LIGHT POLLUTION MEASUREMENT: A PROJECT WORK FOR SECONDARY SCHOOL STUDENTS

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ABSTRACT

Our student group on environmental physics in Garay János Grammar School in Szekszárd started to show interest in light pollution, by reason of necessity of dark sky for our astronomical observations. In the frame of a project work we made measurements with a special portable photometer (SQM) in a nearby area in Tolna county called Hegyhát. We obtained very good data, approaching those of Hungarian International Dark Sky Parks' values.

INTRODUCTION

The Zselic National Park was the first in Europe to win the title of International Dark Sky Park on 16 November 2009. This title was founded by the International Dark Sky Association after realising that there are fewer and fewer places on Earth where the starry sky can be seen in its full beauty.

A hundred years ago every child could naturally experience the Milky Way, falling stars or constellations. However, gaining such experiences today is impossible without outings to places free from light pollution (Fig.1.).

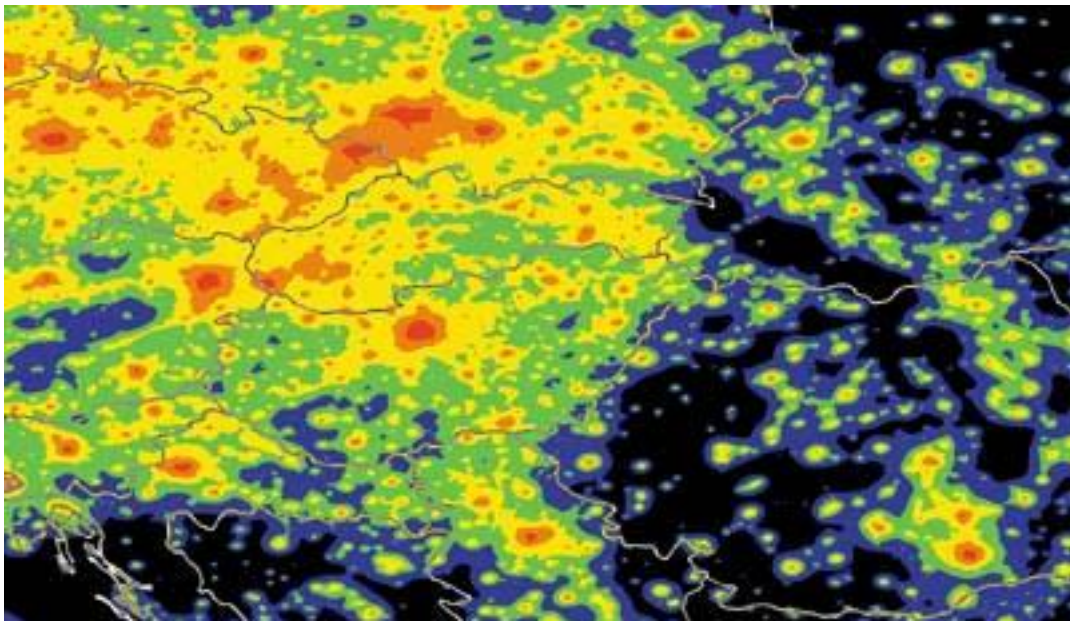

Fig.1. The map of light pollution in Hungary.

Together with some enthusiastic students we wanted to find out about and objectively justify by measuring whether there are places either in the neighbourhood of our school Garay János Grammar School or in Tolna county where the sky can be seen the way it is in Zselic. Our school successfully applies for micro researches and the necessary financial support every year within the frame of "Út a tudományhoz" (The Way to Science), which is a part of "Útravaló" (Provisions) Scholarship Programme. Due to our latest research programme (Shooting with Astrophotographic Mechanics) we got a good quality astrophotographic stand (EQ-6) with the help of which we were able to take highly aesthetic scientific photos of objects in the sky. For photos rich in details we had to find places with dark skies because the darker the sky is, the longer exposition time the photo requires and the more details can be seen in it. Finding such places was our reason for starting to measure sky brightness. Meanwhile, on the Internet we found a map showing light pollution in Hungary (see Fig.1).

The International Starry Sky Parks of Zselic and Hortobágy can be seen well in it and so can the sandy area of Illancs and the hills of Tolna the object of our measures. The lighter the colours are in the map, the shinier the sky is, and the darker they are, the higher quality the sky has (the darker it is) in that area. In the map we could see that the hills of Tolna may have sky similar to the quality of those of Zselic and Hortobágy the two International Starry Sky Parks. We planned to get ground-based measurements to prove this hypothesis.

LIGHT POLLUTION

Light pollution is in fact a skyglow, an increased light density on the nocturnal sky which originates from the artificial light at night scattered on the aerosols and molecules in the atmosphere. Fig.2 indicates that the incorrectly designed and installed lighting devices can be sources of light pollution if their light goes not on the right place, right time and not with the right intensity.

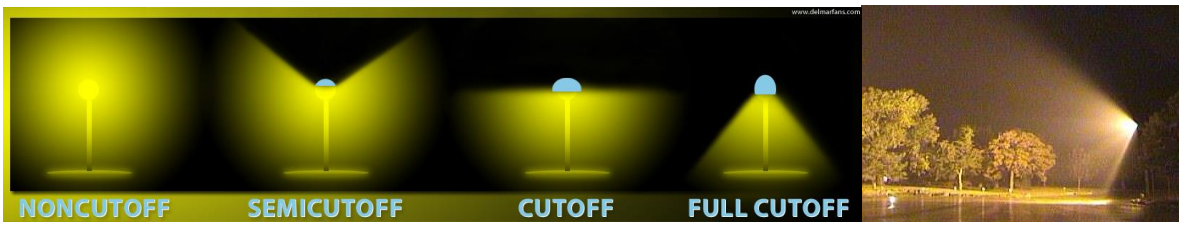

Fig.2. Light pollution sources. Left panel: possible design of the public lighting. Right panel: badly installed lamp

These light sources have a high ULOR (upward light output ratio) value meaning that they spill light above the horizon. The wasted luminous flux causes energy loss, artificial skyglow, panorama destroying, undesired effects on health (including humans and other species) and dazzling.

Artificial light at night increases skyglow, that is why the astronomers and anyone else cannot observe less intense objects and phenomena of the nocturnal sky. Nocturnal artificial light sources (public lamps, illuminated flat houses and church towers etc.) disturb the flying insects', birds' and turtles' ability to navigate or to reproduce properly. Some nocturnally active species (for example bats or owls) or inversely, the daytime active species (for example the songbirds in the cities) cannot live their natural lifestyle because of the light pollution.

Nowadays most of the human beings live in unnatural light conditions. We spend our daytime period at less illuminated indoor places than natural outdoor illuminance, in addition, at night we cannot experience complete darkness. Our endogenous circadian rhythms are affected, for example body temperature, heart rate and melatonin production. With the

artificial light we have altered the natural 24-h light-dark cycle, thus we can observe serious pathophysiological repercussions. Disorganization of our circadian system and perturbations in melatonin rhythm (caused by sleeping with artificial light, use of LED screens at night, shift work, jet lag etc.) denote an increased probability of the development of diabetes, obesity, heart disease, premature aging and some types of cancer [1].

Dazzling represents risk mostly for the traffic and for employees working in dangerous scopes of activities. If the light sources with high ULOR value emit too much light directly to the pupils, it causes temporary sight decrease because of the eye's inability to adapt to the new lighting level. Light pollution can be disturbing in one's property, for example if the incorrectly settled public lighting causes too much brightness in one's room so one can not sleep properly.

OUR MEASUREMENTS

We used a UNIHEDRON Sky Quality Meter instrument to measure the luminance of the sky. This small portable instrument has been used in Hungary for measuring the sky brightness since 2007. The device measures the average luminance of a 1.5 steradian solid angle towards the zenith. The unit of measurement of sky luminance is mag/arcsec^2, which can be converted into cd/m^2 (SI units) using the following formula:

$$\text{Value (cd/m}^2\text{)} = 10.8 \cdot 10^4 \cdot 10^{-0.4[\text{value(mag/arcsec2)}]} \qquad (1)$$

The temperature-calibrated device works with the precision of 10 percent in linear luminance (cd/m^2) units [2]. There are two types of this instrument (SQM and SQM-L) used in practice. The difference between them is in the angle of collecting light (see Fig.3).

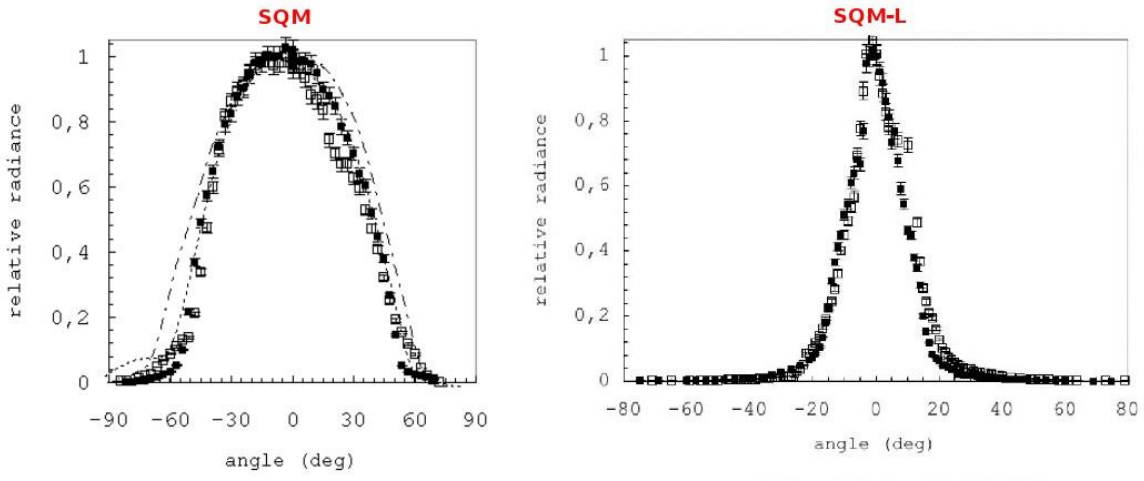

Fig.3. Solid angles of the two types of SQM.

An SQM works with a bigger angle, measures and counts the average of the thickness of the incoming light quantity. An SQM-L does the same but with a smaller angle. All of our measurements were taken with the device pointing to the zenith with an SQM-L to avoid the effect of the disturbing lights of Szekszárd on the horizon.

The favourable conditions for measuring are complex. It can be started when the night sky is clear without the Moon and the Sun is 18 degrees under the horizon, and should end before the Sun approaches the horizon up to 18 degrees again during its way at night. As long as it is possible, artificial sources of light should be avoided. When measuring in the town this condition is imperfect in some cases. Places with objects in the area such as trees that can disturb the detector of the instrument must also be avoided. Directing the instrument towards the zenith five measurements are made, the first two of which are ignored when evaluating

them. These are less accurate data due to the time necessary for the instrument to warm up. The other three data are then averaged. The co-ordinates of the venues of the measurements are fixed by a GPS.

Fig.4. The members of our study circle while measuring.

Certification of the instrument was done with the help of calibrated SQM instruments gathering accurate data on the sand hills of Bácska in the area of Illancs, which is highly free from light pollution. We got evidence that no correction is needed as our instrument measures sufficiently accurately. We measured (Fig.4.) night sky brightness in Szekszárd at places relatively distant from each other. Later during our night outings among the vineyards we surveyed the neighbourhood of Szekszárd as well. A couple of times we drove along different routes in the hills and stopped at places to measure (Fig.5.).

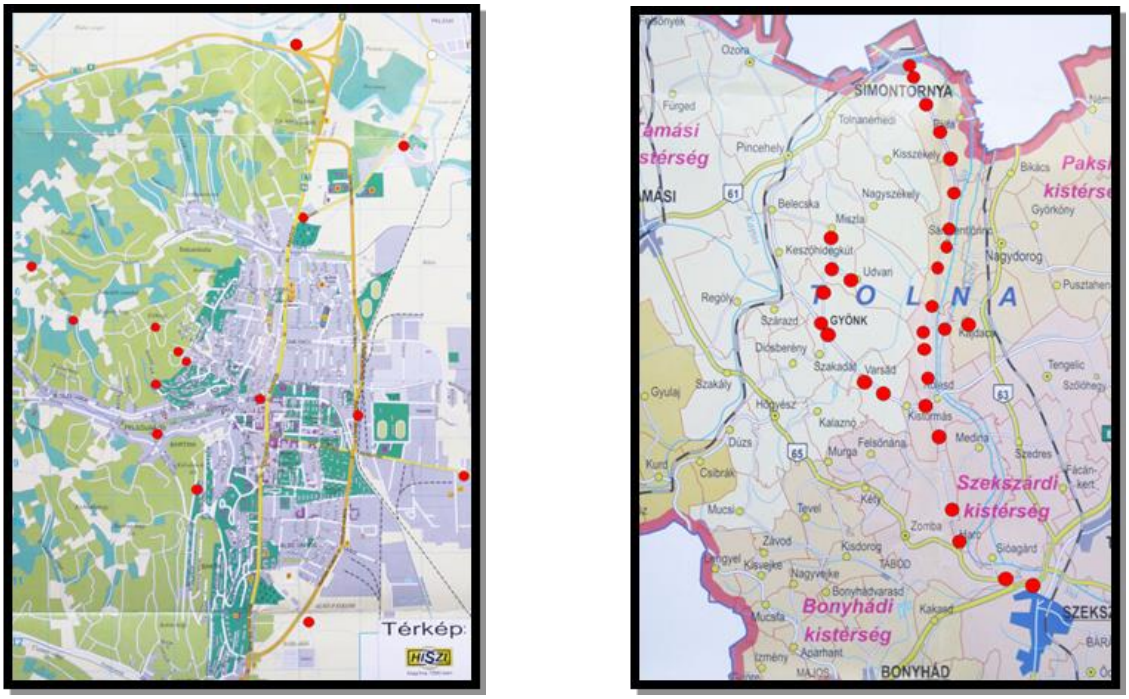

Fig.5. The venues of our measurements. Left panel: Venues in Szekszárd.
Right panel: venues in the hills of Tolna.

Quite a few factors made our measurements in the summer holiday difficult. For example, nature in the first place, the unpredictable weather, the late sunset and the early sunrise.

Because of these latter ones we had to make our measurements in the middle of the night. Besides, other tasks of the students, family holidays or the fact that getting to more distant points of the county is only possible by car also delayed our work.

DSLR PHOTOMERTY

After finishing our measurements in the summer of 2014, public lighting system has been refurbished in Szekszárd. The old high pressure sodium lamps were replaced with white energy-efficient LED lighting. Our research team from the university measured the luminance of the light dome of Szekszárd by DSLR photometry before and after the reconstruction. We used calibrated DSLR cameras with fisheye lens to get images with high ISO setting and long exposure time. Our photos in raw format can be converted to false colour images to show the distribution of sky luminance. With this method we could qualify different lighting systems and draw attention to the possible environmental effects of the changes in lighting. As Fig.6 indicates, we obtained a decrease of the sky brightness in Szekszárd [3].

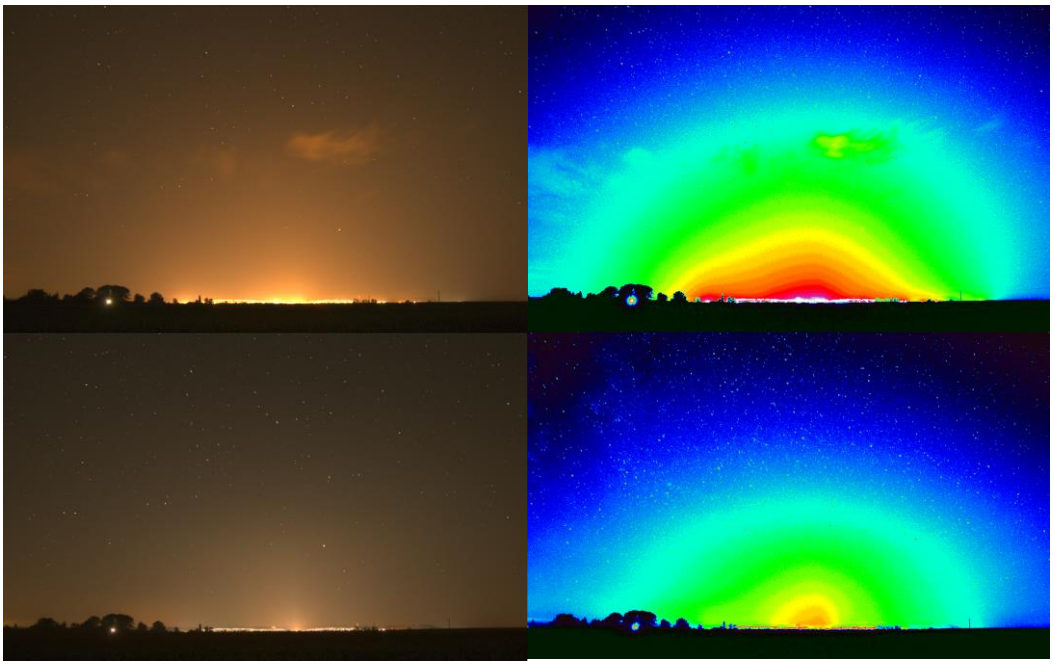

Fig.6. Light dome of Szekszárd. Top panels: before the reconstruction, bottom panels: after the reconstruction. Left panels: normal images, right panels: false colour images (Source: Z. Kolláth).

OUR RESULTS

As it can be seen from the data below our SQM measurements showed that the quality of the night sky of the hills in Tolna County is similar to those of the dark sky parks of Zselic and Hortobágy.

Table 1. The measured data.

measured areas	**SQM-value**
The average of the area of Szekszárd without the centre	20.4
The edge of Szekszárd at the vineyards	20.6
The average value of our measurements among the vineyards of Szekszárd	21.0
SQM-values in the area of Hortobágy Dark Sky Park	21.0 – 21.5
The SQM values of an all-night observation in the area of Illancs	21.0 – 21.5
The average of the measured values in the area of the hills of Tolna	21.1

CONCLUSIONS

The topic of light pollution proved to be an excellent project task. It was suitable to combine biology and mathematics, deepen the students' environmental awareness and last but not least the cooperation within the measuring team, their enthusiasm and the joy of learning playfully are all definitely serious pedagogic results. However, we find the pedagogic results more important than the physical ones. Now it is the students who want to continue measuring. We are going to take pictures of the hills of Tolna with DSLR photometry by our fish-eye lens bought with the help of application sources. It will be exciting to measure the sky brightness in the town and in its neighbourhood again with SQM after the public lighting changes.

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