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ORIGINAL RESEARCH

Dark skies and dark screens as a precondition for astronomy tourism and general well-being

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Abstract

Light pollution is one of the fastest-growing pollutants of the environment and considering the amount and diversity of negative consequences, it is a highly interdisciplinary subject. So far, most of the research about the negative influence of light pollution on human health was based on the disruption of the circadian clock, sleep deprivation, and other physical diseases. Together with artificial lighting, the rapid development of information and communication technology significantly contributed to the increased lighting levels in the indoor environment and at the same time influenced the perception of natural darkness as something unnatural and undesired. On the other hand, the same technologies can be a useful asset in the popularization of astronomy-related activities, thus promoting the necessity for dark skies preservation. This paper aims to emphasize the importance of dark skies and appropriate usage of ICTs in the nighttime hours for our psychological health and well-being in general and at the same time to propose astronomy tourism as a part of the sustainable tourism offer as a tool for fighting light pollution.

Keywords Astronomy tourism · ICTs · Light pollution · Dark skies · Well-being · Mindfulness

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1 Introduction

Light pollution can be considered as one of the negative products of urbanization processes that are rapidly increasing worldwide (Mizon 2002; Bjelajac and Đerčan 2019). The main consequences of this type of pollutant can be grouped into the following categories—the disappearance of dark skies due to the skyglow, the disruption of biological timings and general behavior of animals and plants, significant economic and energy loss, and degradation of human health (Mizon 2002). As most environmental pollutants, light pollution is also perceived as an outdoor threat, thus, Hollan (2009: 3) defined light pollution as "the alteration of light levels in the outdoor environment (from those present naturally) due to man-made sources of light". Furthermore, given the rapid development of artificial lighting technology for the indoor environment that can be harmful as well, Hollan (2009: 3) provided another definition of indoor light pollution perceived as "such alteration of light levels in the indoor environment due to sources of light, which compromises human health". According to the numerous studies (e.g. Punamäki et al. 2007; Ononogbu et al. 2014; Mei et al. 2018), the most common health issue caused by inadequate artificial lighting is sleep deprivation. Likewise, the extensive usage of Information and Communication Technologies (ICTs), TV viewing, or playing video games in the night-time hours can also lead to insomnia, poor sleep quality, and reduce the number of sleeping hours (Punamäki et al. 2007; Thomée et al 2007; Nakajima et al. 2017). Besides delaying bedtime, it also influences on various health problems, such as reduced melatonin secretion, cardiovascular diseases, obesity, or abnormal glucose metabolism (Ononogbu et al. 2014). In addition, the loss of dark starry sky could potentially influence certain psychological or even philosophical issues regarding human existence. Numerous scientists and artists have gazed into the starry night sky searching for answers about natural processes, or just to get inspired. Since such scenery is no longer available for most of the urban and suburban citizens born at the beginning of the twenty-first century, then the question "could starry night skies and natural darkness fall into the oblivion because of the generational amnesia?" must be raised (Lyytimäki 2013).

Together with the disappearance of dark skies and rapid technological development, astronomy tourism has emerged as a counterweight. Given the complexity of such travels, numerous definitions encompass different aspects of astronomy tourism. However, the underlying concept of this form of tourism is based upon the special interest of tourists to engage in astronomy-related activities such as sky observation, astrophotography, or visitation to specific sites (Cater 2010; Weaver 2011; Soleimani et al. 2019). Light pollution played a key role in forcing many of the amateur/professional astronomers to travel long distances to experience the dark starry skies but also provided additional value and the possibility for tourism development in isolated and remote areas with dark skies (Wen 2017). Furthermore, even if the ICTs can negatively influence our health in the night time hours, they can also be a useful asset when it comes to astronomy tourism. Star charts, calendars of astronomy events, and the possibility to use the real-time

location to navigate the vast surface of a night sky are some of the best features that ICTs can bring to astronomy tourism. Not only it is helpful to the amateur/professional astronomers, but also to the various astronomy and nature lovers that are enjoying a simple stargazing experience, thus, widening the group of people interested in similar travels. However, the negative influence of ICTs in overall tourism experience should not be neglected (Pearce and Gretzel 2012; Aayeh 2018). According to Laing and Crouch (2005), astrotourists are mostly motivated by intellectual stimulation through learning, exploring, or imagining which presents a form of active relaxation from everyday life and workplace. Also, most of the dark-sky related activities (e.g. stargazing, astrophotography) are performed in far and isolated areas in a natural setting, so it can be argued whether such travel destinations can be considered also as a restorative tourism destination (Wyles et al. 2017; Gill et al. 2019). As reported by Kaplan and Kaplan (1989) there are four qualities of a restorative environment, where "being away" refers to "being psychologically, and often geographically, removed from normal routines and distractions" (Gill et al. 2019: 2). Therefore, even though ICTs offer useful content to the astronomy-related activities, they can negatively influence the well-being benefits of the tourism experience because of the distractions that go in hand with ICTs (Cai, McKenna and Waizenegger 2020).

The diversity of astronomy tourism is also reflected in the fact that most of the dark-sky observation related travels are perceived as a form of sustainable tourism as well (Rodrigues et al. 2015). According to UNWTO (United Nations World Tourism organization), sustainability principles are reflected in environmental, economic, and socio-cultural aspects of tourism development (WTO 2013). As for the environmental principle, the most important resource of astronomy tourism is dark starry skies which need no maintenance and are an unexploitable environmental resource. However, the preservation of dark skies and mitigation of light pollution is a necessity, considering the alarming rate of artificial lighting in the outdoor environment as well as certain infrastructure (such as roads and accommodation facilities) made for facilitating astronomy tourism. Hence, astronomy tourism destinations with appropriate preservation measures could aid and protect the immediate environment from light pollution, but at the same time, if not properly managed, potentially contribute to air quality degradation, noise pollution, and other unknown negative influences on the so-far isolated areas. As stated, dark skies are usually found in remote areas away from the urban civilization, which is probably one of the most effective ways to bring tourists closer to nature and rural areas providing socio-economic benefits for the so far neglected settlements (Najafabadi 2012; Jacobs et al. 2019). The contribution of astronomy tourism to the inter-cultural understanding and tolerance of host communities is best perceived through the example of the recent solar eclipse in March 2016, that attracted more than 100,000 domestic tourists and 10,000 foreign visitors to the island of Sumatra. The physical setting of the solar eclipse at Sumatra provided an opportunity for locals to organize events such as cultural festivals and dragon boat races around the time of the solar eclipse. Therefore, cultural content added to astronomy tourism has prolonged the stay of astrotourists before and after the astronomical event (Wen 2017).

Starting from the fact that dark skies are rapidly disappearing, while bright screens and artificial lighting are more and more present in our lives, this paper aims to present the negative effects of overly bright nights and screens before us, but at the same time to acknowledge the potential relationship between astronomy tourism and well-being tourism experience. First, we briefly overview the evolution of artificial lighting, to understand the primary causes and negative effects of the disappearance of dark starry skies. After a thorough explanation of causes and effects, the general principles of the well-being concept are presented and linked to the importance of controlled usage of ICTs in nighttime hours, natural darkness, and starry night skies for our physical and psychological health. As finally, astronomy tourism is presented as a great opportunity for changing perceptions towards and bringing more "darkness" in our daily lives, while at the same time improving our general well-being. On the other hand, astronomy tourism is considered as a useful tool not only in reducing light pollution through educational activities but also as adding value to remote or underdeveloped destinations.

2 The disappearance of dark skies and rise of astronomy tourism

Before the dawn of history, early humans saw the world as a small patch of land usually bordered with high mountains or deep rivers and seas. The Sun above them provided them with the energy, light, and warmth, and nights that were filled with countless stars. The sight of the prehistoric night sky often inspired early humans to use some of its motives in primitive art expressions found on everyday tools and jewelry (Malville 2008; Collison and Poe 2013; Fayos-Solá et al. 2014). As humans evolved, so did the fascination with the night sky, which eventually led to some of the most important scientific discoveries that were crucial for our survival. Early cultures managed to predict seasons, rains, droughts, and other climatological events only due to the precise and cyclic movement of celestial bodies. First calendars were mostly based on the movement of the Sun and Moon and the earliest overseas migrations were navigated solely by the position of certain constellations during the year (Boorstin 1983; Williamson 1984; Miller 1997). However, natural darkness was also life-threatening for early humans which had to protect themselves from nocturnal predators and often extremely low temperatures. Since the evolution of humans lasted for more than 2 million years and the first modest public lighting was designed only a few centuries ago, this primal fear of the darkness was and still is significantly present in our response to the nighttime environment (Packer et al. 2011). Therefore, despite the fascination and the knowledge people have gained from nearly observing the night sky, there was an undeniable tendency to penance the night and bring the light into it (Brox 2009).

The evolution of artificial lighting from the first fire torches to the light-emitting diodes (LED) we use at present, had lasted for more than 400,000 years. From the earliest civilizations until today, people have been constantly searching for new ways to improve lighting, not only because of the primal fear mentioned before but also to prolong our daytime activities and accelerate the overall progress (Spear 2013; Bjelajac and Đerčan 2019). However, the first degradation of the night sky quality

began only two centuries ago (1792), when William Murdok invented a gas lamp and lighted his own house with it. Before long in 1820, Paris implemented this invention into the main streets and earned its nickname as "The City of Light", which followed a rapid rise of the gaslighting in other parts of the world as well. One year later, historian Stephen Godlfarb notes that there is no town in the United Kingdom with more than 50,000 people without a company that produces gas lamps. In the next 200 years, every settlement with more than 10,000 inhabitants degraded their dark night sky with implementing this type of public lighting (Brox 2009). Nevertheless, numerous negative effects of the gaslighting system pushed inventors and scientists further into the pursuit of bright nights. Thus, along with the improvement of gas lamps, several factories worked on developing electric lights, or the first electric light bulbs in the world. It can be stated that the modern era of artificial lighting officially started with the invention of low-pressure sodium lamps during the 1930s, and afterward high-pressure sodium lamps in 1964 which quickly spread worldwide and are used by this date (Brox 2009; Spear 2013; Bjelajac and Đerčan 2019). Based on the data presented so far, it can be roughly estimated that modern artificial lighting occupies only 0.01% of the entire period since hominids established control over fire. From the first fire torch, over approximately 400,000 years ago, to the present LED lighting, no form of artificial lighting has succeeded so dramatically in altering the view of the night sky as did the modern lighting over the last 60 years of its existence (Fig. 1).

The first scientific paper about the new form of pollution of the nighttime environment caused by artificial lighting was published in 1973 by the title "*Light pollution—outdoor lighting is a growing threat to astronomy*" (Riegel 1973). Since then, there is a growing body of research showing how scattered and over intensive artificial light negatively influences not only astronomers and their view of the night skies but also living beings and entire ecosystems (e.g. Bennie et al. 2016; Dominoni et al. 2016; Davies and Smyth 2017). At the beginning of the twenty-first century, lighting sources and technology have experienced another revolution, the invention of light-emitting diodes (LEDs), which peak in the

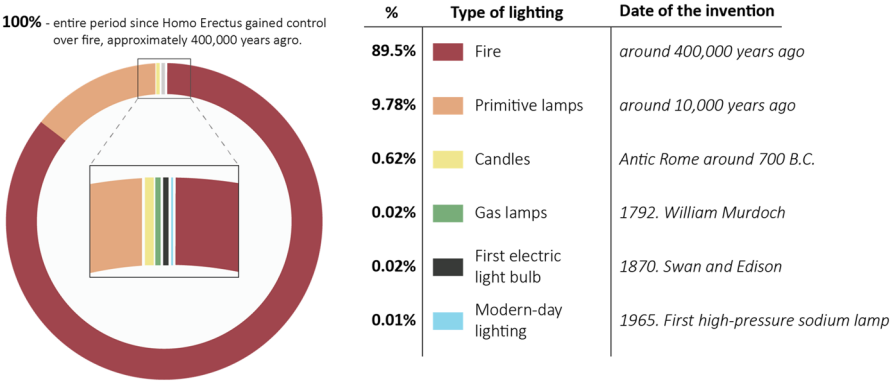

Fig. 1 Schematic representation of artificial lighting evolution since the first-time control over the fire was established (adapted according to Brox 2009)

short-wavelength region, thus emitting the high brightness white light. However, in recent years, numerous studies have shown that short-wavelength light can be responsible for suppressing melatonin secretion in the nighttime hours, leading to disruption of sleep, increased risk for obesity, and other serious diseases. What is more troublesome, LEDs are not only used for outdoor and indoor lighting but have become a part of ICTs as well (Tosini et al. 2016). Nearly all self-luminous devices (such as smartphones, tablets, TV sets, and other devices with displays) have integrated LED technology, and the "worst" of bad artificial lighting solutions is now excessively used in front of our eyes every night (Wood et al 2013). Accordingly, scientists have been quick to realize the ongoing trend of sleep degradation is mostly caused by overstimulating technologies with LED displays (e.g. Figueiro et al 2011; Cajochen et al 2011; Wood et al 2013; Exelmans and Van den Bulck 2016; Hale et al 2018). It is also important to note that throughout human evolution natural darkness and starry skies have influenced not only our biological clock but also inspired our creative expressions, scientific breakthroughs, and general well-being from a psychological point of view. Today, more than 50% of the world population lives in urban environments which are highly polluted with artificial lighting. This means that at least 4.2 billion people have no view of the natural night skies, which played such an important role throughout history (Falchi et al. 2016).

The most astronomical observatories that are built on the outskirts of the settlements in the last century are now endangered, not only by the expansion of the settlements but also by the intensity of public lighting that is constantly on the rise. Some observatories managed to tackle the issue of light pollution in the surrounding cities, but a lot of them are either closed or not fully functioning as they have before (Walker 1970). Likewise, many astronomers that are city dwellers have to travel further from the cities than ever before to find a clear night sky for the observations (Spenneman 2008). However, modern-day astronomical travels were initially triggered by the physical settings of the certain astronomical event (such as solar eclipse), but are now multiplied by the lack of dark skies nearby inhabited areas (Crouch 2001). Since astronomy tourism is still an underrated branch of tourism, there is yet no cumulative data on the scale of the astronomy market. Nevertheless, descriptive statistics indicate steady growth and according to the oldest astronomy education society "Astronomical Society of the Pacific," there are presently around five million astrotourists worldwide. Considering the limited academic literature, scientists and the tourism industry are not in compliance when it comes to defining or naming this type of tourism. In various scientific papers and website searches, this form of tourism is also referred to as "astronomical tourism", "celestial ecotourism", "terrestrial space tourism", "astrotourism" and similar (Weaver 2008; C-Sánchez et al. 2019). The term "astronomy tourism" will be used for this study, as it is most common and widely adopted in many astronomy tourism business operators and it is limited on the terrestrial surface opposite to "space tourism" which occurs in outer or atmospheric space. Astronomy tourism mainly consists of activities that are related to travels to destinations with preserved dark skies to observe and/or photograph astronomic phenomena/events or celestial bodies (it includes diurnal skies), visitations to astronomy-related historical sites or observatories, and tours with the

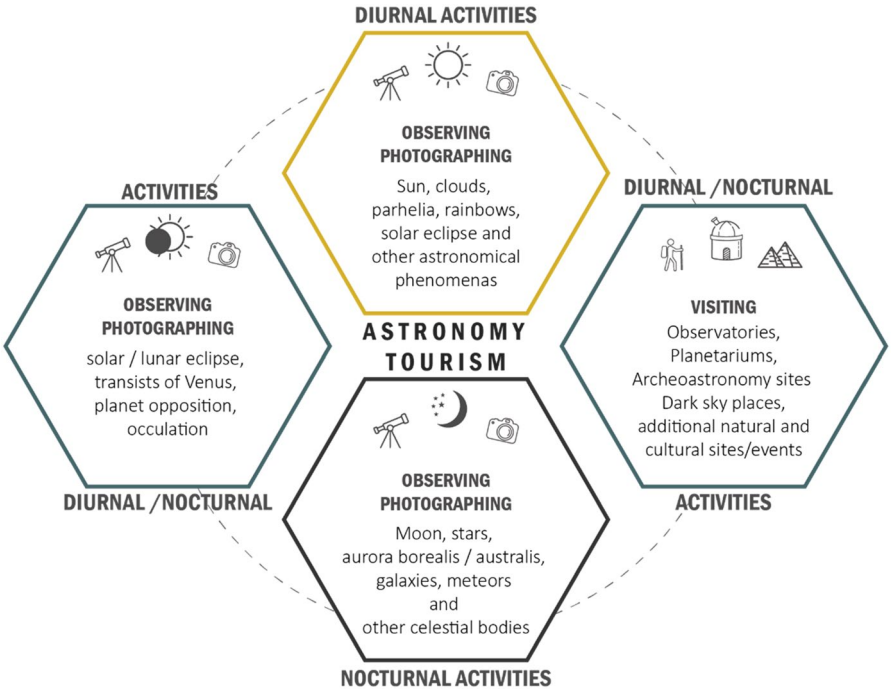

Fig. 2 Forms of activities in astronomy tourism depending on the time of the day (adapted according to Wen 2017)

participation of astronomical activities (Fig. 2) (Collison and Poe 2013; Fayos-Solà et al. 2014; Belij and Tadic 2015).

As stated, astronomy tourism favors stargazing locations such as observatories or important archaeoastronomy sites, but most of all, natural dark-sky areas of outstanding beauty. To experience and observe any astronomical phenomena or events on the night sky, two main conditions must be met—the absence of light pollution and appropriate atmospheric conditions (C-Sánchez et al. 2019). The most important stargazing weather conditions of the site are the absence of clouds, moisture, and high-percent of aerosols in the air (Walker 1970; C-Sánchez et al. 2019). Conveniently, most of the atmospheric conditions can be met in protected areas such as national parks, at high altitudes, and away from the inhabited areas (Fayos-Solá et al. 2014). International Dark-Sky Association (IDA), famous for fighting light pollution on a global scale, is one of the first worldwide organizations that made the big step towards the preservation of dark skies and the promotion of astronomy tourism for almost 20 years ago. In 2001, they formed a program called "International Dark Sky Places" (IDSPC) whose main goal is to encourage public communities, parks, and protected areas to preserve or to improve the quality of a night sky in their whereabouts, through responsible lighting polices and public education. Even though the main idea behind this program is to tackle the issue of light pollution, it is also a good starting point for creating the touristic offer through various workshops and

activities customized not only for astronomers but also for the public in general. This program offers six types of designations that are formed based on the quality of the night sky, the involvement of the local community, and the dark sky program for visitors. It was awarded National Environmental Excellence Award in 2015, for outstanding environmental contributions in the area of public involvement and partnerships by the National Association of Environmental Professionals (NAEP) in the United States (Weaver 2011; Collison and Poe 2013; C-Sánchez et al. 2019).

Besides IDA's Dark Sky Places, around three million tourists per year visit the observatories. Many of them are marketed as tourist attractions and for some of them, it is the main source of funding. Aurora borealis/australis viewing is one of the most attractive forms of astronomy tourism in the remote areas of far north/south areas of the planet and interest for this type of astronomic phenomenon has been rising steadily (Weaver 2011). For example, over the past decade, Northwest Territories of Canada have been investing in the "Aurora viewing market" and in 2015, around 15,000 astrotourists spent approximately 11.5 million dollars on their visits. The majority of them were females and overseas from China, Japan, and South Korea. Some tourism enterprises offer unique tours such as astronomy-themed cruises, international voyages across the Pacific Ocean, watching space shuttle launches, and similar. On the other hand, unlike most tourist activities that take place in daylight, astronomy tourism's underlying resource are the dark starry skies which can enrich the touristic offer for destinations that encountered decline or stagnation phase. Through the implementation of additional astronomy-related content, the length of tourist's stay could be prolonged and their nighttime activities would be diversified (Wen 2017).

In 2007, World Tourism Organization stated: "*it is surprising that tourism, increasingly sophisticated as it is, has limited itself in almost all cases to utilizing its natural and cultural resources only during daylight hours*" (Wen 2017). However, dark skies, as the underlying resource of astronomy tourism, are rapidly disappearing because of the light pollution of the environment. This type of pollution has also been underestimated by scientists for decades and since the most obvious consequence of overly bright artificial lighting is the disappearance of stars and other celestial bodies—astronomers were the first to raise the question about this subject in the 1970s (Riegel 1973). Almost 20 years later, the International Dark-sky Association has been founded (in 1988) as a non-profit organization with the main goal to protect the night skies for present and future generations (https://www.darksky.org/our-work/conservation/idsp/). As mentioned before, astronomy tourism is one of the tools which IDA uses to preserve dark skies or at least spread awareness about it. UNESCO (United Nation Educational, Scientific, and Cultural Organization) has also recognized the necessity to preserve the beauty of a starry night sky and launched an "Astronomy and World Heritage" project in 2003, where the astronomical heritage was defined. Within this project, resources of astronomy tourism were broadened from celestial bodies to terrestrial attractions such as historical sites, monuments, cultural landscapes, and anything related to the history of astronomy (https://whc.unesco.org/en/astronomy/). Furthermore, in 2007, the Institute of Astrophysics of the Canary Islands and other organizations (such as UNESCO, UNWTO, IAU) and institutions have organized the "First International Starlight Conference"

which, under the slogan "Starlight, a Common Heritage", emphasized the need to protect the night sky. The principles and recommendations for protecting the night sky have been brought together in "La Palma Declaration" (Declaration in Defense of the Night Sky and the Right to Starlight) and "The Starlight Foundation" was created in 2009 as an international movement in defense of the Night Skies and the Right to Starlight (https://fundacionstarlight.org/en/section/history/281.html). The tactic to protect the night sky by using responsible astronomy tourism is based upon the possibilities for cooperation among tourism stakeholders, local communities, and scientific institutions (Starlight Initiative 2007; Collison and Poe 2013). The Starlight Foundation invented the first astrotourism certification system called "Starlight Tourism Destinations" (STD) that, similarly to IDA's Dark Sky Places program, recognizes areas with excellent sky quality and conservation measures (https://fundacionstarlight.org/en/section/what-are-they/284.html). The main difference between the two is that Starlight Tourism Destinations already possess certain infrastructure for the astronomy tourism and satisfy atmospheric conditions for observations, while International Dark Sky Places do not necessarily have those conditions met, and are primarily directed towards the protection of dark skies and education about light pollution consequences. In addition to the high-profile organizations that are involved in the preservation of dark skies, "Astrotourism Working Group" has also been established in September 2019, by the joint effort of Starlight foundation and UNWTO. The main idea behind this group is to evaluate the potential of astronomy tourism and to create a space for networking and sharing experiences about how to combine Science and Tourism, starting with the astrotourism (https://fundacionstarlight.org/en/news/starlight-foundation-leads-the-unwto-scientific-tourism-astrotourism-group/148.html). It is also important to mention the activities International Astronomical Union (IAU) conducts through the "Commission 50" and a Working Group on "Controlling Light Pollution". Their main goal is to raise the awareness about the light pollution through scientific papers and conferences, and most of the studies are based upon usage of detailed satellite imaginary, which indicate that there will be no dark skies left for the bigger part of the of Europe within the next 25 years (https://www.iau.org/public/themes/light_pollution/). In the International Year of Astronomy 2009, the working group of IAU in collaboration with the International Council on Monuments and Sites (ICOMOS) produced a Thematic Study on the Heritage Sites of Astronomy which was published in 2010 by the name "Heritage Sites of Astronomy and Archaeoastronomy in the context of the World Heritage Convention: A Thematic Study" (Ruggles and Cotte 2017). Besides activities based on scientific research, IAU also formed "The Dark Skies for All" project in 2019, as a part of IAU100 Global Projects, whose main goal is to involve students and interested citizens as Dark Sky Ambassadors for public engagement on light pollution mitigation actions (https://darkskies4all.org/about/).

However, starry night skies are still rapidly disappearing from the cities and are increasingly scarce even in rural areas (Falchi et al. 2016). Uneven geographical distribution of dark skies has led to the separation between origins and destinations of astrotourists, thus, regions with the strongest market demand are the ones with the brightest night-skies (Fig. 3). According to the world atlas of artificial night sky brightness (Falchi et al. 2016), more than 80% of the world is influenced by light

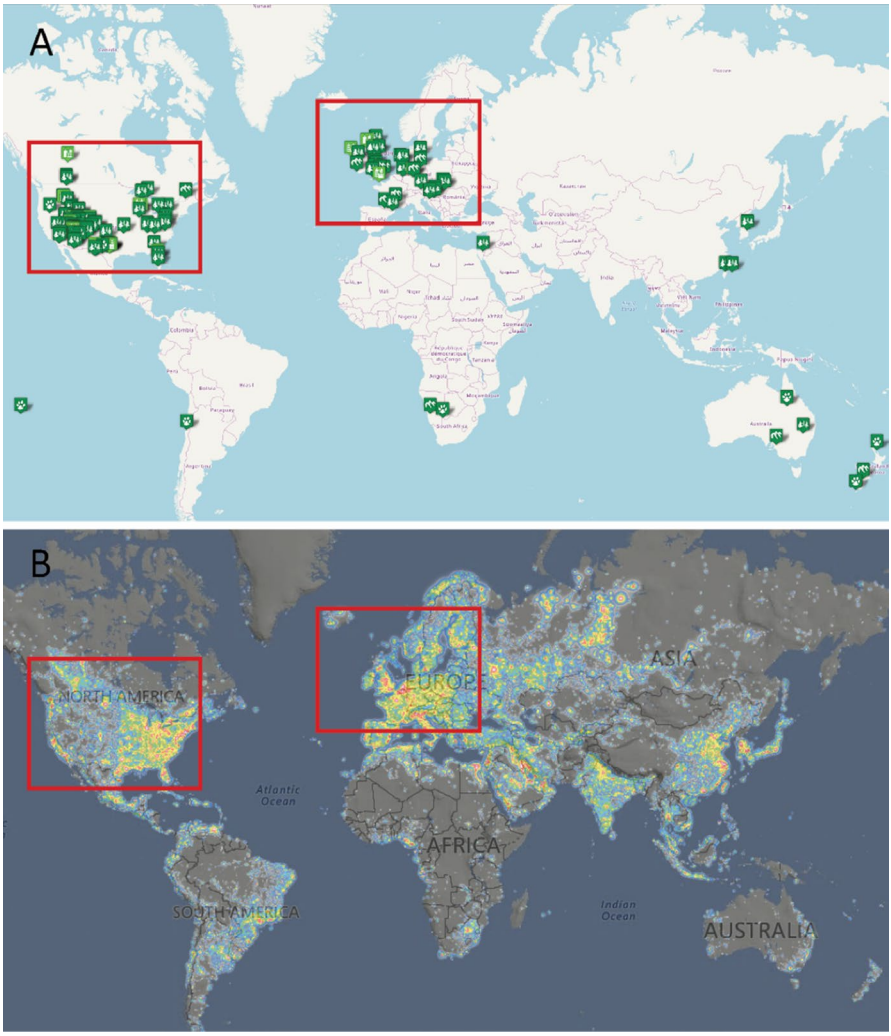

Fig. 3 **a** Dark-sky places locations (**b** Light pollution map (according to Falchi et al. 2016; Map source: lightpollutionmap.info) source: International Dark-Sky Association; Map source: www.darksky.org)

pollution, meaning that Milky Way is hidden for more than one-third of humanity. Correspondingly, 99% of the population in highly urbanized regions such as most of the Europe and United States live under the light-polluted skies. As a result, Europe and North America are the strongest markets, making them world-leading astronomy tourist destinations with more than 55% public observatories and planetariums in the world, and more than 90% of the IDA certified places (Dark-sky Program) (Fig. 3) (https://www.darksky.org/our-work/conservation/idsp/finder/). Astronomy tourism is also developing in Asia, Latin America, and Australia, where Asia mainly promotes educational astronomy programs for students, Chile and Brazil are famous

for their high-altitudes observatories, and Australia together with Oceania has preserved dark starry skies with unique constellations of Southern Hemisphere (Wen 2017).

3 The importance of darkness for general well-being

Almost 45 years ago, astronomer Richard Berry (1976) stated that many amateur astronomers of high school age in the United States have never seen non-polluted sky scenery. Around 30 years later, Cinzano et al. (2001) approximated that 40% of the citizens in the US cannot look at the night sky with the eyes adapted to the night vision because of excessive brightness. Considering the geographical extent of light pollution in the populated areas and repeated warnings about dark skies disappearance that started around 50 years ago, it can be assumed that a large part of the present generations born in urban areas are the first in the history that have grown up without direct contact with the starry skies (Collison and Poe 2013). Lack of natural darkness can seem harmless when comparing to health and environmental issues caused by inadequate artificial lighting. However, according to Lyytimäki (2013), modern people are most likely to suffer from a *shifting baseline syndrome*, defined as an alteration of human perceptions of biological systems due to loss of the experience of past conditions—in this case, naturally dark skies (Kahn and Friedman 1995; Pauly 1995). In such circumstances, people may view the current situation as the typical or normal state, completely unaware of the negative impact of light pollution on their health and environment, leading to both generational and personal amnesia (Kahn et al. 2009; Papworth et al. 2009). Generational amnesia refers to younger generations not experiencing past environmental conditions, or the clear night sky in this case, while personal amnesia occurs when individuals forget their own experiences (Lyytimäki 2013). Since light pollution can be characterized as an inevitable companion of urbanization processes, most of the population that is potentially affected by shifting the baseline syndrome lives under similar modern urban lifestyle conditions. Thereby, spending most of the time indoors especially during the night hours, and under constant artificial lighting (Pilgrim et al. 2008; Kahn et al. 2009; Lyytimäki 2012). Such separation and lack of direct contact with naturally dark environments may lead to the development of negative feelings and perceptions toward natural darkness as something unnatural, undesirable and dangerous (Bixler and Floyd 1997; Lyytimäki 2013). What is more, public lighting is usually perceived as an integral part of the urban nighttime environment, and more often than not, actions towards reducing over intensive and overly bright public lighting are not welcomed and approved by the public community (Mizon 2002).

As mentioned before, inadequate artificial lighting and lack of natural darkness in the urban nighttime environment can cause significant health issues. The most common problem is a sleep deprivation, which can be triggered by light intrusion/trespass (defined as unwanted, intrusive artificial lighting in private homes due to public or private outdoor lighting) or by excessive usage of self-luminous ICT devices (Punamäki et al 2007; Wood et al 2013; Yang et al. 2019). In some countries light intrusion/trespass is even considered as a public nuisance, thus the

owner of the artificial lighting (whether the individual or the city government) can be legally prosecuted (e.g. United Kingdom, France, or Croatia) (Hölker et al. 2010; Lyytimäki 2012). As for the ICTs, there are currently more than 4.5 billion internet users, and more than 2 billion social media users (https://www.worldometers.info/; https://ourworldindata.org/rise-of-social-media). Therefore, it is not surprising that since 2015 more than 7 billion smartphones have been sold, and additionally, there are thousands of TV sets, video games, tablets, and other devices sold globally per day (https://www.statista.com/statistics/263437/global-smartphone-sales-to-end-users-since-2007/; https://www.worldometers.info/). Consequently, a large number of researches in the past decade were based on the impact of screen media on sleep, especially with younger generations accustomed to frequent usage of ICTs. For example, Zhu et al (2020) found that children with sleep disorders spend more time on TV, computer, and telephone comparing to children without the sleep disorder. Certain authors investigated the relationship between nightmares and the use of technology, pointing out to the disruptive potential of cognitive arousal before sleep (Choi et al 2009; Arora et al 2014). Exelmans and Van den Bulck (2016) showed that extensive media use before sleep leads to sleep displacement, or increased time in bed before falling to sleep resulting in shorter sleep duration. Authors Šmotek et al (2020 in press) determined that 90 min of exposure to artificial screen light before sleep is closely related to sleep inertia (heavy feeling after waking up in the morning). They also paid attention the "*light hygiene*" which means a "set of rules and recommendations to mitigate the negative impact of evening/night screen exposure on sleep quality" (Šmotek et al 2020: 2). Light hygiene has been presented before in the work of Erren and Reiter (2009) where they even suggest that light should be considered as a drug equivalent: "In this vein, the very timing, quality (wavelength), quantity (dose) and side effects, including chronodisruption, of light exposures can be critically important for health and disease in man" (Erren and Reiter 2009: 1). However, despite numerous scientific papers sleep deprivation and sleep stress are still largely underestimated, even though sleeping is one of the most important biological processes. Mood swings, unreliable behaviors, and feelings of exhaustion which eventually weaken the immune system are most often related to different sleeping disorders (Kabat-Zinn 1990). Such disorders can be triggered by various sociological/psychological factors in the life of an individual, but also by disrupting the biological clock using inadequate lighting systems or by extending working hours into the late at night. There is a growing body of evidence that working late or just staying late under the constant artificial lighting negatively influences the human body clock and the hormonal system, which can cause health problems such as breast cancer or play an important role in the development of cardiovascular diseases, digestive problems, diabetes, obesity and other disorders (e.g. Davis et al. 2001; Anisimov 2006; Stevens 2009; Dong et al. 2019; Lin et al. 2019).

It can be argued if the loss of dark skies only influences our perception of the nighttime environment and physical health, or also our well-being in general. The term "well-being" is one of the most frequently used terms in the twenty-first century related to human daily life, and yet, there is still no unanimous definition of it. According to Pyke et al. (2016), nearly 70 years ago The World Health Organization (WHO) defined health as not only the absence of disease but more of a general state

of well-being. However, well-being has been a philosophical and sociological question for academics and thinkers dating back to Aristotle who defined it as a "meaningful living" (Gallagher et al. 2009). Throughout human history, the search for understanding well-being has extended over time to various disciplines such as psychology, medicine, economy, and similar. Since recently, there is a growing body of research proving that simply spending time in nature can be beneficial for our health and well-being (e.g. Kaplan and Kaplan 1989; Wyles et al. 2017; van Gordon et al. 2018). These health benefits associated with feeling more connected to nature are defined as "*nature connectedness*" and it is a psychological construct that describes a realization of our shared places in nature (Wyles et al. 2017). The astronomy heritage, stars, galaxies, and other celestial bodies, have always been a part of human natural surroundings. In this manner, the loss of the dark starry skies could have a detrimental effect on the nature connectedness, since humans are losing the sight of their "home galaxy" and their place in the universe. Therefore, the sight of distant celestial bodies, few times the size of the Earth could influence on the development of positive feelings of humbleness and respect towards nature and also activate the need to become more vigilant in preserving their natural surroundings (Mayer et al. 2009; Wyles et al. 2017). Researcher William Kelly was among the first scientists to recognize that certain people have a more pronounced appreciation of the night sky, even if they are not professional or amateur astronomers. To measure individual differences in people's psychological attachment to the night sky he invented the "*Noctcaelador Index*" which is based on an individual's behavior in the nighttime hours (e.g. how regularly they intentionally looked up to the sky) (Kelly 2004). The concept of "noctcaelador" further proves that it is not necessary to possess detailed astronomical knowledge to feel a deep appreciation for dark skies, thus, supporting the idea of astronomy tourism as an additional value to the existing forms of tourism (such as spa tourism, rural tourism and similar) (Blair 2016). According to van Gordon et al. (2018), visualization of different natural landscapes, among which is the sky or space that is without boundaries during the meditational practices, can be beneficial for mental health. Meanwhile, as reported by Lyytimäki (2013) most of the people born in the past few decades in urban environments probably suffer from generational amnesia towards starry night skies, so the question must be raised whether they would be able to experience or at least imagine such scenery. Hence, the lack of dark sky could negatively influence the development of anthropocentric attitudes towards the natural environment and its astronomy heritage.

Besides the "extinction of experience" of natural darkness due to public lighting, people in urbanized areas are, more often than not, resorting to continuous use of electronic devices as sensory aids, rather than to a direct experience of the natural environment (Lyytimäki 2012). The growing use of a digital medium, thus, the consumption of various virtual content about the natural environment can, on the contrary, negatively influence the people's perception of it. According to Hanski (2005), high-quality documentaries about exotic and often time isolated wild nature can lead to depreciation of ordinary everyday natural experiences and less exotic, but still important ecosystems in their immediate environment. When it comes to virtual representations of starry dark skies and night-time setting in high-quality documentaries or photos, it can lead to false and exaggerated expectations, since most of them

are edited and embellished for final users. Furthermore, people are consuming night-time photography or videos in a safe and usually illuminated environment, while the direct contact with natural darkness and clear night skies may feel uncomfortable, contributing to the further devaluation of a starry night sky sight. It is also important to mention the negative impact of the entertainment industry (such as television, films, music, and similar) which usually presents darkness and night-time environment as something evil, unpleasant, and un-welcomed. For example, bad characters are usually presented in black wardrobes, and are active during night hours, while positive characters are presented with bright colors and in the light of the day (Packer et al. 2011). Such polarization of day-time and night-time environment to "good" and "evil" sets the tone for people's desired surroundings, as well as encouraging further aspirations towards the illumination of the night-time environment. Lyytimäki (2013) proposed an appropriate circle of shifting the baseline syndrome related to nocturnal nature (Fig. 4), where urbanization and technological development are contributing to the increased time spent indoor during night hours, using ICTs for entertainment while illuminated with the artificial lighting that imitates day time environment. The more time people spend in the illuminated indoor environment, deprived of contact with natural darkness, the more likely they are to experience increased fear of poorly lit outdoor areas and darkness. It can be expected that this process is especially pronounced with "digital natives" (younger generations raised in a digital world) (Prensky 2001) born after 1980, that are at the same time generations that grow up in urban environments and most likely to suffer from generational amnesia towards natural darkness. Therefore, not only the younger generations are more susceptible to technology addictions (particularly ICTs) (Egger et al. 2020) but are also most likely to be scared of darkness, while perceiving artificial lighting as a natural part of the environment. On the other hand, if ICTs are correctly put to use, they can also provide a solution for breaking that circle through proper education or stimulus to break out of the comfort zone and explore nature in the night time environment, thus, lowering the fear of unlit areas in the city (Lyytimäki 2012, 2013). In addition, ICTs can potentially improve sleep quality, even though

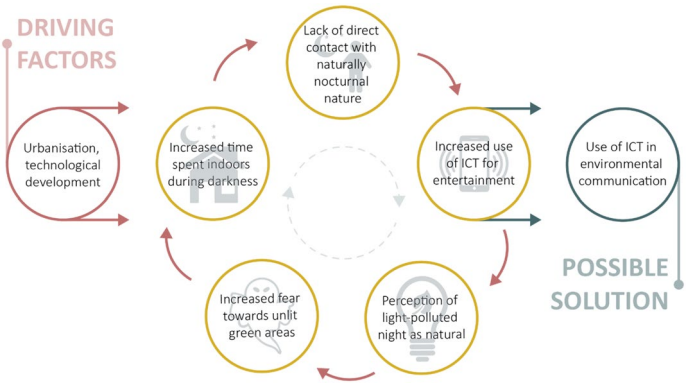

Fig. 4 Proposed vicious circle of shifting baseline related to nocturnal nature according to Pilgrim et al. (2008), Lyytimäki (2012) and Lyytimäki (2013)

in certain cases they are the cause of sleep degradation. There are numerous wearable fitness devices and mobile applications that can track and analyze sleep data in order to provide suggestions on how to improve sleep quality (Baron et al. 2018). Sleep Cycle app, for instance, uses sound analysis to track movements and identify sleep phases so it can analyze sleeping patterns and wake up users during the lightest sleep phase (https://www.sleepcycle.com/). Sleep Monitor app tracks sleep cycle details, but also sleep habits (what users usually do before bedtime) to generate useful information for sleep improvement (https://play.google.com/store/apps/details?id=com.sleepmonitor.aio&hl=en_US).

4 Where the astronomy tourism and well-being meet

As the urban areas become increasingly overcrowded and deprived of natural environments, people and the tourism industry are slowly turning to the beauty of vast open spaces with more meaningful experiences than the mass tourism can offer (Jacobs et al. 2019). Accordingly, many authors have examined the relationship between tourism and well-being, but the conclusions varied greatly (e.g. Wei and Milman 2002; Coghlan 2010; Smith et al. 2015; Uysal et al. 2016). Some of the authors argued that tourism contributes only to the short-term well-being (Nawijn et al. 2010), and even create pre-trip workload stress and post-trip lower level of happiness (Nawijn et al. 2013). On the other hand, Kirillova and Lehto (2015) claim that vacation experiences depending on the type and the goal of travel, and can even trigger transformative changes in the life of an individual. Likewise, Brown (2013) and Reisinger (2015) suggest that tourism influences not only the lower levels of anxiety and the general feeling of relaxation but also offers psychological and spiritual experiences that can change the world views and fundamental structures of a tourist. Therefore, Kay Smith and Diekmann (2017) grouped different well-being concepts and tourism practices depending on the duration of the effects of travel, where long-term effects can be reached through *volunteer tourism*, *retreat tourism,* and *spiritual pilgrimage* and permanent effects through the *sustainable ecotourism* and *ethical indigenous tourism*. Almost all of these forms of tourism (except for ethical indigenous tourism) can be integrated with astronomy tourism—*volunteer tourism* can be experienced at the shores of Mexico where the volunteers protect the sea turtle hatchlings from light pollution, thus becoming aware of the importance of the dark sky for the natural environment (https://vivemexico.org/workcamp/219/en). Some astronomy inspired travels are related to visiting certain historical locations (such as Stonehenge or pyramids) to witness the rising sun at the moment of the summer solstice, or any other important astronomical event (Weaver 2011). Most of these archeoastronomy sites are built in relation to the celestial bodies or phenomena and represented important religious objects in the period of paganism. Therefore, traveling to such destinations to experience simple stargazing at the same starry skies that were an inspiration for our ancestors can be a part of *retreat tourism* and *spiritual pilgrimage*. Furthermore, Blair (2016) reports that certain dwellers on the Sark island (famous Dark Sky Community and first Dark Sky island in the world) had a quasi-religious experience related to the night sky in a form of meditation or

prayer. Two respondents even reported dark skies served as a way for maintaining the connection with the loved ones or homeland (Blair 2016). As mentioned before, astronomy tourism is a form of *sustainable tourism* whose greatest asset are the dark starry skies which need no maintenance or development (Weaver 2011; Najafabadi 2012; Jacobs et al. 2019) and basic activities are in line with environmental, economic, and socio-cultural aspects of sustainable tourism development (WTO 2013). As stated, astronomical observations, which are one of the most important activities in this branch of tourism, are available only at the appropriate atmospheric conditions with minimal light pollution. These conditions are usually met at the locations geographically apart from traditional destinations, at high altitudes, commonly in natural reserves or scarcely populated rural areas. Certain authors (e.g. Weaver 2011; Mitchell and Gallaway 2019; Soleimani et al. 2019) characterize astronomy tourism as part of ecotourism as well, since according to Ceballos-Lascuráin (1987: 14) ecotourism is defined as "traveling to relatively undisturbed or uncontaminated natural areas with the specific objective of studying, admiring, and enjoying the scenery and its wild plants and animals, as well as any existing cultural manifestations (both past and present) found in these areas". However, nighttime ecosystems of the undisturbed natural areas may experience certain pressure from the tourist visits if not properly monitored and regulated. Furthermore, the development of astronomy tourism would include better infrastructure in rural areas nearby favorable observational spots. This could potentially lead to an increase in the light pollution of the environment, because of the higher road density and accommodation units that usually require a certain amount of artificial lighting. For astronomy tourism destinations to maintain or achieve the form of sustainable ecotourism, it is necessary to examine the potential influence of tourist visits to fragile nighttime species, and at the same time to implement adequate ecological lighting which would allow the development of rural areas, but at the same time minimize the effect of artificial lighting on the nearby surrounding. Besides the nighttime activities, it is also important to provide enough content for the daytime activities, which are, in such locations, mostly tied to the variety of outdoor activities or interactions with the local community. Therefore, tourists are not only provided with the content in the field of astronomy, but also experience authentic interaction with the natural landscapes, participate in folk traditions, and consume local products (Jacobs et al. 2019). In this manner, astronomy tourism provides meaningful experience through a variety of educational content (Fig. 5). It could be argued that the resources of astronomy tourism could be of value only for the amateur/professional astronomers or astronomy enthusiasts. However, a simple stargazing experience in the natural setting could trigger an authentic mindfulness experience for people that are deprived of dark starry skies in the urban areas (Fig. 5). Such experience can influence the deeper capacity for meaning-making, thus discovering the beauty of natural elements and processes especially in the night-time environment (van Gordon et al. 2018). Also, certain anthropological studies suggested that night sky watching influenced early humans to gain spiritual and aesthetic inspiration (Hoskin 1999) as well as a trancelike state for mystical experiences (Sheehan 2010). Likewise, people in the urban areas that are lacking direct contact with natural darkness, could potentially change their perceptions toward natural darkness as something unnatural, undesirable, and dangerous. Such

Fig. 5 A model of integrative wellbeing tourism experience according to Kay Smith and Diekmann (2017) combined with the values of astronomy tourism activities that contribute to the overall well-being experience

a shift in perception could influence awareness about light pollution and the active participation of citizens towards reducing inadequate lighting systems by installing ecological lighting.

According to Jacobs et al. (2019), some of the common characteristics of rural areas are scarce population, low economic activity, usually dominated by open areas (forests, pastures, mountains, and similar) with low infrastructure and within a great distance from urban areas. As mentioned before, light pollution, as one of the biggest obstacles for astronomy tourism, can be considered as a byproduct of urbanization processes. Therefore, sparsely populated open areas within a great distance from urban environments are ideal for developing astronomy tourism, thus, once isolated places with no apparent value for developing tourism, have now become an important asset for highly urbanized countries (Ingle 2010). Likewise, local communities that have been disregarded and neglected so far, now benefit from the lack of the infrastructure and remoteness from the urban areas. In a sense of well-being experience, tourists can feel positive emotions regarding the benefits of astronomy tourism for local communities, where at the same time the true nature of the natural

and cultural landscape is not dramatically changed but aims towards more sustainable development (Fig. 5).

As mentioned before, astronomy tourism in its diversity is not relatable only to the amateur/professional astronomers or astronomy enthusiasts, but to the other groups of tourists as well. According to the Stanford Research Institute (2012), there were around 289 million wellness consumers worldwide with the $2 trillion global "wellness" industry in 2012. The same consumers stated that "taking a holiday, vacation or retreat" is one of the most important activities for enhancing well-being, right after exercising, eating better, and visiting a spa. Hence, astronomy and well-being tourism could merge products and services, considering that the main activities of astronomy tourism are integrated into the various forms of well-being experiences.

4.1 The dual role of ICTs in the conservation of dark skies and astronomy tourism

As mentioned above, ICTs can have a significant effect on increasing fear toward natural darkness (Figs. 4, 6), thus, indirectly influencing higher demand for outdoor lighting and the disappearance of dark skies in inhabited areas. Likewise, people that are afraid of darkness probably would not engage in tourism experience which is based on or includes a significant amount of time spent in darkness (Lyytimäki 2012). Nature disconnectedness and perception of the natural environment as something strange and unfamiliar is usually related to spending too much time indoors while consuming ICTs for entertainment (Louv 2005; ; Lytimaki 2012; Gatersleben et al. 2018). Accordingly, Egger et al. (2020) stated that most of the tourists that were engaged in "Digital Free Tourism" reported the feeling of being more connected to the immediate environment, natural surroundings, and overall tourism experience. Besides, Egger (2020) concluded that the traditional idea of tourism which is based upon a sense of escape from everyday life and recovery from work

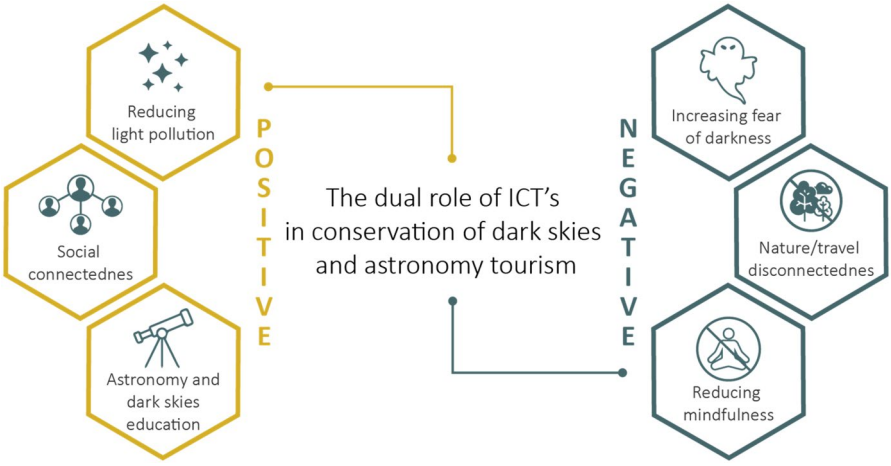

Fig. 6 Positive and negative role of ICTs in the conservation of dark skies and astronomy tourism

(MacCannell 1976) has been blurred because of the extensive usage of ICTs during the travel (Fig. 6). As mentioned before, astrotourists motivation for traveling is usually found in intellectual stimulation and the authentic environment of the dark starry skies. This paper also suggests that dark skies could provide a mindful experience and positively influence general well-being, nevertheless, the tourist is an amateur or professional astronomer. Hence, constant mobile distraction can negatively influence the overall experience and even reduce or eliminate the feeling of mindfulness (Fig. 6).

On the other hand, when it comes to the positive role of ICTs in the "recovery" of dark skies, Geographical Information Systems (GIS) can be a valuable asset in the smart planning of public lighting, by analyzing the data on the dynamics of daily migrations in the settlement and position of street lanterns and their intensity (Chalkias et al. 2006) (Fig. 6). Such geospatial analysis can be a useful tool in zoning the settlement and defining the appropriate intensity of lighting depending on the time of the day and dynamics of human activity. Therefore, citizens would have proper lighting levels in the night-time period for normal functioning, and at the same time light pollution of the environment would be significantly subsided (Kyba et al. 2015). Furthermore, removing the unnecessary public lighting or reducing the intensity of overly bright lighting systems would positively reflect on economy and energy savings, along with the decrease of overall skyglow over the settlement, thus, providing the possibility for citizens to appreciate the dark starry skies at much closer proximity in their whereabouts than before. Contrary to the negative influence of ICTs on tourism experience and feeling of disconnectedness with "here and now", when properly used ICTs can enhance the tourism experience through meaningful communication with the family and loved ones with sharing experiences from the travel—"here and now" (Kirillova and Wang 2016. More importantly, dark skies are usually found in remote and isolated areas where tourists can achieve the feeling of "being away", but at the same time may trigger the negative feelings of being alone and in the dark. In such a scenario, mobile phones and other communication technologies can offer a sense of safety and comfort, which is important for the tourism experiences that are "out of the comfort zone" (Fig. 6). When it comes to astronomy and dark skies education and popularization, Global Positioning System (GPS) can play a significant role in bringing astronomy closer to the citizens, through various applications designed for smartphones. These applications mostly serve as an orientation tool for finding the position of stars and constellations in real-time. Many of them use augmented reality combined with the device's camera to show the exact location of the star, also has a variety of options useful for planning the astronomy-related travels. For example, the application *Star Chart* provides an opportunity to travel back or forth in time for 10,000 years, and the possibility to change the location of observation (https://play.google.com/store/apps/details?id=com.escapistgames.starchart&hl=sr). *Night Sky* application comes with a community that is sharing stargazing experiences all around the world, and at the same time checks the weather conditions for observations (https://apps.apple.com/us/app/night-sky/id475772902). *Loss of the Night* application is more of a worldwide citizen science project which is developed to gather the data about light pollution from all around the world, collected by counting the stars using the navigational tool in the app. The

number of visible stars is an indicator of light pollution of the observation spot and it can be presented in sky brightness map (https://scistarter.org/loss-of-the-night).

A growing number of astronomy-related applications and significant diversification of options included are a good sign of growing interest and useful utilization of ICTs in raising awareness about light pollution and bringing back the forgotten beauty of a starry night sky. However, the mere presence of electronic devices could disrupt and impair even the simple stargazing experience and therefore, diminish the purpose of ICTs to bring back dark skies and people closer together (Stankov et al. 2020).

5 Conclusion and further research directions

The relationship between humans and dark starry skies has always been productive and inspirational, not only for scientific discoveries and breakthroughs but also for various forms of artistic expressions. On the other hand, the relationship between humans and natural darkness has always been a dreadful one. People would admire the heavens, but at the same time, as diurnal beings, we have been and still are relentlessly searching for the best method to tame the night and bring the light into it. Whether from the evolutional fear for the safety or because of the striving for overall progress through extended working hours. However, since dark starry skies have become a rare commodity for most urban and suburban dwellers in the world, such scenery could fall into oblivion for modern-day society. Considering that the global urbanization rates are going higher every year and technology for producing artificial lighting is becoming more advanced, most of the children born today could face a starless future. At the same time, along with the rapid disappearance of natural darkness, astronomy tourism has begun to develop as a response to the light pollution that has taken over the populated areas. So far, astronomy tourism has been mainly considered only as a niche tourism professional/amateur astronomers and astronomy lovers. However, the main characteristics of this type of tourism are in accordance with principles of sustainable ecotourism which is growing rapidly, owing to the growing awareness of nature protection. Moreover, the greatest asset and the underlying resource of astronomy tourism are dark skies which are usually accessible only in the geographically remote areas. This seemingly aggravating factor in further development has turned out to be beneficial for isolated and offbeat host communities. Therefore, astronomy tourism can be considered as one of the unexpected driving forces of rural tourism. Along with the growing awareness of nature protection on a global scale, people are also turning to a more mindful way of living together with improving their general state of well-being. Numerous authors have confirmed the relationship between well-being and nature exposure, yet, natural darkness as a part of the natural environment has been mostly neglected in such research. However, natural darkness and starry skies have always been a part of natural surroundings throughout human evolution, therefore, it must not be underappreciated and further research must be conducted. When analyzing the influence of dark skies on our general well-being, it can be concluded that visits to astronomy tourism destinations can provide a long-term positive effect on people. Because of

its complexity, this type of tourism can satisfy human desire to participate in meaningful activities through various forms of education, offer relaxation and enjoyment in the natural surrounding while stargazing, and at the same time give people the sense of purpose through benefiting the development of remote and isolated host communities.

It is important to outline the complex role of ICTs in moderating the relationship between people, on the one side, and preservation of dark skies and astronomy tourism, on the other side. The negative sides of ICTs are mostly related to the sleep disorders (caused by overly bright screens) and disconnectedness with the natural surroundings because of too much media consumption. Such behavior leads to the increased time spent indoors, especially in the night time hours with an artificially illuminated environment, thus, increasing the fear of unlit outdoor areas because of the lack of experience of natural darkness. While traveling, ICTs may diminish the tourism experience and decrease the sense of authenticity and fascination with the surrounding, therefore, reducing the feeling of mindfulness and overall well-being expected to be increased after traveling. On the other hand, if consumed properly, ICTs may contribute to the lowering amount of light pollution (using GIS technologies) and at the same provide a feeling of safety while traveling to the remote and isolated areas dark sky observations require. A growing number of astronomy-related applications is certainly one of the positive sides of ICTs which can influence on broadening the group of people interested in dark skies, so "digital natives" do not necessarily face the starless future experts are announcing. Further research directions can be aimed toward better understanding the role of ICTs in astronomy tourism through more detailed insight about the advantages or disadvantages of ICTs usage from astrotourists point of view. Moreover, since astronomy tourism is still an underrated branch of tourism, the research about the possibility of incorporation of dark starry skies observations as a part of touristic offers with different primary focus (such as rural, eco, or leisure tourism) can be useful for its further development. Likewise, astronomy tourism has been perceived as a part of sustainable tourism offer, but there is a potential to include this type of tourism into the well-being focused tourism (e.g. wellness, spiritual or restorative tourism).

Based on the information presented above, it can be concluded that natural darkness and sleep quality are of vital importance to our health. Thus, it may seem controversial to promote astronomy tourism for which "staying up late" presents the starting point. However, few nights spent in an outdoor environment, stargazing under starry night skies, while mindfully consuming ICTs, could provide meaningful content and experiences in a long run.

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