Dark Sky Protection for Optical Observatories – D&QS1

Richard Green, Ph.D.
University of Arizona, Steward Observatory
USA

Member of the D&QS1 SOC and Co-Chair Optical Astronomy Working Group

Optical Astronomy WG Members

Juan Pablo Armas, Martin Aubé, John Barentine, Zouhair Benkhaldoun, Chris Benn, Peter Blattner, Costis Bouroussis, Javier Diaz Castro, Maurice Donners, Bryan Douglas, Dionýz Gašparovský, ***Richard Green (Chair)****, Jeffrey Hall, John Hearnshaw, Zoltán Kolláth, Casiana Muñoz Tuñon (Co-Chair), Kathryn Nield, Steve Lau, Tomas Novak, Sergio Ortolani, Jose Miguel Rodriguez Espinosa, Pedro Sanhueza, Antonia M. Varela Pérez & Constance Walker.*

Ground-based Observatories Are Critical to the Mission of COPUOS

Ground-based optical/IR telescopes can be built at a substantially larger scale and lower cost per unit collecting area than those launched into orbit.

There are 40 telescopes in the world with mirrors of effective diameter 3 m - 11 m, sited in the U.S., Chile, Spain, South Africa, Russia, China, Australia, and India, constituting a world-wide investment. (None yet in orbit.)

They support the mission of COPUOS:

- They directly enable “continued research and the dissemination of information on outer space matters”.
- They are often essential to interpret observations from space-based telescopes.
- They provide the critical data for planetary defence and key aspects of space situational awareness.

Purpose of COPUOS Endorsement

Major observatories are now typically funded and operated by international consortia, but they are situated in individual countries whose own laws apply to light pollution control.

The Working Group draft report provides a suite of recommended regulations on regional scale to protect observatory dark skies.

COPUOS endorsement will provide a strong impetus for national and local governments to provide such protection.

Light Domes from Distant Cities Can Impact Major Observatories

Light Pollution at Mt.Graham from LBT dome March 10 2008

Light domes from Tucson (120 km - 1 million population) and Phoenix (220 km - 4 million population), Arizona from the summit of Mt. Graham, site of the world's largest optical telescope. (M. Pedani)

Population growth and resource development has created measurable artificial light contribution at major professional sites such as those in southern Arizona, California, New Mexico, Texas, north-central Chile, the Canary Islands and southern Spain.

Goal of Recommended Framework

The newest professional observatories have been located at sites that are significantly below the IAU limit of artificial light contamination of 10% at 45 degrees elevation.

Therefore, the goal is defined to slow and reverse the rate of increase of artificial skyglow appropriate to each site.

The goal of the model regulatory framework proposed for COPUOS consideration is to reduce the current rate of increasing artificial skyglow at major professional observatories by a factor of two or more over the next decade and to achieve a decreasing rate of additional skyglow in the following decade for these sites.

Basis of Recommended Framework

Take the approach of quality lighting design to match the illumination level to need, to limit unnecessary spectral content, to use precise optics to minimise spill light, and to employ active control to reduce light levels when usage is low.

Define a near zone in proximity to professional observing sites, within which both lighting levels and color rendition are sharply limited, and beyond satisfying basic safety requirements, must be justified to exceed the tightly prescribed limits. Radius ~30 km.

For those urban areas for which light domes impact an observatory's skyglow at more than 30º above its horizon, invoke the tightest limits on the range of recommended best practice and standards, along with active controls to reduce lighting levels when possible. Radius up to 300 km or more, depending on impact.

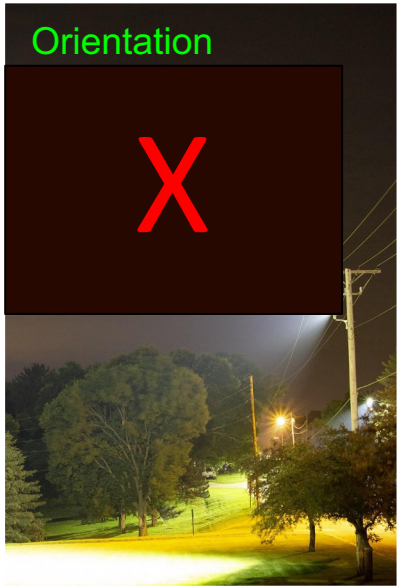
What are near the optical observatories zones?

Table 2: Environmental zones

Zone	Surrounding	Lighting environment	Examples
E0	Protected	Dark (SQM 20.5+)	Astronomical Observable dark skies, UNESCO starlight reserves, IDA dark sky places
E1	Natural	Dark (SQM 20 to 20.5)	Relatively uninhabited rural areas, National Parks, Areas of Outstanding Natural Beauty, IDA buffer zones etc.
E2	Rural	Low district brightness (SQM ~15 to 20)	Sparsely inhabited rural areas, village or relatively dark outer suburban locations
E3	Suburban	Medium district brightness	Well inhabited rural and urban settlements, small town centres of suburban locations
E4	Urban	High district brightness	Town/city centres with high levels of night-time activity

Region with a physical radius of approximately 30 km centered at the observatory

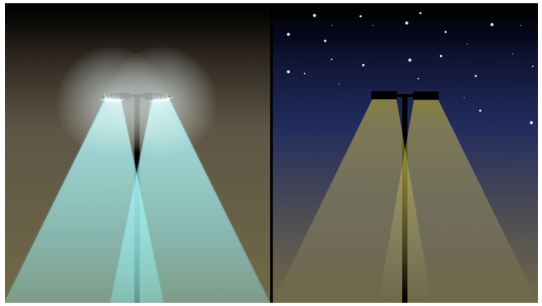
1. Exclusive use of luminaires with no light above horizontal



Removing the upward emissions can reduce the sky radiance by at least a factor of 2. Typically, when the Upward Light Ratio (ULR) is reduced, the luminous flux can also be reduced if one wants to keep the same illuminance on the ground level. The result is that the reduction factor is generally larger than 2.

All luminaires must provide no direct illumination above horizontal.

2. Limiting lamps' spectral content in the blue region

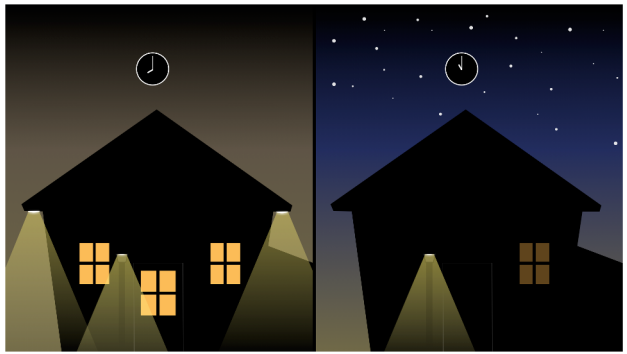


The blue light content should be null. The lighting devices should be quasi monochromatic sources with maximum radiant flux (in Watts per nm) lying within the 585-605 nm spectral range and having Full Width Half Maximum (FWHM) smaller than 18 nm. If modest color rendition is approved as a necessity, spectra with broader FWHM of 110 nm can be used.

3. Limiting the maintained average illuminance

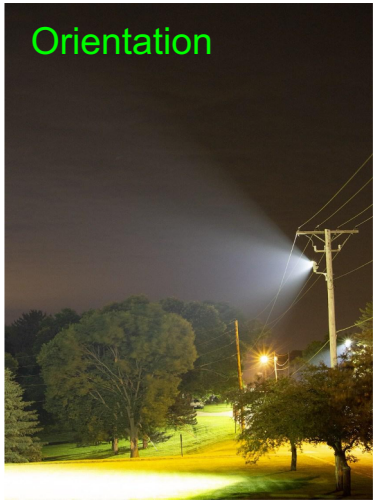
The maintained average illuminance should not be higher than 20% above the minimum maintained average illuminance suggested in technical norms/recommendations published by CIE or IESNA (i.e. 1.2 times the minimum maintained illuminance prescribed by the norm/recommendation) and this upward deviation must be kept at the lowest possible level by proper lighting design and employing suitable lighting controls.

4. Implementing curfews and light level controls



A maximum possible reduction of the light levels, with a target of at least 66%, should be applied after curfew (or before that time whenever possible). Any lighting installation that is not needed for public safety reasons should be switched off at curfew. For isolated areas or hours of low traffic, sensors should be used to increase the light level as needed when any activity is detected. Without detection, the light level should be set down to 10% or less of the maintained average luminance or illuminance.

5. Defining minimum utilance ratio



Utilance (*U*) of an installation is the ratio of the luminous flux received by a defined reference surface to the sum of the individual output fluxes of the luminaires of the installation. Utilance should be higher than 75% (U > 0.75), but any higher value is better.

6. Designing lighting to minimise light propagating toward observatories

Luminaires should be designed and mounted to minimise direct and reflected light propagating in the direction of observatories. Approaches include optical beam forming, directional shielding on the luminaire, and taking advantage of natural shadowing by buildings and topological features when possible.

7. Lumen Caps

Each major professional observatory and controlling governmental body undertake a modeling exercise to determine the total amount of fully shielded outdoor light allowable to slow the rate of growth of artificial sky glow to within the stated goal and to keep the total contribution substantially below the 10% dark site limit. Local pressure for development, topography, marine layer prevalence and other local factors motivate the need for individual studies rather than a global prescription.

Outdoor lighting recommendations and protection of observatories

International Commission on Illumination (CIE)

- At the international level, recommendations for various lighting applications are developed and provided by the CIE
- Independent, non-profit organization with strong technical, scientific and cultural foundation
- Recognized by CIPM, ISO and IEC as a standardization body across its scope , publishing international standards for basic research on light and lighting
- Many national and regional regulations ar
  CIE publications

International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

Outdoor lighting recommendations and protection of observatories

Limiting the obtrusive light from outdoor lighting installations

Recommended maximum values of luminous parameters to control obtrusive light:

- Limitation of illumination on surrounding properties (light intrusion) – vertical illuminance on properties
- Limitation of bright luminaires in the field of view – luminous intensity of luminaires in designated directions
- Limitation of the effects on transport systems – threshold increment and veiling luminance from non-road lighting installations
- Limitation of sky glow – ULR of luminaires and UFR of lighting installations
- Limitation of the effects of over-lit building façades and signs – surface luminance

Outdoor lighting recommendations and protection of observatories

Adaptive lighting as powerful tool to reduce light pollution

Role of adaptive lighting:

- to balance in a holistic way the whole set of luminous parameters to dynamic changes of the current needs of users depending on current conditions and other influencing factors
- to provide proper lighting for different user groups and user patterns sharing the same outdoor space and having different (sometimes contradictory) requirements
- to minimize adverse effects of lighting to all affected subjects (astronomers, inhabited humans, fauna and flora)

Adaptive road lighting incorporating system of sensing devices and smart controllers is capable to considerably reduce unnecessary illumination!

Recommendations to be applicable to urban lighting

1. Follow (and minimize upward deviation to no more than 20% from) the luminance and illuminance levels for road lighting of the appropriate lighting class according to CIE 115*.
2. Whenever possible, dynamically reduce roadway lighting level under low traffic conditions to the appropriate lower lighting class, and down to M6 or even below if the lighting is not immediately needed by any user.
3. Follow (and minimize upward deviation to no more than 20% from) CIE guidance for illumination levels and colour rendition of pedestrian areas by class.
4. Observe (and minimize upward deviation to no more than 20% from) CIE International Standard S 015/E:2005 for illumination of outdoor workplaces, carefully limiting the illuminated area to avoid spill light.

Recommendations to be applicable to urban lighting

5. Adhere to the zone-appropriate limits by CIE environmental zone for lighting levels, Upward Flux Ratio (UFR) and Upward Light Ratio (ULR), with application of curfew-time reductions in lighting levels.
6. For Zones E2 and E3 impacting observatories, do not exceed the CIE maximum standard permitted luminance levels for building façades and do not exceed ANSI/IES standards for maximum luminances for illuminated signs.
7. Employ adaptive lighting technology in new installations and major renovations to minimise illumination when there is minimal demand.
8. Develop and follow lighting master plans that govern the planning, installation and maintenance of outdoor lighting, especially for urban and suburban areas.

Determination of Artificial Skyglow

A truly dark astronomical site has only a few percent of the natural sky glow at zenith contributed by scattering of artificial sources.

Finding the contribution of artificial sky glow depends on both measurement and modeling.

Determination from “top down” (satellite) measurements depends on a spectral source function for aggregate outdoor lighting and radiative transfer model.

Determination from “bottom up” (sky monitor) measurements depends on accurate removal of celestial sources and natural sky glow, which is impacted by solar activity.

Adopt System of Calibration to SI Units

Astronomers gauge a pristine dark site in their measured units of mag / sq arcsec; in V band, that is around 22.0.

In engineering units, that is 174 micro-candela / m^2.

For matters requiring a decision process and the influence of stray optical radiation on astronomical observations, it is worthwhile to establish a common standard that is compatible with standards definitions and traceable to SI units.

The ‘continuous’ component of the natural sky (zodiacal light, scattered starlight and airglow pseudo-continuum) is nearly constant at all visible wavelengths and has a spectral radiance of ~2 nW m^{-2} sr^{-1} nm^{-1}, or 2 *dsu* (dark sky units).

Recommended Skyglow Monitoring and Data Aggregation

Each professional observatory with programmes requiring limiting dark-sky data for which regulation of artificial skyglow is critical should obtain a current baseline and well-sampled time series of night sky brightness measurements.

That information is critical for objective assessment of the efficacy of regulation and for demonstrating to policy makers and implementers that the astronomers value and need their efforts.

International astronomical organisations are advised to form and support a data repository with consistent formatting to aggregate and make publicly available the sky monitoring data collected.

Special Circumstances for Remote Observatory Sites

Mines, wind farms, military installations, border control

- All with lighting guidance and regulation typically local control

Recommendation: Special use cases in remote areas to employ fixtures consistent with the near-zone regulations to the maximum degree possible, consistent with safety and national and local regulations. Direct uplight and colour rendition should be employed if and only if absolutely necessary as required by safety or regulatory requirements.

Recommendation: Civilian regulators and military flight planners should exclude the observatory near zones from approved flight paths, and keep those paths as far from observatories as practicable.

Other Incentives for Protection of Observatory Dark Skies

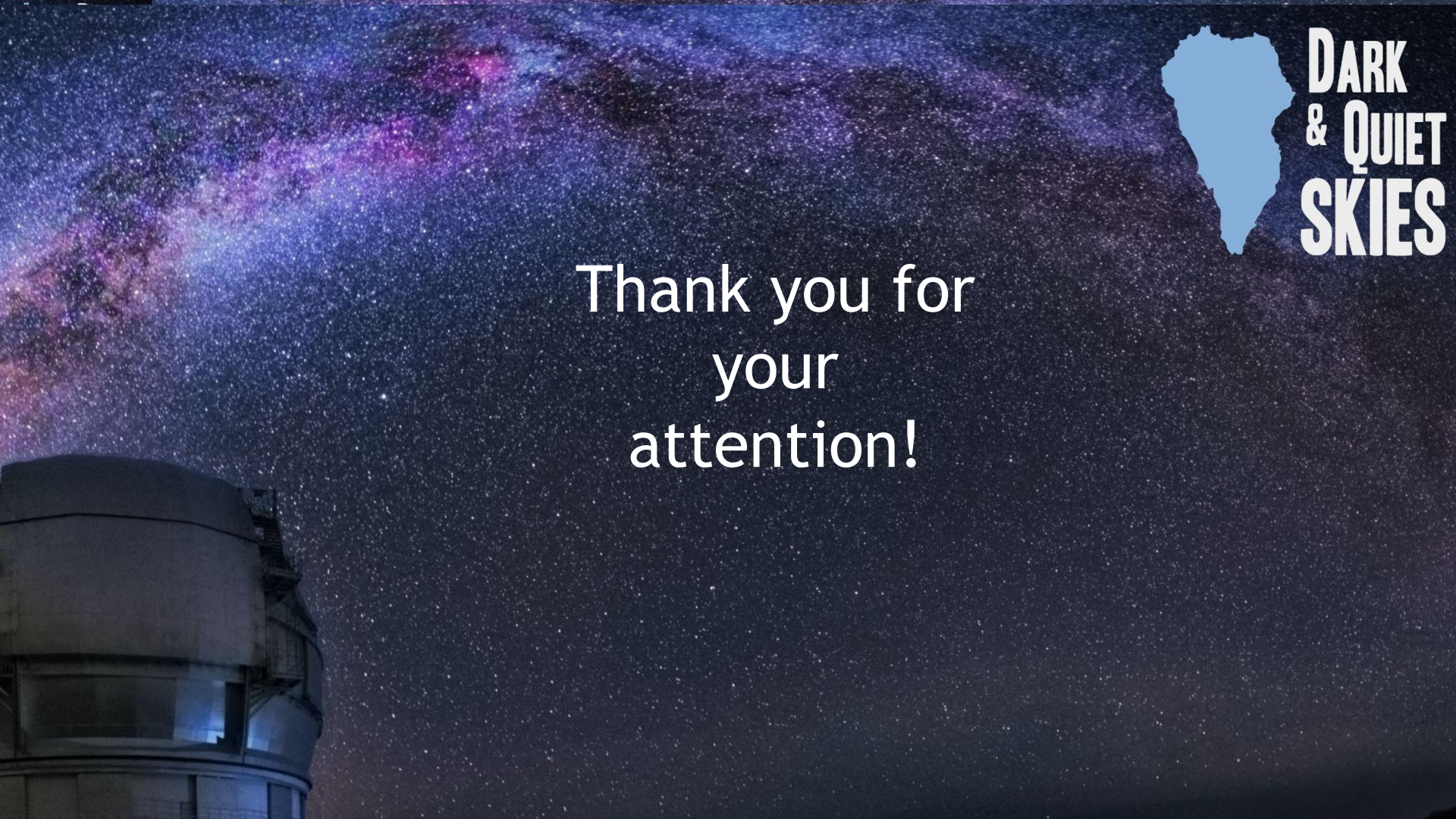
In promoting the adoption of regulations protecting the dark skies of observatories, local governments can be incentivised by corollary benefits.

Sustainability

- Protection of dark skies is an environmental goal per se.
- Consider total cost of lighting to include impact as well as production.
- Bank reduced costs of Solid State Lighting for other public good rather than providing more public lighting at the same cost.

Observatories are sometimes co-located with designated natural areas, creating synergies for mutual dark sky protection.

The WG hypothesises that the same quality lighting design that is best for minimizing light pollution is also most conducive to public safety, by carefully targeting light to outdoor task performance at night.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& QUIET
SKIES
Thank you for
your
attention!