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# LIGHT POLLUTION A TOOL FOR PHYSICS AND ASTRONOMY EDUCATION

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**Abstract.** The problem of light pollution is well known in the world, which is not case in our country. Beside the loss of the night sky, the other negative impacts are: damage to the environment, sky glow, human health consequences and disturbing of sensitive ecosystems. The students from High School “Orde Copela” in Prilep continuously for five years in succession including this year (2012) perform activity within the international educational project “Globe at Night event”. They estimate the light pollution by measuring the limiting magnitude of stars from the constellation Orion or Leo and additionally using the Sky Quality Meters to map a city light pollution at different locations to identify dark sky oases and even measure changes over time. During these investigations through the subjects in physics, astronomy and computer sciences the students are familiarizing with the problems of light pollution, which make them to appreciate the heritage and healthier environment [6].

PACS: 01.40.E- (Science in school), 89.60, 07.88.+y

## 1. INTRODUCTION

What is light pollution? The light disappears without a trace as soon as we turn off the lights. Someone would probably think that it is impossible to call that pollution! Unfortunately, the answer is opposite; light can really pollute the environment. Furthermore, light pollution can have a negative effect on the total plant and animal life, as well as on the humans. Light pollution is an unwanted consequence of outdoor lighting and includes such effects as sky glow, light trespass, and glare.

Men have artificially lit up everything that has come their way. Sky glow phenomenon mostly irritates astronomers. It is a type of light pollution when the public city lights are directed toward the sky where the rays of light in the atmosphere scatter and reflect from the aerosols back toward the ground. Space lovers have lost their stage and the astronomical observations are merely impossible. Light pollution has turned the night into a half-dawn. As a result, today it is practically impossible to see the stars from the city. The “Milky Way” for us exists only in the fairy tales, because we cannot see it [2].

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In addition, there are health consequences of exposure to artificial light at night some of them are increased headaches, increase in anxiety, and reduced production of hormone leading to cancer. Many plants and animals suffer from the newly risen circumstances, some of them are on the verge of extinction and some are already extinct. Birds do not build their nests near the sources of artificial light; they become disoriented at night. Flowers do not close completely and therefore they are exposed to weather conditions. The proud owners of the “decorative light balls” are unaware of the fact that they have out casted tens of animals and plants from their gardens, thus bringing to their global extinction. In fact, Mother Nature acts as we, the intolerant and ignorant humans, tell her.

Everywhere we travel, we can see that the streets, the squares, the crossroads are over-illuminated with inappropriate artificial light. Sometimes the glare light redirecting in the eye causes loss of contrast and leads to unsafe driving conditions. Are we aware of the number of driving accidents caused by over-illumination?

The problem of light pollution has not been seriously considered so far. Fortunately, the governments of some countries have brought many laws and regulations related to the light pollution.

### **Describing the light pollution**

There are three types of light pollution:

*Glare* - when there is a lot of light in the background. Can you clearly see the faces of the children who stand in front of the house that is too illuminated (Fig. 1)?



Fig:1. Glare light pollution.

*Light trespass* - is when unwanted light enters one's property. Would you be able to sleep if your bedroom's window faces the light in the photo above (Fig. 2) [1]?



Fig:2. Light trespass.

*Sky glow* – the most important in astronomy. Would you be able to see the stars in the photo left (Fig. 3) [1]?

As we already saw, these are illustrations of the three types of the light pollution and are made in the town of Prilep.



Fig:3. Sky glow.

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## **Problem solution**

Many things can be implied in order to reduce the light pollution. For example, the lighting fixtures should be improved, meaning we should use ecological lights of better quality, which should direct their light more accurately towards where it is needed [2].

These types of lights are: ecological, safe, economical, can lower the light pollution and they light the surface that needs to be lit, they are also traffic - safety and public - safety friendly, cost less and use less energy. However, we also have to mention the awareness of each human being rationally to use the light and to save energy in any possible way.

When non-ecological light sources are used they do not illuminate the required surface, have a negative impact on plants, animals and humans and cost more. When more energy is wasted, more light is wasted, too [2].

## **2. GLOBE AT NIGHT**

The GLOBE at Night program (GaN) is an international citizen-science campaign to raise public awareness of the impact of light pollution by inviting citizen-scientists to measure their night sky brightness and submit their observations to a website from a computer or smart phone.

The total number of measurements according to the Globe at night campaign until now is 83 000, made in 115 countries. This Campaign is held for 7 years in succession, and these results make it one of the most successful campaigns against light pollution [4].

The total number of observations during the 2012 GLOBE at Night campaign is 16 850, performed in 92 countries. 20 of those countries contributed with about 95% of all observations. The top 20 countries are United States (6072), India (2472), Poland (1196), Argentina (879), Germany (859), South Korea (828), China (628), Chile (488), Croatia (374), Romania (324), Spain (278), Canada (254), Mexico (217), France (206), Czech Republic (173), Hungary (142), South Africa (130), Uruguay (122), Macedonia (115) and Slovakia (98) [4].

About 1 out of every 2 observations of limiting magnitude gave a value of 3 mag or 4 mag (measurements contributed by medium to larger sized cities), 80% of the measurements (or every 4 out of 5 measurements) were taken in light polluted areas and less than 20% (less than every 1 out of 5 measurements) from areas where we could see the Milky Way Galaxy. The numbers are consistent with what the International Dark-Sky Association finds for the United States.

## **3. RESULTS FROM THE OBSERVATIONS OF GLOBE AT NIGHT IN SOU “ORDE COPELA”, PRILEP, MACEDONIA**

Our school had participated for five years till now. It was started in 2008 and was the first school from Macedonia, which took part in GaN. Globe at night is very useful for us because we have used materials for the contests, the students find it very interesting activity, because it brings them closer to the science, they become citizens-scientists, ect. Definetely, if

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we tell about the light pollution to everybody we will be very successful. Also, with this activities increases the level of conscience, IT skills and language skills of our students.

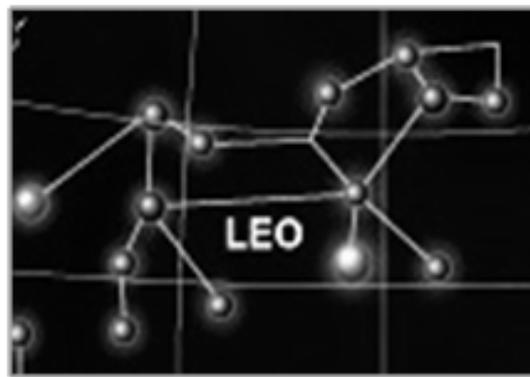
**Instructions how to catch a star in six easy steps:**

Determining longitude and latitude. For this purpose we use the GPS - unit and Globe at night web pages;

1. Locating the constellation Orion or Leo [Fig. 4 and Fig. 5] one hour after sunset (8 to 10 o'clock pm. local time);
2. Magnitude observation using the magnitude graph by Globe at night web site. Here we compare our night sky to the other magnitudes shown in the graph below (Fig. 6 or Fig. 7) in order to decide on the magnitude of our night sky;

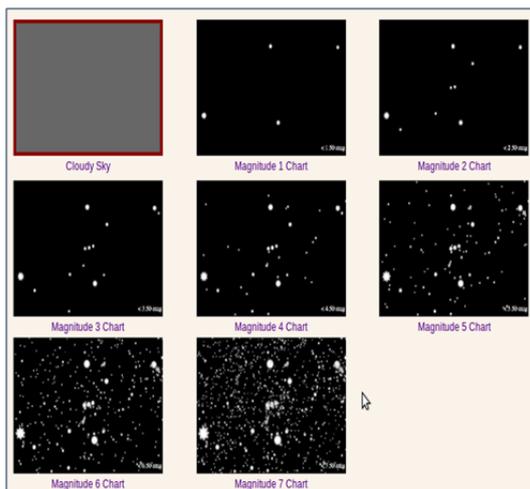


**Fig. 4:** Constellation Orion.

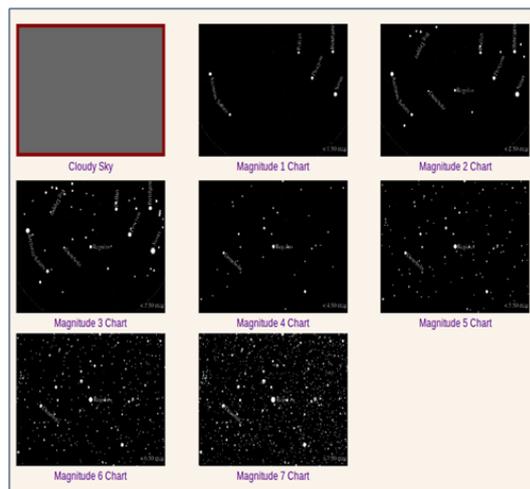


**Fig. 5:** Constellation Leo.

3. *Using the SQM-L* to measure sky brightness;
4. *Sending data.* In order to record the measurements and observations we fill in the forms, which can be found on the Globe at night web page: [www.globeatnight.org](http://www.globeatnight.org).
5. Comparing observations with the other thousands of observations around the world\_[5];



**Fig. 6:** Magnitudes charts (Orion).



**Fig. 7:** Magnitudes charts (Leo).

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## Using Sky Quality Meter (SQM) to Measure Sky Brightness

The measurements conducted using the SQM (Fig. 8) take the activities in GaN program to a higher level - the participants in the Globe at night program gain scientific experience, as well as the measurements are more precise.



**Fig:8:** SQM – L model.

There are two models of SQM's. The SQM-L-model is newer, but both of them are easy to use. The difference between the models is the location of the display and the power button. On the SQM-L model [Fig: 8] the power button and the display are on the same side, which means that you would not have to change the position of the meter in order to observe. On the SQM model the display and the sensor are not on the same side [1].

The observations take place outdoors, in the evening, and after sunset (from 8 p.m. to 10 p.m.). The night sky should be watched before the Moon is set too high, and the sunset occurred at least one hour ago. Otherwise, the glare from the Sun and the Moon will affect the observation.

The SQM is influenced by the outdoors temperature, thus it is better to leave it outdoors at least for 5 minutes to adjust to the temperature and then to continue with the observation. The meter should not be used near any streetlights or any other source of artificial light, nor under the shadows of buildings and trees. Another rule states that the SQM should be away from a street light at least 7.5 meters, if possible. The SQM should be held above the head pointed towards the zenith, so that the shadow or the reflection of the observer would not influence the observation. Also, the instrument should be held firmly, without moving or shaking. The button should be pressed only once in order to start the observation. The SQM will beep every second while collecting the photons. The observation is finished after the last beep, and then the display should be read. Under the urban sky (in urban areas), the result is shown almost immediately. When the sky is very dark, the results appear after a minute or more [5]. To complete the procedure, the serial number of the instrument is required; it will appear if the start button is pressed for one second. Firstly, the temperature appears in degrees Celsius {°C} and degrees

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Fahrenheit {°F}, secondly the result from the observation, and thirdly the serial number of the instrument.

SQM and SQM-L measure how much light is registered by the sensor. Then the meter transforms the quantity of light into unit magnitude on arc-square second. The higher the number shown on the display, the darker the sky is. The value of 21 presents a very dark sky, but the value of 16 presents a light polluted night sky. SQM is a precise instrument with a precision of  $\pm 10\%$  ( $\pm 0,10 \text{ mag/arc sec}^2$ ). The magnitude arc square second is a logarithmic measuring unit, so when there are great changes in the brightness of the sky there are only small value alterations shown by the instrument.

The difference of one magnitude is defined as a factor of  $(100)^{(1/5)}$  in received photons. As a result, the brightness of the night sky of  $5,0 \text{ mag/arc sec}^2$  equals the declination of degree of photon arrival for 100 factor. We can transform the SQM-L value from  $\text{mag/arcsec}^2$  in  $\text{cd/m}^2$  using the following relation:

$$1 \text{ cd/m}^2 = 10,8 \cdot 10^4 \cdot 10^{(-0,4 [\text{mag/arc sec}^2])}$$

The marked points on the maps below (Fig. 9 and Fig. 10) represent the observation of the illuminated night sky. The lighter the point is, the lighter the sky is, the darker the point is the darker the sky [5]. The lightest point (magnitude 1) can be seen over the major cities. There, only few stars are visible in the night sky. The magnitude 7 can be seen over a national park for example, or outside the settlements, where there are not any city lights. According to Bortle Dark-Sky Scale there are few excellent dark-sky sites, where to the unaided eye, the limiting magnitude is 7.6 to 8.0 (with effort) and is possible to see more than 2000 stars at the same time [9]. When so many stars are visible, it is difficult to tell the constellations apart.



**Fig. 9:** Results from Globe at night campaign in 2012 from Macedoni. **Fig. 10:** Results from Globe at night campaign in 2012 from Prilep.

All the above-mentioned results then should be sent via Internet using the following web page: <http://www.globe.gov/Gaiv/report.html> during the Globe at night campaign or in the following two weeks. With our continuous observation we hope that we would contribute to the campaign against light pollution.

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**Table 1:** The results from some of our recent observations:

N:	Date	Local time	Long.	Lat.	Mag.	SQM -L value (mag/arc sec <sup>2</sup> )	Comment on location	Comment on the sky and cloud coverage
11	2012/01/14	20:15	21.562	41.346	3	17,42	The measurement is done on a parking in Prilep. There are two streetlights at a distance 50 m from my location.	No clouds. The sky is clear. Constellation Orion is visible.
12	2012/02/18	20:58	21.534	41.345	4	17,37	There is snow cover and air temperature below zero degrees Celsius.	25% of the sky covered by clouds. Yet Orion is visible.
13	2012/03/16	20:40	21.542	41.354	5	19,31	Near the Faculty of Economy in Prilep. There are lights at 50m distance from my location.	Leo constellation is visible, but also the constellation Orion can be seen.
14	2012/04/11	21:47	21.543	41.352	0	16,30	Urban location	> 50% cloud cover, the Leo is visible. Not actually seen any astronomical source of light in the sky.

### 3. CONCLUSIONS

Is light pollution important? When talking about astronomy, it negatively affects astronomical observations. Astronomy is rooted in history and culture and has practical applications. It contributes to the advancement of mathematics and computer science, science and technology. It is a dynamic science, and every year many of the most important scientific discoveries are in the field of astronomy or in related fields. It also has emotional and aesthetic dimensions, inspired many artists and poets for centuries. In school, it can be used to teach concepts such as light pollution, to give students meaningful appreciation for the scale of distance and time and to illustrate observational approach to the scientific method. Or, according the words of Henri Poincare, „*Astronomy is useful because it shows how small our*

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*bodies, and how large our minds are*". Light pollution is promising topic of promoting science education because it can be transferred in other science topics [3].

Measuring light pollution includes: astronomy activities (students investigate the effects of light pollution and other factors and estimate limiting magnitude of stars which they can see), physics activities (students use instruments, observe various natural and artificial light sources in their local environment), and science and society activities (students investigate the types of lighting in their community, the effectiveness of lighting and promoting better lighting in many different ways).

Our future plans with Globe at night campaign include the following: to continue with this program and measurements; to involve more students; to continue SQM measurements throughout all year; to create new projects inspired from the GAN, etc.

From our experience, education is the first step in preserving the astronomical sky. In addition, the education takes place in variety of situations, outside the classroom. Non-formal education is an ideal way to educate people about the beauty of the night sky. In this direction, a campaign in the town of Prilep is planned in cooperation with the local authorities responsible for that issue. Our intention is to encourage others to take part in citizen science projects to measure light pollution, to write letters to the local newspaper and businesses and finally, to promote the use of compliant fixtures and shielding, which will lead to their installation in our community. Of course, for this purpose we will use the results of the measurements that were made last five years at various locations in the municipality of Prilep and the surrounding area. That does not mean that we have not informed the public yet, but the campaign is planned as series of many activities, on a higher level and with big number of inhabitants. We hope that it will help to consider the issue of the fight against light pollution in our country seriously and finally, to adopt of a law for dealing effectively with light pollution.

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