

# 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.** astronomical heritage, dark skies, artificial light at night, light pollution

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## 1. Introduction

### 1.1. *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 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 (Bortle 2001). A sky brightness nomogram by H. Spoelstra † 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. 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.

As stated in the report by the Dark Sky Oases Working Group of the *Dark and Quiet Skies for Science and Society* Conference (see Section 2.2), 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 center.

† <http://www.darksbiesawareness.org/nomogram.php>

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 22 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.

### 1.2. *What is light pollution?*

Light pollution is caused by the excessive or inappropriate use of artificial light at night. As stated in the report by the Dark Sky Oases Working Group of the *Dark and Quiet Skies for Science and Society* 2020 Conference (see Section 2.2), 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.

### 1.3. *The darkness of the night sky as a scientific and cultural heritage in danger*

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. 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 (Cheung 2018). Today, it is estimated that a huge fraction of the world's population – including millions of children – have never seen the Milky Way. 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.

## 2. Overview

### 2.1. *Good reasons to fight against 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, as documented by the International Dark-Sky Association (see Section 2.2) and the World Health Organization. For a comprehensive review of

publications on this topic see the report of the Bio-Environment Working Group of the *Dark and Quiet Skies for Science and Society* 2020 Conference. Light pollution can be regarded as one of the most widespread forms of environmental pollution. It also causes electricity waste (so energy waste), as it is evidenced by the *New World Atlas of Artificial Night Sky Brightness* (Falchi *et al.* 2016).

Circadian rhythms of roughly 24 hours regulate many of the most important functions of the human body, such as hormonal secretion, digestion, sleep, and metabolism. Many species of fauna and flora show strong sensitivity to the daily light-dark cycles imposed by the earth's rotation, with a vast majority of animals (including crucial pollinators, many mammals and migratory birds) being nocturnal. It should come as no surprise that the uncontrolled sweep of the night darkness due to the increasing light pollution alters the physical and psychological health of humans and animals. For instance, the exposure to light at night decreases the production of melatonin, which as an agent of the immune system helps to suppress many hormonal cancers.

Despite their better energy performance and more modern technology, light-emitting diodes (LEDs) do not help decrease light pollution (Cheung 2018). The low cost white LEDs have a strong blue component in their spectrum, which scatters easily into the atmosphere. For this reason, traditional outdoor Sodium lamps are better to reduce light pollution. These warmer colored lights also have the advantage of a spectrum with relatively narrow bands that can be filtered during astronomical observations.

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, some of these technological developments are turning against it. The sky is also polluted by artificial radio signals, including the increasing contribution of electronic devices such as cell phones, sensors, etc. The aircraft routes also constrain the astronomical sites. But recently a bigger threat has emerged: the mega constellations of satellites. These are large conglomerates of telecommunications satellites in low-altitude orbits that would 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. Mitigation techniques are currently under study, such as reducing the brightness of satellite surfaces, or the development of algorithms to remove satellite trails from CCD images.

## 2.2. Global Initiatives to preserve the darkness of the night sky

Two leading international organizations dedicated to protecting the night sky and promoting astronomy-related activities are the *International Dark-Sky Association* (IDA)<sup>†</sup>; a non-profit organization founded in 1988 based in Arizona, and the *Starlight Foundation*<sup>‡</sup>; a non-profit organization created in 2009 by the Canary Islands Astrophysics Institute, supported by the UNESCO, the IAU and the UNWTO, to promote the *Starlight Initiative*<sup>§</sup>. The International Astronomical Union (IAU) has Commissions and Working Groups on Dark and Quiet Sky Protection under Division C.

*La Ley del Cielo* (Law of the Sky; Law 31/1988) of Canary Islands was a pioneering law in defense of the night sky. The United Nations Office for Outer Space Affairs and Spain, jointly with the IAU, organized on October 2020 the *Dark and Quiet Skies for Science and Society* Conference<sup>¶</sup>. The event will result in a document that describes what measures Governments and private enterprises can adopt to mitigate the negative

<sup>†</sup> <https://www.darksky.org/>

<sup>‡</sup> <https://www.fundacionstarlight.org/>

<sup>§</sup> <https://www.starlight2007.net/>

<sup>¶</sup> [https://www.unoosa.org/oosa/en/ourwork/psa/schedule/2020/2020\\_dark\\_skies.html](https://www.unoosa.org/oosa/en/ourwork/psa/schedule/2020/2020_dark_skies.html)

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.

The International Dark-Sky Association proposes five principles for responsible outdoor lighting: 1. All light should have a clear purpose, and before installing or replacing a light, determine if light is needed, and its impact on wildlife and the environment; 2. Light should be directed only to where needed, and use shielding and careful aiming; 3. Light should be no brighter than necessary; 4. Light should be used only when it is useful, and use controls such as timers or motion detectors if needed; and 5. Use warmer color lights where possible, and limit the amount of shorter wavelength (blue-violet) light to the least amount needed.

Excessive lightning, or poorly designed outdoor lighting, can cause glare and therefore unsafety. We must bear in mind that good outdoor lighting is not about lighting *less* but about lighting *better*.

Education and outreach are essential to create public awareness of the importance of promoting good lighting and preserving the darkness of the night sky. In this sense, some of the most successful and recognized citizen science projects, with the endorsement of the IAU, are: the *International Year of Astronomy Dark Skies Awareness*<sup>†</sup>, *Globe at Night*<sup>‡</sup>, the *International Year of Light Quality Lighting Teaching Kit*<sup>§</sup>, and the *IAU100 Dark Skies for All*<sup>¶</sup>.

### 2.3. Dark sky oases and astro-tourism

Dark sky oases, also known as dark sky places, are areas where the night sky has some form of legislative protection from the effects of the artificial light. Such protected areas are certified by an internationally recognized accreditation organization, mainly the International Dark-Sky Association and the Starlight Foundation. Dark sky oases can be used for different purposes such as astronomical research, astro-tourism, heritage values, wilderness areas for public education and outreach, etc. The Aoraki Mackenzie International Dark Sky Reserve in New Zealand, with IDA accreditation, became in 2012 the first recognized dark sky oasis in the southern hemisphere, and the largest in the world. La Palma Starlight Reserve in the Canary Islands was the first to be certified by the Starlight Foundation in 2012.

Astro-tourism can be regarded as 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. Contributes to revalue the cultural, historical and environmental heritage, constitutes an engine of social-economic development for rural areas and creates quality employment, besides promoting astronomy and science in general.

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<sup>†</sup> <http://www.darks skiesawareness.org/>

<sup>‡</sup> [www.globeatnight.org](http://www.globeatnight.org)

<sup>§</sup> [www.noao.edu/education/qltkit.php](http://www.noao.edu/education/qltkit.php)

<sup>¶</sup> <https://darks skies4all.org/>