

Satellites and Light Pollution: The Fight for Ground-Based Astronomy

By Rebecca Schembri

Humans have looked to the skies since the first night they could see stars. As civilization progressed, astronomy became an important field of study—a way for humans to calculate information about life on Earth, and to understand their origins better by studying the universe. After thousands of years, humans now know where life comes from, how it flourished on Earth, and what is required to maintain it. By using telescopes to look deep into the cosmos, the study of the night sky has become more than an intrigue—it is life-saving science. Now however, such science is threatened by technological advancement: light pollution from cities and human-made space objects are interfering with telescope and radio observations. If the problem grows, it will mean the end for ground-based astronomy. Although talks to mitigate the dilemma have opened, current laws do not offer a clear advantage, and much must be done to save the dark and quiet skies from falling victim to prosperous and ambitious commerce.

Light pollution is “causing a lot of headaches for astronomers,”¹ says Jonathan McDowell, an expert from the Harvard-Smithsonian Center for Astrophysics. The problem is twofold. First: tens of thousands of objects are being launched into Earth’s orbit, causing obstructions in astronomical observations of the night sky. To provide global internet services to three billion humans, companies such as Starlink and OneWeb have plans to place a myriad of satellites in outer space, with China adding an additional thirteen thousand by next year.² These devices “will be at a problematic high altitude for astronomers,” McDowell says, “and others will be at a low altitude which will be problematic just for looking at the night sky.”³ Obstructions will be present both in telescope images, and to the naked eye. As astronomers strive to avoid trails of light streaking through their images caused by reflections from satellites, the problem, if it continues, will become much worse: avoiding trails every twenty minutes is manageable, says McDowell, but if the obstructions occur every moment from every angle, it is not something scientists can deal with: “If there isn’t some kind of management of the night sky,” he worries, “we are going to lose [ground-based] astronomy this century.”⁴ It will become a casualty of technical and commercial growth.

In a recent plea for a moratorium on satellite launches, European astronomers expressed their disdain, saying “the deployment of large fleets of small satellites planned

¹ Jonathan McDowell, Harvard-Smithsonian Center for Astrophysics, Interview, July 14, 2001.

² Stefano Gallozzi, Marco Scardia, and Michele Maris, “Concerns About Ground Based Astronomical Observations: A Step to Safeguard the Astronomical Sky,” *IINAF*, Italian Institute for Astrophysics, February 4, 2020, 4, arxiv.org/pdf/2001.10952.pdf.

³ McDowell, Interview, July 14, 2001.

⁴ McDowell, Interview, July 14, 2001.

or ongoing for the next generation of global telecommunication networks can severely harm ground-based astronomical observations.”⁵ The astronomers requested legal recourse for damages caused by Starlink, saying the investments made to fund their research are being exploited. These damages, they claim, are potentially permanent for observatories if regulations are not set in place to save the night sky:

A particular attention is given to the problem of crowding of circumterrestrial space by medium/small orbiting objects. Depending on their altitude and surface reflectivity, their contribution to the sky brightness is not negligible for professional ground-based observations. With the huge amount of about fifty thousand new artificial satellites for telecommunications planned to be launched in Medium and Low Earth Orbit, the mean density of artificial objects will be > 1 satellite per square sky degree; this will inevitably harm professional astronomical images.⁶ Soon, every area of the night sky will have a satellite in it, and the Earth will lose its cosmic perspective.

Dr. Alissa Haddaji is a Harvard professor and member of the United Nations Planetary Defense Working Group. She sees this issue going beyond harmful interference and damages for liability—it is a global sustainability threat. She believes there is more to worry about with the satellites being placed in *higher* orbits since they are dependent on fuel to reenter Earth’s atmosphere: “the Low Earth Orbit satellites are not as worrisome,” she says, “since they will eventually deorbit, but the ones going into Medium and High Earth Orbit could have complications coming back down, and they have much potential of adding to Earth’s space debris, creating an environmental issue.”⁷

With Earth’s current orbital space debris comparable to twenty-three thousand metal baseballs, half a million metal marbles and golf balls, and a hundred million metal snowflakes swirling in orbit at seventeen thousand miles per hour, adding more gadgets to space is non-intuitive and could trigger Kessler Syndrome—an event like a high-speed racecar crash, when one piece of debris creates a chain-reaction of multiple crashes.⁸ The event would surround the planet with uncontrollable objects, making it impossible to access space for generations.⁹ Because of this, ground-based astronomy is in a dangerous place: “It would be technically reasonably straightforward to launch enough bright satellites to permanently ruin our work,” says McDowell.¹⁰ Eventually, astronomers will not be able to compete with orbital satellites and space debris. An example of this threat is happening today at the ALMA observatory in Chile. Because of its location, satellites are continuously in its view, and the observatory will become unable to make breakthrough

⁵ Gallozzi et al., “Concerns,” 1.

⁶ Gallozzi et al., “Concerns,” 1.

⁷ Alissa J. Haddaji, COSPAR and Harvard Business School, Interview, July 19, 2021.

⁸ NASA, “Orbital Debris Program Office,” orbitaldebris.jsc.nasa.gov.

⁹ Gallozzi et al., “Concerns,” 1.

¹⁰ McDowell, Interview, July 14, 2001.

discoveries such as in 2019, when the telescope played a fundamental role in capturing the world's first image of a black hole.¹¹

Not only do satellites pollute astronomy images, but they also impede detection of approaching asteroids and comets, creating a security risk for humans. "All satellites ... will be particularly negative for scientific large area images used to search for Near Earth Objects, predicting and, eventually, avoiding possible impact events."¹² If telescopes cannot see incoming asteroids, the whole world is at risk from potentially hazardous objects (PHOs) entering Earth's atmosphere, and time-sensitive mitigation will not be an option. In general, at least four months of reaction time are needed to avert an incoming PHO and depending on the method used either to push or to pull the object, years of global deliberation and preparation may be necessary.¹³ Incoming PHOs are, as their name denotes, *potentially hazardous* to humankind and to life on Earth. An asteroid just a hundred meters long could cause a perpetual winter, as its impact dust would shade the sun's light, killing plants on a global level and leaving the survivors to die of suffocation and starvation.¹⁴

After satellites, the second problem for astronomy is local light pollution, which is growing faster than Earth's human birth rate.¹⁵ Due to economic and technological advancement, cities everywhere are employing more and more lighting, which is why astronomer Richard Green of the University of Arizona Steward Observatory is alarmed: "Rapidly growing artificial skyglow is putting the world's observatories under threat."¹⁶ As looking into a flashlight makes it impossible to see what is beyond, ground-based astronomical observation is obstructed by bright lights from sports arenas, billboards, casinos, and security lighting—all of which symbolize modern-day advancement.¹⁷ This is a hit on more than just science: advocates to keep the skies quiet and dark say growing skyglow will affect star and astro tourism as complete industries fashioned around looking at the night sky are threatened.¹⁸

Legally, there is not much that can be enforced until regulations emerge. A review of international law shows that this is an issue between the launching countries and the countries whose astronomical observations are being obstructed. The current treaties include the Outer Space Treaty—which states that space is for all [hu]mankind; the Liability Convention—which holds accountable those who cause damages; and the

¹¹ Gallozzi et al., "Concerns," 10; Kazunori Akiyama et al. "First M87 Event Horizon Telescope Results." *Astrophysics Journal Letters*, 875, no. 1 (2019): L3.

¹² Gallozzi et al., "Concerns," 1, 8.

¹³ NASA, "Planetary Defense," [nasa.gov](https://www.nasa.gov).

¹⁴ NASA, "Planetary Defense."

¹⁵ UNOOSA, "Dark and Quiet Skies Conference: Presentation Day: Slides," October 5-9, 2020, 3:13.

¹⁶ UNOOSA, "Dark and Quiet Skies Conference," 3:15.

¹⁷ "Are We Killing Astronomy? Interview with Astronomer Derek McNally," *New Scientist* 151, no. 2044 (1996): 28-31; International Dark Sky Association. [darksky.org](https://www.darksky.org).

¹⁸ UNOOSA, "Dark and Quiet Skies Conference," 1:52.

Registration Agreement—which makes the launching country responsible for the launchers.¹⁹ Although international law provides legal protection for countries to sue each other over scientific damages, this is not a practical course of action. Not only do cases at the International Court of Justice take over a decade to resolve, but also bickering between nations is a primordial answer, says Simonetta di Pippo of the United Nations Office of Outer Space Affairs: “It is not the time for unilateral actions when we are all affected by the challenges we face.”²⁰ Before pursuing legal disputes, astronomers rallying to have a voice at the United Nations must focus on international awareness and on global support.

Part of this is UNESCO’s campaign to preserve the night sky and the astronomical heritage of humanity.²¹ Supporting the endeavor is the Dark and Quiet Skies annual event sponsored by the International Astronomical Union and UNOOSA. The conference’s mission is to secure international space sustainability guidelines for the world to follow. Organizers are lobbying for the UN Committee on the Peaceful Uses of Outer Space to start talking about ground-based astronomy as something that is in its jurisdiction.²² Oddly, astronomers are now forced to get involved in UN deliberations—a process that is not usually in their job description. But “without international regulation,” McDowell says, “there’s nothing stopping someone else from putting something worse in [orbit].”²³ The astronomy community must make a presence at the law-making table.

Nationally, the American government has the power to protect astronomy, as it does within the National Radio Quiet Zone in Green Bank, Virginia—a town where wi-fi, cell phones, and microwave ovens are illegal because they interfere with the radio frequency science being conducted there.²⁴ However, the observatory is overseen by laws that are a “special case” and do not blanket all national astronomical observations.²⁵ With Starlink, the question is whether expensive business attorneys are persuasively keeping lawmakers from preserving the night sky, or if the government values internet access more than

¹⁹ UNOOSA, “Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies,” unoosa.gov/outerspacetreaty; UNOOSA, “Convention on the International Liability for Damage Caused by Space Objects,” Resolution 2777 (XXVI), unoosa.org/ooosa/en/ourwork/spacelaw/treaties/liability-convention.html; UNOOSA “Convention on Registration of Objects Launched into Outer Space,” Resolution 323 (XXIX), unoosa.org/ooosa/en/ourwork/spacelaw/treaties/introregistration-convention.html.

²⁰ International Court of Justice, “Pending Cases,” icj-cij.org/en/pending-cases; UNOOSAs, “Dark and Quiet Skies for Science and Society,” 1, unoosa.org/ooosa/events/data/2020/dark_and_quiet_skies_for_science_and_society.html.

²¹ UNESCO, “Astronomy and World Heritage,” whc.unesco.org/en/astronomy.

²² UNOOSA, “Dark and Quiet Skies for Science and Society.”

²³ McDowell, Interview, July 14, 2001.

²⁴ Wesley A. Sizemore, “The National Radio Quiet Zone and the Green Bank RFI Environment,” *Astrophysics Data System*, articles.adsabs.harvard.edu.

²⁵ Federal Communications Commission, “Docket No. 11745,” Green Bank Observatory, November 19, 1958, gb.nrao.edu/nrqz/FCC_Docket_11745_NRQZ.pdf.

pictures of outer space. This is highlighted in the 2015 Space Resource Exploration and Utilization Act, a law the US Congress passed allowing companies to bypass bureaucratic red tape, encouraging them to emerge as space commerce leaders in remote sensing—satellites—and in space mining.²⁶

Whether big money or big government is winning has yet to be proven. But the conversation for saving the night sky is promising on other levels: many groups are supportive of regulation, and common interests have united the front. For example, not only is light at night bad for astronomy, but according to doctors, it is also unhealthy for humans. The American Medical Association has announced that light at night contributes to mood disorders, obesity, diabetes, diminished performance, and prostate and breast cancer.²⁷ Also, improper lighting causes night glare, which creates nighttime driving disability in seniors due to changes in their eyes after age fifty.²⁸ This can be easily remedied with better engineering of streetlights. Advocate groups are educating local authorities on the monetary savings from using lighting that does not illuminate the night sky—but instead lights downward the areas needed at night—and in lighting curfews and motion-sensor devices. Therefore, grassroots regulatory frameworks to reduce growth of light pollution are helping astronomy, and they are good for citizens, for skyglow, and light at night; local and state municipalities are learning that it is healthier, more appealing, and less expensive to use efficient lighting.²⁹

Another argument against light at night is that it damages the bio-environment. Sea turtle babies hatching on the Florida coastline, for example, instinctively crawl to the reflective nighttime ocean to find food and habitat, yet with bright oceanfront lighting they seek out the structures along the beach instead—residences and businesses—and die.³⁰ Many species are suffering confusion, accidents, and illness as light at night grows.³¹ Not only is damage to biodiversity a human threat, as ecosystems are intertwined with human survival rates—but with satellite and light pollution, it is a question of space and environmentalism: to what extent is near-Earth space a part of the environment and already covered by environmental legislation?³² As a human rights issue, there is no international law making the night sky a heritage to humans. UNESCO, however, argues

²⁶ US Congress, "H.R. 2262—US Commercial Space Launch Competitiveness Act, Space Resource Exploration and Utilization Act of 2015," [congress.gov/bill/114th-congress/house-bill/2262](https://www.congress.gov/bills/114/house-bills/2262).

²⁷ UNOOSA, "Dark and Quiet Skies Conference," 2:19; Peter James, Kimberly A. Bertrand, Jaime E. Hart, Eva S. Schernhammer, Rulla M. Tamimi, and Francine Laden, "Outdoor Light at Night and Breast Cancer Incidence in the Nurses' Health Care Study II." *Environmental Health Perspectives* August 17, 2017, <https://doi.org/10.1289/EHP935>.

²⁸ UNOOSA, "Dark and Quiet Skies Conference," 2:14.

²⁹ UNOOSA, "Dark and Quiet Skies Conference," 3:9.

³⁰ International Dark Skies Association, "Sea Turtle Conservation," darksky.org/our-work/sea-turtle-conservation.

³¹ UNOOSA, "Dark and Quiet Skies Conference," 2:27.

³² UNOOSA, "Dark and Quiet Skies Conference," 2:27.

there should be as it declares natural resources, environmental sustainability, and freedom from pollution the birthright of future generations.³³ The counterargument to this is that global internet could be viewed as a human right, as well, since it contains access to education, employment, and healthcare: items denoted in the Universal Declaration of Human Rights.³⁴ The question here becomes, which is a greater right to humanity? The argument has legal earmarks on multiple levels.

On the technological side, sharing the night sky with obstructions is not an easy solution. Funding and innovation are needed for software improvements, which can eliminate the light trails in pictures, but the accuracy of the information will still be diminished—such as in determining the precise brightness of a star when a light streak has imposed itself on the take. “It can’t solve the problem, but it can make images look ‘less bad,’” says McDowell, who is an expert in dark sky light pollution.³⁵ Advancements in hardware, on the other hand, can be fitted to large observatory telescopes to adapt a triggering shutter which closes for five seconds when a satellite goes by, but will be much more expensive than changes in software. McDowell does not believe technology will solve this issue—not only would it be grossly expensive—in the billions—to retrofit every telescope in the world, but also it is not the true answer. Technology will not help if there are satellites always coming at all sides. On this issue, talks between interested parties have opened and they have helped: “there are technical regulations that could limit the number of satellites of certain brightness, which is the compromise coming out in the long run, but it’s got to be something that the whole world decides, not just one company or one regulatory agency in the US.”³⁶ For lasting change, balance on all sides will be key.

The constant study of the night sky is bound by the awe that comes from seeing things greater than one—to consider how miraculous life is, and to calculate for its continuance. “If [humanity] loses its cosmic perspective, we are lost,” wrote Derek McNally, a man who spent his life studying the night sky.³⁷ Twenty-five years ago, he foresaw the dangers that would threaten his field and warned that something needed to be done before it was too late.³⁸ Although moves are being made to help earthbound astronomy survive, it will take a team of advocates across multiple disciplines to convince lawmakers that serious consequences are at hand and must be mitigated. Light pollution and satellite placement are more than a threat to ground-based astronomy, they are a security issue, a health issue, an environmental issue, and a humanitarian issue. “The real thing for us,” says

³³ UNESCO; “Astronomy and World Heritage Thematic Initiative,” <https://whc.unesco.org/en/astronomy/>.

³⁴ United Nations, “Universal Declaration of Human Rights,” Articles 23-26, [un.org/en/about-us/universal-declaration-of-human-rights](https://www.un.org/en/about-us/universal-declaration-of-human-rights)

³⁵ McDowell, Interview, July 14, 2001.

³⁶ McDowell, Interview, July 14, 2001.

³⁷ “Are We Killing Astronomy?”

³⁸ McNally, Derek. “The Adverse Environmental Impacts on Astronomy: What Should be Done?” University of London Observatory, 1997, <https://doi.org/10.1023/A:1007961909331.pdf>.

McDowell, as he Zooms in from a networking conference with satellite companies, “is to not have the night sky grossly changed based on the decisions of any one country.”³⁹ He speaks like a true academic, and one who loves the stars enough to fight for access to them. The conversation to save ground-based astronomy has begun, and although it may find opposition before it finds a consensus, there are enough good arguments to reach a formidable agreement. Ad astra.

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About the Author: Rebecca Schembri is a space diplomat and author from Reno, Nevada. She graduated in Social Science, International Relations, and Legal Studies from Harvard University Extension School in 2022. She is Harvard-certified in social justice and business communication. Rebecca advocates for outer space exploration and for ethical space law and policy. She also saves the world from asteroids as the Public Communications Manager at the B612 Foundation.

Editors’ Notes: Space policy expert Rebecca Schembri is a member of the *Overview Round Table* and contributor to the new *Human Space Program* blog. Here she argues passionately for the need to protect humanity’s opportunity to experience the cosmic perspective offered by access to the dark sky from the surface of the Earth. Orbital light pollution (of the sort threatened by new satellite networks with thousands of reflective surfaces in space) raises numerous ethical issues and is a global problem requiring international solutions. This thought-provoking essay is a great primer on the subject and well worth sharing with colleagues, friends, and loved ones who may need to understand the issue better. **Gordon Arthur and Mark Wagner.**

³⁹ McDowell, Interview, July 14, 2001.