

Let's turn off the lights and turn on the night: to the rescue of starlight in an age of artificial lighting

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Abstract. Our ancestors contemplated an inspiring night sky of science, philosophy, art ... today, it is estimated that one third of the world's population have never seen the Milky Way. The progressive degradation of the quality of the night sky due to an inappropriate use of the artificial light at night, as well to other sources of sky pollution, must be considered as the fundamental loss of a scientific, cultural and environmental heritage of humanity.

In this public talk we summarized the most relevant aspects of light pollution, the reasons for promoting good lighting to protect dark skies, and some of the initiatives at a global level that are being developed to preserve the darkness of the night sky.

Keywords. Keyword1, keyword2, keyword3, etc.

1. Introduction

What is meant by a dark sky? A dark night sky is the one that shines only naturally due to the weak emission of molecules from the Earth's atmosphere (known as 'airglow') and the brightness of faint natural sources of light such as the zodiacal light, gegenschein (the sunlight scattered by interplanetary dust particles concentrated around the ecliptic), the Milky Way, and diffuse celestial objects. Of course, the natural sky darkness must be evaluated in the absence of moonlight and twilight (so when the Sun is about 18 degrees or more below the horizon, so their refracted radiation by the atmosphere cannot longer reach our visual).

To assess the brightness of the sky the Bortle (2001) scale is commonly used, which subjectively characterizes the quality of the night sky in a given location, by giving an arbitrary class number to a given site and set of observing conditions. Spoelstra (2002) relates the Bortle scale to the visibility of the Milky way, the limiting visual magnitude, and the number of stars visible above the horizon. For instance, class 1 corresponds to a natural, unpolluted dark sky, with a Milky Way rich in details, an approximate visible stellar magnitude of 7, and between 5.000 – 6.000 visible stars at the hemisphere. A class 9 corresponds to the most polluted skies. Class 4 corresponds to a sky brightness of about 20-21 mag/arcsec² (the Milky Way lacks details, and the approximate visible stellar magnitude is about 6). For class 5 the Milky way is faint in the Zenith, the approximate visible stellar magnitude is 5 to 6, and there are between 1.000 to 2.000 visible stars at the hemisphere. For classes 8-9 the Milky Way is not visible, the approximate visible stellar magnitude is between 0 and 4, and the number of visible stars at the hemisphere is between 5 and 300.

A quantitative way of expressing sky brightness is to use physical units for surface brightness, given that the night sky can be considered as a hemispherical surface with

the observer at the centre. A popular unit of night sky brightness is magnitudes per square arc second (mag/sq arc sec). A star of visual magnitude 21 is a million times fainter than a naked eye star of magnitude 6. Although stars are essentially point sources of light, we can imagine that light being spread over a tiny square in the sky, whose side in angular measure is 1 arc second. If the whole sky had the same surface brightness as this tiny area, then the sky brightness would be 21 mag/sq arc sec. The darkest possible skies are about 21.7 mag/sq arc secs, and this figure represents a typical value of the natural airglow which is always present. A Bortle class 1 corresponds to a sky brightness of about 21-22 mag/sq arc secs. A sky which is 20 times brighter than this natural airglow background would be about 18.5 mag/sq arc secs and this would be a typical value in many urban environments. If the sky is 100 times brighter than the natural airglow background, then the brightness would be 16.7 mag arc secs, a value found in the central areas of the world's large cities with Bortle class 8.

The darkness of the night sky as a scientific and cultural heritage. A dark sky is essential for astronomical observations carried out from ground-based facilities. Without dark skies, astronomers are unable to receive the faint signals of light from distant objects in outer space. Dark skies are also an important part of the cultural and natural heritage of all civilizations. Today, it is estimated that one third of the world's population - including millions of children - have never seen the Milky Way. Many astronomical observatories are built in remote locations in an effort to escape the light of cities and towns. Even so, these observatories are threatened by light pollution. The progressive degradation of the quality of the darkness of night sky must be considered as the fundamental loss of a scientific, cultural and environmental heritage of humanity. The dark night sky must be regarded as an endangered natural resource.

What is light pollution? Light pollution is caused by the excessive or inappropriate use of artificial light at night. Light pollution is the sum of all adverse effects of artificial light at night, consisting of spill light emitted by a lighting installation which falls outside the boundaries of the property for which the lighting installation is designed and because of quantitative or directional attributes, gives rise to annoyance, discomfort, distraction, or a reduction in ability to see essential information. As a result of the artificial light scattered by the air molecules or aerosol particles in the Earth's atmosphere, the brightness of the night sky is increased causing the stars to be less visible as a result of reduced contrast.

Although concern about light pollution arose in the astronomical field, since the beginning of this century studies have been developed that show how light pollution also harms our health, wildlife and ecosystems. These problems, added to the waste of energy resources, show the importance of properly regulating artificial lighting at all levels.

2. Overview

Issues caused by light pollution. In addition to the brightening of the night sky which harms observational astronomy, the light pollution of the night sky has adverse effects on human health, the bio-environment and biodiversity. It also causes electricity and then energy waste. It can be regarded as one of the most widespread forms of environmental pollution. In regard to its effects on plants, animals and human health, it has been proven that the light pollution (mainly its blue-white component) alters the growth of plants, terrestrial and marine species, migratory birds, bats, amphibians, reptiles, insects, etc. Not only animal physiology is affected; so is the human as it affects our circadian rhythms of about 24 hours. Life has evolved in the alternation of day (natural light) and night (darkness). It should come as no surprise then that the uncontrolled sweep of the night darkness alters the physical and psychological health of humans and animals. Excess

of artificial light is a silent threat to our health: it alters our sleep regulators and cell regeneration. Certain cancers of hormonal origin occur significantly in higher numbers in areas contaminated by artificial light. The pineal gland needs darkness to produce the hormone melatonin. Excessive night lights decrease the production of this chemical. As an agent of the immune system, melatonin helps suppress many hormonal cancers.

But light pollution is not the only source of sky pollution due to the increasing radio pollution (cellphones, sensors, etc.), the aircraft routes, the atmospheric pollution, and the mega constellations of satellites. Over the centuries, astronomy has evolved, becoming one of the sciences that most uses and promotes the development of space exploration and new technologies. Paradoxically, today some of these technological developments are turning against it: the sources of light pollution in the night sky must now be added to the mega constellations of satellites. These are large conglomerates of telecommunications satellites in low-altitude orbits that will be starting operations at the end of 2020, and whose brightness and frequency will have a huge negative impact on scientific astronomical images as well to the night sky landscapes.

Global Initiatives to preserve the darkness of the night sky. Some main international organizations involved in dark sky protection are: the International Astronomical Union (IAU) Commissions C.B7 and C1, and the Working Groups on Dark and Quiet Sky Protection, the International Dark Sky Association (a non-profit organization founded in 1988 based in Tucson, Arizona), the Starlight Foundation (a non-profit organization created in 2009 by the Instituto de Astrofísica de Canarias (IAC) to promote the Starlight Initiative, supported by UNESCO, UAI and UNWTO).

Regarding declarations, international and national regulations to protect dark skies it is worth mentioning: the UNESCO Universal Declaration of the Rights of Future Generations, La Ley del Cielo (Law of the Sky; Law 31/1988) of Canary Islands, Spain (to facilitate its application, a technical office for the protection of sky quality was created in 1992), and the Starlight Declaration in "Defense of the Night Sky and the Right to Starlight" (April 19 and 20, 2007, La Palma, Canary Islands). The United Nations Office for Outer Space Affairs and Spain, jointly with the IAU, organized on October 2020 a Conference (online workshop) with the title *Dark and Quiet Skies for Science and Society*. The event will result in a document that describes what measures Governments and private enterprises can adopt to mitigate the negative impact of technological implementations on astronomy (e.g. urban lighting, radio broadcasting and satellite constellations' deployment) without diminishing the effectiveness of the services they offer to citizens. The final outcome document, intended to become a reference to further analysis of the situation, will be presented to the intergovernmental Committee on the Peaceful Uses of the Outer Space (COPUOS) for consideration.

Finally, some highlighted IAU Citizen Science projects/programs engaged in preserving dark skies like Globe at Night, Cosmic light Kit, IYL Quality Lighting Teaching Kit, NASE Kit, IAU100 Dark Sky Ambassador, IAU100 Dark Skies for All, "Turn on the Night" educational kit, Dark Skies Rangers and Adopt an Street.

The astronomical tourism: the dark sky as an economic resource. It is an innovative form of sustainable tourism based on a natural, free and infinitely renewable resource, provided that the darkness of the night sky is preserved. It promotes astronomy and science in general, and revalues the cultural, historical and environmental heritage. It constitutes an engine of socio-economic development for rural areas and a creator of quality employment, fostering roots. It contributes to the seasonal adjustment and decentralization of tourism. It makes the sky unique in the territory: each place has its own conditions (historical heritage, observatories or scientific centers, nature and biodiversity,

archaeo astronomy, paleontology, geology, ethnography and local gastronomy) that must be united with the sky and the interests of the visitors.

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