
CSIRO
Dark Skies Down Under
And what keeps astronomers awake at night
(apart from astronomy)
DARK SKY traveller
Fred Watson AM
Honorary Professor, School of Mathematical and Physical Sciences
Australia's first Astronomer-at-Large
MACQUARIE University
SYDNEY·AUSTRALIA

Dark Skies
Down Under

A trilogy in four parts...

- *Our vantage point on the Universe…*
- *Safeguarding radio-quiet skies*
- *Protecting optical observatories*
- *Just when we thought everything was under control*

Australian National University

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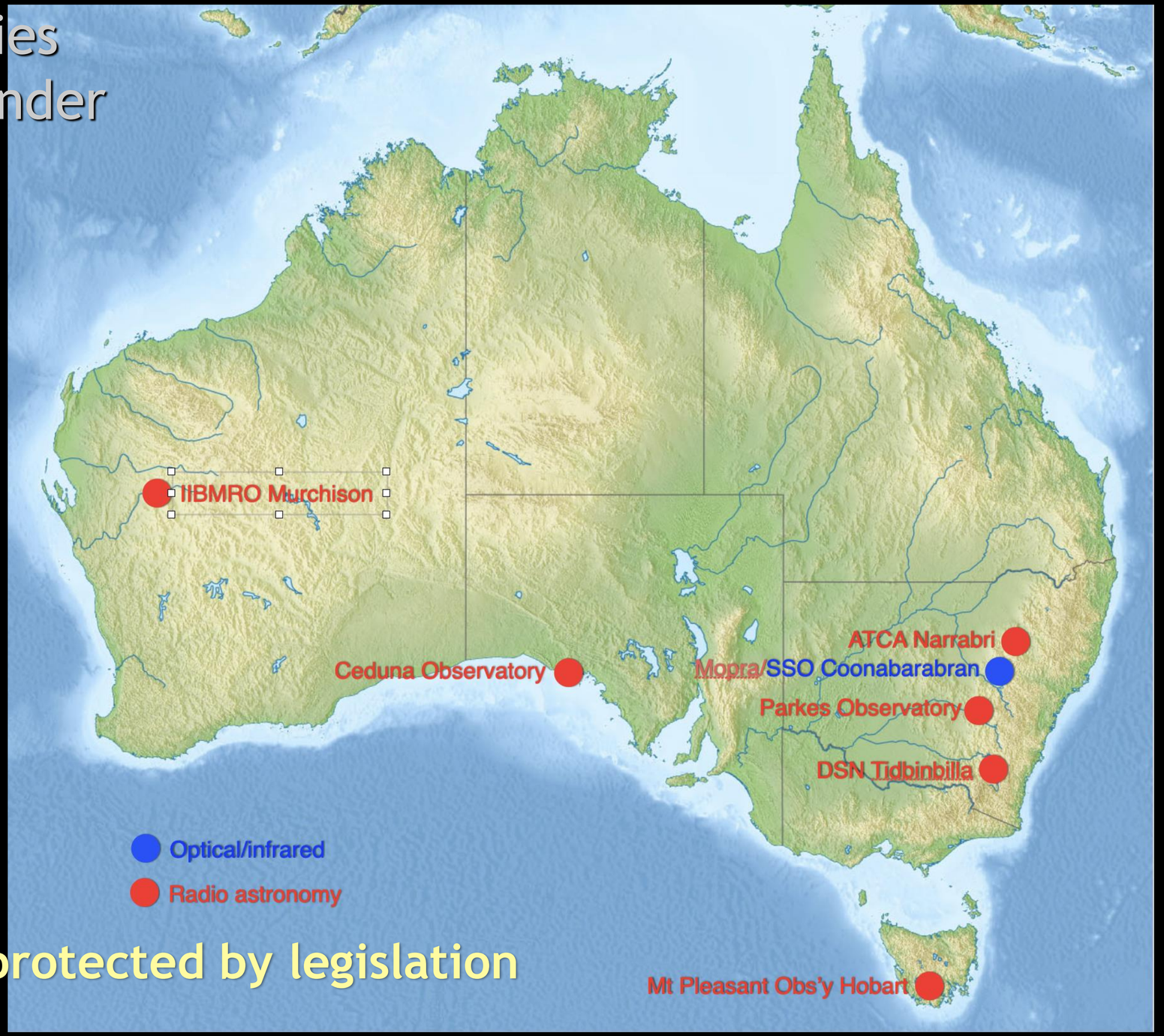
Our vantage point on the Universe…

- *Latitude advantage - important objects*
- *Longitude advantage - fills the southern gap*
- *Stable atmospheric conditions*
- *Dark skies*
- *The most radio-quiet site on Earth*

Tom Elliott, 2018 David Malin Awards

Dark Skies Down Under



Observatories protected by legislation


The daytime sky needs protection from radio-frequency interference
Australia's investment in radio astronomy spans the continent…
From the venerable Parkes antenna (Murriyang) in the east…
Wiradjuri Country
Operated by CSIRO, Australia's national science agency
ATNF/CSIRO

…to the CSIRO Murchison Radio-astronomy Observatory in the west

Inyarrimanha Ilgari Bundara = sharing sky and stars

*Home of the future low-frequency component of the international **Square Kilometre Array***

Wajarri Yamatji Country

CSIRO via Carol Wilson

The new telescope will have 131,072 'Christmas Tree' antennas when it is completed in 2028…

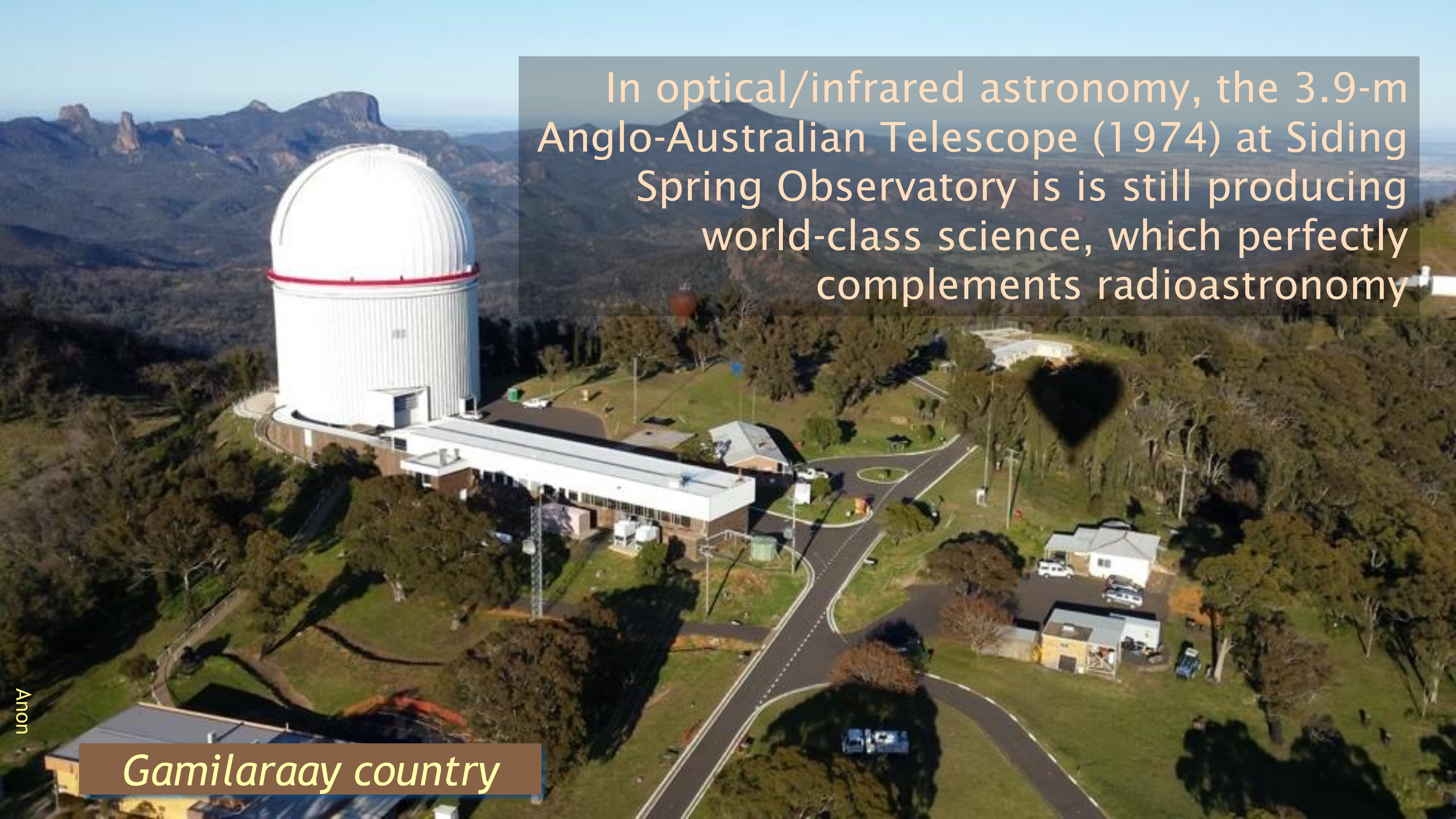
ICRAR/Curtin

The site is legislated to be ‘radio silent’ with unprecedented levels of protection out to 260 km.

ICRAR/Curtin

In detail…

- Murchison Radioastronomy Observatory (MRO) grounds (120 km^2)
  Full/self-control; standards for RFI from observatory equipment
- Boolardy Pastoral Station within which MRO is located (3467 km^2)
  CSIRO held and operated – controls and alternatives
- Mineral Resource Management Area (70 km radius) – WA State Gov't
  Controls for non-licensed radiators (purposeful and incidental)
- Section 19 – Western Australia State Government
  Embargo on new mines in the region
- ACMA Frequency Band Plan – July 2011 – Commonwealth Government
  Radioastronomy is primary within 70 km; consultation within 150 km
- Class licence conditions – devices within 70 km cannot cause interference
- RALI MS 32 – September 2007, rev Dec 2014 - Commonwealth Gov't
  Protection levels at distances up to 260 km (based on frequency)


In optical/infrared astronomy, the 3.9-m Anglo-Australian Telescope (1974) at Siding Spring Observatory is is still producing world-class science, which perfectly complements radioastronomy
Anon
Gamilaraay country

Operated by ANU, owned by the Commonwealth. Dark skies protected by NSW State Legislation out to 200 km

Angel Lopez-Sanchez. AAO-MQ

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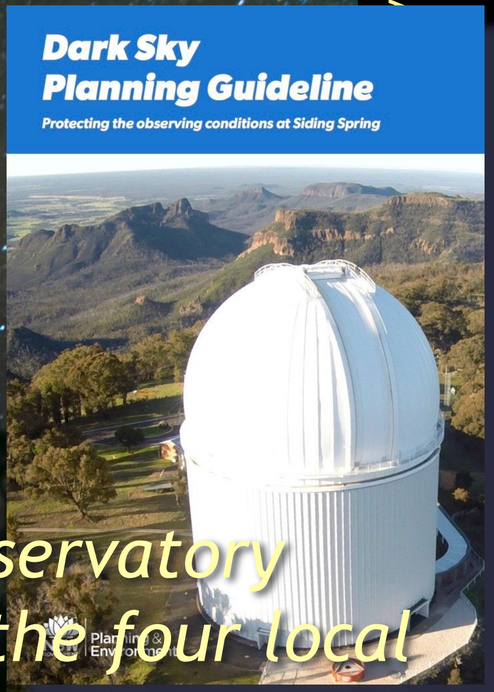


Why do astronomers need dark skies..?

- *Success with NSW legislation protecting Siding Spring Observatory 2016, revised 2024. Four separate legal instruments for the four local government areas involved*
- *Revised Australian lighting standards, 2016-2025*
- *Success with Warrumbungle Dark Sky Park, first southern hemisphere DSI (formerly IDA) Dark Sky Park, 2016*
- *There are now six DSI Dark Sky Places in Australia*
- *Further work ongoing with the Australasian Dark Sky Alliance*

ADSA
AUSTRALASIAN
DARK SKY
ALLIANCE

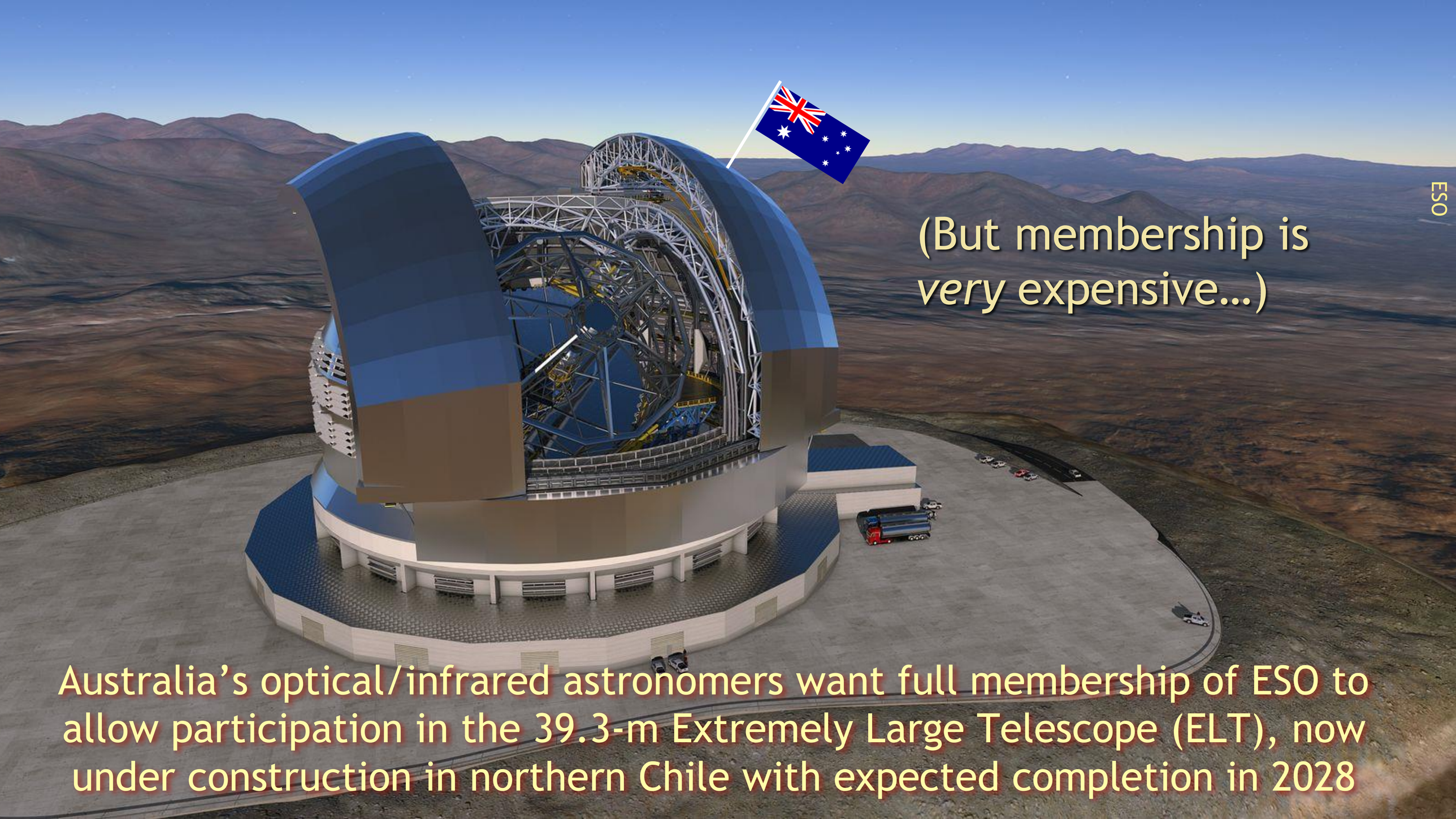
But dark skies are not enough for today's astronomers…

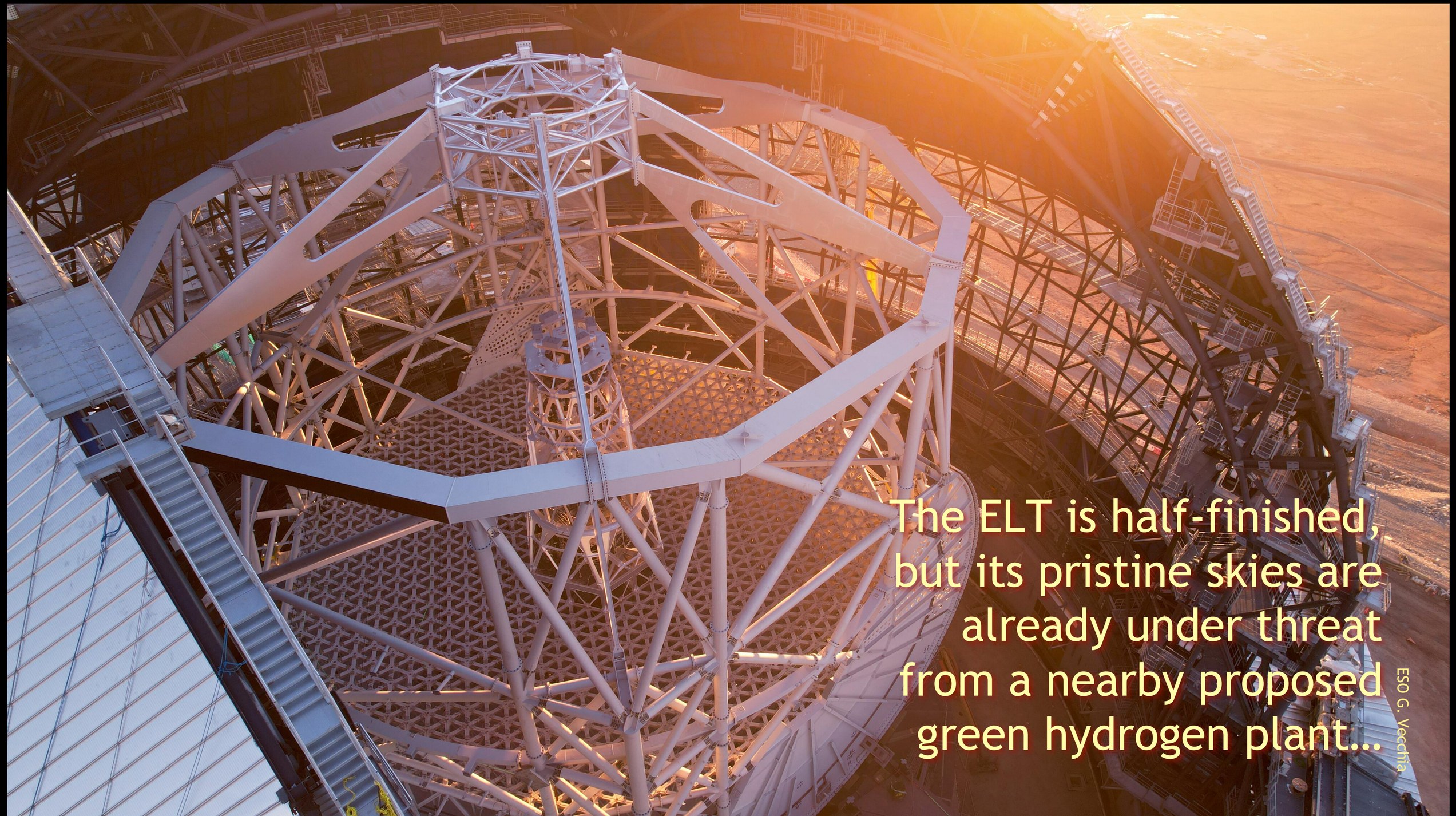
The Australian Government's Strategic Partnership with ESO, the European Southern Observatory, 2017-2027

The VLT: *Antu, Kueyen, Melipal, Yepun in the Mapuche language*

Giving Australian astronomers access to the world's finest southern hemisphere optical/IR telescopes on the finest southern hemisphere site in northern Chile, including the four 8.2-metre telescopes of the VLT

G. Hüdepohl ESO


(But membership is
very expensive…)
ESO
Australia’s optical/infrared astronomers want full membership of ESO to allow participation in the 39.3-m Extremely Large Telescope (ELT), now under construction in northern Chile with expected completion in 2028


The ELT is half-finished,
but its pristine skies are
already under threat
from a nearby proposed
green hydrogen plant...
ESO G. Vecchia

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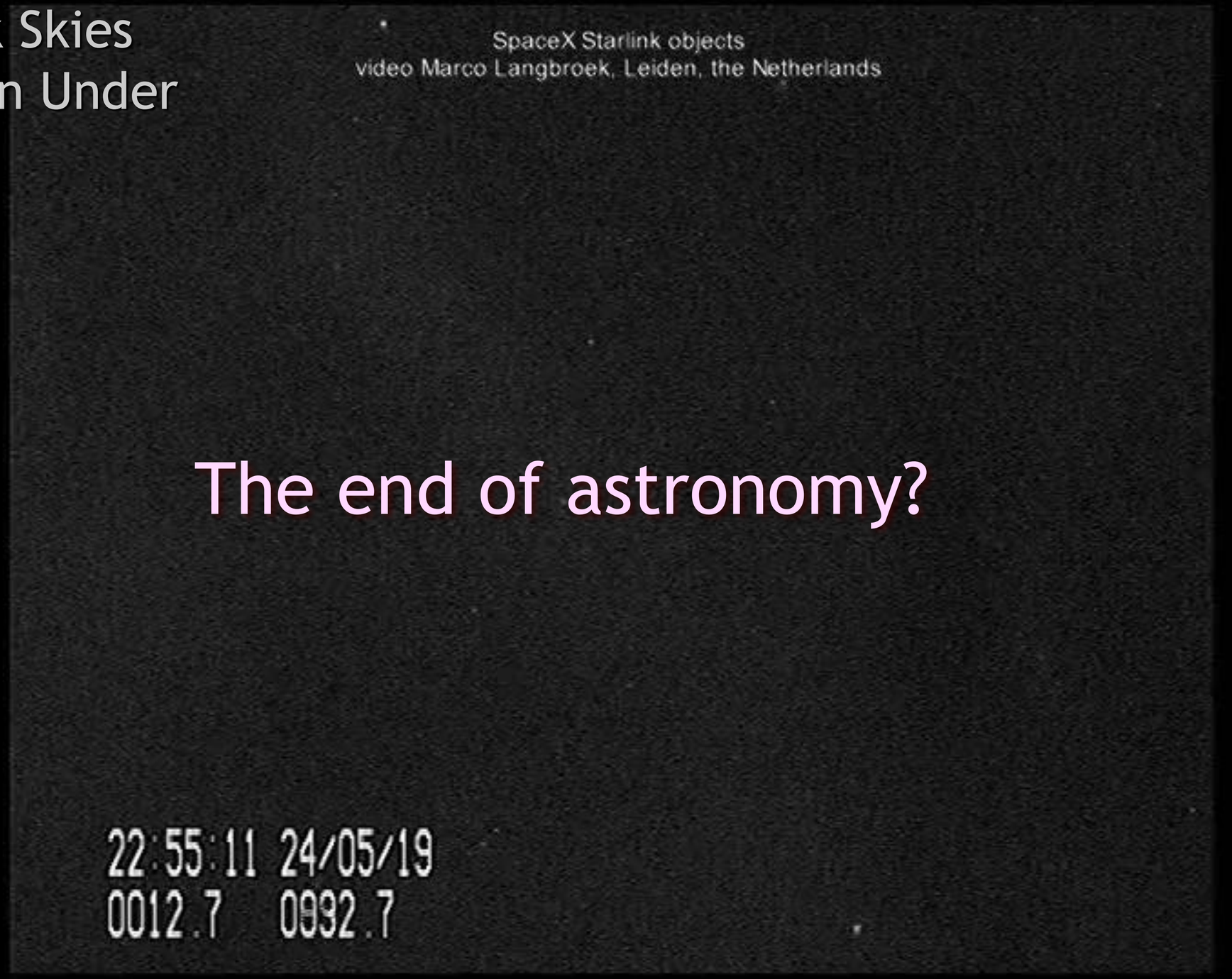


The end of astronomy?

5h after launch (Marco Langbroek, Leiden, the Netherlands)

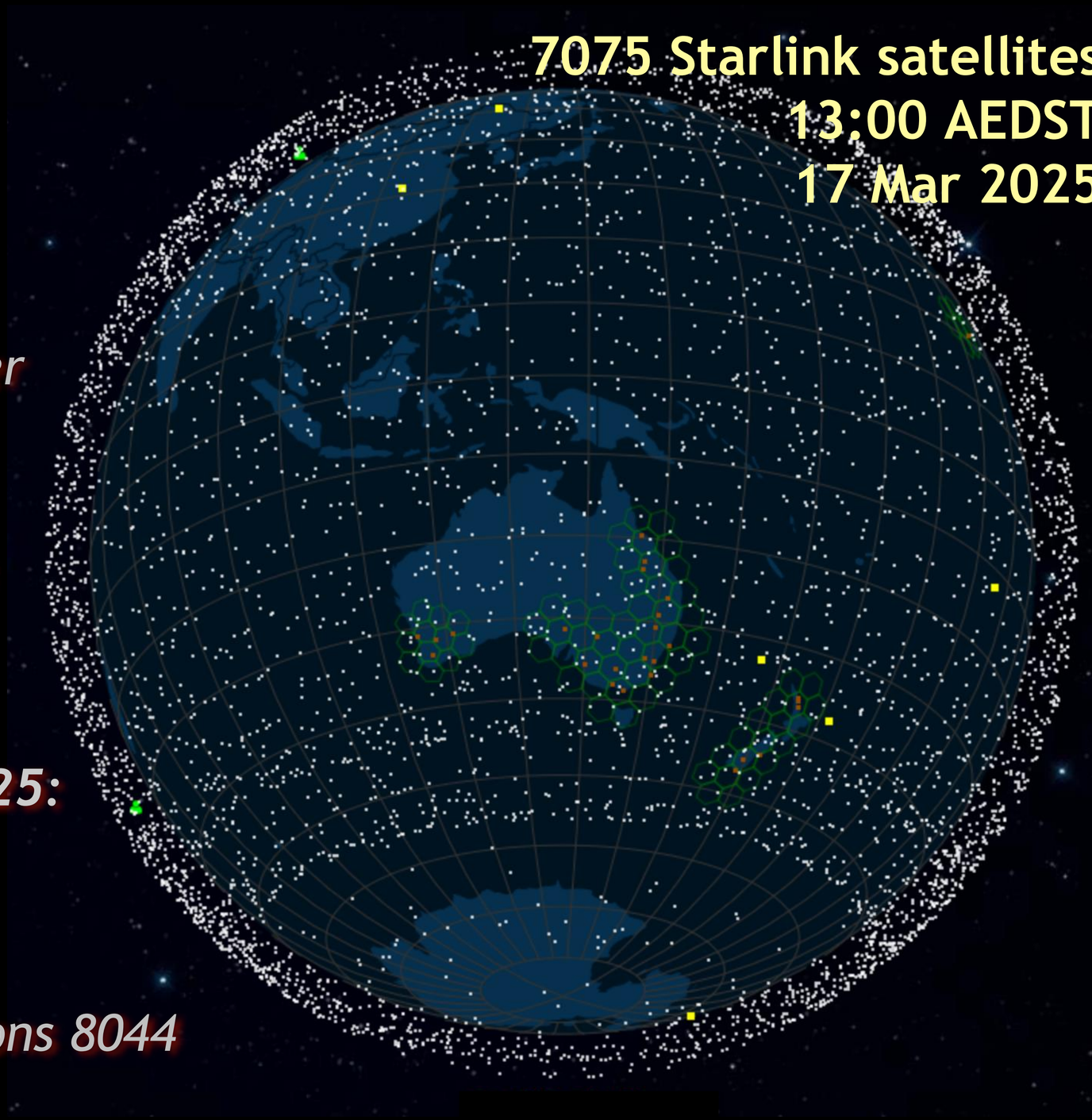
The new challenge…

Australian astronomers share the global challenge of interference from satellite constellations

It affects all sky-watching, whether it's for First Nations traditions or astronomical observation…

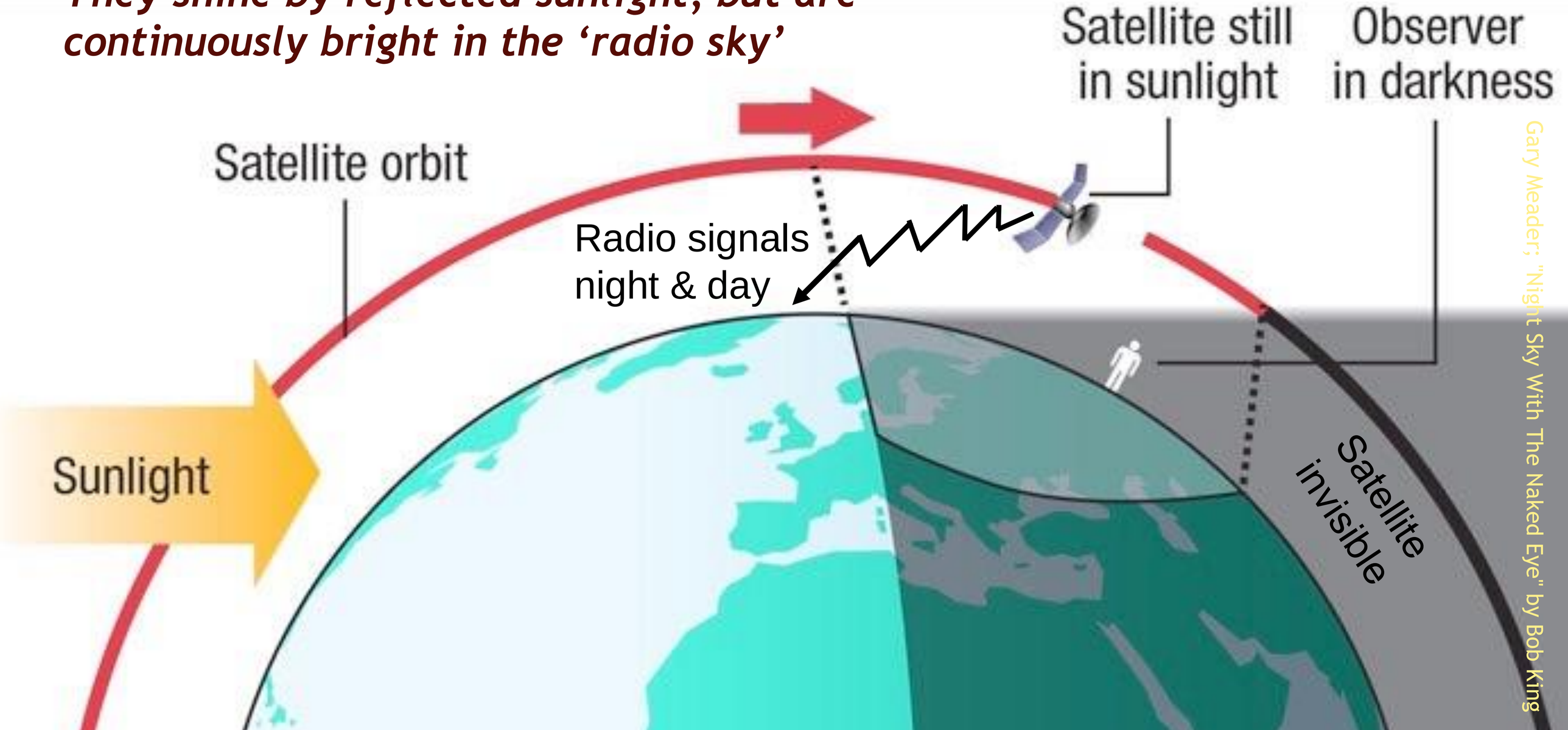
And no amount of legislation from terrestrial interference will protect ground-based astronomy

Constellation stats at 17 Mar 2025:
Planned constellations 22
Planned satellites 560,127
Launched satellites Starlink 7998
Launched satellites all constellations 8044



Why are satellites bright?

They shine by reflected sunlight, but are continuously bright in the 'radio sky'



Gary Meader; "Night Sky With The Naked Eye" by Bob King

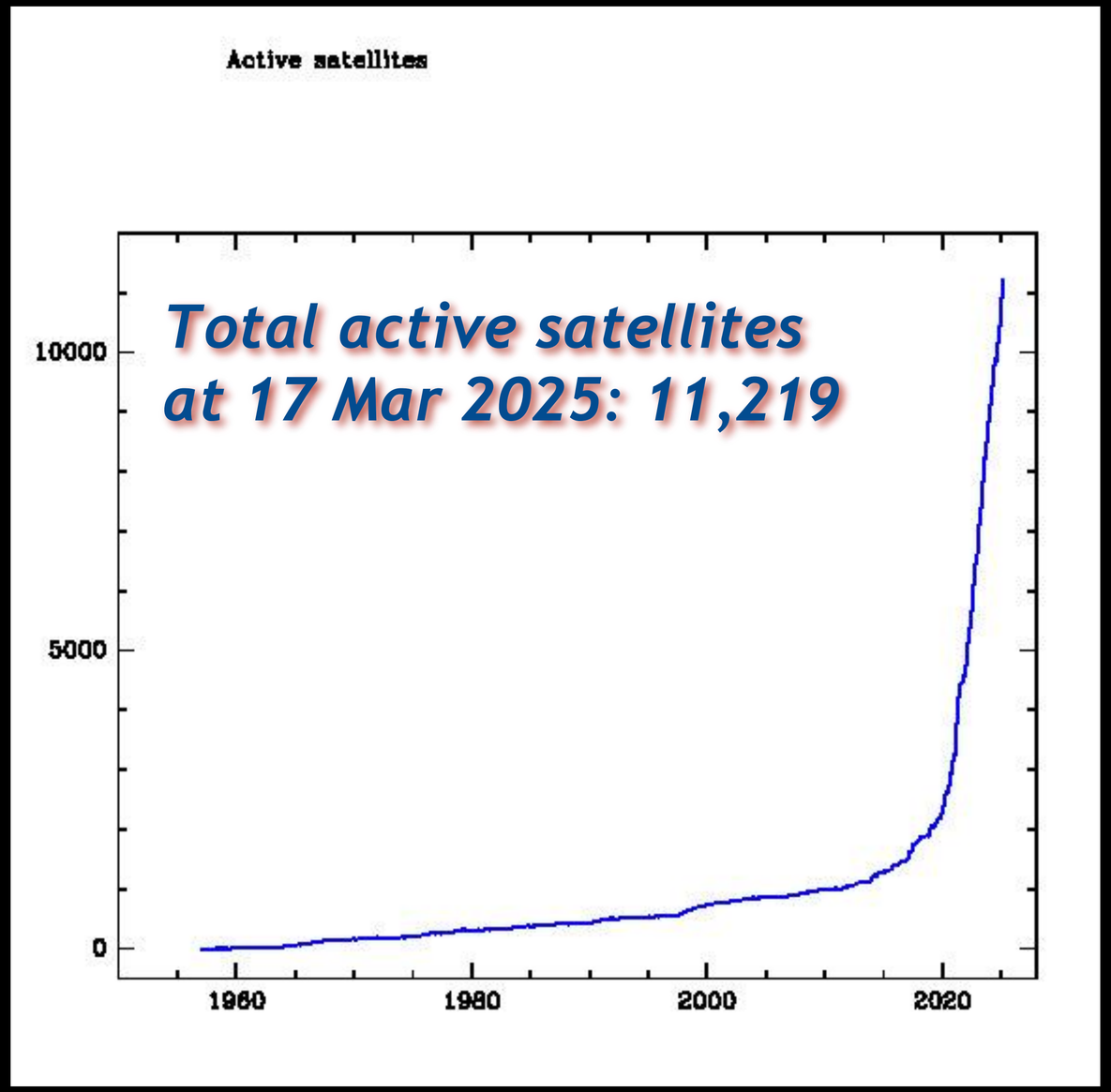
Having started in mid-2019, Starlink (SpaceX) has 7075 of 12,000 planned satellites in orbit (as of Mar 2025)

SpaceX launches at up to 106 satellites per month. ‘Gen2’ is approved to add 30,000 more.

Other players include OneWeb (648), Kuiper (Amazon) 3232 proposed

China Qianfan (Thousand Sails)
14,000 proposed (72 launched)
China Guowang (‘National Network’)
13,000 proposed (10 launched)

Rwandan Cinnamon proposed 327,320 (none launched)



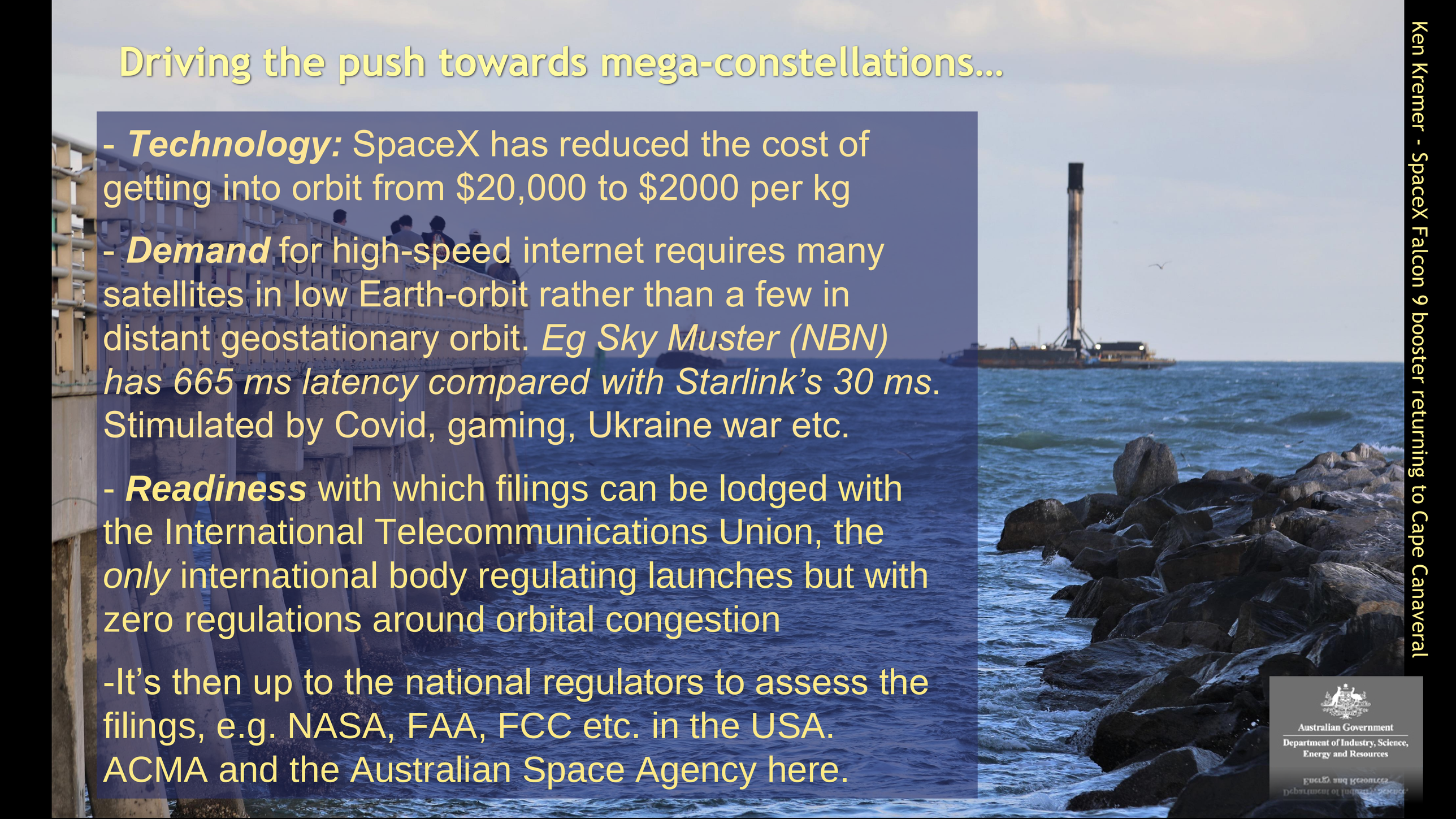
Driving the push towards mega-constellations…

- ***Technology:*** SpaceX has reduced the cost of getting into orbit from $20,000 to $2000 per kg

- ***Demand*** for high-speed internet requires many satellites in low Earth-orbit rather than a few in distant geostationary orbit. *Eg Sky Muster (NBN) has 665 ms latency compared with Starlink's 30 ms*. Stimulated by Covid, gaming, Ukraine war etc.

- ***Readiness*** with which filings can be lodged with the International Telecommunications Union, the *only* international body regulating launches but with zero regulations around orbital congestion

-It's then up to the national regulators to assess the filings, e.g. NASA, FAA, FCC etc. in the USA. ACMA and the Australian Space Agency here.



Ken Kremer - SpaceX Falcon 9 booster returning to Cape Canaveral

Australian Government
Department of Industry, Science, Energy and Resources

A realistic assessment…

‘Take them with a pinch of salt’ (Aarti Holla-Maini, Secretary General of the Global Satellite Operators Association)

The industry itself is concerned about the collision risks associated with very large satellite numbers - ‘a space sustainability crisis’

It’s possible that future generations will be more efficient ⇒ fewer spacecraft

But there could still be 100,000 satellites in low Earth-orbit by the end of the decade, with 5000 above the horizon at any time

Ken Kremer

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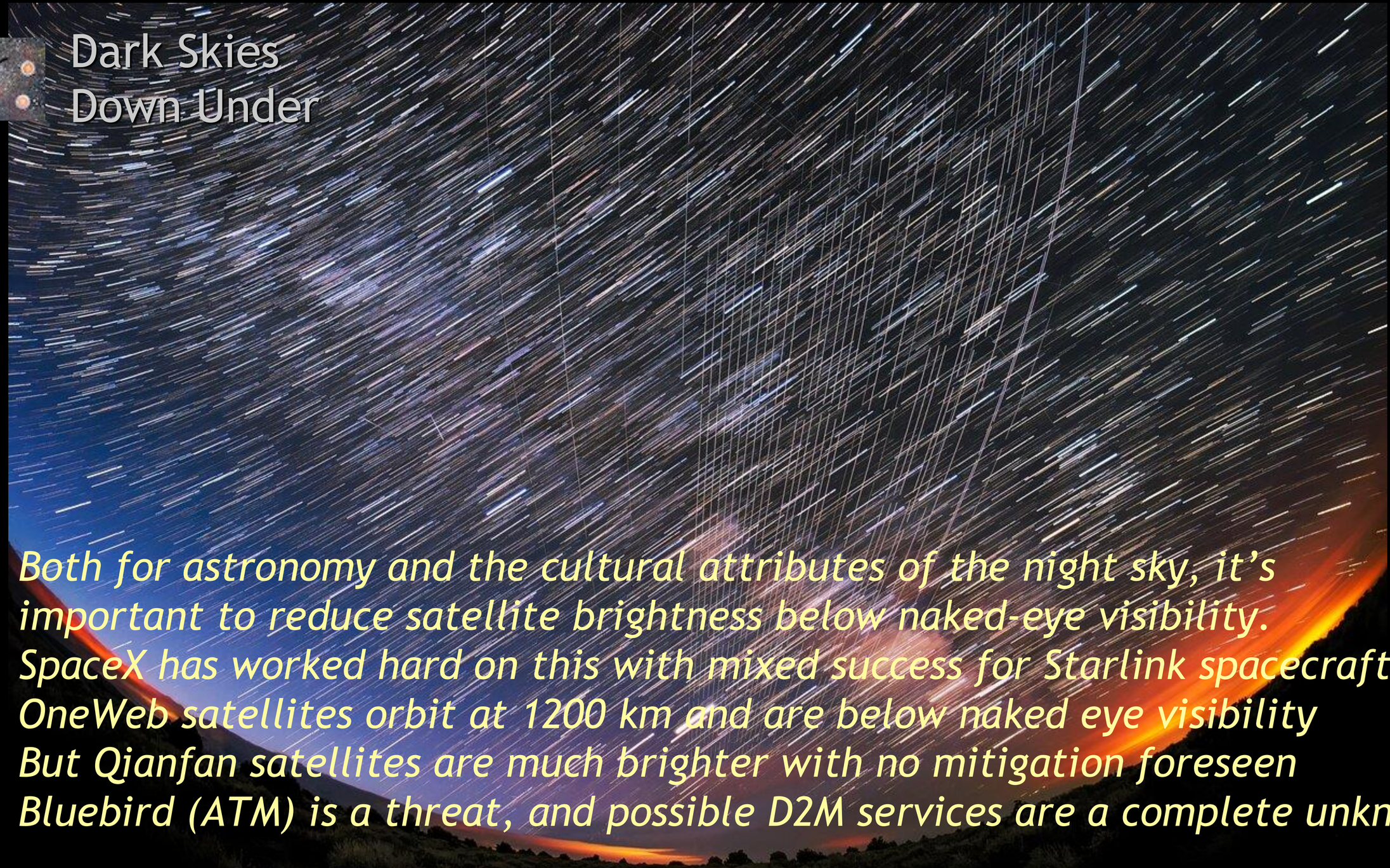

Carson National Forest, New Mexico, M.Lewinsky

- *Both for astronomy and the cultural attributes of the night sky, it's important to reduce satellite brightness below naked-eye visibility.*
- *SpaceX has worked hard on this with mixed success for Starlink spacecraft.*
- *OneWeb satellites orbit at 1200 km and are below naked eye visibility*
- *But Qianfan satellites are much brighter with no mitigation foreseen*
- *Bluebird (ATM) is a threat, and possible D2M services are a complete unknown*

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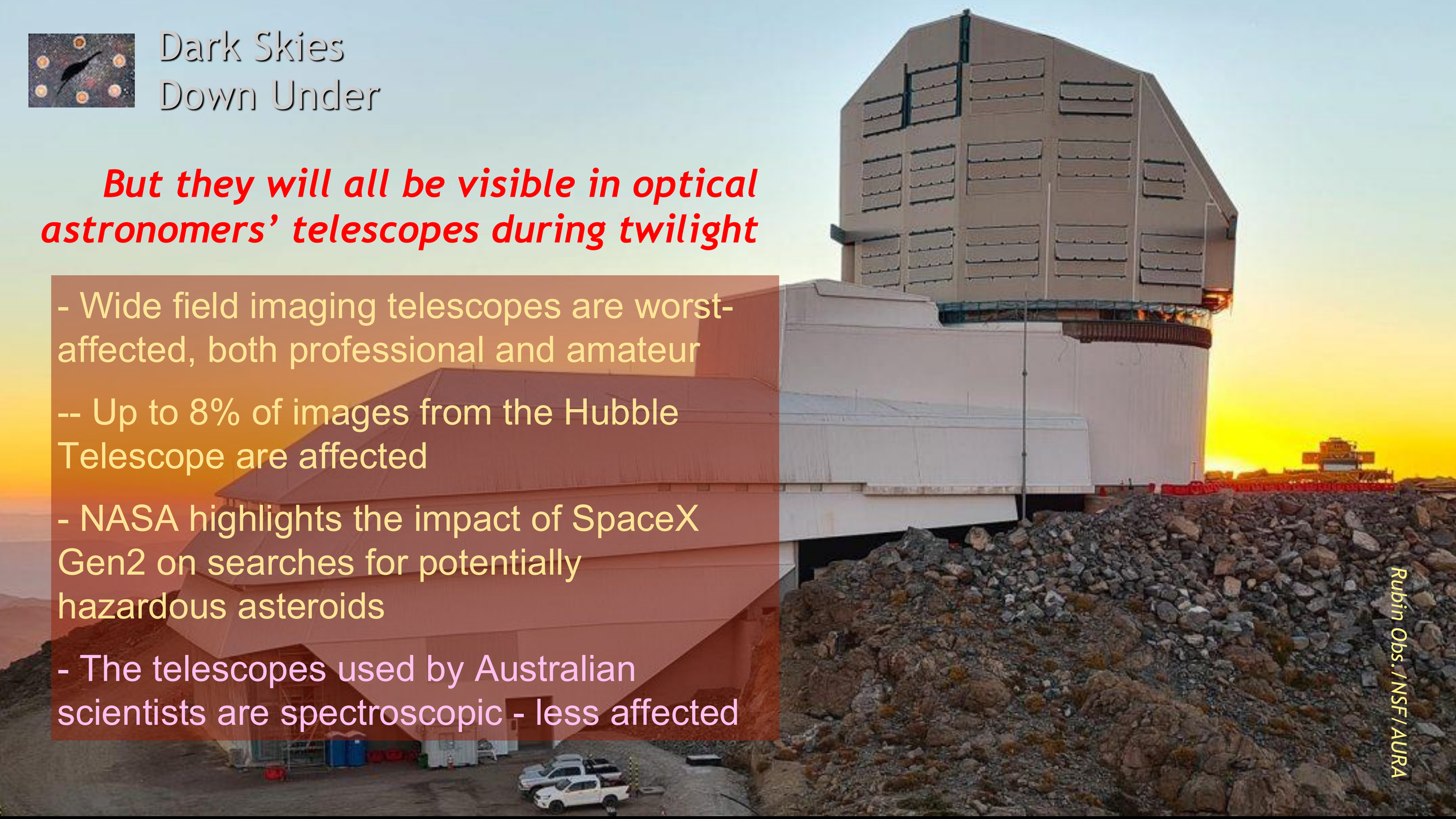
But they will all be visible in optical astronomers' telescopes during twilight

- Wide field imaging telescopes are worst-affected, both professional and amateur

-- Up to 8% of images from the Hubble Telescope are affected

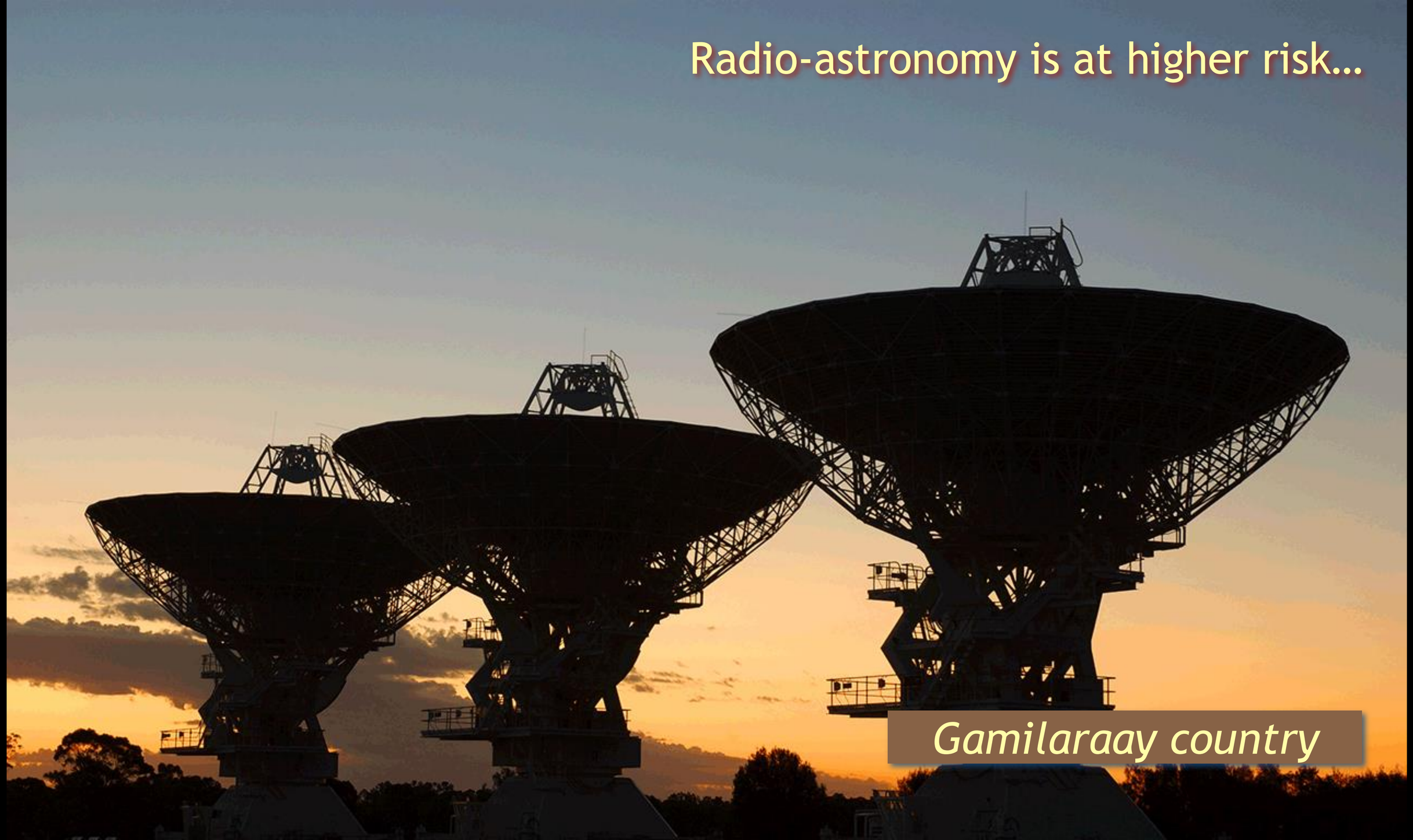
- NASA highlights the impact of SpaceX Gen2 on searches for potentially hazardous asteroids

- The telescopes used by Australian scientists are spectroscopic - less affected



Rubin Obs./NSF/AURA

Radio-astronomy is at higher risk…

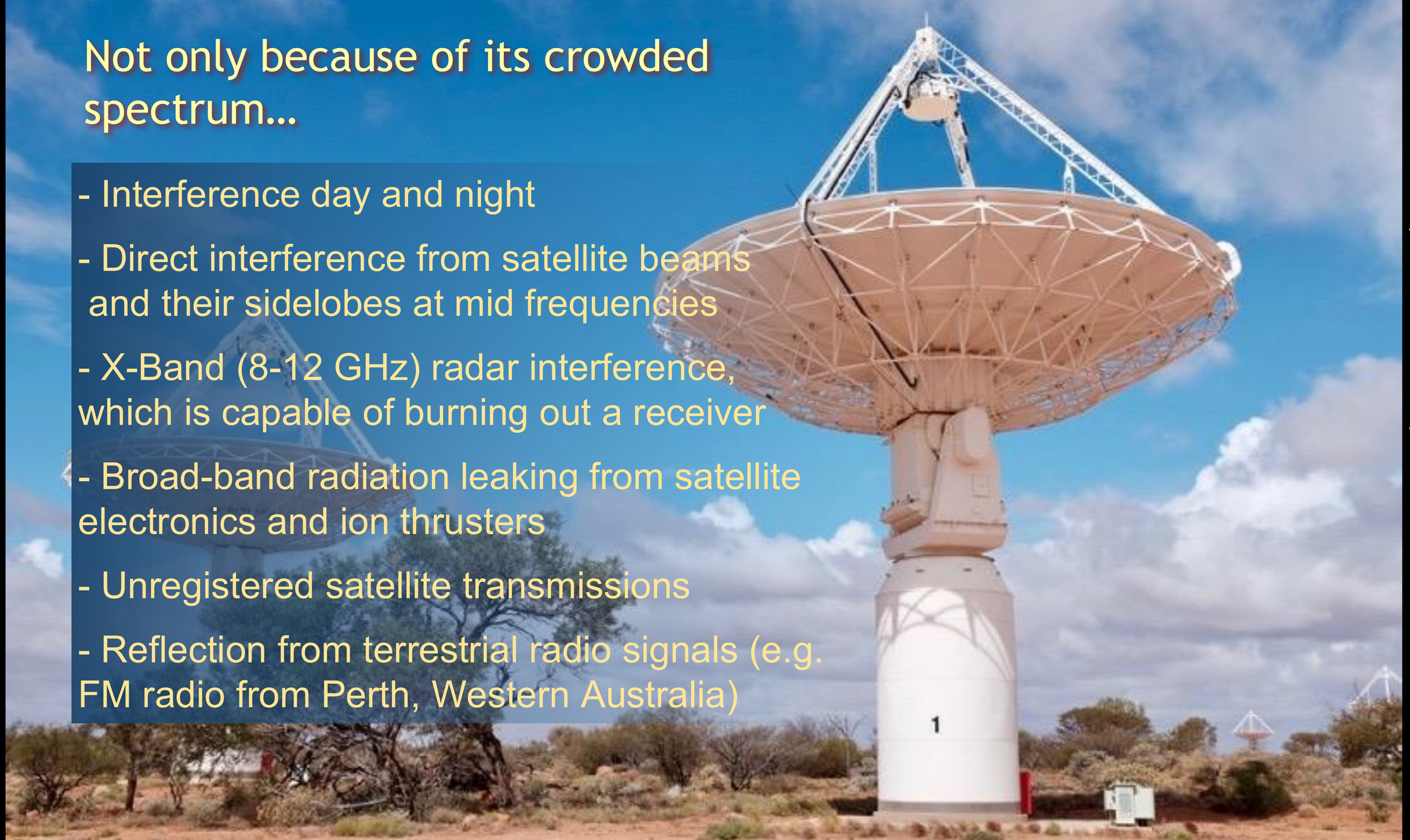


Gamilaraay country

CSIRO

Not only because of its crowded spectrum…

- Interference day and night
- Direct interference from satellite beams and their sidelobes at mid frequencies
- X-Band (8-12 GHz) radar interference, which is capable of burning out a receiver
- Broad-band radiation leaking from satellite electronics and ion thrusters
- Unregistered satellite transmissions
- Reflection from terrestrial radio signals (e.g. FM radio from Perth, Western Australia)



Australian Square Kilometre Array Pathfinder, Mark Stickells, CSIRO

Ruth Vincent

What are astronomers doing?

- Grumbling a lot to start with (despite most astronomers being space enthusiasts!)
- Since Jan 2020, holding (very) numerous meetings
- Producing numerous technical papers from observatories, institutions and professional bodies
- IAU draft submissions to UN COPUOS STSC
- Raising D&QS at the COPUOS in 2022, 2023, 2024 and 2025 (this time successfully)
- Forming a UN ‘Group of Friends’ on the issue in 2023

Australia supports the efforts of the space industry and the astronomical community to build bridges between all stakeholders, continue research and disseminate resources.
Engages with the UN Committee on the Peaceful Uses of Outer Space

Michael Cook, Australian Space Agency

What do astronomers want from the space industry?

- Reduce satellite reflectivity

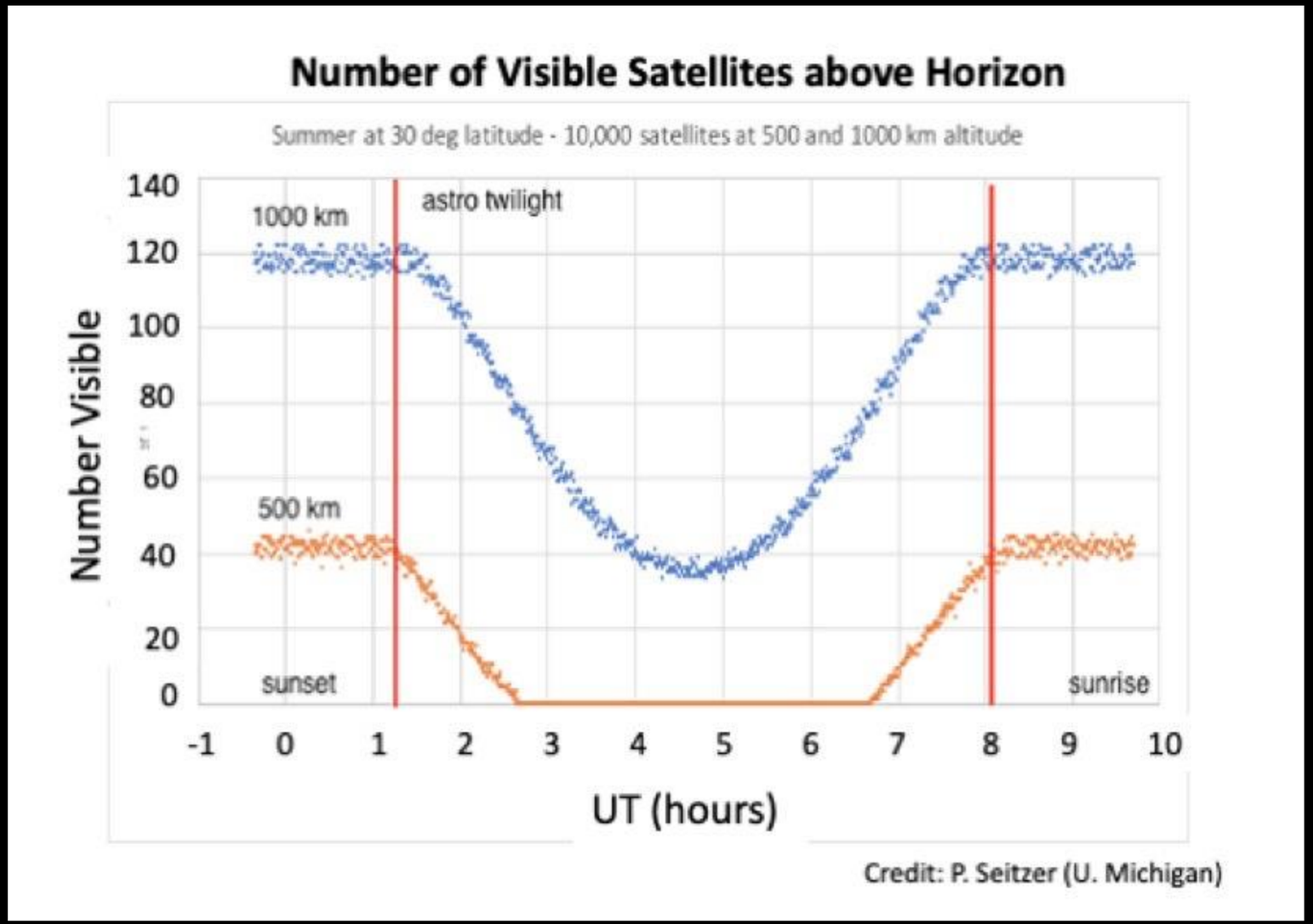
- Minimise satellite numbers and operate them below 600km (SpaceX complied from 2020)

-- Avoid directly illuminating radio observatories (ditto)

- Comply with ITU signal strengths and frequencies

- Better regulation (at present there's none relating to optical astronomy, and limited for radio)

- Provide accurate positions



P. Seither (U. Michigan)

Both optical and radio astronomers are developing pre-and post-observation mitigation strategies

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Opportunities in the wider community

Astronomy outreach

Sightings of the ‘satellite train’ effect feed directly into outreach opportunities. Most folk have no idea what they are and are keen to know.

Once told, they quickly understand the consequences for astronomers.

The IAU Centre is keen to communicate with science communicators at all levels, including amateur groups and individual astronomers.
See https://cps.iau.org

Star Walk

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Astronomy will not be the same in the era of megaconstellations, but will continue to flourish

Dark and quiet locations remain vitally important to us all.

Thanks everyone!

Fred Watson is supplied by *Dark Sky Traveller and Macquarie University*

(Along with the Space Nuts *podcast and fredwatson.com.au)*

Greg Priestley, David Malin Awards 2018