'Protecting Dark & Quiet Skies: Practical mitigation for large satellite constellations (DarkSkies)' Abstracts

Talks

Reducing the Impact of Satellite Brightness for Astronomy: Laboratory Characterisation and Simulations

Authors

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Abstract

The rapid expansion of satellite constellations in Low Earth Orbit (LEO) has raised significant concerns about their contribution to night-sky brightness and the resulting impact on astronomical observations. In this work, we investigate a passive, material-based mitigation strategy based on an ultra-black, aerospace-qualified coating. \\
We characterise the optical behaviour of the coating through laboratory measurements of its bidirectional reflectance distribution function (BRDF), obtained using a calibrated goniospectrophotometer. The measured BRDF is modelled using a parametric binomial function and incorporated into a brightness simulation framework to predict the apparent magnitude of representative LEO satellite configurations.
For a $3.64\,\mathrm{m}^2$ nadir-facing panel at an altitude of $550\,\mathrm{km}$, the coating limits peak brightness to $\gtrsim 6.7$ AB magnitude (mag) across typical observing geometries, approaching the ~ 7 AB mag visibility threshold recommended by the International Astronomical Union (IAU) in the Johnson V band. Compared to conventional specular spacecraft surfaces, such as the Starlink V1.5 chassis, the coating significantly suppresses brightness enhancements across a range of viewing geometries and reduces sensitivity to secondary illumination, including Earthshine.\\
This behaviour is consistent with the measured near-Lambertian scattering properties of the coating, which suppress directional reflectance and contribute to stable brightness across varying illumination and viewing conditions, including extreme terrestrial albedo. These results demonstrate the potential of laboratory-characterised, ultra-low-reflectance coatings as a scalable, material-level component of broader strategies to reduce satellite-induced light pollution. A dedicated in-orbit demonstration is planned with Jovian-1 to validate these findings under operational conditions.

From Unregulated Light to Governed Night though policy framework in India

Authors

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Abstract

Light pollution is an emerging environmental challenge with implications for biodiversity, human health, energy efficiency, and astronomical observation. Despite its growing significance, it remains largely unaddressed within formal policy frameworks in many developing regions. This paper presents the development of a state-level policy framework for dark sky conservation in Maharashtra, India, designed to integrate light pollution mitigation into existing environmental governance systems.

The framework adopts a cross-sectoral approach, positioning dark sky preservation at the intersection of environmental protection, sustainable tourism, and rural development. It outlines a structured pathway for the identification and designation of Dark Sky Places, supported by scientific assessment of night sky quality, implementation of context-sensitive lighting regulations, and establishment of long-term monitoring mechanisms.

A central feature of the framework is institutional coordination. It defines roles and responsibilities across multiple government departments, including Environment, Tourism, Energy, Forest, and Tribal Development, enabling alignment of policy objectives and efficient implementation. The framework also emphasizes capacity building, public outreach, and stakeholder engagement to ensure sustained compliance and community participation.

Importantly, the model demonstrates that effective dark sky conservation does not require extensive new infrastructure. By prioritizing retrofitting of existing lighting systems and optimizing current public spaces for astronomy-based activities, the framework minimizes financial barriers while maximizing environmental and social impact.

The policy approach further links conservation with local economic opportunities through the development of astro-tourism and skill-based employment, particularly in rural and ecologically sensitive regions.

This work contributes a scalable, policy-oriented model for addressing light pollution in emerging economies. By embedding dark sky conservation within established governance structures, it provides a replicable pathway for regions seeking to balance environmental stewardship with socio-economic development.

Event-based sensing for rapid warning of satellite streak contamination

Authors

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Abstract

Satellite streaks are becoming an increasingly frequent source of contamination in long-exposure, wide-field images, degrading the scientific return from valuable observing time. The problem is expected to worsen, with tens of thousands of satellites licensed for launch over the coming decade. Effective mitigation demands timely and accurate orbital state information; however, the growing catalogue of resident space objects is placing significant strain on existing surveillance and tracking capabilities, often resulting in outdated or poorly constrained orbital solutions. Under such conditions, predictive avoidance and static scheduling can become ineffective.

Event-based sensing holds significant potential as a preventative measure. The pixels of an event camera generate an 'event' when they detect a change of brightness in the scene, timestamped with microsecond precision. Importantly, when no change is detected, the pixels remain silent, resulting in much lower data rates than equivalent frame-based alternatives (e.g., CMOS detectors). The resulting high-temporal resolution, asynchronous streams of information provide a strong foundation for rapid characterisation of a satellite's motion, a key quality for low-latency warning of impending satellite streak contamination.

In this work, we carry out a simulation of typical night sky traffic to assess the performance of different warning system configurations comprising event-based fences, spatially offset from a target astronomical field. With a focus on the already mature constellations of Starlink and OneWeb, we examine the warning times achievable for a range of field separations and elevation angles to identify suitable observational strategies. We explore the advantages and disadvantages of event-based sensing when compared with frame-based alternatives, with a particular focus on affordability, scalability, and computing requirements.

With constellations set to proliferate further in low Earth orbit, it is essential that astronomers identify and adopt strategies to safeguard valuable observations of an increasingly congested sky.

Pricing the Night: Market-Based Instruments as a Complement to Soft Law in Regulating Orbital Brightness (Online)

Authors

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Abstract

International efforts to mitigate the photometric impact of satellite constellations on astronomy and the broader nocturnal environment have proceeded almost entirely through voluntary industry guidelines, technical recommendations from the IAU Centre for the Protection of the Dark and Quiet Sky, and aspirational COPUOS resolutions, none of which carry binding force or create enforceable obligations on operators. This paper examines whether economic instruments, including tradeable brightness-impact permits, mandatory photometric liability insurance, and orbital externality levies calibrated to a satellite's apparent magnitude profile, could serve as a structurally superior complement to the prevailing soft-law approach by internalising the costs that constellation operators currently externalise onto the astronomical community, nocturnal ecosystems, and dark-sky dependent economies. Drawing on analogies from international emissions trading under the Kyoto Protocol and CORSIA, as well as domestic spectrum pricing regimes, the paper evaluates the conditions under which a market mechanism for orbital brightness could be designed within existing institutional frameworks, identifies the doctrinal obstacles posed by the non-appropriation principle and the res communis character of the orbital environment, and proposes a model instrument capable of creating genuine financial incentives for operators to adopt brightness-reduction measures beyond those currently undertaken on a voluntary basis.

Overview on the state of Dark Skies

Authors

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Abstract

The IAU Centre for the Protection of the Dark and Quiet Sky recommends that satellites in operational orbits remain fainter than apparent magnitude 7 at a standardised range of 1000 km, with a secondary target of magnitude 6 for naked-eye visibility. This talk uses the public photometric database, MMT, to compare the observed brightness distributions of the major LEO constellations (Starlink, BlueBird, Qianfan, Guowang, OneWeb, and other trackable constellations with sufficient coverage) against these threshold. Means, standard deviations, and compliance are reported and discussed for each constellation, with differences between generations and altitudes noted where the data support it, alongside a summary of the current state of operator mitigation efforts.

IAU CPS: Collaboratively improving our understanding of satellite constellations

Authors

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Abstract

The IAU Centre for the Protection of the Dark and Quiet Sky (IAU CPS) was formed in response to ever-increasing numbers of satellites, particularly in low-Earth orbit constellations. It has four hubs, including SatHub, Policy, Community Engagement, and Industry & Technology hubs. Of these, SatHub focuses on observation campaigns, brightness data analysis, and software curation to improve our understanding of the impact of satellite constellations on observers worldwide. SatHub works with astronomers and sky observers across all wavelengths. SatHub is developing online services to simplify satellite constellation mitigation in astronomical observation planning, such as a satellite pass prediction tool, SatChecker, and the Satellite Constellation Observation REpository (SCORE), a database of measured satellite brightnesses.

I will briefly introduce the IAU CPS, its main areas of work, accomplishments and ongoing efforts, along with its activities to protect Dark and Quiet Skies at the International Telecommunication Union (ITU) and at the UN Committee on the Peaceful Uses of Outer Space (COPUOS). I will share what SatHub has learnt so far about the effectiveness of mitigations through its observing campaigns and tools like SCORE, and look to the future for what may be coming next with the launch of future satellite constellations.

CPS brings together astronomers, industry, policy makers, software developers, and more to collaboratively discuss satellite constellation issues - please join us at https://cps.iau.org/ !

From Voluntary Mitigation to Mandatory Authorisation: Licensing Large Constellations for Dark and Quiet Skies

Authors

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Abstract

As satellite constellations continue to expand, their impacts on dark and quiet skies are cumulative across operators, jurisdictions, and time, rather than episodic or system-specific. In optical astronomy, repeated trails, glints, and increased sky brightness degrade observing efficiency, data quality, and scientific yield. In radio astronomy, the problem extends beyond authorised transmissions to include aggregate interference and unintended electromagnetic emissions that are more difficult to characterise, monitor, and control. The resulting challenge concerns both the technical feasibility of mitigation and the capacity of existing legal and regulatory frameworks to address cumulative interference before it becomes a normalised condition of the observing environment.

This paper examines that challenge through the lens of authorisation and continuing supervision. It argues that the current framework remains structurally incomplete. International space law provides relevant principles, including due regard, responsibility, and the avoidance of harmful interference, while the International Telecommunication Union (ITU) offers important protection within the radio domain; yet neither level has been sufficiently operationalised to manage aggregate impacts from multiple systems or to address optical impacts coherently. Voluntary mitigation measures, while valuable, remain uneven, non-reviewable, and vulnerable to commercial and regulatory asymmetries.

The paper proposes that protection of dark and quiet skies should be integrated more directly into national space authorisation and licensing practice. It explores whether operators of large constellations should be required, before authorisation, to assess cumulative optical and radio impacts, disclose mitigation measures, and demonstrate compatibility with observing conditions at affected astronomical sites and across the wider sky. It further considers how continuing supervision might be strengthened through measurable thresholds, reporting obligations, post-launch monitoring, and adaptive licence conditions capable of responding to evolving aggregate effects. In parallel, it suggests that more consistent international coordination is needed to reduce fragmentation between national regimes and to support common expectations for compliance. The broader claim is that, if dark and quiet skies are to remain available for astronomy and for society, constellation impacts must become a regular subject of authorisation, supervision, and international coordination, rather than an externality only addressed after deployment.

Satellites: Not a Science Problem — Time for a Bottom-Up Approach to a Top-Down Challenge

Authors

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Abstract

The proliferation of low Earth orbit satellite constellations represents one of the most significant challenges to observational astronomy in its history. From a few hundred active satellites a decade ago to over 13,000 today, the numbers are increasing at an exponential rate. According to FCC and ITU licence applications, future satellite numbers now total over two million. It is clear that the pace of deployment is outstripping regulatory frameworks and mitigation efforts. While technical approaches such as improved scheduling algorithms, streak detection, and satellite surface coatings have shown positive results on trail contamination, unresolved impacts to optical, IR and radio astronomy remain and as numbers increase have the potential to get much more severe. The ideal remains that cooperative solutions can be found through industry engagement. However, recent industry opposition to the magnitude seven brightness target has raised serious questions about long-term commitment to astronomy. At a national level, the UK, home to world-class observational and space science institutions, is yet without a coherent national policy framework to address constellation impacts on astronomy. The 2024 Space Regulatory Review and Ofcom's Space Spectrum Strategy, while valuable, prioritise connectivity and commercial enterprise over protection of astronomical observation. We must therefore develop a bottom-up approach to ensure elected representatives understand what is at stake - that astronomy and the LEO environment need sufficient policy to ensure future sustainability and access to the dark and quiet sky. Meaningful legislative action remains the most powerful lever for lasting change, and securing it depends on broader engagement. Hundreds of thousands of active amateur astronomers and public stargazers across the UK cannot be regarded as peripheral to this effort. If adequately incentivised and resourced, this community are uniquely capable of reaching elected representatives and communities in ways that professional institutions cannot.