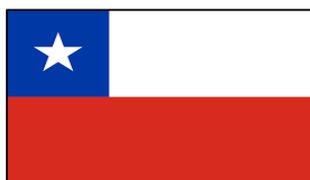


# Technical Presentation on Recommendations from the Dark & Quiet Skies Workshop

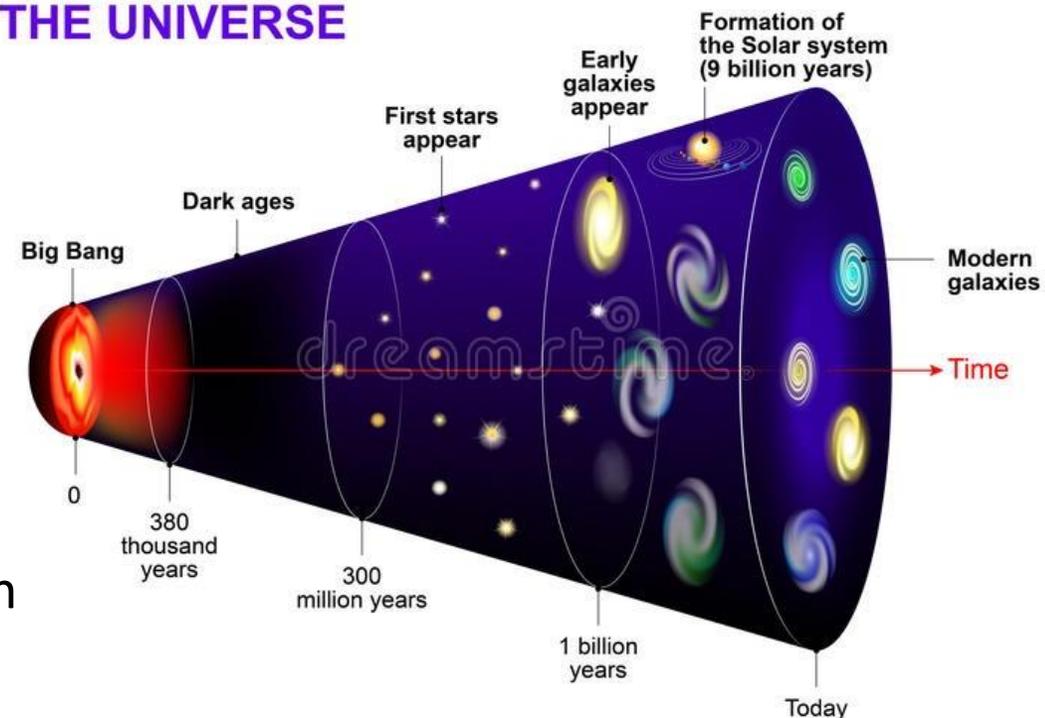
Connie Walker and Piero Benvenuti (IAU)  
on behalf of the UN Delegates supporting the CRP &  
Working Group Members of the D&QS Workshop



# Why the Protection of Astronomy is of Interest to COPUOS

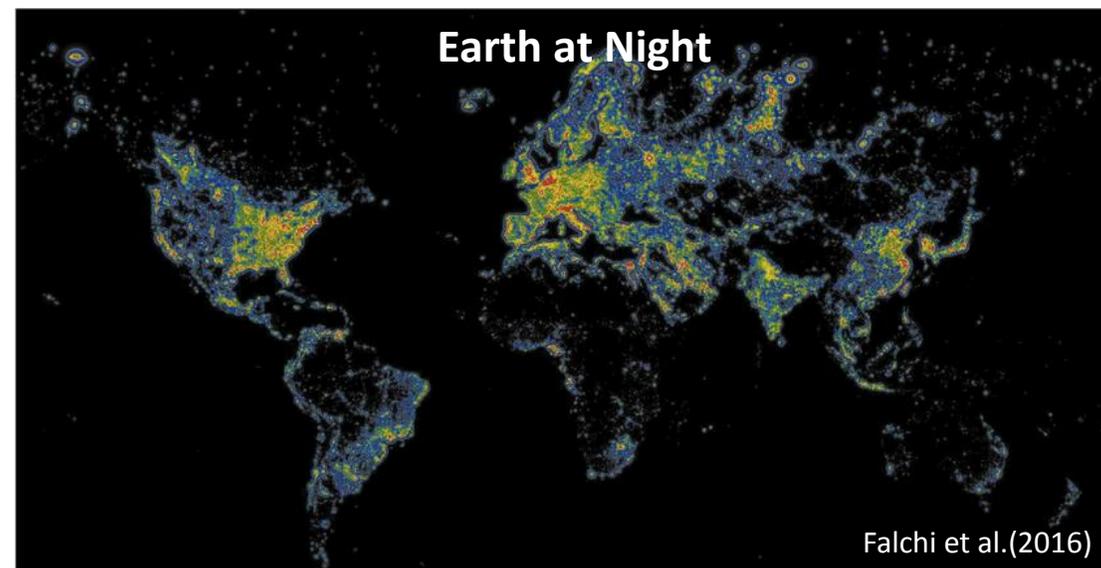
- Throughout the ages, astronomy was instrumental to the progress of scientific knowledge
- New discoveries require unobstructive and undisturbed access to the cosmos
- COPUOS in 2017 approved the organization of a conference aimed at studying all possible protections of dark and quiet skies
- UN/IAU/Spain held the workshop in October 2020 with 1000 participants; conference this October 2021
- 85 international experts produced a comprehensive document **analysing sources of artificial interferences and recommending mitigation strategies.**

## EVOLUTION OF THE UNIVERSE



# Three Categories of “Artificial Interferences” Impacting a Dark and Quiet Sky

- The artificial light at night (ALAN) used to illuminate urban areas
- Transmission at radio-wavelengths
- The deployment of tens of thousands of satellites in Low Earth Orbit (LEO)



- These categories affect astronomy in different ways and also their relevant regulatory framework differs (e.g., regional vs international regulations)
- The impact by the satellite constellations is the most germane to the COPUOS mission, and will be discussed first

# Principal Factors of Impact on Astronomical Observations from Satellite Constellations

- **The number of visible satellites**
  - Tens of thousands to be launched in the next decade
- **The orbital altitude of the satellites**
  - At any altitude, the projected surface density of bright satellites is greatest near the horizon and during twilight
  - Increasingly visible all night long with increasing altitude over 600 km
- **The apparent brightness and attitude of the satellites**
  - Without mitigation, bright enough to saturate detectors
- **Lack of regulation (no requirement to mitigate, crowded space)**



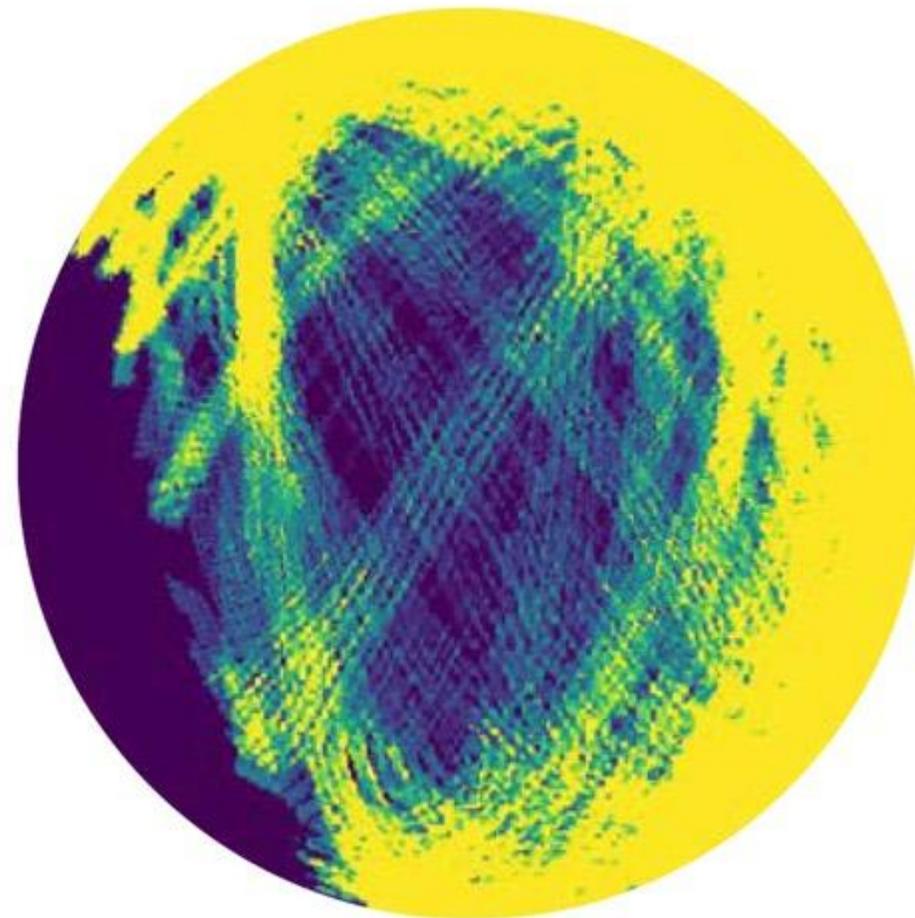
Credit: V. Girgis (Lowell Observatory)

# Primary Impact Assessment on the Science

Wide-field and twilight programs will be critically affected

- Facilities with wide field-of views & sensitive detectors like Rubin Observatory will severely impacted if numbers of satellites reach several thousand
- Low-elevation studies (e.g., NEO searches) will be heavily impacted as well with tens of thousands planned

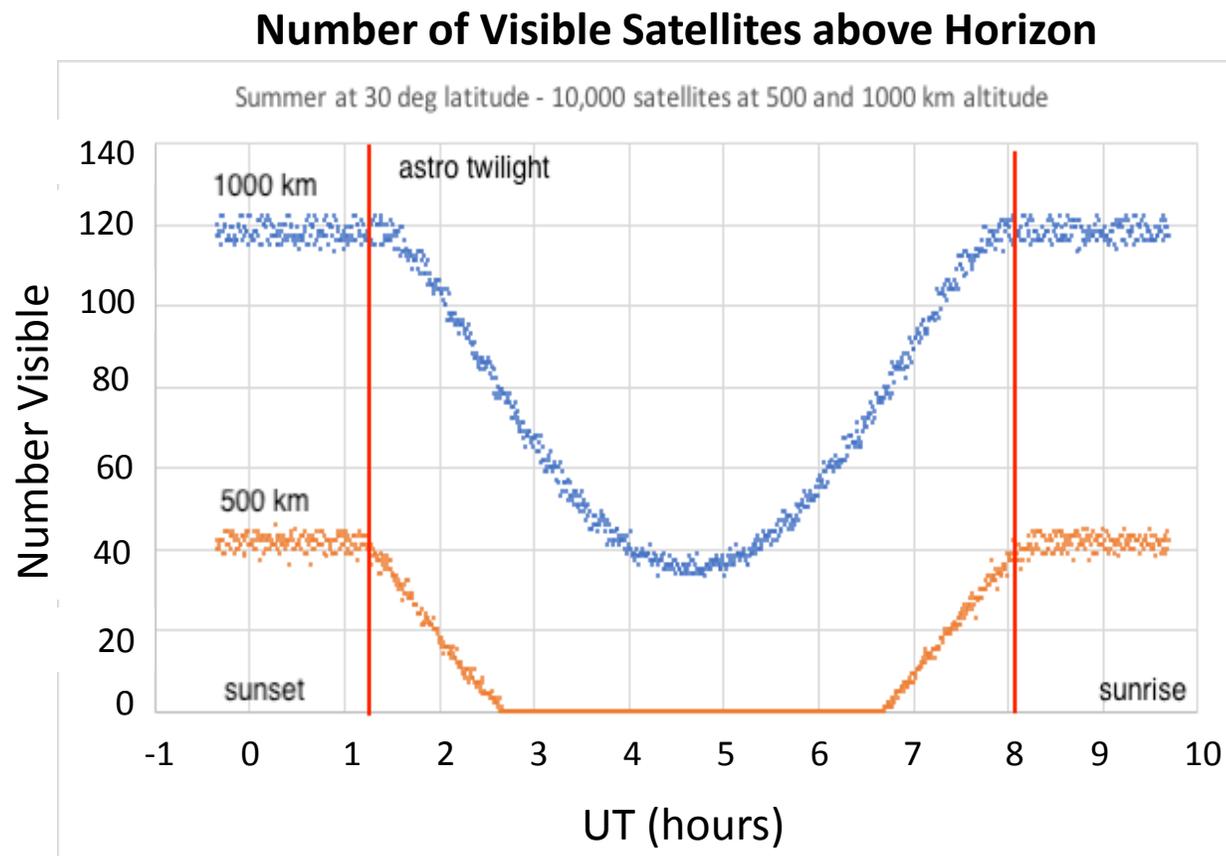
Simulation of Satellite Trails



Credit: P. Yoachim (U. Washington/ Rubin Observatory), private communication

# Recommendations for Mitigating the Impact of Satellite Constellations on Astronomy (1+2)

1. **Encourage awareness** raising, transparency, & collaboration in stewardship of the night sky
2. **Design missions** to minimize negative impacts on astronomical observations
  - Minimize operational altitudes
  - Number of satellites
  - Time spent in orbit



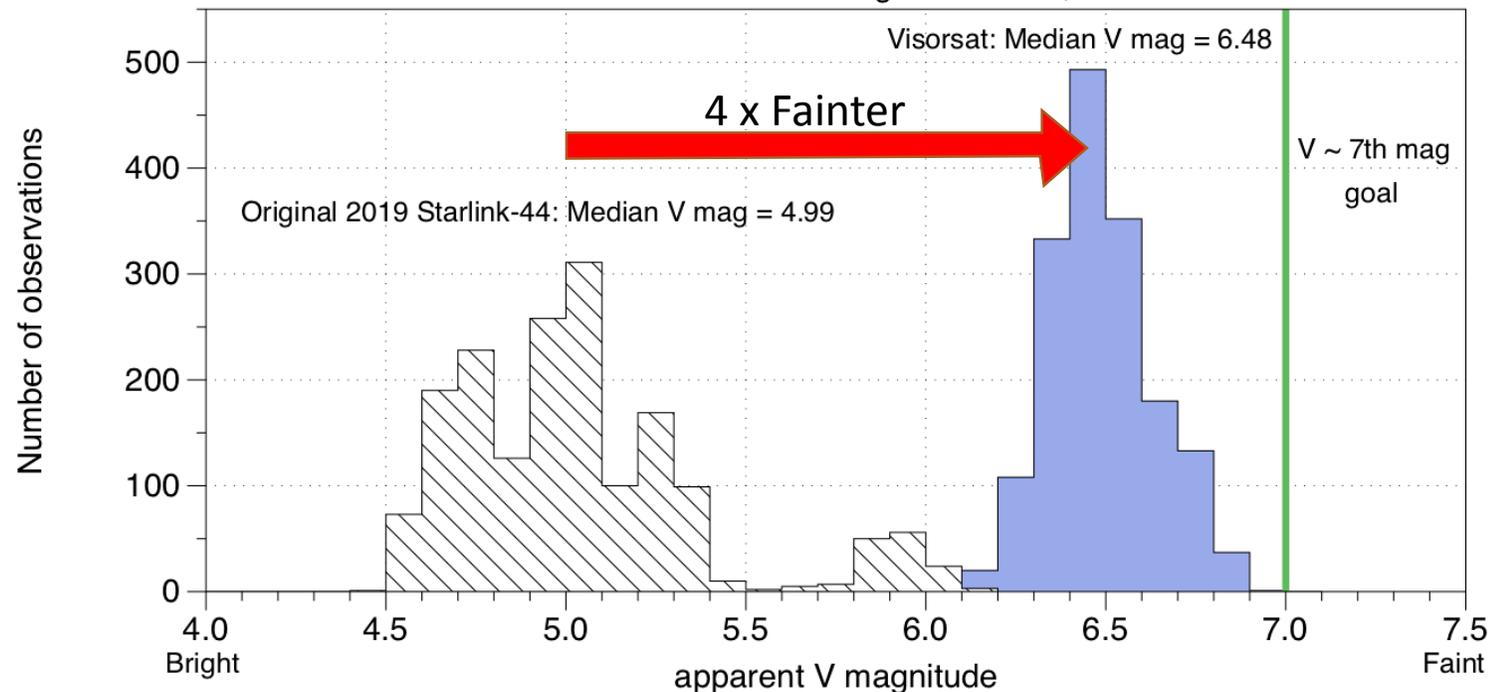
Credit: P. Seitzer (U. Michigan)

# Recommendations for Mitigating the Impact of Satellite Constellations on Astronomy (3)

## 3. Design satellites to minimize negative impacts on astronomical observations and the pristine night sky

- To be fainter than 6<sup>th</sup> mag to naked eye and 7<sup>th</sup> mag at 550km for observatories
- Incorporating dynamic orientation adjustments
- Minimize both direct and indirect illumination of radio observatories

MMT-9 Observations: Visorsat 4 times fainter than original Starlink, both at 550 km altitude

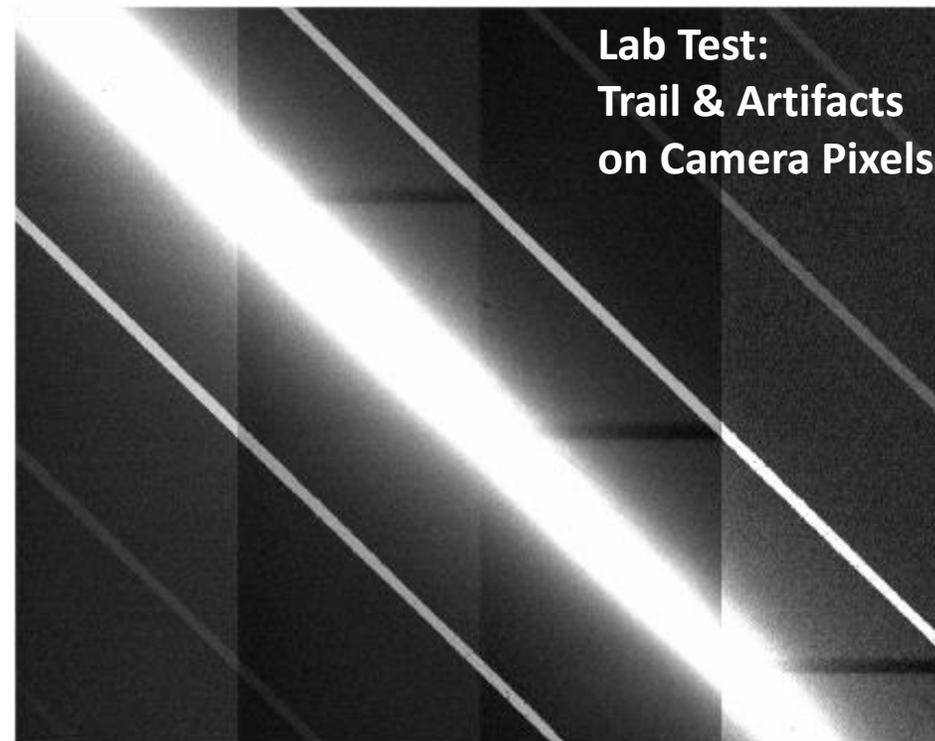


Credit: P. Seitzer, (U. Michigan)

# Recommendations for Mitigating the Impact of Satellite Constellations on Astronomy (4)

## 4. **Develop observatory software** to mitigate impacts

- Identify and mask trails in imaging
- Create observation planning software linked to accurate satellite positions as a function of time
- Develop predictive model for brightness as function of orbital phase, including flares
- Create accurate simulations of expected radio flux density at observing sites

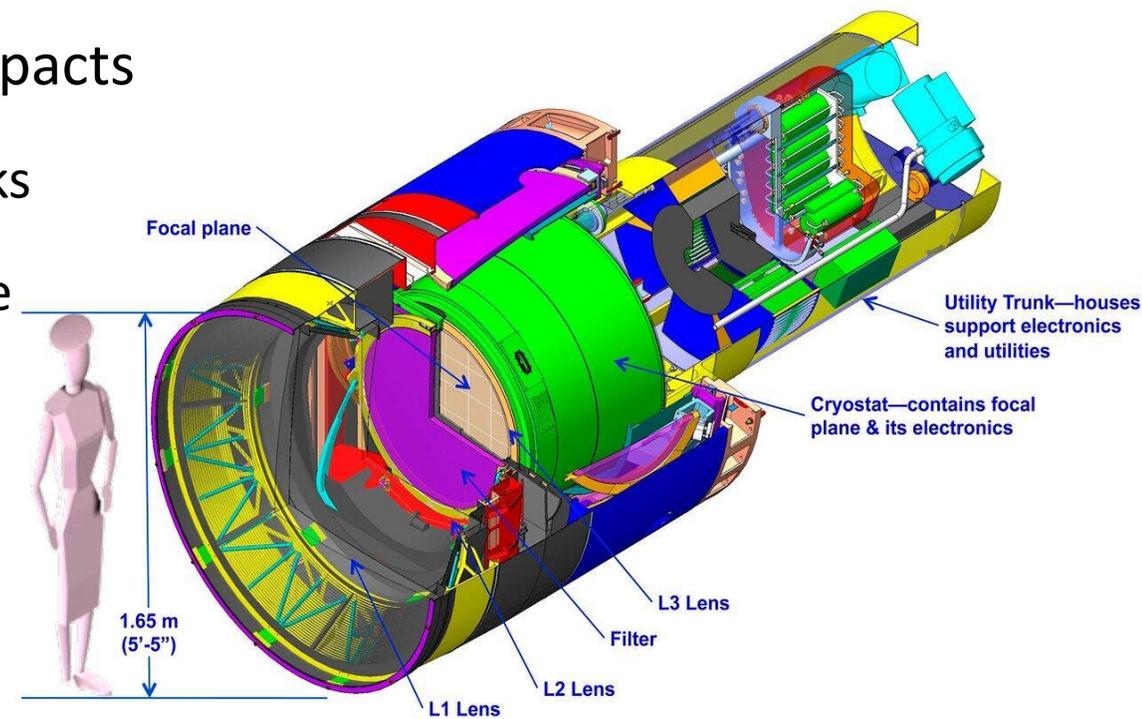


Credit: T. Tyson (Rubin Observatory)

# Recommendations for Mitigating the Impact of Satellite Constellations on Astronomy (5)

## 5. Develop observatory hardware to mitigate impacts

- More telescopes, e.g., in NEO discovery networks
- Instruments that can be shuttered mid-exposure
- Detectors with pixel shuttering, i.e. CMOS
- Increase dynamic range of radio receivers and robustness of low-noise amplifiers



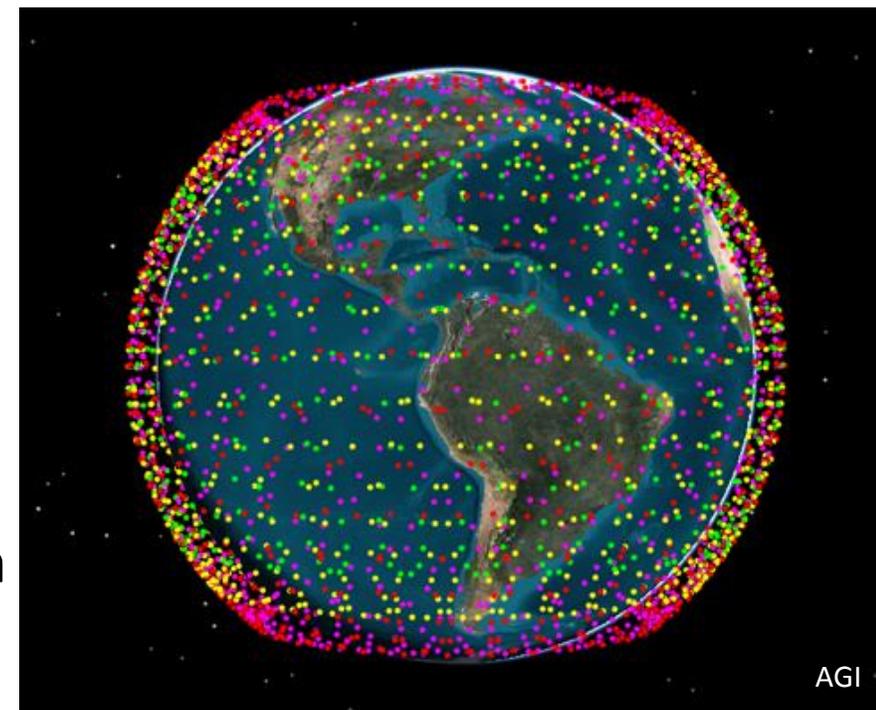
Camera 3/4 Section

Vera C. Rubin LSST Camera

# Recommendations for Mitigating the Impact of Satellite Constellations on Astronomy (6-9)

6. Conduct operations to minimize the impacts on astronomical research
7. Formulate satellite licensing requirements, guidelines and operational standards that take into account the impact on stakeholders
8. Support and expand the development of space domain decision intelligence
9. Provide funding for understanding & mitigating impacts on astronomy & the increased overheads (e.g., more observing time or science losses)

Satellites Orbiting Earth in the next Decade



# Recommendations for Artificial Light at Night

- **The protection of the professional ground-based optical observatories**
  - Safeguard investments in construction and operations made by governments.
  - The CRP recommends defining no-light areas surrounding observatories; eliminating direct illumination above the horizontal; and suppressing blue light content in lighting
- **The visibility of a starry sky for citizens**
  - Communities should be encouraged to establish &/or protect “**dark sky oases**”
  - The CRP provides technical recommendations on urban illumination that regional and national governments can consider
- **The bio-environment**
  - The CRP provides recommendations to minimize the negative impact of excessive illumination at night on human health and wildlife

# Recommendations for Radio Astronomy

- The power level of radar satellites can be sufficient to burn out a radio astronomy receiver
- A LEO communication satellite is expected to be within  $1.3^\circ$  from the line of sight of a radio-telescope; its sidelobes will fall in the telescope's main beam
- The CRP makes two clear **recommendations**:
  - Non-geostationary satellites, especially those with radar and high power, should be able to **avoid direct illumination** of radio telescopes and radio quiet zones (e.g. the Square Kilometer Array area)
  - Non-geostationary satellites should have **sidelobes that are low** enough that their indirect illumination of radio telescopes and radio quiet zones do not interfere

# The Request and Next Steps

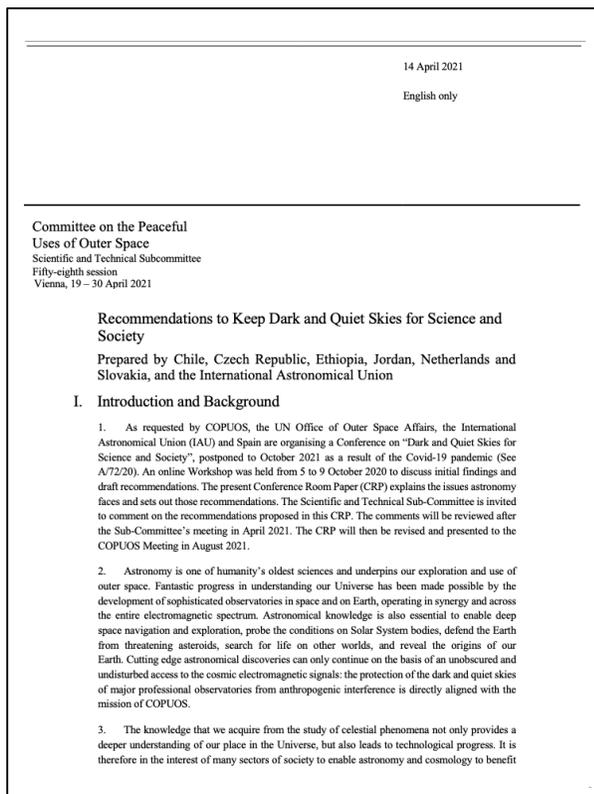
- Co-signing UN Delegations are requesting
  - An **Agenda Item** on the protection of Dark and Quiet Skies for the future STSC meetings
  - An **analysis** of the CRP recommendations **and** a **study** of their possible implementation assigned to UNOOSA
- If allowed, a **Working Paper** → COPUOS meeting in August
- On a parallel track: the **Dark & Quiet Skies Conference** in October is focusing on implementation of the recommendations → Report to STSC 2022

For further information, contact:

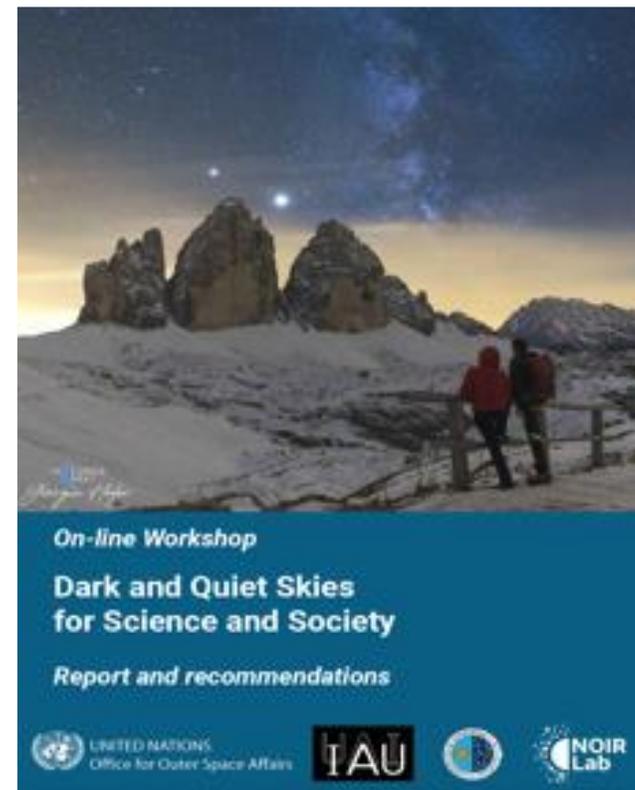
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# The Dark & Quiet Skies CRP and Full Report are online:



**THANK YOU  
FOR YOUR KIND  
ATTENTION.**



<https://www.iau.org/static/publications/uncopuos-stsc-crp-8jan2021.pdf>

<https://www.iau.org/static/publications/dqskies-book-29-12-20.pdf>