Measurement of the light pollution: a project for the Grant Agency of the Czech Republic

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March 28, 2002

The growing light pollution has damaged our twilight and nighttime environment in the last decades to a very large degree. Whereas the implication for the night sky is obvious (qualitatively at least), the consequences for the outdoor safety and visual bearings of people, for their health and for wildlife are just becoming to be studied.

1 Background

An ever increasing part of the public becomes aware that the consequences of poor outdoor lighting are really serious, and that the lighting can be easily improved a lot and at low (mostly even negative) costs. In many places throughout the world the lighting has been reconstructed to be less polluting and obtrusive, demanding less power (and contributing less to the greenhouse emissions). In some municipalities, regions, and states, such efficient lighting is demanded by the law already.

Czechia has joined these pioneers them recently. A requirement to prevent the light pollution is a part of its Act on the Protection of the Atmosphere. In fact, it's the first nationwide case in the world – legal prevention of light pollution is being prepared in another countries (e.g., Italy, Slovenia, Croatia), but Czechia became the first one. This is undoubtedly a result of a strong position (and popularity) of astronomy research and education in our country, and of the fact, that the leading Czech astronomers acted as responsible citizens during the preparation of the law. While prevention of the light pollution is a general environmental issue, astronomers with their intimate knowledge of the night environment are naturally the first part of the society which realized the degree of the problem and worked on solutions. In the regions with longer history of prevention of poor lighting, they have allies from numerous fields (biology, medicine, police, ...) – including lighting engineers. In Czechia such process is still in its infancy but thanks to the new law, to the broad public interest (and to many journalists), the public perception of the seriousness of the problem grows quickly.

The Czech law (valid since June 1, 2002) says (see `www.astro.cz/darksky`) that "light pollution [is] every form of illumination by artificial light which is dispersed outside the areas it is dedicated to, particularly, if directed above the level of horizon."

Being a qualitative definition, the statement in the law is clear enough. Primarily the direct light from lamps radiated above the horizon should be avoided, as it is technically feasible and common in many places already. However,

it would be highly interesting to have quantitative data on the degree of light pollution as well. There is a unique opportunity to document, how the pollution is diminished with application of the rules demanding proper use of outdoor artificially produced nighttime light.

The first task is to quantify the present state.

2 Astronomical photometry

A part of it can be done through the proper use of standard astronomical photometry: in fact, the luminance of the sky is computed routinely during astronomical photometric measurements of celestial objects. To study the level of light pollution of the sky, the sky luminances (or radiances in the corresponding filters) should not be discarded after completing the reduction of the astronomical object's data, but it has to be recorded and published. This holds for the new observations as well as for old archived data. A call for such data came several times already from Pierantonio Cinzano, the lead author of the new classic "The first world atlas of the artificial night sky brightness". Artificial contributions to luminances of the sky (or their infima in zenith) have been computed for most of the world by his group based on the satellite images of cloudless nighttime Earth. However, a validation through the Earth-based direct measurements is scarce and much needed. In Czechia, with a dense network of people doing astronomical photometry, such validation can be made with a moderate effort.

Using the standard photometric data for that purpose assumes that the needed software will be developed, a simple-to-use one. This is one of the goals of the project. The software will be then published with its first results and all the people doing astronomical photometry could consider to use it and either publish the results or make them available to others. The basic version of the software will extend the astronomical image processing software Munipack (see `munipack.astronomy.cz`), but another standard photometric packages should also get an option to report sky radiances.

Another goal is to do dedicated measurements of the night sky luminance both in remote locations far from the artificial lighting and in selected areas of high level of light pollution, observing zenith and selected most interesting azimuths at various elevations above horizon. Such remote sites are most influenced by the direct just-above-horizon light from the lamps and should reclaim almost pristine skies when the lighting is made as non-polluting as possible in the future. A new portable equipment is necessary for this research. A straightforward method of the calibration of the measuring device can be developed from the method of classic CCD astronomical photometry.

3 Terrestrial photometry

The same equipment (an over-8-bit digital camera, a notebook and further accessories) will be then used for terrestrial imaging of nighttime scenes as well. One goal is to view the same locations (settlements, industrial areas) at different angles down from the horizon. The amount of direct polluting light from the lamps will be quantified this way and its proportion to other light measured (from, e.g., the illuminated surfaces, windows, neon advertisements, car headlamps). This proportion is largely unknown – simple looks from hills and towers down to the inhabited nighttime area shows that poorly aimed lamps are vastly dominant, but some advocates of the current public lighting practice still claim that the role of direct light from street and area lighting is minor. Thus, there is a need to measure their actual contribution.

In some cases, the same area should be inves-

tigated at various downward angles, to study the angular dependence of the upward going light – a key issue for the computation as made for "The first world atlas .." and previous works, but a rather uncertain one. An plane flying over the area should serve for this purpose while a series of images would be taken from its bottom.

The two tasks mentioned above concern the sources of the artificial contribution to the nigh sky luminance, i.e. the original "astronomical" concern about light pollution. However, even other polluting (and directly obtrusive) light should be investigated.

Illumination of the interiors of the sleeping rooms by poorly aimed lamps, nighttime advertisement or excessively lit surfaces should be measured as well, with the same imaging system and with some calibration tools (common to all terrestrial measurements, i.e., with high-sensitive meters of illumination and luminance).

Finally, the street and area lighting from the perspective of pedestrians and drivers will be investigated. The illumination and luminances of those surfaces, which are lit on purpose as well as of those, which should not be lit at all, will be measured and compared with the direct light from lamps in the field of view. Glare from the lamps and overly lit billboards will be quantified and compared with human judgements (of people with and without sight disabilities).

For making and evaluating terrestrial photometry, a new technique and software will have to be developed. Curiously, a part of the evaluation can be done by using a sw for astronomical photometry. Namely the distant lamps are behaving like stars and their brightnesses can be computed in a similar way just like the brightnesses of celestial objects. What remains, the background, is like a sky containing some nebulosities. Again, a software will be sought for (or developed), that will enable other people worldwide to pursue the same tasks.

Apart from using the most adequate hardware for terrestrial photometry, a possibility to get useful results with most common digital cameras will be investigated. It can be however supposed that the capabilities of common cameras on the market will grow over the next years, so what will be developed for the most advanced today-ones, may be immediately useful for many other types in the near future.

4 Documenting the expansion of quality outdoor lighting

In some areas, the old polluting lamps are being replaced by less polluting ones. The improvement achieved this way will be documented for some cases. Even more important is the documentation of changes within the pilot areas around major observatories (or perhaps nature reserves), where the improvement of outdoor lighting is envisaged (by the law and the proposed implementing regulations demanded by the law) even before the old lamps die of age. Even though such adaptations and replacements of old lighting systems will be cost-effective in most places, inevitably they need some initial investment. The investors will naturally ask: how much has the light pollution diminished? The quantitative answer could and should exist and be published, and the procedure how anybody can get such results should become quite clear, so that it could be used by lighting engineers too.

5 Collaboration

The whole topic is rather new. The applicant is well acquainted with the field's state of the art and is in contact with most researchers at this field (and with some in related fields) in the world. As a person contributing to the adoption of the anti-light-pollution legislation in Czechia, he feels that the newly emerged leading role

of his country at this field should be pursued further, with scientific (rather than just educational, as it was up to now) goals. Of course, an educational outreach and publicity of the results will be pursued as well.

The current project can in many aspects of investigation methods use the results of another project supported by the Grant Agency of the Czech Republic, namely that one by Petr Baxant, ... and can proceed partly side-by-side along it. New people, students, astronomers and lighting engineers will be engaged for the investigation of consequences and remedies of outdoor lighting. In future the research may expand to another countries as well, some international cooperation may emerge even during the project.

Linking the measured photometric quantities (mesopic, twilight-seeing photometry will be pursued as far as possible apart from a standard photopic, daytime-seeing one) with the health effects, traffic accidents rate, birds behaviour etc. is also possible, but difficult to plan. Some research of this kind is probable to emerge (in case of the ecological consequences of nighttime lighting, people participating at the conference of that name are promising collaborators, see `www.urbanwildlands.org`, as well as some Czech zoologists interested in this new field). Our project welcomes interdisciplinary cooperation, but will concentrate on photometry itself.

The running results will be publicly available on Internet and the major achievements published on the conferences and in the scientific press.

A by-product may be photometry of bright stars, which is anyway necessary for getting the values of the actual extinction of light by the atmosphere – knowing the extinction coefficients enables using all luminance data, not just their infima, to know the magnitude of light pollution.

6 The main participants

The applicant, Jan Hollan, works at the N. Copernicus Observatory and Planetarium in Brno. He is the sole Czech member of the International Dark Sky Association (honored by an award from its executive director recently, for his achievements at the promotion of non-polluting lighting and his contribution to legal framework in Czechia), a founder and leader of a Czech group of dark sky advocates. He has advised at photometry tasks his students a long time. He has written a lot of astronomy software, including a programme for evaluating the "sky light pollution increment of luminaires" (see `amper.ped.muni.cz/light/ies2`). The Observatory itself is doing astronomical photometry with a standard CCD+telescope equipment at two sites (Brno and Vyskov) and its data are among those to be processed (including the new ones acquired directly for this purpose).

The co-applicant Petr Pravec is doing photometry at Ondrejov Observatory of the Astronomical Institute of Academy of Sciences of the Czech Republic. He leads a team investigating minor planets, esp. the Near Earth Objects. Reducing light pollution of the sky is a vital issue for his research in Ondrejov, the long series of the old and new data will enable documenting the reversal of the trend from getting worse to getting better. The standard equipment for astronomical photometry in Ondrejov is the best one in Czechia and it is in a continuous operation since 1994.

The collaborator Petr Baxant is evaluating luminance information from digital images with respect to glare and visual comfort. His expertise will add much to the calibration and evaluation of outdoor terrestrial photometry. Through his Department of Electrical Power Engineering, Faculty of Electrical Engineering and Computer Science at Brno University of Technology he is

able to share some equipment for initial investigation to help in choosing appropriate hardware for the project.

Jan Hollan, March 2002

References

[1] Cinzano, P. 2001: private comm., amper.ped.muni.cz/jenik/letters/public/msg00022.html

[2] Cinzano, P. – Falchi, F. – Elvidge, C. D. 2000: The first world atlas of the artificial night sky brightness, Monthly Not. of Royal Astron. Soc, 328, 689-707, see also www.lightpollution.it (also for further papers of Cinzano)

[3] Cinzano, P. 2000: The growth of light pollution in north-eastern Italy from 1960 to 1995, in Measuring and Modelling Light Pollution, ed. P. Cinzano, Mem. Soc. Astro. It., vol.71, 159-166 (2000) - submitted April 1998

[4] Cinzano, P. 2000: The Propagation of Light Pollution in Diffusely Urbanised Areas, in Measuring and Modelling Light Pollution, ed. P. Cinzano, Mem. Soc. Astro. It., vol.71, 93-112 (2000) - submitted May 1998

[5] Baxant, P: Luminance distribution analysis using digital photography, PhD thesis, Brno 1999, for a pdf summary see bear.ro.vutbr.cz/nakl/thesis/baxant.pdf

[6] Hollan, J. 2001: Let's illuminate just that, what we really want to (a leaflet, in Czech), Czech Astron. Society, for a crude English draft see amper.ped.muni.cz/light/zakon_oo/letak