The Loss of Dark Night Skies: How Cultural and Scientific Advocates are Pushing Back

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Abstract

Dark night skies are crucial to astronomers' ability to observe the universe, indigenous cultural practices, wildlife ecology, and human health. Yet the darkness of these skies has been dwindling over the years as light pollution increases with urbanization, LED lights, and most recently artificial satellites. I considered how and why various social groups, focusing on astronomers and indigenous people, are striving to protect dark night skies. By considering the approaches from various groups, we conclude that a transdisciplinary approach incorporating perspective shifts, social, and technical solutions is necessary to best address light pollution and the loss of dark night skies.

Introduction

In the 19th century, public gaslight made the popular expression, “turning night into day” (Schivelbusch 1988), a feasible reality (Stone 2017) . Little did they know, “the inappropriate or excessive use of artificial light” would become such a concern as to be dubbed “light pollution,” as defined by the International Dark-Sky Association (IDA 2022) just two centuries later. While urbanization has been increasing the impact of city light since its inception, increased use of LED lights and mega-constellations of artificial satellites make the encroachment of light pollution on dark skies a more pressing issue than ever. In this paper I investigate the subject of light pollution and preserving night skies within the framework of the social construction of technology (SCOT). SCOT provides “an integrated social constructivist approach towards the study of science and technology,” in which “scientific facts and technological artefacts are understood to be social constructs” (Pinch and Bijker 1984). This leads to the consideration of various social groups and their interpretations of the sociotechnical problem. Many social groups, including astronomers, indigenous people, and dark sky advocates are concerned about

the loss of dark night skies for scientific, cultural, human health, and ecological reasons. This paper examines several cases of groups pushing back to preserve night skies to show the motives and results of these social groups.

Night Skies through the Lens of Science and Culture

I approached this problem by a method combining that of Utah's Workforce Services Community Development Office's guide on "Dark Sky Planning: An Introduction for Local Leaders" and Venkatesan et al.'s study on "The impact of satellite constellations on space as an ancestral global commons (2020). The Workforce Services breaks the necessity for dark skies into the categories of economic, ecological, and cultural, and then provides city planning advice accordingly. Meanwhile, Venkatesan et al. consider how satellite constellations' effects on astronomy, treaties, planetary protection, and cultural practices will interact with various stakeholders, including private companies, NASA's Planetary Science Division, and "minoritized communities, including Indigenous peoples" (2020). In combining these perspectives, I break the problem down into categories of scientific research, culture, ecology, and human health. More specifically, I apply the SCOT approach to consider how specific social groups in the first two categories, including astronomers and Dark Sky Project organizers, are motivated by each lens and are responding in kind. These groups are selected for their apparent representation of technical and social perspectives, respectively. By examining these groups' motives and approaches closely, we can study the interplay of technology and society as it relates to protecting dark night skies.

Ground-based and Satellite Light Pollution

A baseline understanding of how light pollution has come to encroach upon dark night skies is necessary to understand the context in which social groups are acting. Light pollution is considered one of "the most chronic environmental perturbations on Earth" (Drake 2019). The IDA breaks light pollution down into categories of "*glare* – excessive brightness that causes visual discomfort, *skyglow* – brightening of the night sky over inhabited areas, *light trespass* – light falling where it is not intended or needed, [and] *clutter* – bright, confusing and excessive groupings of light sources" (2022). This paper focuses on the effects of skyglow as the brightening of the night sky prevents visibility of celestial objects whether for astronomical or cultural purposes. This problem is vast, as the Milky Way is already hidden by skyglow from a third of humankind and nearly 80% of North Americans, according to observations from the Suomi NPP satellite (Drake 2019).

Light Emitting Diode (LED) lighting is now taking over cities and households, and producing more light pollution than the 20th century electric lighting or 19th century gas lighting (CDO 2018). LEDs make for a higher quality, more efficient, and cheaper source of lighting than the conventional high-intensity discharge (HID) lights, but have the adverse effect of emitting excessive blue light. This can increase sky glow because "shorter wavelengths scatter more readily in the Earth's atmosphere than longer wavelengths" (Kinzey et al. 2017). The blue light is also more impactful to humans and animals (Drake 2019).

In the early 2020's, low-Earth orbit satellites pose a newly significant threat to telescope observations and navigational practices that depend upon "relative rise and set locations of stars, constellations, the Moon or Sun," (Venkatesan 2020). These satellites come with the expansion of commercialization into near Earth space, and . SpaceX has already acquired permission from

the Federal Communications Commission (FCC) to launch 12,000 satellites, which they intend to make up a mega constellation of ultimately 42,000 satellites to "provide low-cost internet to remote locations" (Mann & Pultarova 2022). Meanwhile Amazon has announced their Project Kuiper prototype launch for late 2022 (Roulette 2021) and other private companies plan to launch similar satellite constellations in the near future, amounting to a predicted 100,000 total satellites by 2030 (Venkatesan et al. 2020).

With the long history of ground-based light pollution continuing to increase skyglow and the more recent deployment of artificial satellites escalating, a wide range of people are pushing back. The following two sections will examine two groups of these people, astronomers, who have become increasingly vocal about light pollution impacting astronomical observations since their response to the announcement of Starlink, and indigenous people, who have long-valued and sought to preserve dark sky cultural practices.

Astronomers

Observing the Light-Polluted Night Sky

All astronomical observations are rooted in identifying a contrast between dark and light, that being the darkness of the night sky and light emitted or reflected by the celestial object. In the "Light Pollution Handbook," Kohei Narisada and Duco Schreuder explain that "any stray light causes a veil, reducing all contrasts" and thus decreases how well the objects can be observed (2004). They calculate the contrast as a ratio of object luminosity - background luminosity to background luminosity. Then, by adding a veiling luminosity to both object and background terms, they prove that and quantify how this contrast ratio is decreased by the addition of stray light. Sky glow is the primary example of such stray light, thus most telescopes

are built in rural areas far from glowing cities. This problem is not new. In 1973, Kurt W. Riegel published a paper on the threat outdoor lighting poses to astronomy where he stated that "suitable sites in the United States for new dark sky observing facilities are very difficult to find" (Riegel 1973). He encouraged observatory programs to "routinely monitor sky brightness as a function of position, wavelength, and time" and the astronomical community to offer support and coordination to these programs. He describes the increased illumination as a result of both a "character of national growth and developments" and "changes in outdoor lighting technology," demonstrating that he viewed it as a sociotechnical matter. Similarly, Riegel cites solutions ranging from "protective policies that governments might adopt" to "changes in lighting technology," furthering his presentation of this problem as both technological and social.

The more novel impact that the growing number of artificial satellites will have on telescope observations has been well studied by astronomers such as Olivier R. Hainaut and Andrew P. Williams at the European Southern Observatory, who model 26 thousand satellites forming 18 constellations from private companies (2020). By order of magnitude estimates and a simplified model they find that approximately 1100 to 1600 satellites will be above the horizon overnight with 110 being bright enough to be "visible in good conditions." They find less than 1% of narrow to normal field telescopic exposures, about 3% of medium to wide-field exposures, and 30-40% of ultra-wide imaging exposures would be contaminated by these artificial satellites in visible to near-infrared wavelengths. One such ultra-wide imaging telescope is the Vera C Rubin Observatory, which is "designed to begin the deepest survey of the night sky ever in 2022" after over 20 years of development and millions of dollars. Hainaut and Williams acknowledge that "the emotional and moral dimensions of the issue … go beyond the impacts on astronomical science" but seek to take an objective research-oriented approach to the subject to

provide “a factual and quantitative assessment of the impacts.” They believe this assessment is prerequisite for “the astronomy community to respond to these developments and work constructively with industry, funding agencies, and regulators.” In other words, they view satellite constellation infringement on dark night skies as an issue that extends beyond just astronomy, believe its solution requires a collaborative effort, and elect to focus their work on one integral part of this solution: a technical assessment.

Perspectives on the Night Sky

Robert Massey, the deputy executive director of the Royal Astronomical Society, acknowledges “‘that there are multiple uses of spaces, and that astronomers are not the only community with a stake in that,’” but, “‘On the other hand private companies are not the only organisations that have a stake in the now burgeoning commercialisation of low-Earth orbit [and] they should be regulated,’” (Clark 2020). This viewpoint is not uncommon among astronomers. For example, Dr. Aparna Venkatesan, a professor in the Department of Physics and Astronomy at the University of San Francisco, and fellow academics published an article in Nature Astronomy titled “The impact of satellite constellations on space as an ancestral global commons” (2020). In their paper, they argue for space to be viewed as a global commons, as opposed to “treating space as the ‘Wild West’ frontier that requires conquering continues to incentivize claiming by those who are well-resourced.” Such a view goes hand in hand with the perspective that space should be treated as “an ancestral global commons that contains the heritage and future of humanity’s scientific and cultural practices” (Venkatesan 2020). However, this conflicts with Executive Order 13914–Encouraging International Support for the Recovery and Use of Space Resources, in which President Donald Trump states that “Outer space is a legally and physically

unique domain of human activity, and the United States does not view it as a global commons" (EO 13914).

Privatization and Policy

One approach astronomers have taken to solve the problem of light pollution is by shifting government policy. Some claim that "space is becoming the playground of billionaires" as privately funded initiatives are not accountable to the public or the bureaucracy slow-down that governments experience (Venkatesan 2020). This applies to broader concerns around space including planetary protection and avoiding imperialism in space science missions. Thus, researchers must also be policy makers to protect their ability to research outer space. George Mason student Monica Vidaurri explains,

> "Given the inevitability of the private sector in influencing future crewed missions both in and beyond low-Earth orbit, it is essential to the science community to agree on universal standards of safety, mission assurance, planetary protection, and especially anti-colonization" (Vidaurri et al. 2020).

International policy has been developed in the form of several treaties such as the Outer Space Treaty in 1967 and the Moon Agreement in 1979. However, these international treaties lack oversight or enforcement, are vague in defining the 'colonial competition', 'militarization' and 'peaceful purposes' they seek to prevent, and are non-binding in nature, they have little concrete impact in regulating the goings-on of private companies.

While astronomers have protested private company endeavors like starlink, others find their benefits to outweigh the costs. SpaceX's starlink mission has promised to deliver high-speed broadband internet globally, including locations like rural America that still lack cable internet. As of March 2022, Starlink serves over 10,000 customers and has distributed over 100,000 satellite internet terminals (Crist 2022). It is not difficult to imagine that these users may

value their internet access more than the astronomical research, indigenous cultural practices, and ecology of wildlife that does not impact their daily lives. However, it is also likely that most of these individuals are unaware of the extent of light pollution impacts, and there are alternative internet solutions. Soon after the first Starlink satellite deployment, the International Astronomical Union "released an alarm sounding statement warning of unforeseen consequences for stargazing and for the protection of nocturnal wildlife" (Crist 2022), demonstrating that this issue is internationally recognized as a worthwhile concern.. Elon Musk has acknowledged these concerns and has begun testing means of reducing the satellites brightness.

Technical Solutions

While astronomers have pushed for policy-oriented solutions and regulations as a means of mitigating the growing impact of artificial satellites, they have also supported efforts working with the private companies to implement technical solutions. These solutions take the approach of minimizing the light emitted or reflected by the artificial satellites, as opposed to minimizing the number of artificial satellites. Theoretical astrophysicist and science writer Dr. Ethan Siegel published an article "This Is How Elon Musk Can Fix The Damage His Starlink Satellites Are Causing To Astronomy." Dr. Siegel claims that "either regulators or SpaceX executives themselves will need to mandate a change" and proposes a four step solution. First is to de-orbit current Starlink satellites and pause the launch of new ones "until the proper modifications have been made.". Second, "redesign or coat the satellites to significantly reduce their reflectivity," third, "provide real-time trajectory plans, predictions, and adjustment information for each satellite to observatories worldwide," and fourth, "provide funding to assist astronomers in the development of hardware and software-driven solutions to subtracting out as much of the

satellite pollution as possible. While the solutions themselves to reducing reflectivity and subtracting out satellite pollution may be technical in nature, Another approach is to consider how to make successful observations despite these satellites, enabling and enforcing their implementation is a social problem.

Indigenous People

Cultural Practices dependent on Dark Skies

Many indigenous groups have cultural practices that also depend upon visibility of celestial objects. For example, Polynesian navigation practices "depend on the circumpolar skies or the relative rise and set locations of stars, constellations, the Moon or Sun, utilizing the horizon sky at dawn or dusk" (Venkatesan 2020). Related social groups include the Polynesian Voyaging Society, who "seek to perpetuate…traditional Polynesian voyaging and the spirit of exploration" (PVS 2022) and the Imiloa Astronomy Center of Hawai'i, who "link to early Polynesian navigation history" ('Imiloa 2021). To name another example, the Euahlayi Aboriginal Australian peoples similarly use star maps, but for "learning and remembering waypoints along their routes of travel" instead of navigation. Researchers of Indigenous Studies and Astronomy explored this role of night skies in the extensive travel common to most Aboriginal groups, ultimately suggesting "further research may find that this was common to many Aboriginal groups in Australia" (Fuller et al. 2014). These examples all illustrate indigenous peoples' use of dark night skies historically as a technological means to an end, which has since become a tradition ingrained in their culture.

Other applications of the night sky to indigenous people include using stars to "preserve and inform complex knowledge systems, which are used for things like navigation, food

economics, forecasting weather, predicting seasonal change, informing social structure, and serving as a mnemonic for committing information to memory and passing it to successive generations" (Hamacher et al. 2001). One of "the most widespread Aboriginal asterism" is the celestial emu, a shape formed by the dust in the Milky Way whose visibility and position "informs Aboriginal people about the bird." The Gunnai people of east Gippsland, Victoria pass on oral traditions based on the emu and the Moon man, with the Moon providing natural light pollution that sends the emu into hiding. However, this cyclic increase and decrease in emu visibility is now overshadowed by the human-made light pollution. (Hamcher et al. 2001). Losing sight of the celestial emu serves as a direct example of light pollution wiping out an indigenous cultural practice rooted in dark night skies.

Indigenous Astronomy

There is also a great history of indigenous astronomy, which has been washed out by Western biases in favor of Western astronomy (Hamacher et al. 2001). Indigenous civilizations charted the sky, by methods such as using "fixed locations on the horizon to chart celestial movements." This was the basis of the Hopi-Navajo's strategy for denoting "'important days in the solar year by fixing the position of sunrise and sunset" on their landscape (Bretcher). Ancient Mesoamericans used their observations of the night sky as a foundation for timekeeping, including the Mayans and Aztecs who developed calendars based on the solar year (Perles 2021). Hamacher et al. investigate how "the erasure of the night sky acts to erase Indigenous connection to the stars" and find that this serves as "an ongoing cultural and ecological genocide" (2001). They conclude that a transdisciplinary approach founded on Indigenous philosophies and decolonising methods is the best way to diminish light pollution.

Perspectives on the Night Sky

Dr. Venkatesan and Dr. Hamacher both mention how perspectives from indigenous people are key to informing dark-sky protection policies and astronomy. Several of these perspectives are shared by speakers in the Indigenous Education Institute's series of talks titled the "Sense of Place Series: Indigenous Perspectives on Earth and Sky." In the first video of the series, President Nancy Maryboy explains "in native ways everything is interconnected, so rather than a specific focus on biology, astronomy, or other separate disciplines" their talks present, "worlds of interrelationships and processes of reciprocity" (IEI 2020). In keeping with that theme, Dr. Leroy Little Bear presents a comparison of "historical foundations of scientific thought from European and Indigenous perspectives." Dr. Little Bear explains how colonization of North America occurred during the age of reason, which had "no room for anything that cannot be measured…or subjectivity." Native Science, being about wholeness, spirituality, relationships, and "everything being animate," was "totally discounted by the rationalists." Dr. Little Bear argues that "Western Science is aimed at exploration," while "Native Science is aimed at sustainability." Thus scientists and policy makers wishing to prioritize sustainability may do well to look towards Native Science for solutions.

Dark Skies Projects

Various groups have sought to protect dark skies by blending indigenous culture with astro tourism. A prime example of this is the Dark Sky Project in New Zealand, located on the Aoraki Mackenzie International Dark Sky Reserve, the first of many dark sky projects, and run by an indegenous Polynesian people, the Māori. This project "blends research from the

University of Canterbury at the Mt John Observatory with tātai aroraki (Māori astronomy)" in their tours and stargazing experiences(Atlas Obscura 2022). While the past setion discussed how indigenous perspectives may advise astronomers and Western policymakers, this serves as an example in which Indigenous people integrated tourism and Western astronomy into their Dark Sky Project to share and preserve their cultural heritage. This serves as a model for how such components can be integrated to create transdisciplinary solutions to the loss of dark skies.

While the Māori Dark Sky Project was the first of its kind, the IDA now recognizes 195 International Dark Sky Places, which can fall into the categories of International Dark Sky Communities, Parks, Reserves, or Sanctuaries, or Urban Night Sky Places. The Kaibab Paiute Indian Reservation in northern Arizona was recognized as one of these International Dark Sky Communities in 2015. Dubbed a 'Dark Sky Nation,' the IDA described this as the first time "an entire group of ethnically and linguistically related people come together to collectively embrace dark-skies principles" (IDA 2015). Tribal Chairperson Roland Maldonado states that the reservation "'is meant to be preserved as our cultural homeland for its natural resources and untouched qualities." Demonstrating their view of dark skies as one of these natural resources, he "[acknowledges] 'the immense value dark skies bring to our traditions, conservation of wildlife, and to future generations'" (IDA 2015). The Dark Sky Community adopted the official title of "Thunder Mountain Pootsee Nightsky" and began outreach and educational activities around "Pipe Springs National Monument, the site of most tourist visits to the reservation." Like the Māori people, the Kaibab Paiute have utilized tourism and outreach to support their goals of protecting the dark skies above them.

Other Social Groups

City Planners

There are several other groups worth mentioning who have stakes in preserving dark skies and means of addressing the matter. One such group is city planners, for example the Utah Community Development Office. They consider economic values of dark skies including energy savings, property value, astro-tourism; ecological reasons including circadian disruption, safety, and natural ecosystems; and cultural reasons like "heritage and rural character" (CBO 2018). As Utah is both one of the "fastest growing states" and "home to some of the darkest skies" in the nation, they seek to design their growing urban areas to strategically protect these dark skies. In their guide for "Dark Sky Planning - An Introduction for Local Leaders" (CBO 2018) they emphasize many low-cost, low-tech solutions such as lighting only what, when, and how much, and how you need. For example, street lights can be shielded on top to only light the desired region below and reduce light trespass and warmer-toned LED lights offer a new alternative to the heavily-blue ones. While the warmer LEDs are more expensive, they emphasize that improving light use efficiency to protect dark skies also saves money, with a calculated Return on Investment of about 50%.

Nature Preservation Groups

Nature preservation groups, like the U.S. National Park Service (NPS) and the International Union for Conservation of Nature (IUCN), are also invested in protecting dark skies. The NPS describes dark night skies as "part of a complex ecosystem that supports both natural and cultural resources" and thus one of "the critical park features the [NPS] protects." They emphasize the importance of night skies to "undeveloped wilderness character that animals depend on for survival" (NPS 2022-a). The NPS Natural Sounds and Night Skies Division takes

a varied approach in their protection measures which includes both policy guidance, scientific leadership, and technology. Specific examples of these methods include "collecting baseline data for…night sky quality," identifying and engineering solutions for anthropogenic source specific impacts, assisting in park planning, conducting external park project reviews, and providing airspace and overflight assistance (NPS 2022-b). The IUCN's Dark Skies Advisory Group writes that "a night sky without artificial light is…vital to the proper functioning of natural ecosystems." They state their aim to be providing "IUCN endorsement of dark skies initiatives" and "signposts to further information," and have done so by hosting several dark skies symposiums, conferences and workshops and designating categories of dark sky protected areas including Starlight Reserve, Dark Sky Park, Dark Sky Heritage Site, Dark Sky Outreach Site (urban, suburban, or rural), Dark Sky Reserve, and Dark Sky Community. These steps form a framework-building approach by setting common language standards and platforms for sharing of knowledge.

Conclusion

Many groups care about preserving night skies for different reasons, but share a common goal. The Utah Community Development Office demonstrates how proactive decision-making can mitigate light pollution from urban areas in very low-cost and low-tech ways. Astronomers seek to shift policy in a way that values and protects dark skies while also pushing for technical solutions to mitigate the impact of light from satellites on observations. Meanwhile, indigenous groups like the Māori people in New Zealand and the Kaibab Paiute in Arizona turn to astro-tourism through Dark Sky Projects and IDA-recognized Dark Sky Communities to protect the dark night skies above them. All of the social groups considered have found that, like with

most problems, a combination of technical and social solutions are necessary to push back against light pollution and protect dark night skies.

Among these case studies, the Dark Sky Project serves as the best example of success through a transdisciplinary approach, in that the Māori people were able to integrate tourism and Western astronomy with their cultural heritage to create a region of protected dark skies that benefits all these fields. On the other hand, Western researchers and astronomers have begun investigating how indigenous people's perspective on astronomy may be key to reversing the trend of light pollution. While conflict between astronomers and indigenous people has arisen when astronomy groups have sought to build telescopes in dark sky areas of cultural importance to indigenous groups, these two parties now find themselves on the same side of the issue of light pollution, and will be most successful through a collaborative approach. Thus a transdisciplinary, sociotechnical approach will best serve both these, and other groups motives. For example, a combined committee of astronomers, city planners, nature preservation groups, and representative of indigenous people would be most effective at lobbying the government for regulations regarding sky glow and artificial satellites, as they each have a stake in the matter but different approaches to the problem.

Communication between fields is a limiting factor in implementing these types of collaboration-based solutions. Initiatives like the IEI's Sense of Place Series and Dr. Venkatesan's paper on dark skies as an ancestral global commons are beginning to break down these barriers. Furthering and beginning new initiatives for communication between fields are thus a key actionable step towards the transdisciplinary collaboration necessary to combat the loss of dark skies.

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