SPINOR: Exploring the sub-30 MHz Radio Sky in Fine Resolution

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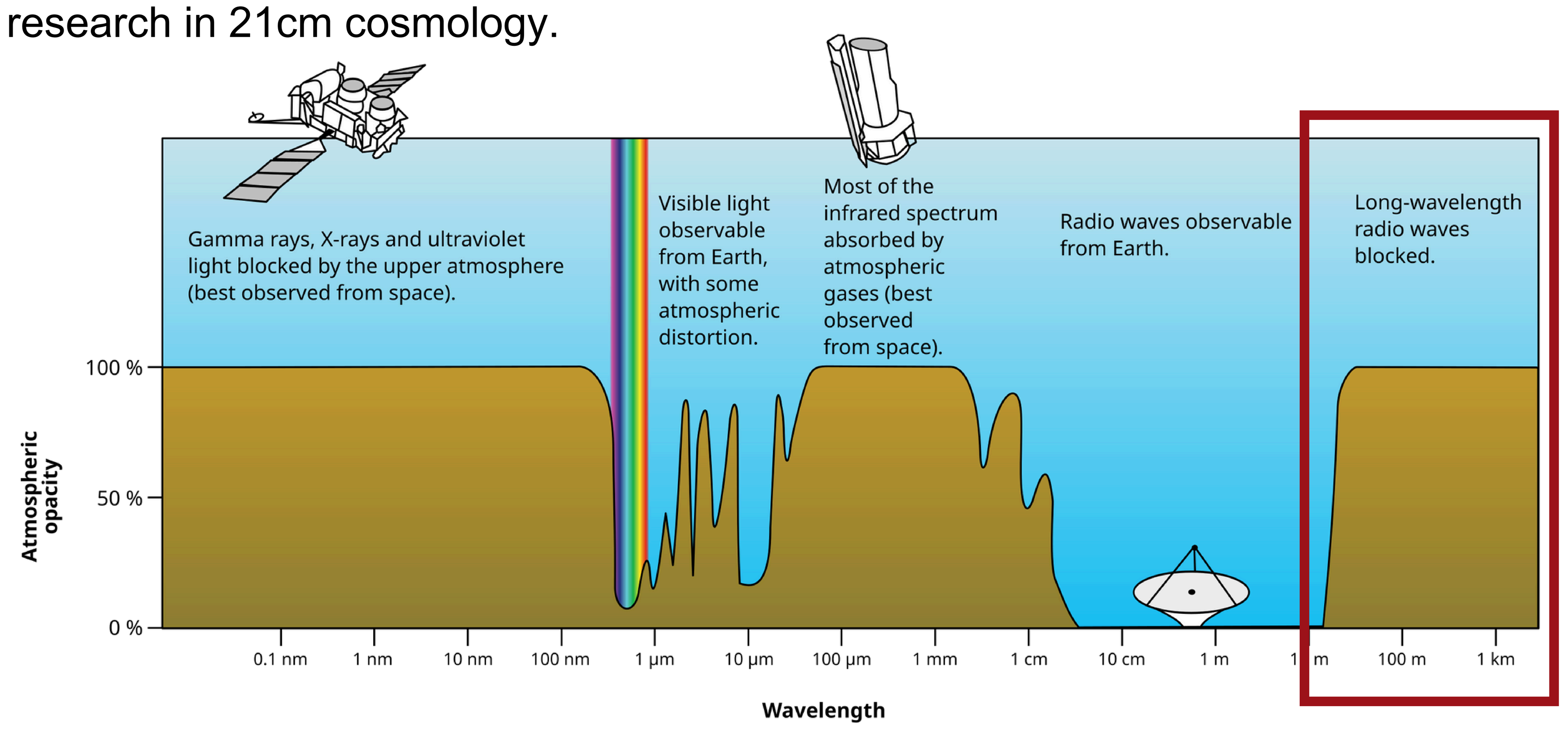
Abstract

SPINOR is a program designed to image the sub-30 MHz radio sky in fine resolution for the first time, which promises discoveries ranging across exoplanet magnetic interactions, heliophysics and space weather, and 21-cm cosmology. Its hardware consists of a set of spin-stabilized conductive tethers located outside of the ionosphere, acting as configurable, low-frequency resonant antennas, with possible data processing techniques including imaging, beamforming, and interferometry.

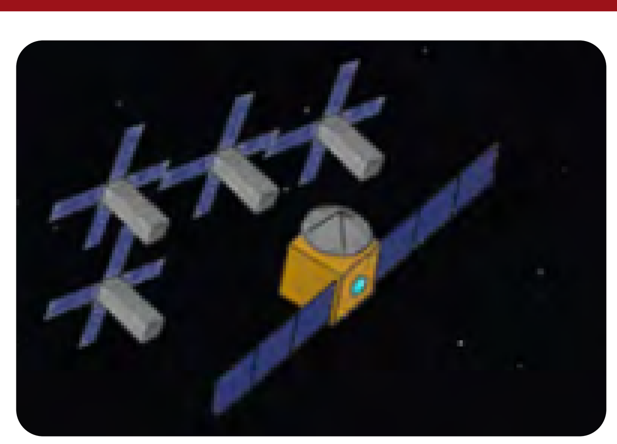
Why sub-30 MHz?

Observations within the 30 MHz frequency band are obstructed by ionospheric effects in the Earth's atmosphere, preventing ground observations. This requires all data collection to occur in space, beyond the ionosphere. In the 1970s, the RAE-1 and RAE-2 missions deployed lunar-orbiting, 229-m travelling-wave V-shape antennas to conduct directional surveys across 22 frequencies ranging between 0.25 and 9.18 MHz, at a spatial resolution of roughly 1 steradian. [1] [2]. Further advancing this work to high-resolution, high-sensitivity imaging in this band opens up a plethora of scientific opportunities, including direct observations of exoplanet magnetospheres and their interactions with their solar magnetic fields, heliophysics and space weather data collection, investigations into planetary magnetospheres and lightning strikes within our solar system, and research in 21cm cosmology.

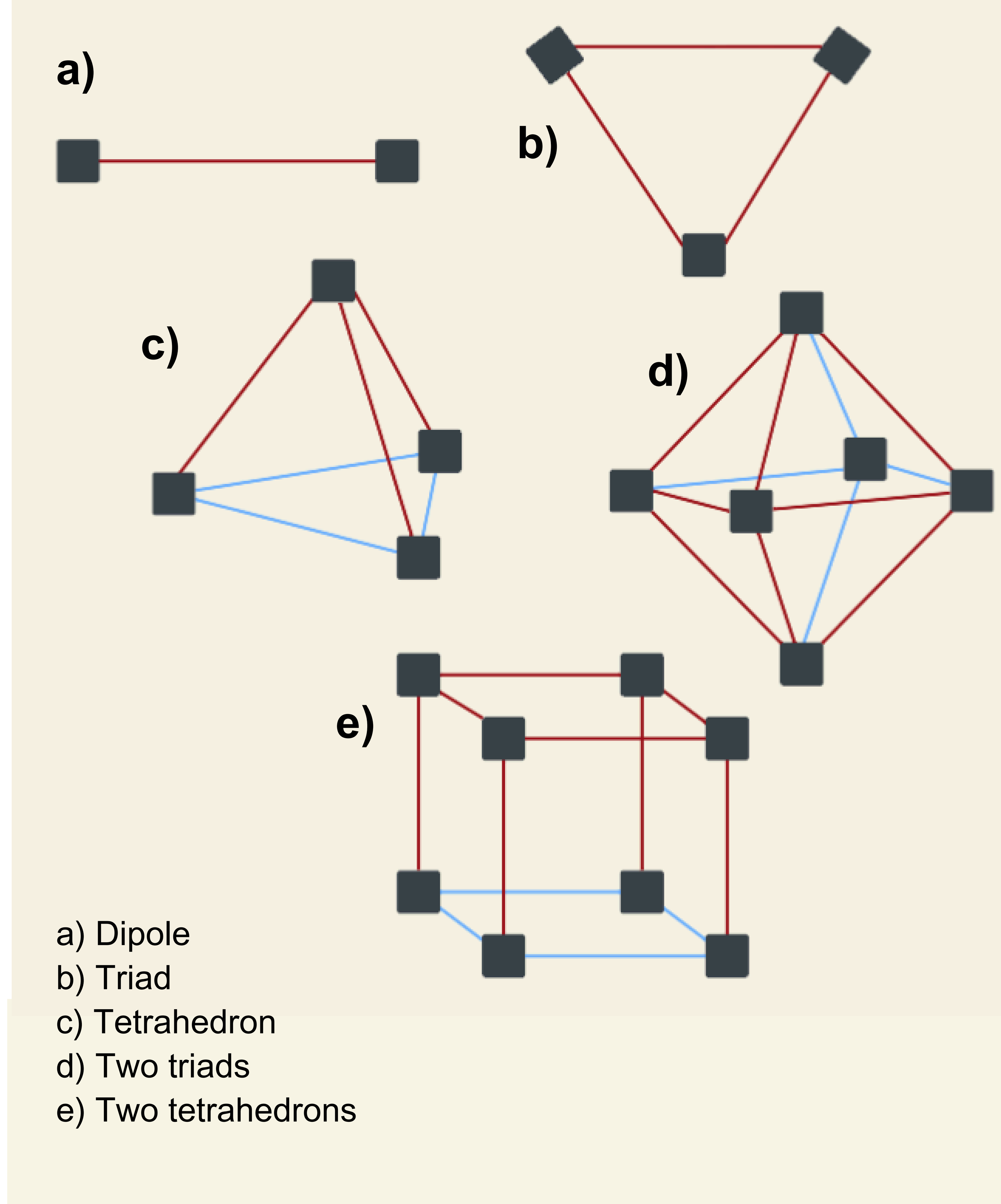


The GO-LoW Proposal

A proposal for a mega constellation of 3U CubeSats equipped with electrically short vector sensors to give initial directional and spectral information using interferometry to enable simultaneous full-sky fine spatial and spectral resolution mapping. A key drawback of their proposal is the constellation size, largely due to the low sensitivity of the electrically short antenna. [4]



GO-LoW's constellation network



a) Dipole
b) Triad
c) Tetrahedron
d) Two triads
e) Two tetrahedrons

SPINOR's Architecture

SPINOR uses resonant antennas, which offer much greater sensitivity per element, allowing a reduction in constellation size. At these wavelengths, very large deployable structures are required, so simple, spin-stabilized conductive tether designs are preferable to reduce system risk and complexity. Tether geometries range from a two-mass system (a simple dipole), to a general case of N-vertex convex polyhedra. To address the narrow bandwidth, the tethers can be extended and retracted to sweep the mapping across frequency space.

The major disadvantage of this hardware architecture is its very limited directionality, especially for dipole setups. This may still be an effective interferometric element, but the rotation enables repeated sampling, allowing the use of computational inverse imaging techniques to obtain high sensitivity and resolution.

	D	S	B	P	R	SW	C	Total
Weight	1	2	1	1	1	2	1	
Electrically short antennas								
Crossed dipole variants	3	3	1	3	1	1	1	17
Tripole variants	3	3	1	2	1	1	1	16
Vector sensor	2	2.5	1	1	2	1	2	15
Resonant antennas								
Crossed dipole variants	3	1	3	3	1	2	1	17
Tripole variants	3	1	3	2	1	2	1	16
Dish reflector - folding	1	1	2	1	3	3	3	18
Dish reflector - inflatable	1	1	2	1	2	3	2	16
Patch	2	1	3	1	3	3	3	20
Horn & corrugated variant:	2	1	2	1	3	3	3	19
Quadrifilar helix	2	1	3	1	2	3	2	18
Log-periodic	2	1	1	1	2	3	2	18
Tetrahedron vector sensor	2	1	2	1	2	2	2	15

Comparison of antenna options. Vector sensors have the best (lowest) score. – D: Directionality; S: Sensitivity; B: Bandwidth; P: Polarizability; R: Risk; SW: SWaP; C: Cost

SPINOR's Development Roadmap

Due to SPINOR's novel mission architecture, several key technologies will need to be de-risked, including the imaging techniques, rotating tether deployment, readout electronics, and satellite bus design. To address this, an aggressive test campaign will be carried out, including senior design projects flying on high-altitude balloons in Q4 2025 and Q3 2026, sounding rocket missions, a gravity-gradient deployment method on our SCALAR satellite in Q4 2025, and a 3U mission to HEO, which will demonstrate full system functionality. These will culminate in circumlunar and deep space missions, eliminating the anthropic background and enabling highly sensitive cosmology missions.

Acknowledgments

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References