

On the Path to Convergence

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The progress, challenges, and potential of light pollution research

2023 was a landmark year in the history of the dark-sky movement. It was the 50th anniversary of the publication of Kurt Riegel's paper "[Light Pollution: Outdoor lighting is a growing threat to astronomy](#)" in the journal *Science*. It was the 35th anniversary of the founding of the International Dark-Sky Association, which recently rebranded as "[DarkSky International](#)." The movement has come a long way since astronomers first sounded the alarm over a half-century ago.



Photo credit: NASA image of city lights at night

Three important international conferences took place in the last year. The results presented at these meetings give an idea of where this field is now and where it's headed. All three conferences are part of a recurring series. First was the [8th International Conference on Artificial Light at Night \(ALAN\)](#), held in Calgary, Canada, from 10-13 August 2023. Second, was "[Light Pollution: Theory, Modelling and Measurements](#)" (LPTMM), held in Altmünster, Austria, 9-12 July 2024. And finally, the world's largest meeting of astronomers held every third year, the [32nd International Astronomical Union General Assembly \(IAU GA\)](#), held in Cape Town, South Africa, between 6-15 August 2024. Each conference included a mix of both in-person and remote attendees, enabling more people to take part.

Participants discussed light pollution, dark skies, and the potential impacts on night skies from satellite "megaconstellations" at all three events. In

summarizing what transpired at these meetings, broad conclusions about the state of the field are organized here around three themes.

Areas in which we're making progress

Light pollution remains a significant social and environmental challenge. But there are some reasons to be hopeful about advances in our understanding of the problem.

- **Measurement of light pollution.** Ground-based devices used to measure night-sky brightness continue to be measurement workhorses. Tech and design innovation are making ground-based sensors smaller and more affordable. For example, IAU GA session attendees were shown the [Free Dark Sky Meter \(FreeDSM\)](#), a night-sky photometer based on an open-source design costing around \$40 to make. As devices and software improve and costs come down, an increasing number are making it into the field. As a result, we are learning more about the detailed distribution of artificial light at night (ALAN) in three dimensions, particularly in urban contexts. "Hyperspectral" devices, which measure both the intensity and color of light, are also becoming more affordable supporting development of rich data sets across various spatial and temporal domains. New remote sensing platforms, like balloons and drones, are similarly giving us new views of light pollution that can be correlated with "ground-truthed" outdoor lighting inventories.
- **Modeling of light pollution.** Cheap computing power has revolutionized our ability to model light pollution. Data has become increasingly accurate and models more realistic; taking into account factors such as real-world weather conditions, multiple orders of light scattering, and the polarization state of ALAN. This has important implications for many kinds of studies, especially those involving ALAN's effects on wildlife and human health.
- **Satellite impacts on the night sky.** Following 2023's successful [IAU symposium](#) at La Palma, Canary Islands, astronomers organized a daylong session at the IAU GA on the topic of "dark and quiet skies". They have organized their efforts in response to the issue by establishing the [Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference \(CPS\)](#). The Centre engaged commercial satellite operators to develop and test new ways to mitigate the effects of satellites on astronomy, and GA attendees heard about a range of international developments. This topic is

now on the agenda with organizations like the United Nations Committee on the Peaceful Uses of Outer Space and the International Telecommunication Union.

Areas in which we're experiencing the greatest challenges

There are many unanswered scientific questions about light pollution. Additionally, there are some important barriers to the advancement of our research agenda.

- **Standardizing the ways we measure light pollution.** It's clear the research community would benefit from standardized protocols and units for measuring ALAN and reporting. However, agreement on which body might set these standards and how they would be decided, has yet to be determined.
- **Long-term measurements of light pollution in the field.** Our current devices are still far from perfect. Some show signs of "aging" due to effects like irradiation with solar ultraviolet light during the daytime. These effects can cause the accuracy of measurements to drift over time. The cost of devices remains high relative to the need for their broad deployment and operation.
- **Global views of artificial light at night.** We are also a long way from a detailed global view of the dynamics of "nighttime lights" from space. Only [one satellite system](#) freely provides nightly, global images of ALAN. We still have no dedicated, purpose-built space-based sensor platform. Such a facility would revolutionize light-pollution studies, but convincing funding agencies to greenlight such a project remains difficult.
- **Slow development of social science aspects.** Further engagement with those exploring ALAN issues from a humanities perspective would benefit a broader understanding of light pollution effects. Professionals in those subjects find it very difficult to sustain research agendas due to lack of consistent funding. And as in the case of many transdisciplinary areas, physical and social scientists struggle to understand the "language" that each speaks.
- **The unclear long-term status of satellites.** The rate of new satellite launches remains high, with more launched into space in the past five years than in the preceding six decades. As orbital space becomes more crowded, the chances of debris-generating collisions is rising. Commercial operators have not yet found fully effective mitigation

techniques for their satellites. As a consequence, the number of satellites visible to the unaided eye at night continues to increase, fundamentally changing the appearance of the sky.

The need for systemic change

Human beings, with all their faults, drive scientific discovery. They also hold the keys to preserving dark skies. The needs are evident for addressing both priorities.

- **Achieving social equity in outdoor lighting.** Light pollution science now interacts with society more than ever. It influences policy making; lighting technology development; and decisions about where, when and how to use ALAN. The next frontier of dark-sky conservation practice involves social and environmental justice concerns. As the global population ages, we need to rethink why and how we light our world. Otherwise, we will fail to recognize the amount of "visual diversity" that now exists. In the same vein, people harmed by outdoor lighting policies should be consulted as a matter of basic democratic principles. We should ensure that public policy in this realm serves the public rather than disadvantaging already marginalized people.
- **Professionalizing the field.** The time may have arrived for this maturing field to formally organize itself. Participants at the IAU GA heard a call to recognize the emergence of "nocturnal environmental studies". This approach tries to bridge the gap between the sciences and considers ALAN and natural darkness on more of an even footing.
- **Motivating social change.** The evidence for ecological harms associated with ALAN exposure continues to mount, yet engaging the public and moving people toward solutions remains difficult.

The dark-sky movement and our knowledge of the sources of (and solutions to) the problems, have clearly advanced. The questions asked, and methods used to answer them, have changed over the decades. What's clear from recent developments in the scientific community is we're closer than ever to breakthroughs in many areas. Much of this work is now realizing the importance of the human element in our research and practice. With luck, that will lead to discoveries that serve both science and society.

Learn More

- [Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference \(CPS\)](#)
 - [General Publications & Resources](#)

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- [Community Engagement Hub](#)
 - **Riegel, K. 1973. "Light Pollution: Outdoor lighting is a growing threat to astronomy"** Science, Vol 179, Issue 4080 (pp. 1285-1291) DOI: 10.1126/science.179.4080.1285
 - **Conferences:**
 - **LPTMM 2024 - Light Pollution: Theory, Modelling and Measurements**, July 9-12, 2024, Altmünster, Austria
 - **IAU GA 2024 - 32nd International Astronomical Union General Assembly**, August 6-15, 2024, Cape Town, South Africa
 - **ALAN 2025 - 9th International Conference on Artificial Light at Night**, October 28-30, 2025, Westport, Ireland
 - **Prior Spotlight Article by Author:**
 - **Satellite Light Pollution: Is The Sky Really Falling?**, February, 2022