SURO-LC
Space-based Ultralong wavelength Radio Observatory

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SURO Core Team:
ASTRON (NL)
Institute for Space Research (SE)
Psi-tran (UK)
Space Enterprise Partnerships (UK)
Surrey Satellite Technology (UK)
Motivation for LF space-based observatory

- Research objectives - why do it?
- Technical requirements - how to do it?
- Technical requirements - can we find components to do this?

Using innovation to put things together to reach a certain objective

Concept has been explored before but technology was not ready
All Sky Surveys

Omni-directional Imaging of All Sky
3 arcmin at 10 MHz & 30 mJy sensitivity
1 arcmin at 30 MHz & 20 mJy sensitivity

=> Detect 2 million sources in 1 yr

Source populations and their Evolution
Nuclear startup sources
  (numerous at $z = 20$)
Long-term evolution of radio sources and AGN feedback (lower energy component)
Relics of radio sources
Cool holes in clusters ($10^5$ sources)
**Stage A: The very Dark Ages** - Until $z = 40$ the hydrogen in the universe continues to absorb the CMB radiation field.

**Stage B: Ignition of Star Formation** - $z = 30$, the CMB photons and UV photons from first generations of stars absorbed by cold HI.

**Stage C: The first Black Holes** - $z = 20$, first Galaxies and accreting black holes heat HI bubbles in the IGM.

**Stage D: Hot Bubble Dominated** - Around $z = 13$, stars and galaxies make hot ionized bubbles in IGM causing of HI 21cm emission.

**Stage E: Ionization** - IGM becomes completely ionized by stars and galaxies after which HI 21-cm signature disappears.
Well-known 21cm transition of neutral Hydrogen provides accurate tracker of the ionization history during Dark Ages of the Universe.

SURO experiment would fill in the rest of the story after ground-based experiments.
HelioPhysics & Solar Weather Studies

Solar activity at lower freq
Radio Imaging - 3’ at 10 MHz

Imaging Type II & III bursts
Imaging and following CMEs to larger distances
Complementary to terrestrial
Planetary Studies

Radio Planets = Solar planetary magnetospheric emissions
- Jupiter, Saturn & Uranus

Complex spectral structures in 0.1 - 20 MHz range
Search for Jupiter-like Exoplanets in known systems
Galactic Interstellar Medium
Local clumpy Warm Ionized Medium
(RAE-2 & IMP-6 sats 1975, 2002)

3D Origin of Cosmic Rays
- nearby HII & SNR sources

Radio Recombination Lines
- also foreground for EOR

Strong pulsars - low frequency properties
Transient phenomena
Motivation for LF space-based observatory

• Research objectives - why do it?

• Technical objectives - how and where to do it?
  • Observe whole sky all the time -
  • Application of existing antenna theory - three dipoles
  • Multiple satellite stations - formation flying
  • Use radio interferometry - omni-directional
  • Far away from Earth - Sun-Earth Lagrange point 2

• Technical requirements - can we find components to do it?
Three Orthogonal Dipole antennas

Antenna technology explored with terrestrial radio observatory LOFAR
Daughters slowly drift back and forth through constellation
Radio interferometry works if we know the positions
No need to maintain positions as in 'formation flying'

Daughters are observing stations
Mother has correlator and is relay station for correlated data
Lissajous Orbit at Sun/Earth L2

Distance 1.5 Mkm
Closer to terrestrial RFI

VEGA launcher
1900 kg mass limit
Motivation for LF space-based observatory

- Research objectives - why do it?

- Technical requirements - how and where to do it?

- Technical requirements - can we find components to do it?
  - Weight limitations - launching cost and weight
  - Power consumption limitations
  - Technology developments - use small satellites
  - Operational limitations - how to get the data back to Earth?

- System Requirement: Technological Readiness Level >5
Launch Concepts

Solar Wind stabilization Daughters and Mother Daughters based on cubesat (minisat) technology
Quiet deployment (magnet release)
Thrusters for orbit corrections within group
Adapted LISA Pathfinder concept
Small Sat technology

Cubesat - small satellites

Daughter dry mass 11.1 kg  
Power 29 W

Mother dry mass 366 kg  
Power 350 W

Total dry mass 499 kg

Total launch mass 1886 kg
Minimalist version of SSTL SNAP small Satellite

Stripped down LISA Pathfinder platform for mothership
Dipole antennas about 3m tip-tip
System Noise dominated by Galactic background
Blanking/Nulling Terrestrial Interference at L2
Innovative deployment mechanism
Drifting configuration and multiple snapshots improve imaging capability \(\Rightarrow (u,v,w)\) infilling and improved psf.

Distributed aperture using multiple stations

\(\Rightarrow 8\ (9)\) stations give 28 (36) baselines.

Image results from FFT of coherence function (3 x 3 matrix).

Phasing system for any source direction gives brightness distribution in 2 x 2 matrix which contains all Stokes information.

Omni-directional imaging.
Putting Components Together

Using small satellite technology
Using innovative metrology /sensing techniques
Stripping existing satellite platforms
Newest hardened FPGA processing chips for daughters and mother
Using proven radio interferometry techniques
High data rate between satellites (android technology) and reduced data rate to Earth
Using mitigation algorithms reduce terrestrial radio interference
Use omni-directional antennas for all-sky imaging
New ranging methods to determine distances
Release mechanism - to be perfected

Putting existing know-how/knowledge together in a new way
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<thead>
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<th>PROGRAMME ELEMENT</th>
<th>COST M€</th>
<th>COMMENT</th>
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<td>Payload</td>
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<td>Antenna and receivers</td>
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<td>Mothership</td>
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Space based Ultra long wavelength Radio Observatory

SURO-LC (Low-cost)
ESA Small-Class Call – June 15, 2012
5 yr project – flight in 2017

Current core team UK, NL, SE
Further participation from IT, FR, DE, PL, CN, USA, RUS, AUS, IN