Technical Presentation on Recommendations from the Dark & Quiet Skies Workshop

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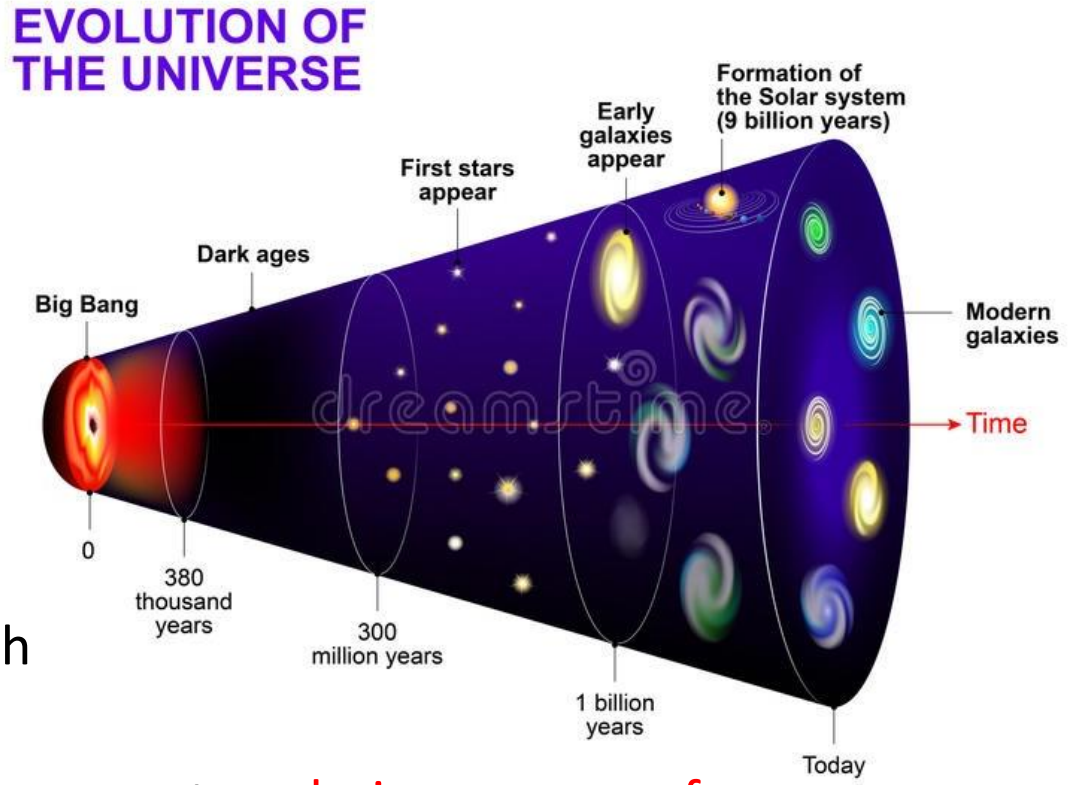
on behalf of the UN Delegates supporting the CRP & Working Group Members of the D&QS Workshop

Why the Protection of Astronomy is of Interest to COPUOS

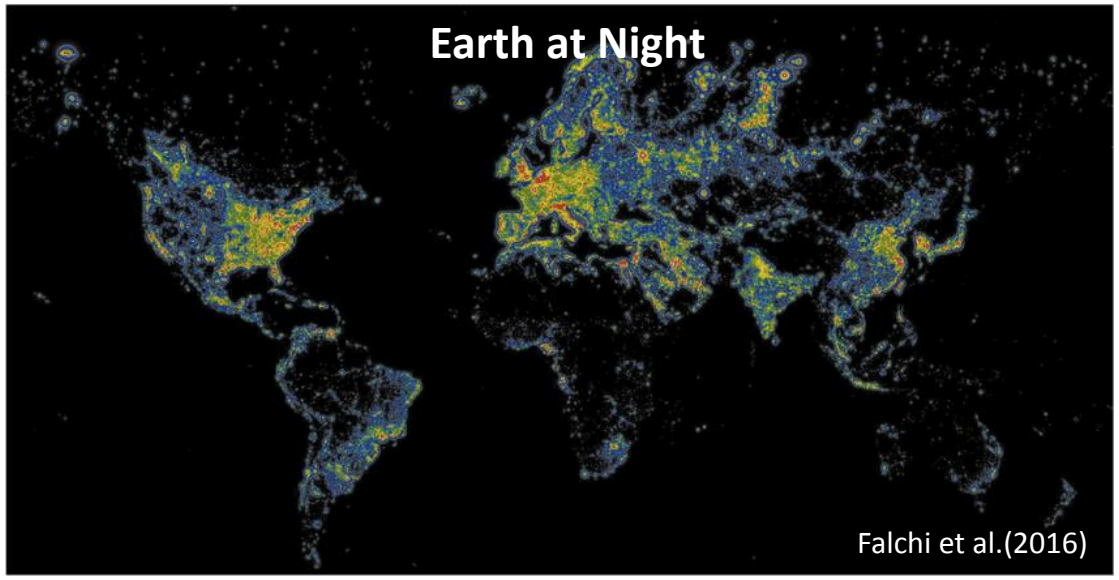
- Throughout the ages, astronomy was instrumental to the progress of scientific knowledge
- New discoveries require unobstructive and undisturbed access to the cosmos
- COPUOS in 2017 approved the organization of a conference aimed at studying all possible protections of dark and quiet skies
- UN/IAU/Spain 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.

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

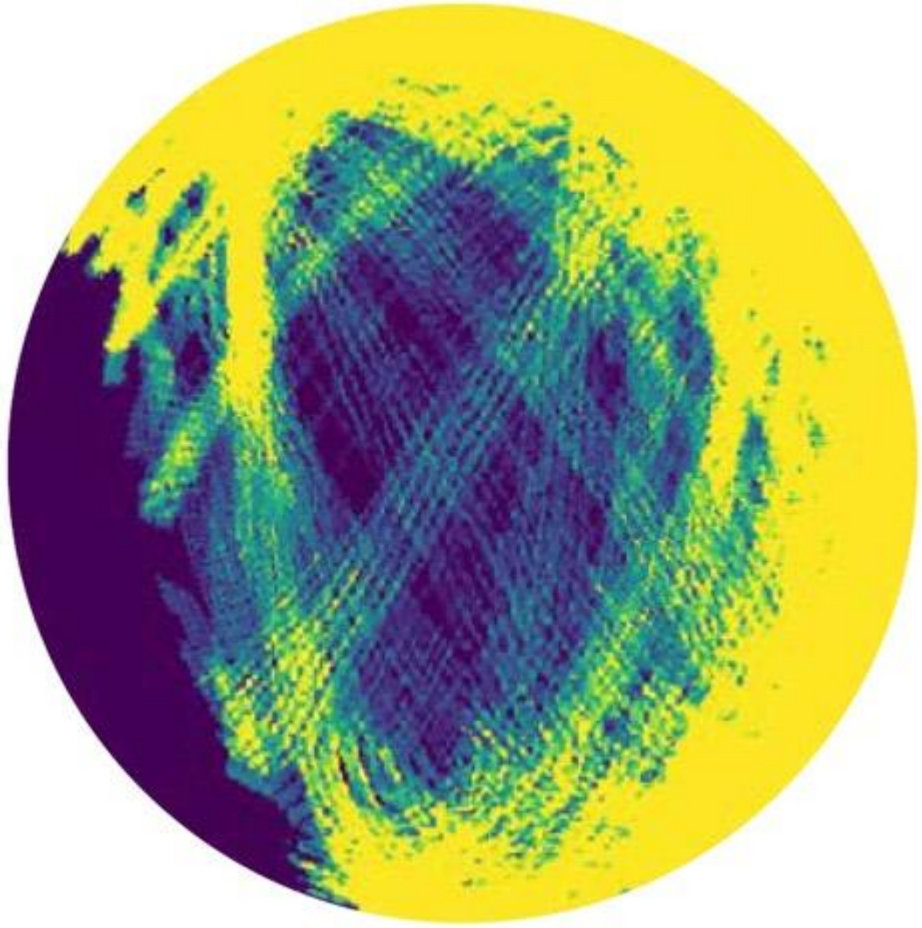
- **The number of visible satellites**
  - Tens of thousands to be launched in the next decade
- **The orbital altitude of the satellites**
  - At any altitude, the projected surface density of bright satellites is greatest near the horizon and during twilight
  - Increasingly visible all night long 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)**

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

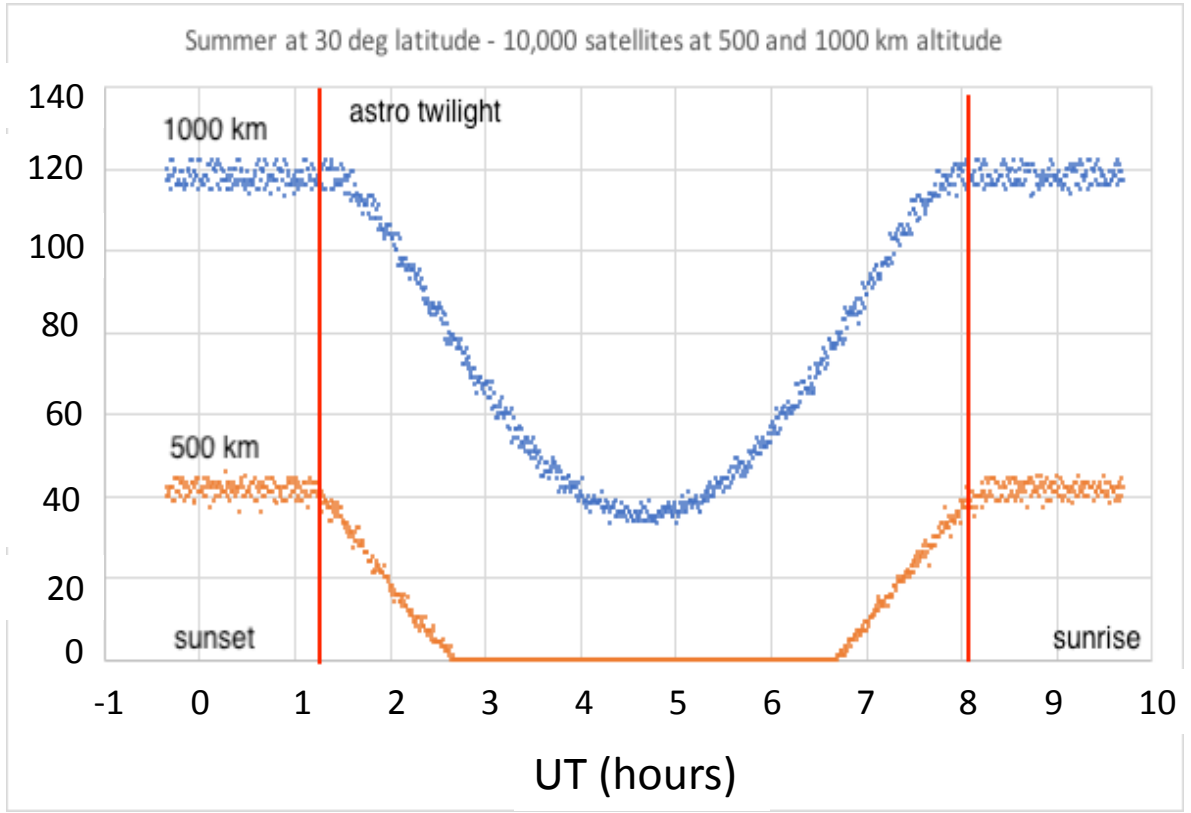


Credit: P. Yoachim (U. Washington/ Rubin Observatory), private communication

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

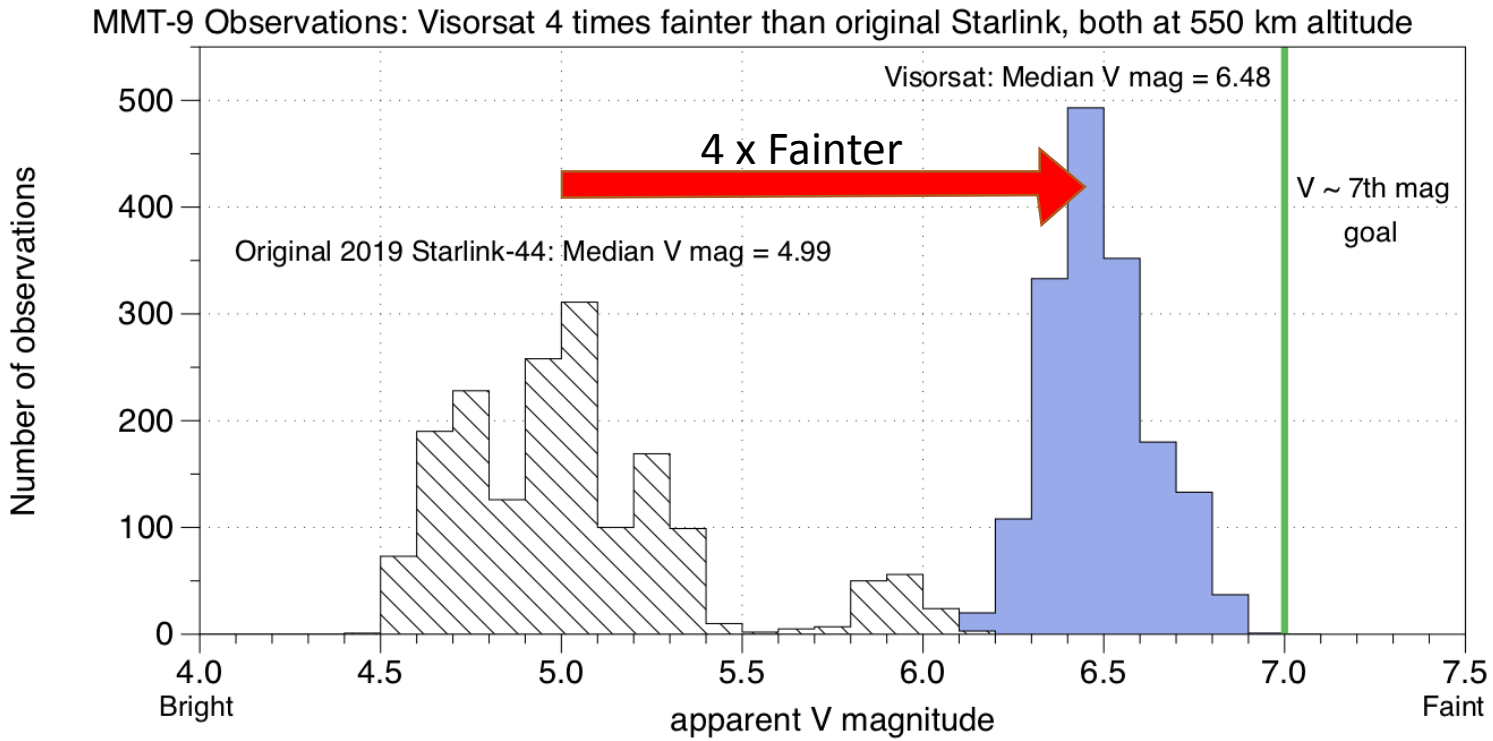
Number of Visible Satellites above Horizon



Credit: P. Seitzer (U. Michigan)

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

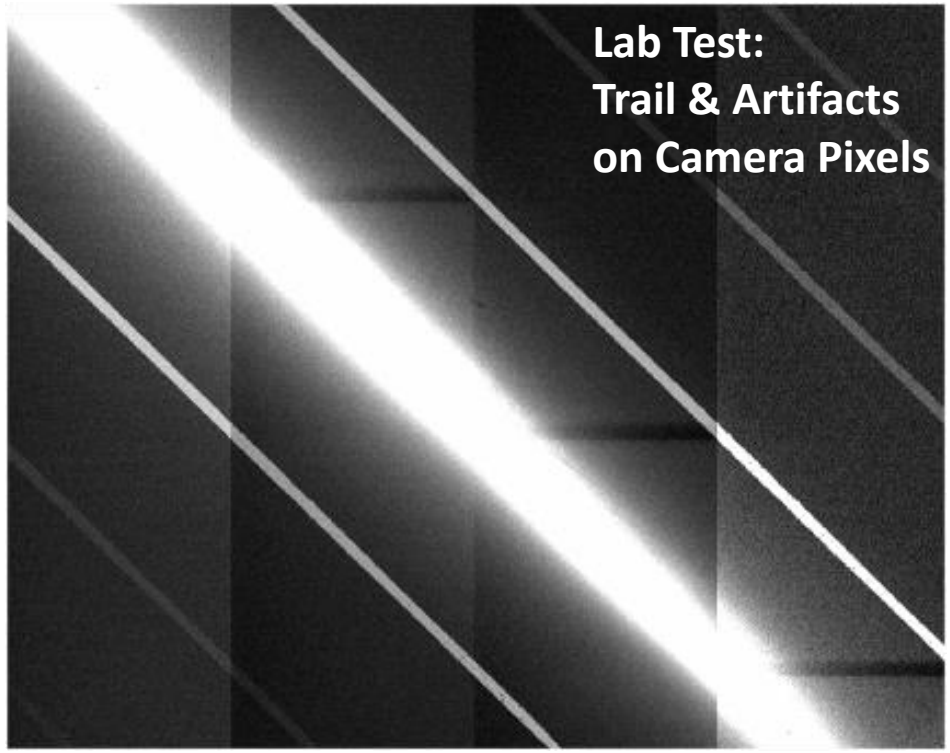
3. **Design satellites** to minimize negative impacts on astronomical observations and the pristine night sky
   - To be fainter than 6th mag to naked eye and 7th mag at 550km for observatories
   - Incorporating dynamic orientation adjustments
   - Minimize both direct and indirect illumination of radio observatories



Credit: P. Seitzer, (U. Michigan)

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

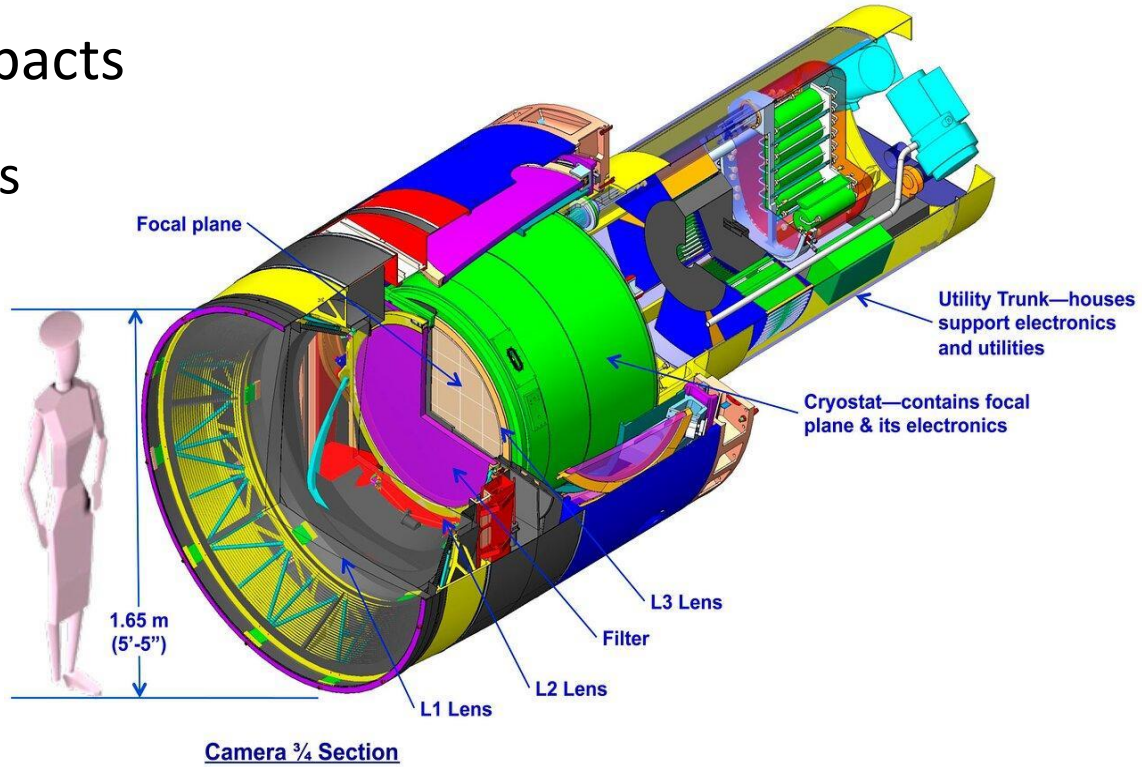
4. **Develop observatory software** to mitigate impacts
   - Identify and mask trails in imaging
   - Create observation planning software linked to accurate satellite positions as a function of time
   - Develop predictive model for brightness as function of orbital phase, including flares
   - Create 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)

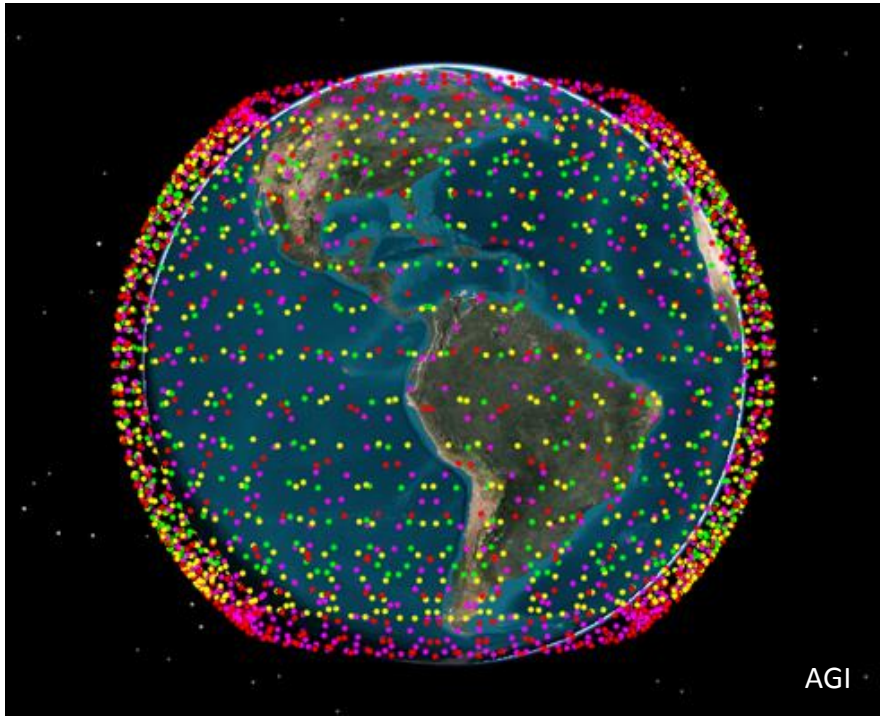
5. **Develop observatory hardware** to mitigate impacts
   - More telescopes, e.g., in NEO discovery networks
   - Instruments that can be shuttered mid-exposure
   - Detectors with pixel shuttering, i.e. CMOS
   - Increase dynamic range of radio receivers and robustness of low-noise amplifiers



Vera C. Rubin LSST Camera

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

Satellites Orbiting Earth in the next Decade



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)

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° 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

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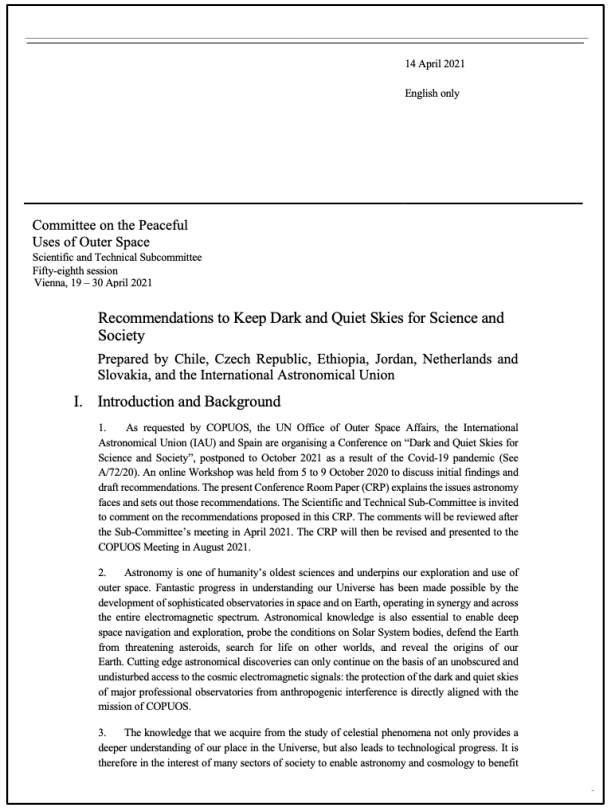
The Dark & Quiet Skies CRP and Full Report are online:



14 April 2021

English only

Committee on the Peaceful
Uses of Outer Space
Scientific and Technical Subcommittee
Fifty-eighth session
Vienna, 19 – 30 April 2021

Recommendations to Keep Dark and Quiet Skies for Science and Society

Prepared by Chile, Czech Republic, Ethiopia, Jordan, Netherlands and Slovakia, and the International Astronomical Union

I. Introduction and Background

1. As requested by COPUOS, the UN Office of Outer Space Affairs, the International Astronomical Union (IAU) and Spain are organising a Conference on "Dark and Quiet Skies for Science and Society", postponed to October 2021 as a result of the Covid-19 pandemic (See A/72/20). An online Workshop was held from 5 to 9 October 2020 to discuss initial findings and draft recommendations. The present Conference Room Paper (CRP) explains the issues astronomy faces and sets out those recommendations. The Scientific and Technical Sub-Committee is invited to comment on the recommendations proposed in this CRP. The comments will be reviewed after the Sub-Committee's meeting in April 2021. The CRP will then be revised and presented to the COPUOS Meeting in August 2021.

2. Astronomy is one of humanity's oldest sciences and underpins our exploration and use of outer space. Fantastic progress in understanding our Universe has been made possible by the development of sophisticated observatories in space and on Earth, operating in synergy and across the entire electromagnetic spectrum. Astronomical knowledge is also essential to enable deep space navigation and exploration, probe the conditions on Solar System bodies, defend the Earth from threatening asteroids, search for life on other worlds, and reveal the origins of our Earth. Cutting edge astronomical discoveries can only continue on the basis of an unobscured and undisturbed access to the cosmic electromagnetic signals: the protection of the dark and quiet skies of major professional observatories from anthropogenic interference is directly aligned with the mission of COPUOS.

3. The knowledge that we acquire from the study of celestial phenomena not only provides a deeper understanding of our place in the Universe, but also leads to technological progress. It is therefore in the interest of many sectors of society to enable astronomy and cosmology to benefit

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