

EURODARK 2026

17th European Symposium for the
Protection of the Natural Night

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Code of Conduct

Light is not only a technical thing to see something. It's about emotions and feelings, too. So is darkness. We all have different experiences, needs, and opinions. Here in Kaunertal, we meet to connect and talk to each other. "We" means quite different people. We come from different countries, have different backgrounds, different levels of knowledge about light and light pollution. We have different expectations about light and night.

At EURODARK, we believe in the equality of all humans, regardless of their gender, age, ethnicity, nationality, religion, sexual orientation, etc. We believe that we can only solve problems if we treat each other with respect, even if we disagree. For these reasons, we do not tolerate harassment of or by conference participants in any form. To create a constructive and respectful atmosphere, please be kind and considerate. Be mindful of others around you. Discuss with facts, experiences, and emotions, but don't insult others or start moralising. Treat others like you want to be treated.

If you feel harassed in any way or observes others being harassed, don't hesitate to contact one of the organisers. The same is the case if you need assistance with anything due to handicaps including language barriers, physical limitations, or medical needs.

Exhibitions at EURODARK 2026

We welcome two lighting manufacturers to the EURODARK Symposium. Their contributions help us to reduce the registration fee for the attendees. More important, they are here to add their thoughts, ideas and expertise to the protection of the night.

Please take this chance to have a look at their products and have conversations with these representatives. There is no "we protectors of the night here" and "those from the lighting manufacturers there". We all have come to the Kaunertal to connect and work towards better lighting design and less light pollution. We are here to learn from each other.

By giving them exhibition space we do not endorse their products, nor are they in any way preferred to other manufacturers. We have not excluded any manufacturer.

Names and titles

We have decided to not use titles like MA, MILP, Dr., PhD, Prof., etc. during this Symposium. In our experience, the knowledge on light pollution and emissions does not necessarily correlate with such titles. EURODARK is a meeting of peers, and we want to interact on the level of specific expertise, not titles, no matter how well earned. At EURODARK you will find experts with no official title, but enough knowledge to deserve one.

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Greeting words from the Tyrolean Environmental Ombudsoffice

Diligent management and use of artificial outdoor light at night allows for an unobstructed view of the starry sky, is environmentally significant, and demonstrates respect for living beings and the natural world. For over 20 years, the Tyrolean Environmental Ombuds-office has been advocating for this goal. The Tyrol Competence Center on Light Pollution and Dark Skies serves as a hub and focal point for knowledge, practice, and exploration in this field.



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tirol kompetenzzentrum
für lichtverschmutzung
und nachthimmel

We are proud to organize the 17th European Symposium for the Protection of the Night Sky in the Kaunertal Valley in Tyrol in collaboration with the European Light Pollution Coalition, the Kaunergrat Nature Park, and numerous local and regional partners.

Thanks to consistent engagement, light pollution and its effects are becoming increasingly relevant to decision-makers, planners, industry, and society. Nevertheless, the extent and intensity of areas affected by artificial light at night continue to grow. We are convinced that transformation is possible, where people from different backgrounds and disciplines come together, engage in dialogue and share practical and sensory experiences. The European Symposium is such a platform and brings together science, business, art, lighting engineering and planning, nature conservation, regional development, and public authorities, to present progress, share solutions, and forge partnerships across sectors, needed to protect and strengthen the natural night.

We look forward to a Symposium filled with insights, networks and inspirations to shape our environment diligently for all living beings and future generations.

Johannes Kostenzer (Tyrolean Environmental Ombudsman)

Lena Maria Oberdorfer (Organisation EUODARK 2026)

Stefanie Pontasch (Divisional Manager International Cooperation)

Stefanie Suchy (Divisional Manager Light Pollution)

Greeting words from the European Light Pollution Coalition (ELPC)

Welcome to the 17th European Symposium for the Protection of the Night Sky in the Kaunertal!

From this number you see that it is already a long time symposium, that started 28 years ago, in 1998, in the science centre Cité des Sciences in Paris. As it was and is a meeting mainly organized by people and or organisations that voluntarily engaged in fighting light pollution, it could not be held every year. As I had the privilege, that I could attend all, I also saw the engagement of so many - often amateur astronomy - clubs. All meetings attracted mainly local, but also international activists and the talks and discussions helped to exchange knowledge, experiences and motivations for new actions in Europe.



Though we couldn't stop the general increase of light pollution, mainly through the change to energy efficient and meanwhile cheap LED lighting, several regional successes were achieved. The symposium 2007 in Bled, Slovenia, accompanied the introduction of the first national law against light pollution. At or near many of the symposium locations Dark Sky Places were certified by the International Dark Sky Association, now Dark Sky International. In France we see how the protection of the night sky merges with the protection of biodiversity and the switch-off of artificial light at night reduces light pollution and saves energy. In June at the meeting of the French international Dark Sky Reserves (RICE - Réserve Internationale de Ciel Étoilé) in the French alps with about 200 participants, I saw how important the movement is there, but unfortunately the cooperation with them, but also the Spanish and Italian groups could be better. It might be due to language problems, but hopefully modern translation techniques might help to overcome this.

This EURODARK Symposium is the first event of our new coalition. It will be as diverse as the night and its protectors. The change from "Protection of the Night Sky" to "Protection of the Natural Night" supports the interdisciplinary character of the symposium.

We are thankful to the Tyrolean Environmental Ombudsoffice and especially to the two Steffis and Lena Oberdorfer that we can meet for the second time in Austria and in a hopefully future International Dark Sky Park!

Andreas Hänel (co-founder of the European Symposium and of the European Light Pollution Coalition)

Greeting words from the European Light Pollution Coalition (ELPC) - continued

At the last symposium two years ago in Groningen the new title EURODARK was introduced. However, this wasn't the only step towards change. The idea of a European network has been taken up a couple of times but was never pursued. In Groningen, I agreed to start such a network and asked Yana Yakushina to help. Powerful as she is, she started to work out the plan for an NGO to connect night protectors in Europe and beyond. Now, two years later, with the help of Christoph Pütz and a handpicked team of supporters, we have a website and a vision. Right now, we are in the process of registering as a charity. The name we picked is European Light Pollution Coalition, because this coalition is not about darkness, but about fighting light pollution - which can mean restoring natural darkness but also putting good lighting design into place where light is really needed.

The only thing that is missing is: YOU. We have built the framework, now it's time to fill it with life and people. No matter if you are an activist, a scientist, a lighting professional or just somebody who wants to protect the night, you are welcome. Since we work in cooperation with Dark Sky International, Dark Sky chapters can also join our coalition of night protectors. You won't have to give up your ideas or affiliations to a group, you are simply invited to join something that hopefully will make us more powerful.



Talk to us and get involved with your projects, talents, ideas, and energy. Let us make this a coalition of many people.

For more information go to: www.lightpollutioncoalition.eu

Annette Krop-Benesch (co-founder and CEO of the European Light Pollution Coalition)

Exhibitors



Siteco is a leading provider of innovative lighting solutions, supporting customers with intelligent, sustainable, future-proof lighting concepts for indoor and outdoor applications.



Preworks supplies high-quality stage technology and LED architectural lighting solutions, with a specialty for sports venues, including intelligent spotlights, lighting control systems, and media servers. The company focuses on quality, service, and expert advice to deliver lighting solutions tailored to each customer's individual requirements.

Keynotes

Dan Oakley: Evolving the DarkSky program – update on upcoming guidelines

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Overview: The Dark Sky Places program certified its first place, Flagstaff, Arizona, 2001 and has grown to over 250 places worldwide. The program caters to communities to protected areas and covers around 240,000km². Since its inception, lighting has moved on. The use of LED and the growing evidence base of the impact of artificial light at night shows that the dark sky program must change to meet this growing challenge and cater to new audiences. To do this the DarkSky is updating its place program by incorporating new approaches, categories and lighting policies. The aim is to provide a flexible certification program that enables all communities and protected places to join the program and embark on a journey to protect the night sky.

About Dan

Dan has been active in night sky protection for over 15 years and now works to manage and certify dark sky destinations around the world. A graduate of the University of Surrey with a degree in Physics, Dan transitioned from systems engineering in the defense industry to become a countryside ranger for the South Downs National Park in southern England. He went on to earn a Master's degree in Environmental Policy and a foundation degree in Wildlife Management.

After helping the South Downs achieve DarkSky Reserve status, Dan collaborated with the lighting industry, conservation organizations, and other protected areas across the UK to establish the UK Dark Sky Partnership and was a founding member of DarkSky UK. He founded Darkscape Consulting, specializing in developing technical guidance and policies for sustainable development planning. Dan also served as the Dark Sky places committee chairman and now works for DarkSky International as the Policy and Destination Senior manager. He also volunteers with the South Downs Planetarium.

Valéry Jacobs: Connecting Light Pollution Research: Towards Interoperable and Future-Proof Data

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Light pollution is studied across astronomy, lighting engineering, ecology, chronobiology, remote sensing and other fields. Each discipline has developed its own concepts, quantities, units, instruments and spectral conventions, reflecting different research questions and different ways of observing the nocturnal environment. This diversity is scientifically legitimate, but it makes results difficult to compare and validate across disciplines, and can limit the reuse of measurements for questions they were not originally designed to answer. This keynote explores how we can preserve that disciplinary diversity while making light-pollution data more interoperable and future-proof. This challenge lies at the heart of the CIE Research Forum on Light Pollution, which brings different communities together to connect their approaches and work towards shared terminology, measurement principles and reporting practices that increase the comparability and long-term scientific value of light-pollution data.

About Valéry

Across astronomy, lighting technology, photography and governance, my focus has always been on how we understand and make sensible use of light. I studied astronomy to understand the stars and enjoy the night sky, earned a PhD in lighting metrology to master how we measure and design light, and later obtained an executive master in public governance and leadership to bring research into practice. In 2023, scuba diving also opened my eyes to another dimension: underwater beauty that depends on darkness, just like our night skies. That experience fuels my work on light pollution and ecologically aware-lighting; once more combining measurement expertise and urban design with ecological and societal perspectives.

Birgit Högl: The role of darkness in human sleep

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The close interaction of human sleep and circadian rhythms has been established by A Borbely almost 5 decades ago. The strongest circadian Zeitgeber is light, and the underlying biological mechanism including involved brain structures, the effect of light spectrum and the phase – response – curve are established.

While insufficient daytime light exposure and its negative impact has been investigated for a long time, the importance of night time darkness for human sleep has only recently gained more attention.

This brief keynote talk will treat aspects of outside and inroom light-at-night and associations with melatonin levels and negative health outcomes. More recent studies providing evidence for biological effects even of minimal residual ambient light at night will also be presented.

The keynote will end with some practical suggestions.

About Birgit

Birgit Högl is a full professor of Neurology and Sleep Medicine at the Medical University of Innsbruck, Austria, current Director of the Center of Sleep Medicine at Medical University of Innsbruck and Vice Director of the Department of Neurology.

After completing Medical School at Technical University of Munich and residency in Munich (1989-1995), she underwent clinical research fellowship at the French Hospital in Buenos Aires (1995-1997), and then joined the Movement Disorder and Sleep working group of Professor Claudia Trenkwalder at the Max-Planck-Institute in Munich, Germany.

In 1999 she was appointed head of the sleep laboratory, sleep disorder outpatient clinic, at the Medical University of Innsbruck, which was converted in Center for Sleep Medicine in 2024.

She has served as officer in executive committees of multiple professional societies, namely President of the World Sleep Society 2019 – 2022, President of the Austrian Sleep Research Society (2006-2010 and 2016-2018), President of the European RLS study group secretary of the international RBD study group and others.

Birgit Högl has published more than 500 manuscripts, more than 45 book chapters, and has acted as a coeditor of 4 scientific books (AMW please add) , Her popular book (“Besser Schlafen” was published in 2023 by Brandstaetter Verlag Vienna (in German). In addition, she has delivered more than 500 lectures (in English, and Spanish) in Europe, the Americas, Asia and Australia/New Zealand. Her research is much cited, so her Hirsch Index is 99 in Google scholar, 87 in Scopus and 77 in google scholar. (Sept 2026).

Birgit Högl has received several honors and awards, in particular the Tiroler Landespreis für Forschung 2019 (Science Award of Tyrol).

Out of the Bubble, Into the World – An interactive Workshop by LTG

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Expert knowledge on light pollution is abundant - yet it rarely reaches the people who most need to act on it. Who exactly needs to understand this issue better? Local decision-makers? The wider public? Even the experts at this very symposium?

This interactive workshop aims to bring different perspectives into one room to work through that question together, and from there, to develop concrete, shareable approaches for making expert knowledge land outside the room it was created in. We won't assume we already understand each other's challenges. Yet you most probably have some valuable experience in communicating outside our profession.

So let's find out what might happen when researchers, activists, manufacturers, and lighting designers share and work together on a question that affects all of us: how do we make our expertise land outside our own professional bubble — accessible, credible, and actionable?

This session is for anyone who has felt the gap between what we know and what actually gets done - and who's ready to close it, together.

Cooperation, Projects, Future

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Light pollution projects across Europe have produced a wealth of valuable knowledge, tools, guidelines and other materials. Yet these outputs can be difficult to find, and work is sometimes repeated because existing resources or expertise are not known across projects, countries and organisations. This workshop will explore how we can better connect and build on existing project results, expertise and networks across Europe. We will also look ahead to future cooperation: where are the gaps, what could new projects build on, and where could stronger collaboration add value? Together, we will identify opportunities to strengthen continuity between past, current and future initiatives, avoid unnecessary duplication, and support new collaborations on light pollution across Europe.

“How to become a ‘Rising STAR’?”

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Initiatives such as “Helle Not” and “Paten der Nacht” have been drawing attention to the issue of “light pollution” for many years. Nevertheless, there is still a lack of widespread public awareness and a general understanding of the problem in Austria. As part of the “Talente regional” project “Rising STARS – students explore natural darkness, light pollution, and sustainable lightning”, an interdisciplinary team of scientists, practitioners and educators is raising awareness of the issue, particularly amongst young people, and is working with them to find solutions.

The “Talente regional” programme, run by the FFG, the national funding institution for industry-related research and development, aims to inspire children and young people to pursue a career in research. The topic of light pollution is ideally suited to this.

In the “Rising STARS” project, students and teachers from five schools (two primary schools and three secondary schools) are working alongside experts in the fields of protection of the night, conservation and environmental protection, biodiversity, lighting technology and architecture, as well as local authority staff, on the issues of light pollution and the protection of the natural night.

What “Rising STARS” aims to achieve:

1. Sharing knowledge: on the importance of the night and the far-reaching consequences of light pollution for the environment, health and energy consumption
2. Strengthening skills: developing the ability to analyse and assess lighting situations and to devise solutions and measures independently
3. Participation and networking: students implement measures both within the school environment and within their family and local communities, acting as advocates who raise awareness of the issue amongst those around them.

Young students become part of the research team themselves and experience how research can, in practice, help to improve their own immediate living environment. Teachers discover the wide range of opportunities for incorporating the topics of light pollution and the protection of the night into their lessons, and for engaging with regional businesses and scientific institutions. Participating scientific institutions and businesses benefit from the diverse disciplinary approaches and from meeting potential future employees.

In their workshop, the Rising STARS project team will begin by providing a brief insight into how this collaboration came about and sharing their initial experiences of the project.

They will then invite workshop participants to discuss the challenges and success factors associated with such initiatives and to consider, together, opportunities for collaboration or for launching similar projects in their own communities. Workshop participants can play an active role in raising awareness of light pollution and the protection of the night, networking with others, and taking away ideas from the workshop that they can put into practice.

Darkness Matters

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Introduction

A meditative journey from dusk till dawn, *Darkness Matters* became an immersive fulldome film and VR experience exploring the ecological, perceptual and emotional consequences of light pollution and its impact on ecosystems, while celebrating the resilience of nocturnal environments. It is a homage to what thrives at night and the Milky Way, revealing what still survives, rather than what is lost, in a world increasingly flooded by artificial light.



Fig. 1: Human POV, credit: Oliver Akermo.

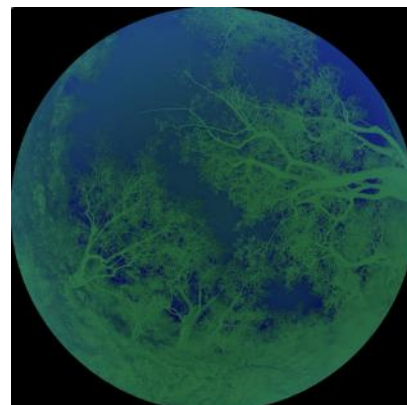


Fig. 2: Fireflies POV, credit: Oliver Akermo.

From fireflies flickering in olive groves in the Tuscan hills by Pisa, to hedgehogs, owls, wolves, inhabiting forests, to ibexes on alpine meadows and mountains ridges, *Darkness Matters* follows the gradual passage of night across altitudinal zones accessing the valleys of the Maritime Alps.

As the camera tilts from earthly habitats and landscapes toward the stars, the film reconnects viewers with the fragile beauty of darkness and the celestial rhythms that shape life on Earth. Showing us not only what we see if the night is dark enough, but also what the animals see, as distorted as it may look like. The project is designed to combine scientific storytelling with a powerful artistic experience for global audiences.

Methods

Filmed with a nodal set-up and specifics from a camera able to reproduce animal vision, *Darkness Matters* traces a cycle from dusk to dawn, guided by an other-than-human perspective. The multimedia project has 2 versions: fulldome and VR (apple vision pro). We wanted to create a piece of art on scientific grounds to bring the fireflies and the Milky Way also to the ones you might not be able to see them and show the world through some other's crepuscular and nocturnal animals' vision.

Visual & Immersive Approach: The fulldome version sustains a slow, contemplative experience designed for immersive environments, supporting presence and ecological empathy through camera movement, sound, and pacing. The VR version encourages interaction and invites to increase or decrease light pollution levels in different eras (before industrial revolution or in the near future, considering the average 10% rise per annum, calculated today).

Technical Innovation / creative technology: A novel high-resolution workflow.

We have been using the specs of a specific camera developed at the Dept. of Biology at the University of Lund in Sweden and with further hardware and software development at the George Mason Biology Dept. in Virginia, USA.

The footage introduces a new approach to creating true 8K dome masters in different tilts at 60 fps, using a RED Raptor camera's full 8K sensor area (width and resolution) for every captured/recorded plane. Instead of recording a single 180° circular fisheye image that only uses about half of the sensor's pixels, our method uses a 12 mm lens, which captures roughly half of the fisheye circle but in full 8K 17:9 resolution. We captured 6 to 12 overlapping nodal planes (8192 × 4320). When we stitched them together, we produced a native 17K equirectangular master (360×180° / 2:1). From that master, we could then crop out / enable true 1:1 8K dome renders with exceptional fidelity, without any resolution loss. By doing this, we maximized the pixel efficiency and image detail for each view. Traditional 8 mm fisheye setups deliver a full circular image in one shot, but since that circle only covers part of the frame, the effective dome resolution is often around 4K × 4K - even when shot on an 8K camera. Most productions then upscale this footage through AI enhancers. Our technique instead also enabled flexible remapping for different dome configurations and projection geometries, offering unmatched image fidelity and adaptability for immersive environments.

Conclusions

Darkness Matters was conceived from the start as an immersive and speculative multimedia project rooted in transdisciplinary artistic research and set up as an independent film production, by Fellonica Film AB. It addresses, indirectly in the fulldome and more directly in the VR version, the impact of light pollution on nocturnal ecosystems and it foregrounds darkness as a shared habitat across species, as a space of co-existence. Not to be afraid of. It was originally developed to combine moving images, sound, research-based storytelling, and site-specific practices. Its development into a fulldome film has marked a conceptual and formal shift: from a multi-screen and installation-based format towards planetarium; from human-centered observation toward an other-than-human perspective. WHY? The dome for us enabled much stronger multispecies storytelling, a non-anthropocentric visual language, where scale, orientation, and duration could invite the audience to inhabit nocturnal worlds rather than observe them from a distance. The dome format promoted a different standpoint. Besides, this transition allowed *Darkness Matters* to integrate more evidently scientific research, environmental data, and poetic narration into a spatial experience that mirrors more the complexity of the ecosystems portrayed. In this way the fulldome format became both a narrative and ethical tool, recalibrating perception, decentering the human gaze, and fostering ecological attentiveness. With the VR version we added one more experience for the viewer: interactivity, with the possibility to decide to have a fruition of the landscapes in a more or less light polluted state, using data given by the European Space Agency and implemented within a cooperation with InfraVIS, Sweden's National Research Infrastructure For Data Visualization.

Summarizing: the choice of the formats was conscious from the start and served both the storytelling and the purpose and aim of the film and its audiences.

Fulldome and the VR experience are meant to guide better than a classic documentary into the fragile balance between light, dark, human and animal presence.

Five years of measurements in a reference site at the Sölkttäler Naturpark: experiences and consequences

Zoltán Kolláth,^{*} János Sztakovics, and Tamás Hajdu

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Over the last five years, we have collected high-resolution and high-precision data at exceptionally dark locations in Austria's *Sölkttäler Naturpark*. At this site the level of light pollution around the zenith is minimal (Kolláth & Jechow 2023). Given these pristine conditions, it is our hope that the nature park will be officially designated as a Dark Sky Park in the near future, serving as a potential (Central-)European reference site for dark skies.

We used a photography-based sky quality measurement tool and obtained dozens of high-resolution all-sky mosaics over this period. In most of the measurement campaigns, we also have measured the spectrum of the night sky. This provides the best method to distinguish artificial components from natural ones, and thus proves outstanding sky quality over the Naturpark. One of the major results of our measurement campaigns is that the variation of airglow intensity alone provides significant changes of night sky brightness.

Figure 1 demonstrates the wide range of airglow variation by artificially enhanced colours

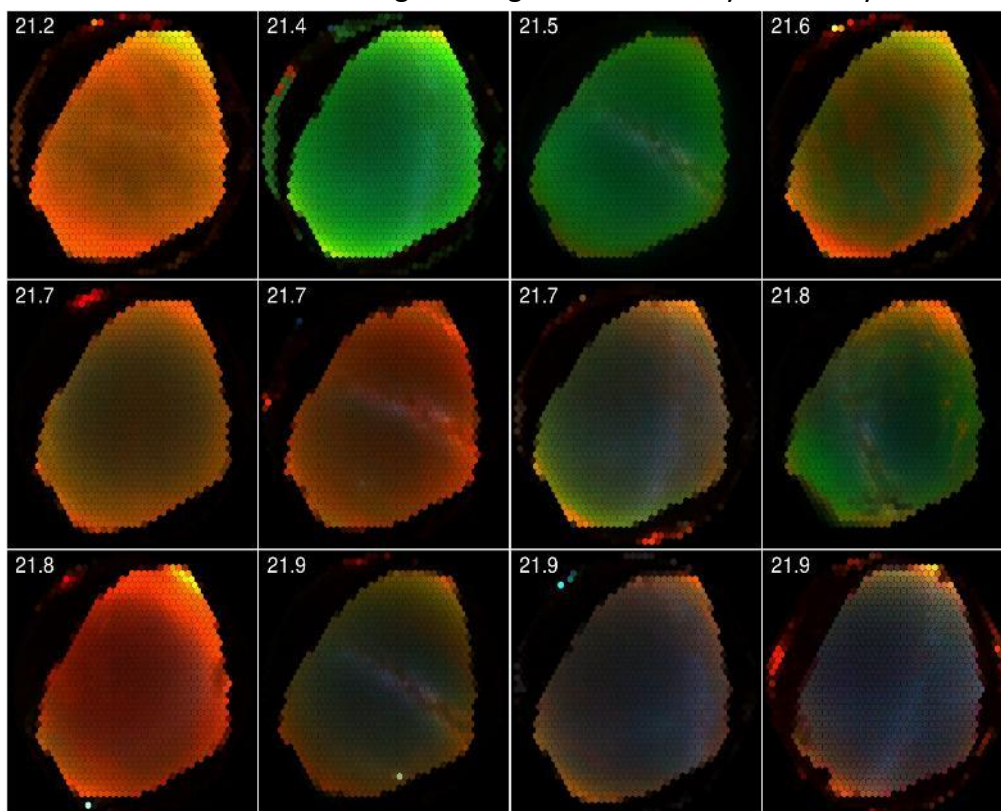


Fig. 1: Selected nights from our measurements ordered by the radiance of the darkest part around zenith. The brightness is indicated by magnitude / squared arcseconds in the top left corner of each images.

(False Colour Enhancement). The brightest night corresponds to a sodium event, with strong orange light. The second in the radiance order is with very extreme green (558 nm oxygen)

airglow. Interestingly, when the oxygen airglow dominates, the sky remains relatively dark in the V band.

The spectral and photographic measurements in the Sölktal valley helped a lot in establishing the transformation between different photographic bands (Kolláth et al 2025). Correct conversion from digital camera RGB radiances yields frequently used quantities with reasonable precision. In addition, colour information is essential to interpret the measurements correctly.

When I realised the beauty of natural variations in sky colour, I turned my measurement data into a photography exhibition and a fulldome (planetarium) film. The film shows the results of our study on the quality and the variation of the colours of the night sky. We cannot see the night sky's colours, but spectra taken under the pristine sky can tell us precisely the actual colour of the night sky. The planetarium show demonstrates the natural beauty of the night. The film premiered at the Fulldome Festival Brno 2024, winning the Best Short Award.

Acknowledgments

This research was supported by the Hungarian Scientific Research Fund (OTKA K143376)

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The Music of Teddie Hwang: Discovering Light

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In this presentation and performance, Teddie Hwang weaves together music and photography to show the beauty and value of the night sky, and the deep sense of unity which connects us all. She believes the arts hold a unique power to move us emotionally, and this emotional resonance is key to raising awareness and taking care of our dark skies. During the presentation, there will be moments where the audience may voice what the night sky means for them. In this way, **Discovering Light** is not just a musical slideshow, but a collective experience of shared reflection. The program features flute music from the 18th century and Teddie's landscape astrophotography from Europe and the USA.

Teddie Hwang is a professional flutist based in Germany. She holds a Bachelor's degree in Music and Germanic Studies from Indiana University USA, where she graduated with high distinction. She received her Master's degree in Historical Flute Performance from the Royal Conservatoire in The Hague, the Netherlands. A member of DarkSky International, she has a special interest in promoting night sky appreciation through her multimedia programs. The unique combination of music and her own photography has led her to perform for a variety of communities in Germany, Denmark, Ireland, Switzerland, and the USA. For further impressions of her programs, visit Teddie's website at <https://www.teddiehwang.com/music-programs.html>



Submitted Talks and Posters

Talks are sorted alphabetically by first author.

This is not always the presenter.

South Tyrol Illuminated – Characterizing Sky Brightness in Urban Areas

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Introduction

Artificial light at night has become one of the fastest-growing environmental pressures worldwide, affecting ecosystems, human health, energy consumption, and astronomical observations. Although regulations aimed at reducing light pollution have been implemented in South Tyrol since 2011 and were further strengthened in 2022, the actual contribution of different lighting sources to urban sky brightness remains largely unknown.

The project South Tyrol Illuminated was initiated to characterize light pollution in South Tyrol and to quantify the relative contributions of public street lighting and private lighting sources. Particular attention is given to the urban areas of Meran and Bruneck, where detailed long-term measurements and analyses are conducted.

In addition to continuous monitoring of night-sky brightness using dedicated photometric instruments, webcam observations spanning almost a decade were analyzed to reconstruct the long-term evolution of urban illumination. The project also investigates specific periods associated with increased artificial lighting, such as Christmas lighting and nighttime skiing operations.

Methods

The study combines several complementary datasets and measurement techniques.

First, long-term webcam observations from elevated locations overlooking the cities Meran and Bruneck were analyzed. For each city, clear-sky nighttime images were selected and processed using fixed regions of interest representing the urban areas, taking into account Camera-related variations such as exposure time and ISO. Annual mean luminance values were then derived and analyzed using log-linear regression models to estimate long-term trends in urban brightness. The results obtained from our ground-based observations were compared with satellite-derived radiance measurements from the VIIRS Day/Night Band.

Second, continuous measurements of night-sky brightness have been performed since spring 2024 using eight TESS-W photometers installed at urban, suburban, and rural locations. Measurements affected by twilight, moonlight, clouds, or unstable atmospheric conditions were removed using an automated quality-control procedure. The remaining observations were combined to obtain representative nightly brightness profiles.

To estimate the contribution of public lighting, the known municipal dimming schedules of street lighting systems in Meran and Bruneck were incorporated into a mathematical model. Smooth public-lighting profiles were generated using spline-based representations of the scheduled dimming events. These profiles were compared with the measured temporal evolution of sky brightness using a derivative-based regression approach. Bootstrap techniques were applied to quantify statistical uncertainties.

Conclusions

Our results demonstrate that light pollution in South Tyrol continues to increase despite existing regulatory measures. Long-term webcam observations reveal persistent growth of sky brightness above the cities Bruneck and Meran. At the same time, the analysis shows that public street lighting accounts for only a fraction of the total observed sky brightness, indicating that private, commercial, and decorative lighting sources represent an important component of urban light pollution.

The combination of long-term photometric monitoring, webcam analysis, and knowledge of municipal lighting schedules provides a powerful framework for separating different sources of artificial light. These findings can support future lighting policies and mitigation strategies aimed at reducing unnecessary light emissions while maintaining public safety.

Beyond its scientific objectives, the project contributes to public awareness through outreach activities, citizen-science initiatives, and educational programs focused on the environmental impacts of artificial light at night.

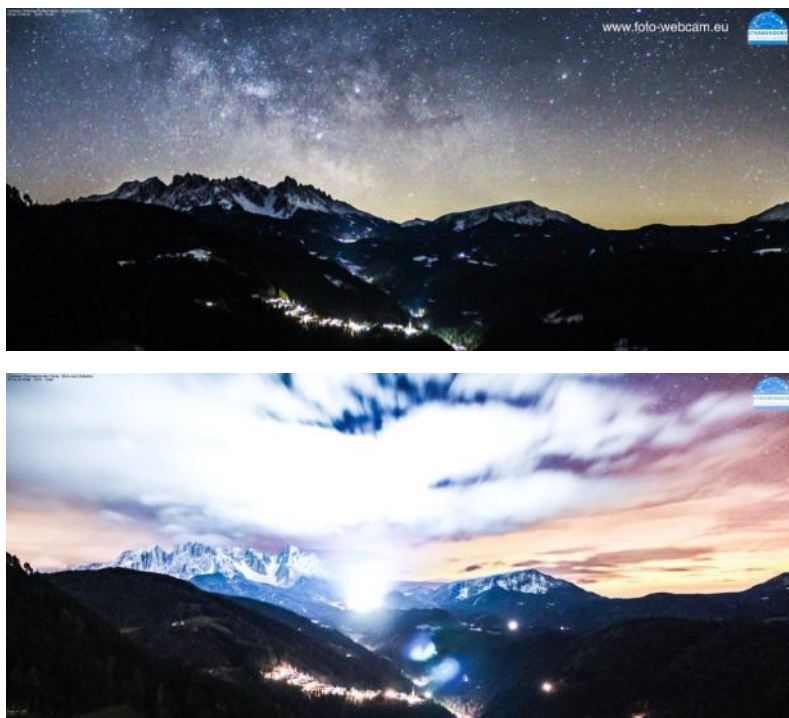


Fig. 1: Comparison of the night-time view from the Max Valier Observatory in Gummer towards the Latemar mountain range, with and without floodlighting during nighttime skiing operation (Picture: www.foto-webcam.eu)

Monitoring light pollution from all-sky images by compensating weather, twilight and moonlight effects

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Introduction

All-night long-term light pollution monitoring by all-sky cameras is often complicated by weather conditions. High thin clouds – by reflecting ground light – usually lead to brighter images, while low thick clouds or fog can pretend deeper darkness. Moreover, as it is common practice to measure light pollution in absence of moonlight in clear skies, more than half of the observation time becomes virtually unusable, requiring extended observation periods and impede long-term trend evaluation, especially in non-optimum weather that are common in the northern part of Europe.

We present a method aiming at increasing usable observation data by compensating the effects of weather, twilight and moonlight. The approach combines a weighting of data by cloud cover, with the subtraction of natural residual light due to twilight and moonlight, which rely on astronomical models. Extraction of environmental brightness from all-sky imagery is based on wide-bracketed exposure series complemented by an estimation of overexposure with direct light, which is essential in moon-lit nights.

Methods

Our all-sky camera is equipped with an aside-mounted TESS-W Sky Brightness Photometer. This instrument serves to measure the zenithal sky brightness, as well as the sky temperature, which we use as an indication of cloud cover.

We developed an empirical formula to estimate cloud cover from the TESS measurements. As a simple approach, we weight every measurement with the estimated cloud cover at that time: A clear sky enters with full weight, overcast only uses a very low weight, in case of rain or fog, the data is discarded. The remaining, weighted data can then be average per night, week, month or year to expose the long-term trends.

The measured zenithal sky brightness serves to calibrate the brightness as seen on the images, which we mask for the zenithal region to match the cone that the TESS instrument measures. This relates our imagery to real-world brightness.

Extracting the brightness of a digital image is relatively simple: by masking away the foreground including the borders in the corners of the image outside of the circular lens coverage, undoing the gamma-correction which maps real physical brightness to perceptible brightness, and pixel-wise stacking the results of an exposure-bracketing series weighted by the exposure time and sensor gain (which is governed by the camera software). Finally, in case of direct moonlight, the overexposed part of the darkest image of the series is added with appropriate

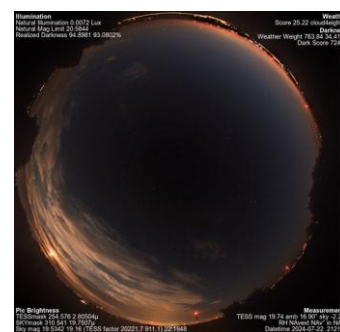


Fig. 1: A typical night-time all-sky image. Environmental brightness estimation is hampered by dusk (top right), cloudiness, and moonlight (bottom left).

Image: Own work

weight to account for the real brightness of the moon, which is hard to capture by photography – but substantially contributes to the environmental illuminance.

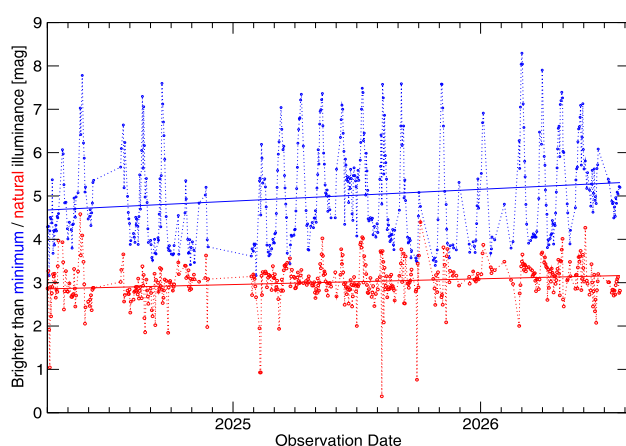
The natural environmental illuminance is calculated from astronomic models. The main contributors are the sun and the moon. The position of the sun and the moon (elevation and azimuth) in the sky as seen from a particular location and date and time, is readily calculated from astronomic formulae. The illumination by the sun is heavily modulated by its elevation; we use a formula that reproduces illuminance values as tabulated in Wikipedia. For subhorizontal sun, this formula also includes tiny light contributions by planets, stars, the milky way, and air-glow, in an average fashion. By fitting to measured illuminance, this formula also includes atmospheric effects such as atmospheric extinction, and of course, the twilight.

For the moon, the moon phase is a major effect. Counter-intuitively, the brightness of the moon is not proportional to its illuminated area, but is much brighter towards full moon. We use an empirical formula by Krisciunas and Schaefer. The apparent radius of the moon, due to its varying distance from earth, is also taken into account. Finally, the atmospheric effects dependent on the moon's elevation are calculated in a similar way as for the sun.

Finally, we obtain an idealized baseline for natural environmental brightness – or the darkness ideally achievable in the absence of artificial light. Of course, this approach approximates and disregards many effects, especially weather and atmospheric conditions, which are beyond our control. However, the idea is to level out the most important light contributions. For the final evaluation, we compare our imagery-derived brightness data to the maximum-realizable darkness, resulting in a “brighter-than-natural” measure. For readability, we use a log-scale (magnitudes as common in astronomy), rather than linear scales.

Conclusions

By applying those procedures, we obtain data cleaned from seasonal and lunar correlations. Long-term trends can now be extracted with minimal bias.



This graph shows the results of this natural light compensation method in red, contrasted to an uncompensated evaluation in blue. Per-night averaged data is shown as dots, connected by thin lines as an eye guide. The solid lines represent a linear regression of the respective data set.

The blue data clearly exhibits seasonal yearly, and lunar monthly correlations, a larger overall variation, and overestimates the long-term trend, which well may be due to having higher summerly values at the end of

the current observation period – effects neatly remedied by the presented method.

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Beyond Astronomy: Building a Transboundary Dark Sky Reserve for Biodiversity, Research, and Sustainable Light Management

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The path to becoming one of the largest Dark Sky Places in Europe

The Eisenwurzen International Dark Sky Reserve was designated by DarkSky International after several years of preparation and an unique cooperation across protected-area, municipal, and provincial borders. The initiative originated from the recognition that natural darkness is an ecological resource that deserves protection alongside species, habitats, and landscapes.

The area unites two national parks (Kalkalpen and Gesäuse), three nature parks (Ötscher-Tormäuer, Styrian and Lower Austrian Eisenwurzen), and one wilderness area (Dürrenstein-Lassingtal). The reserve covers 2,396 km² with a 975 km² core zone, extends across Styria, Upper Austria, and Lower Austria, and includes 20 municipalities. It is the largest contiguous natural nightscape in Austria and one of the largest Dark Sky Reserves worldwide. The region belongs to the darkest areas of Central Europe. Mountain ranges exceeding 2,000 m naturally shield the core zone from external light pollution, preserving visibility of the Milky Way and faint celestial objects. At the same time, the area contains outstanding natural assets, including UNESCO World Heritage beech forests, primeval forest remnants, Austria's largest unfragmented forest landscapes, and numerous endemic species ("Naturnachtgebiet Eisenwurzen, Dark Sky Reserve Application," 2025).

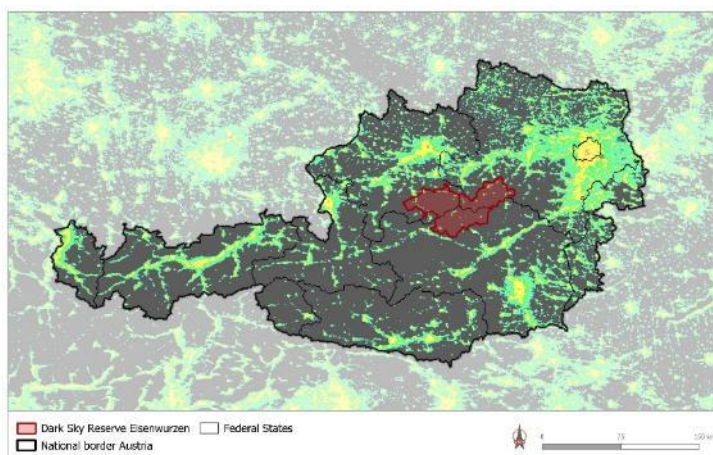


Fig. 1: location of the Dark Sky Reserve Eisenwurzen ("Naturnacht-gebiet Eisenwurzen, Dark Sky Reserve Application," 2025)

The decisive step was the LE project "Stars above the Three-Province Corner – Foundations for a Transboundary Dark Sky Area" (2023–2025), which produced a feasibility study, sky-quality measurements, lighting analyses,

and the certification dossier. The key challenge was that the reserve is located within a populated landscape comprising numerous municipalities, tourism providers, businesses, infrastructure operators, and local communities. As the success of the initiative depended on the support of all municipalities and key stakeholders, intensive awareness-raising and inclusive participation processes were essential from the outset. All participating municipalities adopted council resolutions supporting the reserve and committed themselves to light-management plans ("Naturnachtgebiet Eisenwurzen, Dark Sky Reserve Application," 2025). Demonstration projects with dark-sky compliant lighting were implemented, while

discussions with railway operators, tourism stakeholders, and neighboring municipalities established a broader framework for long-term light reduction. The reserve therefore represents not only an astronomical initiative, but also a new model of transboundary cooperation for the protection of natural darkness and biodiversity.

Night-time ecology and the protection of natural darkness

The Eisenwurzen Dark Sky Reserve is primarily a nature conservation project. Many species depend directly on natural darkness, and artificial light at night can alter movement, foraging, pollination, reproduction, and predator-prey interactions (Degen et al., 2016; Hölker et al., 2021; Sordello et al., 2025, 2022). Night-depending umbrella species of the region include the Bechstein's bat, the Eurasian lynx, and the Ural owl (“Naturnachtgebiet Eisenwurzen, Dark Sky Reserve Application,” 2025). In Kalkalpen National Park alone, 1,611 butterfly species have been recorded, with 94% of it being moth species, representing the highest known Lepidoptera diversity of any Austrian protected area (Nationalpark Kalkalpen, 2026).

Because both light pollution and nocturnal habitats extend beyond the borders of strictly protected areas, the reserve has initiated a study to identify conservation measures from a species perspective instead of an institutional perspective. A central objective is the development of a Nocturnal Species Management Plan that links monitoring, and practical conservation. The planned framework is based on the selection of indicator species according to light sensitivity, conservation status, spatial representativeness, and monitoring feasibility. Potential focal groups include bats, moth communities, amphibians, and nocturnal birds. Standardized monitoring is intended to provide evidence for future lighting regulations, habitat restoration, and evaluation of management effectiveness (Bruckner, 2025).

Protecting the night is therefore understood as protecting a distinct and still insufficiently studied ecological habitat.

Future outlook: Building a “Natural Night Research Cluster”

The next phase of the Eisenwurzen Dark Sky Reserve will focus on night-time ecology as a research and conservation priority. We aim to establish a “Natural Night Research Cluster” in the Gesäuse National Park and invite researchers, universities, and conservation institutions to work with us. The region offers a rare combination of very low light pollution, permanent sky-quality monitoring, well-managed protected areas, with existing ecological data. We intend to provide logistical support and research infrastructure in order to attract expertise on nocturnal biodiversity.

Our goal is to generate the scientific knowledge needed for evidence-based conservation decisions and to develop the Eisenwurzen Dark Sky Reserve into a field laboratory for night-time ecology, where research, monitoring, and management are closely connected. The exceptionally large and contiguous core zone may represent a key prerequisite for achieving measurable conservation successes, while simultaneously creating opportunities for low-impact tourism and public engagement with the value of natural darkness.

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How to measure and define limits for light pollution

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Introduction

To reduce light pollution it is important to define exactly the measurement method and limiting values. We will compare different measurement methods, especially horizontal and vertical illuminance. Limiting values should ideally be defined from scientific research or experience and should be incorporated into policies. However often the use of the different criteria is mixed and some ambiguity exist in the use. Therefore we will discuss this on two quantities often used to reduce light pollution: limiting the spatial emission of light and its blue content.

Measurement techniques

Generally light pollution is described by measuring the **sky brightness** (more exactly: the luminance) **in the zenith**, mostly using the astronomical unit mag/arcsec². Besides natural sources this sky glow is the light emitted from light sources on the ground and scattered and reflected in the atmosphere. This value does include nearby surrounding light sources only marginally though their impact on the measurement place may be considerable. In biological studies (e.g. Schittko et al., 2026) mainly the **horizontal illuminance**, that is the light coming from the whole upper hemisphere onto the horizontal ground, is used, measured in Lux [lx]. The main problem is that most illuminance (lux)meters are generally not sensitive enough to measure these values, while using a calibrated digital camera will be a solution. To detect long-term changes of light emission the **VIIRS satellite radiance data** can be used and **vertical illuminances** determined with a digital camera are sensitive to detect and measure short-term changes, especially changes during one night. We will discuss and compare these different methods on several examples.

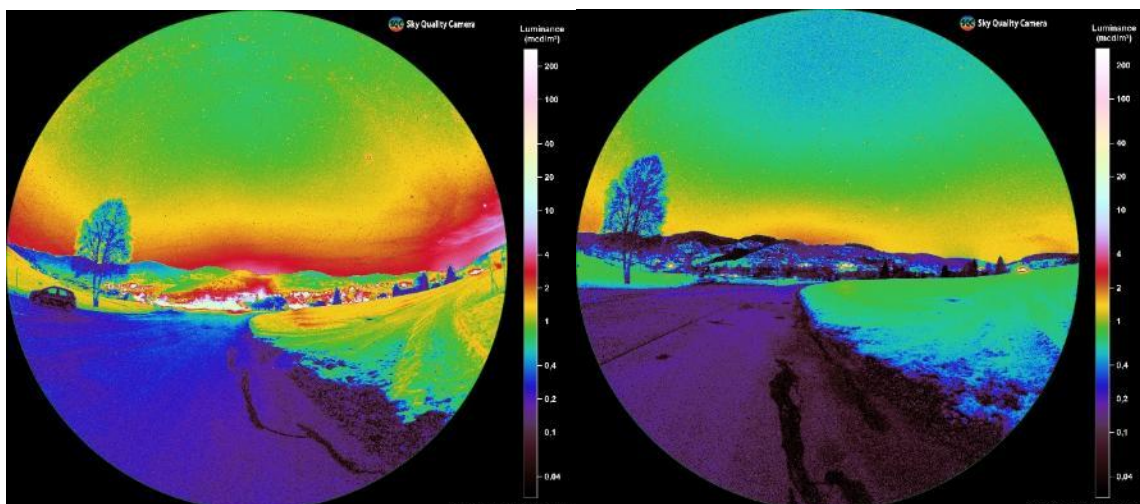


Fig. 1: Horizontal luminance maps demonstrating the switch-off in the village Bernau. From these vertical illuminance can be calculated using the software Sky Quality Camera.

Spatial emission

It is generally accepted that no light should be emitted towards the sky. This has been analyzed (together with the spectral energy distribution) e.g. in a study by the Department of Energy in 2017 (*B. Kinzey et al, 2017*). They used the models SkyGlow Simulator and ILLUMINA (*Aubé Kocivej, 2012*). In practice different quantities are used to describe the upward light emission, which we will discuss and compare:

- “full cut-off”,
- upward light ratio ULR and upward light output ratio (ULOR),
- upward flux (ULF),
- lighting efficiency,
- Luminous intensity class G*6,
- CIE code (which is used e.g. in France regulation),
- Back-Upward-Glare (BUG)
- Light distribution curves

Spectral emission

The negative impact of light with short wavelengths (ultraviolet and blue) on the attraction of insects and other animals (e.g. *Longcore, 2023*) is known since long time, as well as the disturbance of natural rhythms in living species. In addition blue light is stronger scattered in the atmosphere and therefore brightens the night sky more than longer wavelengths (e.g. *B. Kinzey et al, 2017*). The following quantities are used to describe the blue content of visible light:

- percent % of blue light of visible (used mainly at astronomical observatories)
- scotopic/photopic S/P ratio
- G-index based on astronomical photometry
- correlated color temperature cct
- “warm white” light

We try to show that it is important to define the correct values in policies for reducing light pollution.

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Light-on-Demand: Reclaiming the Natural Night

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Introduction

Artificial Light at Night (ALAN) represents a rapidly growing global threat to the integrity of the natural night, driving widespread light pollution that degrades municipal and natural habitats alike and disrupts planetary biodiversity. For municipalities and road operators, public lighting has traditionally required a rigid trade-off between public safety and environmental preservation. Traditional mitigation strategies like static dimming or midnight shutdowns offer fragmented solutions, either maintaining unnecessary emissions or compromising safety. This abstract explores the paradigm of adaptive light on demand as the ultimate middle ground, utilizing non-invasive sensor networks to maximize energy savings and minimize light pollution as well as emissions, while fully preserving human infrastructure requirements.

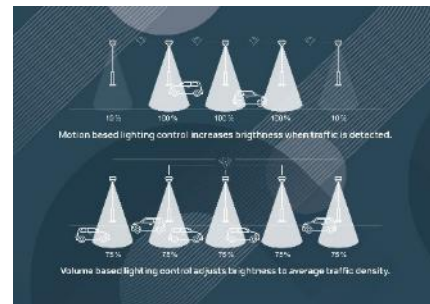


Fig. 1: Motion based and volume-based lighting control. Design by lixtec GmbH.

Main Part

When evaluated against traditional static control systems, dynamic sensor-driven lighting infrastructure operates on the core principle of aligning lighting levels strictly with human demand, thereby actively reclaiming the natural nocturnal environment. On a weighted nightly average, this precise, real-time scaling yields a total energy reduction of up to 80% compared to unmanaged legacy systems, outperforming both static dimming and rigid shutdowns.

Within this adaptive framework, two operational methodologies can be strategically deployed to mitigate Artificial Light at Night (ALAN):

- **Motion-based lighting control:** Suited for low-to-medium traffic areas, this approach relies on instantaneous movement detection. The sensor detects a moving object, smoothly raises brightness to a predefined, standard-compliant level, and returns to a minimal baseline (e.g., 10%) or shuts off completely once the participant leaves.
- **Volume-based lighting control:** Designed for higher-density corridors, this method adjusts brightness gradually according to the measured traffic density. Instead of tracking individual objects, light levels scale with traffic volume.

The technical, economic, and legal viability of this real-time approach is fundamentally supported by the procurement and design guidelines of the Austrian Energy Agency, which define the integration of traffic detection and dynamic dimming as central components for energy-efficient infrastructure [1, p. 27]. Shifting public lighting from permanent over-illumination to interactive tracking remains fully compliant with the strict illuminance and

uniformity thresholds required by European safety standards (EN 13201) as confirmed by these guidelines [1, p. 27].

By transitioning to dynamic lighting, current research on 'dark infrastructure' emphasizes that restoring natural light rhythms is essential to guarantee ecological continuities and preserve the physiological integrity of nocturnal species [2, 1.3, 2.2, 3.3]. Keeping vacant infrastructure at a 0-10% baseline preserves vital migration corridors, as illuminated infrastructure has been proven to act as a physical barrier that fragments habitats and disrupts the dispersal movements of diverse fauna [2, 1.3]. Adaptive lighting directly safeguards regional biodiversity by eliminating these structural barriers through demand-based control [2].

Furthermore, this ecological optimization does not necessitate cost-prohibitive overhauls. Sensor networks can be retrofitted directly onto existing Zhaga/D4i standard luminaire architectures.

The immense ecological and financial dividend of this technological paradigm is structurally validated by the procurement guidelines of the Austrian Energy Agency, which note that combining advanced traffic detection with dynamic dimming schemes can yield energy savings of up to 85% [1, p.27]. Within municipal deployment scenarios, an efficiency profile of up to a maximum of 80% is targeted. Based on this 80% threshold, a deployment of 1,000 sensor-controlled 30W luminaires curtails approximately 100,000 kWh annually, preventing 19 tons of CO₂ per year within the European energy grid mix [3]. Additionally, reduced burning hours structurally decrease hardware degradation, extending maintenance cycles and the physical lifespan of the LED units.

Conclusions

The transition from static lighting regimes to algorithmic, sensor-driven control represents a critical leap forward for global dark-sky conservation, ensuring that light is active only when and where human presence requires it. By restricting artificial emissions to actual demand, this infrastructure directly safeguards vulnerable nocturnal ecosystems and limits the disruption of species-specific orientations, rhythms, and vital ecological services [2, 3.3]. Ultimately, dynamic light-on-demand proves that traffic safety, financial efficiency, and the active protection of dark infrastructure is no longer mutually exclusive, but seamlessly attainable through intelligent, ecologically calibrated public lighting.

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Light Pollution Goes Underwater: Aspects of Aquatic Light Pollution

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Artificial light at night (ALAN) is increasingly recognized as a threat to biodiversity (Hölker et al. 2021), yet aquatic environments have received much less attention than terrestrial ones. This is particularly relevant because freshwaters are biodiversity hotspots and are often closely associated with human settlements and thus exposed to ALAN (Hölker et al. 2023).

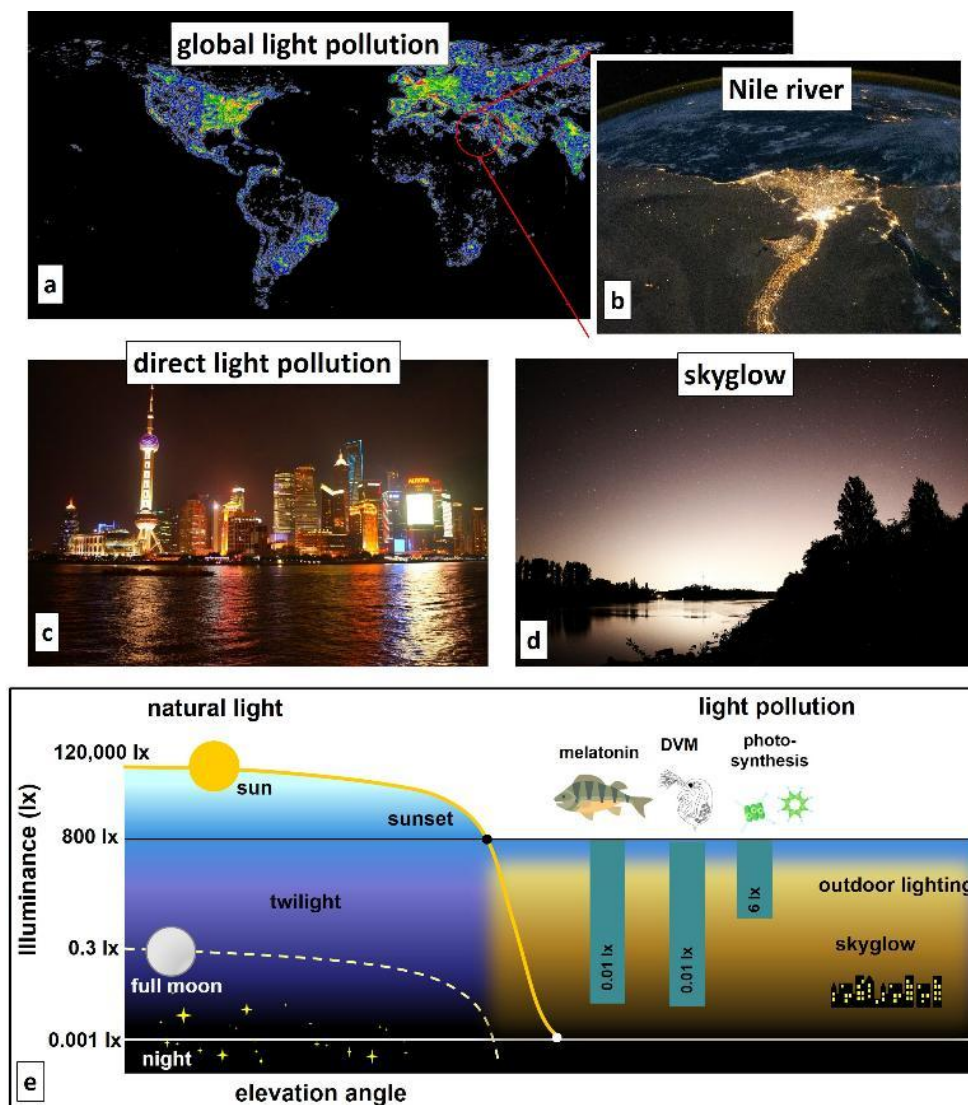


Fig. 1: Aspects of aquatic light pollution. a) Global map of skyglow, b) Nile River, c) Shanghai Bund, d) Skyglow over Rhine River, e) Night-time illuminance and impacts. Figure adapted from Hölker et al. (2023), *Phil. Trans. R. Soc. B* 378: 20220360, CC BY 4.0. Individual image credits as in the original publication.

At the same time, quantifying aquatic light pollution is challenging: the light field experienced by an aquatic organism can differ substantially from quantities measured above the water surface. Refraction and reflection at the air–water interface, followed by wavelength-dependent absorption and scattering within the water column, modify the intensity, spectrum and angular distribution of nocturnal light (Mobley 1994, Hölker et al. 2023).

Even variations at moonlight levels can influence light-mediated biological processes under water such as diel vertical migration (DVM) of zooplankton (Dickerson et al. 2026). Conversely, even low levels of ALAN, including skyglow, can affect zooplankton's DVM (Moore et al. 2000). As an example of biological responses, we investigated zooplankton distributions in the shallow urban River Spree in Berlin using high-resolution underwater in-situ imaging. Pronounced nocturnal upward shifts occurred under lower-light conditions, whereas these shifts were reduced at illuminated locations, particularly for cladocerans. These observations illustrate how relatively small-scale spatial differences in the nocturnal light environment may translate into altered aquatic behaviour.

Finally, current challenges in quantifying ecologically relevant underwater lightscapes will be discussed in the context of the ISOLUME project, which extends our work on freshwaters into marine environments in the Baltic Sea and the Mediterranean Sea. By combining measurements above and below the water surface under different natural and artificial night-time light conditions, ISOLUME aims to improve our understanding of how nocturnal light penetrates and propagates through aquatic environments and how the actual light exposure experienced by organisms can be quantified.

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Towards a light pollution atlas for overcast cloudy skies

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There are existing light pollution maps and atlases for clear skies; see, e.g., Falci et al. 2016, and several variants on the web. These maps are outstanding for evaluating night sky quality and the visibility of celestial objects. Typically, these maps report zenith brightness, which is not optimal for ecological studies. Moreover, overcast clouds alter the environmental light field significantly (see e.g. Jechow and Hölker 2019). Dark regions can be darkened by a significant factor, while the clouds backscatter the light to brighten the sky by several factors.

Using our Monte-Carlo radiation code (Kolláth et al. 2021), we calculated the radiation transfer with overcast mid-level clouds. A significant number of scattering events should be considered. At a cloud optical depth of 50, the maximum number of photon interactions can reach 2000, compared to 10-20 with clear atmospheric conditions.

Here we present our preliminary result of the calculated overcast light pollution map.

We calculated not only the zenith brightness but also the ground-level illuminance, which is a far more important parameter for the ecosystem.

For a selected 30-degree by 30-degree Central European region, we calculated statistics for possible illuminance. With clear sky, the mean horizontal illuminance is in the order of 0.5 mlx, which is amplified by clouds to 7 mlx. The expected illuminance level with quarter Moon is around 10 mlx; we can consider it a critical limit, as it is clearly visible to animals. With the modelled overcast sky, close to 20 per cent of the considered part of Europe reaches this limit, compared with only 0.1 per cent with clear sky. In contrast, the expected natural illuminance of ~0.8 mlx drops to about 0.2 mlx with the overcast sky. This darkening of the natural sky is in agreement with our measurements - the extreme effect we obtained was a 10-fold decrease with a very thick cloud layer.

Acknowledgments

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Light pollution caused by interior lighting installations

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Introduction

Sports lighting, road lighting, outdoor workplace lighting, façade lighting, billboards – these are some well-known examples of the many different light sources that contribute to light pollution. Another source of light pollution constitutes an interior lighting installation that emits light through the building envelope. However, this topic has barely been addressed so far.

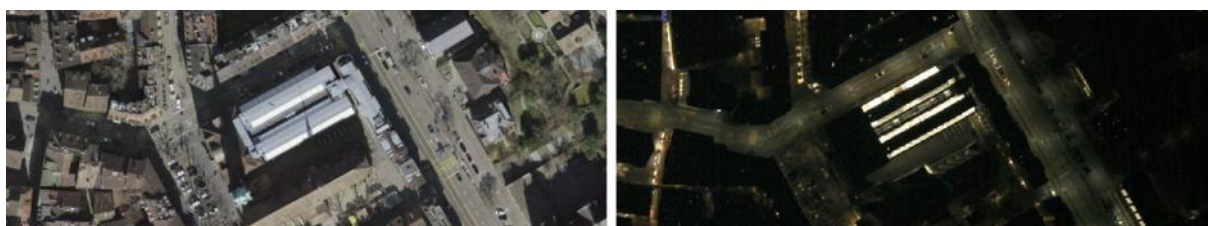


Fig. 1: Example of light emissions from the interior: A library in Zurich (source: *map.geo.admin.ch*)

Method

This paper analyses in what way interior lighting contributes to light pollution. Therefore, selected recommendations referring to this topic were examined. Moreover, several cases from planning approval procedures were analysed. Based on these findings, measures to reduce the negative impact of interior lighting on the environment are being discussed.

Results and conclusions

Lighting standards require mostly illuminance values of several hundred lux for indoor spaces. According to the standard SN EN 12464-1, a corridor requires ≥ 100 lx, an office desk ≥ 500 lx and tool manufacturing ≥ 750 lx (Schweizerische Normen-Vereinigung, 2021), to give examples. Some of the light emitted by indoor luminaires is reflected (and partly absorbed) inside the interior space before it transmits through a window or skylight – and some light is even emitted directly through them. Due to the relatively high illuminance levels, considerable amounts of interior light are likely to be emitted to the outdoor environment.

Such light contributes to the amount of sky glow and can affect also animals. However, it might also cause a disturbing effect by entering another interior space from outside (light trespass) – thereby exceeding a certain vertical illuminance on its window. Moreover, interior light sources can have a disturbing effect on people by producing glare that is perceived from an opposite window. In Switzerland, for instance, indoor lighting emissions have already been dealt with by the Federal Supreme Court (Hörhager, 2024).

There is a conflict of objectives between daylight harvesting and light pollution reduction. Hence, the Swiss guidance for the daylighting standard SN EN 17037 demands to prevent light emissions from spreading into the outdoor environment by implementing preventive measures (SIA, 2025). The law enforcement aid ‘Recommendations for limiting light emissions’ (German title: ‘Empfehlungen zur Vermeidung von Lichtemissionen’) of the Swiss Federal Office for the Environment (FOEN) outlines such measures (BAFU, 2021):

- Only light rooms when they are actually in use (using intelligent lighting controls).
- Use blinds, shutters or opaque curtains¹ in large buildings or those with large window areas when they are in use.²

The law enforcement aid also highlights the role of shop window lighting and refers to the possibility of turning the shop window luminaires inwards (which links to the lighting design).

Experience gained from planning approval procedures shows that the earlier such measures are considered in a project, the easier it is (usually) to implement them.

In Switzerland, there is also a lighting standard (SN 586 491) which deals specifically with the subject of light emissions (SIA, 2013). This standard is currently being revised, and the draft published in 2026 during the consultation procedure contained detailed information on this subject. It addresses mainly the shading of daylight openings (by using, for example, blinds) the role of lighting operating times, and the shielding of luminaires towards daylight openings.

Nevertheless, many questions require further research. This relates in particular to the quantitative scale of indoor light emissions as well as to potential solutions for reducing them through lighting design and/or shading measures. Moreover, the question of how to address excessive light trespass and luminaire glare requires further attention.

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¹ Further information on shielding options can be derived from Du et al. (2018).

² The law enforcement aid illustrates this measure by pointing to a planning permission of two skyscrapers in Lucerne, where the bird migration route passes. One of the conditions specified in the planning permission was that the blinds in the 283 appartements must be lowered automatically during the bird migration season.

The forest dormouse *Dryomys nitedulain* Terra Raetica

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The tree dormouse (*Dryomys nitedula*) is a rare and strictly protected species of dormouse whose westernmost range lies in Terra Raetica. Since 2021, the species has been the subject of more intensive research there as part of Interreg projects. Previous studies show that the tree dormouse inhabits a wide variety of habitats—ranging from coniferous and mixed forests to shrub-rich areas—as well as elevations between 800 and 2,200 meters. Despite this high adaptability, the species remains rare, which is why the causes of its low population density must be further investigated. The follow-up project, “The Tree Dormouse and Friends in Terra Raetica,” is studying the species’ biology in the UNESCO Engiadina Val Müstair Biosphere Reserve, the Ötztal Nature Park, and the Stelvio National Park—as a basis for cross-border conservation measures. In addition, citizens are being involved in recording sightings through a citizen science project and are being educated about dormice and nature conservation through public outreach and a travelling exhibition.

Optimised light sources reduce nocturnal insect attraction at railway stations

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Artificial light at night (ALAN) is increasingly recognised as an anthropogenic stressor contributing to global insect decline through the disruption of natural behaviour and attraction to artificial light (Owens & Lewis, 2018; Owens et al., 2019). Despite the widespread use of continuous nighttime illumination at railway stations for operational and passenger safety, its ecological impacts and the effectiveness of mitigation measures under real-world conditions remain insufficiently studied.

We therefore compared the attraction of flying insects to conventional high-pressure sodium lamps (2000 K), cool white LEDs (4000 K) currently used by Deutsche Bahn InfraGO AG, and a novel amber LED (1800 K) with reduced short-wavelength emissions at six rural railway stations in the Westhavelland Dark Sky Reserve, Germany. Insect abundance, biomass, and species richness were quantified using AI-based image analysis and DNA metabarcoding.

The amber 1800 K LED consistently attracted fewer insect individuals, biomass, and species, as well as threatened and legally protected taxa, than both high-pressure sodium lamps and 4000 K LEDs. No significant quantitative differences in insect attraction were observed between high-pressure sodium lamps and 4000 K LEDs, despite their distinct spectral characteristics and correlated colour temperatures.

Our results demonstrate that amber 1800 K LED lighting reduces nocturnal insect attraction under real-world conditions, representing a practical mitigation measure to minimise the ecological impacts of ALAN. The lower attraction of threatened and legally protected taxa further highlights the potential of this LED technology to support insect conservation through sustainable outdoor lighting strategies. Based on our findings, the platform lighting at all six studied railway stations in the Westhavelland Dark Sky Reserve has been converted to amber 1800 K LED lighting.

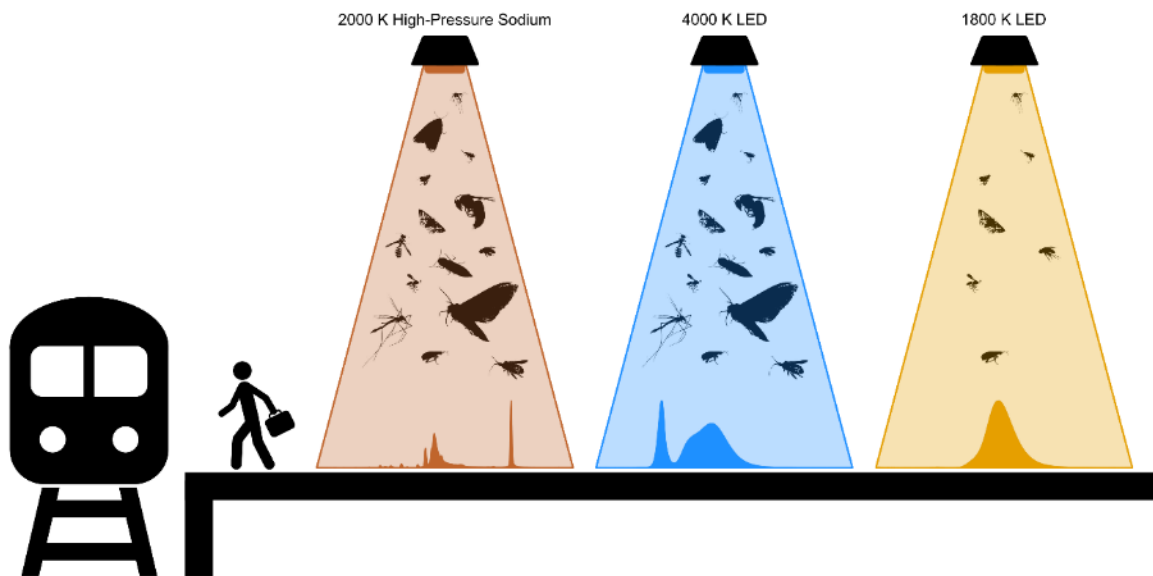


Fig. 1: Graphical abstract: Optimised light sources reduce nocturnal insect attraction at railway stations (Ludreschl et al., 2026).

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How does artificial light at night affect the breeding strategy of a cosmopolite passerine?

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Light is an important Zeitgeber for the life history of temperate bird species and it has long been known that artificial light sources in anthropogenic environments can interfere with natural light cues. Female reproductive strategies do not follow a fixed pattern but underlie high plasticity to optimize reproductive success by responding to environmental changes. These can occur on several levels, for example by adjusting clutch size, incubation behaviour and/or nestling feeding. They also change resource allocation into the egg, a process which is known as early maternal investment. While these behaviours have been well described in the context of different environmental factors, such as predator presence or even mate attractiveness, to date our knowledge about the effects of artificial light at night (ALAN) on female reproductive decisions remains scarce.

In an experiment, we explored the impact of artificial light on the breeding behaviour of a cosmopolite bird species, which is well known for successfully coping with anthropogenic environments, the house sparrows (*Passer domesticus*). In spring 2024 and 2026, we exposed breeding pairs of captive house sparrows, kept in large outdoor aviaries to different light regimes: i) ALAN exposition during egg laying or ii) nestling rearing and iii) a control group with no additional light. We recorded the breeding phenology, egg-mass and the carotenoid content of the second egg as well as nestling development of the first brood.

Overall, in both years temperature was the main driver of clutch initiation, but we observed that in 2026 birds exposed to ALAN during egg laying showed a tendency to breed earlier than controls. However, they spent fewer days incubating their eggs regardless of the temperature. Neither egg-mass nor clutch size were affected by ALAN, but our data from 2024 hints that females exposed to ALAN during egg-laying deposited less carotenoids into the yolk than control females. Most surprisingly, in 2024 nestlings that were exposed to ALAN were heavier than birds of the other experimental groups.

In 2024, breeding pairs may have taken advantage of ALAN by starting to feed their young earlier, resulting in nestlings with a higher body mass. While the higher nestling observed in ALAN2 seems beneficial under experimental conditions with an unlimited food supply, this effect may not necessarily translate into fitness benefits in the wild. Although this may seem counterintuitive, research has shown that females experiencing elevated stress levels spend more time incubating their clutch. This could result in a shorter incubation period, which might explain our observations in 2026. The slightly decreased carotenoid content in the eggs of the ALAN exposed females in 2024 corroborates this idea, as this may indicate a stress response to ALAN. These contrasting responses in different years suggest that the effects of ALAN depend strongly on the environmental context. Further research is required to understand these subtle effects and their consequences.

From Urban Lights to Festival Nights: a multi-angle view of skyglow

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Introduction

Since the mid-20th century, interdisciplinary researches about the effects of artificial light at night (ALAN) has exploded (Hao, et al., 2023). The modification of light sources and the increase of its numbers modify this light pollution over the years. One main contributor is the introduction of light-emitting diodes (LEDs), whose blue-rich emissions may contribute to increased sky glow (Sanchez de Miguel, et al., 2021) (Bustamante-Calabria, et al., 2024). The modification of the spectral composition of the night sky will hide the natural nightlike leading to implications ranging from astronomy to environmental sciences. Numerous instruments and methods were developed to quantify the dome of skyglow observed from the ground. While some are more expensive than others, some of the more affordable ones originate from astronomical research and lack SI traceability (Hänel, et al., 2017). The standardization of skyglow and its monitor stays today a main challenge for the scientific community that must satisfy different fields of research. Recent studies have highlighted the growing importance of spectral measurements for the characterization of skyglow (Kocifaj, et al., 2019) (Aubé, et al., 2016). Spectrometric observations have proven valuable for identifying lighting signatures and investigating the influence of atmospheric conditions, such as cloud amplification, on night-sky radiance (Aubé, et al., 2016). These developments suggest that measurements combining spectral information with observations of different sky regions could represent an important step toward the standardization of ground-based skyglow monitoring.



Fig. 1: multi-angle spectroradiometer on METAS roof pointing toward Bern city.

While some are more expensive than others, some of the more affordable ones originate from astronomical research and lack SI traceability (Hänel, et al., 2017). The standardization of skyglow and its monitor stays today a main challenge for the scientific community that must satisfy different fields of research. Recent studies have highlighted the growing importance of spectral measurements for the characterization of skyglow (Kocifaj, et al., 2019) (Aubé, et al., 2016). Spectrometric observations have proven valuable for identifying lighting signatures and investigating the influence of atmospheric conditions, such as cloud amplification, on night-sky radiance (Aubé, et al., 2016). These developments suggest that measurements combining spectral information with observations of different sky regions could represent an important step toward the standardization of ground-based skyglow monitoring.

Since 2024, the Swiss National Science Foundation Sinergia project Spotlight has aimed to improve our understanding of light pollution and support the development of sustainable outdoor lighting practices (WSL Spotlight, 2024-2028). As part of this effort, the Swiss Federal Institute of Metrology (METAS) is using a multi-angle spectroradiometer to address the lack of standardized, SI-traceable ground-based skyglow measurements. In parallel, a low-cost portable rotative spectrometer is being developed that could offer a practical solution for researchers requiring affordable measurements. This study presents the first steps toward a standardized characterization of skyglow through observations conducted under different spatial and temporal conditions. The analysis of the measured spectra enables the identification of different lighting signatures, while meteorological data are being investigated to derive emission-based indicators that are less dependent on atmospheric conditions. In addition, measurements performed during a local music festival provide a unique opportunity to assess the effect of temporary lighting installations on the night-sky.

Methods

The observations are performed using a sensitive multi-angle spectroradiometer measuring spectral radiance with a resolution of 5 nm. The instrument measures sky radiance in different viewing directions across the hemisphere. Covering the visible range and extending into the near infrared (350-1000 nm), it provides detailed information on the spectral composition of skyglow. Spectral signatures are used to investigate the contribution of different lighting technologies to the observed sky radiance. Measurements are combined with atmospheric information, including cloud conditions and all-sky imagery, to support the interpretation of the observations. This approach is used to investigate whether spectral measurements can be exploited to estimate the underlying skyglow emission independently of cloud contribution. In parallel, controlled laboratory experiments are conducted using an integrating sphere illuminated by a spectral tunable LED light source. The setup allows controlled spectral variations to be introduced while maintaining a known reference radiance, and additionally provides a test bench for the evaluation of the performance of the low-cost spectroradiometer prototype.

Conclusions

The presented observations highlight the value of directional and spectral measurements for the characterization of skyglow. The relationship between spectral measurements and lighting technologies makes it possible to link specific wavelengths and source signatures to the observed brightening of the night sky. Monitoring the temporal evolution of spectral radiance offers a promising approach for detecting modifications of the illuminated sky caused by cloud cover or human activities. The development of a portable low-cost spectroradiometer further explores how spectral skyglow measurements can be made more accessible for future monitoring applications. Ultimately, the evolution of this research may contribute to the development of SI-traceable methodologies and standardized skyglow indicators, providing objective tools to support environmental monitoring and informed policy decisions.

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Cel Fosc, asociación contra la contaminación lumínica: Activism for the Protection of the Night

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Cel Fosc is a Spanish non-profit organisation dedicated to the protection of the nocturnal environment and the prevention of light pollution from scientific, environmental and societal perspectives. Its activities encompass public outreach, technical consultancy, policy advocacy and citizen engagement, with the aim of preserving natural darkness as a shared heritage that is essential for biodiversity, human health, astronomical research and the appreciation of the starry night sky.

Today, the nocturnal environment is facing growing threats resulting from the increasing extent and intensity of artificial lighting. The widespread adoption of LED technology, frequently installed with high correlated colour temperatures and without appropriate lighting design criteria, has led to increased emissions of blue-rich light and a significant rise in night-sky brightness. These challenges are compounded by emerging pressures, including the proliferation of large-scale digital advertising displays, the expansion of ornamental lighting, the deployment of satellite constellations, and the expected growth of new energy and urban infrastructure, all of which may further accelerate the loss of natural darkness unless they are planned and managed according to robust environmental criteria.

In this context, activism is one of the defining features of Cel Fosc. Membership of the association entails promoting and supporting initiatives aimed at protecting the night from light pollution while safeguarding nocturnal wildlife, human health, and the right of present and future generations to experience natural darkness. To this end, Cel Fosc develops public awareness campaigns, contributes to legislative and regulatory processes, collaborates with public authorities, and works in partnership with environmental and scientific organisations to integrate the protection of the night sky into broader environmental policies and conservation strategies. Protecting the night requires an informed and engaged society capable of translating scientific knowledge into collective action and effective public policy.

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Fifteen Years of *Salvem la Nit*: The Light Pollution Working Group at the Universitat de València

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In 2011, two researchers from the Universitat de València joined forces to address the growing problem of light pollution by establishing *Salvem la Nit* ("Let's Save the Night"), a multidisciplinary working group dedicated to the protection of the nocturnal environment.

Ángel Morales-Rubio, from the Department of Analytical Chemistry, and Enric Marco, from the Department of Astronomy and Astrophysics, were particularly concerned about the excessive artificial lighting affecting the Turia Natural Park, a protected area located within the Valencia metropolitan area. Many surrounding municipalities were using inappropriate outdoor lighting systems without considering their impact on nocturnal wildlife and ecosystem functioning.

The group was later joined by Joaquín Baixeras from the Department of Zoology, further strengthening its interdisciplinary approach.

The first stage of our work focused on documenting lighting deficiencies and environmentally harmful installations throughout the park. Although our initial reports and complaints to the relevant authorities achieved limited success, sustained public engagement through lectures at schools, cultural institutions and local organisations, together with regular meetings with public authorities, gradually led several municipalities to adopt more environmentally responsible lighting practices.

Our educational and outreach activities have since expanded to other protected natural areas across the Valencian territory, where we regularly organise awareness campaigns highlighting the ecological, cultural and scientific importance of preserving natural darkness.

This long-term commitment has contributed to the consolidation of the annual *Jornada de Contaminación Lumínica de Riba-roja de Túria* and to our regular participation in *Expociència*, the Universitat de València's annual science outreach fair.

Over the years, we have also been invited to deliver specialised training courses on light pollution, including programmes at Tortosa Hospital (Catalonia), and to contribute to conferences and workshops held throughout Spain, including in Andalusia, Madrid and Galicia. In addition, we collaborate with schools through educational and cultural initiatives promoting environmental awareness.

Beyond outreach and public engagement, a major component of our work has been the systematic monitoring of night-sky brightness and its temporal evolution. To this end, we have established an extensive monitoring network based on Sky Quality Meters (SQMs) and TESS photometers. We have also conducted mobile measurement campaigns across the Valencian territory using vehicle-mounted instruments to characterise the darkest areas and quantify light pollution far from major urban centres.

Fifteen years after its creation, *Salvem la Nit* has become a recognised reference in light pollution awareness, monitoring and advocacy in València. Our work has contributed to increasing public awareness, fostering dialogue with public administrations responsible for outdoor lighting, and establishing a comprehensive database documenting long-term changes in night-sky brightness. Nevertheless, the expansion of artificial lighting continues to pose significant environmental challenges. Although important progress has been achieved, much remains to be done. We remain committed to promoting evidence-based policies and to protecting the natural night for the benefit of biodiversity, scientific research and society as a whole.

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Third-party certification as a driver for lower ALAN emissions

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Outdoor lighting products are often marketed as "dark-sky friendly" or "wildlife safe" — but these claims are rarely checked by anyone outside the manufacturer. As artificial light at night (ALAN) continues to rise, a consequence of increasing human-made lighting emitted into the lower atmosphere, this gap between marketing and verification is becoming a real obstacle to protecting the night.

The impacts of ALAN on human health and natural ecosystems are well documented across a wide range of scientific disciplines, even though concrete mitigation on the ground still lags behind (Rodrigo-Comino et al., 2021). Regulation is starting to catch up too, an international analysis of national frameworks for the International Astronomical Union's Centre for the Protection of the Dark and Quiet Sky shows a global rise in regulatory amendments addressing ALAN (Yakushina et al., 2024), but significant gaps remain across countries, and rules alone cannot guarantee what happens at the product level.

This is precisely the gap independent, voluntary third-party certification is positioned to close. By replacing self-declared conformity with objective, verifiable proof, certification turns a manufacturer's claim of responsible ALAN (ROLAN) practice into something a planner, authority, or buyer can actually trust. It also addresses a structural limitation that regulation alone does not resolve: without a common, independently verified standard, claims of ROLAN performance are not directly comparable across products, a gap that becomes more consequential as more manufacturers adopt such language.

This trust and comparability pay off for everyone along the lighting project supply chain, not just manufacturers. Manufacturers gain a credible way to stand out in a sustainability-conscious market. Lighting designers and specifiers gain a shortcut through due diligence and a reliable basis for comparing products on ALAN-sensitive projects. Procuring authorities and tendering bodies gain a verifiable criterion for procurement policy and sustainability assessments. What begins as a technical fix for the trust gap becomes a shared incentive structure - one where reducing ALAN is no longer a cost of doing business, but a competitive advantage.

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A Methodological Framework for Data Cleaning and Intercomparison of SQM and TESS Sensors in Night Sky Monitoring Networks: a Case Study in Austria

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Introduction

The rapid expansion of natural night sky brightness (NSB) monitoring networks calls for shared protocols that reconcile instruments with different optical characteristics and spectral responses, while rigorously separating natural sky background from anthropogenic light pollution. Currently, there is a lack of a standardized, homogeneous cleaning workflow that comprehensively integrates astronomical, meteorological, and physical background components. Within DARKERSKY4CE – a transnational Interreg Central Europe project focused on reducing light pollution through coordinated efforts – we present a methodological framework to harmonize cleaning procedure from Sky Quality Meters (SQM), TESS-W, and TESS-RGB photometers across representative Austrian environments. Our goals are to: (i) implement a reproducible pipeline addressing solar/lunar contamination, cloud interference, and site-specific atmospheric constraints; (ii) correct for the natural nocturnal sky background using a locally parameterized physical radiation model (ESO SkyCalc) (Noll et al., 2012; Jones et al., 2013); and (iii) assess intercomparison limits between SQM and TESS sensors, given that different photometers measure distinct spectral bands and fields of view. Ultimately, this framework aims to enable integrated assessments across mixed networks and support light pollution mitigation policies and local efforts.

Methods

We adopted a streamlined workflow guided by published methodologies while minimizing location-specific assumptions. The open-source scripted pipeline was applied and tested across few representative Austrian monitoring sites where SQM and TESS data were available, following a gradient from dark, natural environments to bright, urban areas (including alpine regions such as Weissensee and Gesäuse, as well as urban locations in Vienna and Villach). Astronomical screening retains only measurements from astronomical night and excludes strong lunar contamination based on ephemerides. Cloud influence is addressed with a dual strategy tailored to instrument capabilities: variability-based screening complemented by satellite cloud masks for SQM (Shah et al., 2025; Puschnig et al., 2023) and a thermal-differential indicator for TESS (Zamorano et al., 2026). The method proposed by Shah et al. (2025) uses fluctuations in sky brightness to quantify the standard deviation and determine an optimal threshold through Receiver Operating Characteristic (ROC) analysis, allowing the identification of cloudy and cloud-free conditions. For the TESS sensor, the difference between the ambient temperature and the sky temperature measured by the sensor is used to classify the degree of cloud cover. The natural sky background is modelled with an ESO SkyCalc-based approach adapted to local conditions via simple, explicit parameter sets including atmospheric molecules spectra, atmospheric profiles and meteorological data. The ESO SkyCalc model was developed and calibrated for the Cerro Paranal Observatory, making it unsuitable for direct



application to our study sites in Austria. Following “the Cerro Paranal Advanced Sky Model User Manual” (Noll et al., 2018), we adapted all the input data to our Austrian sites (European Southern Observatory, 2013). The model used is a Line-by-Line Radiative Transfer Model (LBLRTM) which simulate scattered moonlight, scattered starlight, zodiacal light, and applied airglow emission. Intercomparison has focused mainly on bandpass- and field-of-view-aware transformations, supported by co-temporal overlaps and color information from TESS-RGB to mitigate spectral response differences. The pipeline is implemented in open, scripted form to facilitate reuse by observatories and citizen-science networks.

Conclusions

A streamlined, site-adaptable pipeline combining astronomical constraints, tailored instrument cloud screening, and locally parameterized sky modelling has the potential to materially improve the comparability of SQM, TESS-W, and TESS-RGB data across Central Europe. By testing this framework across Austrian environments spanning natural dark sites to urban gradient locations, we outline a concrete procedure on how to clean dataset from heterogeneous formats and structure intercomparison tests despite intrinsic differences in sensor optics and spectral responses. By emphasizing portability, explicit parameterization, and a transparent documentation, the protocol aims to advance practical monitoring within DARKERSKY4CE and can ideally be adopted by regional observatories and local networks to support integrated assessment and mitigation of light pollution.



Figure 1 - Installation of the SQM and TESS-W sensors at the Weißensee Lake. Photo by Sabrina Muscolino.

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A nationwide approach to reduce light pollution in the Netherlands The LuNa project

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Introduction

The Netherlands, with its high population density, is one of the most light polluted countries in the world. At the same time, the light pollution is still increasing by a few percent every year. Since light pollution is disturbing our ecosystem, and has negative effects on human health, it is important to try to reduce the amount of unnecessary light.

In the Netherlands, we have two Dark Sky Parks, in Terschelling and in the Lauwersmeer area. The University of Groningen, which has a robotic telescope in the Dark Sky Park Lauwersmeer, has been active fighting Light Pollution since a decade. During the project *Donkerte van de Wadden* (2020-2024) many activities were organised in the Waddensea area to create awareness for darkness, including monitoring, educational activities, activities for tourism, etc. One of the outcomes is that Lauwersoog is informally known as the *Darkness Capital* of the Netherlands.

As part of the Interreg North Sea *Darker Sky* project, eco-friendly lighting was installed in the pilot Lauwersoog (see presentation Nynke Visser), in an example of a bottom-up approach, where many stakeholders together decide about their future lighting.

As a result of the positive outcome of the project *Donkerte van de Wadden*, we could start a new project, named LuNa (Licht uit Nacht aan). The project, with a budget of 2.5 M€, is financed by the Postcode Lottery. It is led by the Natuur en Milieu Federaties (NMF), with the University of Groningen as the Knowledge Partner. The NMF, with offices in each of the 12 provinces, is well suited to roll out activities across the whole country. The aim of the project is to create awareness of light pollution across the whole country and to influence policy makers in municipalities and provinces. The project started in Summer 2025 and will run for 3.5 years. Its website is the website of Nacht van de Nacht (Night of nights).

Activities

To realise our goals, three pilots were identified: Eemshaven, Markerwadden and the Veluwe (see Fig~1). At each pilot 10 SQMs and a Digital Camera are placed to monitor the sky

brightness. The goal of LuNa is to reduce the sky brightness significantly there. The pilot in Eemshaven, for example, is a much larger harbor than Lauwersoog.

Together with the pilots, we are

- Lobbying to modify the current lighting regulations.
- Setting up a network of 20 volunteers per province per year to help us with our activities.
- Developing a knowledge center light pollution, that should remain after the project. This is to be developed by the University of Groningen.

The University is preparing the monitoring devices, doing the monitoring, and the analysis afterwards.

Summary

During my presentation I will talk about the LuNa projects, its achievements up to now, and its plans for the coming years.

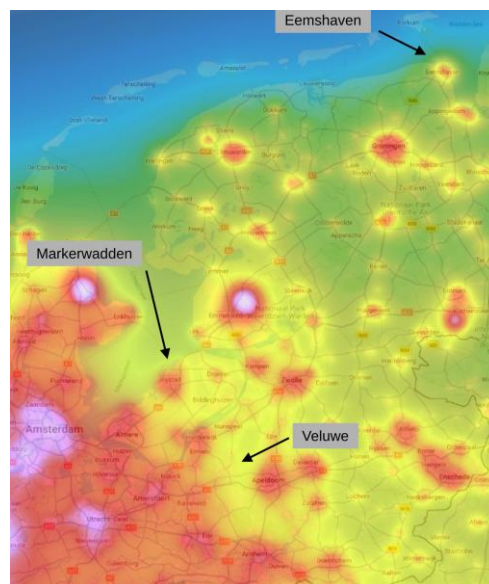


Fig. 1: VIIRS-DNB map indicating the 3 pilots of the LuNa project. The bright spot on the left is Amsterdam.

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Bat conservation and research in Tyrol

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Abstract

Bats are creatures of the night and depend on natural darkness more than almost any other group of animals. While some species have adapted to human-altered environments and tolerate artificial light at night, others, such as horseshoe bats, strongly avoid illuminated areas during foraging and commuting flights. Artificial light at night therefore represents a significant conservation challenge for many bat species.

Light pollution, however, is only one of several human-induced pressures affecting bats. To ensure their conservation, all bat species are strictly protected throughout the European Union under the Habitats Directive (92/43/EEC) and, in Tyrol, under the Tyrolean Nature Conservation Act and the Tyrolean Nature Conservation Ordinance.

Over the past three decades, bat conservation in Tyrol has achieved important successes, including improved protection of roosts and increased public awareness. Nevertheless, significant challenges remain, particularly in integrating bat conservation into construction projects, reducing the impacts of artificial light at night, and addressing remaining research gaps. The presentation reviews 30 years of bat conservation and research in Tyrol, highlighting achievements, ongoing challenges and priorities for future conservation efforts.

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When Darkness Becomes a Place of Wonder: Creative Pathways for Public Engagement on Light Pollution

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Introduction

The scientific community has long recognized the ecological, biological and cultural importance of natural darkness. However, one of the greatest challenges in protecting the night is reaching people beyond the scientific community – people who have never considered that artificial light at night can be a serious environmental issue.

Participants of dark sky conferences and professional networks already share a high level of awareness. The much greater challenge is to inspire the wider public: to help people experience darkness not as an absence of light, but as a valuable part of nature, a habitat for nocturnal life and an essential element of our own human rhythms.

This contribution presents a practitioner's perspective on public engagement and explores how emotional, sensory and creative approaches can complement scientific communication. The aim is not to replace scientific knowledge, but to create bridges between research and everyday life – because the protection of the night ultimately depends on the choices people make in their own homes, gardens and communities.

I am not a scientist; my background lies in creative communication, photography, storytelling and mindfulness-based experiences in nature. I work as a WALDWOHL® trainer for forest and health-related programs, as a certified instructor for forest bathing and mindfulness in the forest, as a children's book author, freelance designer and trained photographer. For many years, the night has been a source of fascination and inspiration for me. My goal is to encourage people to reconnect with darkness through curiosity, wonder and personal experience.



Methods

My approach combines nature experience, storytelling, poetry, photography, mindfulness elements and accessible information about nocturnal ecosystems and artificial light. The focus is not only on knowledge transfer, but on creating memorable experiences that allow participants to develop an emotional connection with the night. Several formats have been developed and offered within regional environmental programmes:

“JOHANNISFÜNKCHEN – A mystical forest experience with fireflies” uses the natural phenomenon of bioluminescence as an emotional gateway to the night. Through observation, poetry, sound and mindfulness elements inspired by Shinrin Yoku, participants discover the beauty of naturally occurring light and the richness of darkness.

“AUF MOTTENTOUR– A sensory journey through darkness” invites participants to experience the night from the perspective of nocturnal creatures. Silence, scents, sounds and stargazing reveal a hidden world that often remains unnoticed during the day and encourage a more respectful relationship with darkness.

“LICHTER DER NACHT – From starlight to streetlights” addresses the topic of light pollution directly. Developed in cooperation with local environmental partners, this programme explores the difference between natural and artificial light and encourages participants to reflect on how lighting choices influence humans, animals and plants.

An additional indoor format, **“CANDLES & LIGHTS”**, transfers this approach into an evening setting. In an almost completely darkened room, photography, audio-visual elements, poetry and personal reflections create an atmosphere in which participants can explore the beauty of the night sky, the fascination of the universe and the value of preserving natural darkness.

Storytelling is another important element of my work. In my children’s book series **“DIE KLEINE WALDFEE SCHIMMERIE HARZTROPF”**, as well as in poems and short stories, I explore themes of nature connection, imagination and our relationship with darkness. Creative approaches can open additional pathways for ecological awareness, especially among audiences who may not initially engage with scientific information.

Conclusions

Scientific research provides the essential foundation for understanding the impacts of artificial light at night and for developing effective strategies to protect natural darkness. Translating scientific knowledge into everyday awareness and action is an important additional step towards long-term change.

The experiences presented here suggest that sensory encounters, storytelling and creative approaches can serve as valuable complements to scientific communication. By allowing people to experience the beauty and importance of darkness personally, abstract concepts such as light pollution can become more tangible and relevant to everyday life. Protecting the night is a shared task that requires both robust scientific evidence and meaningful public engagement. Reaching people beyond the scientific community is therefore not a replacement for research, but a way of helping scientific insights become part of everyday decisions and collective action.

Beyond ULOR: A Component-Level Stray Light Analysis of Outdoor Luminaires and Their Environment Using Ray-Tracing Simulation

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Introduction

When it comes to reducing light pollution from outdoor lighting, the discussion often centres on a single question: how much light does the luminaire emit directly above the horizontal plane? Metrics like the Upward Light Output Ratio (ULOR) or the BUG rating (IES TM-15) have become the standard tools for answering it. However, these metrics only tell part of the story. As Luginbuhl et al. (2009) demonstrated on a macroscopic scale, the dominant contribution to artificial sky glow does not originate from direct upward emissions at all — it comes from light reflected off ground surfaces and surrounding objects. Yet despite this insight, the lighting industry and municipal decision-makers continue to rely almost exclusively on direct-emission metrics when selecting luminaires.

Methods

Detailed 3D optical models of representative luminaires from each category were built in Ansys Speos and Synopsys LightTools, incorporating measured material properties (BRDF/BTDF) for all optically relevant surfaces. To isolate the contribution of each element, individual surface interactions were selectively activated and deactivated — effectively allowing us to ask: how much stray light does this single component cause?

Internal contributors under investigation include the optical system itself (lens-based vs. reflector-based designs), the colour and reflectance of the PCB substrate, the geometry and surface finish of the housing edge, as well as the shape and material of the cover glass or protective flat panel.

Beyond the luminaire, external factors were varied systematically: pole attachment geometry, pole diameter and surface colour, mounting height, road surface — including a comparison between dry and wet conditions, where specular reflection characteristics change drastically — and the presence of nearby objects such as building façades that can redirect stray light towards the night sky.

A hemispherical detector arrangement around each installation scenario captures the full angular distribution of upward-directed flux, enabling a quantitative attribution of sky-bound light to each individual source.

Conclusions

Preliminary results reveal a striking imbalance: even for decorative luminaires equipped with state-of-the-art optics, the direct upward light emission — the very quantity captured by ULOR — is small. Yet the total effective upward flux, once indirect pathways via pole surfaces, housing scatter, and ground reflections are accounted for, can exceed the direct component by a significant margin. The relative ranking of contributors shifts considerably between luminaire types and installation configurations, underscoring that a one-size-fits-all metric is insufficient.

These findings carry practical implications. A municipality selecting luminaires solely on the basis of ULOR or BUG classification may overlook installation-level factors — such as pole finish or mounting geometry — that have a larger impact on actual sky glow than the optical design of the luminaire itself. Based on the simulation results, we propose an extended evaluation framework and offer a prioritised set of recommendations for specifiers and urban planners: if you can only change one thing, what should it be?

A more detailed discussion of the quantitative breakdown, the comparison across luminaire types and road conditions, and the outline of a possible extended metric that captures both direct and indirect upward light contributions will be presented at the conference.

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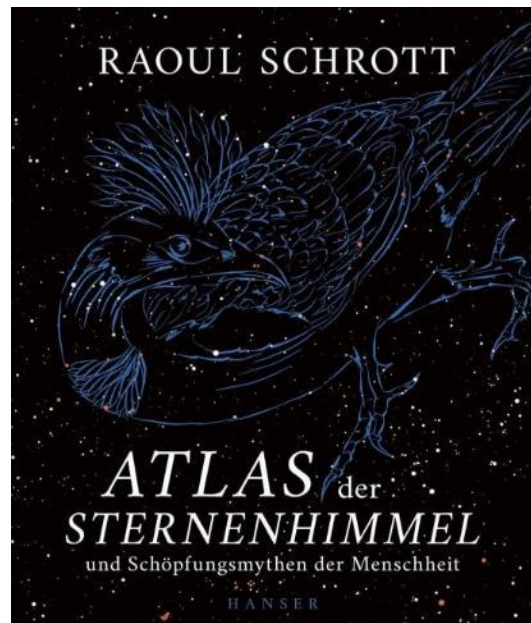
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The starry skies of different cultures around the world - their functions and form

Raoul Schrott

Raoul Schrott, an austrian lecturer in comparative studies spent years researching a large-format reference work about the ways 17 different cultures across continents have given meaning to the stars and planets, to sun, moon and the comets (*Atlas der Sternenhimmel und Schöpfungsmythen der Menschheit*, Carl Hanser Verlag, Munich, ISBN: 978-3-446-28122-6, 1300 pages). For the first time, all constellations of these 17 cultures were fully documented in all of their functions and forms (with over 500 detailed drawings), the complete starlore associated with them collected, and everything contextualized in their respective origin myths.

The constellations and planets represented what was central and fundamental to each culture: its gods and heroes, its most important objects, animals and plants. Starfields were thus interpreted differently by each culture, e.g.: the patterns in Ursa maior were to Indoeuropeans a female bear with its cubs, a ceremonial waggon for an important goddess to the Mesopotamians, a divine parrot to the Maya, a one-legged storm god to the Inca, a moose to the Inuit, and a funeral bier to the Arabs. In a time before writing the night sky served to transmit knowledge via its images and stories, fulfilled religious and healing functions, was an important calendar for the whole year and a navigational instrument. With this work Schrott brings a hitherto almost unknown but elementary chapter of the history of mankind to light.



Paving the Way for Darkness in Luxembourg's Nature Park Our

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Introduction

DarkSky Switzerland was asked in 2016 to present the light pollution situation to the environmental minister of Luxembourg in OekoZenter Paffendal. At the aperitif, we were asked to discuss further with the minister for energy and sustainable construction. For the first time in history, it was agreed that Suomi NPP VIIRS data was worthwhile to compare situations on a country and community level, and a series of studies began.

Methods

We studied and compared all 105 communities of the country of Luxembourg for their nightly light emissions by evaluating their current VIIRS data and identified the maximal values by comparing daytime satellite images and Google street view for detailed research of public lighting, parking lots, industrial and commercial zones, and similar light emittents.

After that, the Nature Park Our approached us for a more detailed analysis of the brightest zones that the satellite detected in their territory. In some cases, we could not immediately explain the reported brightness of a certain landscape by looking at building data. But always, the satellite is right: Far-shining horizontal lighting can reflect a lot of light in a rural spot, e. g. on a hillside. Once it was a car dealer not having installed proper lighting shielding, causing light flood the terrain. The other case was military barracks, that impacted the hillside 2 km away from it.

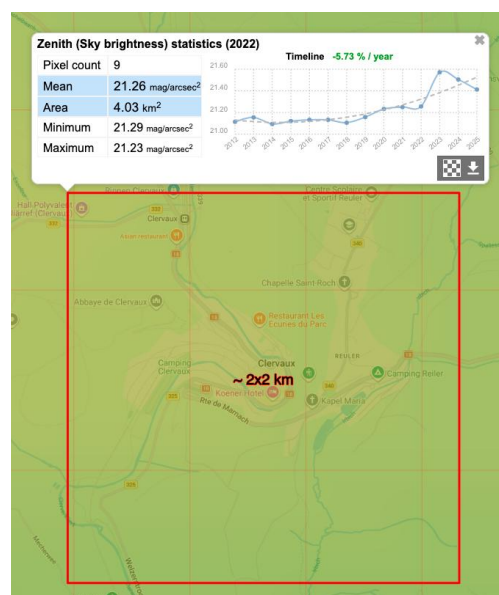
Field visits allowed us to decide how to address the issues. In a collaborative effort, we decided to look at bright public-owned zones to showcase how light straying and spilling is captured by aerial photography. We obtained ortho-photogrammetry by drones to document the bad examples.

In the community of Clervaux, the small and picturesque city of Clervaux had outdated bad lighting of the



Top: Clervaux Church and Castle before (left) and after (right) renewal of the illumination. The light emission hotspot, discovered by the Suomi NPP VIIRS satellite, was reduced.

Below: Lightpollutionmap.info shows increasing magnitudes (deeper darkness) between 2018 and 2024 for Clervaux.



main church and castle. Our aerial documentation led to a new lighting plan by Uwe Knappschneider, with directed light and warm LED street lighting chosen differently for the old town and for the main roads. The reduction seen by the satellite for the center of the castle was substantial. The aerial image confirms less direct lighting.

The minister of territorial planning and energy asked us to further focus on two villages in the community of Putscheid (a municipality well aware of the topic), which was about to renew their public lighting to LED. We used the chance to evaluate whether the full renewal was superior to retrofitting street lamps.

Aerial before/after imagery revealed that both methods worked nearly equally well for reducing stray light. This is thanks to a professional lighting planner, Daniel Gliedner, who was engaged by Nature Park Our as a helping hand for addressing and consulting lighting issues in the Park.

Nature Park Our was interested to obtain a certification for darkness. Our studies stated that the close neighborhood to Belgium, with a lot of light emissions in the south, with densely populated major cities and suburbs near the border to France, would it make difficult to qualify for a certification as a Dark Sky Park, as the darkness threshold of $> 21.2 \text{ mag/arcsec}^2$ would not be reached. Instead, it was decided that the municipality of Putscheid, with its two villages with renewed full-cut-off warm LED, and the an all-sky monitoring established, would apply as a Dark Sky Community as a start. Certification was completed in 2026.

As some neighbouring areas (like a highway in Belgium in Wallonia, Villages d'Étoiles in France) switch off some lights at night-time, this might help mitigate atmospheric light pollution over Nature Park Our on the long run. However, our all-sky long-term monitoring still reports a slight increase in light pollution.

Conclusions

For rural nature parks closer than 100 km to densely populated areas, it might be difficult to reach sky qualities required for Dark Sky Certification. Instead of giving up, it might be worthwhile to consider proceeding in small steps, like a Dark Sky Community, or an Urban Dark Sky Place Certification as a start. We are convinced that the sensitizing work that such a place can initiate can empower the government to address the issue of light pollution and establish good lighting practice, as the population will better understand the connection to nature and the universe as part of quality of life.

We showed that our consulting and measuring work has enabled the Nature Park Our and the Government of Luxembourg introduce better lighting practices at places under their control. Luxembourg is now pioneering with the consulting work of a professional for lighting issues. Proceeding in small steps is a viable way of improving, but also supraregional efforts and awareness is required.

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Urban growth, skyglow, and upward radiant energy in Antalya, Türkiye: an assessment of artificial light at night

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Introduction

Artificial light at night is increasing across many urban and peri-urban landscapes, with consequences for astronomy, ecosystems, human health, and energy sustainability. Mediterranean coastal cities are particularly relevant case studies because tourism, transport infrastructure, greenhouse agriculture, and rapid urban expansion can all contribute to changing nighttime light patterns. This contribution presents a spatiotemporal assessment of light pollution in Antalya, Türkiye, and examines whether satellite-observed nighttime radiance is related to urban air quality.

Methods

We examined ground-based night sky brightness measurements, satellite data and air-quality observations. Sky quality meter data from the TÜBİTAK National Observatory in Saklıkent, Antalya were filtered to remove the influence of twilight, moonlight, cloud cover, and the Milky Way. Cloud conditions were evaluated using EUMETSAT cloud masks. Long-term nighttime light trends were analysed using NASA Black Marble VIIRS products from 2012 to 2023, with monthly and annual composites processed in QGIS and Python. Administrative district boundaries were rasterised to match the spatial resolution of the satellite products, and filtering based on observation counts and the coefficient of variation was used. To investigate possible interactions between atmospheric particles and observed nighttime radiance, PM_{2.5} measurements from four air-quality monitoring stations were compared with same location Black Marble radiance values on monthly and daily timescales.

Results and discussion

The results show a sustained increase in total nighttime radiance across Antalya between 2012 and 2023. While mean radiance in some districts stabilized or declined after 2020, total integrated radiance continued to increase, showing that the illuminated area expanded even where average brightness did not. Several hotspots could be linked to identifiable land-use and infrastructure changes, including the construction of Antalya City Hospital, airport expansion, and increased greenhouse coverage in peri-urban areas. Ground-based measurements provided additional context for the satellite observations. After strict filtering, the darkest anthropogenic sky background at the observatory was estimated at approximately 21.43 mag arcsec⁻², while seasonal variation was influenced by cloud cover and the position of the Milky Way.

No statistically significant correlation was found between ground-level PM_{2.5} and satellite-observed nighttime radiance, either at monthly scale or in a daily clear-sky case study. This suggests that surface air-quality measurements are not sufficient proxies for the vertically integrated aerosol conditions influencing radiative transfer and satellite detection of artificial

light. The finding is particularly relevant for coastal and mountainous regions, where atmospheric structure may decouple surface pollution from upper-air scattering conditions.

Finally, the upward radiated energy detected in the VIIRS-DNB spectral band was estimated as a conservative lower bound. For 2023, at least 860.75 GWh of radiant energy was emitted toward space from the analyzed districts, corresponding to approximately 0.25% of Türkiye's total electricity consumption for that year. This value should not be interpreted as total lighting waste, because it is band-limited and does not include full spectral or angular emission.

Conclusions

Antalya's nighttime light environment is being reshaped primarily by spatial urban growth and large infrastructure development. The absence of a direct PM_{2.5} and radiance relationship shows that the interaction between air quality and light pollution is more complex than can be resolved using surface particulate measurements alone. For light pollution mitigation in Mediterranean urban regions, the results support a multi-scale monitoring strategy combining ground-based photometry, satellite observations, land-use analysis, and atmospheric profiling.

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LINA: an initiative against excessive advertising lighting

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Introduction

In recent years, employees of the provincial capital Linz (Austria) have actively addressed the issue of light pollution through investigations and targeted measures. Public outreach has also been a key objective, exemplified by the creation of the mascot LINA, who serves as the ambassador for all light pollution initiatives in the city.



Fig. 1:: Mascot LINA, designed to represent Linz's light pollution activities

A major focus of our efforts has been the excessive use of lighting for advertising purposes. Drawing on extensive experience from citizen complaints, we conducted a study on several streets to assess the luminance and operating hours of advertising lights. The results highlighted significant opportunities for improvement in both areas.

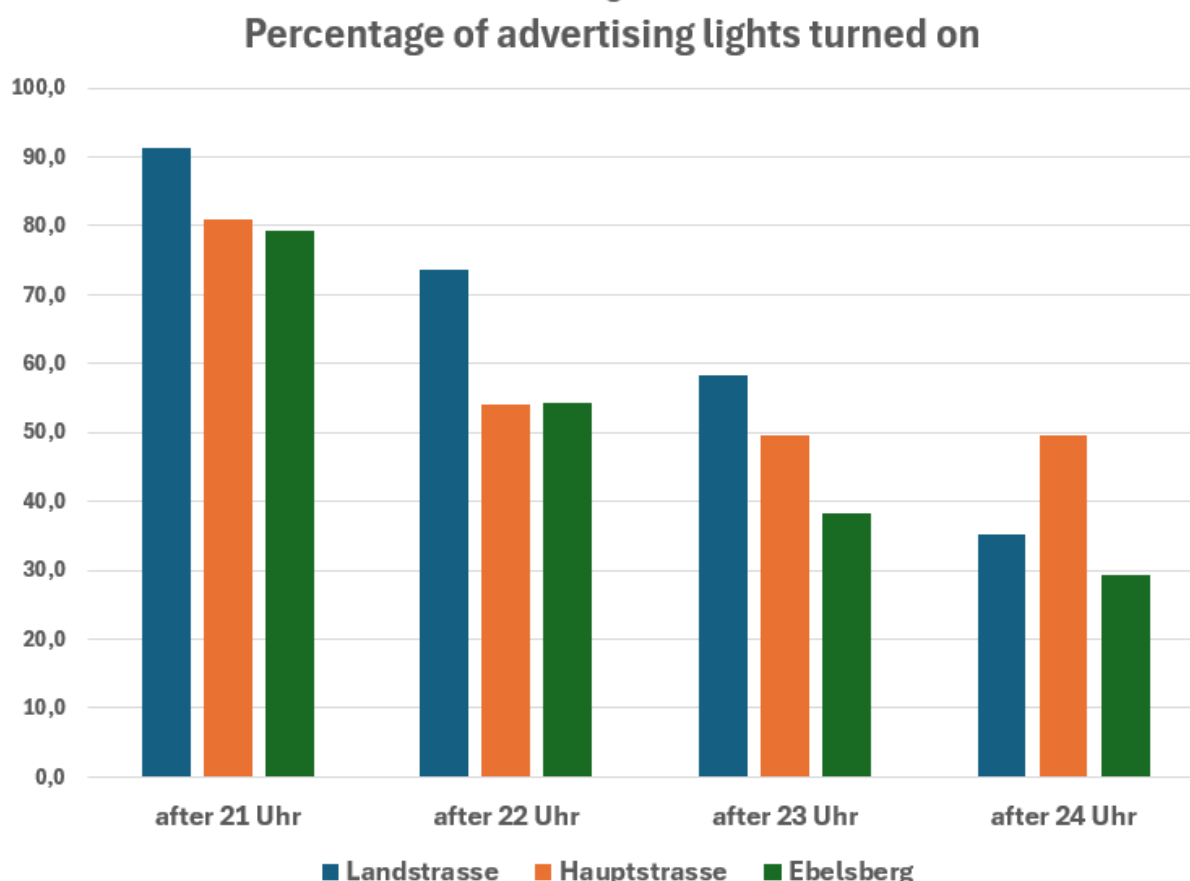


Fig. 2: Operating hours of advertising lights on three typical streets

As a next step, we launched the initiative “LINA – Lights Off at 22:00,” contacting approximately 250 companies by email and encouraging them to voluntarily switch off advertising and other decorative lights at 22:00 or earlier.

Methods

We measured luminance and carried out simple investigations into the operating hours of lights.

Conclusions

Our findings indicate considerable potential for reducing both luminance and operating hours of advertising lights in accordance with standards such as Austrian ÖNORM O 1052. For example, roughly 30 to 50% of advertising lights remain on after midnight.

Regarding our “LINA” initiative, out of the 250 companies contacted, around 60 have agreed to switch off their advertising lights by 22:00. Although only about 20 companies responded to decline participation, their reasons were evenly distributed among concerns about security, technical limitations, and the need for visibility.

Presentation of BfN Publication 772: 'Regulatory Approaches to the Protection of Animals and Plants from Artificial Light'

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Introduction

BfN Publication 772, 'Regulatory Approaches to Protecting Animals and Plants from Artificial Light' developed by the Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB) and published in June 2026.

The publication brings together the scientific, legal and administrative foundations for the implementation of Section 41a of the Federal Nature Conservation Act. Section 41a was introduced with the amendment to the Federal Nature Conservation Act in 2021 and is to be fleshed out by a statutory instrument yet to be enacted, setting out specific and binding requirements for outdoor lighting; the protective provision will only come into force once this regulation has been issued.

The regulatory approaches for protecting wild animals and plants from the adverse effects of artificial light include, amongst other things, a spatial protection concept, ecological thresholds and the 'virtual assessment wall' method, which allows light levels and light distribution to be assessed at the planning stage and monitored subsequently.



Presentation

In my presentation, I will outline the key content, the proposed regulatory instruments, their application and their potential significance for the planning, approval and design of outdoor lighting systems.

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<https://www.bfn.de/publikationen/bfn-schriften/bfn-schriften-772-regelungsansaetze-zum-schutz-von-tieren-und-pflanzen>

Co-design of sustainable lighting in the Port of Lauwersoog (the Netherlands)

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Artificial light at night (ALAN) is increasingly recognised as a major environmental pressure affecting biodiversity, ecosystem functioning and human well-being. Reducing ALAN in ports is particularly challenging, as artificial lighting is indispensable for safety and operational activities while many ports are located adjacent to ecologically valuable coastal environments. This talk discusses a study about the conditions that enable stakeholders to support lighting transitions in Lauwersoog. The study examines how stakeholders perceive existing harbour lighting and its ecological impacts, and how these perceptions relate to their willingness to participate in reducing ALAN. It further investigates how governance, institutional and social factors (e.g. perceived safety, environmental values and existing policy frameworks) influence stakeholder engagement.



Figure 2: The Harbour of Lauwersoog at Night. Here, a community-led “Masterplan Donkerte” (Darkness plan) is guiding the replacement of harbour lighting with dark-sky friendly fixtures (Picture by Piet Zijlstra)

The Port of Lauwersoog is located between the UNESCO World Heritage Wadden Sea and the Dark Sky Park Lauwersmeer. In 2022, the harbour became a pilot location within the Interreg North Sea project DARKER SKY. Building on this pilot, the initiative received additional funding from the Waddenfonds and evolved into the Masterplan Donkerte Lauwersoog, which aims to substantially reduce light emissions while maintaining safety, functionality and economic activity. Rather than approaching lighting solely as a technical issue, the project explicitly adopts a bottom-up co-design approach in which public authorities, harbour users, businesses, nature organisations and researchers jointly develop and implement lighting interventions.

The Masterplan is organised around the Sustainable Harbour Coalition, a long-standing collaboration between the port authority, municipalities, provinces, entrepreneurs, fishers, ferry operators, Rijkswaterstaat, nature organisations and the University of Groningen. Through recurring coalition meetings, community workshops, lighting demonstrations and participatory night walks, stakeholders jointly identified lighting problems, explored alternative lighting solutions and discussed trade-offs between ecological quality, safety and harbour operations. These activities formed the basis for the Masterplan Donkerte and the ongoing replacement of conventional lighting with adaptive, warm-coloured and shielded luminaires.

Semi-structured interviews, actor mapping and institutional analysis are used to examine how collaborative governance, perceived safety, environmental values and existing policy

arrangements shape decision-making. Particular attention is paid to the interaction between local stakeholder networks and the relatively weak institutional embedding of light pollution within environmental policy, which often allows competing economic and operational priorities to prevail. Despite growing scientific evidence, light pollution remains one of the least regulated environmental issues in the Netherlands, making Lauwersoog a valuable case for understanding how collaborative governance can support transitions towards more sustainable harbour lighting.

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Colour temperature is not enough: How many spectral bands night-sky monitoring actually needs

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Introduction

Correlated colour temperature (CCT) is the spectral descriptor of record for outdoor lighting. It appears on product labels, in certification schemes, in ecological guidance, and in regulation, which commonly sets limits in Kelvin.

Two practical problems follow. Several European networks replaced Sky Quality Meters with TESS-W photometers during the same years their surroundings converted from sodium to LED, and the two instruments do not see the same sky in the same way. Limits written in kelvin, meanwhile, assume CCT predicts what organisms absorb. We ask what the shortcut costs, and what replaces it.

Methods

We took 235 measured spectra of real lamps and luminaires and worked out what each would read on five instruments. These were the Unihedron SQM, the STARS4ALL TESS-W, the astronomers' V band, the VIIRS Day/Night Band at four points in its mission, and the four channels of the TESS-4C (Bará et al. 2019; Zamorano et al. 2022). What we compare is a colour index of the kind defined by Galadí-Enríquez (2018). It depends only on the shape of a spectrum, so calibration, unit-to-unit differences and detector ageing all cancel: no calibrated instrument is needed. Every prediction below is tested on lamps left out of the fit. We then ran the analysis again with 549 measured insect photoreceptor sensitivities from 207 species (van der Kooi et al. 2021) in place of the instruments.

Results

Across 171 lamps intended for general lighting, the gap between what an SQM and a TESS-W report spans 0.632 mag, while a complete conversion from high-pressure sodium to 3000 K LED changes it by 0.047 mag. The artefact of changing instruments is an order of magnitude larger than the lighting change it would be used to measure.

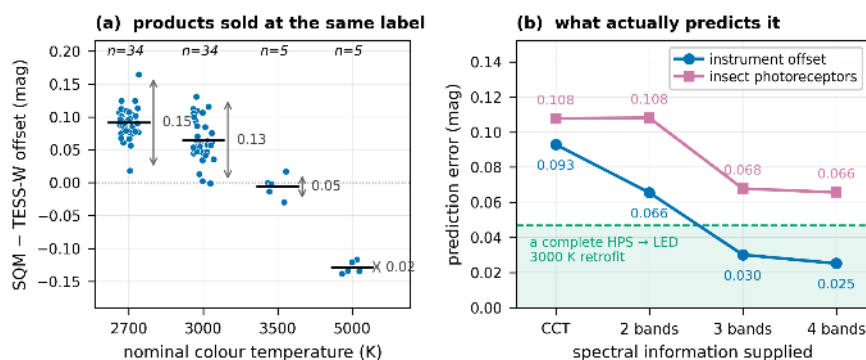


Fig. 1: (a) White LED products sold at the same nominal colour temperature, and the instrumental offset each produces. (b) Prediction error for the instrument offset and for insect photoreceptors; shading marks a complete HPS-to-LED 3000 K retrofit.

Colour temperature does not close that gap. It works inside a single lamp technology, where it leaves 0.030 mag, but fails between technologies: four of them at an identical 3000 K span 0.250 mag. Nor does the product label rescue it. Thirty-four white LED products all sold within 150 K of 3000 K differ by 0.131 mag among themselves (Fig. 1a), i.e., three times the retrofit they would be used to measure.

Measured spectral bands do close it (Fig. 1b). Once three bands are recorded, colour temperature contributes nothing further. Note the trap for anyone writing a specification: two colour ratios need three physical channels, not two, so a specification written in ratios quietly asks for one channel less than it needs. The same answer holds for eyes: across the 549 receptor classes two bands buy nothing at all, and three recover 95% of the available benefit.

Finally, for six of seven retrofits at equal pavement luminance, ground instruments register a brightening while the VIIRS Day/Night Band registers a darkening, purely because of what each instrument can see. This holds at every point in the mission we tested, and the satellite's own colour sensitivity has shifted, 58% of it during the years the record has been used to measure change.

Conclusions

1. Three spectral bands are the practical minimum; two are not a cheap approximation to three.
 2. Write the specification in physical channels, not in colour ratios.
 3. Do not use CCT where the technology mix is changing. It is dependable only within one technology.
 4. A network that changed instruments must recompute its offset against its own source population.
 5. Ground and satellite records are not comparable across a lighting transition, and the gap moves over time.
- None of this asks for hardware that does not exist, e.g., TESS-4C already provides four channels. It asks for a change of habit: describe a light source by three measured bands rather than by a single colour temperature.

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Sunlight and Moonlight Day/Night Variations in Atmospheric Extinction under Clear Sky Condition

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Introduction

The night sky has fascinated humans for millennia and continues to do so today. In recent years, however, nighttime light has gained increasing scientific importance beyond astronomy. Today, it is the subject of interdisciplinary research in environmental science, ecology, and medicine. A detailed understanding of atmospheric influences is essential for the interpretation of nighttime light measurements, the analysis of long-term trends, and the comparison of different observation sites (Reimann et al., 1992; Wuchterl & Reithofer, 2020). While seasonal variations in atmospheric extinction have already been extensively studied, this study presents the first comparison of atmospheric extinction under cloud-free daytime and nighttime conditions at the Kanzelhöhe Observatory for Solar and Environmental Research. Knowledge of these Day/Night differences is essential for extending atmospheric models and concepts developed from daytime measurements to nighttime conditions.



Fig1.: The picture shows a ARAD Station with the pyranometer on the right and the flat white Lightmeter Mark2.3L on the left (indicated by the yellow arrow) on the roof of the Kanzelhöhe Observatory. The picture was taken on March 12, 2023.

Methods

The comparison is based on Global Horizontal Irradiance (GHI) measurements research covering the period 2013–2020. Daytime data were obtained from a pyranometer (Kipp & Zonen CM22) from the ARAD Station using the Sun as the light source, while nighttime data were obtained from a photometer (Lightmeter Mark 2.3L) using the Moon as the light source (Müller et al., 2011; Olefs et al., 2016). The Moon serves as the nighttime analogue of the Sun because of its comparable apparent angular diameter, the same geometric path across the sky, and spectral properties similar to those of sunlight (Kieffer & Stone, 2007). To enable a consistent Day/Night comparison, terminology, definitions, and units from meteorology and astronomy were harmonized, and a global extinction coefficient was introduced as a common comparison metric. Atmospheric extinction was determined under cloud-free conditions over the same air mass range (AM 2–4, altitude between 30° and 15°, zenith angle of 60°–75°).

Conclusions

For the first time, a method enabling the direct comparison of daytime and nighttime atmospheric extinction under comparable clear-sky conditions is presented, revealing a distinct Day/Night difference. With the exception of one case, the global extinction coefficient was higher under nighttime than daytime conditions; in 38 cases, nighttime extinction exceeded daytime extinction by an average of 42%. In one case, nighttime and daytime extinction were equal.

Furthermore, the variability of nighttime extinction was approximately three times higher than that of daytime extinction. Among the investigated meteorological parameters, only wind speed correlated with the observed Day/Night differences in atmospheric extinction.

A comparison between the Lightmeter Mark 2.3L and the Kipp & Zonen CM22 confirmed the statistical significant comparability of both instruments, indicating that the use of two different instruments did not affect the comparison of daytime and nighttime measurements.

These findings provide the first experimental evidence of a systematic Day/Night difference in atmospheric extinction and establish an important basis for future studies aimed at identifying the physical mechanisms underlying this phenomenon.

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Environmental Knowledge of Artificial Light at Night: A Representative Study in Austria

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Introduction

Artificial light at night (ALAN) has become one of the fastest-growing environmental pressures globally, primarily through the generation of skyglow that fundamentally transforms nocturnal light environments even in rural landscapes [1, 2]. Ecological consequences range from disrupting nocturnal behaviour and endocrine regulation in vertebrates, to impairing insect orientation and pollination networks [3], and degrading habitat quality across terrestrial and aquatic ecosystems [4, 5]. Despite increasing scientific evidence of these consequences, empirical research into public comprehension remains scarce.

For the transition toward biodiversity-sensitive lighting design, this gap is critical, as it depends not only on technical capacity but also on public acceptance and informed stakeholder engagement. Without basic knowledge, lighting interventions risk being contested, misunderstood, or reduced to cost-related concerns. This study establishes an empirical baseline of public knowledge on artificial lighting in Austria across four domains, with particular attention to environmental impacts on animals, plants, and night sky brightening.

Methods

A representative cross-sectional online survey was conducted in October 2025 with $n = 1,004$ adult participants recruited via quota sampling (gender, age, education, federal state) from the Austrian general population. The questionnaire assessed four thematic domains: (1) health aspects, (2) visual quality, (3) energy efficiency, and (4) environmental impacts. Each domain comprised four multiple-choice questions with five statement items each.

Objective performance was scored using Balanced Accuracy (BA) to account for class imbalances in the dataset, which would bias a standard percentage-correct metric. Additional psychometric analyses included Bayesian Multidimensional Item Response Theory modelling (3PL-MIRT) to estimate latent knowledge abilities (θ) per participant, and a Latent Profile Analysis (LPA) to identify subgroups with distinct cross-domain knowledge patterns.

Results

Overall Balanced Accuracy across all 16 questions was $65.2 \pm 11.2\%$, indicating moderate performance. However, significant between-domain differences emerged (repeated-measures ANOVA: $F(2.97, 2976) = 35.4$, $p < .001$, $\eta^2 = .034$). Health aspects (BA = 66.7%) and energy efficiency (BA = 67.1%) showed the highest accuracy, followed by visual quality (BA = 65.0%). Environmental impacts yielded the lowest domain-related performance (BA = 62.2%).

IRT analysis indicated that the environmental impacts domain showed the highest median item difficulty of all domains, with strong variation across subtopics (Figure 1). Knowledge was highest for effects on animals (BA = 70%), where, however, only 48% recognized aquatic responses to surface light ($b = 0.83$). Light pollution and skyglow showed moderate performance (BA $\approx$ 60–62%), with 42% underestimating skyglow intensity.

Effects on plants were by far the most difficult subtopic (BA = 50%, chance-level). While only 9% underestimated plant sensitivity, misconceptions remained widespread. 28% assumed only UV drives responses, 40% restricted effects to greenhouse conditions, and 74% failed to recognize that light affects plants independent of light source type. Correspondingly, the item showed the highest difficulty across all 80 items ($b = 3.72$), indicating discrimination mainly among respondents with above-average environmental knowledge.

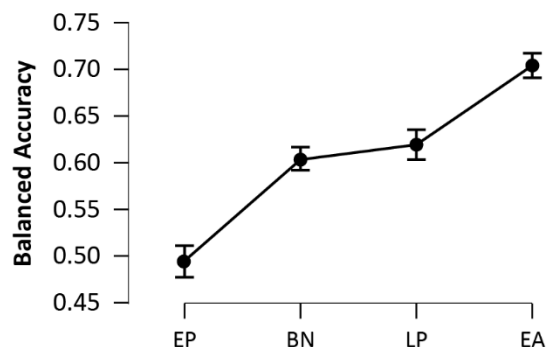


Fig. 1: Balanced Accuracy for the four environmental subtopics (left to right: Effects on Plants (EP), Brightening of the Night (BN), Light Pollution (LP), Effects on Animals (EA)) with 95% CIs.

Latent Profile Analysis identified two distinct knowledge profiles, with the largest between-profile gap observed in the environmental domain ($d = 2.24$), indicating that ecological lighting knowledge is more sharply polarized than any other domain.

Conclusions

This study provides the first representative assessment of public knowledge on the environmental impacts of artificial lighting in Austria. Results reveal a consistent pattern. The ecological effects of ALAN are the least understood dimension. Misconceptions are widespread, particularly regarding plant responses and the extent and intensity of skyglow.

These findings have direct implications for policy and practice. The pronounced knowledge gap on plant-related effects highlights the need for accessible communication of photobiological principles in contexts such as roadside and façade lighting. The underestimation of skyglow suggests that its impacts in rural and peri-urban areas remain largely invisible, limiting public support for mitigation.

To support the transition to biodiversity-sensitive lighting, strengthening environmental lighting literacy should therefore be treated as a key component of evidence-based policy.

Acknowledgements

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