Chilean Contributions to Sky Protection: Extensions from Ground to Space

Eduardo Unda-Sanzana

Astronomy Center (CITEVA) of the Universidad de Antofagasta, Chile

Vienna, 2025-12-11 - UN/SKAO Workshop

Where we were

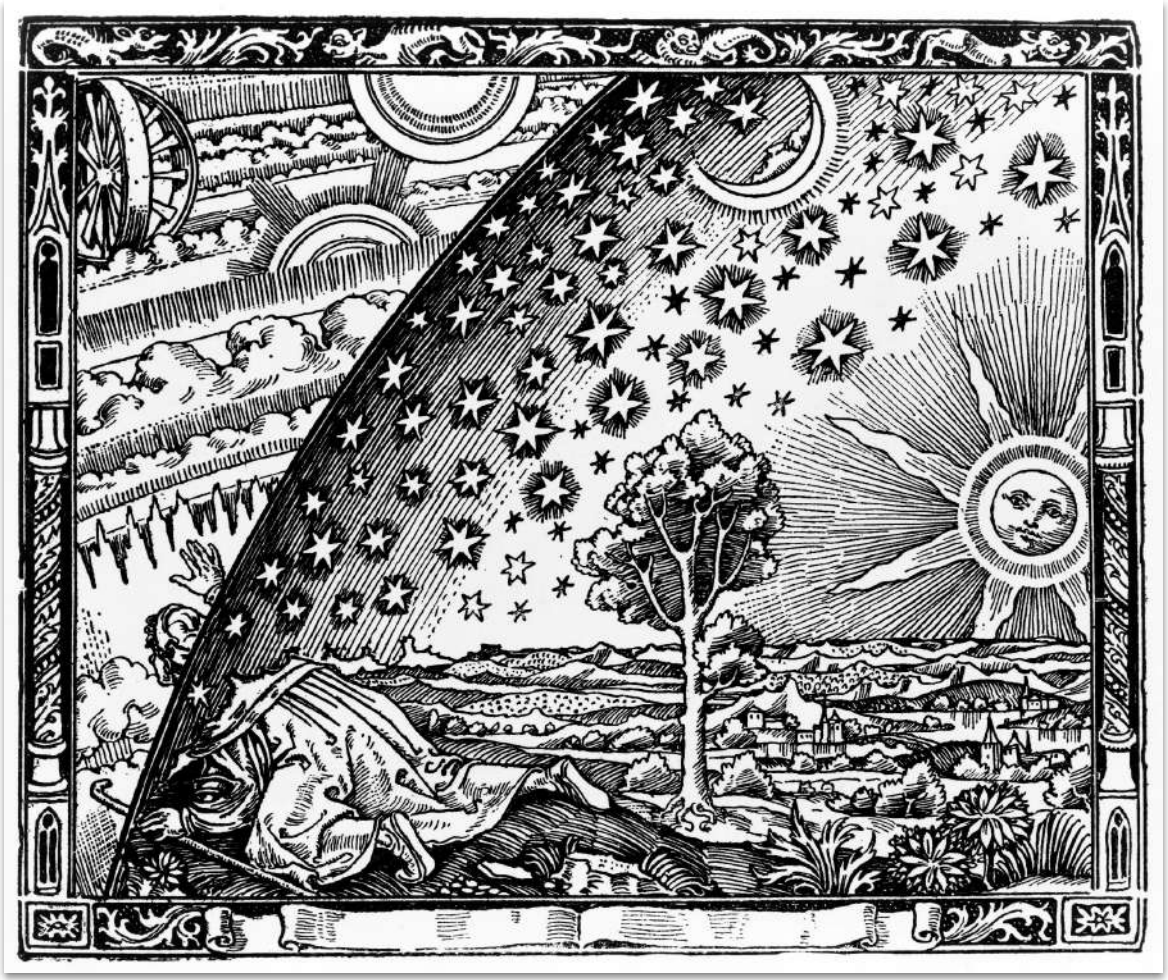


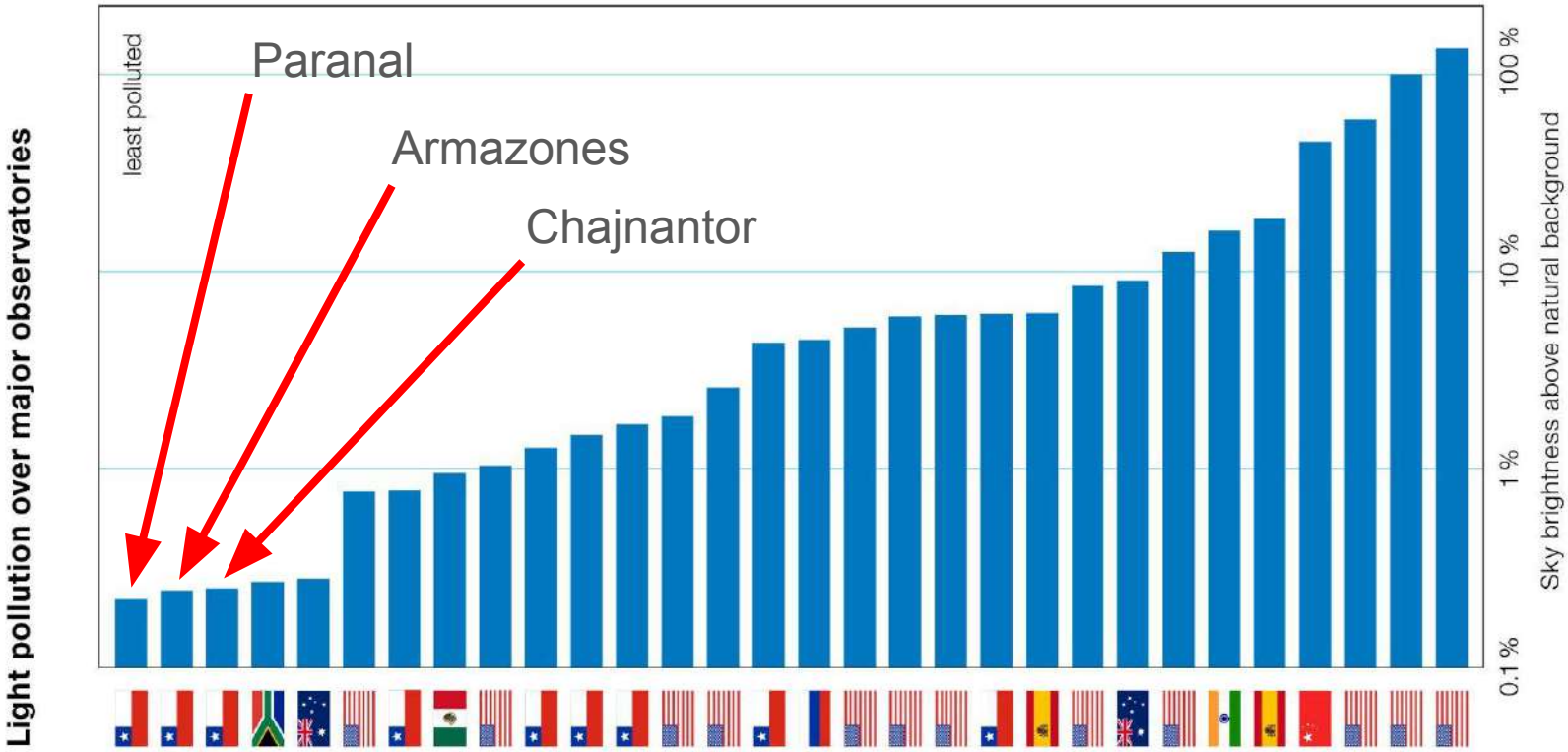
Image: Engraving in Flammarion’s L'atmosphère: météorologie populaire (1888)

Where we are

Image: Bruno Araya Godoy (Universidad de Antofagasta)

Why is Chile interested in the impact of satellites on astronomy?

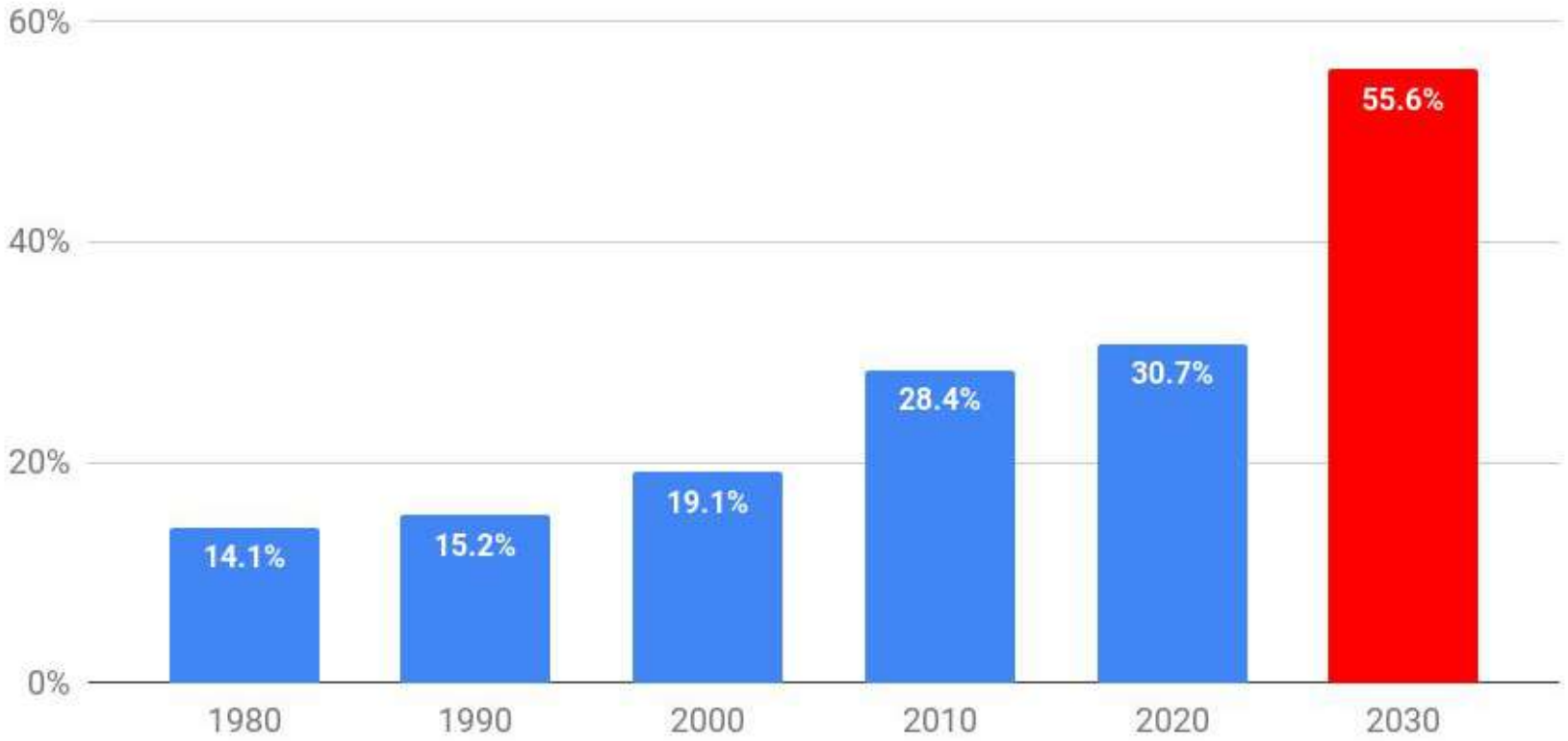
Chile is a global reserve of dark sky



Source: https://www.eso.org/public/chile/images/eso2501b/ based on Falchi et al. 2023

Optical and IR collecting area in Chile as fraction of the world's total

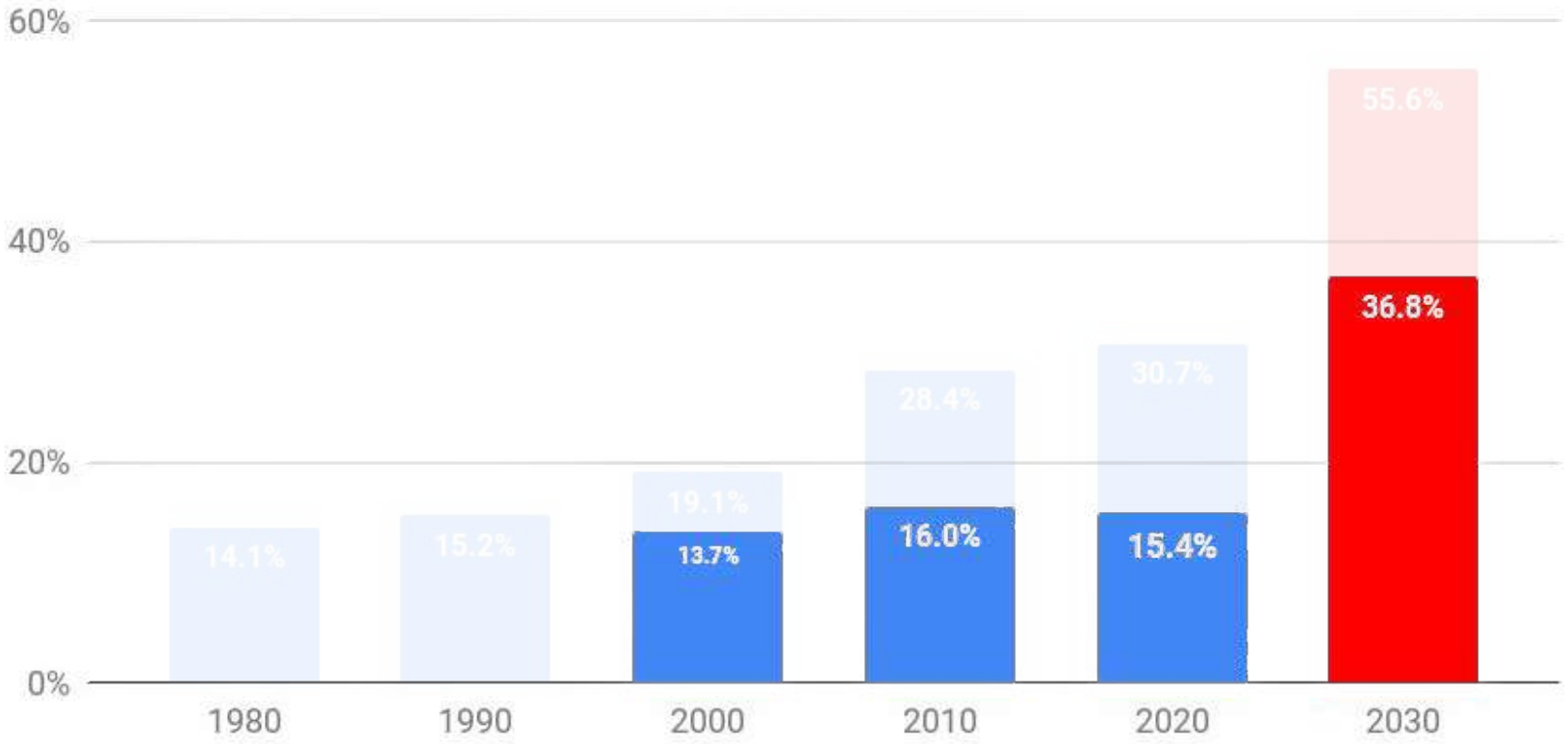
Computed by Eduardo Unda-Sanzana (CITEVA, U. of Antofagasta)



https://sochias.cl/articulos-de-interes/

Optical and IR collecting area in the Antofagasta Region as fraction of the world's total

Computed by Eduardo Unda-Sanzana (CITEVA, U. of Antofagasta)



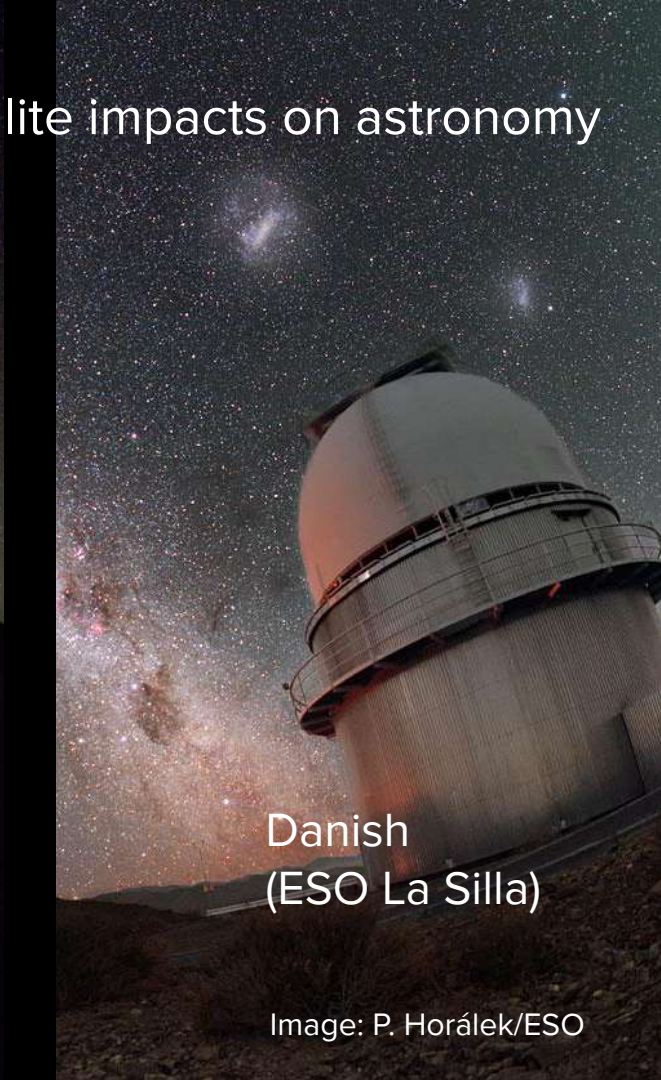
Very early, telescopes in Chile began studying satellite impacts on astronomy

Ckoirama
(Universidad de Antofagasta)

Image: Rodrigo Maluenda

VISTA
(ESO Paranal)

Image: ESO

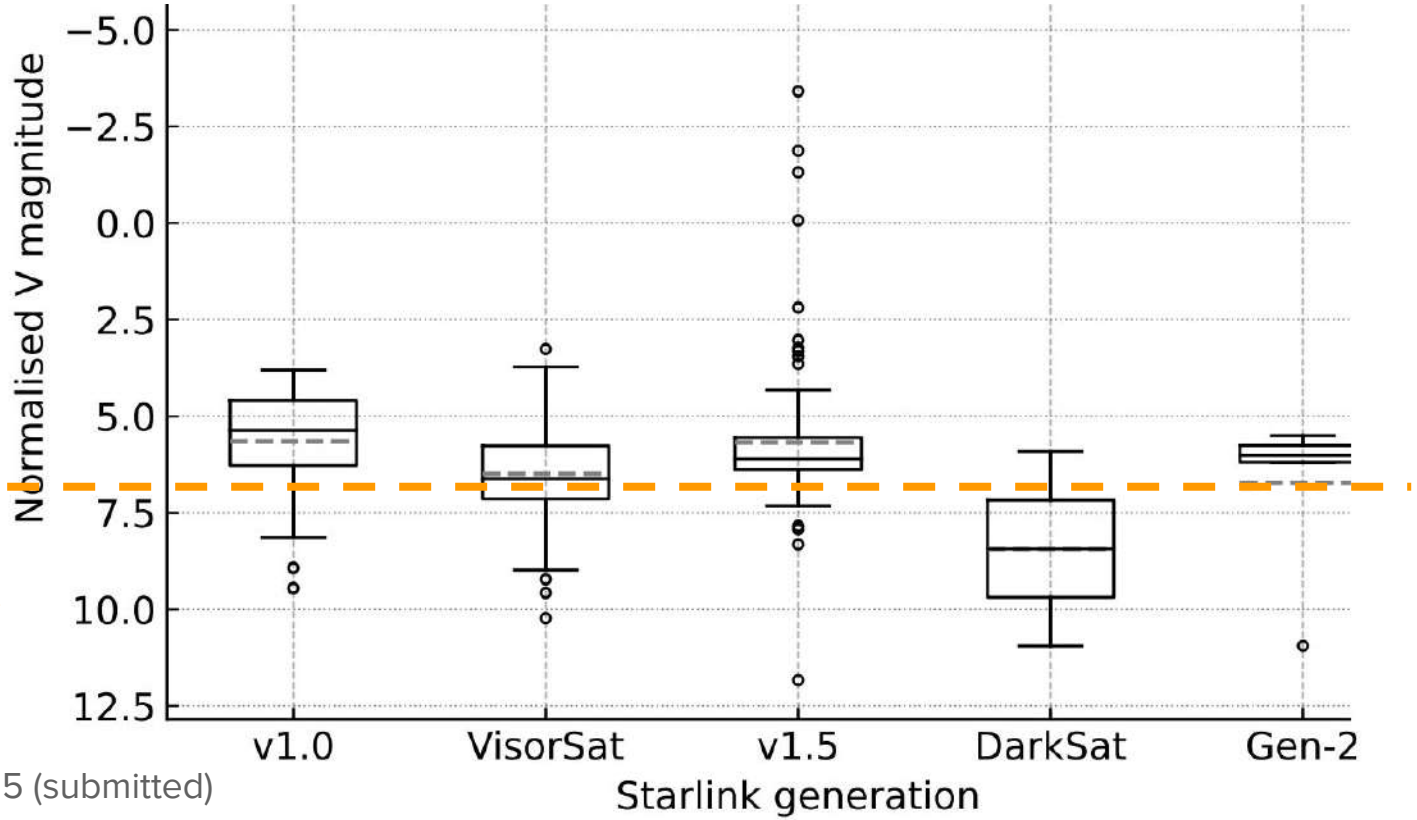


Danish
(ESO La Silla)

Image: P. Horálek/ESO

What have we learned?

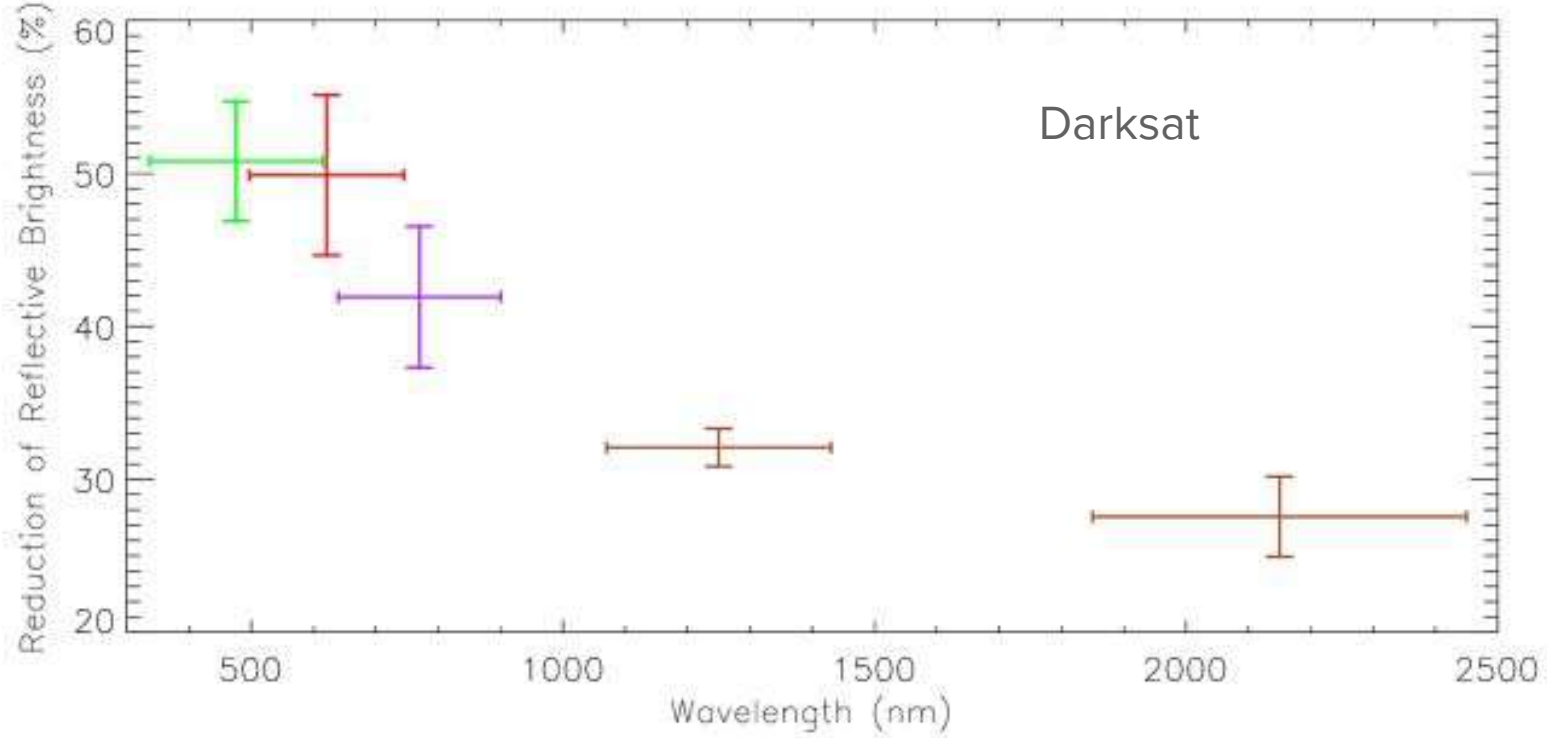
Effectiveness of mitigations varies greatly between satellite models



Acceptable magnitude limit at 550 km height

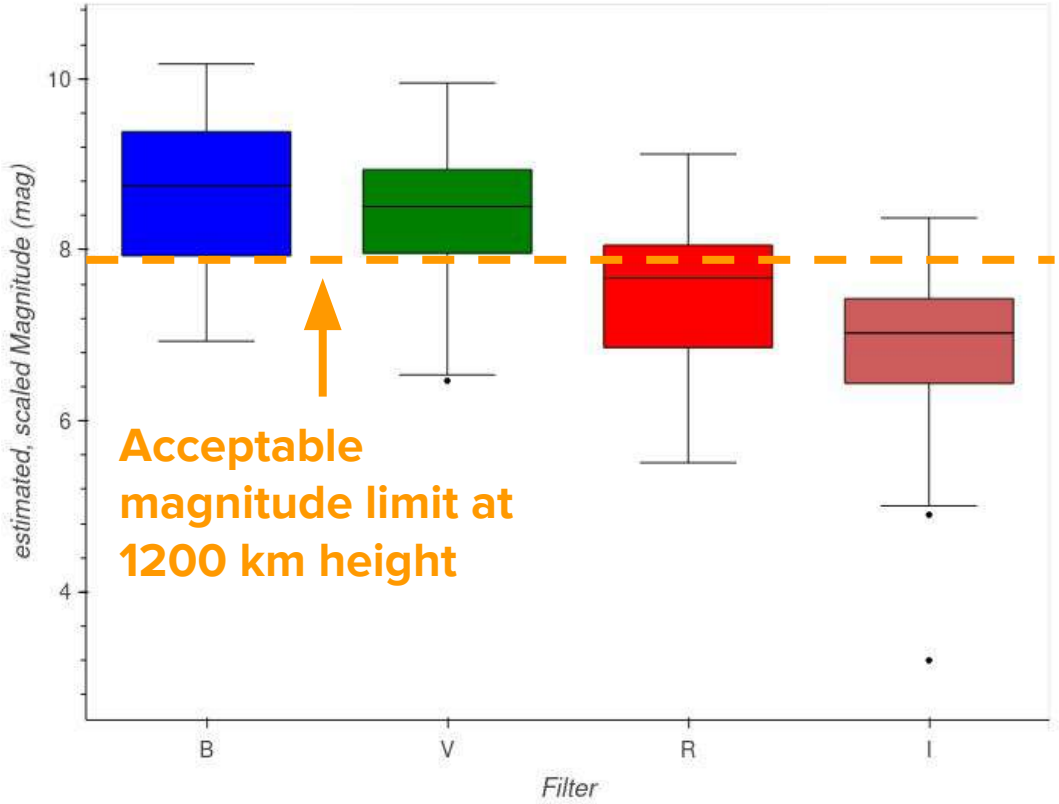
Longa-Peña et al. 2025 (submitted)

What have we learned?
Effectiveness of mitigations varies greatly with wavelength



Tregloan-Reed et al. 2021 https://doi.org/10.1051/0004-6361/202039364

What have we learned?
Effectiveness of mitigations varies greatly with wavelength



Eutelsat OneWeb

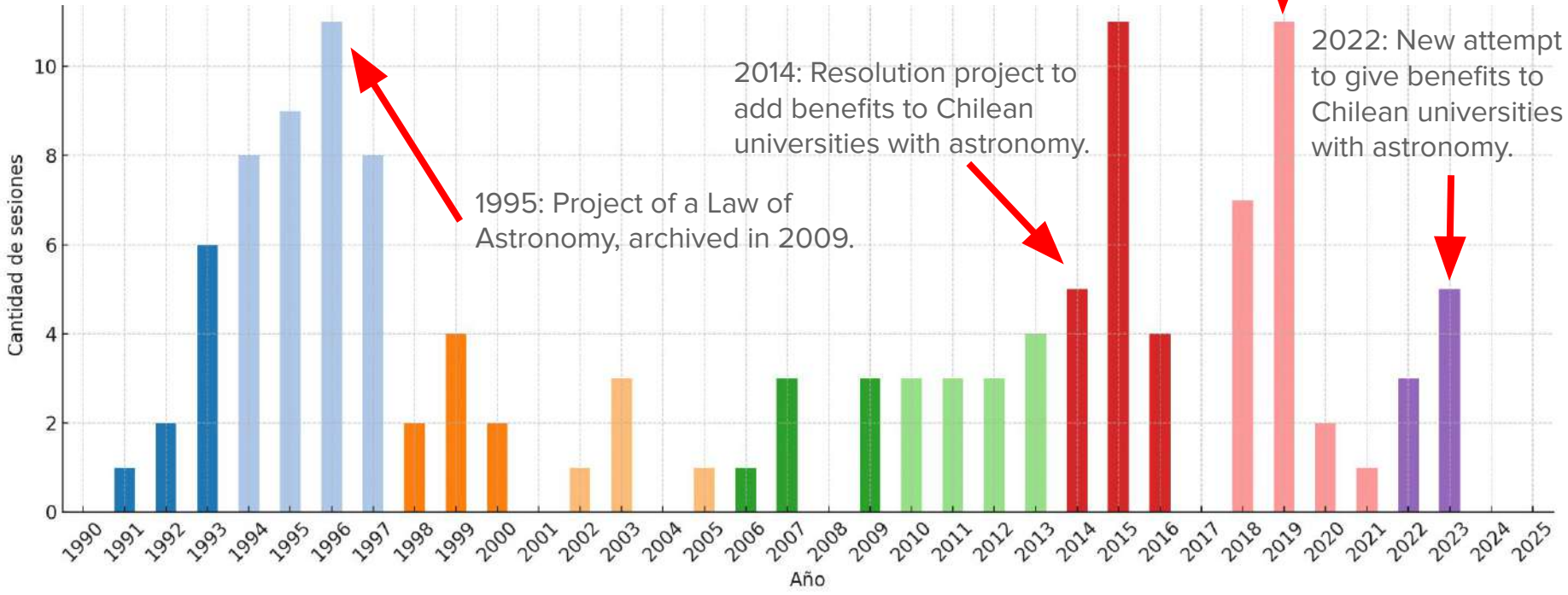
500+ observations from the Danish 1.54m telescope, ESO La Silla, Chile.

B = 8.68 +/- 0.95
V = 8.36 +/- 0.86
R = 7.49 +/- 0.80
I = 6.79 +/- 0.91

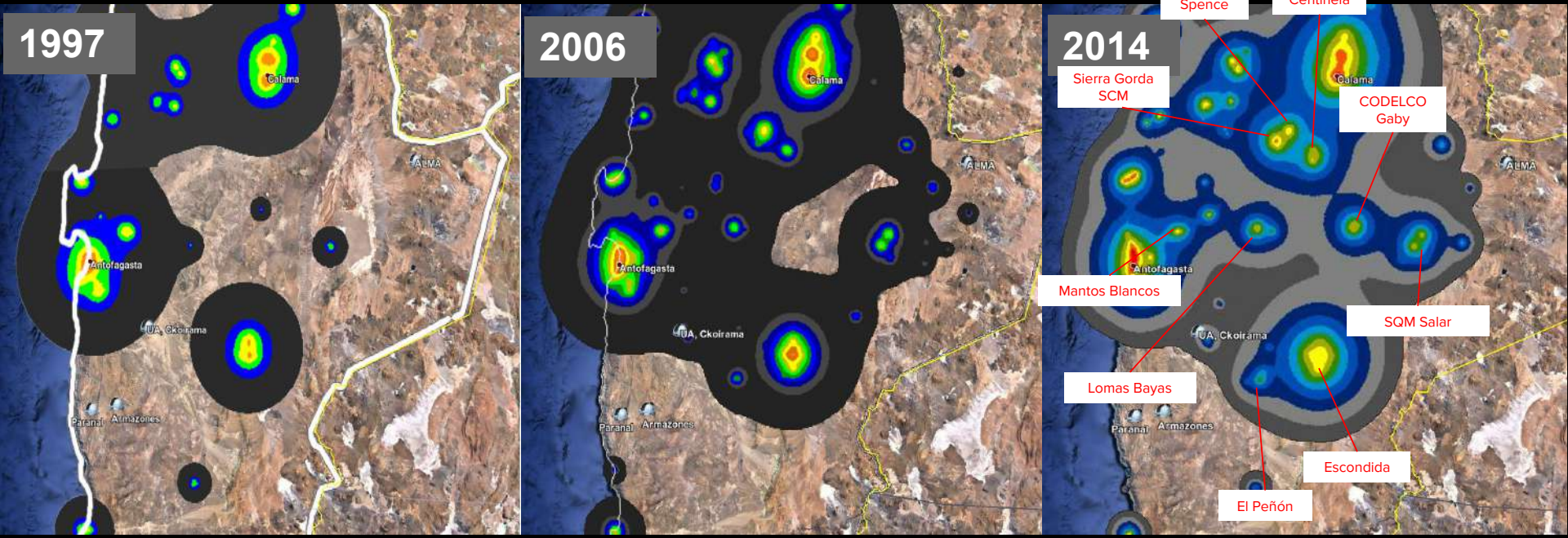
Adam et al. 2025 (in preparation), supported by Chile-China CCJRF2104 project.

Astronomy discussions in the Chilean Congress

(although only concerning ground-based issues)



This is why in 2019 we were interested in developing new protections against ground-based sources of light pollution



Images: Comparison by Eduardo Unda-Sanzana, based on data and maps by Cinzano et al. 2001, Lorenz 2006 and Falchi et al. 2016.

2023: Following a proposal submitted by an advisory committee in 2021, the Ministry of Science decreed the “astronomical areas” in Chile.

DIARIO OFICIAL
DE LA REPUBLICA DE CHILE
Ministerio del Interior y Seguridad Pública

I SECCIÓN

LEYES, REGLAMENTOS, DECRETOS Y RESOLUCIONES DE ORDEN GENERAL

Núm. 43.586 | Martes 27 de Junio de 2023 | Página 1 de 3

Normas Generales

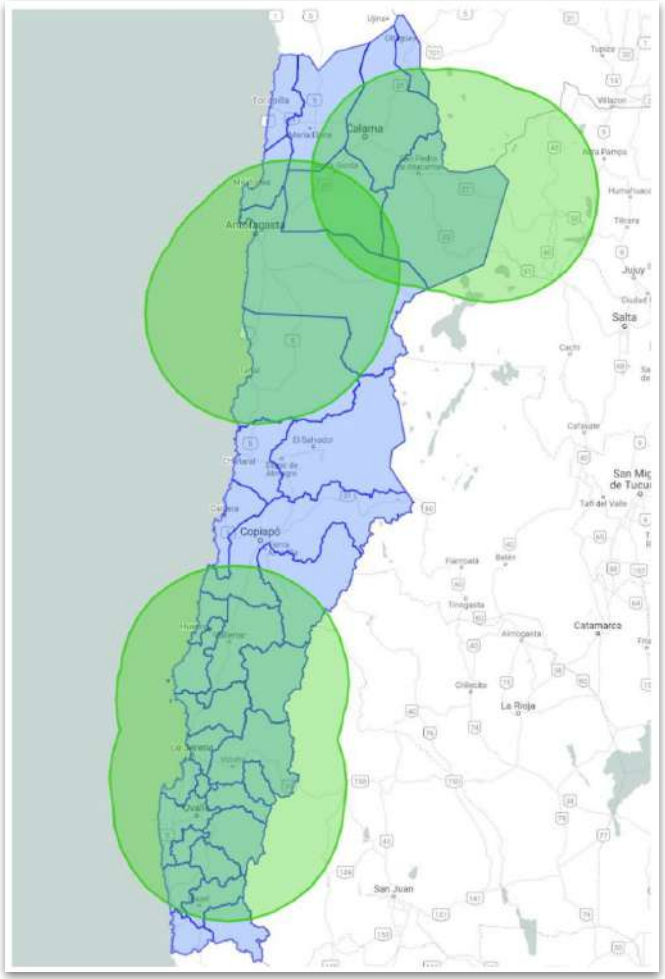
CVE 2334253

MINISTERIO DE CIENCIA, TECNOLOGÍA, CONOCIMIENTO E INNOVACIÓN

DECLARA ÁREAS CON VALOR CIENTÍFICO Y DE INVESTIGACIÓN PARA LA OBSERVACIÓN ASTRONÓMICA

Núm. 2.- Santiago, 8 de febrero de 2023.

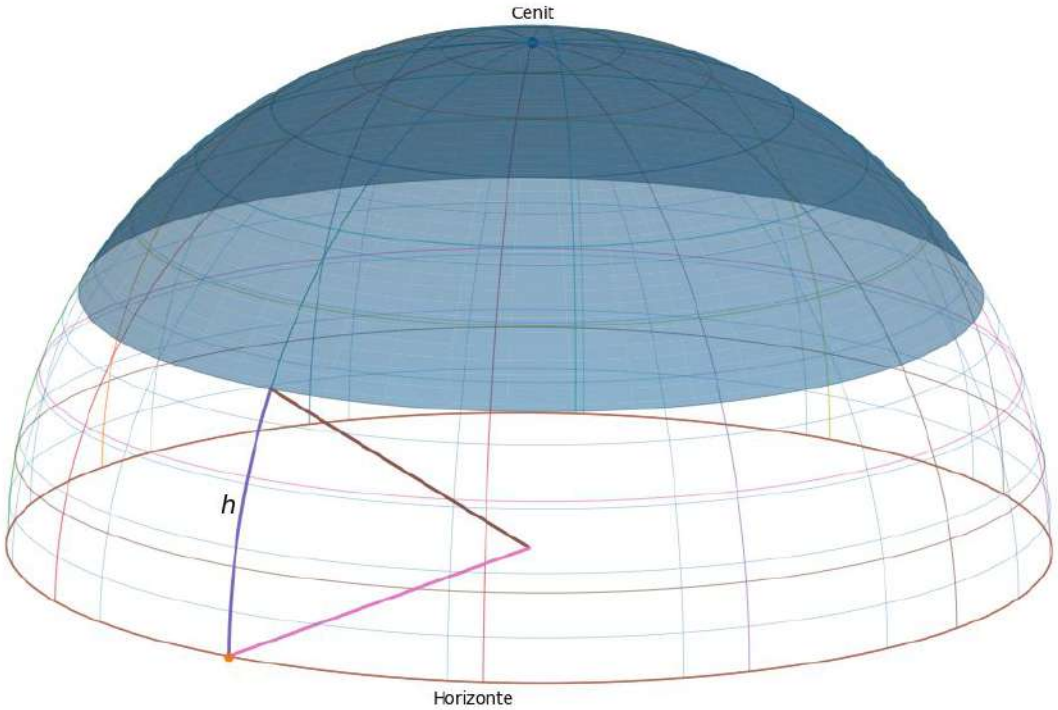
Any new industrial project in these areas is subject to an Environmental Impact Assessment (EIA) that includes the evaluation of artificial light at night. The first project to test this new regulation is the mega-industrial INNA project (AES Andes), aiming to operate near Paranal.



2025: The Ministry of Science called an advisory committee to propose a revision to the decree of astronomical areas, in the spirit of strengthening their protection.

The Committee finished the work on October 31, delivering their recommendations to the Ministry of Science. These recommendations are public now.

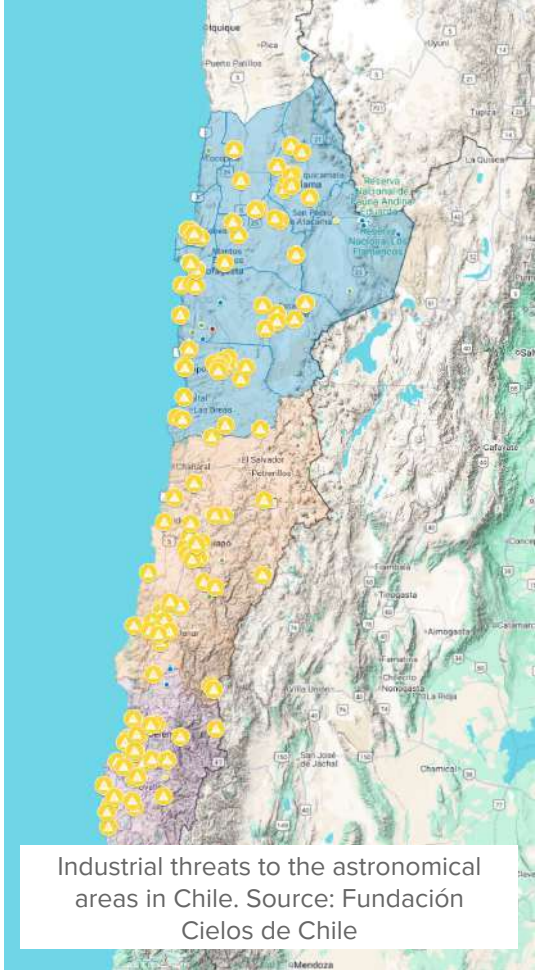
How much of the sky should we protect?



h=0° ➜ 100% of the sky (relative to the horizon)

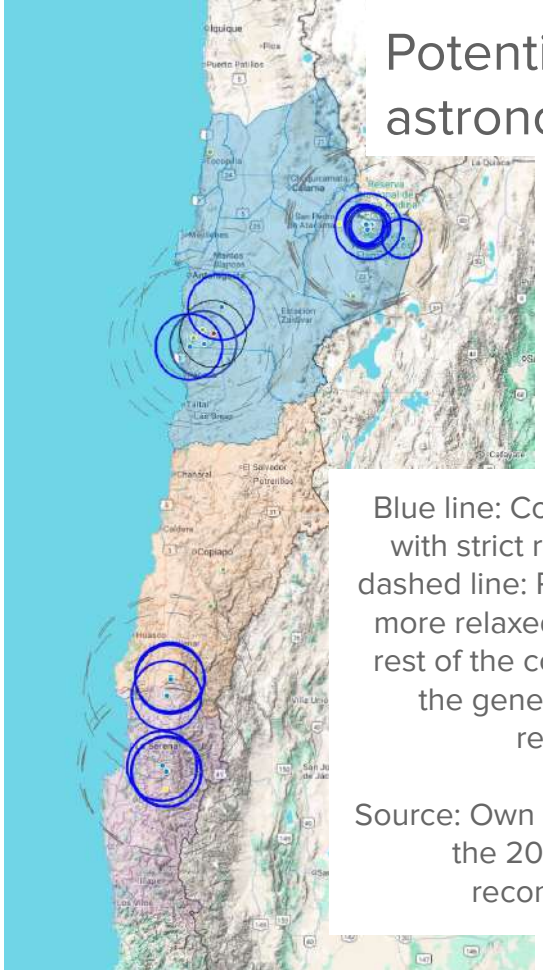
h=30° ➜ 50% of the sky (relative to the horizon)

h=45° ➜ 50% of the sky (relative to the fraction of the sky more commonly used for research)



Industrial threats to the astronomical areas in Chile. Source: Fundación Cielos de Chile

Potential new astronomical areas?

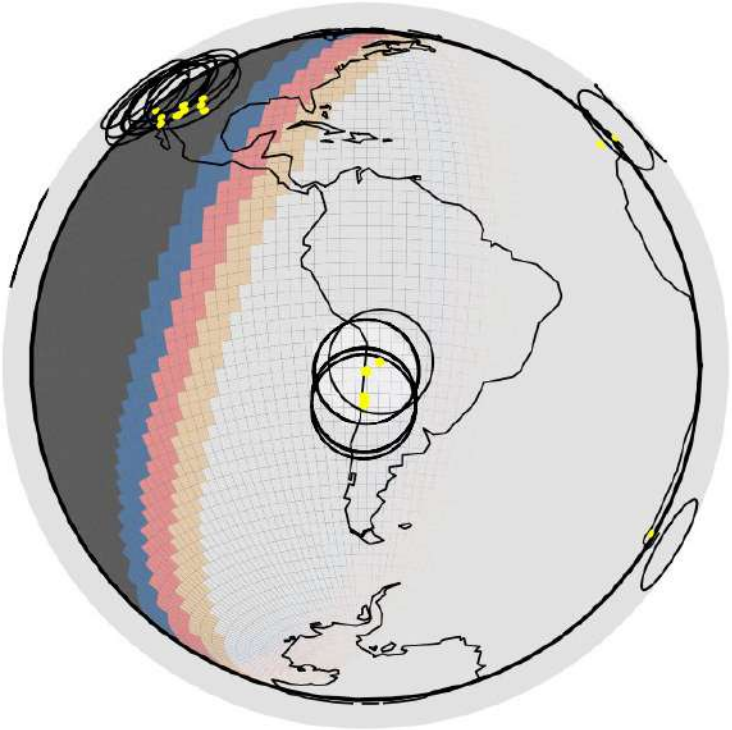


Blue line: Core protection areas, with strict requirements. Gray, dashed line: Protection areas, with more relaxed requirements. The rest of the country should follow the general light-pollution regulations.

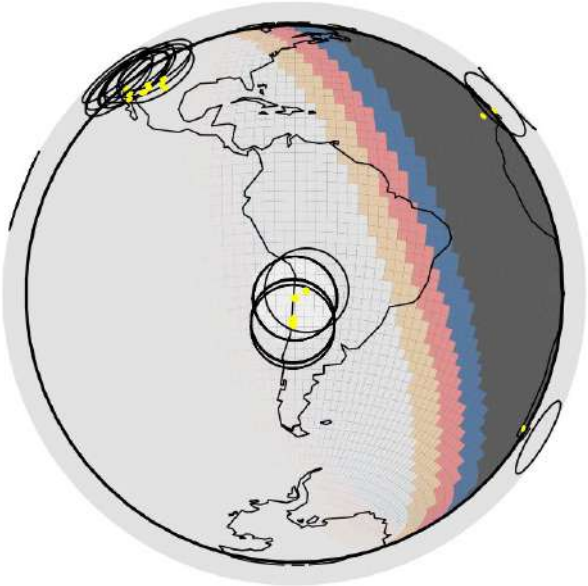
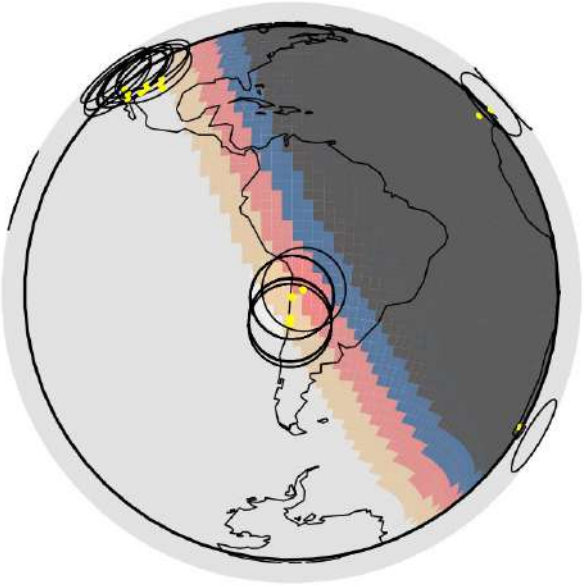
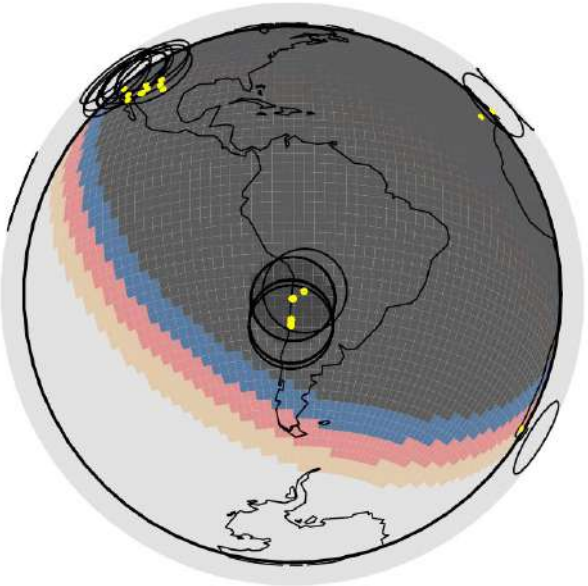
Source: Own elaboration based on the 2025 Committee recommendations

Can we extend this idea of core protection areas to a global scale?

An idea: Global Astronomical Areas



- Aim 1: To prioritise the protection of the sky above 30°.
- Aim 2: To prioritise the protection of sites that serve as hubs of astronomical data production, especially those where wide-field sky surveys are conducted.
- A corresponding geometry is thus defined, centred on a catalogue of priority sites. Falchi et al. (2023) may be used as an initial reference for this.

Attitude changes are triggered or prioritised when modeled sunlight reflections from the satellite are predicted to exceed a critical magnitude threshold while occurring at elevations above 30° as viewed from designated priority sites.

Caveats

- **BRDF uncertainty**: May be proprietary or unknown; empirical reconstruction may be needed. Effectiveness depends on directional reflectivity.
- **Operational constraints**: Even small attitude offsets can affect communications, power, or thermal management; feasibility must be evaluated per constellation.
- **Detector-relevant impact**: Brightness reduction does not always reduce streak surface brightness; index must incorporate detector-level effects.
- **Governance**: Agreement on priority “astronomical areas” requires a transparent and globally acceptable framework.
- **Benefit vs cost**: Operators will require clear evidence that each adjustment yields significant scientific improvement.

Conclusions

- Mitigation of sunlight reflections requires both passive (design) and potentially active (attitude) approaches.
- Priority astronomical sites are well characterized, enabling targeted protection zones.
- Active adjustments could be triggered only in short windows over these sites as a complementary strategy.
- Effectiveness depends on BRDF directionality and operational feasibility and must be quantified using detector-relevant metrics (e.g., streak surface brightness).
- Implementation requires voluntary coordination with operators and clear demonstration of scientific benefit.

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Eduardo Unda-Sanzana
Centro de Astronomía
Universidad de Antofagasta
eduardo.unda@uantof.cl

Image: Rodrigo Maluenda, 2019. ISS seen from the Hand of the Desert in Antofagasta.