900 with fisheye lens (continuously) and all-sky SQM measurements using the NixNox project procedure with SQM over a Cube mount.

The lens and polarization filter from Kyba et al. (2011) were used to measure the skyglow degree of linear polarization in Madrid, using the Nikon D3 camera.

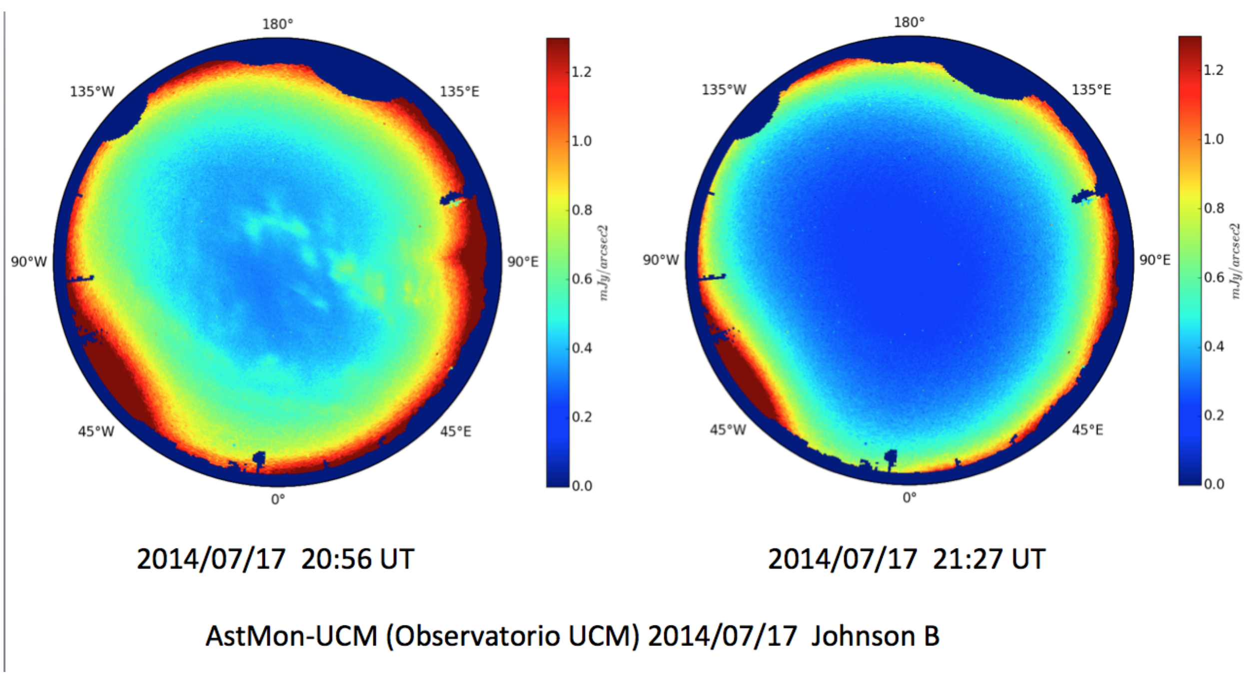

Figure 7: Two all-sky brightness maps from AstMon-UCM in Johnson B band at the beginning of the night. Lights from Zarzuela horse race course (bottom left) brighten the NW horizon.

A measurement of all-sky radiance was obtained using a handheld SQM-L with the NixNox procedure (Zamorano et al 2014). The map of radiance could be generated (Figure 8) can be compared to the AstMon or cameras measurements (Figure 7).

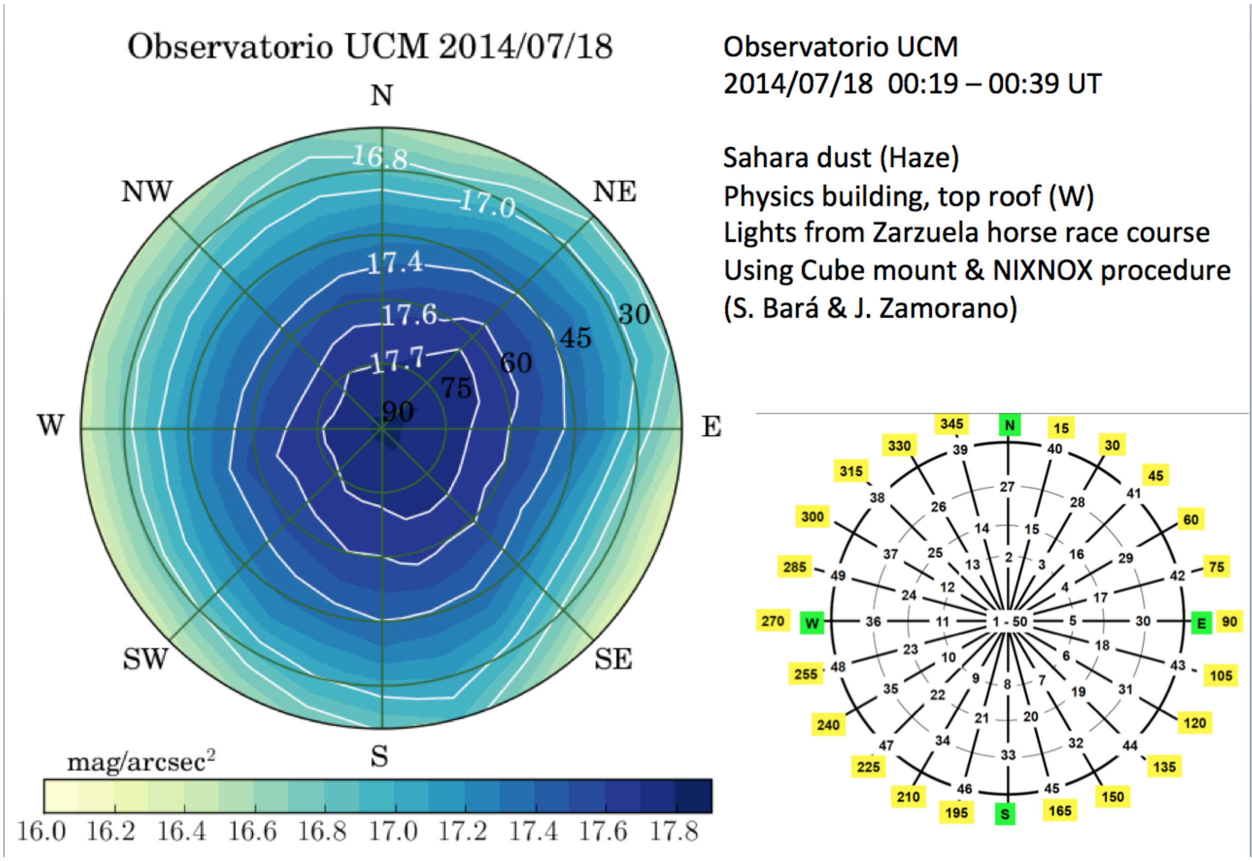

Figure 8: All-Sky Brightness map from multiple pointings of SQM using the NixNox procedure.

<u>Day of July 18</u>

Laboratory measurements were taken in the afternoon. These included:

- Spectral transmission of B (Optec), V (Schuler), R (Schuler) Johnson Cousin filters, Custom Scientific LRGB set and ND2, Johnson photometric set (UBVRI), UG1.
- Spectral response of Sigma 8 mm EX DG Fisheye (Posch)
- Spectral response of fisheye for CCTV.

Discussion of each of our research programs, as well as future measurement strategies. Some analysis of results (e.g. all-sky map of observatory data, evolution of the night sky with SQMs), and then all participants left for the hotel outside of Madrid.

Night of July 18-19

Measurements were taken on the drive to the hotel. Measurement started about 80 km from Madrid. The sky was cloudy when measurements began, and cleared as we drove towards the hotel. Shortly after we arrived at the hotel, the sky was nearly clear overhead. Two cars set off from the hotel at about 1 am. Zamorano's group drove about 40 km, the other group drove only a short distance and stopped in a field for observations.

Instruments:
Ribas's car: 2 lightmeters, 1 SQM-LU (Roadrunner configuration)
Sanchez de Miguel's car: 2xSQM-LU
Zamorano's car: SQM-LU, Coelofot (4 channel device: R G B and clear)
Stationary observations in field with SQM-L (submitted to GLOBE at Night), all-sky photographs.

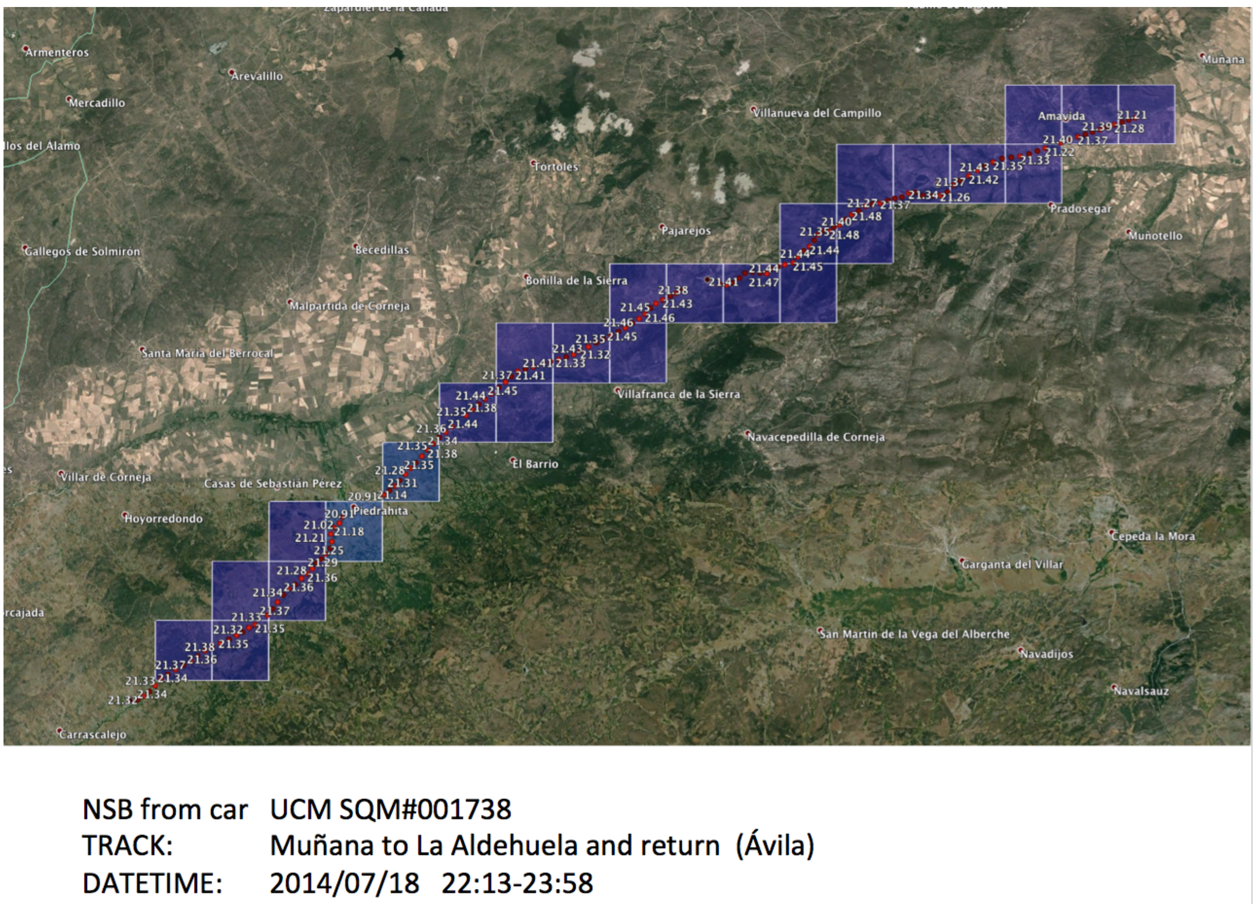

Figure 9: Night Sky brightness along the track from Muñana to La Aldehuela (and return).

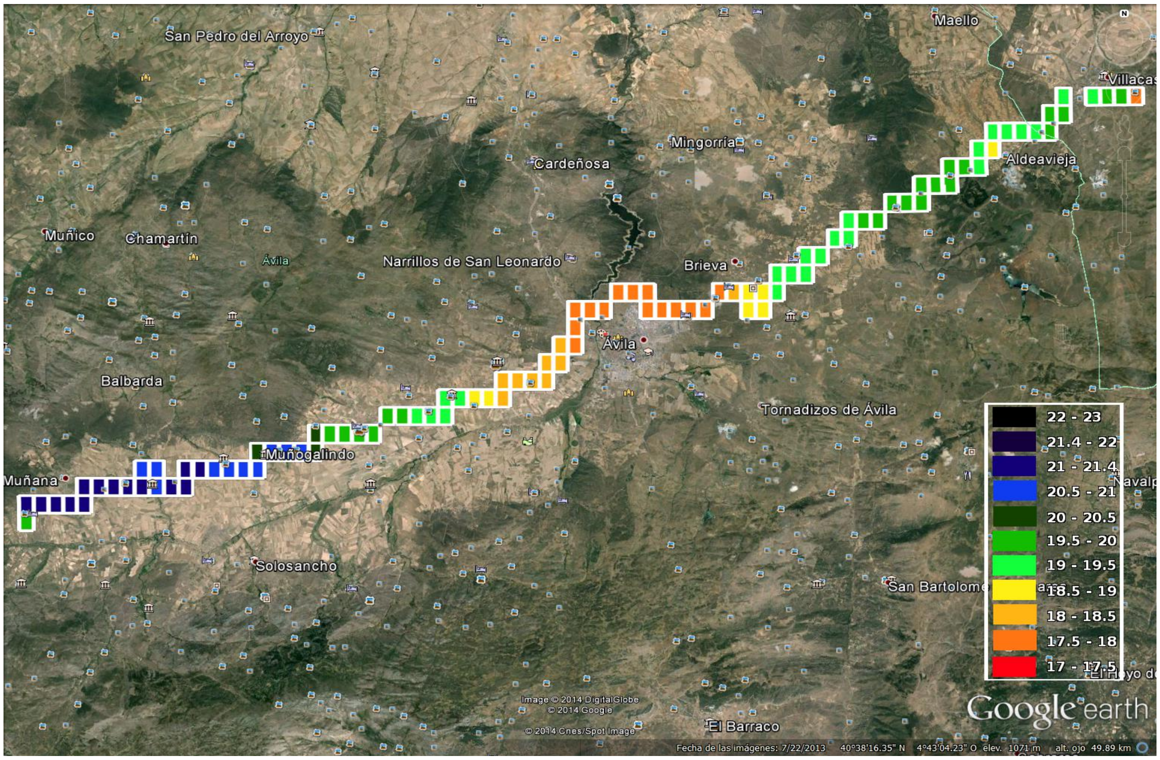

Figure 10: An example map of what was obtained using SQM-LU with Roadrunner configuration during the night 18-19 July (instrument from Parc Astronòmic Montsec, managed that night by Philip Staubmann and Salvador J. Ribas). The sample of data is binned in boxes of 0.5ºx0.5º.

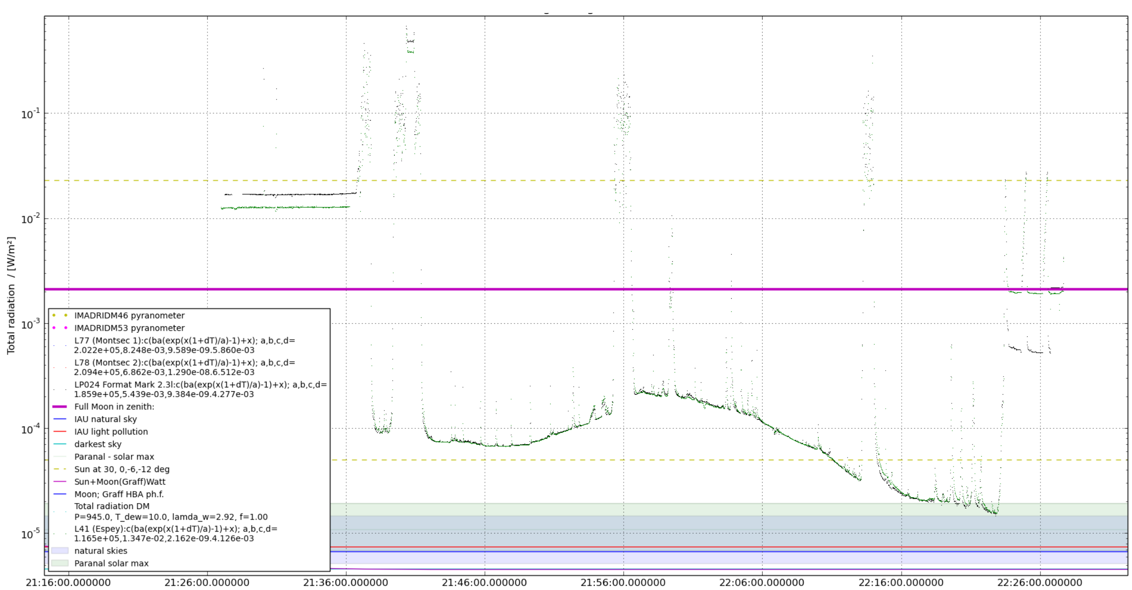

Figure 11. Measurements obtained with Lightmeter above a car in the trip from Madrid to the Hotel. The darkest places at the end of the sequence are in agreement with the Westernmost positions of Figure 10.

Figure 12: Milky way from Ávila near Rivera de Corneja just before dawn of the Moon (Photo by J. Zamorano, UCM)

<u>Day of July 19</u>

During the day, participants engaged in several discussion sessions. Participants questioned what the biggest bin size that should consider as a single measurement is, and what strategies should be used for interpolation of ground data and all-sky maps. Participants also discussed strategies for networking with people outside of the research community who are making maps. Finally, the value of making data available under a CC license was emphasized.

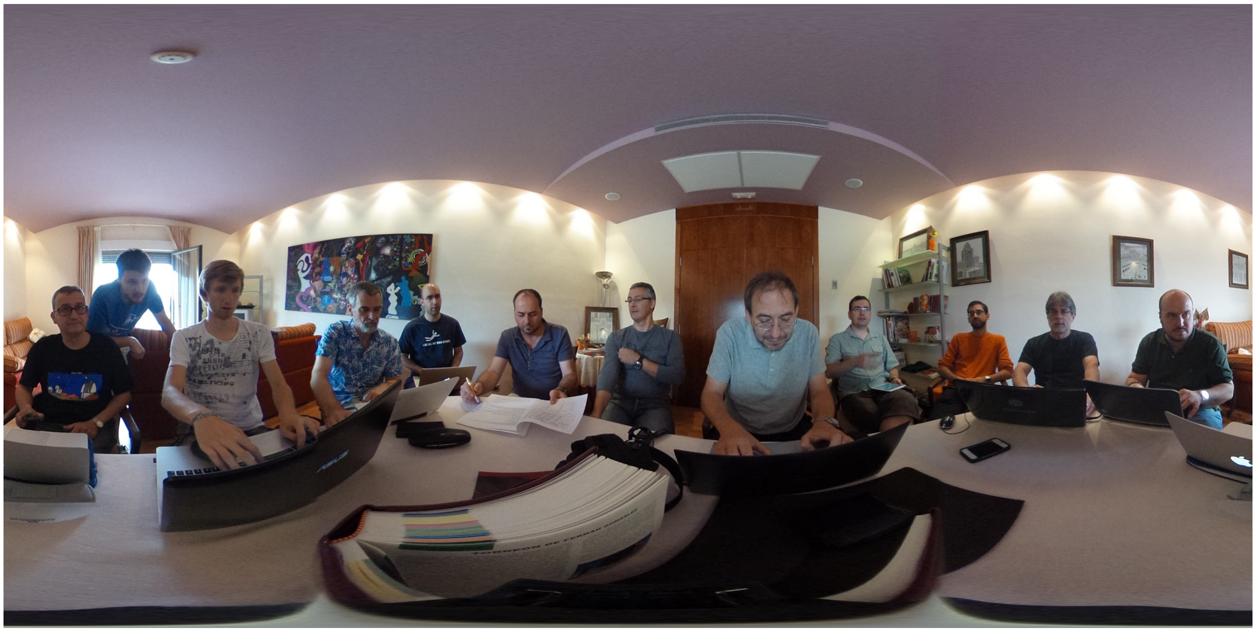

Figure 13: Panoramic view of the discussion. From left to right: Jaime Zamorano, Miguel Nievas, Philipp Staubmann, Brian Espey, Christopher Kyba, Paolo Pescatori, Fabio Falchi, Günther Wuchterl, Alejandro Sánchez de Miguel, Carlos Tapia, Salvador Bara, Salvador Ribas (Photo by J. Zamorano).

Participants also discussed the goals of mapping. The following goals were identified:

1. Understanding the effects of skyglow on ecology.
2. Understanding how small cities/villages work in order to be able to model the effects of future development on skyglow. Note that development along trunk roads eventually fills in the sky between the roads.
3. Understanding how far you have to travel from a city to enable observation of phenomena such as meteors or the Milky Way, or to do astrophotography.
4. Understanding the effects of changing/replacing lamps lamps in a small village.

In the afternoon we discussed the strategy for taking measurements during the coming evening, devised a protocol for SQM-L measurements, and discussed limitations of the SQM. This discussion resulted in the recommendations that follow below. The team then split into smaller groups to analyze data or engage in smaller discussions.

<u>Night of July 19-20</u>

At midnight, the weather was not favorable, so the team split into two groups to maximize the chances of successful observations. One group stayed on the terrace of the hotel, where the hotelkeeper turned off a brightly illuminated sign to facilitate observations. A lightmeter was used to evaluate the effect that the hotel sign turning off had upon the local skyglow. The group that stayed at the hotel unfortunately had partly cloudy skies.

The second group traveled to a mountain pass (Puerto de Menga) located at 40.57476N, 5.03415W (Figure 14). This group had favorable conditions (extremely clear sky at zenith, some clouds on the horizon), and made observations with three lightmeters, two SQM-LU, and five handheld SQM-L, as well as Photographs of the Milky Way (Figure 15), and all-sky images. Observations were briefly stopped when a small cloud passed overhead. The rest of this section describes the observations taken at that site. Measurements were made during astronomical night, as well as during the lunar twilight.

Figure 14: The sky towards the northeast horizon at Puerto de Menga pass.

Figure 15: The Milky Way with clouds near the southwest horizon at Puerto de Menga pass. Whether clouds brightened or darkened the sky depended on their position. (Photo by G. Wuchterl).

Handheld SQM-L measurements were taken to evaluate the consistency of observations taken in a real field situation. A pair of SQM-Ls was randomly selected by Kyba and handed to Sanchez de Miguel. Sanchez de Miguel pointed the pair of SQMs to the sky, and pushed the sampling buttons simultaneously. Sanchez de Miguel called out the value of the SQM facing him, and Tapia Ayuga called out the value of the SQM facing the other direction. Kyba recorded the data on a laptop several meters away. Tables 2 and 3 show the results of the observations.

Table 2: Handheld SQM-L observations during astronomical night (01:57-02:04). Values are $mag_{SQM}/arcsec^2$. Mean value of all observations is 21.35 $mag_{SQM}/arcsec^2$.

SQM ID	North	East	South	West	avg
5855	21.48	21.35	21.21	21.33	21.34
2164	21.19	21.29	21.25	21.14	21.22
6386	21.48	21.48	21.38	21.34	21.42
3204	21.23	21.36	21.34	21.19	21.28
1892	21.54	21.47	21.45	21.48	21.49
5855	21.25	21.30	21.43	21.36	21.34

Table 3: Handheld SQM-L observations during lunar twilight (02:35-02:41). Values are $mag_{SQM}/arcsec^2$. Mean value of all observations is 21.16 $mag_{SQM}/arcsec^2$.

SQM ID	North	East	South	West	avg
1892	21.34	21.30	21.29	21.27	21.30
5855	21.09	21.09	21.21	21.11	21.13
3204	21.11	21.09	21.04	21.06	21.08
6386	21.20	21.15	21.25	21.23	21.21
1892	21.28	21.32	21.28	21.25	21.28
2164	20.93	20.97	21.01	20.94	20.96

Lightmeter data was also taken at Puerto de Menga. Figure 16 compares the observations obtained from an International Year of Astronomy Lightmeter (Mark 2.3, green dots/line, provided by B. Espey) and a newer version, type (Mark 2.3l, black). Spikes in the data represent occasional cars passing by the measurement location. The handheld SQM-L measurements are also shown (N,E,S,W represented by coloured triangles pointing up, right, down, left, respectively), along with each instrument's directional average (red circles). For clarity, the directional data have been ad-hoc shifted by equal time intervals across the respective recorded measurement period, with the average shown first.

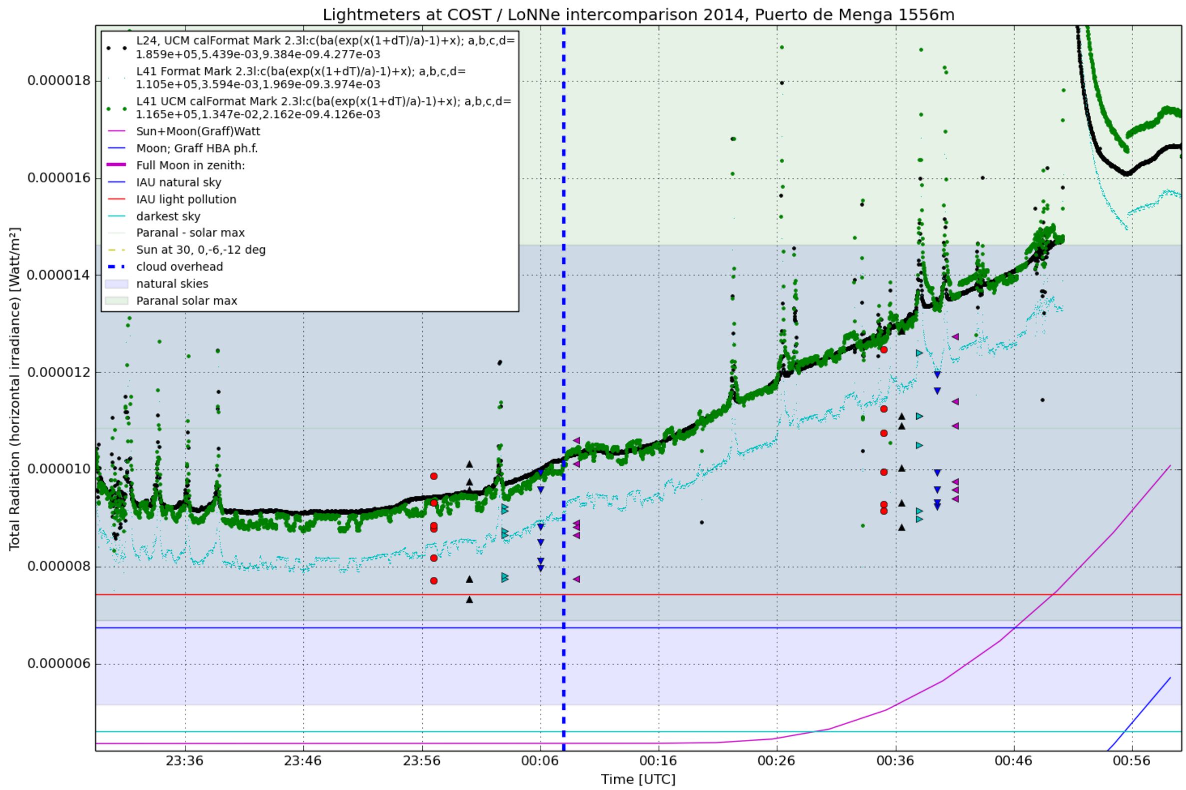

Figure 16: Comparison of Lightmeter and SQM-L measurements at the Puerto de Menga pass (1564m) in the night of 19th to 20th July 2014. Total radiation (horizontal irradiance) expressed in Watt/m² is shown vs. time (UTC), see text.

The lightmeter results use calibrations derived from the measurements on the UCM roof during the campaign. They illustrate how the complete lightmeter-measurement concept (calibration procedure and instrument) react. Measurements at the UCM roof were photometrically challenged by clouds, aerosols and the moon competing with high-amplitude time-dependent light-pollution. This resulted in comparatively large uncertainties of the calibration fit with systematics, likely due to the removal of apparently cloud-affected data. To estimate the consequences of these effects, data for the Mark 2.3 lightmeter are shown a second time, with a calibration obtained at its home-site, in Dublin under stable (cloudless and clear) atmospheric conditions (small, cyan points).

The SQM-readings were converted from the conventional SQM-L $mag_{SQM}/arcsec^2$ to cd/m² using luminance = 10800 x $10^{(-0.4*SQM)}$), as recommended by the manufacturer. Illuminance is obtained by assuming isotropy and integration across a hemisphere. Conversion from these "SQM-Lux" to Watt/m² is done consistently with the Lightmeter-calibration. The latter relies on an atmospheric model for the absolute connection to the values measured at the Sun to obtain the irradiance/total-radiation calibration (Müller et al. 2011).

Several reference lines and horizontal bands are shown to provide additional information. The magenta line is a natural sky model including moonlight. In addition, the modelled Moonlight alone is show explicitly as a thin blue line, that appears towards the end of the displayed time interval, after moonrise. Note the effect of the lunar twilight (not included in the model) is noticeable in both lightmeter time-series at about 23:50 UTC, half an hour before the moonrise (00:20). Ranges for the natural light of the night-sky under conditions of solar minimum and maximum are shown as horizontal bands. They are calculated from background sky brightness measurement at ESOs Cerro Paranal site compiled by Patat (2004). Conversion again assumes isotropy.

The moment at which a cloud passed directly overhead is marked by the vertical blue dashed line. The bump around the "cloud is overhead" line at 00:08 is likely the effect of remote artificial light scattered back to ground by the cloud. Thin horizontal lines show several converted IAU reference values (usually defined at 45° height) for the sky-background, and an estimate for the background of the darkest sky (i.e. one with a Milky Way pole in the zenith and very low airglow).

Results and continuing analyses

Study of the data is ongoing. Team members continue to analyze the results of

1) The spectral response calibration of the lightmeter, SQM, iPhone DSM, and cameras.
2) The Extinction and sky brightness at the UCM site from Astmon.
3) Further analysis of the SQM data.
4) Analysis of the sky polarization photographs from UCM.
5) The Coelofot instrument.

SQM

The sample standard deviation of the observations from the 5 SQM-Ls was 0.11 $mag_{SQM}/arcsec^2$ during astronomical night (Table 1), and 0.13 $mag_{SQM}/arcsec^2$ during astronomical twilight (Table 2). These differences are slightly larger than the manufacturer's claimed systematic uncertainty of 0.1 $mag_{SQM}/arcsec^2$, and those reported by den Outer et al. (2011, 2015) in campaigns using stationary meters. However, due to the small sample size, the observations are consistent with the observations of den Outer et al.

Coelofot

This was the first "on the road" test of Coelofot. An absolute calibration still needs to be done for each channel, and even if we got some useful data (for instance, fast changes in sky color due to close street lights), the speed of the device may pose a problem when the data is taken on top of a car due to changing light conditions.

Recommendations

During the discussion periods, the team decided to make the following recommendations for skyglow researchers:

Recommendation #1: When making observations with a handheld SQM-L, you should average the result of four observations, rotating your body after each observation to a different compass direction. If the SQM-L is being affected by stray light, this may minimize or reveal the effect. If the four observations are not self-consistent (maximum range about 0.2 $mag_{SQM}/arcsec^2$), then it is probably not a good location, and the data should not be recorded. This technique has been suggested by Andreas Hänel in the past, and we advise all handheld SQM-L users to adopt it. The value of the method can be seen by comparing the data from SQM-L 5855 in Table 2 and SQM-L 1892 in Table 3. The difference in the average of the two individual sets of four measurements was small (0 and 0.02 $mag_{SQM}/arcsec^2$), despite the fact that each individual observation set had sample standard deviations of 0.11, 0.08, 0.03, and 0.03 $mag_{SQM}/arcsec^2$.

Recommendation #2: Individual observations obtained by single channel devices like the SQM in areas with little artificial light ($mag_{SQM}/arcsec^2$>20.8) should not be considered quantitative measurements of artificial light levels. In such areas, all-sky imagery will provide a much better characterization of the site.

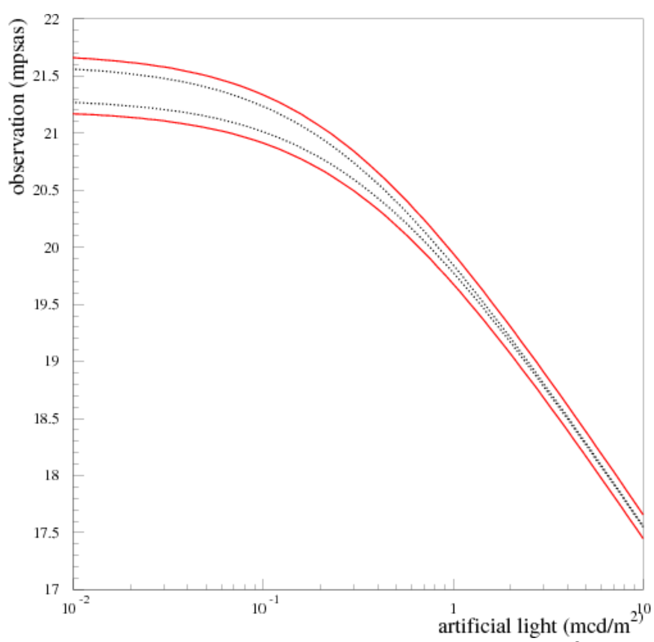

Figure 17: The dotted black curves show the value in $mag_{SQM}/arcsec^2$ that would be expected for a range in artificial light under assumptions of a natural sky background of 21.6 $mag_{SQM}/arcsec^2$ (top) and 21.3 $mag_{SQM}/arcsec^2$ (bottom). The solid red curves show the effect of shifting these values up or down by 0.1 $mag_{SQM}/arcsec^2$.

The brightness of the clear moon-free natural night sky is highly variable. In general, the two most important factors in determining SQM measurements in pristine locations are the presence of the Milky Way, and the brightness of the airglow. Variation over the range of at least 21.3 to 22 $mag_{SQM}/arcsec^2$ is to be expected. Figure 17 shows how this variation affects measurements, coupled with a unit-to-unit uncertainty +/-0.1 $mag_{SQM}/arcsec^2$. In highly polluted areas, the SQM measurement mainly depends on the amount of artificial light, but the natural variation becomes much larger than the SQM's uncertainty at pristine sites.

At polluted sites, SQM measurements can be used to estimate the artificial sky brightness by subtracting off an assumed natural sky brightness. The solid black curve in Figure 18 shows how this conversion works for an assumed background of 21.6 $mag_{SQM}/arcsec^2$. The dotted blue curve shows the incorrect conversion that would result in the case that the real value of the natural sky background was 21.3 $mag_{SQM}/arcsec^2$, and the dashed red lines show these two curves shifted left or right by 0.1 $mag_{SQM}/arcsec^2$. Extremely large (and non-normal) errors will result if the artificial sky brightness is estimated using SQM values larger than about 20.8 $mag_{SQM}/arcsec^2$.

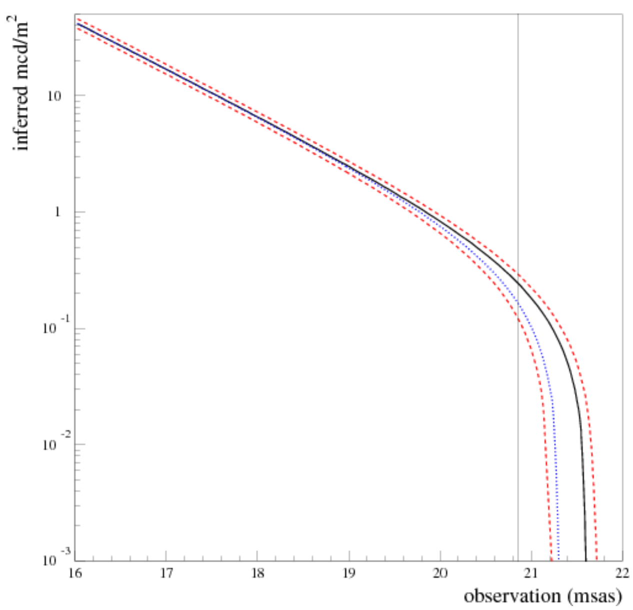

Figure 18: The solid black line shows the conversion from SQM observation to estimated artificial sky background under an assumption of a natural sky background of 21.6 $mag_{SQM}/arcsec^2$. The blue line shows the values that would be inferred if the sky background was really 21.3 $mag_{SQM}/arcsec^2$, and the dashed red curves show the two shifted left or right by 0.1 $mag_{SQM}/arcsec^2$. The solid vertical line is at 20.85 $mag_{SQM}/arcsec^2$ (double the value of the natural sky background).

Note that this does not mean that single channel device observations are useless for measurements of skies darker than 20.8 $mag_{SQM}/arcsec^2$, it just means that they must be interpreted with caution. For example, such observations are valuable in the context of a long-term single location monitoring campaign, or a regional mapping campaign with a single SQM. Observations taken at the same time in multiple years can also be compared in the context of a

long-term monitoring campaign (assuming that the SQM sensitivity is stable over several years). The problem that we have experienced is that statements have been made regarding the relative quality nearly pristine sites based on only a handful of SQM measurements. Handheld SQM observations do not provide the precision required for such statements.
Finally, if an orientation device is used, single channel devices can be used to take measurements pointed in different directions.

Recommendation #3: It is the opinion of the group that the SQM-L should in general not be used to report measurements on clear moonlit nights.

Our first concern is that there are a number of anecdotal stories about SQM-Ls that report unusual values during some periods of moonlit nights, and that the angular response of the SQM may not be azimuthally symmetric. Second, several members of the group have examined the SQM-L internally, and are concerned that the design and placement of the IR filter is likely to allow stray light to irradiate the sensor. Third, the SQM-L is designed to measure the radiance of an approximately uniform (i.e. slowly varying) surface, not point sources. Without evidence that the angular response of the SQM-L is the same from unit-to-unit, it is in principle possible that the measured radiance of a point source would differ. The exception to this are experiments in which the SQM views a collimated patch of sky, as was done in Puschnig et al. (2014), or for completely overcast skies, as in Kyba et al. (2015b).

Future research questions identified during the meeting

- Is the angular sensitivity of the SQM-L (both zenith and azimuth angles) the same from unit-to-unit?
    - A test of several units could reveal whether internal reflections are an issue.
- Is the spectral sensitivity of the SQM-L the same from unit-to-unit?
- Is the response of different SQM-Ls to point sources consistent?

Recommendations for next intercomparison workshop

The schedule included both daytime meetings and nighttime measurements. This was much too strenuous. Future campaigns should greatly restrict the daytime program, have a much later start time, and generally focus the main effort on nighttime measurements.

Salvador Ribas has agreed to coordinate planning of the future LoNNe Intercomparison campaigns.

Conclusion

The campaign was successful. A large amount of data was taken, and continues to be analyzed.

References

den Outer P, Lolkema D, Haaima M, van der Hoff R, Spoelstra H, Schmidt W (2011) “Intercomparisons of nine sky brightness detectors. Sensors, 11(10), 9603-9612.

den Outer P, Lolkema D, Haaima M, van der Hoff R, Spoelstra H, Schmidt W (2015) “Stability of the Nine Sky Quality Meters in the Dutch Night Sky Brightness Monitoring Network”. Sensors 15, 9466-9480; doi:10.3390/s150409466

Kyba CCM, Ruhtz T, Fischer J, Hölker F (2011) "Lunar skylight polarization signal polluted by urban lighting." Journal of Geophysical Research: Atmospheres 116.D24

Kyba CCM, et al. (2015a) “Report of the 2015 LoNNe Intercomparison Campaign.” Report of the ES 1204 (LoNNe) EU COST Action. URL: http://tinyurl.com/pd2rbvk Accessed July 22, 2015

Kyba CCM, et al. (2015b) “Worldwide variations in artificial skyglow.” Scientific Reports 5, doi: 10.1038/srep08409

Müller A, Wuchterl G, Sarazin M (2011) “Measuring the night sky brightness with the lightmeter.” Revista Mexicana de Astronoma y Astrofsica, 41, 46-49

Patat F (2004) “Night sky brightness during sunspot maximum at Paranal.” The Messenger 115: 18-21

Puschnig J, Posch T, Uttenhalter S (2014) “Night sky photometry and spectroscopy performed at the Vienna University Observatory.” Journal of Quantitative Spectroscopy and Radiative Transfer 139: 64-75; doi: 10.1016/j.jqsrt.2013.08.019

Zamorano, J., Sánchez de Miguel, A., Nievas, M, Tapia, C. (2014) “NixNox procedure to build Night Sky Brightness maps from SQM photometers observations”. E-prints UCM (http://eprints.ucm.es/26982/)

Acknowledgements

We thank the EU COST program for financing this event of the ES1204 Action (Loss of the Night Network).