Protecting the Quiet Sky

Why Satellites Matter for Radio Astronomy

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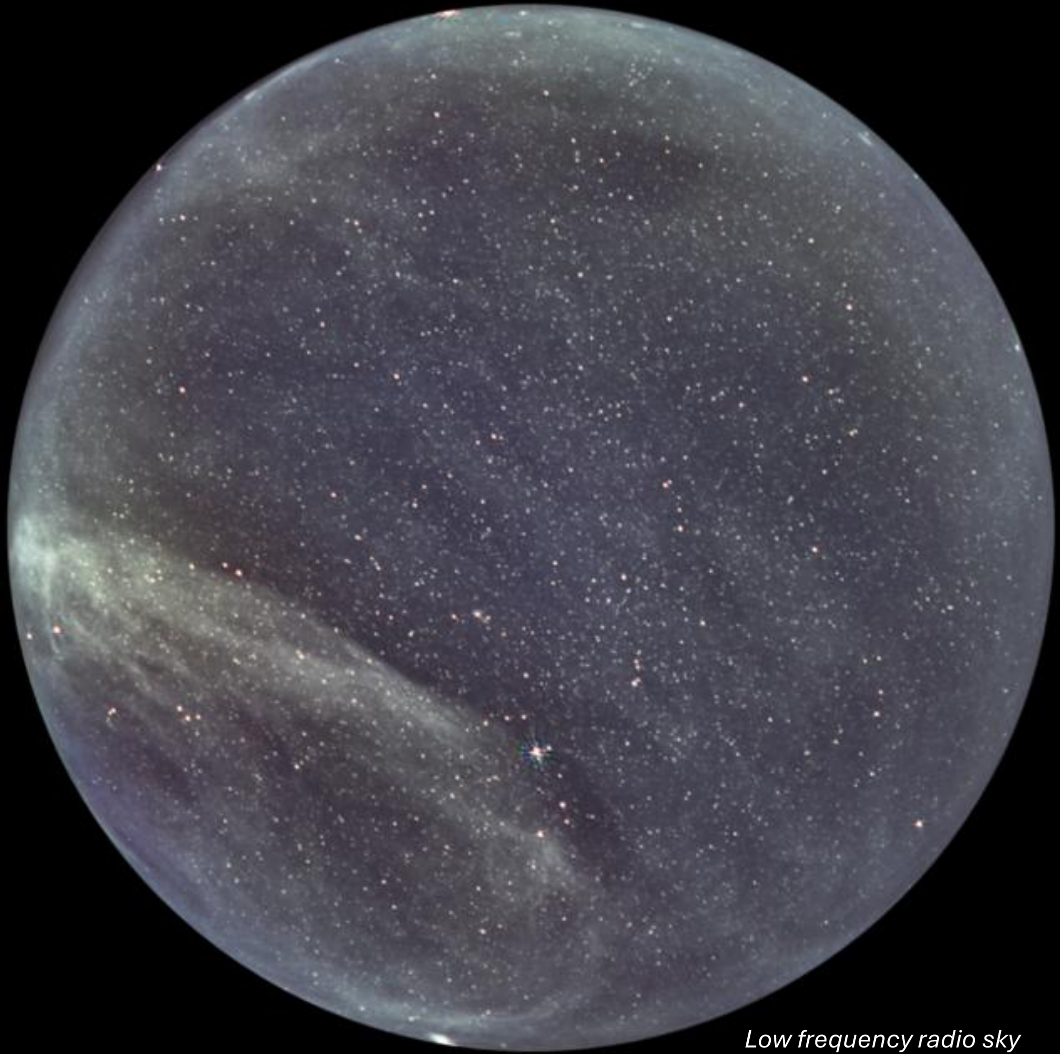
What is Radio Astronomy?

Radio astronomy detects natural radio waves from the Universe

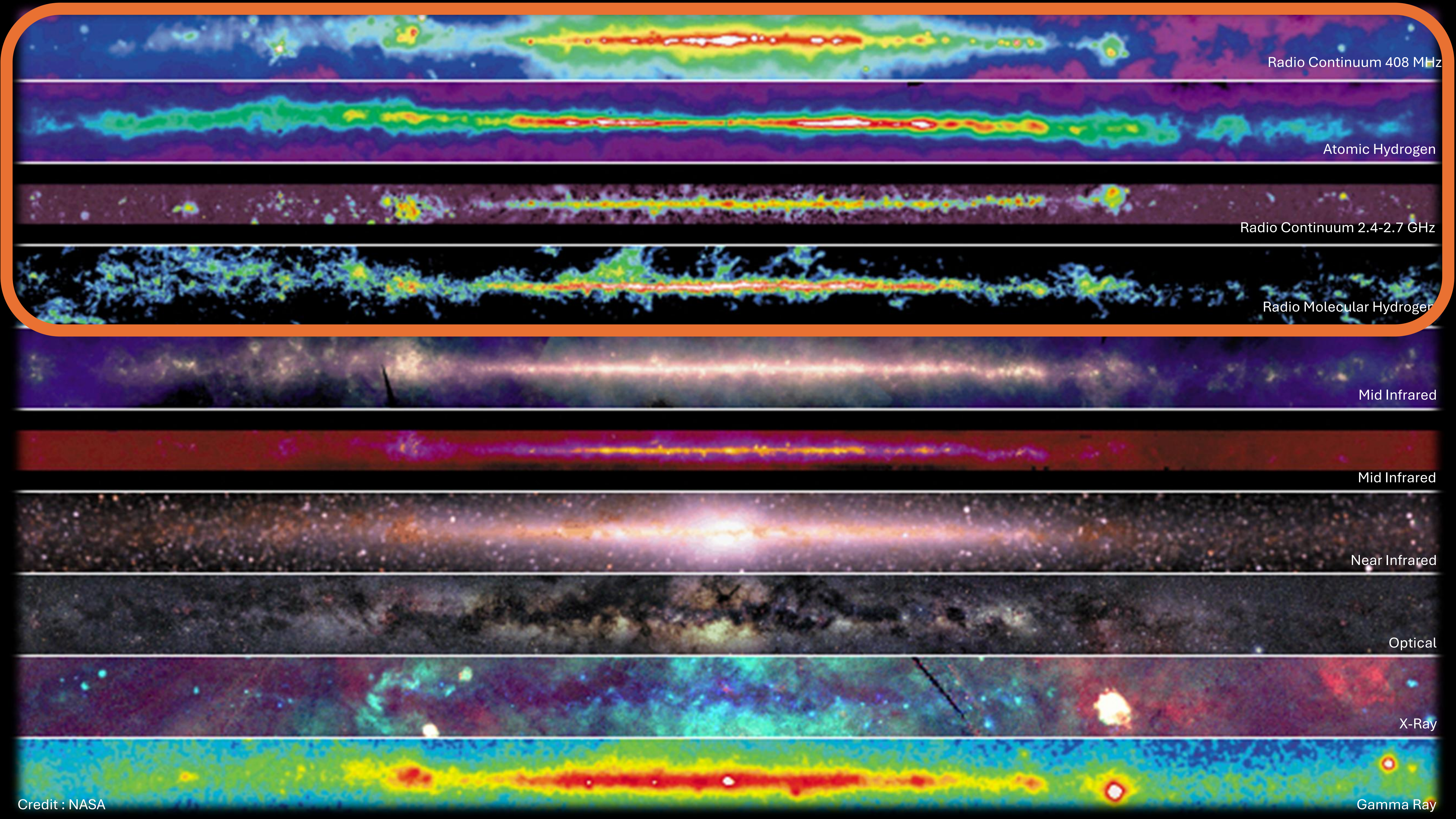
These waves are astonishingly faint, often **10 trillion times weaker** than a phone signal received on Earth

We use them to study:

- hydrogen in galaxies
- black holes
- planetary atmospheres
- cosmic magnetism
- the early Universe



Low frequency radio sky
Credit : G.Hallinan
Caltech/OVRO-LWA


Radio Continuum 408 MHz
Atomic Hydrogen
Radio Continuum 2.4-2.7 GHz
Radio Molecular Hydrogen
Mid Infrared
Mid Infrared
Near Infrared
Optical
X-Ray
Gamma Ray
Credit : NASA

Why Is Radio Astronomy Valuable to Society?

Navigation and GPS stability

- VLBI networks anchor the reference frame used by GNSS.
- Without radio astronomy, global navigation would slowly drift.

Space weather / solar bursts monitoring

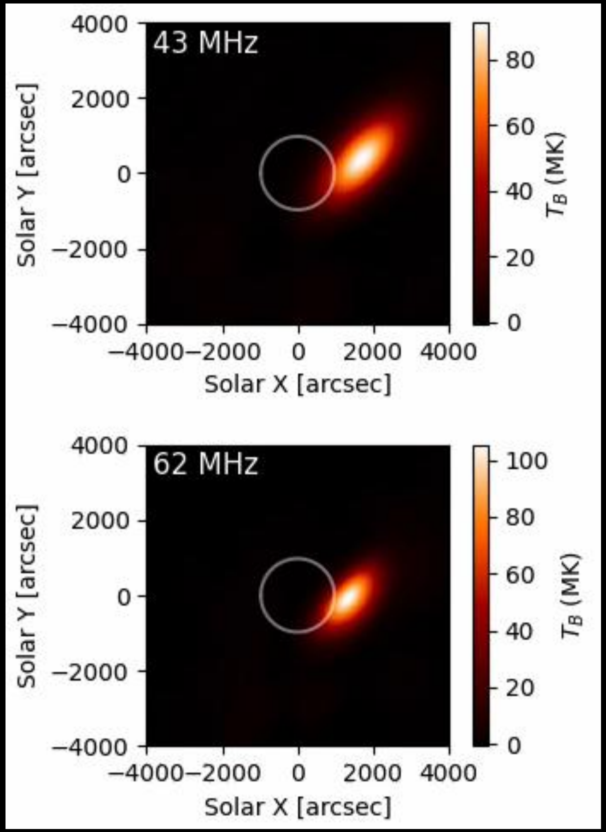
- satellites
- power grids
- aviation
- GNSS

Technology spin-offs

- low-noise amplifiers → used in telecom
- fast signal processing → Wi-Fi
- imaging algorithms → MRI
- timing → finance, navigation

Global scientific prestige

Radio astronomy is part of the world's scientific identity.



X2.8 solar flare
2023-12-14
Caltech/OVRO-LWA/NJIT

Why Are Radio Telescopes So Vulnerable?

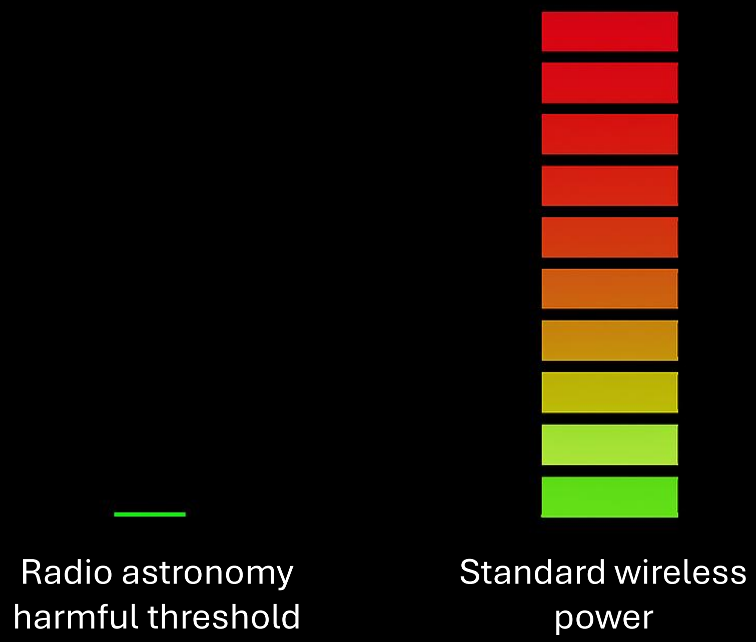
Radio telescopes are designed to hear extraordinary silence.

A harmful interference threshold may be as low as –250 dBW, essentially zero power.

These thresholds are **1 billion times lower** than levels relevant to telecom systems.

Why?

- Large collecting area
- Large frequency bandwidths
- Low noise receivers
- Coherence between antennas kilometers apart



What Has Changed: The Satellite Boom

Historically:

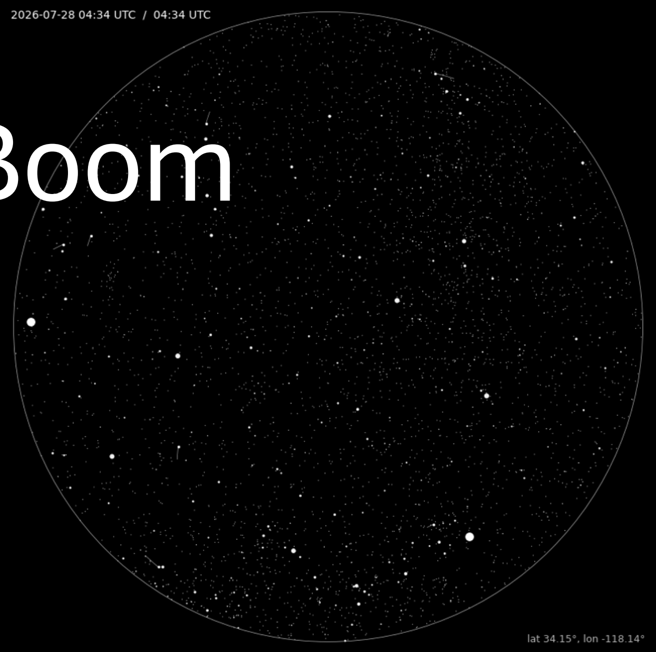
- < 1,000 active satellites
- Rarely aligned with telescope beams

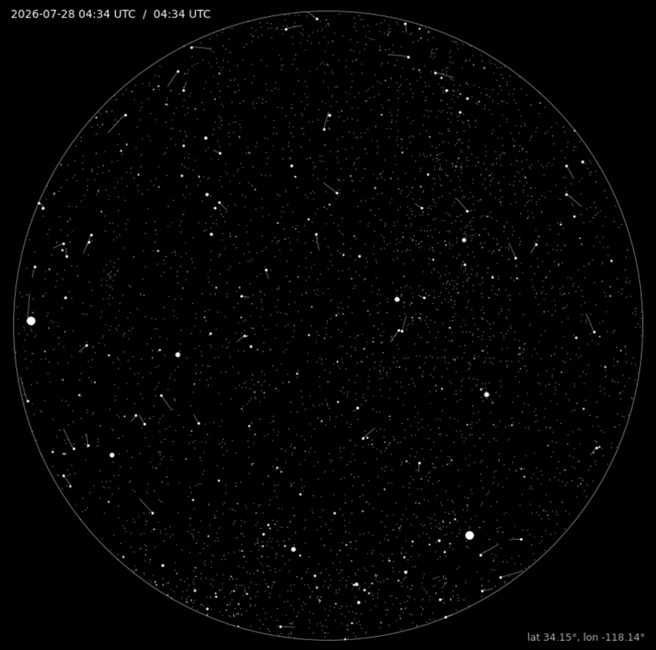
Now:

- 12,000 satellites already
- Constellations may reach 30,000–100,000
- GNSS, broadband, Earth observation, IoT

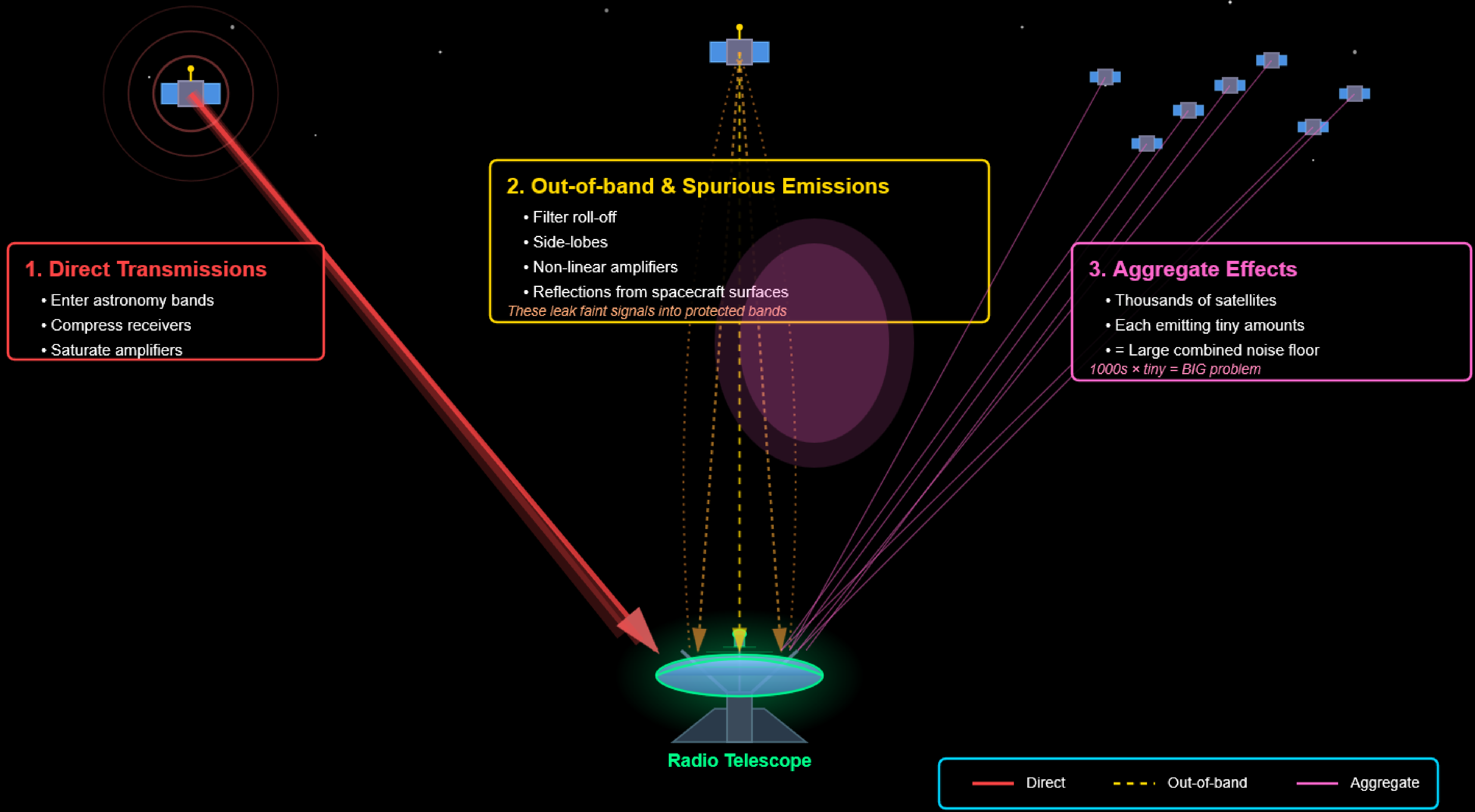
Result:

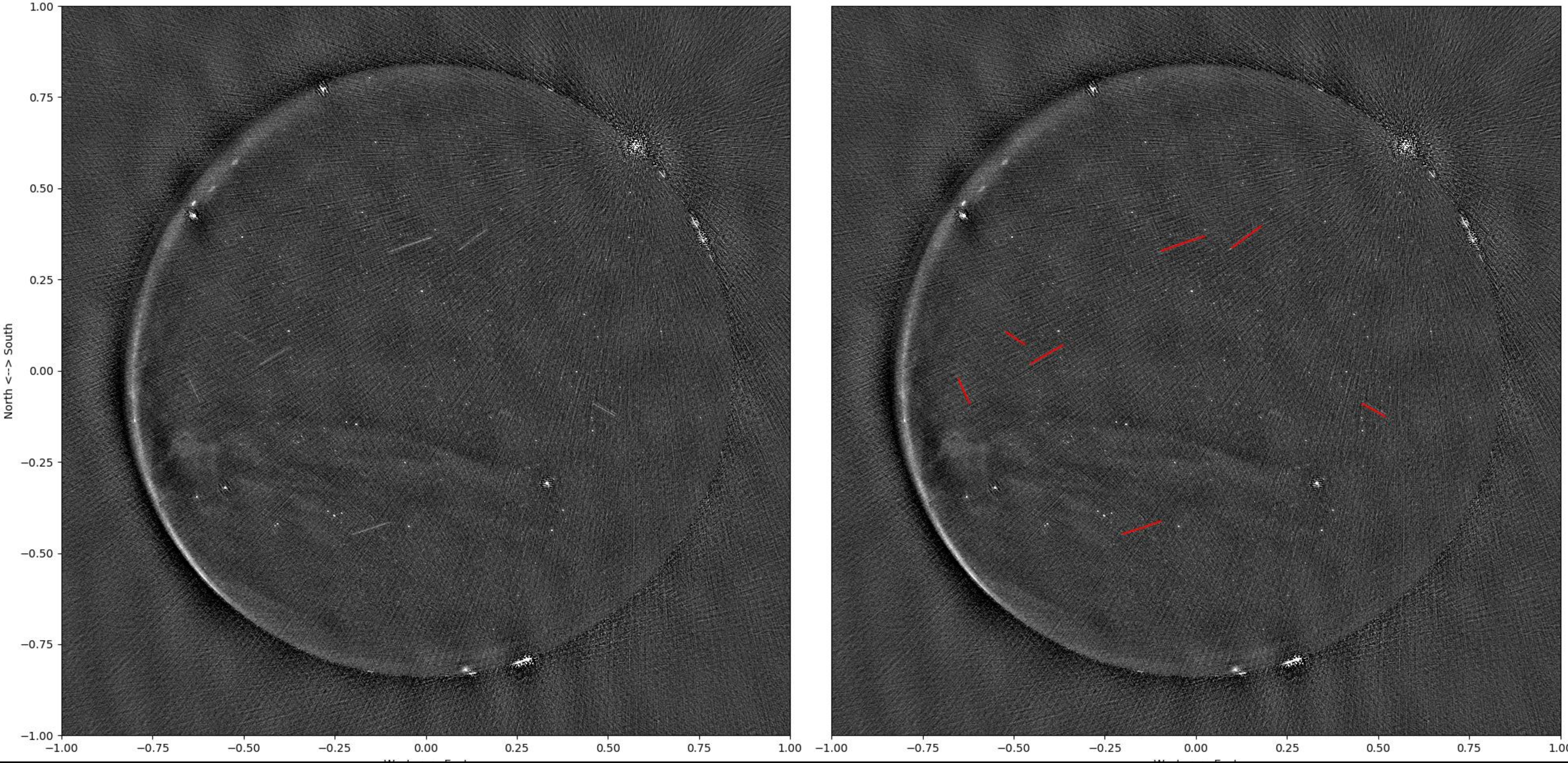
- The probability a satellite crosses a telescope beam becomes **near-continuous**.





How Satellites Interfere with Radio Astronomy





North <--> South
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00

The Economic Cost

Cost per hour of observing time

- Green Bank Telescope: $1,400–$2,000/hr
- VLA: $1,700/hr
- ALMA: $12,000/hr
- SKA (projected): €10,000+/hr

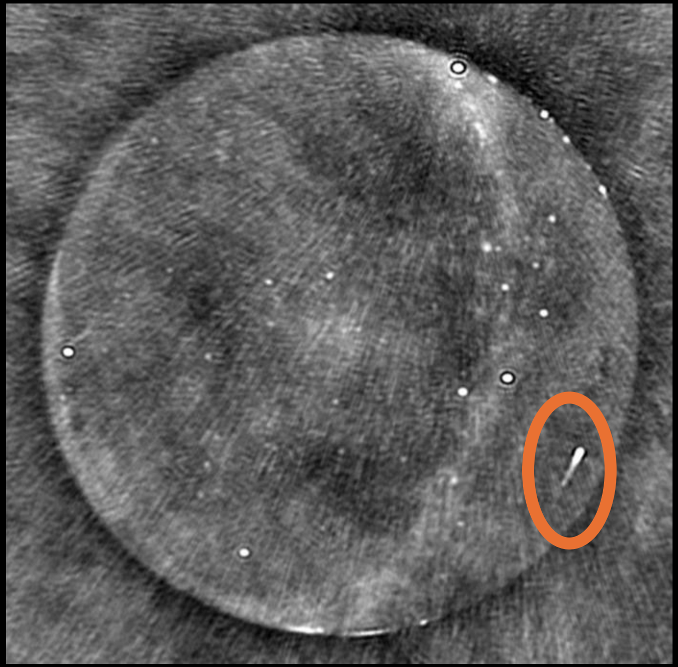
If interference raises system temperature 2–3×

- ➢ observing time increases 4–9×
- ➢ direct economic losses = hundreds of thousands to millions per project

Other costs:

- extra staff
- more computing
- longer calibration
- regulatory engagement
- lost scientific opportunities

Atmospheric & Launch Effects

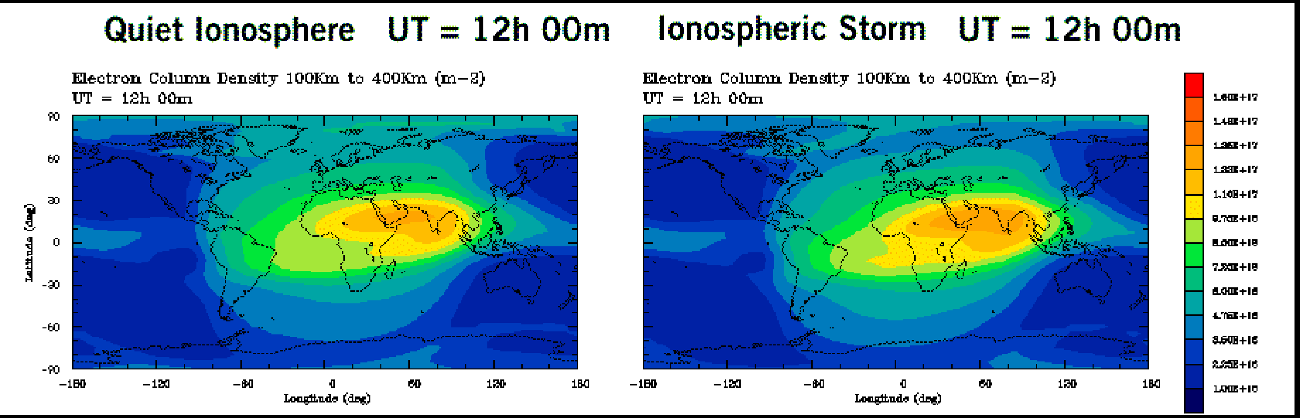


Rocket launches and satellite re-entries create:

- plasma trails
- shock-induced electron variations
- ionospheric disturbances

These disrupt:

- radio cosmology
- Earth rotation measurements
- 21-cm experiments



Conclusion : The radio sky is no longer quiet

Astronomical signals remain extraordinarily faint

- often far below thermal noise
- requiring extreme sensitivity and stability

Satellite presence is now continuous

- thousands of spacecraft across all orbits
- beams, reflections, and spurious emissions are always present

Interference accumulates

- even tiny out-of-band levels become significant when thousands of satellites contribute
- system temperatures rise, sensitivity decreases

Scientific impact is already measurable

- longer observing times
- reduced data quality
- increased operational load
- some experiments (e.g. 21-cm cosmology) becoming more difficult

The Quiet Sky Report: