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Night Sky Brightness monitoring in Spain.

Jaime Zamorano[1], Carlos Tapia[1], Sergio Pascual[1], Cristóbal García[2], Rafael González[2], Esteban González[3], Oscar Corcho[3], Lucía García[1], Jesús Gallego[1], Alejandro Sánchez de Miguel[4], Enrique Solano[5], and J. Manuel Alacid[5]

[1] Departamento de Física de la Tierra y Astrofísica, Universidad Complutense de Madrid
[2] Asociación Astronómica Astro Henares
[3] Ontology Engineering Group, Facultad de Informática, Universidad Politécnica de Madrid
[4] Environment and Sustainability Institute, Cornwall, TR10 9FE University Exeter
[5] Spanish Virtual Observatory (SVO), Centro de Astrobiología (INTA-CSIC) ESA - ESAC

Abstract

The estimation of the light pollution and the study of its eventual evolution can be established by monitoring the night sky brightness. We present the monitoring stations of the Spanish Light Pollution Research Network (REECL) and some results. The advantages of the new TESS-W photometer developed for the STARS4ALL project are described, along with the incipient global network of monitoring stations using TESS-W.

1 Introduction

One of the unwanted effects of the light pollution is the brightening of the sky at night. The dark natural brightness of unpolluted skies is only found in remote locations far from big cities. The sky brightness depends on the number, nature and location of the light emitting sources and can be predicted using models of the dispersion of the light by the atmosphere. We are interested in measuring the sky brightness in dark protected places (national parks, astronomical observatories, etc.) and also in places with medium and heavy contamination at different distances from the main urban areas. The spatial and temporal variation of the sky brightness is used to test and improve the models (see for instance [3] & [6]).

The sky brightness at night can be used as a proxy of the light pollution. Besides the natural component, introduced by the moon for instance, the variations in the artificial light input and the conditions of the atmosphere are reflected in the brightness. A monitoring station with a fixed photometer measuring the sky brightness in the zenith should be used to record these changes. After a long term series of measurements it is possible to perform statistics to determine the characteristics of the sky brightness at this location and one can

determine the eventual evolution of the light pollution.

The change of artificial light technologies in our cities, mainly from high pressure sodium (HPS) to LED lamps, is changing the sky in brightness and also in color [4]. It is important to measure these changes over time (before, during and after the retrofit) to establish whether we are really reducing the impact of light pollution in our skies.

2 The Spanish REECL monitoring network

Most of the Spanish researchers that study the light pollution effects from different aspects (astronomy, biology, human health, etc) are collaborating under the framework of the Spanish Light Pollution Network (REECL). One of the results of these collaborations is the network of monitoring stations that was originally created by the Universidad Complutense de Madrid which is in charge of its maintenance.

The SQM (Sky Quality Meter, Unihedron) photometer are being used in most of the stations. The photometer should be protected with an enclosure and linked to a computer. To record, plot and share the data we are using the PySQM free software developed at the Universidad Complutense de Madrid [2]. The data is plotted in realtime at the SQM-REECL network webpage and it is stored for free access at the Spanish Virtual Observatory [1]. The description of the network and some results were presented at XXIX IAU meeting [5].

Figure 1 shows the locations of the SQM stations that are linked to the REECL network. Note the one in Porto (Portugal). There are other monitoring networks in Spain. The Galician NSB monitoring network which is a collaboration of Universidade de Santiago and Meteogalicia [1] and the Catalan network which depends of the Parc Astronomic Montsec and the Generalitat de Catalunya, and also some institutions or individuals with photometers that are not sharing the data.

A comparison of the results for the heavily polluted city of Madrid and a rural village (Villaverde del Ducado) is presented in Fig. 2. The upper panel shows the evolution of the brightness recorded at the astronomical observatory of the UCM located on top of the Physics building. The vertical axis represents the time along the night while the x-axis runs along the days during several years. The brightness of the sky is color coded; most of the data is around 18 magnitudes/arcsec^2 in the SQM magnitude system. The sinusoidal shape of the graph is due to the variation of the length of the night along the year. It is interesting to note the effect of ornamental lights, traffic and other human activity that yield a brighter sky at the beginning of the night. The same plot for a rural area shows darker skies reaching 21.5 mag/arcsec^2 in the SQM system. In this case the brightening due to the presence of the moon over the horizon is apparent in every lunation. Figure 3 presents an histogram for the values obtained from Villaverde del Ducado during long series of measures. Even at this rural area the sky brightness is affected by Madrid at 130 km in linear distance.

There are 47 monitor stations sending data at the time of writing this contribution. Most of the persons in charge of the photometers are individuals. The PySQM software

[1] http://sdc.cab.inta-csic.es/pdd/jsp/busSQM.jsp

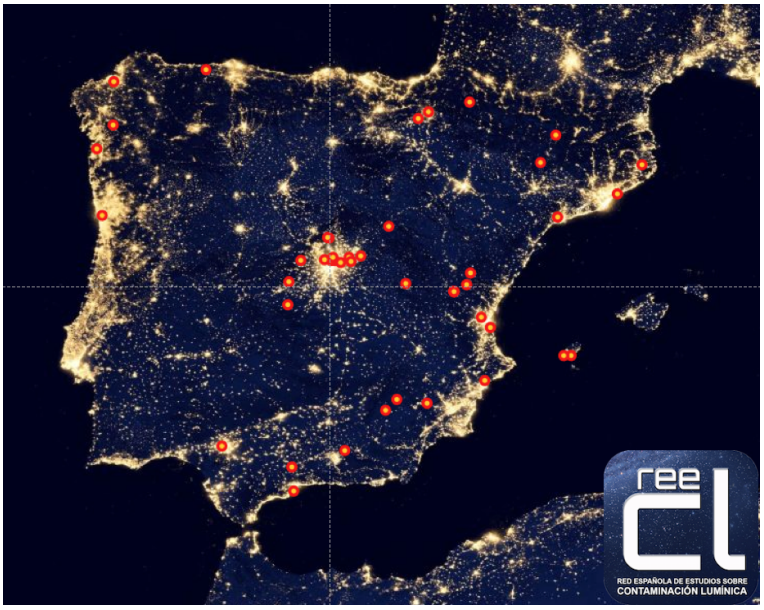

Figure 1: Distribution of SQM monitor stations on the Iberian Peninsula and Balearic islands that are linked to the network.

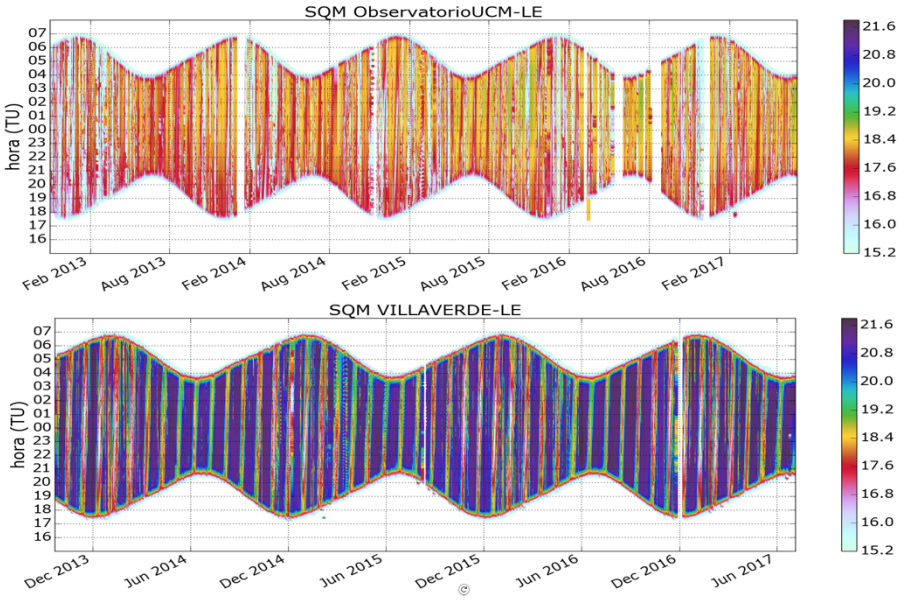

Figure 2: Record of observations from the Observatorio UCM station inside Madrid (upper panel) and a rural village (Villaverde del Ducado) (lower panel).

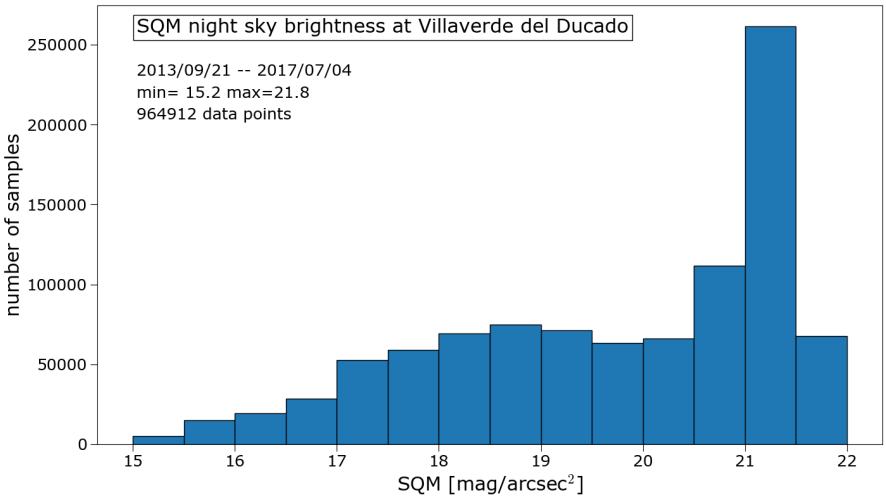

Figure 3: Histogram with the observations obtained with one of the SQM photometers at a rural location. The sky brightness is affected by Madrid at 130 km in linear distance.

creates the plot for each night and stores the data following the IDA-IAU standard format. Besides a monthly data file is also stored. The data is shared via dropbox or google drive.

3 The European Photometer Network

3.1 The TESS-W photometer

Mounting a SQM monitor station implies the purchase of the photometer and the enclosure, and the connection of the photometer to a personal computer linked to internet. The computer should be connected to the electrical power all the time waiting to the twilight for storing the measures of the whole night and it is idle during the day.

One of the goals of the STARS4ALL European project is to extend this network to an European night sky brightness network and also to include the other smaller or local existing networks in Europe. Our plan is to grow the number of monitor stations with the help of interested citizens. We have designed a low-budget photometer (TESS-W) which is open hardware and software and have some interesting features. The photometer works unattended without the need of a dedicated computer. It only needs a quick setup to communicate with a local wifi that is used to send the data using the internet of things (IoT) protocols. The photometer has also an infrared sensor to estimate the cloud coverage by comparing the ambient temperature with that of the sky. More information on the photometer at [7].

The data obtained by each TESS-W unit is sent in real time to the repositories and is inmediately ready for the public (open data) and also from the Spanish Virtual Observatory[2]. The researchers and interested citizens can browse the plots, compare the readings from

[2]http://sdc.cab.inta-csic.es/pdd/jsp/tessindex.jsp

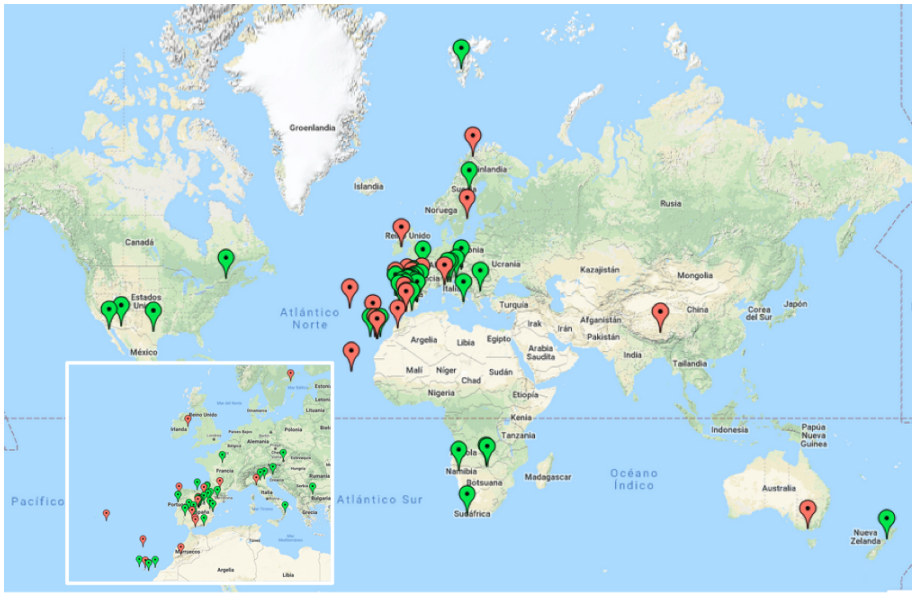

Figure 4: Map with the location of the TESS-W photometers sending data. The inset shows a better view of the photometers in Europe.

different stations and also to download the data[3].

3.2 The TESS-W photometer network

The first units produced were tested and calibrated, before sending to the beta testers. They perform as expected and only some minor changes were made to the second series. There are 180 TESS-W photometers built, 50 of them in the process of calibration at *Laboratorio de Instrumentación Científica Avanzada* (LICA-UCM).

Although the network was originally designed to cover Europe, the first 60 photometers that are sending data from several places along the globe (see Fig.4). This reflects the location of the citizen science volunteers and that of the interested researchers working in the field of light pollution. Most of the first series of photometers (37) are located in Spain.

The data gathered with the photometers is already available for the interested scientist to research. In Figure 5 we present example of the measures for one night in four locations of different geographical coordinates. We are waiting for a long series of observations to determine eventual evolution and other interesting statistical results.

Acknowledgments

The devices were tested LICA, a facility of UCM-UPM Campus de Excelencia Internacional. The support of the Spanish Network for Light Pollution Studies (REECL) (Ministerio de Economía y

[3]http://tess.stars4all.eu/plots/

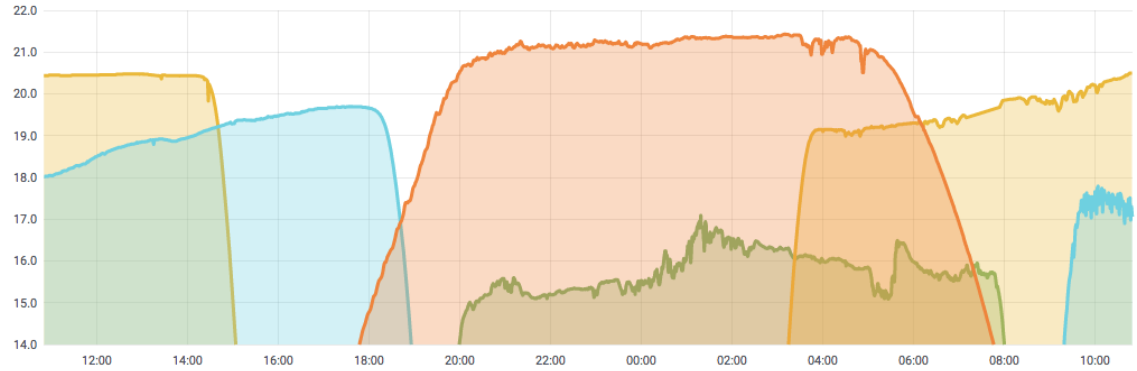

Figure 5: Variation of the night sky brightness measured in four locations of the network during the night (2018/10/18-19). Wellington (New Zealand) in yellow; Coslada near Madrid in green; Tucson (Arizona) in blue and Svalbard (Norway) in orange.

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