Dark and Quiet Skies for Science and Society

UNITED NATIONS
Office for Outer Space Affairs

International Astronomical Union

With the support of NOIRLab

Dark and Quiet Skies for Science and Society

Opening Remarks
SOC Member
Nathalie Ricard
UNOOSA

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Dark and Quiet Skies for Science and Society: Draft Reports

Five Draft Reports are available and open for comments until 16 October

- Download them from http://bit.ly/DQS_reports
- Please comment recommendations at http://bit.ly/DQS_comment

If you registered for today's Workshop then you have received the links on Thursday in an email from UNOOSA-Events@un.org and on Friday in an email from DQSkies@iac.es

Not received even though you had registered? Please email UNOOSA-Events@un.org

Dark and Quiet Skies for Science and Society

Opening Remarks
Special Guest
Simonetta Di Pippo
Director, UNOOSA

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Lab
Dark and
Quiet Skies
for Science
and Society
Online workshop
5 to 9 Oct. 2020
DARK
& QUIET

Dark and Quiet Skies for Science and Society

UNITED NATIONS
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Astronomical
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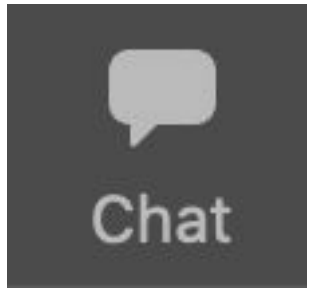
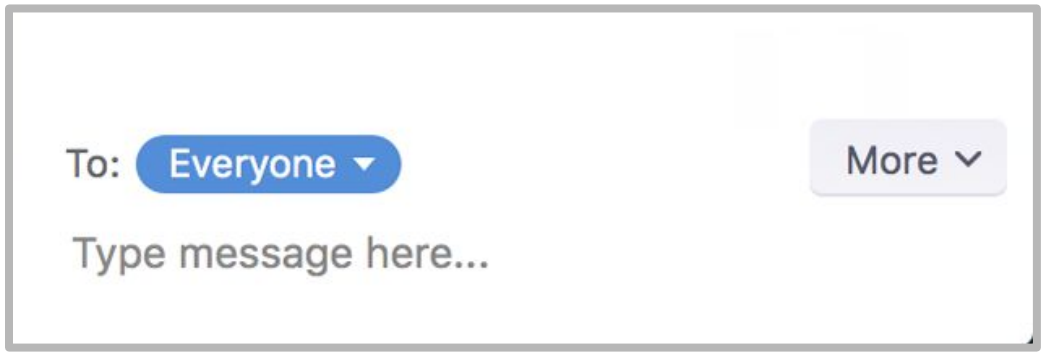
Zoom Meeting Housekeeping

Have a question?

- Use the chat at any time
- Keep it short!

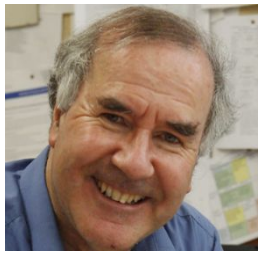




Participants will **not** be unmuted

Q&A monitors will read a subset of questions

Dark Sky Oases WG



John Hearnshaw - NZ
WG Chair, Presenter
University of Canterbury, IAU

Antonia Varela - ES
WG co-Chair, Presenter
IAC, IAU

John Barentine - US
Presenter
IDA

Costis Bouroussis - GR
Presenter
Technical University Athens, CIE

Jose-Miguel Espinosa – ES
IAC, IAU

Pedro Sanhueza – CL
IAU

Casiana Muñoz-Tuñón - ES
IAC, IAU

Zouhair Benkhaldoun – MA
Université Cadi Ayyad, IAU

Steve Lau – CN
Hangzhou Yongdian
Illumination, CIE

Kathy Nield,
AT
CIE

DARK & QUIET SKIES

Dark and Quiet Skies for Science and Society

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With the support of NOIRLab

What is light pollution?

Light pollution is the sum of adverse effects of obtrusive artificial light at night (ALAN). It comprises:

- Glare
- Light trespass (spill light)
- Skyglow – resulting in a brighter night sky which impedes our ability to see the stars.

Skyglow is caused by scattering of light by air molecules and aerosols in the Earth's atmosphere.

SAirglow seen from space

Natural airglow photographed from the ISS by Italian astronaut Samantha Cristoforetti in 2014.

Airglow is emission by air molecules high up in the atmosphere.

Skyglow adds to the low brightness natural airglow.

Six reasons for good lighting

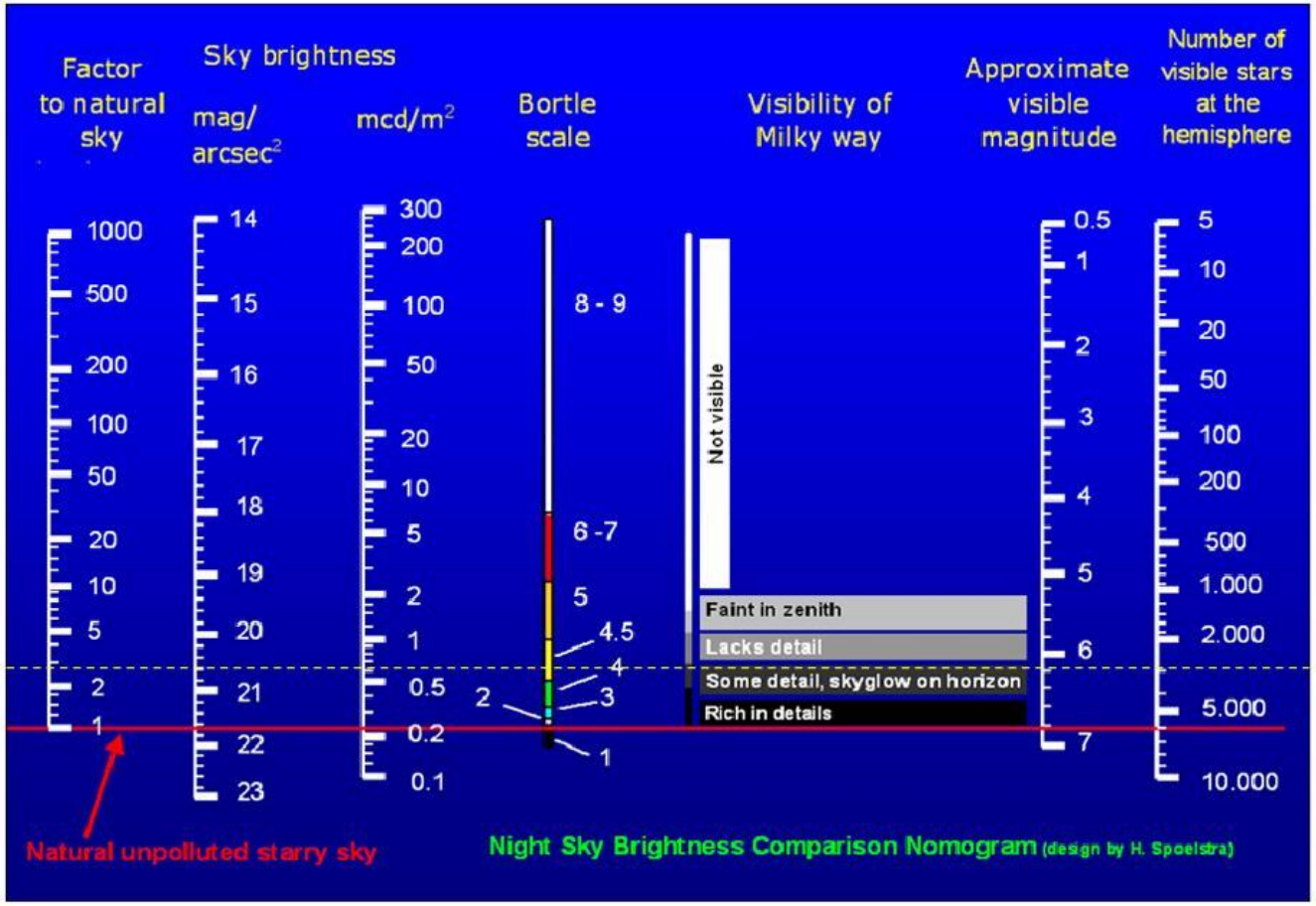
- ALAN may have an adverse impact on human health.
- ALAN can be damaging to the bio-environment and to biodiversity
- Poorly installed outdoor lighting, especially installations that allow light to be projected upwards, wastes electricity.
- **ALAN brightens the night sky and this makes it more difficult to see the stars.**
- Good outdoor lighting installations promote greater public safety.
- Dark skies can be a resource for a sustainable economy through astro-tourism.

Measuring the brightness of the night sky

The Bortle scale (J Bortle 2001) uses a nine-point scale.

- Bortle class 1 is for the darkest sites.
- Bortle class 9 is for the most light polluted sites.
- The Bortle classes are a scale based on the faintest stars just visible to the naked eye.
- ALAN reduces visibility of stars when they are viewed against a bright background sky.

The Bortle scale and Spoelstra nomogram



John Hearnshaw

Quantitative measures of sky brightness

A popular unit of sky brightness is magnitudes per square arc second.

Stellar magnitude is an inverse logarithmic scale used by astronomers (larger numbers refer to fainter stars, 2.5 magnitudes = factor of 10.).

About 21.8 mag/sq arc sec corresponds to a natural unpolluted dark sky (Bortle class 1).

Many highly polluted urban sites have sky brightness ~16 to 18 mag/sq arc sec, Bortle class 8 or 9 and only a dozen (or fewer) stars visible.

Photometric units for sky brightness

A useful unit for sky brightness is the S_{10} unit – the equivalent number of 10^{th} magnitude stars per square arc minute that correspond to the sky brightness level.

Unpolluted sky is at about 145 S_{10} (or 21.8 mag/sq sec arc).

A heavily polluted sky at 16.7 mag/sq arc sec has about 27,000 S_{10}.

Note that magnitudes refer to the visual (yellow) passband to which our eyes in daytime are most sensitive (λ_{max} = 555 nm).

Photometric SI units

The surface brightness or luminance of the night sky is also measured in SI (Système International) photometric units of milli-candela per m^2.

The natural airglow is about 0.25 mcd/m^2 (unpolluted night sky) though the figure is somewhat variable in direction, time and location.

Significantly polluted skies have luminance > 1 mcd/m^2.

The candela is defined in terms of the visual photopic passband, as defined by CIE and peaking at 555 nm. This bandpass is not very sensitive to blue light ($\lambda < 500$ nm).

What is a dark sky oasis?

A **dark sky oasis** (also often referred to as a '**dark sky place**') is a location where the night sky is protected by an outdoor lighting policy, or in legal terms, by *a lighting ordinance.*

This limits the amount and the wavelengths of light that shine upwards into the sky. Blue light ($\lambda < 500$ nm) is especially harmful, as it scatters the most.

Most dark sky oases will have controls on

- street lighting,
- the lighting of sports facilities at night,
- outdoor lighting of commercial facilities (ports, factory yards),
- flood lighting of buildings.

Accreditation agencies for dark sky oases/places

International agencies:

- The International Dark-Sky Association (IDA), Tucson, Arizona
- The Starlight Foundation (Tenerife, Canary Is, Spain).

National agencies include:

- The Royal Astronomical Society of Canada (RASC)

By mid-2020, there were 223 dark sky places in 27 countries with accreditation, covering over 20 million hectares.

The IUCN classification scheme for dark sky places

Class	Type of Dark Sky Place	Number world-wide (May 2020)
1	Dark sky astronomy site	15
2	Dark sky park (protected natural area)	114
3	Dark sky heritage site	9
4	Dark sky outreach site (e.g. public observatory)	25
5	Dark sky reserve (mix of cooperating community, rural and natural area jurisdictions)	21
6	Dark sky community (rural area, village or town)	39
	TOTAL	**223**

IUCN = International Union for the Conservation of Nature. The classification is from the IUCN Dark Skies Advisory Group

The New World Atlas of Artificial Night Sky Brightness

Falchi, F.; Cinzano, P.; Duriscoe, D.; et al. (2016). The new world atlas of artificial night sky brightness. *Science Advances*, 2, 1-25.

The atlas is based on satellite data of light going from Earth into space recorded in the years 2013-2014, in wavelength interval 500-900 nm.

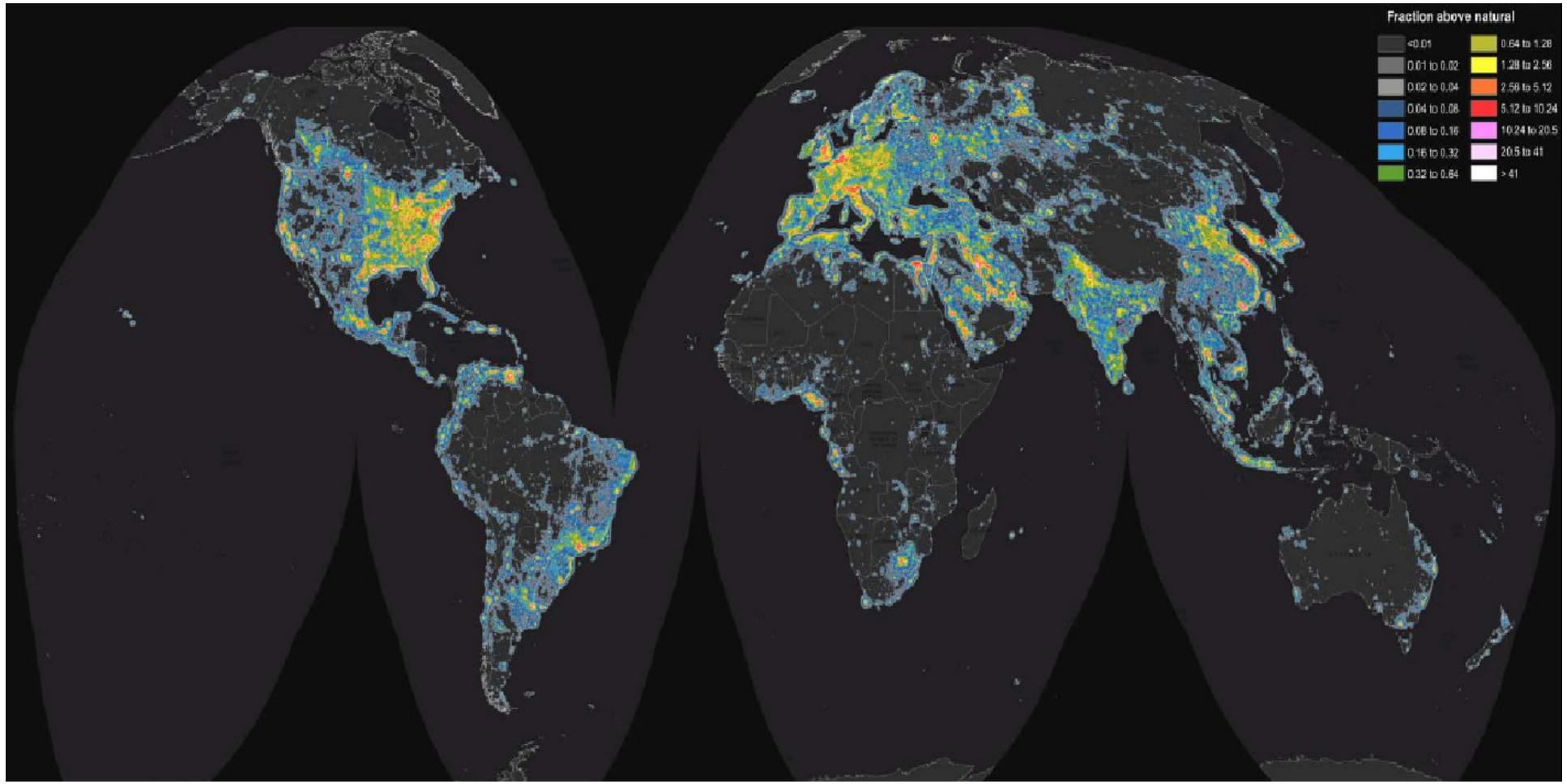
Computer modelling then predicts the night sky brightness in µcd/m^2 that would be observed from the ground.

The New World Atlas of Artificial Night Sky Brightness

Predictions of the New World Atlas:

- 80 per cent of the world and more than 99 per cent of the US and European populations live under light-polluted skies.
- The Milky Way is hidden from more than one third of humanity, including 60 per cent of Europeans and nearly 80 per cent of North Americans.
- 23 per cent of Earth's land surface area between 75°N and 60°S, experience light-polluted nights.
- 88 per cent of Europe and nearly half the area of the US experience light-polluted nights.

The New World Atlas of Artificial Night Sky Brightness



The red areas are highly light-polluted and have typically 5 to 10 times the natural night sky brightness, generally in excess of 1250 µcd/m^2 and up to 2500 µcd/m^2.

Impacts of ALAN on the visibility of stars

Visual Magnitude	Magnitude Range	Number of Stars per Range (in a full sphere)	Cumulative Number of Stars	Approx. number of stars visible above 10°
-1	-1.50 to -0.51	2	2	1
0	-0.50 to +0.49	6	8	3
1	+0.50 to +1.49	14	22	9
2	+1.50 to +2.49	71	93	38
3	+2.50 to +3.49	190	283	116
4	+3.50 to +4.49	610	893	368
5	+4.50 to +5.49	1,929	2,822	1165
6	+5.50 to +6.49	5,946	8,768	3621
7	+6.50 to +7.49	17,765	26,533	10958
8	+7.50 to +8.49	51,094	77,627	32059

Classifications of Dark Sky Oases (DSOs)

We sort the DSOs by two characteristics: night sky quality and land use type.

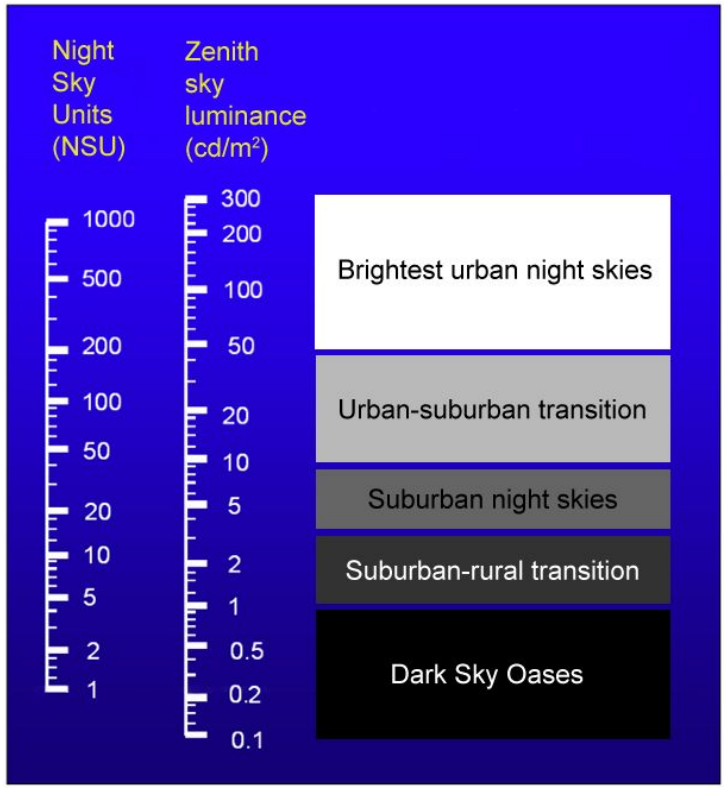
Night Sky Brightness (NSB)

Atmospheric

+

Astronomical

1 ‘Night Sky Unit’ (NSU)



Adapted from work by H. Spoelstra

DSOs are further distinguished by land use type

Built Environment

Amenity, public safety, utility

Harun Mehmedinović

Protected Places

Biology, aesthetics, astrotourism

Kevin Johnson

Dark Sky Oasis Schema

IUCN-DSAG Class	Zenith Brightness Threshold (NSU)	International Dark-Sky Association (IDA) Category	Starlight Foundation Category	Royal Astronomical Society of Canada (RASC) Category
1	1.1	International Dark Sky Sanctuary	Starlight Reserve	Nocturnal Preserve
2	1.6	International Dark Sky Park	Starlight Landscape; Starlight Wilderness	Dark Sky Preserve
3	4.0	(none)	Starlight Heritage Site	(none)
4	2.6	Urban Night Sky Place	Starlight Astronomy Site; Starlight Tourism Destination; Starlight Stellar Park; Starlight Camp	Urban Star Park
5	2.6	International Dark Sky Reserve	Mixed Starlight Site	(none)
6a	4.0	International Dark Sky Community	(none)	(none)
6b	3.0	International Dark Sky Community	Starlight Oasis; Starlight Village	(none)

Recognition programmes encourage active DSO conservation

Identify

To conserve a resource,
first you have to understand it.

Jeremy White/NPS

Manage

Careful attention to outdoor lighting should be the first thought – not an afterthought.

Incentivise

Sustainable tourism =
rural economic development.

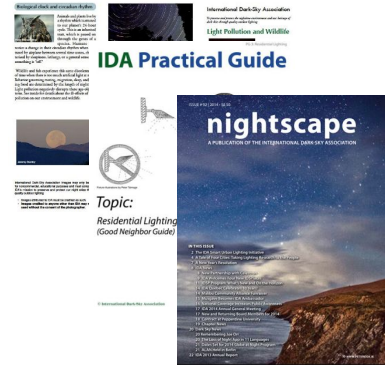
John Barentine

The International Dark-Sky Association

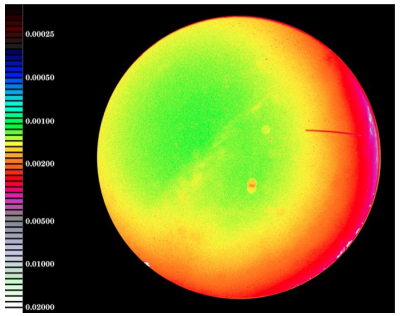
IDA is the world's premiere NGO dedicated to saving the night.

Lighting Technology Development & Promotion

Publications



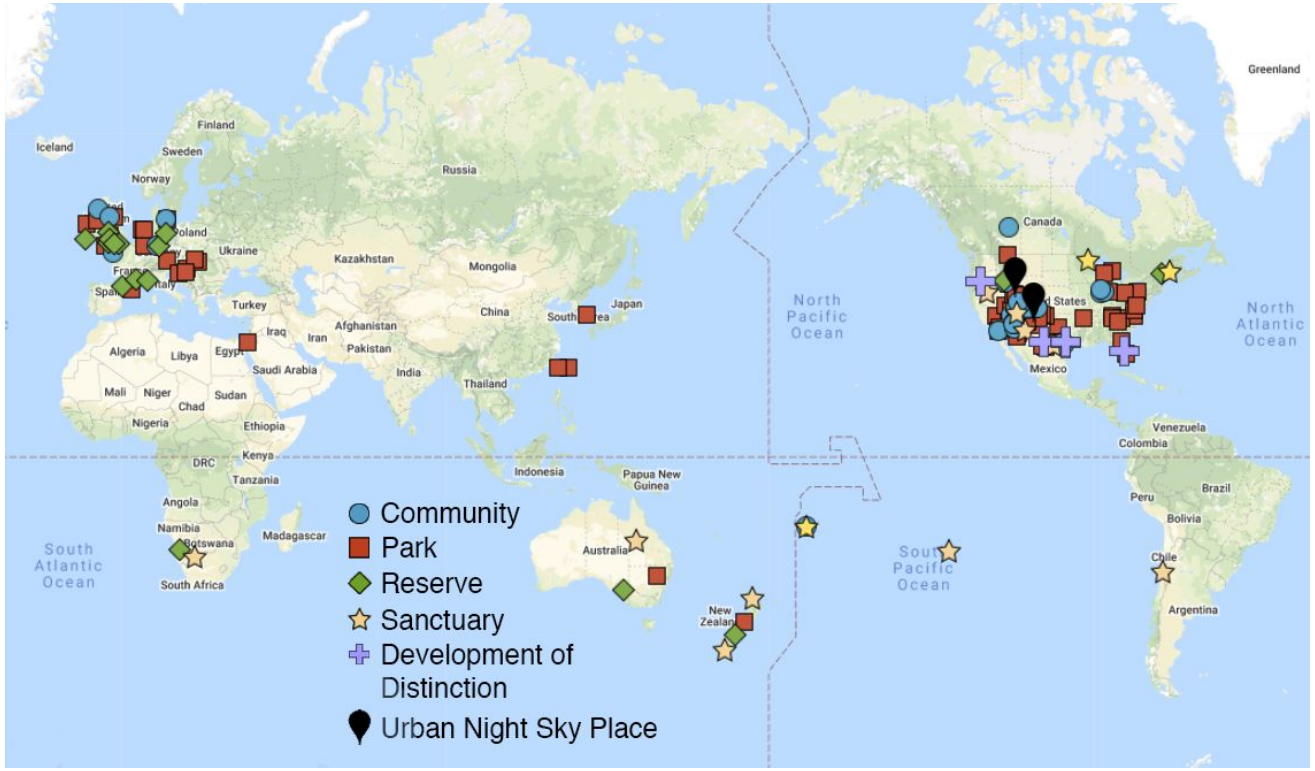
Research



Education & Outreach

IDA International Dark Sky Places Programme

153 designations on six continents; 104,000 km² protected.

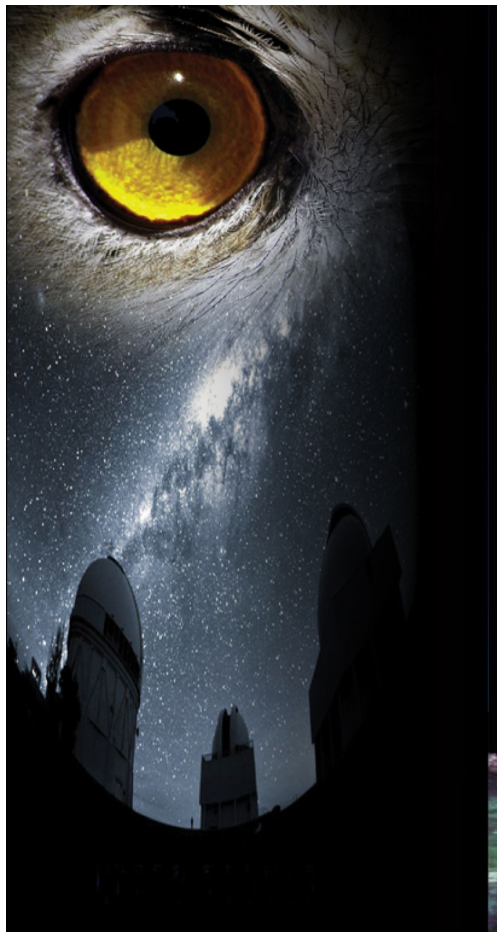


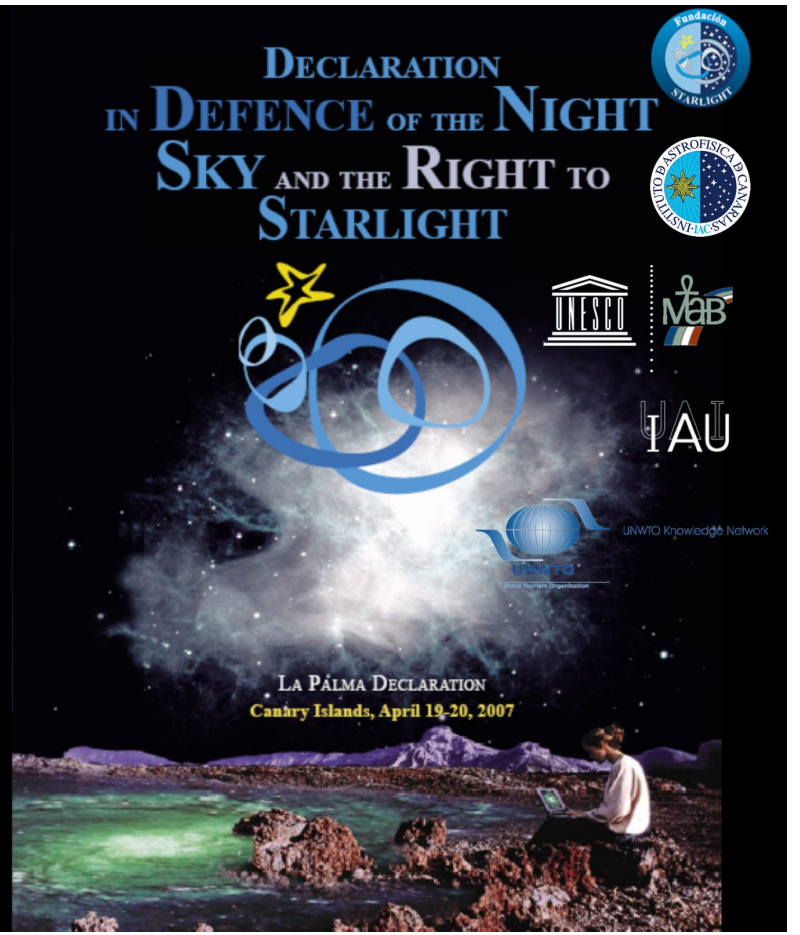
The IDSP Programme

- Demonstrates DSO conservation at scale in a variety of geographies and societies
- Recognises DSOs not just for being dark, but for efforts made toward achieving conservation goals
- Requires a comprehensive, peer-reviewed nomination
- Establishes a global network of DSOs that share talent, resources, and information

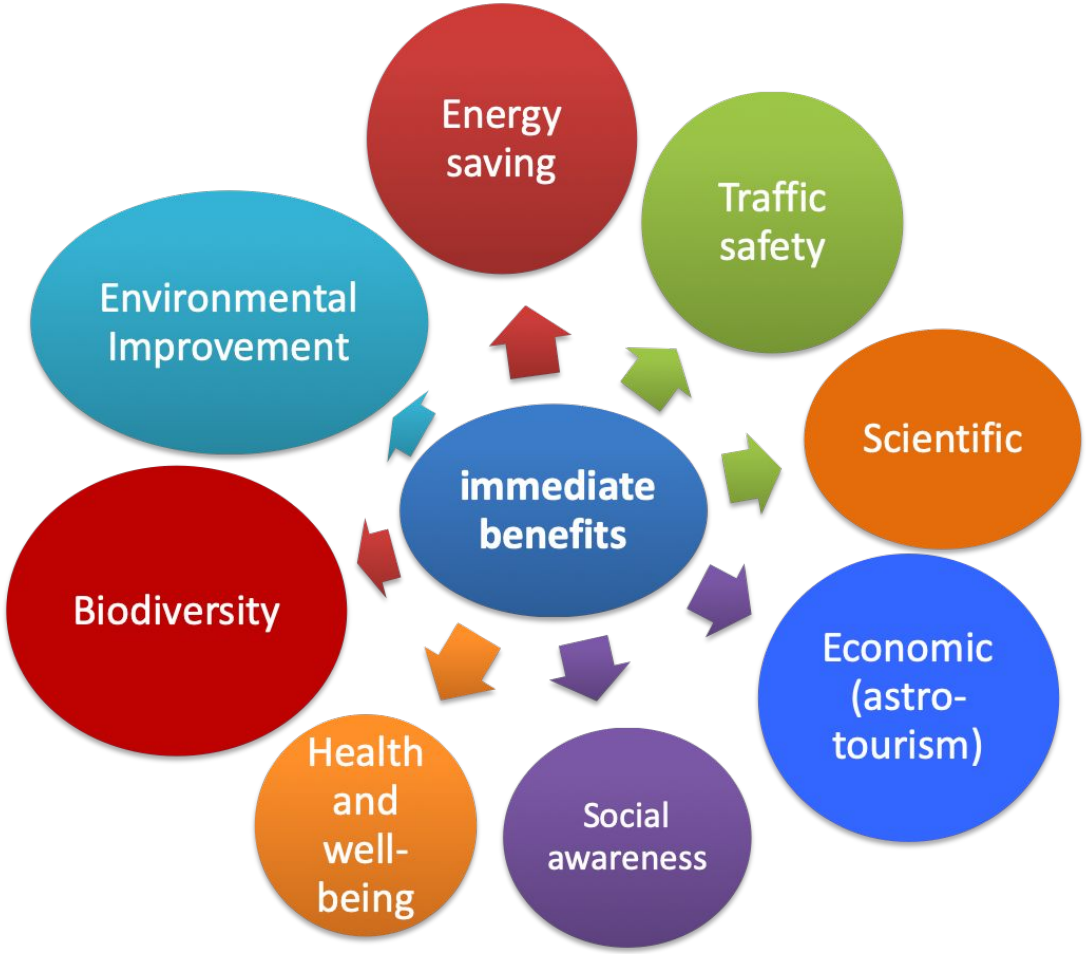
The Starlight Declaration (La Palma, 2007)

www.fundacionstarlight.org

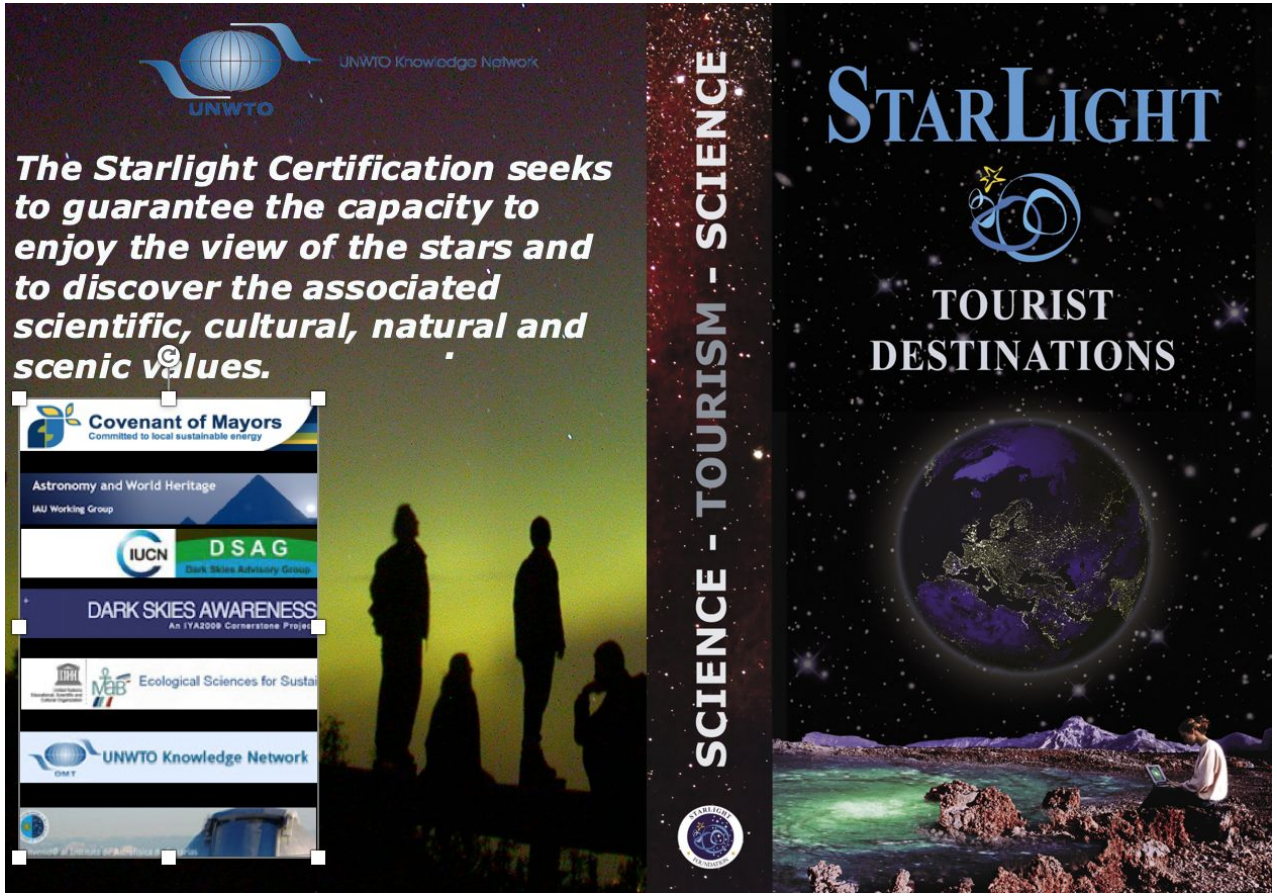




The Starlight Foundation: the commitment with Starlight Declaration

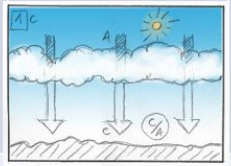
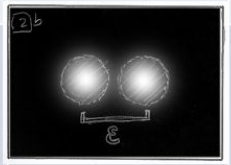
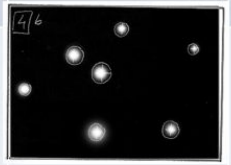


The International Starlight Certification: bringing for first time science and tourism together



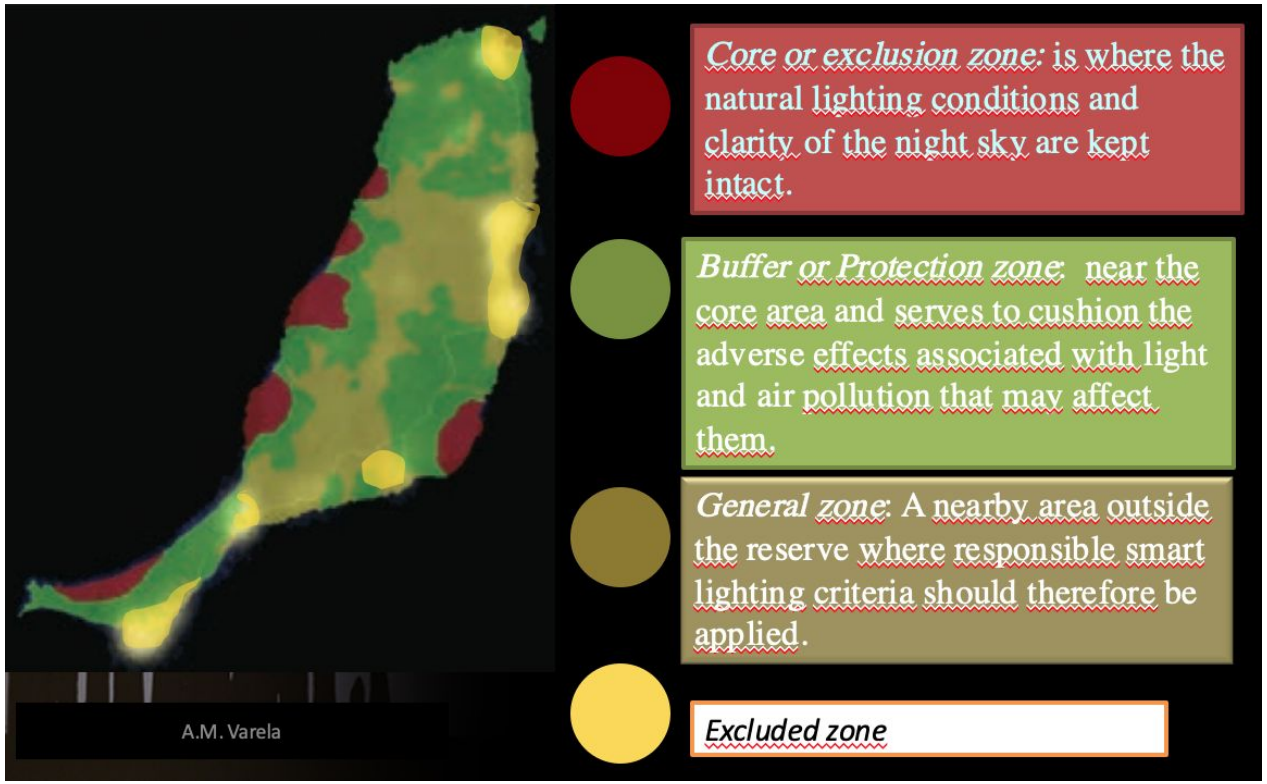
Sky parameters in the Starlight sites

SKY QUALITY -ASTRONOMICAL PARAMETERS
(Varela, Muñoz-Tuñón, Sánchez-Martínez, Martínez-Sáez, 2012, Proc. Third Int. Starlight Conference, New Zealand)

PARAMETER		DESCRIPTION	THRESHOLD		INSTRUMENTATION
			Destin.	Reserve	
Clouds coverage		Percentage of cloud covering sky	50%	60%	AWS Satellites
Sky brightness		Light pollution	>21 mag/ arcsec^2	>21.4 mag/ arcsec^2	SQM ASTMON Satellites TESS CoSQM New proposals?
Seeing		Blurring caused by turbulence	≤3”	<1”	Telescopes DIMM
Transparency		Clear atmosphere, degree of visibility	6mag	Kv<0.15mag/arcsec 2	NELM Telescopes

- ❑ Covenant of majors
- ❑ Audits
- ❑ Review and renewal every 4 yrs

Monitoring, zoning, lighting projects



DARK & QUIET SKIES

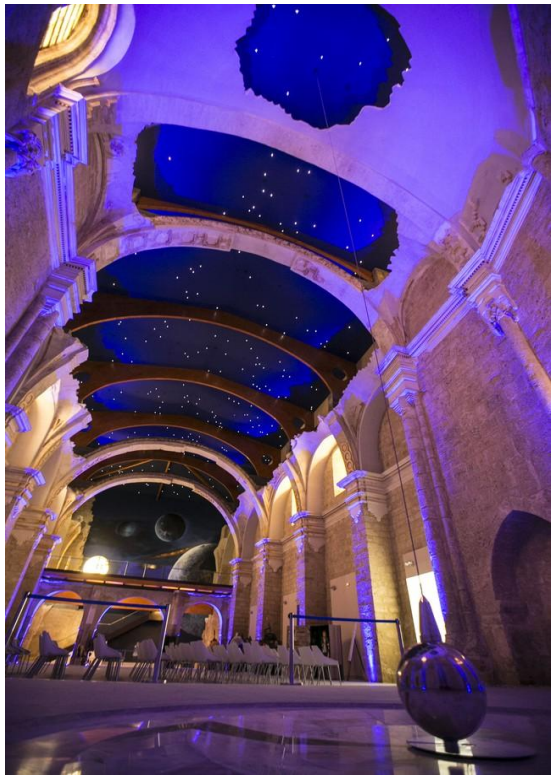
Antonia Varela

Starlight Rural Hotel & Houses and other modalities

Rural Hotel&Houses, Inns, Camps,

Stellar Parks, Wilderness, farms, activities

Cultural Monuments



Antonia Varela

The Starlight Network

- 45 Starlight Reserves & Tourist Destinations
- 70 rural hotels and others lodges
- 7 Stellar Parks
- 10 other modalities

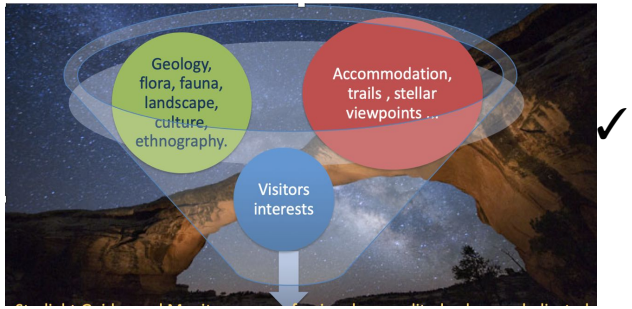
500 Starlight Declaration Adhesions
75,000 km^2

Biosphere Reserves of La Palma, La Rioja, Fuerteventura, Sierra Morena, Monfragüe, Gran Canaria, Alto Turia, Menorca,... (Spain), Fray Jorge (Chile) and South West Nova (Canada) or the Teide NP, the first World **Herltage site** labelled. Responsible lighting and light pollution control are key requirements for the certification in these sites

DARK & QUIET SKIES

Antonia Varela

The Starlight training: formation, education, outreach



✓112 Starlight Guides
✓402 Starlight Monitor
✓35 Introduction in Astrotourism
✓18 Starlight Auditors
✓>50 Starlight Professors
✓30 journalists
15 nationalities

* Programs for teachers and students in schools

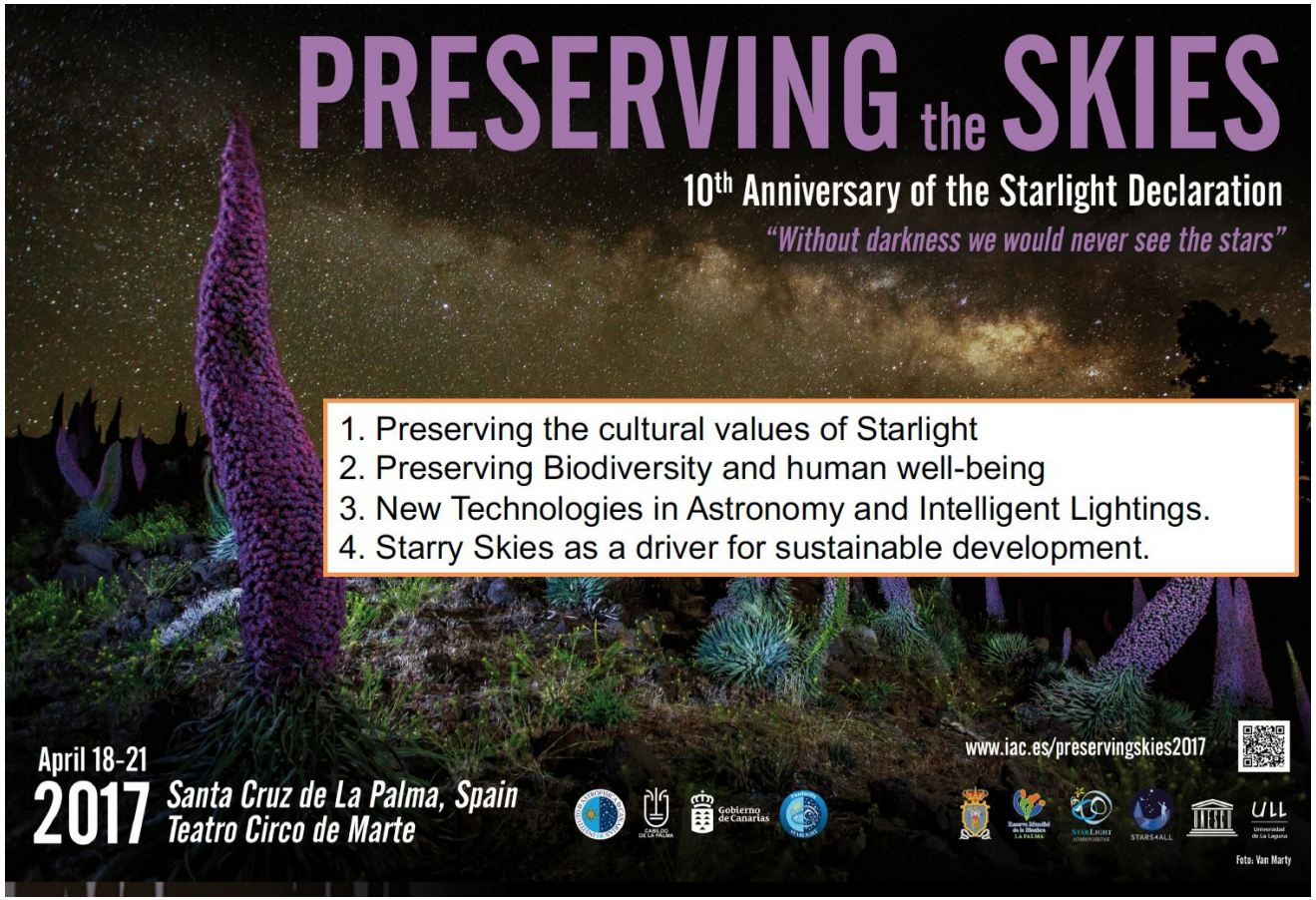
* Women in astronomy

* Recovery of empty buildings for exhibitions

* Wokshops

*Inclusive astrotourism

The Tenth Anniversary of the Starlight Declaration



Complementary Activities

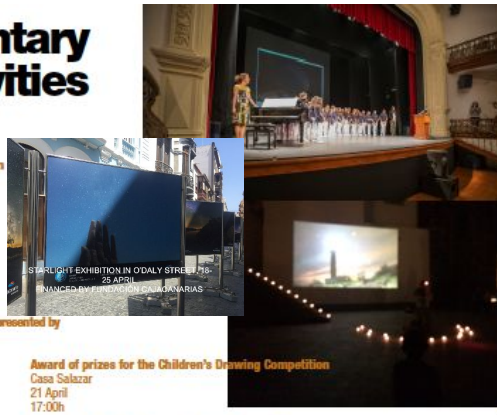
Starlight Exhibition promoted by CajaCanarias Foundation
Calle O'Daly
18–25 April
Calle O'Daly

Exhibitions at Casa Salazar
•Entries for the Children's Drawing Competition
•"The Divine Presence" by Andrés Acosta
•"Women for a stellar island"
18–25 April

Public Talk "Fireflies, stars and city lights" (just in Spanish), presented by Romano Corradi (GTC)
Teatro Circo de Marte
19 April
19:00–20:00h

Cinema Season: About the Universe

Award of prizes for the Children's Drawing Competition
Casa Salazar
21 April
17:00h



Preserving the Skies

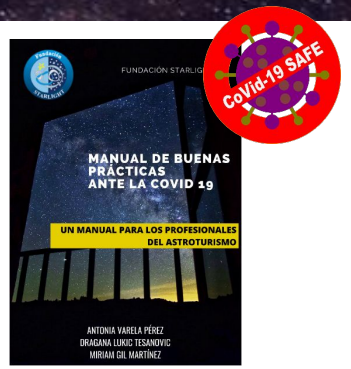
10 YEARS AFTER STARLIGHT DECLARATION
LOOKING AHEAD

Vision and Resolutions

La Palma 2017 - 10th Anniversary of the Starlight Declaration
April 20, 2017

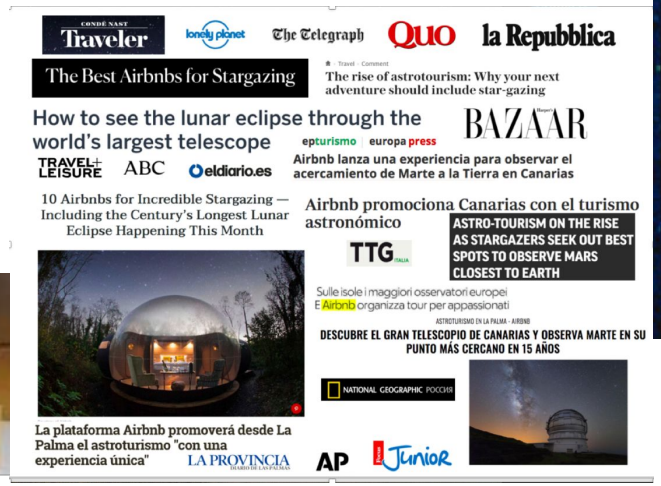
The Socio-Economic Impact of Astro-tourism

Annual growth up to 350%
Montsec…32.000 visitors, 2.5 millions €/2018
Iles Atlanticas…71.000 visitors for Starlight activities
Tenerife ……200.000 visitors
Mackenzie & Aoraki/Mt Cook 150.000 visitors
La Palma …more than 70 business or registered projects, 29.5 millions €/year (Cabildo de La Palma)



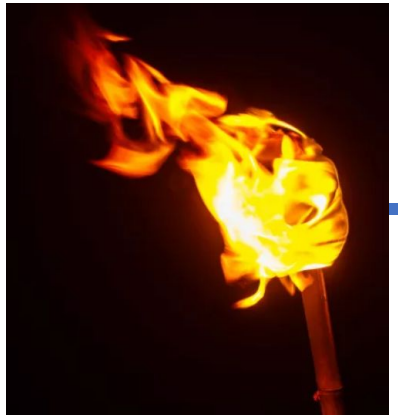
From Airbnb study in Starlight sites:
Antofagasta (Chile)…… 327%
La Palma (Spain) ……. 90%
Yarmouth (Canada)…… 221%

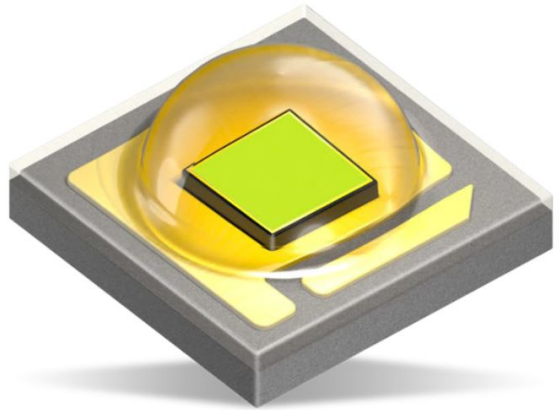
SF Winner in FiturNext 2020 Challenge among more than 250 innovative sustainable tourism projects of more than 50 countries.



The evolution of light sources and luminaires

- From Torch to LED: A long way towards the energy efficiency

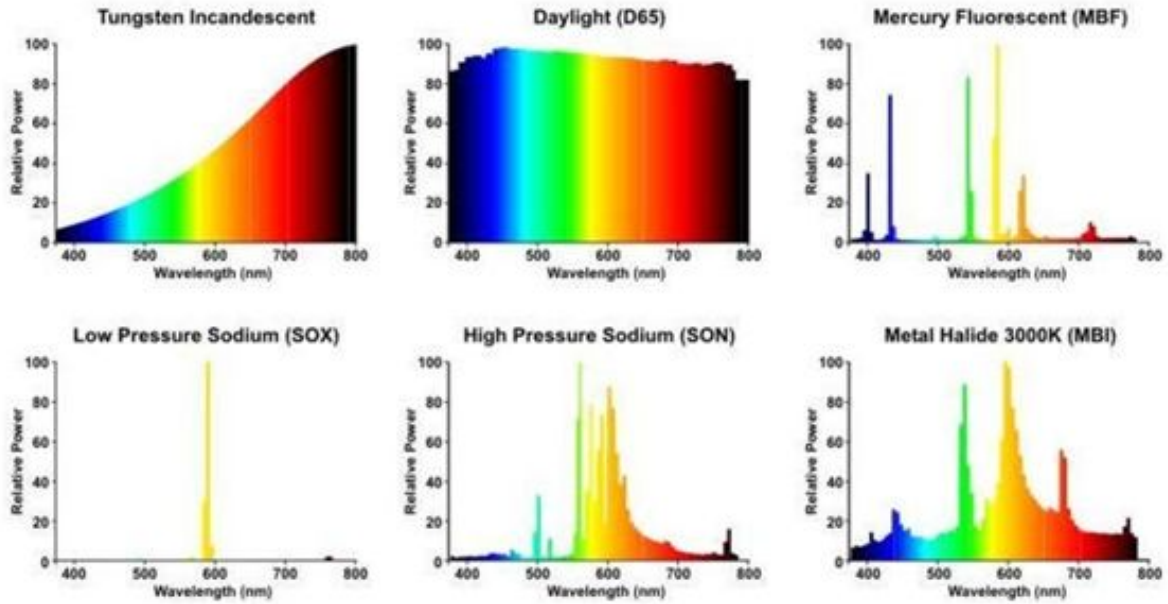


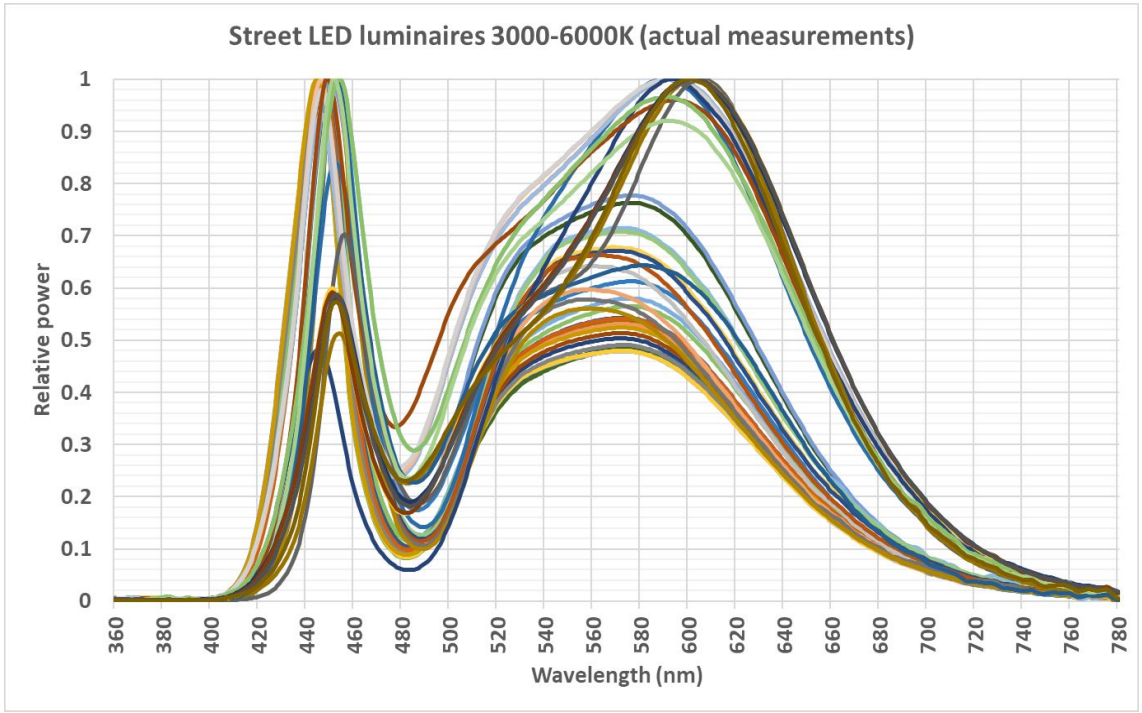


3 major groups (Filament, Fluorescent and High Intensity Discharge)

The evolution of light sources and luminaires

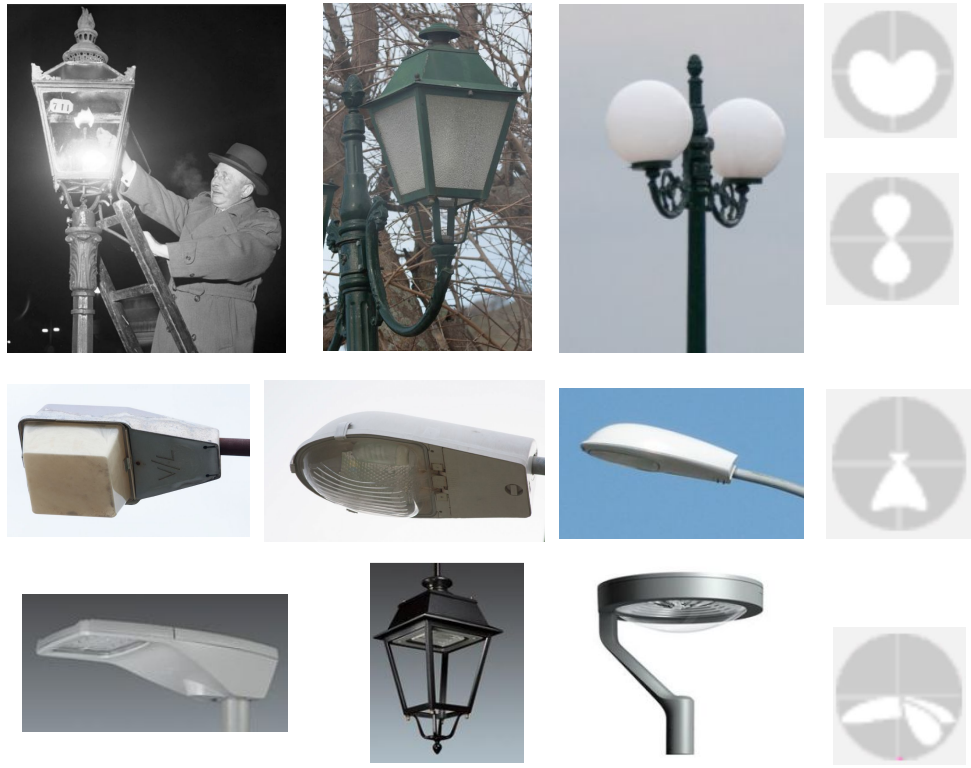
- Spectral content of light sources and blue content





The evolution of light sources and luminaires

- Initially, luminaires functioned as housings for the light sources without any control on light distribution.
- Later street luminaires distributed the light mainly towards the road but also upwards.
- Street luminaires with conventional sources had/have cut-off design and had better optics while additional accessories reduce spill light.
- LED street luminaires are based on lens and reflector design and can achieve maximum control of light distribution.



The evolution of light sources and luminaires

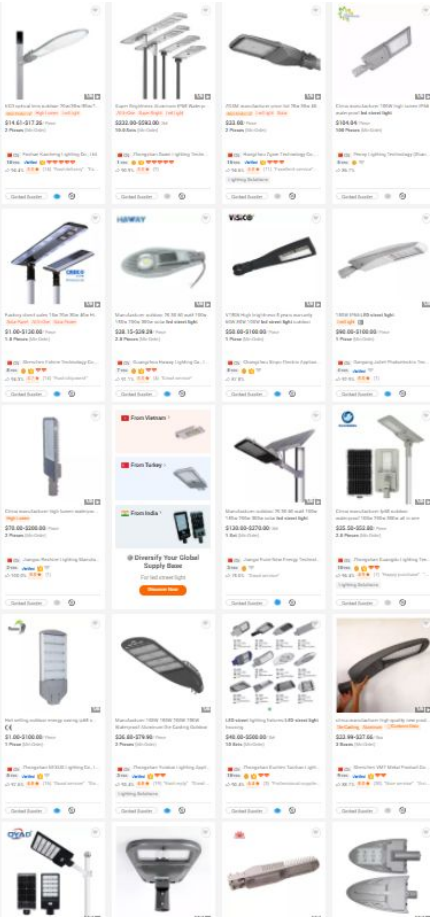
How LEDs revolutionized the luminaire technology and lighting control

- Increased efficiency compared to traditional sources (expect from LPS 😊)
- Small light source compared to traditional lamps
- Lens, diffuser and reflector design is more flexible than ever
- LED permits full control on luminous flux over time or via adaptive systems
- Luminaire can be equipped with LEDs with various colour temperatures
- Tunable white (e.g. 2200-3000K) tends to become a standard for both indoor and outdoor applications
- Huge energy saving potentials compared to existing lighting installations

The evolution of light sources and luminaires

But why did LED technology create a negative reputation?

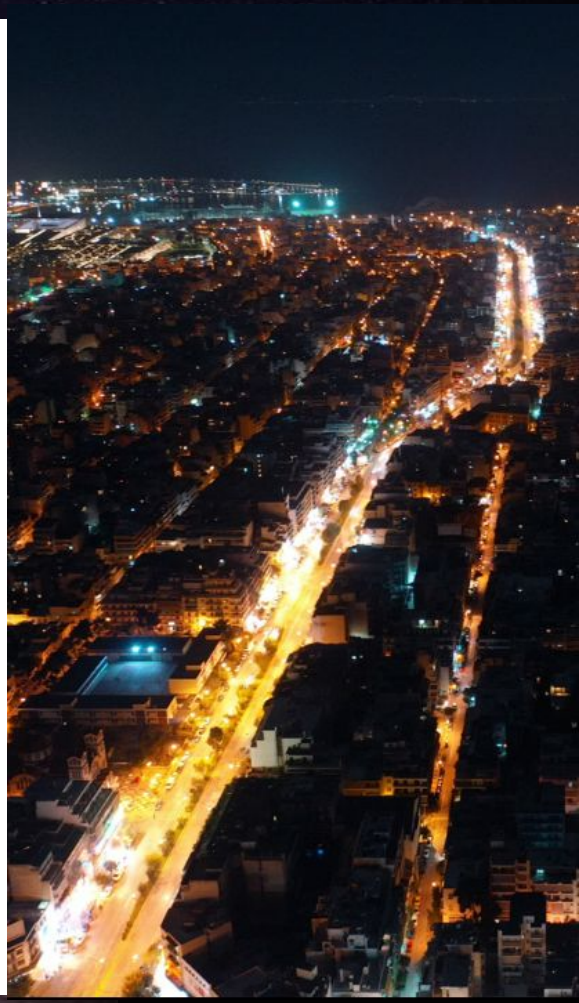
- Massive renovations with priority in energy saving
- Endless number of cheap and low quality “me-too” products
- Bad or no lighting design at all
- Noticeable difference of efficacy between warm and cool white LED (during the early days) which promoted >5000K
- No commissioning, measurements and monitoring
- Lot of complains about blueish light and glare



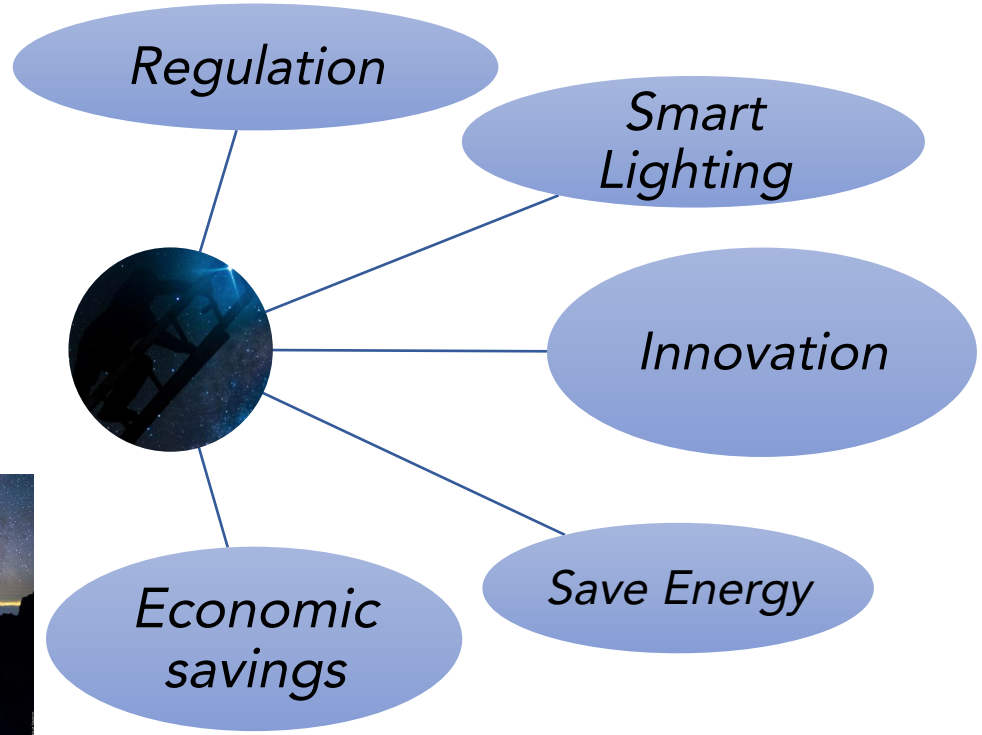
The evolution of light sources and luminaires

Some thoughts…

- Each light source is not an "*a priori*" source of light pollution
- Obtrusive light & sky glow are affected by the combination of light sources, luminaires, lighting design, over-illumination, etc.
- Traditional light sources offered only certain wattages, while luminaire technology was limited by the size of the light source and the optics
- Today's technology offers almost full control of light distribution and fine-tuning of emitted spectrum.
- The synergy between new luminaire technology, modern light sources and lighting control can significantly reduce the adverse effects of ALAN



The Value of Dark Sky Oases: Economic value



The Value of Dark Skies Oasis: Scientific value

The Value of Dark Sky Oases: Cultural value

Heritage sites

Skyscapes

History & Ethnography

Preserving the tanginble and intangible cultural heritage associated to the light of the stars.

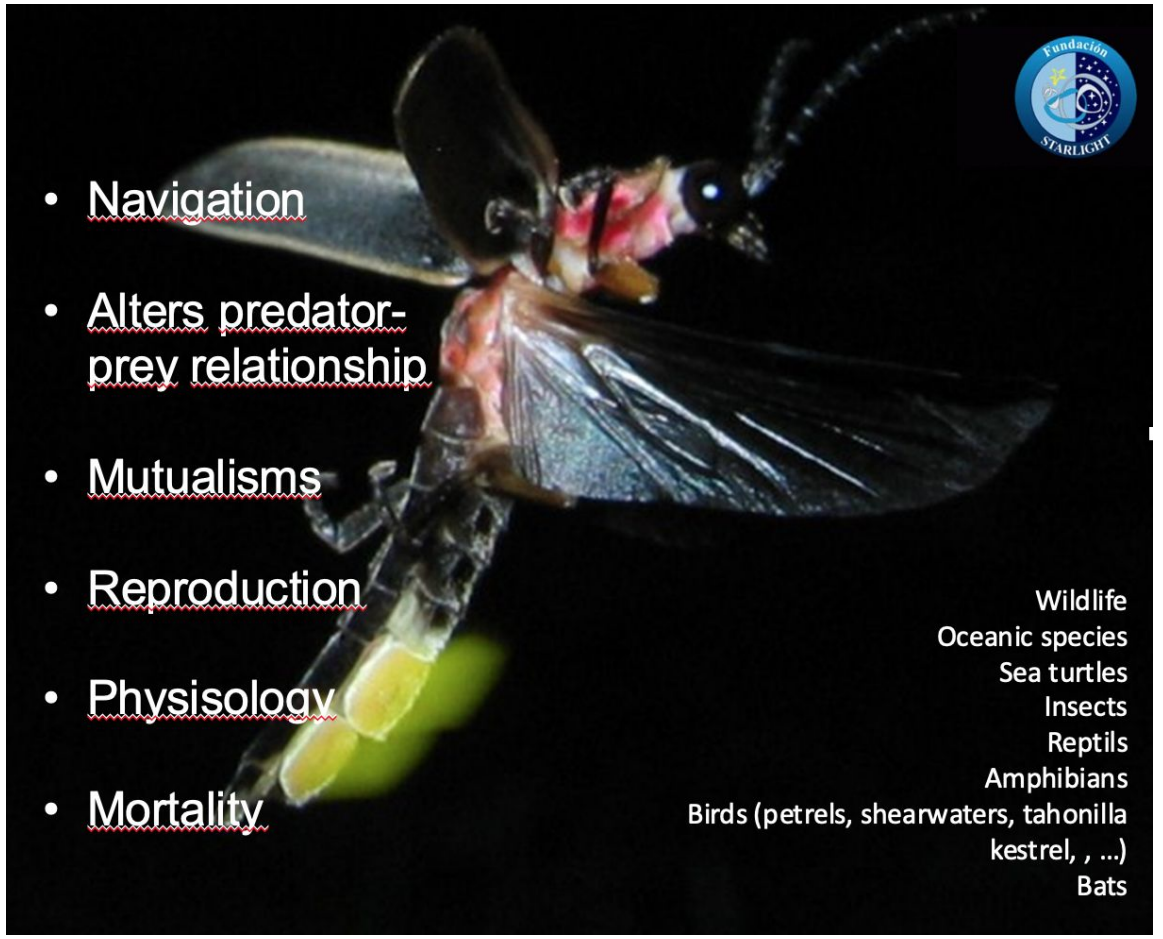
DARK & QUIET SKIES

Antonia Varela

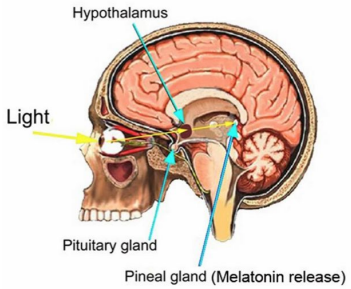
The Value of Dark Sky Oases: Environmental and Biodiversity value

The loss of quality of nocturnal skies, caused by the negative effects of atmospheric emissions and of the increased intrusion of artificial lights and skyglow, has become a serious threat for many species, disturbing their habits and habitats, as well as the basic functions of ecosystems.

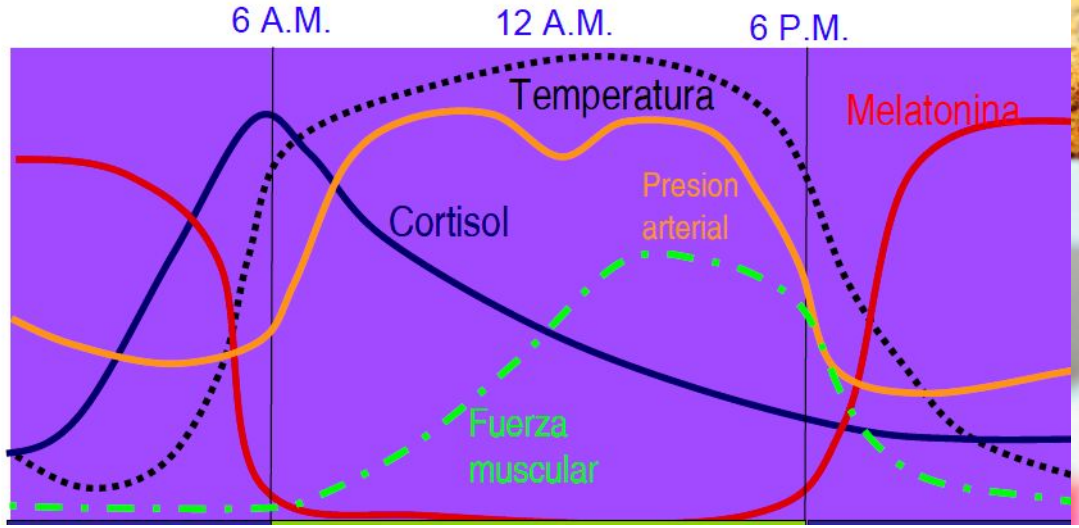
Marín et al. 2015.



The Value of Dark Sky Oasis: Human Health and Well-being value



Too much light can affect people's health, by changing circadian rhythms.



World Health Organization 2007 and US Medical Association 2012

CIRCADIAN RYTHMS OF HORMONES AND BIOLOGICAL VARIABLES

Melatonin
Cortisol
Immunosuppressants
Temperature
Muscular strength, …

Regulate circadian cycles
And annual cycle

DISEASES

Insomnia
Obesity
High cholesterol
Diabetes
Cardiovascular diseases
Cancer, ...

Astrotourism: Enjoying Starry Skies

SCIENCE as a WORKING METHODOLOGY IN TOURISM

Tourism as an instrument to **mitigate climate change**
Tourism as an instrument for **sustainability**
Tourism as an instrument for **development**

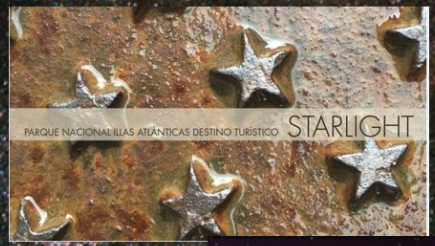
Astronomy is a **transversal element** to the whole of humanity, cultures and countries
Astronomy is the **starting point of science** for many cultures
Sky is a **worldwide resource x 24hrs x 365 days**

ASTROTOURISM RESOURCES

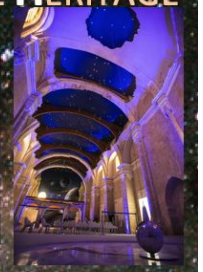
FOOTPATHS

PROAM OBSERVATORIES AND PLANETARIUMS

NAVIGATION



CULTURAL HERITAGE



ARCHEOASTRONOMY

MUSIC & ART

GEOLOGY

G-ASTRONOMY

MERCHANDISING

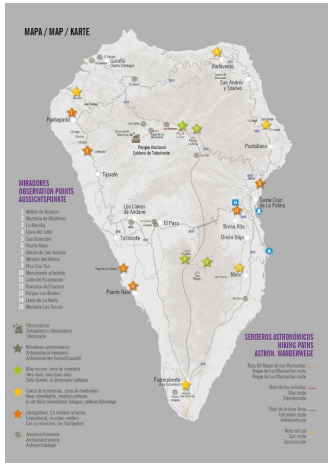
ASTROPHOTOGRAPHY

DARK & QUIET SKIES

Antonia Varela

Starlight Tourist Destinations

To be leaders in astrotourism, it is necessary to innovate, diversify and sophisticate the offer, personalizing it in each destination and promoting the development articularly.



SPECIALIZED COMPANIES

Consult the list of companies of services specializing in the astronomy

GUIDES STARSLIGHT

Guides Starslights

ACCOMMODATIONS

List of Country houses where to stay and to enjoy the astronomy

RESTAURANTS

Establishment with astronomic theme (astrophotos, drawings, audiovisual media, binoculars, iPad, guided path).

SHOPS

Shops and Wine vaults with sale of products associated with the astronomy

OTHERS COMPANIES

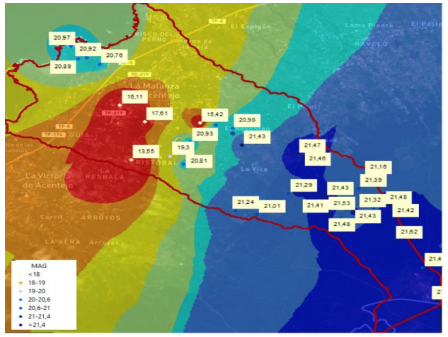
Companies that offer, inside its service catalog, activities related to the stars

- ❑ **Overnight stay**
- ❑ **Unseasonalization**
- ❑ **Against Depopulation**
- ❑ **Decentralization**

- **Stargazing viewpoints network**
- **Stargazing trails**
- **Places of astronomical interest**
- **Archaeoastronomy**

etc.

Scientific Group/ Astrotourism of Affiliate Members UNWTO



MONITORING AND PRESERVING THE SKY

STARLIGHT TRAINING

Monitors, guides, auditors, lighting technicians

ADVICE & CONSULTANCY

Science and Tourism in the horizon of the touristic industry and to reach the SDG's of Agenda 2030

CONSTITUTION OF THE WG ON SCIENTIFIC TOURISM (ASTROTOURISM) OF THE AFFILLIATE MEMBERS OF THE UNWTO LED BY THE STARLIGHT FOUNDATION

SAN PETERSBURGO (RUSIA), 9-12 SEPTIEMBRE 2019

DARK & QUIET SKIES

Antonia Varela

Recommendations to COPUOS

Aspirational night sky brightness limits recommended for dark sky oases

IUCN class	DSO type	Maximum sky brightness recommended in terms of natural airglow		μcd/m^2		mag/sq arc sec	
1	Astron. observatory	1.10x		<260		>21.7	
2	Dark sky park	1.50x		<360		>21.4	
3	Dark sky heritage site	2.75x		<660		>20.7	
4	Dark sky outreach site	2.0x		<480		>21.0	
5	Dark sky reserves	2.0x		<480		>21.0	
6	Dark sky community	3.0x to 4.0x		<750 to <1000		>20.6 to >20.3	
		rural	semi-urban	rural	semi-urban	rural	semi-urban

Recommendations to COPUOS

- In all protected dark sky oases the default condition should be no artificial light.
- In ecological reserves and similarly sensitive sites with little or no human presence at night, artificial light should not be used. If it is used, it should be a narrowband amber LED or equivalent emitting no light at $\lambda < 500$ nm. Lighting should be strictly controlled and switched on only when it is needed.
- If phosphor-converted amber LED lights are used, the amount of blue light ($\lambda <$ 500 nm) should be below 5 % of the total spectral power. Generally this requires using LEDs with a correlated colour temperature of 2200 K or less.
- All exterior lights should only distribute light below the horizontal, and the upward light output ratio (ULOR) should be no more than 0.5 %. This requires luminaires to be mounted horizontally and have flat screen glass below the light source.

Recommendations to COPUOS

- No development in or near highly ecologically sensitive sites should be permitted.
- Monitoring of night-time conditions in/near dark sky oases is encouraged through a combination of ground-based and remote sensing methods.
- Active management of natural night-time darkness as a natural resource is encouraged through recognised conservation best practices.
- Restoration plans should be implemented when sky brightness thresholds are routinely exceeded.

Dark Sky Oases

Southern Cross and Pointers, Aoraki Mackenzie International Dark Sky Reserve, New Zealand.

Photo Fraser Gunn

DARK & QUIET SKIES

John Hearnshaw

Dark and Quiet Skies for Science and Society

UNITED NATIONS
Office for Outer Space Affairs

International Astronomical Union

With the support of NOIRLab

Dark and Quiet Skies for Science and Society

Closing Remarks
SOC Member
Nathalie Ricard
UNOOSA

UNITED NATIONS
Office for Outer Space Affairs

International
Astronomical
Union

With the
support of NOIR Lab

Thank you!

DARK & QUIET SKIES