



Radio Astronomy Protection for Direct-to-Device Applications

Interaction between satellites and
astronomy

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Presenting on behalf of Federico Di Vruno – SKAO Spectrum Manager

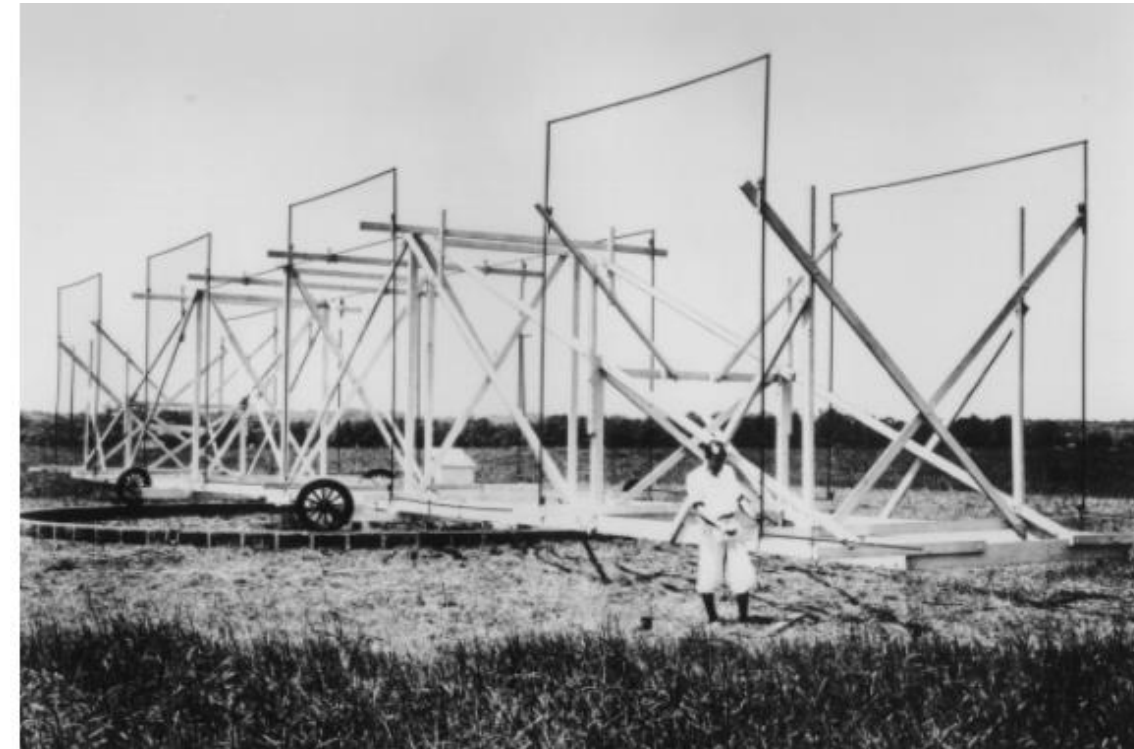
13 Oct – NTN Days 2026, Session 1

What is Radio Astronomy?

1932

Karl Jansky detects radio waves from the Milky Way

Radio waves pass through dust and gas, showing what optical telescopes miss



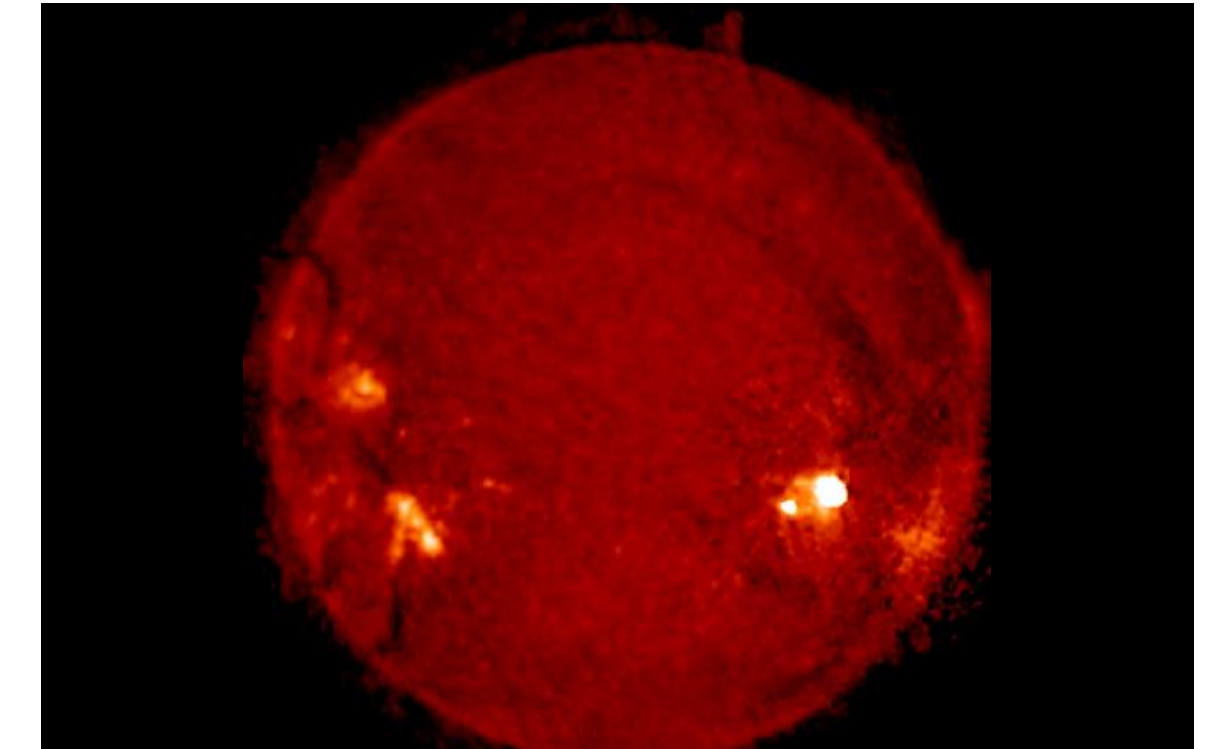
Jansky's merry-go-round antenna

Credit: AT&T / Bell Labs



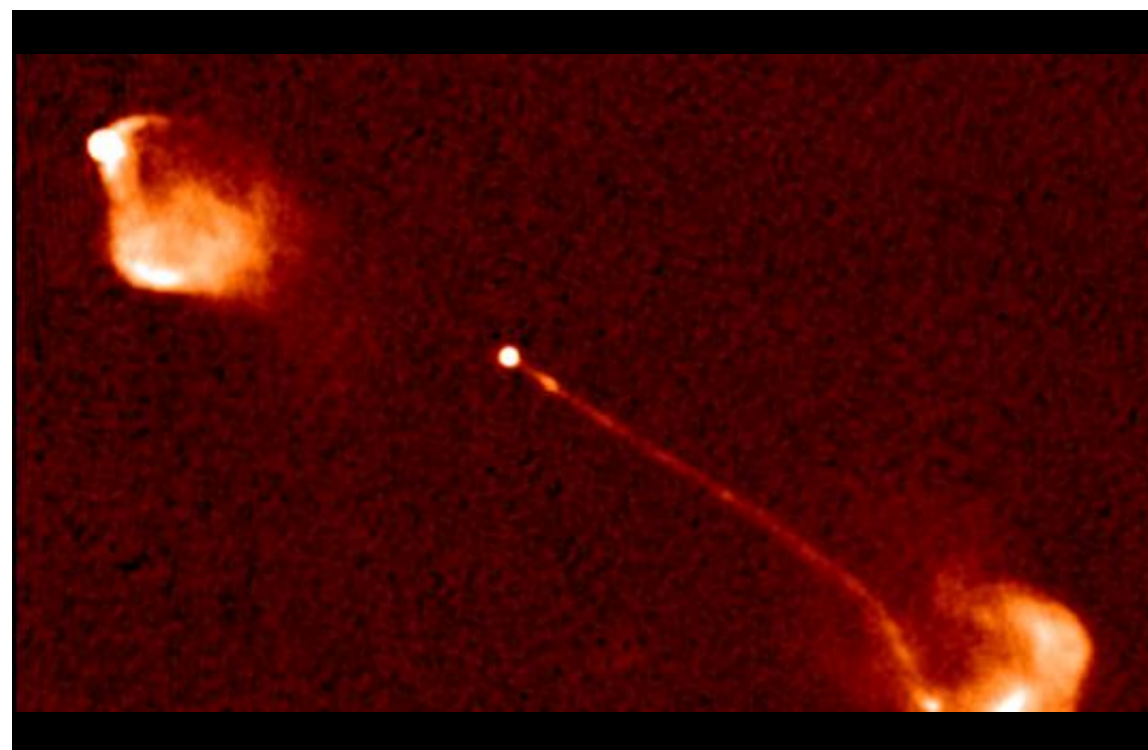
Grote Reber's backyard dish

Credit: NRAO



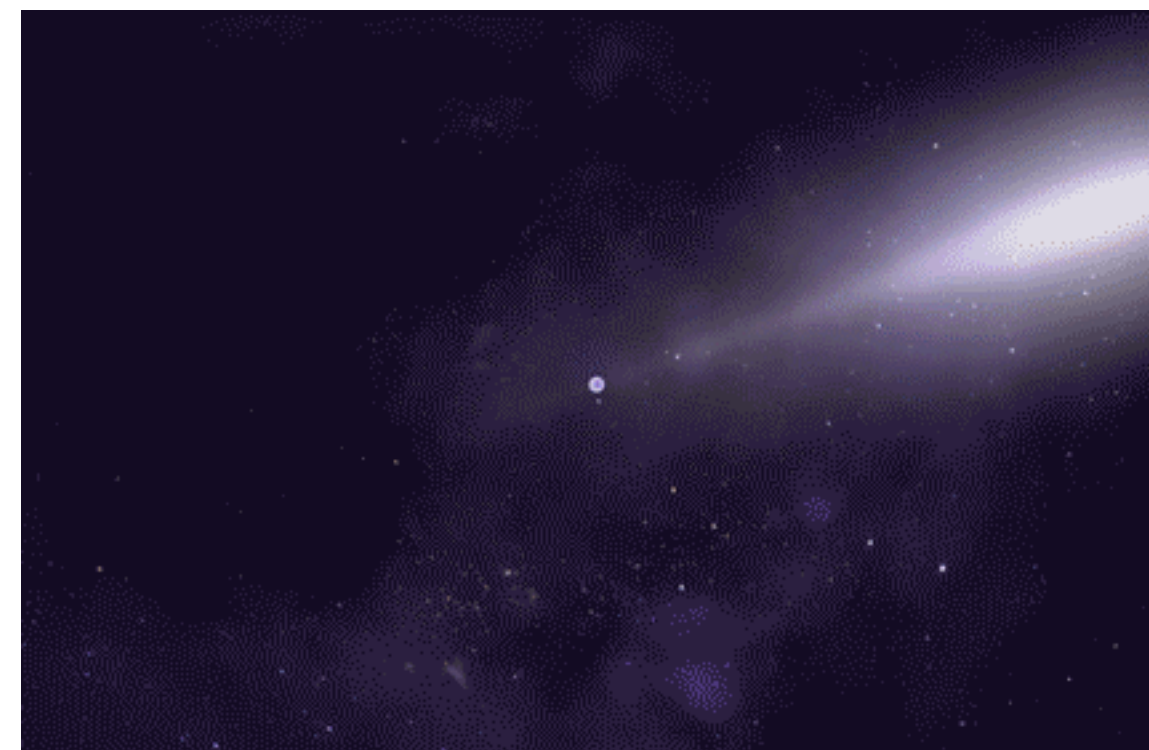
The Sun at 4.6 GHz (VLA)

Credit: NRAO



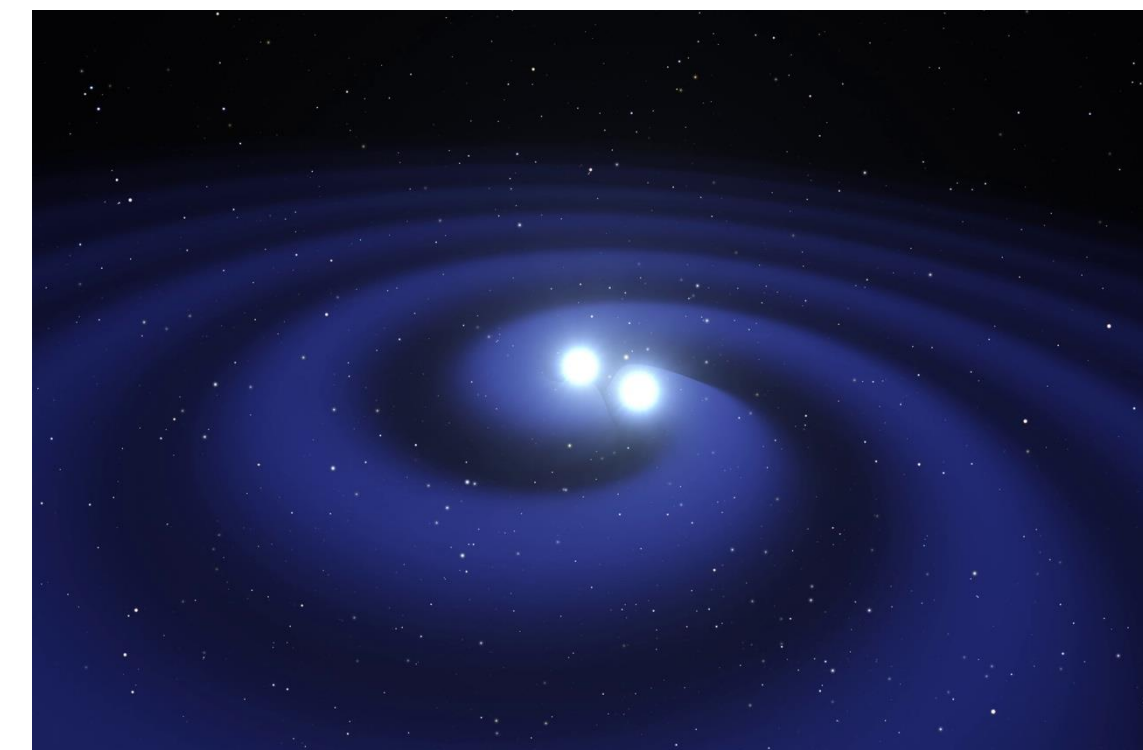
Quasar 3C175

Credit: NRAO



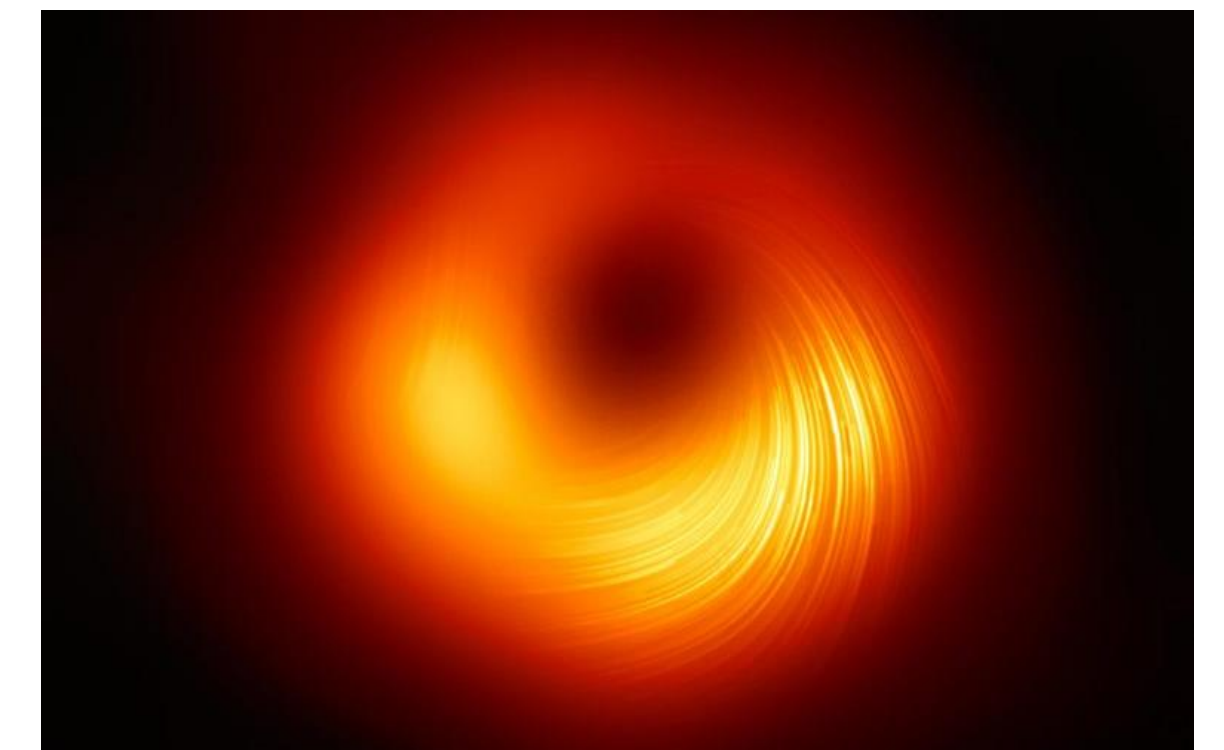
Pulsar

Artist's impression · NASA



Neutron-star merger

Artist's impression · ESA

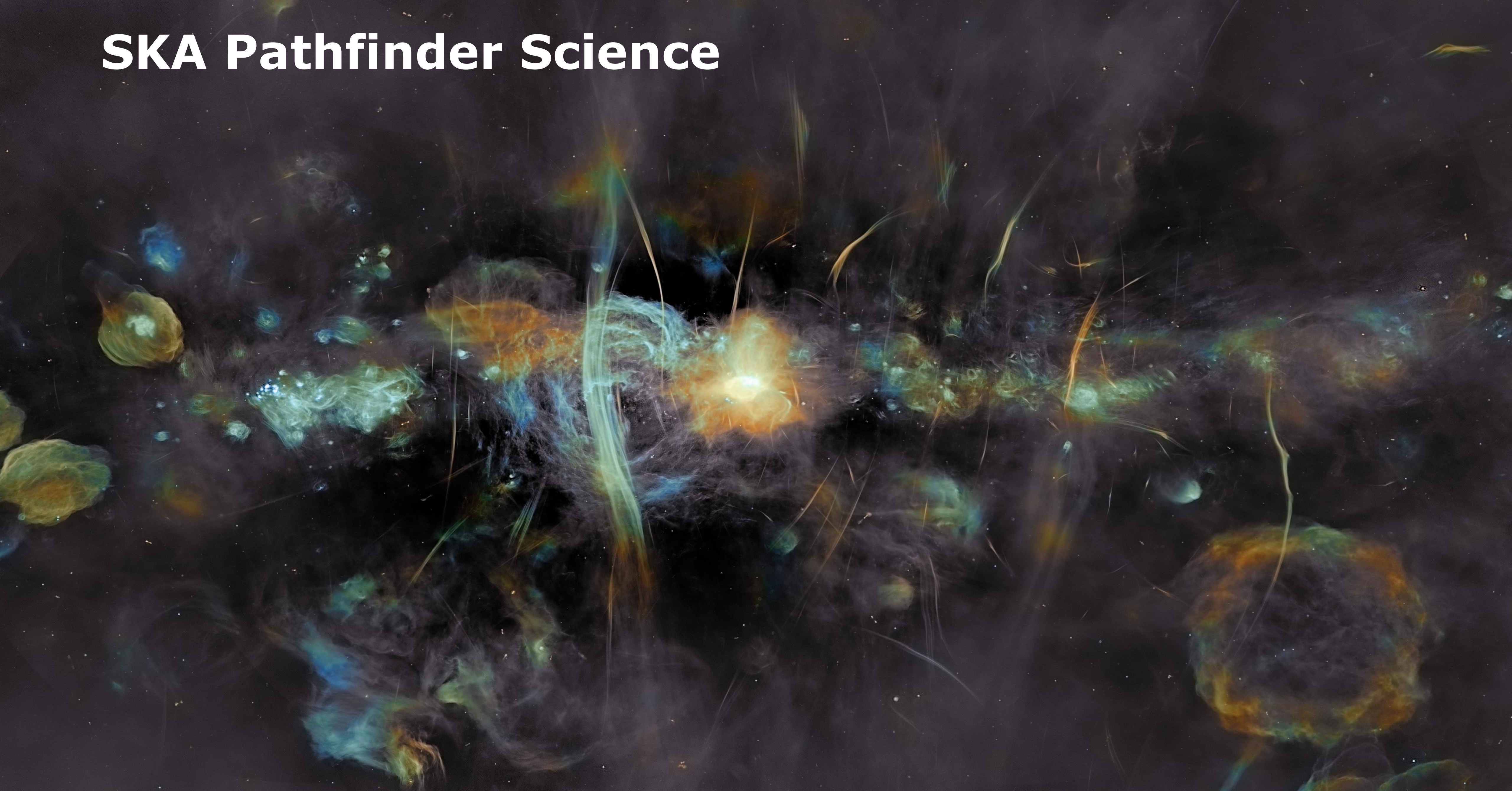


The black hole in M87

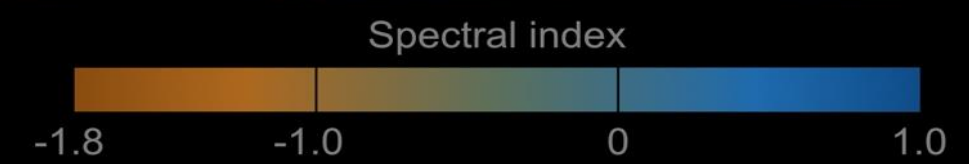
Credit: EHT Collaboration



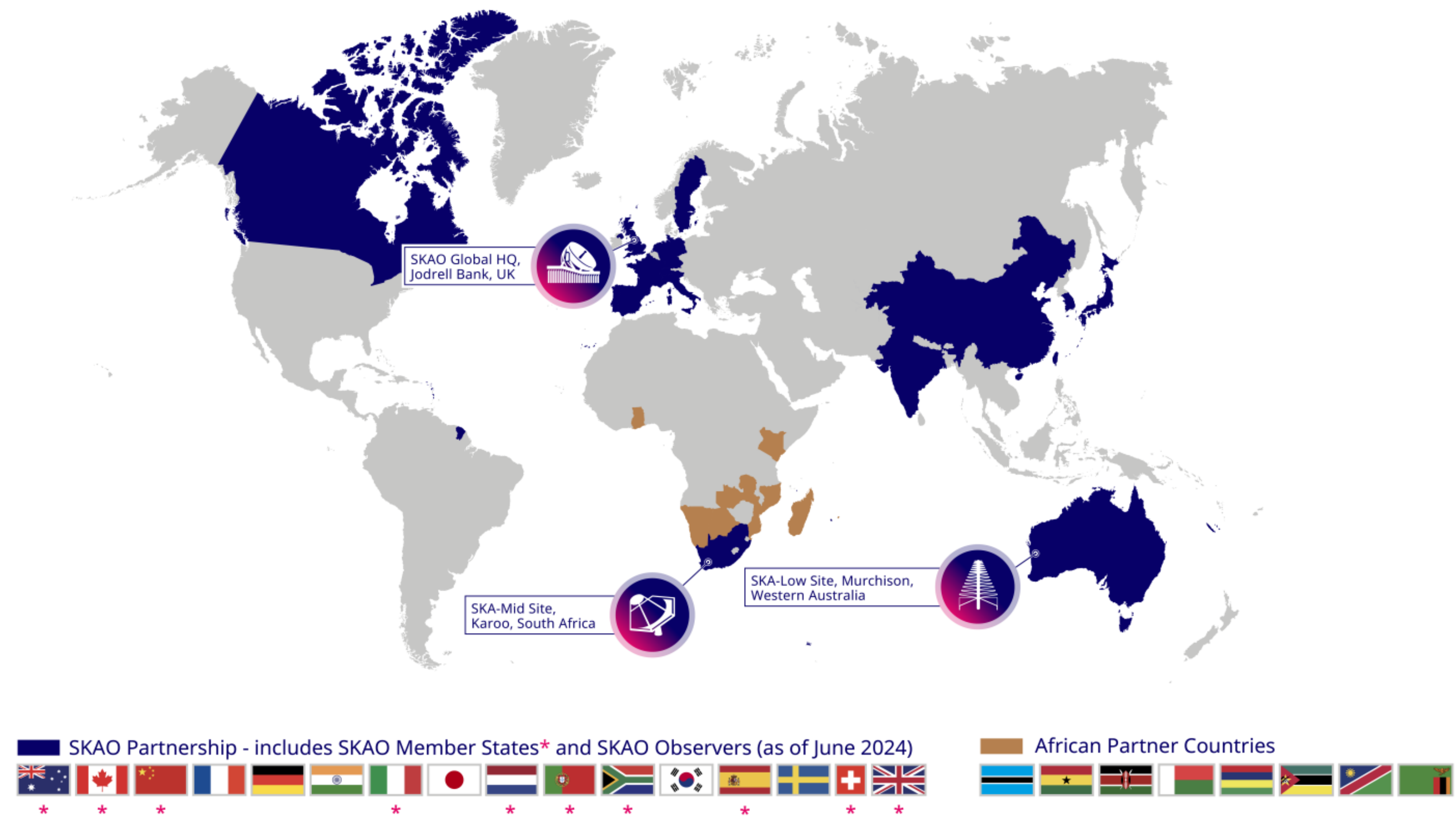
SKA Pathfinder Science



SARAO, Heywood et al. (2022) / J. C. Muñoz-Mateos



The SKA Observatory



Source: SKAO. Partnership as of June 2024.

THE PARTNERSHIP

10

SKAO Member States

6

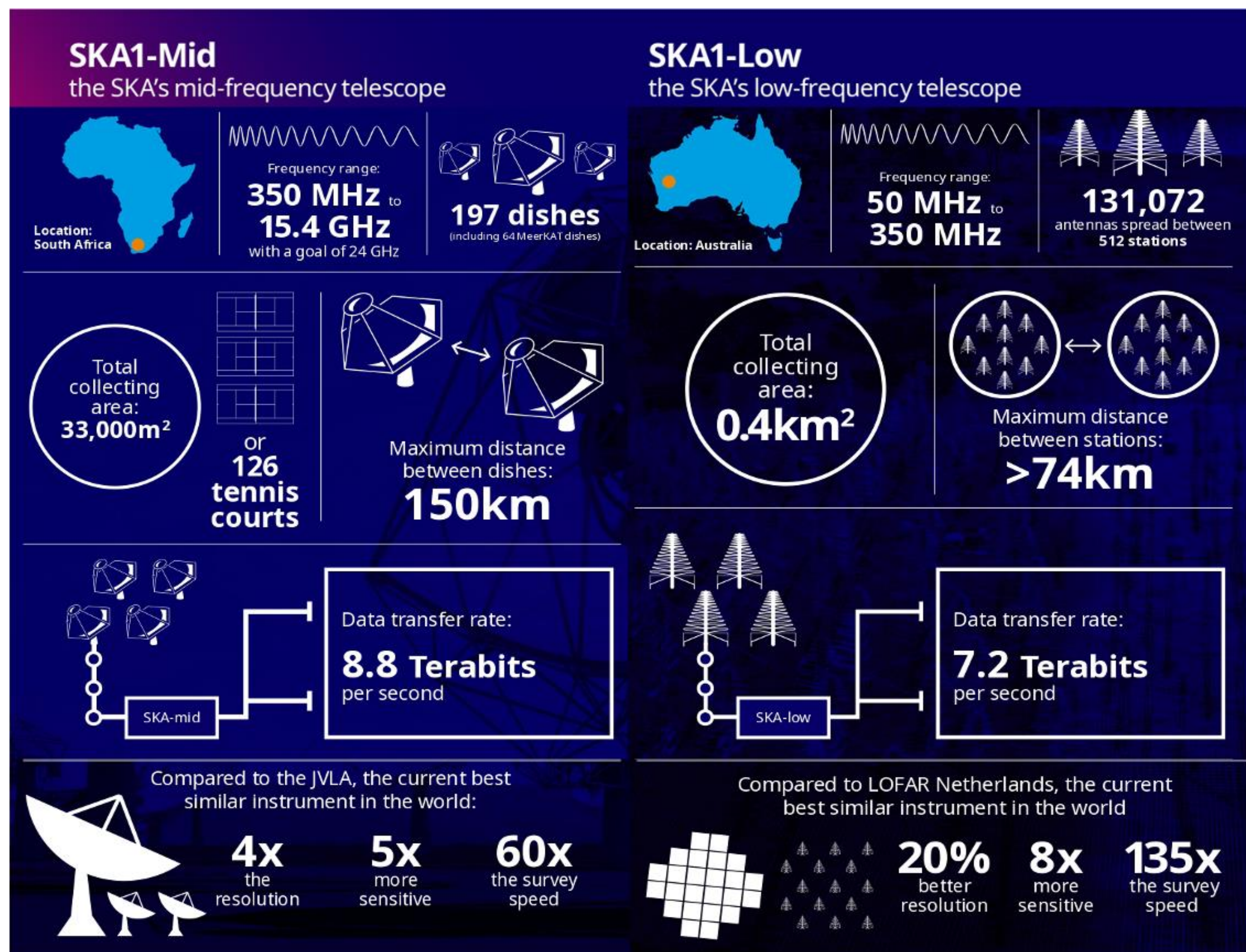
Observer countries

8

African partner countries



Some Tech Specs for SKA Telescopes



SKA-MID · SOUTH AFRICA

60x

the survey speed of the JVLA

4x the resolution · 5x more sensitive

SKA-LOW · AUSTRALIA

135x

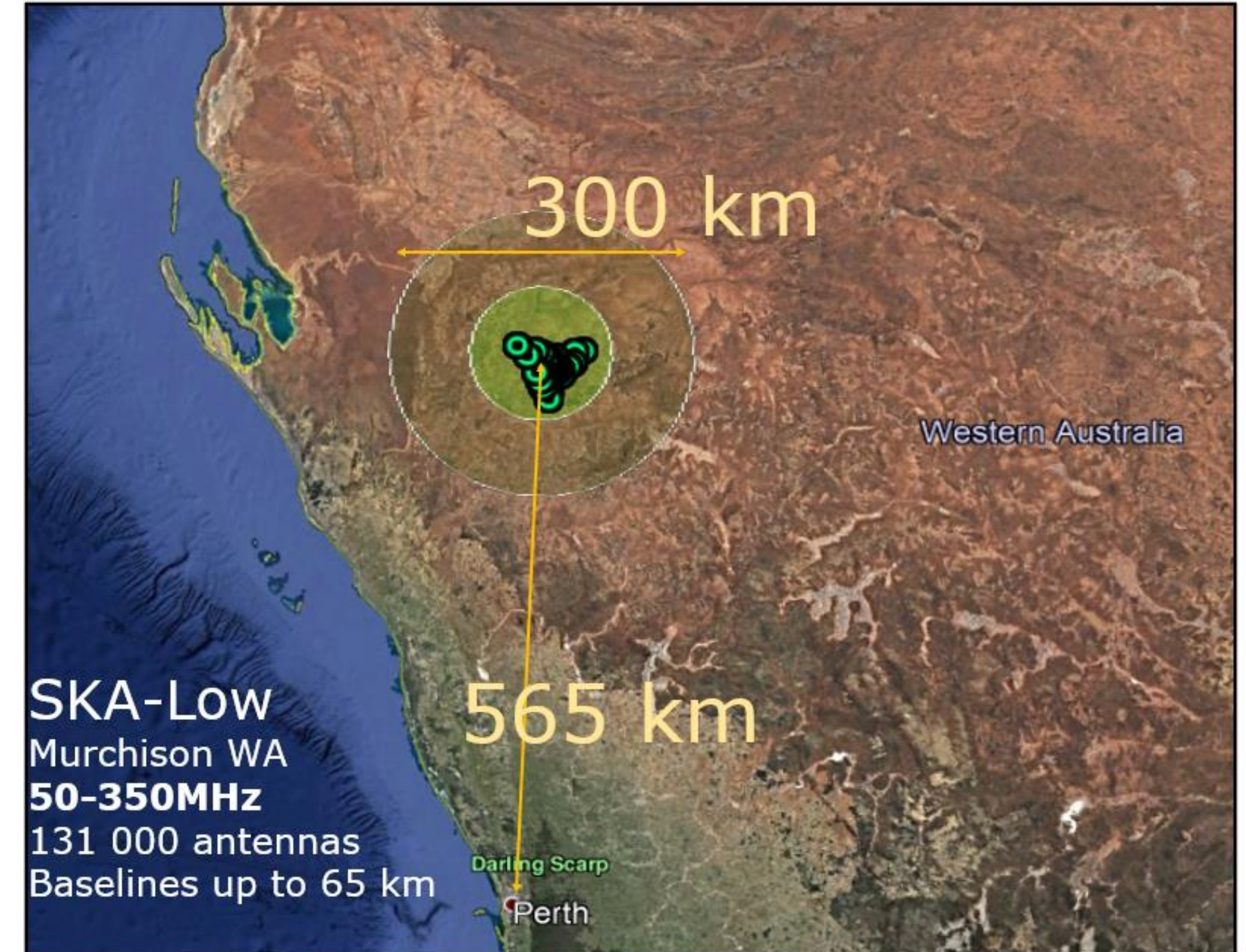
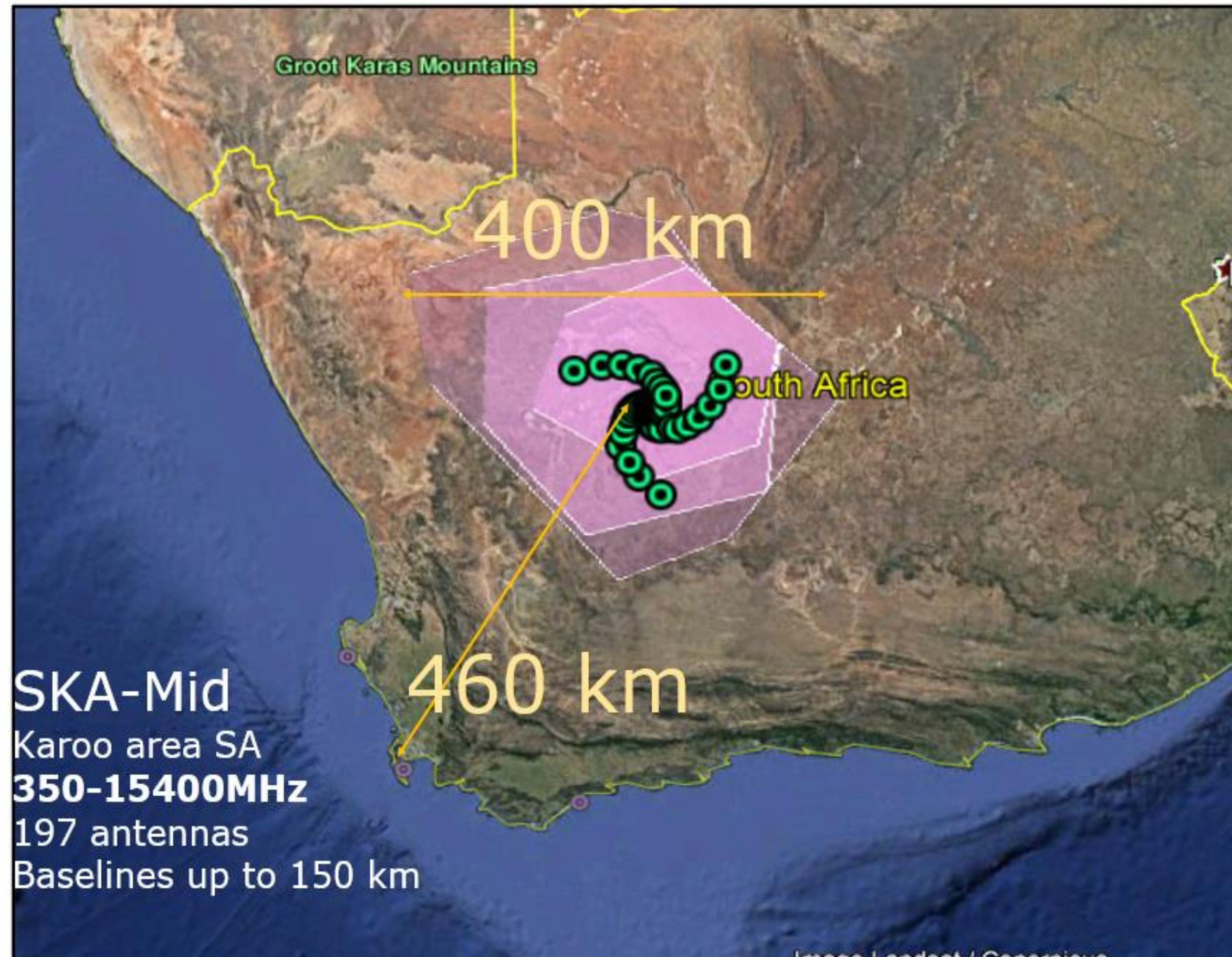
the survey speed of LOFAR

20% better resolution · 8x more sensitive

Comparisons: SKA-Mid against the JVLA, SKA-Low against LOFAR. Source: SKAO.



Radio Quiet Zones



Radio Quiet Zones do not affect air- or space-borne transmissions

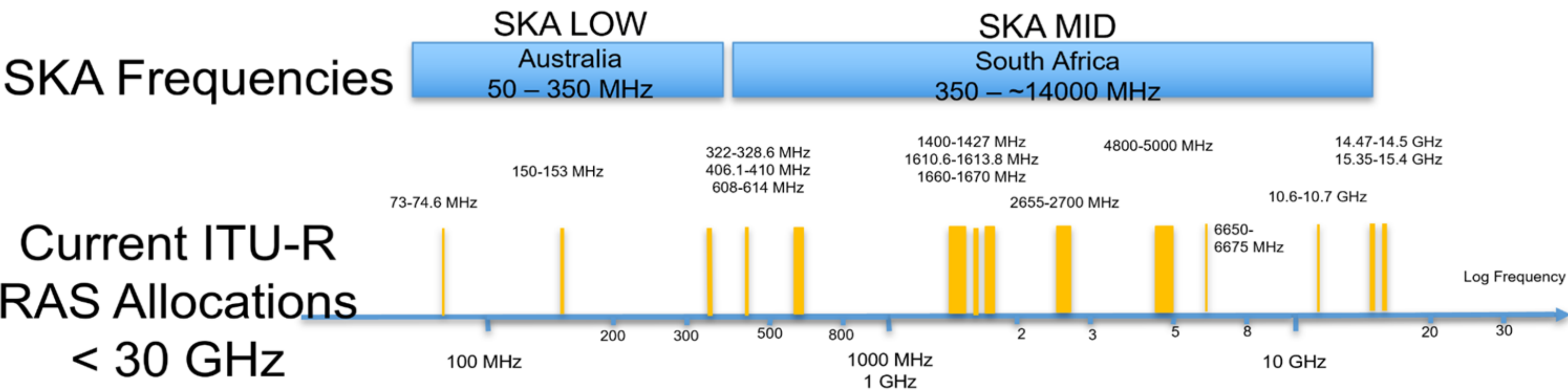


The SKA Radio Telescopes Frequencies



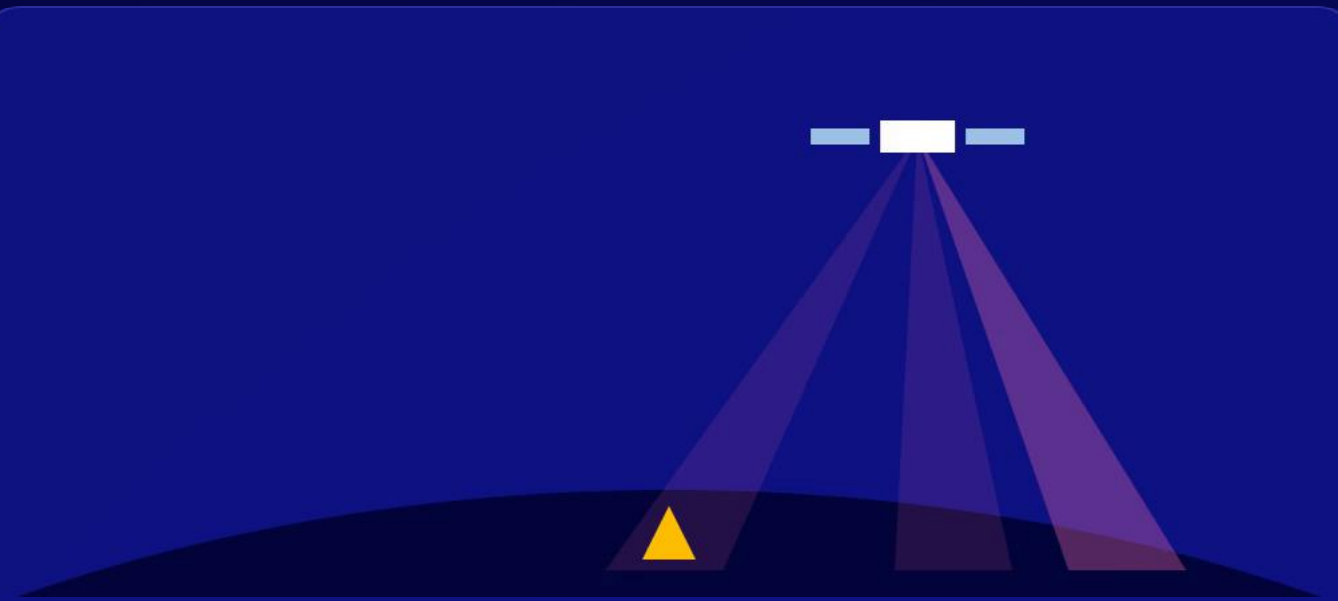
RQZ frequencies

South Africa: 100 MHz – 25.5 GHz
Australia: 70 MHz – 25.25 GHz



THE PROBLEM

Three ways a satellite reaches a radio telescope



1 · INTENDED

Service transmissions

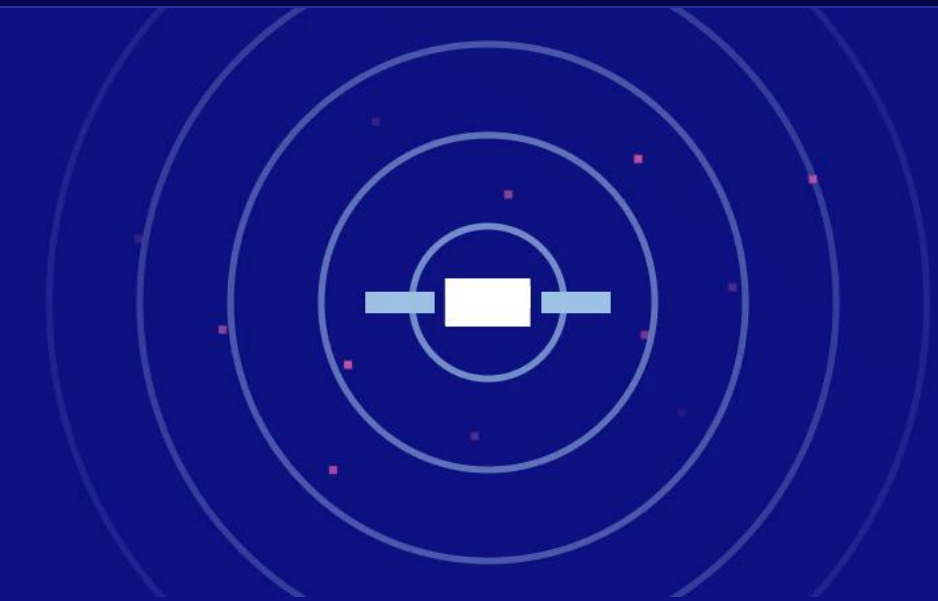
Main beams and side lobes aimed at cells near and far from the telescope



2 · UNWANTED

Out-of-band emission

Power spilling from 10.7 GHz downlinks into the radio astronomy band next door



3 · UNINTENDED

Electronics radiation

Unintended emission from the spacecraft, with no frequency allocation at all

Assessing impact means connecting each emission and the network's behaviour to **one observatory's** response.



How is D2D Different?

	Traditional MSS	D2D
Target	Ground station / dedicated terminal	Unmodified consumer phone
Transmit power	Matched to a sensitive ground terminal	Much higher, to close the link to a tiny phone antenna
Frequency bands	Dedicated MSS bands (Ku/Ka)	Shares IMT/mobile bands, down to 694–698 MHz
Exposure pattern	Predictable passes	Continuous ground illumination & repeated beam crossings



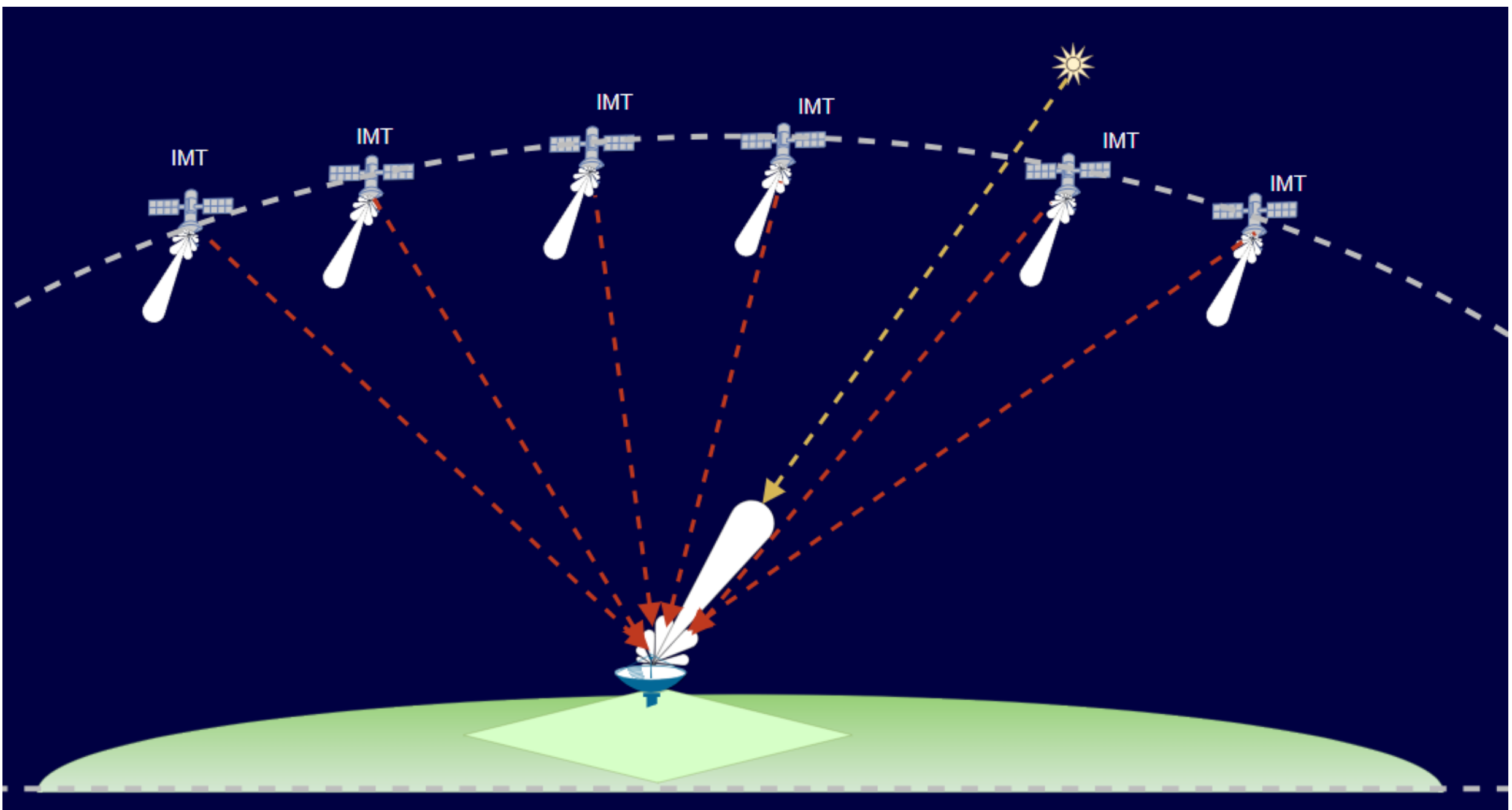
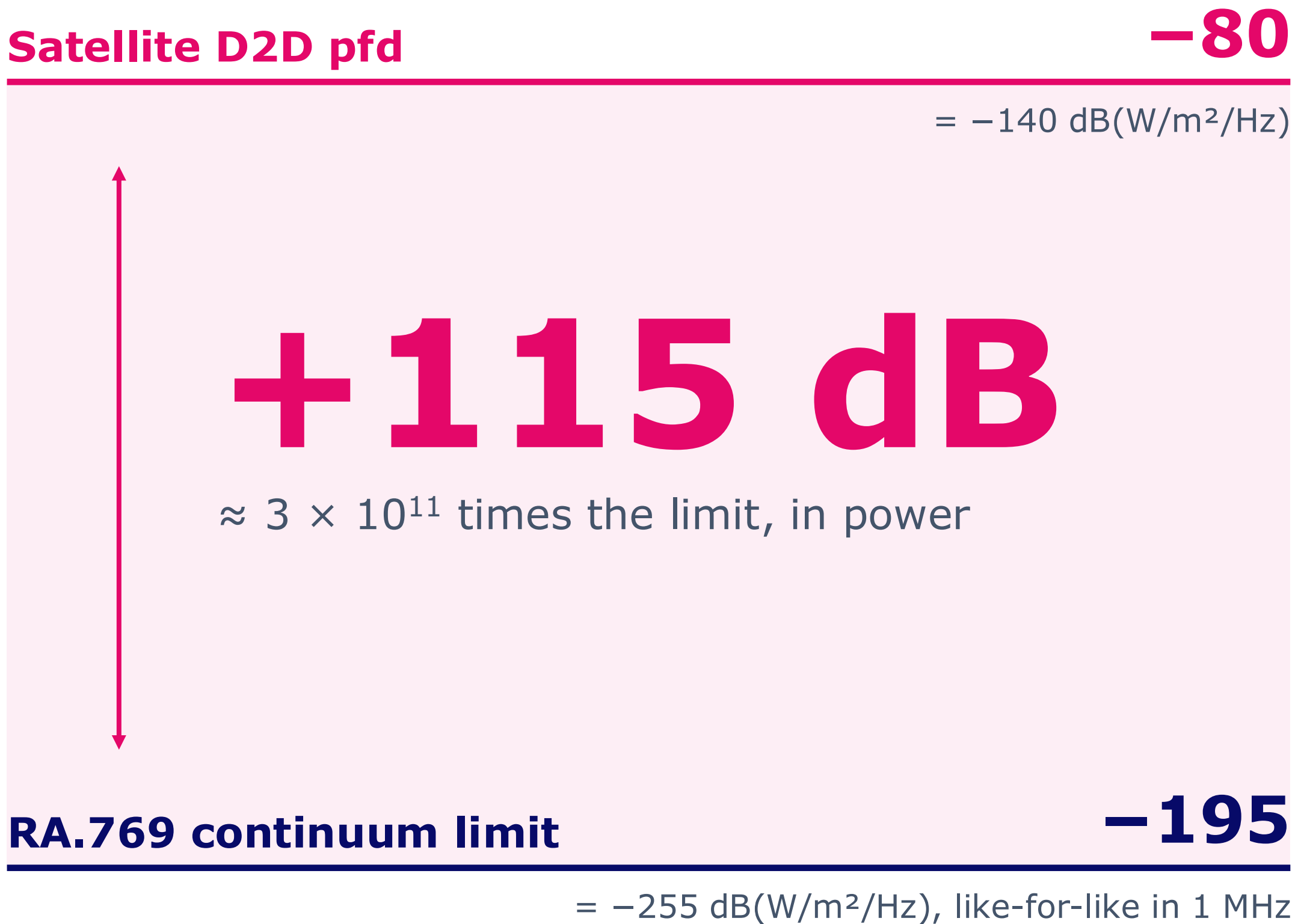
Protecting Radio Astronomy

- **ITU-R RA.769**
 - Defines harmful interference limits
- **ITU-R RA.1513**
 - Defines acceptable limits for data loss over time



One D2D Satellite PFD Against RA.769

SPECTRAL PFD AT THE TELESCOPE, dB(W/m²/MHz)



The formal test is epfd, not pfd

$$\text{epfd} = 10 \log_{10} \sum \text{pfd}_i \cdot G(\theta_i) / G_{\max}$$

It sums every satellite in view, weighted by the telescope's gain toward each. With one satellite in the main beam, $\text{epfd} \approx \text{pfd}$, so 115 dB is the main-beam case.

RA.769 reference case: 1413.5 MHz continuum, 27 MHz bandwidth, 2000 s integration, 0 dBi antenna gain. epfd method: Rec. ITU-R M.1583; data-loss criterion: Rec. ITU-R RA.1513.



Noise Effect of Telescope Receivers

SPECTRAL DENSITY

Satellite pfd, one satellite **-80 dB(W/m²/MHz)**

Dish effective area, 15 m, $\eta = 60\%$ **+20 dB(m²)**

Received power density, P_{rx} **-120 dB(W/Hz)**

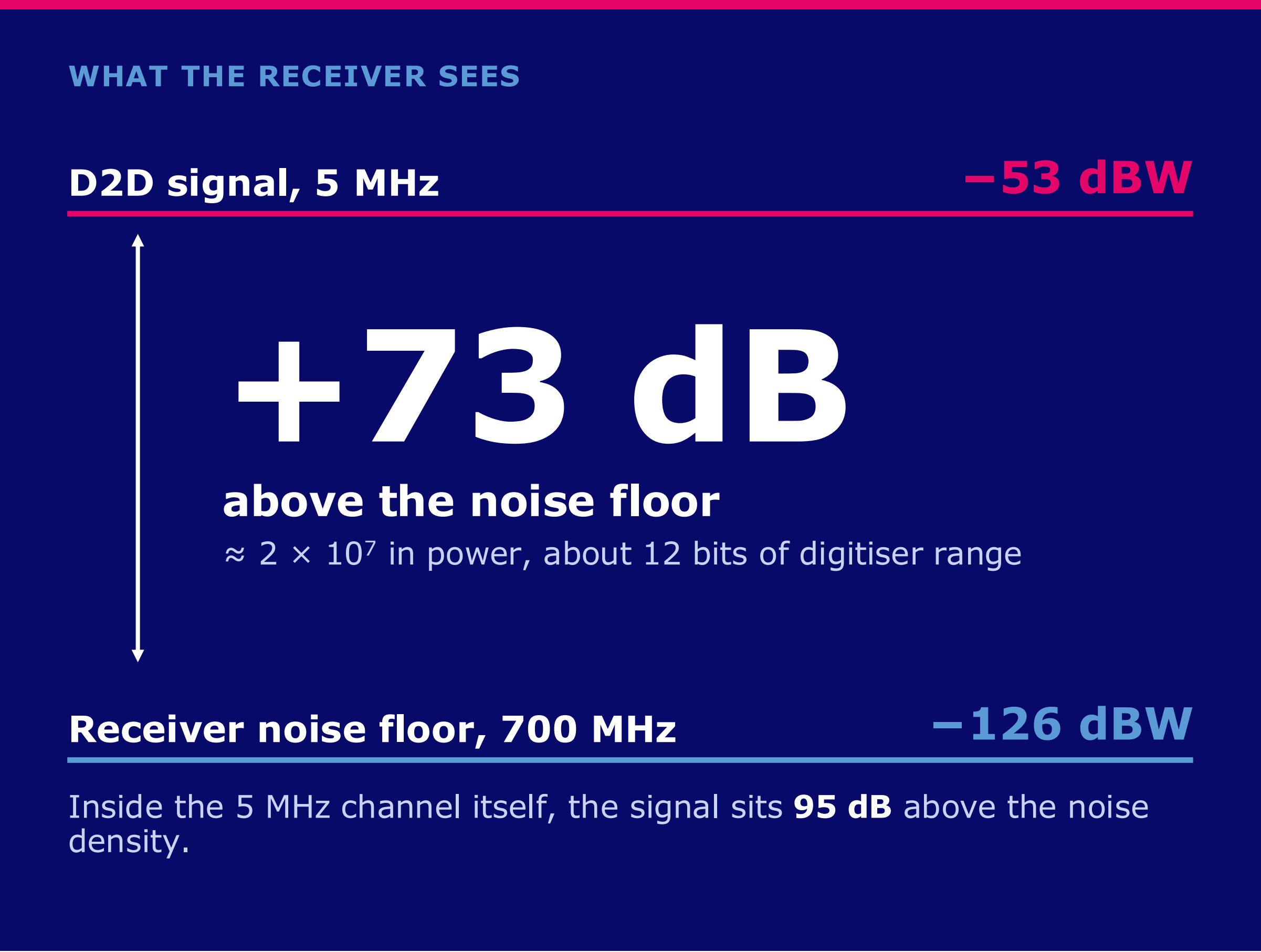
Noise density, $T_{sys} = 22\text{ K}$ **-215 dB(W/Hz)**

TOTAL POWER

Signal in its 5 MHz channel **-53 dBW**

Noise across the 700 MHz band **-126 dBW**

One satellite only: the full epfd is higher.



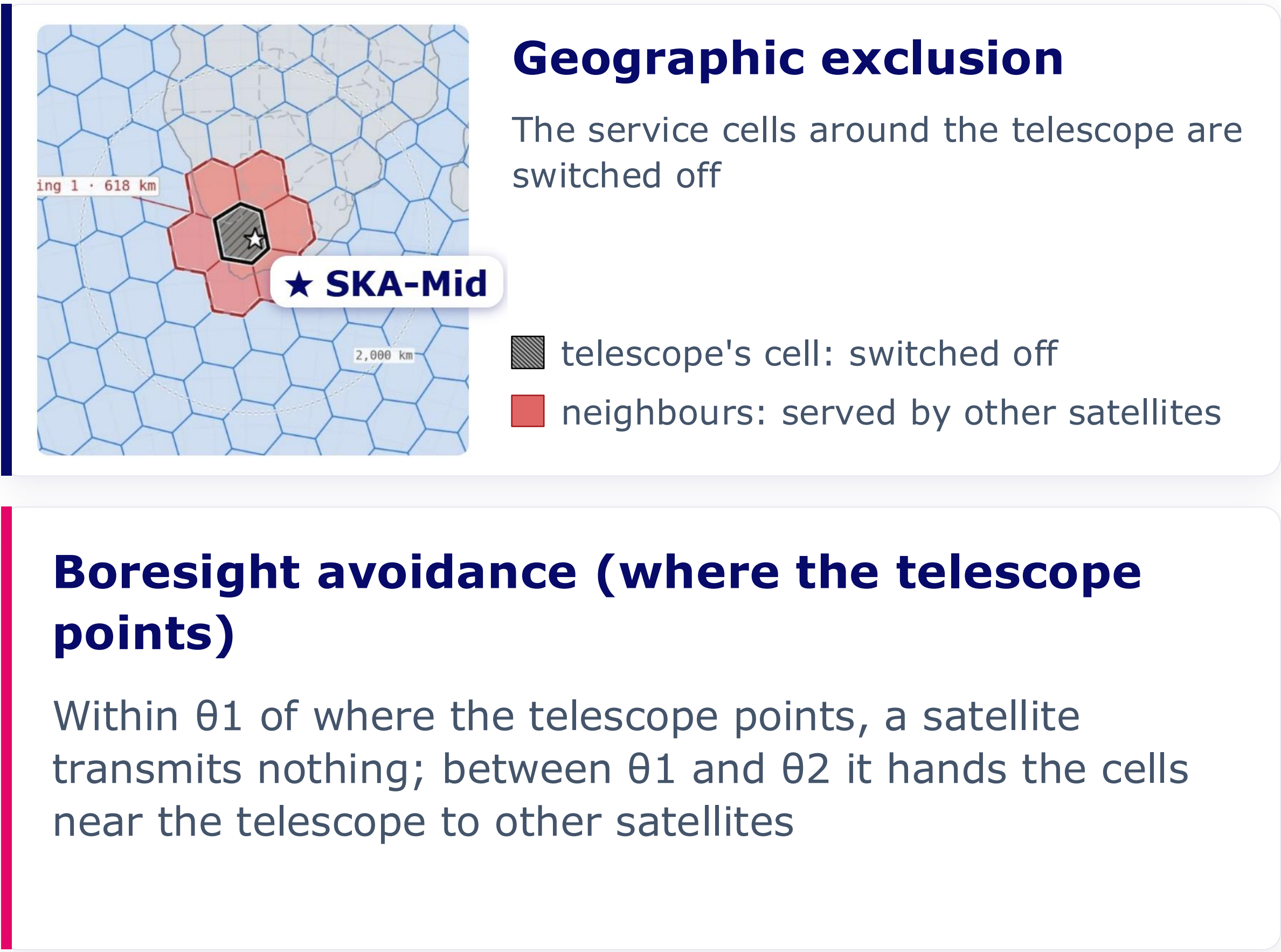
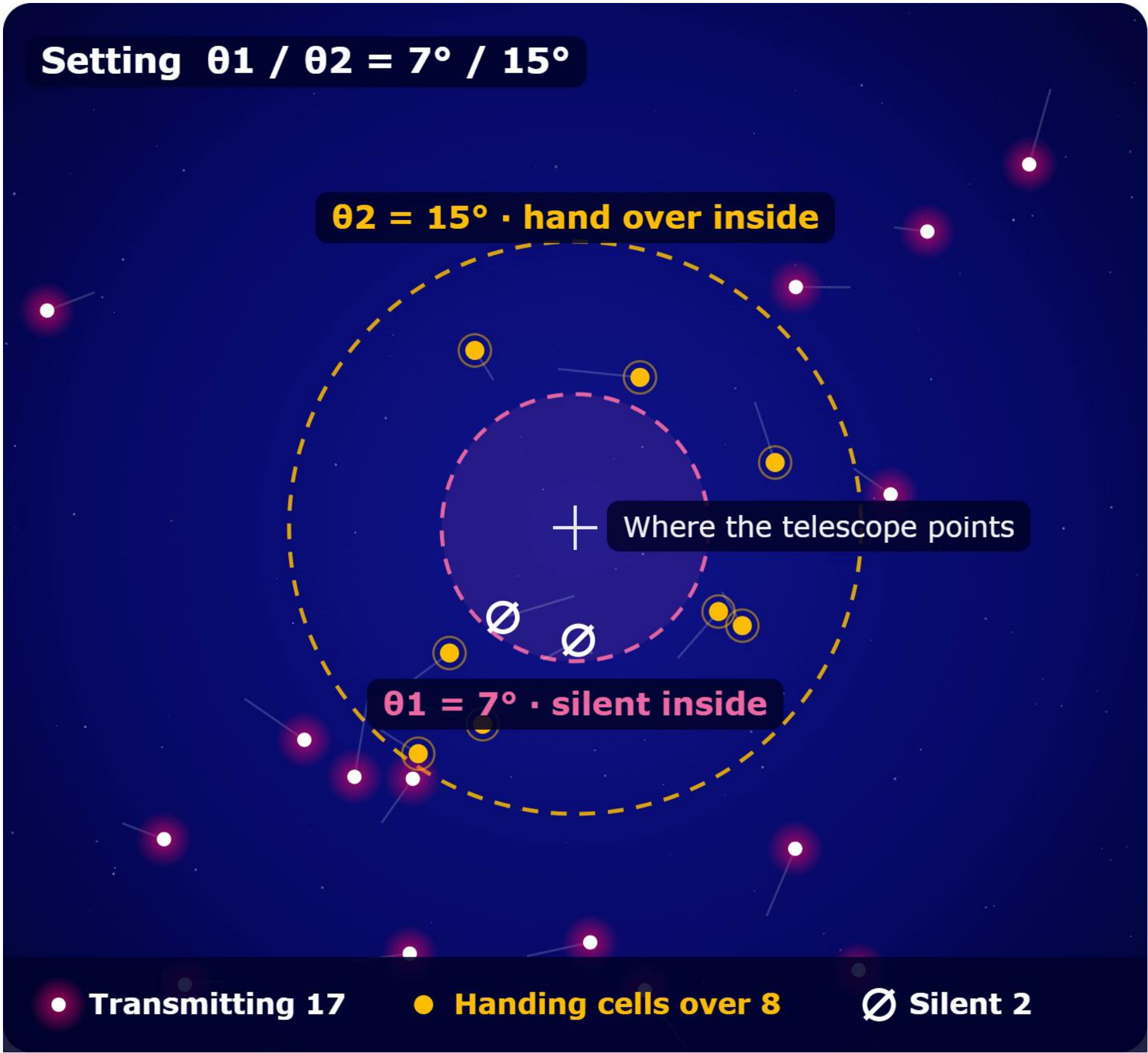
Effective area $A_e = \eta \cdot \pi D^2 / 4 \approx 106\text{ m}^2$ ($\approx 45\text{ dBi}$ at 1.4 GHz). Noise density $= k \cdot T_{sys}$. Total powers integrate the densities over 5 MHz (signal) and 700 MHz (noise). 6 dB $\approx$ 1 bit.



OPERATIONAL MITIGATION

Two measures an operator can apply

One SKA-Mid dish (15 m) · 10.7–10.95 GHz downlinks beside the 10.6–10.7 GHz radio astronomy band



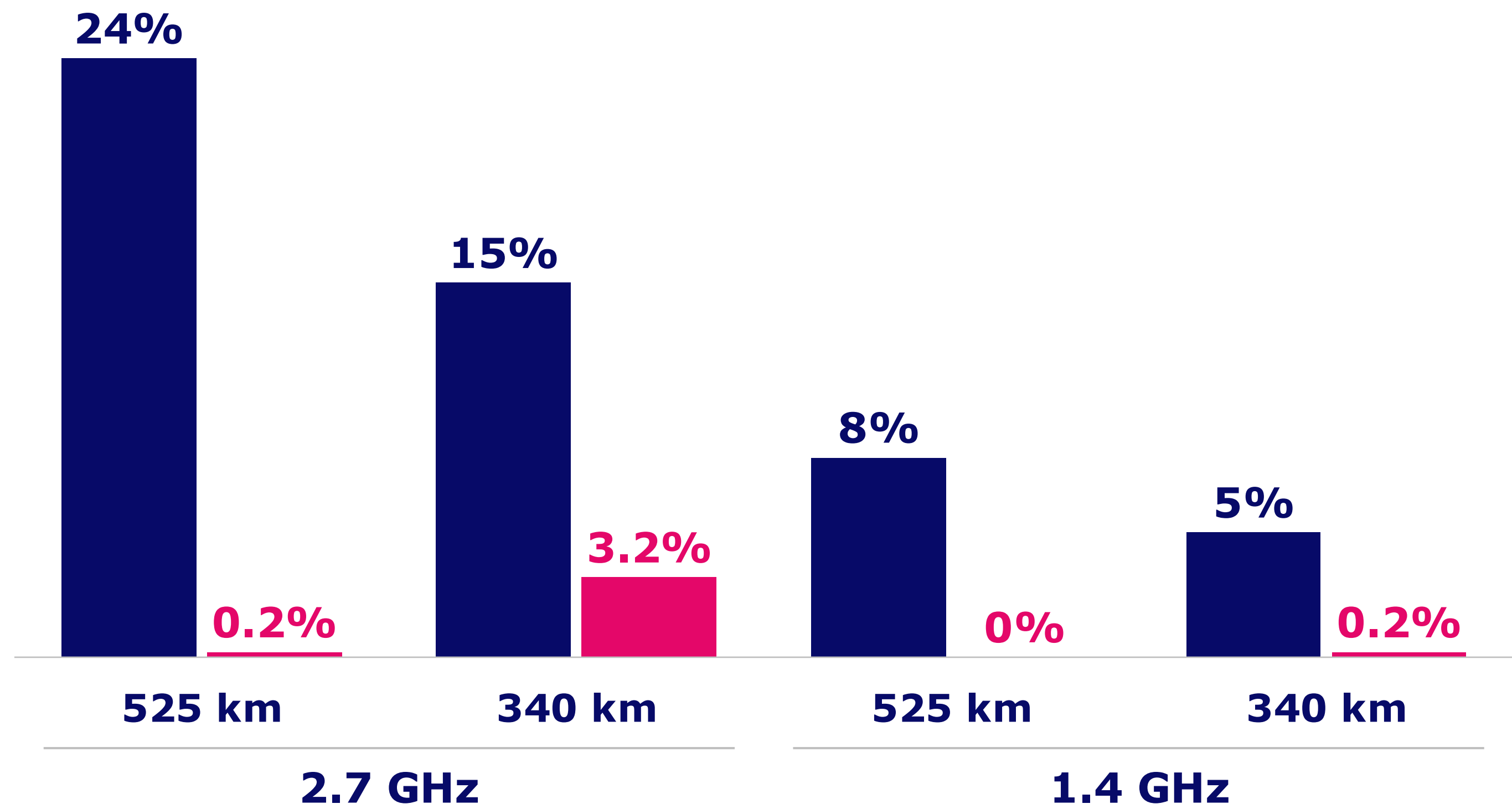
Schematic sky around where the telescope points, to scale in angle, alternating the $7^\circ/15^\circ$ and $5^\circ/7^\circ$ settings. Studied θ_1/θ_2 pairs: 1/3, 3/5, 5/7 and 7/15°. Hexgrid: service cells around SKA-Mid with the excluded zone.



SKAO Risk Investigation for D2D Mitigation

● Baseline saturation ● With mitigation

Saturation incidence by band and orbit (share of time the receiver is 'blind')



24%

worst-case baseline saturation (2.7 GHz, 525 km orbit)

≤ 3.2%

Saturation with mitigation, in every band and orbit studied

≥ 99.9%

Of demand still served

Illustrative study · 525 / 340 km orbits · 20% activity · SKA-Mid Bands 2 & 3 · -120 dBW saturation threshold



D2D harmonics fall in primary RAS bands

D2D transmit ranges whose harmonics land in primary RAS bands (up to 5th harmonic)

RAS primary band	RR Provision	Harmonic	Transmit range	D2D band
1400–1427 MHz	RR 5.340	2nd	700–713.5 MHz	700 MHz
1610.6–1613.8 MHz	RR 5.149	2nd	805.3–806.9 MHz	800 MHz
1660–1670 MHz	RR 5.149	2nd	830–835 MHz	800/850 MHz
2690–2700 MHz	RR 5.340	3rd	896.7–900 MHz	900 MHz
4990–5000 MHz	RR 5.149	2nd	2495–2500 MHz	2.5 GHz
10.6–10.7 GHz	RR 5.340	4th	2650–2675 MHz	2.6 GHz
		5th	2120–2140 MHz	2.1 GHz

Protect primary RAS bands from all unwanted emissions: binding limits on out-of-band emissions and harmonics in the AI 1.13 regulatory text

REQUIRED HARMONIC SUPPRESSION

≈100 dB

attenuation of harmonic emissions that studies show is needed to protect RAS

~60 dB

what general spurious-emission limits for space stations require (RR Appendix 3)

Harmonic n of frequency f falls at $n \times f$. RR 5.340: all emissions prohibited (at 10.6 GHz, in 10.68–10.7 GHz). ≈100 dB indicative, from SKAO contribution to WP4C.



How the NTN community can help

1

SHARE TECHNICAL INPUTS

Provide constellation geometry, beam patterns, power control, activity factors and out-of-band emission data.

2

MODEL AGGREGATE EXPOSURE

Assess the full constellation over time, not only a favourable single-satellite or best-case geometry.

3

BUILD OPERATIONAL CONTROLS

Enable exclusion cells, angular or boresight avoidance, power reduction and observation-aware scheduling.

4

RETAIN TELEMETRY

Keep configuration and operational records so unexpected interference events can be identified and resolved.

5

ENGAGE DURING DESIGN

Include radio astronomy in standards and deployment discussions while architectures can still be changed. **Especially harmonic suppression.**

THE DESIGN PRINCIPLE

DESIGN FOR COEXISTENCE

Transparent parameters

Aggregate analysis

Operational coordination



D2D and the RAS can share the sky

Thank you

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*We recognise and acknowledge the
Indigenous peoples and cultures that have
traditionally lived on the lands on which
our facilities are located.*



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