Light Pollution: Theory, Modelling and Measurements 2019

LPMM

Studying light pollution in a color changing world: a new research challenge?

Presented by

Eötvös Loránd University,

Savaria University Centre

Zselic Valley Leisure Farm

Hungary

25th–28th June, 2019

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Dedicated to our friends
Thomas Posch
&
Abraham Haim

LPTMM 2019

The meeting will focus on recent advances in scientific investigations on light pollution and its impact on astronomical observations.

The study of light pollution is undergoing a renaissance due to development of high-performance computers that can significantly reduce the time needed for more accurate numerical simulations. Theoretical solutions, numerical modeling, and field campaigns represent diverse approaches to the analysis, prediction, and characterization of light pollution levels and behaviour.

The meeting's aim is to bring together the experts in that field to discuss the current state of the art and to formulate new research directions. The conference aim to facilitate a more intensive development in this field of research.

Topics

- Theoretical concepts of modelling light pollution
- Numerical experiments — effects of aerosols, clouds, terrain, obstacles, spectrum, and angular function
- Observational techniques, data, and products
- Design and evaluation of dark sky friendly lighting technologies, regulations

Useful information

- The timetable will be strictly observed by the chairpersons.
- Prior to your session, upload your files on the conference laptop during a coffee break with the help of our technical staff.
- Always keep your identification badge with you to get access to the meals, coffee breaks, etc.
- Remember to take some clothes with you for nocturnal social activities.

Program

25 June, 2019

Duration	Session (talks)	Time	Speaker & title (Event)	Page
1:00		**11:00**	**Bus departure from Budapest center**	
4:00		**12:00**	**Bus departure from Budapest airport**	
1:10		16:00	Check-in with coffee and sandwiches	
0:10		17:10	Opening talk by Zoltán Kolláth and Miroslav Kocifaj	
0:10		17:20	*Tribute to T. Posch* by Stefan Wallner	
0:05	**A**	**17:30**	**Theoretical concepts of modelling light pollution Chair: Tomasz Ściężor**	
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0:20	A–2	17:55	Hector Solano — A theoretical characterization of skyglow effects in the natural park of Cimatario	12
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0:20	A–5	18:55	Miroslav Kocifaj — An investigation of ground albedo impacts on multiple light scattering in night-time atmosphere	15
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26 June, 2019

Duration	Session (talks)	Time	Speaker & title (Event)	Page
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0:20	B–3	10:25	Anna Czaplicka — The impact of atmospheric aerosol particles on the brightness of the night sky	19
0:30		10:45	Coffee Break	
0:20	B–4	11:15	Hector Linares — Modelling the night sky brightness and light pollution sources of Montsec protected area	20
0:20	B–5	11:35	Salvador Bará — Evaluating light pollution impacts at aggregated territorial levels	21
0:20	B–6	11:55	Kornél Kolláth — Interpreting sky camera images together with laser ceilometer backscatter profiles at night	22
1:30		12:15	Lunch	
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0:30	**E–1**	**13:50**	**Key speaker: Alejandro Sánchez de Miguel Tracking color change of the night: Use of CCDs, DSLRs and Phones and DMSP, VIIRS, ISS and CubeSats to track color change of the night**	**23**
0:20	E–2	14:20	Dominika Karpińska — Analysis of light pollution of the night sky in Toruń	24
0:20	E–3	14:40	Pietro Fiorentin — Calibration of digital compact cameras for sky quality measures	25
0:20	E–4	15:00	Li-Wei Hung — A concise set of metrics for describing night sky quality based on principal component analysis	26
0:30		15:20	Coffee break	
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Duration	Session (talks)	Time	Speaker & title (Event)	Page
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1:30		21:00	Visit of the planetariun and observatory	
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27 June, 2019

Duration	Session (talks)	Time	Speaker & title (Event)	Page
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Duration	Session (talks)	Time	Speaker & title (Event)	Page
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4:00		10:00	Transport to Budapest airport and city center — provided by conveeners	
1:00		14:00	Arrival at the airport	
		15:00	Arrival at the city center	

Abstracts

The effect of spheroidal aerosol particles of various species on the skyglow level

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Abstract

Several studies indicate the need to take into account the aerosol non-sphericity in modeling the scattered optical signal influencing the skyglow level near urban areas. A model of the spheroidal particles is convenient for description of the optical properties of the non-spherical aerosols with finite sizes. The method such as the separation of variables for simulating the scattering of light by spheroidal particles is well known and was implemented into Skyglow Simulator to demonstrate the effect of aerosol non-sphericity of commonly occuring particle species (black carbon, sea salt, rural/urban, etc.). Additional parameter *a/b*, denoting the ratio of the major semi-axis of spheroid to the minor one, appears in the calculations varying from unity (sphere) up to needles (prolate spheroids) or disks (oblate spheroids). Log-normal size distribution of the aerosol particles with effective radii <0.1 μm; 1.6 μm> is considered, while the simulations are provided for different distances from the modeled city. It has been found that spheroidal aerosols reduce the total amount of scattered light in the direction opposite to the city proportionally to increasing *a/b* parameter while the skyglow level remains almost unaffected in the direction toward the city.

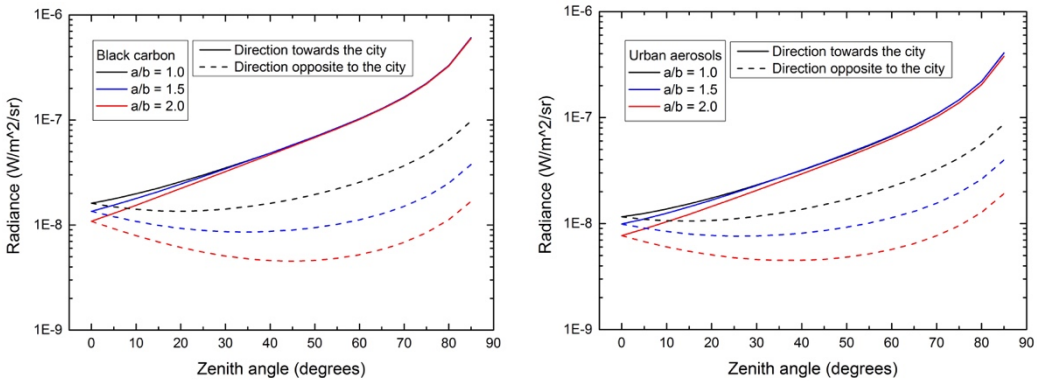

Fig. 1 Radiance on the meridian crossing the city for black carbon (left) and urban spheroidal aerosol (right) with various a/b parameter.

A theoretical characterization of skyglow effects in the natural park of Cimatario

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Abstract

Mexico is experiencing an important urban growth both demographically and geographically, with a concern for the care of the environment based on criteria of human health and preservation of organisms that inhabit the territory. Mexican urban areas should provide a good environment for citizens to enhance their life quality. However, urban developers use available information resources with limited knowledge of their surroundings, reducing their capacity to take better decisions. The consequences that artificial night lighting could bring to the biodiversity have become an important issue recently. It is well known that Skyglow disrupts the biological rhythms of all photosensitive organisms. However, little has been done to regulate the ecological consequences of artificial night lighting in Mexican cities. By simulating the skyglow produced by the city of Queretaro in Mexico, this work intends to study the further presence and evolution of light pollution in the natural preservation zone of el Cimatario, which is part of the Querétaro Metropolitan Area. The sky glow effects can be interpreted correctly only if the lamp types and the required amount of scotopic luxes at the territory are taken into account simultaneously. The results of this research may be equally useful for lighting engineers, biologists and researchers who are studying the effects of sky glow on biodiversity.

City emission function as the solution of an inverse problem

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Abstract

Modeling of an artificial light distribution on the night sky requires, in principle, the knowledge of optical characteristics of the atmosphere and a function appropriately describing light emissions from ground sources (cities). The atmospheric optical properties defined predominantly by physical parameters of aerosol can be achieved from daylight measurements and considered to be known at stable conditions. The bulk city emission function (CEF) is hard to obtain by direct measurements. But it can be retrieved indirectly from a night sky radiance distribution measured near a city. Retrieval of CEF from noisy sky radiances represents an ill-posed problem and so its solution requires application of some regularization technique. Probably the most popular one is the Tikhonov method. A key role in Tikhonov's regularization is to use an appropriate stabilizing functional and to find an optimal value of the regularization parameter. Investigation of these tasks is of the main interest in this contribution. For this purpose the radiance patterns over the night-sky were simulated in a vicinity of a hypothetic city for a few chosen emission radiance functions. These radiances loaded by a various perturbations served as input data to the inverse problem. The results suggest that assuming the emission function varies very slowly at low and medium zenith angles but then steeply increases, the second order Tikhonov regularization should be applied instead the prevalent zero order method. An optimal value of the regularization parameter is mostly estimated from the discrepancy principle. This approach may be problematic because it requires knowledge of measurement errors and model inaccuracy. The generalized cross validation method also fails when the noise is not distinguishable from the true data. That is the case of systematic errors caused, e.g., by model inaccuracy. The performed numerical experiments showed that the L-curved method works well without the need for knowledge of any input perturbations.

Modelling artificial night sky brightness with the ILLUMINA model using discrete light sources inventory

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Abstract

The modelling of the artificial night sky brightness is a complex task that many have tried to accomplish over the years with the greatest possible accuracy. A large number of improvements have been made since the simple Garstang model of the 80s, including taking account of heterogeneous light emissions and environment characteristics such as the aerosol distribution and the presence of terrain features. This was achieved notably though the usage of satellite imagery to obtain the properties of the environment accurately for vast territories. However, some limitations still exist. Detecting anthropogenic light emissions requires high sensitivity, and this comes at the expense of spatial and spectral resolution of the acquired data. This problem could be solved by better instrumentation, or by knowing the characteristics of the emitted light. As it turns out, many cities have inventories of the public lighting infrastructure containing all relevant information for the modelling of the artificial light emissions.

The present work aims to modify the ILLUMINA model to use those inventories as an input to describe the optical properties of the light emissions of cities. The modified model will then be tested on La Palma island, Spain, both for Observatorio Roque de los Muchachos and downtown Santa-Cruz. We will compare the model results with the one obtained using the standard input data and try to estimate the errors associated.

Aubé, M., Franchomme-Fossé, L., Robert-Staehler, P., Houle, V. (2005). *Light Pollution Modeling and detection in a heterogeneous environment: Toward a Night Time Aerosol Optical Depth Retrieval Method.* Proceeding of SPIE Vol. 5890, San Diego, USA.

Aubé, M. (2015). *Physical Behaviour of Anthropogenic Light Propagation into the Nocturnal Environment.* Philosophical Transactions of the Royal Society-B, Vol. 370, Issue 1667.

Aubé, M., Simoneau, A. (2018). *New features to the night sky radiance model Illumina: Hyperspectral support, improved obstacles and cloud reflection.* JQSRT 211: 25-34.

Garstang, R. H. (1986). *Model for artificial night sky illumination.* Publications of the Astronomical Society of the Pacific, 98(601):364-375.

An investigation of ground albedo impacts on multiple light scattering in night-time atmosphere

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Abstract

One of the pressing needs of basic light-pollution research is the fundamental theoretical treatment of artificial light propagation into the nocturnal environment for meteorological conditions, landscape morphology and surface types that normally occur in populated areas. The radiance field at arbitrary altitude or horizontal distance from a light-emitting source depends on many factors including the surface albedo. Normally, the downward radiation flux increases as the surface albedo approaches large values because the optical signal detected is due to superposition of ground-reflected and scattered radiation components. However, the atmospheric-induced optical distortion, due to scattering of artificial light, is significantly disordered under elevated turbidity conditions. This is because of increased importance of multiple scattering effects. The mechanism in which multiple scattering phenomenon influences the radiance of a night sky has been poorly quantified until recently, and the intrinsic role of ground albedo in this process is also highly uncertain. In this study I will bring a fundamental understanding and satisfactory treatment of ground albedo impacts on multiple light scattering, while addressing the principal questions: How do the higher orders of scattering contribute to the mechanism of sky-glow amplification? Does the relative contribution of higher-order scattering radiances change as the ground albedo approaches that of snow cover?

Asymptotic formula for skyglow modeling over a large territory

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Abstract

In our paper, we present an analytical framework to predict skyglow due to distant sources. The aim is to model sky radiance from zenith toward horizon along a vertical plane crossing the hemisphere in the position of a light source. We treat the problem of high amount of time needed for calculations over large territories by introducing an analytical formula that replaces the remainder of the infinite radiance/luminance integral. To proof the suitability of this formula, field experiments were done in Eastern Austria between the cities of Vienna and Bratislava with allsky images on seven location sites. The distances to these cities were kept variable to have both as light emitting sources but with different proportions of the night sky brightness. The analysis of images taken shows that the formula is well-suited for light sources located at intermediate and long distances and allows tremendous time savings in numerical computations. Also, errors are reduced significantly in our approach.

The impact of clouds on the brightness of the night sky

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Abstract

Clouds are a kind of atmospheric factor that most effectively scatters the artificial lights coming from the earth's surface. Therefore, they have the greatest impact on the brightness of the night sky. The paper analyses the influence of both the level of cloudiness, as well as the genera of clouds and their base, on the above-mentioned value. The impact of cloudiness on the brightness of the night sky in places with different levels of light pollution was researched. The parallel measurements of meteorological elements and the visually determined genera of clouds were used. The introduction of an innovative method of identifying some genera of clouds on the base of the all-night continuous measurements of the sky's brightness allowed for a similar analysis in the absence of observational data specifying the genera of clouds.

A linear correlation between the cloudiness and the brightness of the night sky was found. The determined linear correlation parameters allow to specify the three types of light-polluted areas, possibly related to the density of population. It was found that among the nine genera of the identified night clouds, the Altocumulus, Cirrocumulus, and Cumulonimbus ones are responsible for the described linear correlation. No dependence of the brightness of the night sky on the clouds' albedo was found. In the case of overcast, there was a clear relationship between the average height of the individual genus of clouds and the brightness of the night sky. The largest contribution to the night sky brightness comes from the light scattered on the lowest clouds genera Stratus and Nimbostratus, while the smallest one from the light scattered on the high altitude Cirrocumulus, Cirrus, and Cirrostratus clouds. It was also found that at the freezing temperatures the layer of aerosols forms below the level of the genera Nimbostratus or Stratus. This layer, thickening with the decreasing temperature, additionally scattered the artificial light. The influence of fog, treated as an earthbound cloud, on the brightening of an otherwise cloudless night sky was also examined.

The analysis of the measurements made during the lunar nights allowed to compare the effect of high altitude clouds on the brightness of the night sky in the presence and in the absence of light pollution. It was found that the share of the natural factor of the night sky brightness, which is the lunar light, decreases with the increasing level of light pollution.

Towards a deeper understanding of composite images of night lights

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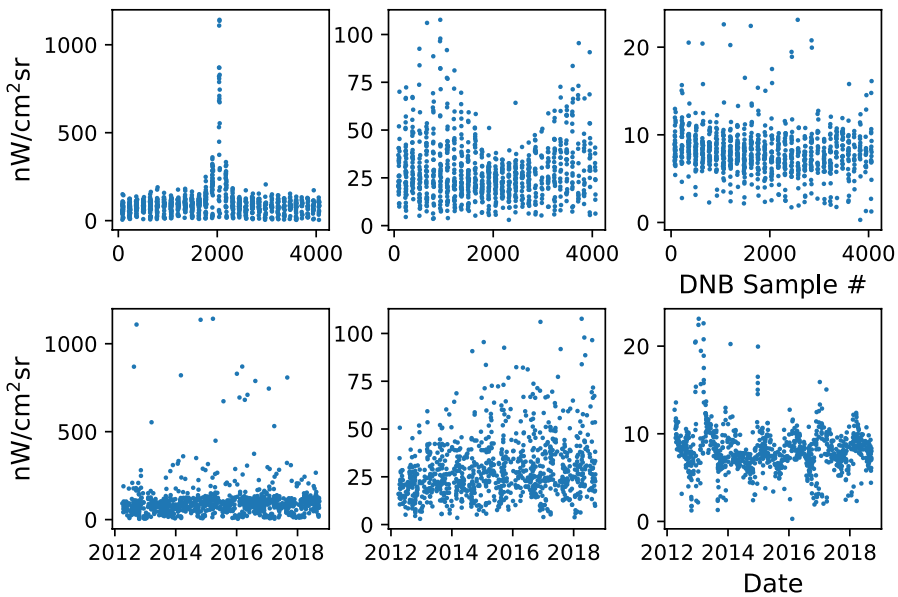
Abstract

Composite images of the Earth at night from the DMSP and VIIRS-DNB satellite sensors have been essential to our field. They have allowed the creation of the two "World Atlas" skyglow models, they allow us to examine lighting trends, and they have made a great deal of other analyses possible, thanks to the identification and quantification of light emissions. But what do the values in these composite images really mean?

The figure below shows DNB clear-sky moon-free radiance observations for three locations in Berlin from April 1, 2012 to September 30, 2018. At left is an urban commercial area, in center is an illuminated church, and at right is a suburban region. The data are shown twice, above against DNB sample number (related to both the nadir angle and acquisition time) and below against acquisition date. The two plots at top left show that for some sites, radiance can be enhanced or suppressed for specific viewing angles. The right hand site is closer to Lambertian emission, but shows that areas with significant vegetation can display a strong seasonal cycle. This talk will explore the reasons for variation in VIIRS DNB data, and raise questions about how trends in night lights should be interpreted. It is hoped that the talk will spark a discussion about and how compositing strategies could affect analyses based on night lights data, and what strategies are most appropriate for the various types of analyses that make use of DNB data.



The impact of atmospheric aerosol particles on the brightness of the night sky

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Abstract

Atmospheric aerosols, defined as the solid or liquid matter suspended in the atmosphere, are often an unnoticed factor, increasing the brightness of the night and cloudless sky. The paper presents studies on the relationship between the concentration of both mentioned types of atmospheric aerosols and the brightness of the night sky. It was found that a volcanic or desert dust is one of the factors most impacting on the brightness of the night sky glow. In Europe, the special importance have the spring inflows of the Sahara air masses significantly increasing the brightness of the sky over some part of the British Isles and, to a lesser extent, even over the Central and Eastern Europe. A similar effect was observed in the case of volcanic dust coming from nearby eruptions, particularly in Iceland. The impact of particulate matter coming from low-emission heating systems on the brightness of the night sky was also researched. There was a clear linear correlation between the brightness of the night sky and the particulate matter concentration not only in urban areas but also in ecologically clean, protected areas, such as national parks. Measurements of the brightness of the cloudless night sky in the presence of liquid atmospheric aerosols allowed to find a correlation with the concentration of such aerosols.

Preliminary measurements of the night sky glow brightness dependence on the aerosols particles size were also done, both in the case of fog and particular matter. It seems that with the presence of fog such dependence was not found, while in the case of the particulate matter this correlation increases with the decreasing size of particles.

The effect of aerosol concentration on the brightness of the night sky in the presence of the Moon was also researched. It was found that with the increasing aerosol concentration the brightness of the sky glow induced by the lunar light is also increasing, and this effect is especially pronounced for phases close to the first and last quarter.

Modelling the night sky brightness and light pollution sources of Montsec protected area

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Abstract

The main goal of this study is to evaluate the light pollution that Parc Astronomic Montsec (PAM) is receiving from any relevant light pollution source nearby. Montsec region, located in the northeast of Spain, is protected and labeled as Reference Point according to the legal framework of Catalonia and also certified as Starlight Reserve due to its pristine conditions.

The present study is based on the light pollution numerical model ILLUMINA (Aubé 2005). Ground based measurements (Ribas 2016), including both photometric and spectroscopic data, has been used to fit and evaluate the input parameters of the model. The output of ILLUMINA helps us better understand what kind of light sources produces light pollution and in which manner. We also used it, after converting it to astronomical magnitudes, to know how they affect astronomical observations: the resulting data is used to build all-sky maps comparable with the ones obtained with ground based measurements. The effect of light pollution are studied using both Johnson-Cousins photometric system filters B, V and R in any line of sight, and integrated all sky indexes such as Artificial Light to natural light Ratio (ALR).

In the first modelling attempt (Linares 2018) the city of Lleida, 140k inhabitants located 50km south-west from the observatory, was considered as the unique source of light pollution. After simulations were validated qualitatively by measurements a spectral comparison between the light pollution produced by Lleida before and after updating is lighting system in 2014 were performed.

Here we present: 1) an extended version of the simulated all sky maps that includes any source of light within 50km from the observatory, including known polluting cities as Balaguer (17k inhabitants) and Tremp (6k inhabitants) located at 15km and 20km respectively, and the distant city of Barcelona (>2M inhabitants) located at 150km from the observatory; 2) a light pollution contribution study by municipalities within the area similar to the one presented by Bará (2018); 3) full comparison between the light pollution produced by Lleida before and after updating its lighting system and the simulation of other hypothetic cases.

Evaluating light pollution impacts at aggregated territorial levels

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Abstract

We describe in this communication a basic mathematical framework to quantify the light pollution impacts at aggregated territorial levels. The results are expressed in the form of a light pollution transfer matrix whose generic element $(\mathrm{M})_{k,i}$ shows the accumulated effects that the light polluting sources located in territory i have on territory k. If the light pollution impacts under study depend linearly on the artificial radiance present in the target territory, then the $(\mathrm{M})_{k,i}$ elements can be directly calculated as integral transforms of the light source distributions, with kernels that are linearly related to the basic point spread functions accounting for the light propagation through the atmosphere.

As an example of application we discuss the relative contributions of the surrounding municipalities to the light pollution levels experienced in the Galician Atlantic Islands Maritime-Terrestrial National Park, measured using several night sky brightness metrics (zenithal sky brightness and all-sky average light pollution ratio). For this particular area, the overall light pollution levels turn out to be built up from the contributions of a relatively high number of municipalities. While a few of them are individually responsible for significant amounts of the total zenithal sky brightness (from 9% to almost 40%), the remaining ~40% of the overall light pollution is due to the combined effects of a large number of territories. This poses some basic constraints on the practicable strategies for light pollution abatement.

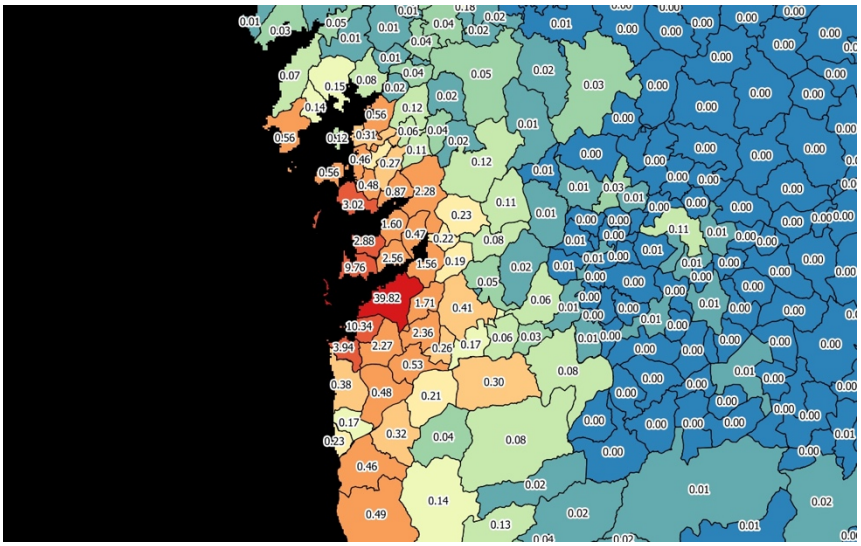

Fig 1. Relative contributions of the surrounding municipalities to the zenithal night sky brightness at Cíes Islands (Galician Atlantic Islands Maritime-Terrestrial National Park).

Interpreting sky camera images together with laser ceilometer backscatter profiles at night

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Abstract

Ground-based sky camera images could provide complementary information in the routine meteorological analysis. Such camera systems became increasingly popular recently in meteorological applications, but only a few studies address the various aspects in the nighttime. A test camera (DSLR with a wide-angle lens) has been installed in a standard meteorological observation site in Siófok, Hungary, situated in the south coast of Lake Balaton. The station is also equipped with a laser ceilometer instrument (Lufft CHM15k) providing height information of the cloud and aerosol layers in the atmosphere and also raw backscatter data. We present a simultaneous analysis of the processed sky camera images and ceilometer data to pick up typical scenarios of weather and site-specific interpretation problems. We studied the effect of the tendencies of different atmospheric conditions for some reference cases with typical cloud and aerosol profiles. Also, we performed Monte Carlo simulations with the dominant light sources to verify the numerical predictions of sky radiance.

Acknowledgements

The project is supported by the European Union and co-financed by the European SocialFund (Grant no. EFOP-3.6.2-16-201-00014; Development of international research environment for light pollution studies).

Tracking color change of the night: Use of CCDs, DSLRs and Phones and DMSP, VIIRS, ISS and CubeSats to track color change of the night

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Abstract

The importance of the spectrum of light pollution has been acknowledged since at least the 1970s. However, until the late 2000s the main tendency was to replace white light by orange light sources, and the main efforts to measure light pollution focussed on variations in luminance. Since the early 2010s, the trend in developed countries has been to maintain the luminance levels or to reduce them with a change from orange to white light according to most governments. In many developing countries, the change to white lights is often accompanied by an increase of the luminance.

Most of the popular sensors used to measure light pollution are unable to detect these changes accurately, so the current results are difficult to interpretate Some of them can produce misleading interpretation of the evolution of the Light at Night field. This happens with the SNPP/VIIRS-DNB, DMSP-OLS. There are some specific instruments like CCDs with filters that provide a very accurate vision of the color changes but are extremely expensive and will take a long time to deploy in a fast changing situation.

Currently, the accurate calibration of DSLRs and mobile phones images are promising initiatives for cheap and fast to deploy solutions to trace a real time change of the color of the night.

EMISSI@N a parallel project to the Cities at Night project for the calibration of the DSLR images of the ISS. This project has shown how DSLR cameras, and probably also smart phones, can potentially provide an accurate estimate of different environmental variables like the intensity on the following bands: Photopic and Scotopic vision, MSI and SLI, S-, M-, L-cones, rods, and ipRGCs and CCT. Spectral responses of some living species are also potentially traceable with color camera based sensors. “Timeline” is a citizen science project to track the color change from the ground using DSLR cameras, but many other are on development to acquire images and spectra using DSLRs and smart phones.

This data will be essential to complement the panchromatic sensors like the SNPP/VIIRS-DNB that have infrared sensitivity, so can be a good complement for the current multispectral sensors (DSLR and phones).

Analysis of light pollution of the night sky in Toruń

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Abstract

Light pollution is one of the types of environmental pollution. The sky illuminated by the excessive light emission is an inherent element of the modern world. This phenomenon has been known for over a century, but research has been carried out only for several decades. Analysis of the brightness of the sky was made for Toruń and neighboring areas. The main aim of the study was to study the distribution of brightness of the sky over a medium-sized city. The important assumption of the research was also comparison of two measurement methods together with the verification of their correlation. The basic research method was a direct measurement of brightness made with the SQM photometer. The second technique was a photographic method, based on the analysis of photos of the night sky. The conducted research was carried out throughout the calendar year on 24 measurement sites located in Toruń. Measurement sites represented various types of buildings occurring in every city. On the basis of the obtained data, a map was made showing the extent of light pollution and its intensity, as well as the spatial distribution of this phenomenon. The brightness of the sky was also examined in terms of astronomical and weather conditions. Each aspect is documented in tabular and visual form.

Calibration of digital compact cameras for sky quality measures

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Abstract

The use of calibrated digital cameras provided with wide angle or fisheye lens are increasing in sky photometry. In particular they allow recording images of artificial sky glow with very high resolution, thanks to the improved sensors. All-sky brightness maps can be obtained which allow to quantify the extent and the severity of light pollution [1]. Artificial sky luminance depends on many causes like changing atmospheric conditions, variations (continuous or on and off switching) of artificial lights throughout the night and dismounting and new installation of systems for outdoor lighting. Repeated image recordings and measurements with Sky Quality Meter allow to track these variations, identifying the major contributions to artificial sky glow, can help to evaluate the effect of changes in the outdoor lighting systems and the impact of awareness initiatives [2, 3].

This work presents the possibility of using the extremely popular compact digital cameras of smartphones or action cameras to perform sky photometry. The newest generation of these devices allows to save raw images. They are not as good as digital single-lens reflex camera, in particular in terms of sensitivity, noise and pixel depth (10 bit versus 12 bit), but they have the advantage of being extremely widespread on the population and relatively cheap. These economical digital compact cameras work with an electronic shutter, it overcomes the consumption of mechanics and allows to gather images for long time. The work compares different calibration methods used to transfer raw data from the proprietary RGB color space to standard CIE color spaces, it allows the measurement of sky luminance in cd m^{-2} and in mag $arcsec^{-2}$. Furthermore, the colorimetric calibration could allow to identify the kind of most polluting sources. Aiming at better clarifying the performances of calibrated digital compact cameras, a comparison with more performing devices, like calibrated DSLR, is presented both in laboratory controlled conditions and in outdoor situations.

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[3] Jechow, A., Hölker, F., Kolláth, Z., Gessner, M. O., & Kyba, C. C., Evaluating the summer night sky brightness at a research field site on Lake Stechlin in northeastern Germany. Journal of Quantitative Spectroscopy and Radiative Transfer, (2016), 181, 24-32.

A concise set of metrics for describing night sky quality based on principal component analysis

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Abstract

Numerous metrics have been used to describe the night sky quality, such as the zenith brightness, horizontal illuminance, vertical illuminance, all-sky light pollution ratio, Bortle class, and limiting magnitude. Which metrics and ultimately how many are needed to confidently evaluate the quality of the night sky? This study uses a suite of matrix decomposition algorithms, including principal component analysis, to exam the relationships among different metrics and identify latent dimensions of night sky quality.

The National Park Service Night Skies Program has been collecting night skies data throughout the United States since the early 2000s. This effort resulted in more than 1,500 data sets to date. For each data set, about 70 metrics are measured through the combination of the captured images and field assessments to quantify different aspects of the night sky quality. While all of these metrics together provide a comprehensive description, it is a challenge to present the measurements in a concise manner to various audiences. To reduce this complexity, I use matrix decomposition algorithms to eliminate highly correlated metrics. These algorithms further identify the contributions of retained metrics to the variation in the data sets. Ultimately, I report a concise set of metrics to account for most of the variation in the data for characterizing night sky quality.

Keywords: night sky quality, metrics, sky brightness, principle component analysis, PCA

Assessment of ecological light pollution for (almost) all weather, all terrain and all directions

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Abstract

The assessment of the impact of artificial light at night on flora and fauna (ecological light pollution - ELP) demands for nocturnal light measurements for all weather conditions (for example clouds, fog or snow) and different habitats. In the context of ELP it is also important to have radiance information in several spectral bands and from all directions, requiring measurements beyond zenith and all-sky. Here, I will discuss how such information from the full solid angle (4π) can be acquired rapidly with a commercial digital camera and a fisheye lens by taking images in the vertical plane. Several advantages will be discussed and examples ranging from urban and rural skyglow to winter conditions will be given. I will also present recent results on the impact of clouds on skyglow in rural areas [1], the search for dark places in Europe during a stars4all light pollution initiative [2] and show how public events like WWFs Earth hour [3] or a rock music festival [4] impact the nocturnal light field and skyglow.

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Characterizing properties of artificial light at night at two test sites in Hungary

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Abstract

The public lighting was replaced in two Hungarian settlements in December 2018, one close to the Zselic Starry Sky Park in southwestern Hungary, and another one inside the Bükk Starry Sky Park near the city Eger in northeastern Hungary. The new system provides possibilities for interdisciplinary light pollution research. Both the flux and the spectral distribution of the new LED-based luminaires can be controlled within a specific range. We will monitor the differences in lighting by standard light pollution measurement techniques, and also perform biomonitoring at the respective locations. We refer to this whole system as Living Environmental Lab for Lighting (LELL), and the preliminary results obtained from the sites will be presented.

The goal of this system is to provide local and detailed assessments of the environmental impacts of ALAN. The oft-used fish-eye digital camera imagery for sky radiance and luminance measurements (see, e.g. Jechow et al. 2017) usually fail at the horizon and close to light sources due to the very high dynamic range of the scene. Therefore, we are developing a method for spherical high-resolution and high-dynamic-range luminance/radiance mapping using a robotic panorama head and a calibrated digital camera. From the spherical mapping, the irradiance or illuminance on all the possible planes can be calculated. This method gives the complete information of the local light field, which can be used to estimate the impact to a possible observer or specific living creature in order to help to understand the results from biomonitoring.

Acknowledgements

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Open Source Non-imaging Color Sensitive Sensors for the Detection of Light at Night

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Abstract

We report the design and first implementations of two non-imaging color sensor for the light pollution detection: 1-the LANcube (LAN^3), a new device intended to sample the multispectral and multidirectional properties of the direct artificial light at night into the urban or natural environment (indoor or outdoor), and 2-the CoSQM, a new portable device which aims to sample the multispectral properties of the indirect artificial light at night scattered by the atmosphere. Both instruments were designed under an open source model, in such a way that the software, the component list, the 3D printing files, and the documentation (users manual and system installation/configuration) are released under Creative commons Attribution-ShareAlike 4.0 International License. Both instruments are cheap (respectively ~100€ and ~300€) and can be easily replicated by anybody. Such characteristics may accelerate the advent of worldwide color light at night measuring networks. We expect that they will become widely used tools to foster new light at night related research in the fields of human health, environment, and astronomy. Having color detection capabilities is essential given the new color changing trend of the night lighting.

LAN^3 is a cube having on each of its face four sensors of various spectral bands in the visible range (red, green, blue and clear). Each band has been calibrated in a way to deliver the integrated fluxes. Thanks to its multispectral capabilities, the sensor will provide by default an estimate of the luminance (lux), the correlated color temperature (CCT), the melatonin suppression index (MSI), the induced photosynthesis index (IPI) and the star light index (SLI). Any other relevant color indicators may be included in further versions. The minimum light level detected is of the order of 0.01 lux (in the hight sensitivity mode). It is optimized to detect light at night for relatively bright environments. LAN^3 comprise a real time clock, a remote RF control, a micro-SD card to store the data, a GPS, and humidity/temperature sensors. LAN^3 can be operated in automatic sampling mode or in manual sampling mode.

CoSQM, a color hack to the SQM-LE for light at night sensing, is a cylinder shaped instrument composed of a filter wheel with five different spectral bands in the visible range (clear, red, blue, green and yellow). The light sensor being the standard SQM-LE, it allows a backward compatibility with historical measurements made with Sky Quality Meters. The device comprise a raspberry pi computer, a real time clock, a color camera, and a GPS module. The instrument can be operated remotely via the ssh protocol and the data may be accessed via an integrated web server.

ALAN Veneto network: statistical analysis of NSB measurements and correlation with environmental and meteorological data

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Abstract

The developing of a monitoring network for artificial light at night (ALAN) in the Veneto region, coordinated by the Regional Environmental Protection Agency (ARPAV), and based on SQM sensors located in urban, rural and mountain areas, has enabled recording and analyzing a large amount of data, useful to understand the factors that influence the brightness of the night sky and the trend of light pollution in the region.

We present the results of some elaborations from night sky brightness data, like statistics for a set of stations, histograms, annual and cumulative plots and, in particular, correlations of NSB with meteorological parameters and atmospheric pollutants (for example PM10), with the aim to identify the factors that governs the variability of the NSB, especially in urban stations with significant environmental and light pollution.

Protocol for absolute radiometric calibration of night sky brightness meters (TESS and SQM)

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Abstract

We describe in this communication the steps required for performing an absolute radiometric calibration of the readings provided by commonly used night sky brightness meters, with particular application to the TESS and SQM detectors. By absolute radiometric calibration we mean the precise determination of the constant G relating the output frequency ν (in Hz) of the semiconductor light sensor (e.g. the TSL237) to the actual 'outside-world' band-weighted radiance L_{ow} incident on the detector (in W m^{-2} sr^{-1}). In this way the absolute band-weighted radiance can be determined as $L_{ow} = G(\nu - \nu_D)$, where ν_D is the dark frequency, being

$$L_{ow} = \int T(\lambda) \left| \int P(\omega) L_\lambda(\omega) d^2\omega \right| d\lambda,$$

where $T(\lambda)$ is the normalized spectral sensitivity of the device (i.e., the measurement band), $P(\omega)$ is the weighting function describing the detector field of view and $L_\lambda(\omega)$ is the spectral radiance incident on the detector from each direction ω.

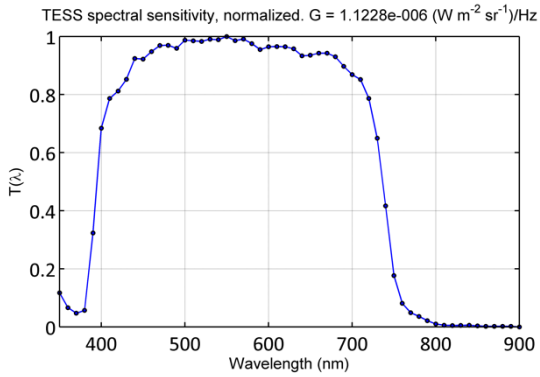

Fig 1. Normalized spectral sensitivity band of a TESS device, with absolute calibration constant G.

This calibration procedure allows, by determining the corresponding zero point (ZP_{AB}), to express the measurements in a rigorous AB astronomical magnitude system with precise physical meaning, as:

$$m\left[mag_{AB}/arcsec^2\right] = ZP_{AB} - 2.5log_{10}(\nu[Hz] - \nu_D[Hz]).$$

Sky brightness empirical cartography: the Andalusian QSkyMap

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Abstract

The empirical approach to the cartography of sky brightness is based on the combination of measurements taken on the ground, on the one hand, with night-time satellite imagery on the other hand, to link the contaminant sources with their effect through numerical fits. The regional government of Andalusia has undertook an effort to diagnose the current status of the night skies all over its territory (comparable in size and population to that of Portugal, and including many natural protected areas) and this strategy included the generation of QskyMap, a cartographic product that represents zenith sky brightness in the SQM photometric system. We describe the raw observational and satellite material, the process to build the map, and its main features (including advantages and drawbacks). We also summarise several results deduced from the exploitation of QskyMap through geographical information systems. Finally, the map is compared to other similar products, and we discuss the prospects for the future development of this empirical procedure applied to the Andalusian skies, including considerations on possible multi-band future extensions that may significantly contribute to diagnosing the impact of the current blue-shift tendency in outdoor lighting.

The evolution of the Night Sky Brightness in Madrid: a statistical study

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Abstract

The objective of this research is to investigate the evolution of the light pollution of Madrid using monitoring data of the brightness and color of the night sky.

We are gathering data since 2010 from the astronomical observatory of the Universidad Complutense located inside Madrid. Several instruments have been monitoring the astronomical quality of the nocturnal sky every night. Sky brightness at zenith is measured with SQM and TESS-W photometers using panchromatic bands while the All Sky Transmission Monitor camera (ASTMON) records images in Johnson B, V and R astronomical bands. The SAND spectrometer monitors the night-sky spectra. SAND spectrometer provides detailed spectral information of the new lamps, while ASTMON provides information about the evolution of the colour of the skyglow caused by such lamps which leads to an impact on the sky brightness.

We are applying nonparametric statistics to investigate night sky brightness and sky color evolution with these large and complete datasets. We hope that the tools developed during this study could be used to explain the possible trends of the temporal time series and its associated variability in other polluted places with available monitoring data.

A portable multi-wavelength optical analyzer for in-situ aerosol characterization

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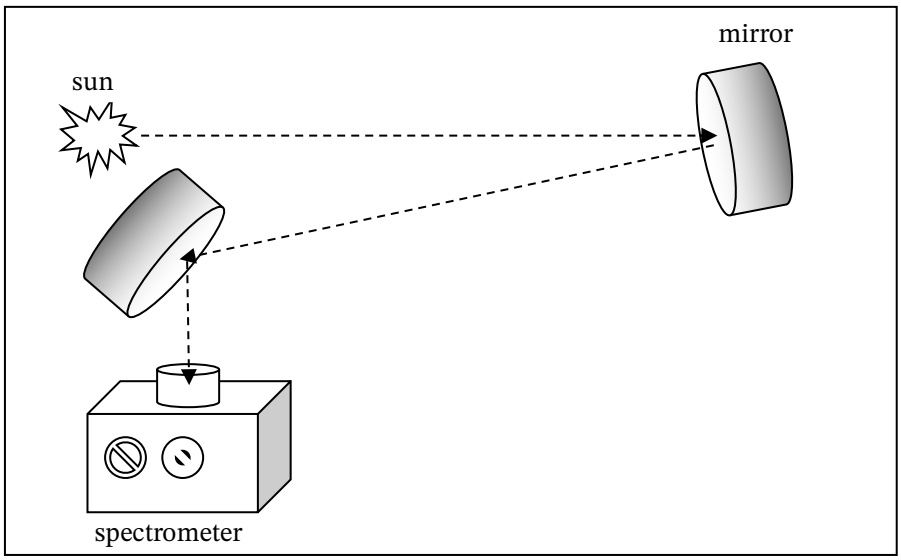
Abstract

Scattering by aerosols and molecules cause a certain fraction of artificial light emitted upwards to be received at the ground in a form of night-sky radiance. Of all atmospheric constituents the aerosols are most important modulators of the optical parameters of light signals, especially at long distances from the source of light. We show that scattering properties of aerosols can be obtained under clear-sky conditions, when the atmosphere remains stable for a few days. The night-time observations can be complemented by daytime radiometry using solar spectrophotometer providing supplementary information about aerosols (such as aerosol optical depth as a function of wavelength). The size distribution, mean refractive index, and/or size-dependent aspect ratio of aerosol particles can be obtained by inversion of optical data collected during daytime. Note, that aspect ratio relates the largest and smallest size of aerosol particles and is intended to substitute for a wide spectrum of particle sizes that can be realized in nature. Basically, it is impossible to describe geometries of all particles in the system, thus the aspect ratio is generally accepted as a desired tool to characterize prevailing morphologies. Using auxiliary data (like filtering, chemical analysis, size analysis) available from other sources and/or instruments, we can characterize the properties of ambient aerosols at the measuring station in more detail. By combining both daytime and night-time radiometry we can achieve much higher specificity in sky-glow characterization than ever before.

We have developed a new portable multi-wavelength optical analyzer for in-situ aerosol characterization that operates Ocean Optics spectrometer. The equipment provides the radiance data from 350 nm to 1000 nm with spectral resolution of 2 nm. Due to high sun radiance levels we use a system of mirrors each reducing the signal to about 4%, while keeping the integration time very short. The minimum integration time of 3 milliseconds allows for detection of direct sunlight.



Sky brightness in the visual and near infrared range

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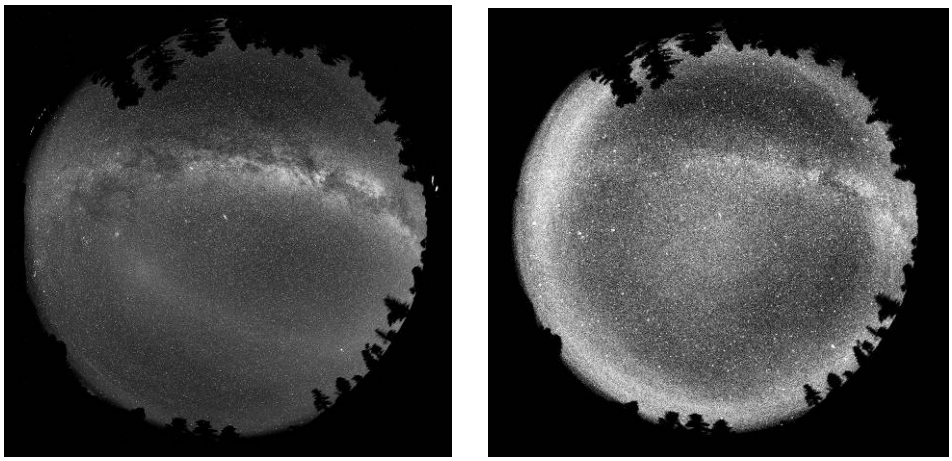
Abstract

Sky brightness measurements seem to vary considerably with humidity and thin clouds – at least in Central Europe. Especially near infrared (nir) observations are strongly influenced by water vapor in the atmosphere through the OH Meinel bands. At very dark places furtheron the airglow influences the sky brightness. We try to get nir data (770 – 1000 nm, peak at 820 nm, modified Canon 700D + Wratten WR87 filter) parallel to observations in the visual band. The instrumentation and first results in some very dark places (Germany, Switzerland, Zselic, US parks) will be discussed.



Images taken in Bryce Canyon National Park, left V Band, right nir band 770 – 1000 nm

Wuxi Night Sky Brightness Monitoring Network Construction Report

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Abstract

The rapid development of cities has brought tremendous pressure to astronomical observation, energy security, ecosystem and so on. The automatic monitoring of night sky brightness changes can help us to understand the regional differences and time variations of night sky brightness effectively and to analyze the human and natural factors leading to the changes of night sky brightness. This paper takes the construction of Wuxi city night sky monitoring network as an example, introduces the equipment and construction points of the automatic monitoring station, and analyses the data obtained from the station.

Calibration of the MINLU photometric and spectrometric instruments

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Abstract

Satellite and aerial observations of the upward light emission present some limits in terms of horizontal spatial resolution, detection of emission directions and information on the wavelength distribution of the spread light. Drones and air balloons can allow to overcome these limits. They fly at lower altitude therefore a good spatial resolution can be obtained also when wide angle lens are used. These optics frame light sources out of their optical axis considering their emission at angles far from the zenith, the most harmful emissions in the production of artificial sky glow. Spectral measurements of the upward light require longer times the higher the desired wavelength resolution. Drones can be used to scan relatively wide area at slow speed, therefore they allow to collect detailed information on the light spectra. The measuring system MINLU [1] was designed to be carried by either drones or air balloons, it aims at measuring the situation of the upward light emission and identifying important light sources emitting towards the sky in Italian Veneto Region. It is an autonomous imaging system directly commanded by an independent central data management unit. The instruments include three cameras and a spectrometer; telemetry is also present. A photopic filter is placed in front of the lens of the first camera. This filter provides a good approximation of the spectral sensitivity of the human eye and converts a monochromatic camera into a multi-luminance meter. A diffracting grid (300 groves/mm) is paced in front of the lens of the second monochromatic camera. The assembly becomes a raw multi-spectrometer with a wavelength resolution of about 2 nm. It is enough to identify the different lamp technology used in street lighting. The third camera has an RGB color sensor with the purpose of documentation. The instruments consider rays away from the nadir direction up to more than 40°. One shot of the cameras covers a surface 360m×240m with a spatial resolution about tenths of meter. A calibration in terms of SI units was carried on for both monochromatic cameras. The linearity error was evaluated too. The calibration was obtained exposing the instruments to the output of a luminance reference source provided with an integrating sphere and a halogen lamp, able to approximate with good accuracy the Illuminant A. The spectrometer made by the camera and the diffracting grid is calibrated in terms of power spectral density by comparison with a laboratory spot spectroradiometer. The performances of the instruments are evaluated analyzing the light from sources commonly used in street lighting, too. During the calibration the cameras are also placed on the MINLU structure to allow a better identification of the correspondence between framed light sources and the respective spectra, when the system operates on the field. To confirm the results of the calibration, the MINLU system is compared with imaging devices like calibrated DSLR, the measures are collected both in laboratory controlled conditions and in outdoor situations.

[1] Fiorentin, P., Bettanini, C., Lorenzini, E., Aboudan, A., Colombatti, G., Ortolani, S., & Bertolo, A. (2018, June). MINLU: An Instrumental Suite for Monitoring Light Pollution from Drones or Airballoons. In 2018 5th IEEE International Workshop on Metrology for AeroSpace (MetroAeroSpace) (pp. 274-278). IEEE.

The design of the wireless network device measuring light pollution

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Abstract

Light pollution is an important global problem that can be measured using a variety of devices. Instrumental measurements of the brightness of the night sky have been used for a short time. For several years this topic has been approaching an increasing number of scientists from various disciplines. The main objective of the project is the construction of a low-cost photometer measuring the intensity of light at night, which will be able to work in the wireless network. The monitoring device will be a self-acting system with a light sensor and wireless communication. This device will be measure low light intensity, corresponding to the emission of artificial light at night. The device is supposed to work automatically, processing the received signal to a known unit of light intensity and recording the result in its memory. By calibrating the device it will be possible to implement repeat observational series and it will be possible to compare results from around the world. It will also be possible to include measurements in the global monitoring network of this phenomenon. The constructed device will be the basis for measurement and monitoring of light pollution in the night sky in Toruń in a specially designed fixed measuring network.

About the long-term stability of the SQM-L and variations of the sky quality on the island of Gozo (Malta)

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Abstract

The sky brightness has been continuously measured on the Mediterranean island of Gozo (Malta) since the end of August 2014 using two SQM-LU-DLs. The project aimed to monitor variations of the sky quality due to varying meteorological conditions and to determine how the sky quality develops in time. The latter objective of particular interest, since nearly all of the island's street lights and other public lighting fixtures have been exchanged from SON to LED lamps with a correlated color temperature of approx. 5000 K. Through several intercomparison exercises and though handheld measurements, which were done in parallel and over the years, it could be established that the SQM-Ls demonstrate a relative stable long-term stability, suitable to analyze trends of the sky quality as such, assuming that the spectral characteristic of the night sky remains unchanged. Results on the variation of the sky brightness under clear and moonless conditions, as well as the impact of dimming by the newly install LED streetlights will also be discussed.

Stars4All photometer network; online tools to monitor and analyze worldwide the sky brightness

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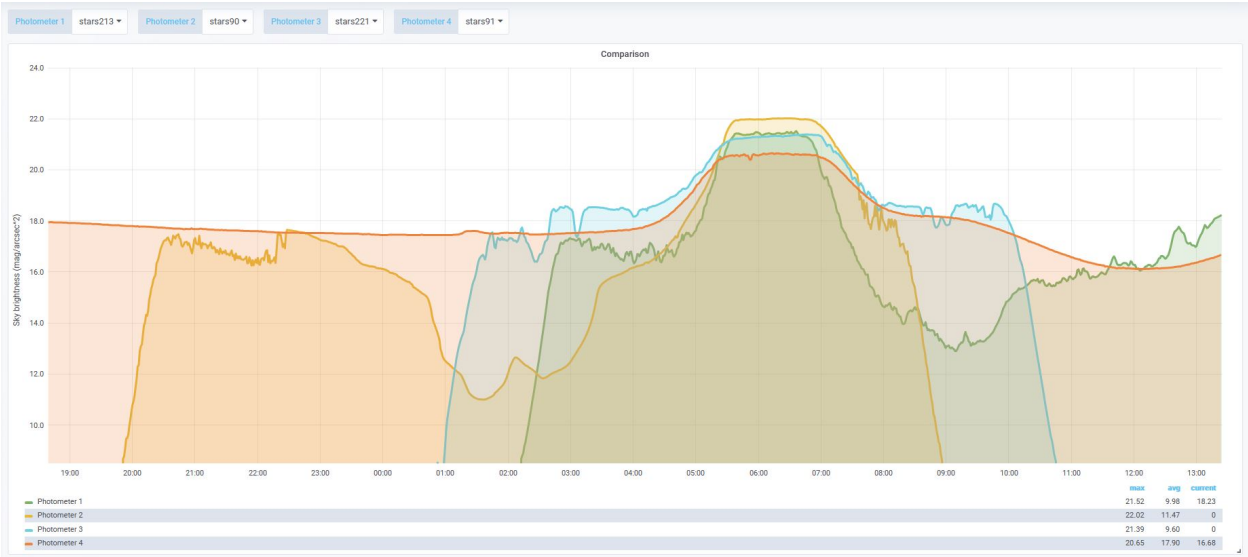
Abstract

In 2017, in Stars4All project we started to develop a low-cost photometer to measure the night sky brightness. This photometer uses the protocol of Internet of Things (IoT). To monitor the growing worldwide photometer network, we developed an online platform using Grafana services. This platform allows to see the latest graphs of any photometer, check the records for a personalized timespan, made comparisons and basic statistical analysis with just one click and from any platform connected to Internet.

On this research we present the powerful of Grafana for any photometer network connected to Internet. And some interesting results we found with the help of this analytical tool comparing photometers from very different places, from low to high latitudes, dark and bright places, and the changes along the night.



Comparison using the online tool for 4 photometers from Stars4All network during the moon eclipse of January 21th. Green: stars213, Ensenada, Mexico; orange: stars90, La Palma, Spain; blue: stars221, San Juan, Argentina; red, stars91, Svalbard, Norway.

Skyglow changes in Mexico City resulting from a LED lighting system conversion

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Abstract

Estimations presented by the United Nations for 2019 place 80.3% of the population within urban areas. This growth will demand new ways of facing the challenges that each city presents. In particular; information related to the state of the environment and urban configurations will be key to understand the urban phenomena and adequately address the requirements of highly populated spaces. Currently, a great number of Mexican cities have been established an action plan in the municipality with the aim of meeting the needs of night lighting and promote energy saving in public lighting installations through a massive change of technology (white LEDs). However, the environmental consequences of changing the current lighting system are unknown. In this work, we theoretically analyze the possible outcomes that a massive LED lighting system conversion will have in the skyglow produced by Mexico City. We hope the results can motivate urban developers to overcome with better decisions in this matter.

Light pollution colour changes at MHAONB, from distant town conversions to blue-rich LED lighting, implications for rural UK skies.

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Abstract

The sky in the Malvern Hills Area of Outstanding Natural Beauty (MHAONB) has been monitored continually since 2012. A dark sky survey of the area was carried out at that time commissioned by Malvern Hills conservators. Ever since then at Mathon observatory, the sky brightness has been measured continually, in the last few years at two minute intervals in all weathers. On the darkest of nights a fisheye lens camera was used at the same intervals, for several years now with views to the horizon in all directions. Despite changes of cameras over the period, each with different colour balances, there is still a clear trend in colour changes on the sky, especially towards the horizon, with more individual bright sky domes. The SQM photometry data near zenith does not show any great change, but the SQM is not sensitive to such colour changes.

In 2015, Malvern Hills Conservators asked the author to do modelling of the effect on the MHAONB sky, of the ongoing blue rich LED re-lighting throughout Herefordshire. A description of this is in a proceedings paper of LPTMM 2017. The SQM photometry shows the sky brightness are very weather dependent, a monitoring station at Clanfield observatory, of the Hampshire Astronomical group, showed similar results. Colour changes from orange-pink where not converted, to blue-grey, where converted to blue-rich LEDs; are also very weather dependent, especially in conditions of cloud or mist on the horizon, where high CCT LED lighting predominates over greater distances.

This images and discussion here concern the colour changes from the relighting to LEDs in Herefordshire and the Severn Vale, together with most towns and cities in the surrounding areas and beyond the horizon. The results equally apply to the whole of rural UK.

For the MHAONB, the Milky Way is only at 20% contrast to background at zenith on the darkest nights (21.1- 21.2 Mag.arcsec^{-2}). Typical of dark location rural UK skies.

Doubling the average road lighting levels by increasing uniformity, as considered by the European lighting industry, would render the Milky Way invisible over most of the rural Continent and UK. Reducing the commonly used high correlated colour temperatures to about 3000° Kelvin, would make a significant reduction in the sky brightness away from zenith.

The introduction of blue rich colour, Correlated Colour Temperature (CCT) 6000K road lighting could increase skyglow significantly compared with lower CCT (3000K) temperature types, if the blue content reaches the sky. Atmospheric molecular Rayleigh scattering in deep blue is 16 times greater than red. The highly directional properties of LEDs, if fully utilised in luminaire designs, could minimise this, and even result in less light pollution to the sky.

Modelling was then done on request by the Malvern Hills Area of Outstanding Natural Beauty (AONB) authority, for the nighttime environmental impact of the Herefordshire county LED rollout replacement of low pressure sodium programme throught Herfordshire. When this was done with the specific manufacturer's LED photometric data, a reduction in sky glow was predicted, contrary to general expectation. This was due to the very sharp cutoff designs. Tarmac roads, grass and other vegetation reflect and scatter little blue light to the sky.

A Dark Sky Survey for the Malvern Hills AONB in 2012 formed a base reference. It is entirely rural but bordered by hills and towns. For each year since, regular dark night sequential zenith sky brightness monitoring has been carried out using a networked calibrated Unihedron Sky Quality Meter (SQM). There are no luminaires visible from the observatory to any horizon. Samples were compared with photometric all sky camera images, after vignetting correction. This covers the period before, during and since the rollout programme (2014-15). From 2015 the samples have been taken at 2 minute intervals continuously on many nights over all seasons. In 2016-17 this has been extended to all noted weather conditions which can be used for filtering the analysis. All night time plots proved useful.

The analysis used histograms of the photometric data at each incremental brightness binning level, clear and part cloudy nights show to have longer darkest periods than previously by >15%. This depends on cloud and visibility conditions near the horizon, which can obscure sources. The criterion was the brightness of the Milky Way and background, which was measured; the fixed SQM is now tilted slightly North to avoid it ever entering the field of view. Darkest periods near Zenith after the luminaire changeover, reach 21.2 magnitudes per square arcsecond.

The angular distribution across the sky follows the changes in luminaire replacements; the colour shift can also be seen from the images.

It would require National adoption for the reduction to be very significant. The zenith brightness is still set by distant cities, while towards the horizon, commercial and private uncontrolled non-directional LED lighting now dominates, negating the improvements in road lighting.

Illumina: New model features, capabilities, and future developments

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Abstract

The propagation of artificial light into real environments is a complex phenomenon involving many physical processes. For an accurate modeling, the spectral properties of the lighting devices as a function of their geographic positions, the spectral properties of the underlying ground reflectance, the size and distribution of small scale obstacles, the masking effect of topography, the lamps angular photometry and the atmospheric transfer function have to be taken into account. For the later, aerosol distribution, composition and size are of major importance because of the high variability with time and position (both horizontally and vertically). It is therefore difficult to understand intuitively what would happen to the sky brightness under changes in the lighting infrastructure or in the environment characteristics. One good way to overcome this difficulty is to use a detailed radiative transfer numerical model. Numerical modeling allows setting some parameters while changing others and hence estimates the related changes in sky brightness.

In this paper, we will show how the Illumina model (Aubé, 2005, 2007, 2015, Aubé & Simoneau 2018) can be beneficial to increase the darkening/investment ratio of a given lighting conversion plan. We will then describe the recently implemented features along with what features are expected to be incorporated in a near future. We will finally suggest the use of Illumina as a benchmark platform to develop or optimize simpler and faster light pollution models.

Testing a cloudless model of light pollution propagation on two dark sky regions in Portugal

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Abstract

Light pollution (LP) affects Mainland Portugal in accordance to its asymmetric demographic distribution. The strongest LP sources are distributed along the densely populated coastal line, whereas the interior north and south of the country is still generally well preserved due to a much lower demographic density. In the period 2010-2015, on selected moonless and cloudless nights, we assessed the skyglow of two dark sky regions with a portable SQM-L unit pointed handheld to the zenith during. One of the regions is the Peneda-Gerês National Park (PNPG), gradually more affected by the close northern coastal line. The other region is the current Starlight Tourist Destination Dark Sky Alqueva Reserve (DSA). The measurements taken during the campaigns were used to the certification of the DSA. To predict the sky brightness at the zenith on both regions, we implemented a light-pollution model for cloudy and cloudless night skies with ground-based light sources (Kocifaj, 2007), using VIIRS DNB cloud free composites (provided by the team of Jaime Zamorano, Dept. de Astrofísica y CC. de la Atmósfera, Fac. de Ciencias Físicas, Universidade Complutense, Madrid, Spain) as input source for the upward visible and infrared radiance. The predictions from the model compare favourably to the data taken in the terrain during our campaigns. We also show the differences between comparing the whole data from the period of the campaigns to the predictions of the model and comparing the data on a day by day analysis. A comparison with the data from the recent New World Atlas of the Brightness of the Night Sky (Falchi et al, 2016) will be also presented.

"The Things We Have Always Known": Design and Evaluation of Dark-Sky Friendly Lighting

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Abstract

The concomitant issues of artificial light at night (ALAN) and light pollution are a global challenge whose effects run along multiple axes, from ecological harm to human health detriments to the inability to view and appreciate the natural night sky. These negative externalities stand opposite legitimate human needs for ALAN that touch on public safety, rural economic development, nighttime placemaking, and other purposes. Motives for lighting are further dependent on geography and development status, complicating the analysis of both why and how we light. Lighting engineering can contribute to solving problems associated with light pollution by developing and promoting designs for products and installations that maximize the social benefits of outdoor lighting while reducing overall artificial light emissions to the greatest practical extent. I will review the philosophy of lighting design as regards concern for the nighttime environment, examining a number of common applications such as streets and areas, outdoor sports and recreation, churches and public monuments, and ecologically sensitive sites. The scope of this review naturally extends beyond outdoor lighting products themselves, encompassing both control equipment as well as public policies that regulate the installation and operation of lighting systems. Finally, I will give special consideration to the current industry-standard evaluation regime, which emphasizes experience and consensus over evidence and empiricism, as perhaps the greatest obstacle to advancing the best possible lighting designs.

NITELite: Balloon-borne Observations of Nighttime Lighting

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Abstract

Modern inventories of the large-scale night time lightscape are typically based on remote sensing from satellites or airplanes. Both suffer from a variety of issues, including cost and an inability to measure real-time variations. Here we describe NITELite, a high-altitude balloon-borne night time imaging system. Although conceived as a precursor to NITESat, a future satellite night-time imager, NITELite has many attractive capabilities of its own: very low cost, repeatability, high resolution, high cadence, three color photometry and the ability to image large regions within a single mission. NITELite will provide many unique opportunities. Among these are the ability to conduct real time variation experiments, characterization of moving and variable sources, and an exploration of the angular dependence of light sources on an individual and statistical basis. We also discuss GONet, a companion (but standalone) system of extremely cheap (~$100) automated all sky imagers. GONet is intended to be deployed in bulk across a region to give a detailed picture of the sky illumination and ground fluxes as a function of position during a NITELite flight. It will provide ideal data for calibration of light propagation and scattering models as well its utility for ecological studies. In addition, we will discuss results from recent NITELite missions.

Brightness of Signs and Billboards – from measurements to recommendations

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Abstract

Illuminated signs and especially billboards are significant contributors to overall light pollution. LED display screens are every year more affordable and outdoor advertising is going in direction of video advertising. This is not just environmental problem but very often a big threat of safety on roads. Video LED screens are often in areas where they disturb not just sleep of people but even normal life in living rooms. We will present a new technique which could asses brightness and separate colors of signs and billboards. Color of images and their histograms will be analyzed, and we will try to give recommendations of size, color, uniformity, brightness changes and brightness limits for urban and rural areas. Real cases from several countries will be presented where wide range of brightness from 1 cd/m^2 to more than 2000 cd/m^2 are becoming normal parts of modern life.

Spectral measurements in the Living Environmental Laboratory for Lighting

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Abstract

The public lighting in the Living Environmental Laboratory for Lighting (LELL — see K.P. Tong et al. presentation) sites makes it possible to change the spectral content of the emitted light. The luminaires consist of warm white (CCT ~3000K) and amber (~1900K) LEDs. During the timeline of the project, it is possible to set different mixtures of the LEDs at different periods of the night. Then it is possible to make differential measurements of the sky radiance and spectral content.

Sky quality measurements by digital cameras have become a routine procedure in protected areas; however, these observations lack the wavelength dependence of sky radiance. We have started a spectral sky quality survey in the principal LELL and the Zselic Starry Sky Park. Our mobile laboratory consists of a Konica-Minolta CS–2000A spectroradiometer and a digital-camera-based measurement system. Our initial tests show that the spectroradiometer can measure spectral radiance within 4 minutes with a low noise level and high accuracy even at pristine sky conditions. The digital-camera-based system calibrated by the spectroradiometer further enables measurements at remote locations.

The differential spectral measurements make it possible to separate the sky glow originated at the site of the LELL from all the other sources (both natural and anthropogenic). It gives an excellent opportunity to test radiation transfer models and to estimate the environmental effects of a single settlement.

Examples of how the spectral radiance distribution varies as a function of the location on the sky will be given in the presentation. The spectral radiance distribution is decomposed by templates based on the measurements of the given area, which allows mapping of the whole hemisphere. We will also discuss how the standard observations are affected by the different spectral sensitivities of the devices.

Another potential use of the measurements is the variation of the spectral radiance as a function of the distance from the source, for example, major cities or towns, or industrial areas with a high emission of artificial light. The relative brightness of the sky at the different wavelength ranges depends on the spectral extinction coefficient of the atmosphere. Thus, the measurements provide information also on the aerosol content of the air and other essential properties. These data provide substantial input data for radiative transfer modelling.

Acknowledgements

The project is supported by the European Union and co-financed by the European Social Fund (Grant no. EFOP-3.6.2-16-201-00014; Development of international research environment for light pollution studies).

Categorisation and quantification of the sources of artificial light at night from Ireland

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Abstract

We will present results of ground- and space-based monitoring of the light output from Ireland aimed at diagnosing the nature, and quantifying the amount of, artificial light to provide data to support local and national actions to reduce light and energy use. Our work takes a number of different, although complementary, directions and we have now achieved "critical mass" in terms of the data and skills necessary to quantify and utilise our results. In our presentation we will outline three strands of our work:

Ground-based light output budgets: Using a combination of calibrated ground-based luminance and illuminance meters we will present updated data for the total energy loss from Dublin city to arrive at an improved figure in terms of energy, CO_2 and cost. Using data obtained at our city centre university over the past five years we will also comment on the growth of light pollution as monitored using SQM data-logging meters, including colour filter observations designed to track the growth in white light use, and to complement VIIRS DNB satellite observations.

Monochromatic satellite imagery: We will also present our initial analysis of 18 images covering the majority of the island of Ireland obtained at a resolution of 129m per pixel during a single overpass by the Chinese LuoJia 1A satellite on the night of 1st November 2018. Comparison of the images with known ground sources has enabled us to correct for the offsets of each image from the nominal orientation. Additionally, because of the overlap between individual images during the overpass we have multiple observations for the same source made with differing slant angles. For a suitable range of targets (e.g. heavily built-up to open environments) these data enable us to determine the effect of differing viewpoints on the observed intensity which is of relevance to other studies, including those involving VIIRS.

Colour ISS imagery: Using a high-resolution International Space Station colour image calibrated by Alejandro Sanchez de Miguel, we have determined the proportion of light emitted from different categories of land use within a 230 km^2 region encompassing Dublin City. Using databases of landuse information together with council lighting databases, we have corrected the emission for streetlights and find that discontinuous urban fabric (basically residential buildings outside of the city centre) accounts for more than half of the total light, followed by industrial and commercial areas in the suburbs (23%), with the continuous urban fabric of the inner city accounting for a further 17%.

We have also performed a study using OpenStreetMap data which allows us to identify individual structures and buildings. We find the light output from identified industrial, commercial and retail developments to be 9%, 7%, and 3% of the total light, respectively, with the difference from the landuse data being due to incompleteness of the OSM data. Four identifiable large public buildings alone count for nearly one percent of the city light or, equivalently, one quarter that of the total light produced by the seaport, and many times more than the Dublin Airport.

Funding for this work is provided by SEAI Research Grant Project Award 15564

Monitoring Light Pollution with the STARS4ALL TESS photometers

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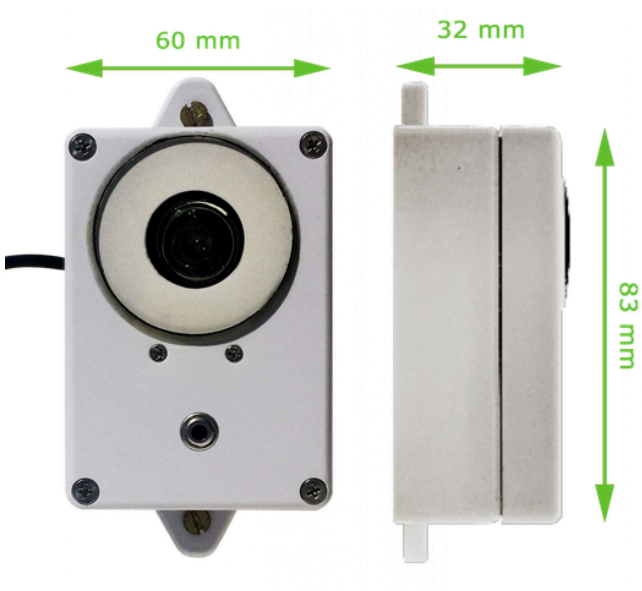
Abstract

The TESS-W photometer is a scientific instrument to monitor night sky brightness that has been developed within the STARS4ALL H2020 European project. Our aim was to provide an easy to use and low-cost photometer for citizen science. TESS-W design is open source (hardware, and software) and was developed to facilitate data sharing via WIFI using Internet of Things protocols without the need of a computer. The open data can be accessed as data files using the IDA standard format or can be browsed using plotting tools in real time. The initial goal was to build a European network of sky brightness sensors but the first units have been distributed along the whole globe under skies with very different light pollution conditions. The first photometers have been working and sending data for three years. There are more than 100 photometers sending data.

We describe the capabilities of the TESS-W and some new developments of the photometers including the hand-held device (TESS-P) that can be connected to a smartphone, and the mount for automatic all-sky maps (TESS Auto Scan).



Nocturnal evolution of night sky brightness

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Abstract

Studying NSB variability during the night is important to understand how to act in better way to limit light pollution: these studies are usually performed by examining the sky brightness integrated in a solid angle around the zenith, with Sky Quality Meter instrumentation.

With the aim to better understand the different contributions of light pollution sources, in particular in the anthropized area, for an urban station belonging to Veneto network we have combined the SQM measurements with the photometric study in two dimensions of the night sky, carried out by processing of images taken at regular intervals with a calibrated reflex camera.

In this work we will study the trends of brightness in some nights and the correlations with the main sources of light pollution (streets, residential, vehicular, monumental lighting), also considering the meteorological and atmospheric variables.

Quantifying circalunar periodicity, long-term trends and seasonal variations in the night sky brightness based on the Austrian SQM network

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Abstract

Based on the paper by Posch, Binder & Puschnig (JQSRT 211, 144), we extend the study of the night sky brightness (henceforth: NSB) at 26 locations in Eastern Austria in time and complement it by a new method to quantify the amplitude of the circalunar periodicity.

Using a novel weighting technique for SQM measurements, we evaluate the long-term development of the night sky brightness between 2012-18 for one of our sites, the Vienna University Observatory. Additionally, we present new spectra of Vienna's skyglow, obtained with a 0.8m reflector, and compare them to the spectra obtained five years earlier (i.e. after versus before the installation of thousands of LEDs in the city).

The large dynamical range of NSB levels found at our 26 SQM stations further allows us to study and quantify the impact of light pollution on the amplitude of the circalunar periodicity. We present first results from our Fast Fourier Transform based approach.

For two selected regions where the measured NSB values are close to those expected for unpolluted skies [Losenstein - Hohe Dirn, Feuerkogel - NP Attersee-Traunsee], we compare the results of our SQM measurements to those obtained with a calibrated all-sky-camera and discuss the implications for two planned Dark Sky Parks.

We show suitable ways to plot and analyze huge long-term NSB datasets, such as mean-NSB histograms, circalunar, annual ('hourglass') and cumulative ('jellyfish') plots. Based on the 'hourglass' plots, we find a strong circalunar periodicity of the NSB in small towns and villages (< 5.000 inhabitants), with amplitudes of up to 5 magnitudes. Using the 'jellyfish' plots, on the other hand, we demonstrate that the examined city skies brighten by up to 3 magnitudes under cloudy conditions, which strongly dominate in those cumulative data representations. Nocturnal gradients of the NSB of 0.0-0.14 $mag_{SQM}/arcsec^2/h$ are found.

A Large-Scale Municipal Street Lighting Dimming Experiment

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Abstract

Anthropogenic skyglow dominates views of the natural night sky in most urban settings, and the associated emission of artificial light at night (ALAN) into the environment of cities involves a number of known and suspected negative externalities. Various means of reducing the impact of ALAN must be weighed in terms of costs and benefits against the lighting preferences of residents of places in which reductions are proposed. One approach to lowering consumption of ALAN in cities that may be possible to achieve politically is dimming or extinguishing publicly owned outdoor lighting during overnight hours; however, to date, there are few reports in the literature about the efficacy of these programs. Here we report the results of one of the largest municipal lighting dimming experiments to date, involving approximately 20,000 roadway lights owned and operated by the City of Tucson, Arizona, U.S., conducted on the nights of UT 12 and 13 September 2018. We analyzed both single-channel and spatially resolved ground-based measurements of broadband night sky luminance obtained before and during the tests, as well as upward radiances in the optical Day/Night Band (DNB) of the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument aboard the *Suomi* National Polar-Orbiting Partnership spacecraft. On both nights of the test, the signal associated with the dimming was clearly detected from the ground. At five measurement stations distributed throughout the city, we recorded broadband luminance changes at the zenith during the first test night of -46 to -363 mcd m^{-2} (-4.3% to -9.3% departures from the pre-dimming condition). Consistent with expectations, the magnitudes of the measured changes depended on the radial distance of the stations from the city center. Less definitive results were obtained from an analysis the orbital satellite data. We discuss the outcomes of the test in the context of both engineering challenges and policy interventions to reduce skyglow over cities and electrical power consumption through selective dimming of municipally owned lighting installations.

Evaluation of Night-time light images from Luojia-1 Satellite

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Abstract

Launched in June 2018, Luojia-1 satellite acquires night-time light images at 130 m resolution, which is much higher than that of the Visible Infrared Imaging Radiometer Suite (VIIRS)'s Day and Night Band (DNB). At first, the basic features, including sensor and orbit characteristics, of Luojia-1 will be introduced. Consequently, the radiometric and spatial characteristics of Luojia-1 images were evaluated, by comparing them to VIIRS DNB images, in several global cities. The analysis shows images acquired by Luojia-1satellite are highly correlated to VIIRS DNB images, but they are brighter than VIIRS DNB images, probably resulted from later overpass time of Luojia-1 and wider range of wavelength than VIIRS DNB. In addition, Luojia-1 images are more capable to detect roads and road intersections, indicating that Luojia-1 images provide more spatial information than VIIRS DNB. Furthermore, the change detection capacity of Luojia-1 images was also evaluated. The analysis results show that two Luojia-1 images, acquired within two months, are capable to detect the new constructed roads and buildings. This study shows that the Luojia-1 images provide rich information of radiometric, spatial and temporal night-time light, suggesting that Luojia-1 images is a good data source for light pollution analysis at regional and global scales.

Assessment of outdoor lighting installations and their impact on light pollution using unmanned aircraft systems

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Abstract

Outdoor lighting installations are currently inspected and validated according to standards, guides and regulations with the use of ground-based measurements or measurements limited to the position of the typical observer. In most of the cases, lighting quantities are measured towards the ground or towards the relevant task area, depending on the type of the installation. The excess or spill light that is reflected or directly emitted towards the upper hemisphere, is in most of the cases not measured or it is not possible to be measured. Therefore, the limitation of the light pollution and the obtrusive lighting in general, is achieved using specialized lighting calculation software and by implementing several application guides. The lack of field measurements at the commissioning stage or during its lifetime of a lighting installation, increases the chances of over-illumination and light pollution. This is also strengthened by the unknown reflectance of the surfaces, the form or surroundings of the illuminated area, factors that usually are expected or assumed.

This paper presents the ongoing work of the lighting laboratory to develop a standardized method of measurement of several types of lighting installations using unmanned aircraft systems. The technology of unmanned aerial systems can incorporate multiple types of sensors and can be programmed to fly in predefined areas and routes in order to perform complex measurements with limited human intervention. This technology provides the freedom of measurements from several angular positions and altitudes in a fast, easy, accurate and repeatable way. The aim of the work is to assess the lighting installations, not only against the applicable lighting standards but to also investigate and reveal issues related to light pollution and obtrusive lighting in general. The latter, are issues that in most cases are neglected or due to the lack of standardized methods of calculation / measurements, are very hard to be defined during the design phase. This approach will provide a holistic evaluation of the installation even if the desired, by the requirements, illumination target is just an average illuminance or luminance of a single surface.

In the scope of this work, several test cases will be presented including the commissioning and assessment of a city's square, roads with conventional lighting system and LED lighting system, outdoor sport facilities, etc.

Spatio-temporal networks of light pollution

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Abstract

Light pollution is an environmental problem produced by an unjustified escalation of upward propagated artificial lighting in night environments as a direct consequence of urbanization and industrial installations. That aforementioned light pollution is provoked by inaccurately situated or designed artificial night lighting systems that degrade the nocturnal environment. Artificial lighting spreads through cities semi-randomly as a complex network. In an image, such network is represented by the intensity of each pixel.

The application of graph theory has been well documented to model and analyze different problems and systems in multiple fields of science and technology. The environment is not the exception. In this work we analyze satellite images that represent light pollution in a specific time frame. The analysis involves a systematic application of graph theory to the understanding of complex artificial lighting networks. The results indicate that graph theory is a good approach to determine aspects of light pollution that may be related to urban processes. Therefore, we hope this work will serve as a motivation for future research that links urban features with the increase of nocturnal radiation.

Color mapping of the night sky brightness over the Mont Bellevue natural reserve in Canada

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Abstract

In this paper we present a methodology to map the night sky brightness in 4 spectral bands on the territory of the Parc du Mont-Bellevue natural reserve (Sherbrooke, Canada). In the long term, we aim to estimate a part of the exposure of living organisms to the indirect urban light as a function of the colors scattered in the atmosphere overhanging the natural reserve. The reserve is located near the Sherbrooke city center inside the city perimeter. If repeated regularly, the mapping technique can become an influential tool to estimate the light pollution transformation as a function of the ongoing Sherbrooke's light fixture replacement program. In most cases, HPS are replaced by phosphor converted amber LED. Such transformation may shift the color composition of the sky, the major source for the artificial light propagating into the reserve. Our project is part of a new initiative aiming the creation of an "Urban Starry Sky Oasis", an urban public area where we hope to give back, to the citizens, an easy access to the Milky Way. We performed the mapping with the data acquired with the CoSQM, a new portable device which aims to sample the multispectral properties of the artificial light scattered by the atmosphere.

Study on Night Sky Brightness Change and Urbanization of Wuxi City

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Abstract

New town development, old city transformation, and new countryside construction are all important parts in the process of urban development. The use of night light remote sensing data can effectively monitor the urban development in a wide area of space, and the manually measured data can be used to investigate and study the urban development in a small area. This study provides a new perspective on the simultaneous use of two methods in urban development research.

A methodology for a light pollution network construction

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Abstract

The study of light pollution through network theory, allows us to identify, describe and predict in space and time, the consequences of executing public policies in association with land change and street lighting design. The framework provided by network theory helps to study the phenomena from the structural point of view at different scales: from municipal to international scale, including the metropolitan one. Since the study of light pollution is sometimes based on images taken by cameras installed in satellites, it is necessary to perform a quality data analysis and data processing with the aim of detecting, reducing and removing spatio-temporal image inconsistencies, such as spatial camera vibrations, and temporal atypical lighting values to avoid spurious network components. These undesirable effects are produced by the inherent characteristics of measurement equipment, such as random noise from variations of external optical processes, camera angle variations, atmospheric conditions and substitution of satellites. This paper attempts to develop a light pollution network identifying similar dynamic patterns among the lighting fluctuation of each geographical location of an area of interest. Our main objective is to use the satellite data straightforward to build the light pollution network and perform an accurate analysis of the phenomena.

The evolution of the zenithal night sky brightness at the stations of the Galician NSB Measurement Network (2015-2018)

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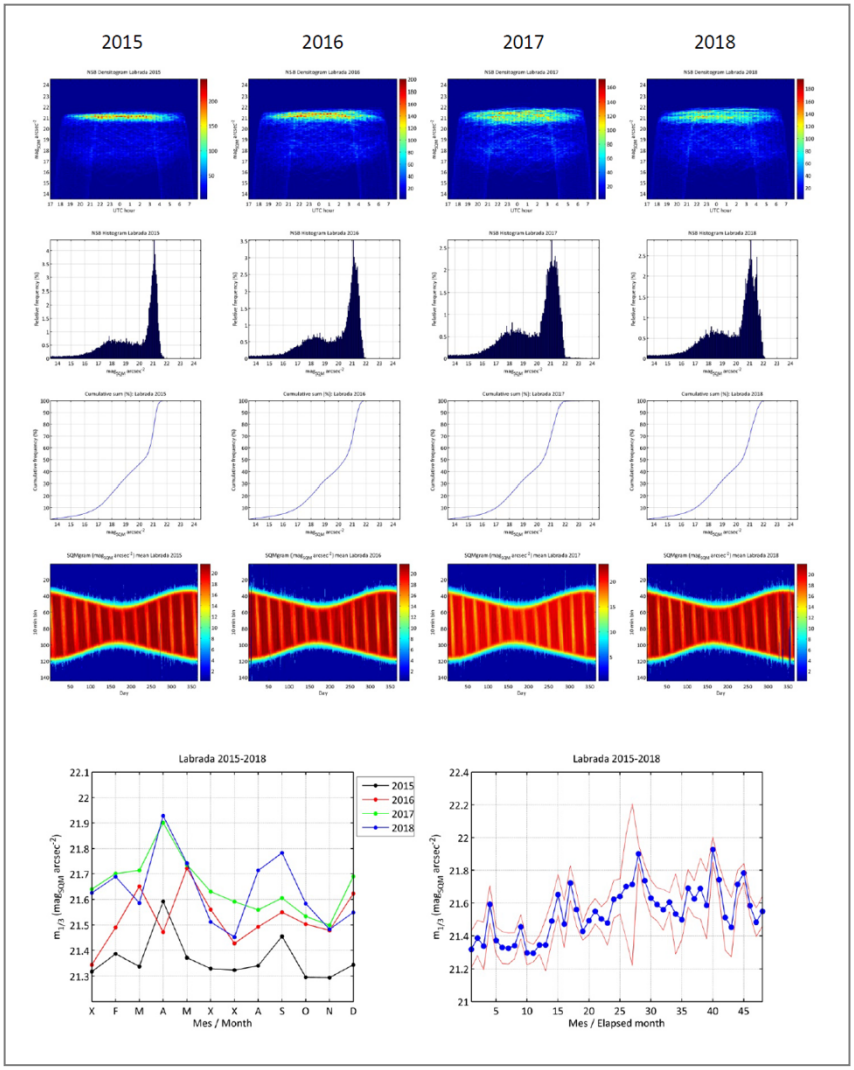
Abstract

The 2015-2018 evolution of the night sky brightness statistics (in the SQM-band) at the 14 stations of the Galician Night Sky Brightness Measurement Network (GNSBMN) is analyzed in this poster. Several statistical descriptors allow to estimate the current trends. The behavior of the recorded data is strongly dependent on local conditions.

The GNSBMN is jointly operated by MeteoGalicia, the public meteorological agency of the Galician government (Xunta de Galicia) and by the Light Pollution Lab of Universidade de Santiago de Compostela.



The IES Sky Glow Calculations Committee

Bruce Kinzey, Chair,[1] Ian Ashdown, Vice-Chair,[2] Robert D. Clear,[3] Dan Duriscoe,[4] Fabio Falchi,[5] Michael Grather,[6] Miroslav Kocifaj,[7] Lindsay Malbon,[8] Brad Schlesselman,[9] Richard Wainscoat,[10] and Constance Walker[11]

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Abstract

The preservation of dark skies in the face of continued growth in anthropomorphic use of electric lighting has been of mounting astronomical concern for decades. The recognized authority in North America for lighting standards and recommendations, the Illuminating Engineering Society (IES), has until recently mostly confined its efforts to addressing sky glow through luminaire classification systems that directly call out uplight (TM-15-11) and to promoting recommended best practices that help mitigate their sources (for example, the IES collaborated with the International Dark-Sky Association to produce the Model Lighting Ordinance in 2011.) In 2017, the IES established the Sky Glow Calculations Technical Committee (SGCC) to address this notable gap. The purpose of the SGCC is to develop and detail recommended procedures and tools for estimating quantifiable contributions to sky glow from individual lighting applications, thereby helping identify practical means of reducing sky glow for use by lighting designers, specifiers, owners and agencies responsible for outdoor lighting (e.g., municipalities). The scope of the SGCC includes not only street lighting but also other important applications that fall under IES purview, such as sports, landscape, and building architectural lighting.

The Committee's first expected product will be a Technical Memorandum (TM) to describe a "state of the current science." This first version will identify what is known about human-based sky glow and its causes and provide related guidance and recommendations, while recognizing other areas still under investigation. To benefit from international expertise in these areas, in addition to the USA the committee also includes members from Canada, Italy and Slovakia. The Committee welcomes the participants of the LPTMM conference to assist the SGCC in providing accurate information by keeping the Committee informed of their corresponding efforts in light pollution theory, modeling and measurement.

Spatial Analysis of Light Pollution Dynamics Around Bosscha, Timau, and ITERA Lampung Astronomical Observatories Based on VIIRS-DNB Satellite Images

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Abstract

Bosscha Observatory is the largest and oldest observatory in Indonesia that has been actively doing astronomical research since 1928. Bosscha Observatory was originally very suitable for observing astronomical objects because of its ideal night sky conditions and covered most of the northern and southern sky areas. However, starting at the end of 1980, the quality of the night sky at Bosscha Observatory has decreased along with the development of cities around the observatory. One of the main causes of the decreasing quality of the night sky at Bosscha Observatory is light pollution. Therefore, the construction of a new observatory in Indonesia is currently underway, i.e. the Timau National Observatory and ITERA Lampung Astronomical Observatory. The problem of light pollution around the Bosscha Observatory is a spatial problem, so to overcome it, it is necessary to analyze the dynamics of light pollution spatially, one of them is by using VIIRS-DNB satellite imagery and as a comparison, a similar study was carried out around the Timau National Observatory and ITERA Lampung Astronomical Observatory. Based on the analysis of the dynamics of light pollution in a radius of 20 km from Bosscha Observatory and ITERA Lampung Astronomical Observatory, and at a radius of 90 km from the Timau National Observatory in 2013-2017 using VIIRS-DNB satellite imagery, it is known that there is a change in light pollution area for the very low, low, medium, high, and very high categories. The average rate area of light pollution at a radius of 20 km from Bosscha Observatory for the category of very low, low, medium, high, and very high categories experienced a rate of -41.3 ± 135.2 km^2 / year, 5.9 ± 97.2 km^2 / year, 15.1 ± 14.6 km^2 / year, 18.0 ± 42.6 km^2 / year, and 2.1 ± 10.2 km^2 / year. The rate of increase in the extent of light pollution for the medium, high, and very high categories occurs south of the Bosscha Observatory, which is towards the city of Bandung. The average rate area of light pollution at a radius of 20 km from ITERA Lampung Astronomical Observatory for the category of very low, low, medium, high, and very high categories experienced a rate of -59.0 ± 73.1 km^2 / year, 55.5 ± 70.8 km^2 / year, 10.9 ± 22.4 km^2 / year, 8.5 ± 14.8 km^2 / year, and 0.0 ± 3.4 km^2 / year. The rate of increase in the extent of light pollution for the medium, high, and very high categories occurs northeast of the ITERA Lampung Astronomical Observatory, which is towards the city of Bandar Lampung. The average rate area of light pollution in a 90 km radius from the Timau National Observatory for the very low, low, medium, and high categories experienced a rate of 20.8 ± 43.4 km^2 / year, -22.1 ± 40.9 km^2 / year, 3.0 ± 7.3 km^2 / year, and -1.7 ± 7.3 km^2 / year. From these observatories, Timau National Observatory is still relatively ideal as a location for observing astronomical objects, but it is necessary to monitor the dynamics of light pollution in the direction of 207-215 degrees azimuth which leads to Kupang City.

Keywords: Light Pollution, VIIRS-DNB Satellite Imagery, Bosscha Observatory, Timau National Observatory, ITERA Lampung Astronomical Observatory

M2M: creating LP maps from dynamic SQM measurements

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Abstract

Here we present a user friendly software to ease and standardize the process of creating light pollution maps of large areas from SQM measurements. The methodology is based in the PhD Thesis of Ribas (2016).

Sky Quality Meter (SQM) photometers are largely known and used within the light pollution community to measure the night sky brightness of key locations. The popularity of this photometer, produced by the company Unihedron (Grimsby, ON, Canada), is mostly due to its relative low cost compared to similar instrumentation.

Currently it is used by several scientific groups to measure the quality of the night sky in large areas. The SQM is installed pointing to the zenith on the roof of a vehicle, connected to a computer and a GPS localizer. It takes measurements every time lapse defined (normally few seconds) that are stored, along with the coordinates where each measurement was taken, in a CSV file or similar. After filtering the data, the resulting file can be used to create light pollution maps, but currently there is no standard methodology to do so. This lack of homogeneity hardens the comparison between maps created by different teams.

The software presented, M2M, available in Windows OS and Linux based OS, standardizes the process at the same time that makes it easier. M2M is prepared to work with files coming from the two main measurement acquisition programs for dynamic SQM measurements: Unihedron Device Manager, from the company Unihedron; and Sistema de Medición de Contaminación lumínica (formerly known as RoadRunner), developed by Daniel Rosa in collaboration with the Sociedad Malagueña de Astronomía.

Light Pollution Around the World - Southern Africa

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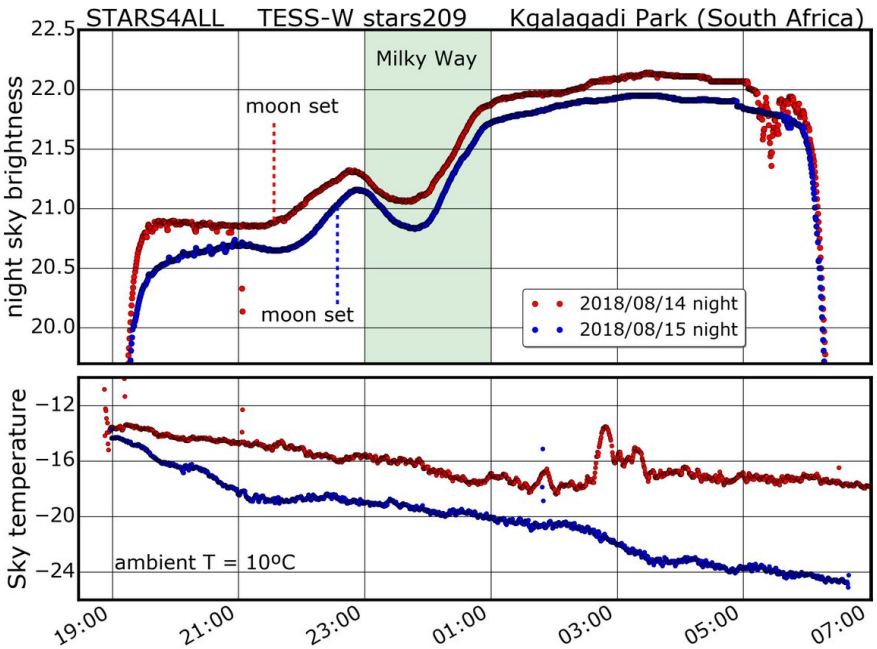
Abstract

TESS-W photometers have been used for estimating the environmental impact of the Light pollution in southern Africa. Some STARS4ALL TESS-W photometers are sending data every night since they were set up as fixed stations between July the 27th 2018 and October the 6th 2018 at Cape Town (South Africa), Victoria Falls (Zimbabwe), Kasane (Botswana), Etosha National Park (Namibia), and Hakos Astrofarm (Namibia). Variations of the brightness of the sky have been record in 18 additional remote locations around that 4 countries during 24 different nights within the same period of time getting remarkably dark results.



Spectral irradiance computation in parallelepiped enclosures

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Abstract

Circadian rhythms of people who spend a lot of time in indoor lighting conditions depend on the spectral radiance of the light sources. The spectral irradiance in the plane of the cornea is the input function to compute different circadian parameters. In a closed room the spectral irradiance depends on the position, the spectral radiance and the geometry of the light sources, the geometry and the spectral reflectance of the enclosure, as well as the position and orientation of the measurement sensor. Although the spectral irradiance is very simple to measure with a spectroradiometer, there are no analytical formulas that allow its calculation in an easy and direct way. A method to calculate the spectral irradiance, for different positions and orientations of the sensor, in any closed environment, taking into account the above factors, was developed in [1] and calculated analytically for a particular case in [2]. In this paper we present a numerical implementation of this method in the case of a room with parallelepiped form, with light sources of different spectral radiances that are located in different positions. It is considered that the walls, ceiling and floor of the room have different curves of spectral reflectance. From the results obtained it is concluded that spectral irradiance depends heavily on of successive reflections of light on the surfaces that delimit the room.

Using SkyGlow Simulator (SG-S) on different territories: conversion from VIIRS-DNB image to intrinsic SG-S maps

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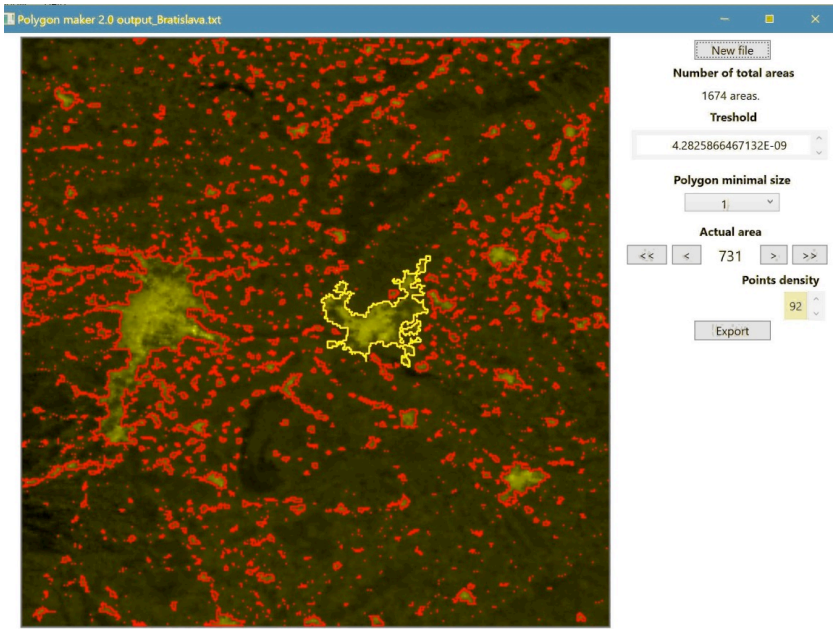
Abstract

The different geometries of artificially lit areas (cities or towns) are treated in SkyGlow Simulator as enclosed surfaces of polygonal shape with small or high number of vertices (depending on resolution requirements). Each polygon or its part can be characterized by specific emission function and total lumen output. The luminous energy as a function of position on the city-map can be now easily managed using a PolygonMaker Tool. This tool semi-automatically identifies bright areas in a VIIRS-DNB image and exports the data in form of polygonal city-model. The brightness threshold and the density of points in the polygons can be chosen freely. First, VIIRS data of Day/Night Band Channel are downloaded for a specific locality in HDF5 (hierarchical data file) format which contains geographical position of each pixel, geocentric position of the satellite, moon phase and radiance of each pixel. Data such as geographical position and radiance are extracted via freely available viewer (e.g. HDFView) and saved into ASCII text file as data array that is input to the further processing. The ASCII file is then imported to PolygonMaker tool.



All cities and towns in the area of interest are identified when the threshold is properly adjusted (see the figure above with Bratislava city highlighted on the map of metropolitan area Vienna-Bratislava). All cities in the area will be exported in SkyGlow city format with just a single click. The cumulative uplight from the polygon can be used to calibrate the emission function.

Preliminary Light Pollution Maps in Indonesia Based on Sky Quality Observation

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Abstract

We observed night sky quality in several LAPAN stations (Agam, Bandung, Pontianak, Sumedang, Garut, Pasuruan, and Biak) which were conducted from April until November 2018 using Unihedron Sky Quality Meter LU-DL type. Observational data from all of the observational points were then sent regularly to a centralized database for further use. Although most of the measurements were done in overcast conditions, we were able to determine the representative clear sky brightness statistically. The results showed that the light pollution level of the most of the stations are moderate (the values at Biak, Agam, Sumedang, and Pontianak are 20.0, 19.5, 19.6, and 17.7 mpsas respectively) and the stations which are located near or in cities are high (Bandung and Pasuruan with 17.1 and 18.0 mpsas, respectively). In a particular station (Garut) the light pollution is low (20.7 mpsas). It is planned that in the first semester of 2019 we will make light pollution maps in several places in Indonesia, especially in some cities in Java using Sky Quality Meter attached to drones and moving vehicles.

Keywords: night sky observations; Unihedron Sky Quality Meter; light pollution

Efficient computation of night sky brightness maps using Fast Fourier Transforms

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Abstract

The calculation of night sky brightness maps for wide geographical regions with high spatial resolution requires performing multiple weighted sums over pixels which are computationally time expensive. In this communication we show that, for a wide class of these problems (those with shift-invariant kernel), the calculation can be restated in terms of a convolution whose calculation can be done very efficiently using the standard Fast Fourier Transform routines (FFT) available in most mathematical software packages. In such way the calculation time can be substantially decreased (to a typical demand of 10^{-6} s or less per output map pixel, including the time required to save the resulting geotiff files). Light pollution maps for wide regions of the planet can thus be calculated in a few seconds, without any loss of accuracy, using moderate-performance off-the-shelf personal computers.

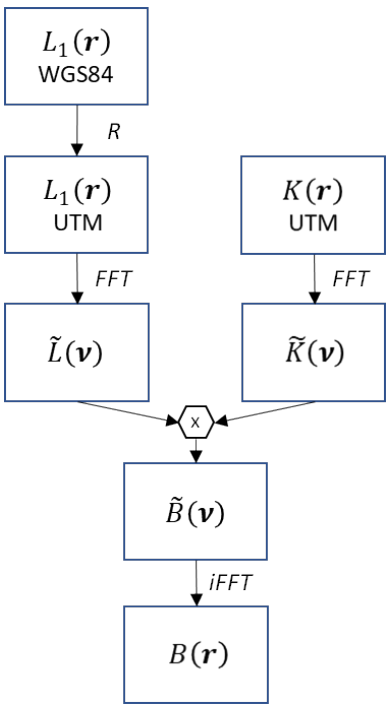

Fig 1. Basic steps of the FFT map calculation algorithm.

The PyASB, All Sky Brightness free software

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Abstract

The PyASB software (Absolute photometry and Sky Brightness) is a Python program developed to analyze CCD images obtained with AstMon all-sky camera. This free software currently provides values of calibrated night-sky brightness and extinction and was developed to analyse images taken with fixed all-sky astronomical cameras.

We have extended the functionality of the software to work with RAW pictures taken with all-sky digital cameras (DSLR fitted with fisheye lenses). The initial field recognition is performed using astrometry.net web services. Then, the complete astrometric solution is obtained and the camera is flux-calibrated by using the stars in the field (all-sky astronomical photometry). Part of the astrometric solution can be precomputed for different camera models and lenses used.

Our goal is to develop a web based tool, without any human intervention if possible, for analysing all-sky pictures that provides calibrated sky brightness maps from uploaded pictures.

Skyglow: towards the characterization of the reflectance of different urban surfaces

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Abstract

Depending on the physical characteristics of a surface, as well as the wavelengths that affect it, it is the quantity and distribution of the radiant energy that it will reflect. The reflectance of an urban surface increases linearly with the wavelength, its slope depends on the type of material and the humidity on the surface. The urban soil, when it is not covered by vegetation, does not present great variations in the spectral reflectance with the wavelength. Using the spectral characteristics of common urban surfaces, the amount of the reflectance in a city can be classified from the data obtained from the series of polar orbiting satellites (NOAA), which have a relatively high spatial resolution, and a global daily coverage. In order to calculate the radiation reflected by the cities, we propose a methodology for the detection and classification of urban materials through remote access tools and machine learning algorithms. Our methodology employs the ENVI Spectral Library Builder to automate and improve the cataloguing. The classification method is evaluated to ensure an acceptable accuracy. The expected results can provide an approximation of the reflectance quantification in a city and give us an idea of the impact that different urban materials could have in the emission function of ground based light sources.

Measuring Night Sky Brightness with smartphones: The new version of the Dark Sky Meter App

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Abstract

The Dark Sky Meter app converts the smartphone into a scientific instrument to measure Night Sky Brightness. The main advantage is that any interested citizen is provided with a photometer in his pocket. We have prepared a new version of the DSM app using a different approach to read the camera RAW data in order to made the calibration more reliable. We are characterizing smartphones to determine the sensitivity and spectral response of their cameras. We intend to provide laboratory and field calibrations and to refine the calibration using the users feedback (citizen science). This step is necessary due to the variety of smartphone cameras on the market.

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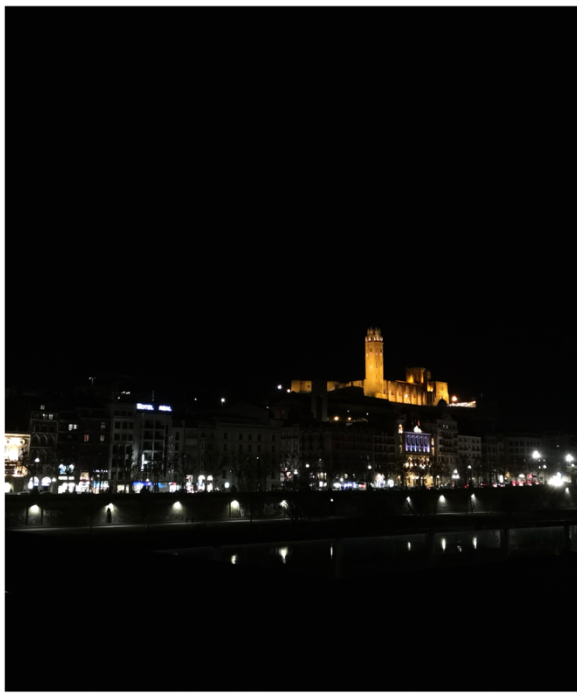

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