Continuum Surveys with LOFAR, SKA and its Pathfinders

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LAGRANGE

Observatoire de la CÔTE d'AZUR

Université Nice Sophia Antipolis

A Golden Age for Radioastronomy:
SKA Precursors and pathifinders

LOFAR
Europe
30-80 MHz +
110-240 MHz

MWA
Australia
80 - 300 MHz

APERTIF
The Netherlands
1000 - 1750 MHz

ASKAP
Australia
700 - 1800 MHz

MeerKAT
South Africa
1000 - 1750 MHz

+ JVLA

LWA

eMERLIN

eEVN

...

SKA
Australia / New Zealand / South Africa
~ 50 MHz - 10 GHz

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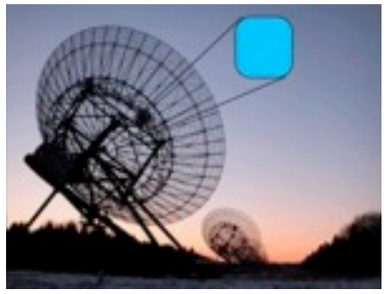
Key Project "Surveys"

Key Project "Magnetism"

MWA
Australia
80 - 300 MHz

GLEAM

(Continuum & Polarization)



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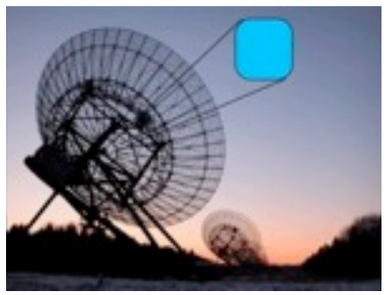

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Home

Science Planning Workshop

White Paper Library

Call for White Papers

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Timeline & Structure

Jansky VLA Capabilities

Frequently Asked Questions (FAQ)

VLA Sky Survey

News Update: Initial White Papers Received and Posted

There are now 21 VLASS White Papers or abstracts received and posted online. Thank you for your responses to our call!

News Update: VLASS Workshop at the 223rd AAS Meeting a Success!

The VLASS Science Planning Workshop was held on 5 January 2014 at the 223rd AAS Meeting in National Harbor, MD. You can find the agenda and posted talks here.

In the 20 years since the initial observations were made for the *NRAO VLA Sky Survey (NVSS)* and the *Faint Images of the Radio Sky at Twenty-Centimeters (FIRST)*, these pioneering programs have defined the state-of-the-art in centimeter radio sky surveys and produced a steady stream of excellent science. Given the enhanced capabilities of the Jansky Very Large Array (VLA), now is an appropriate time to discuss the scientific potential of new centimeter-wavelength sky surveys.

The astronomy community has already recognized that several of the high priority science goals of the 2010 decadal survey *New Worlds, New Horizons in Astronomy and Astrophysics* could be addressed by a new VLA sky survey. At the May 2013 *Radio Astronomy in the LSST Era* held at NRAO-Charlottesville, for example, many scientists expressed keen interest in employing the VLA to conduct new, wide-area centimeter wavelength sky surveys in support of multi-wavelength synoptic surveys using existing and future facilities, such as the Large Synoptic Survey Telescope (LSST).

Thus, we are announcing a NRAO VLA Sky Survey (VLASS) initiative that will explore the science and technical opportunities of a new centimeter-wavelength survey. A community-led Science Survey Group (SSG) will define the science program and key components of VLASS, and NRAO will support its technical

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W.G. Continuum Surveys

W.G. Cosmic Magnetism

Summary plot for radio surveys (I)

Similar comparison for low-frequency surveys in Tingay+ 13

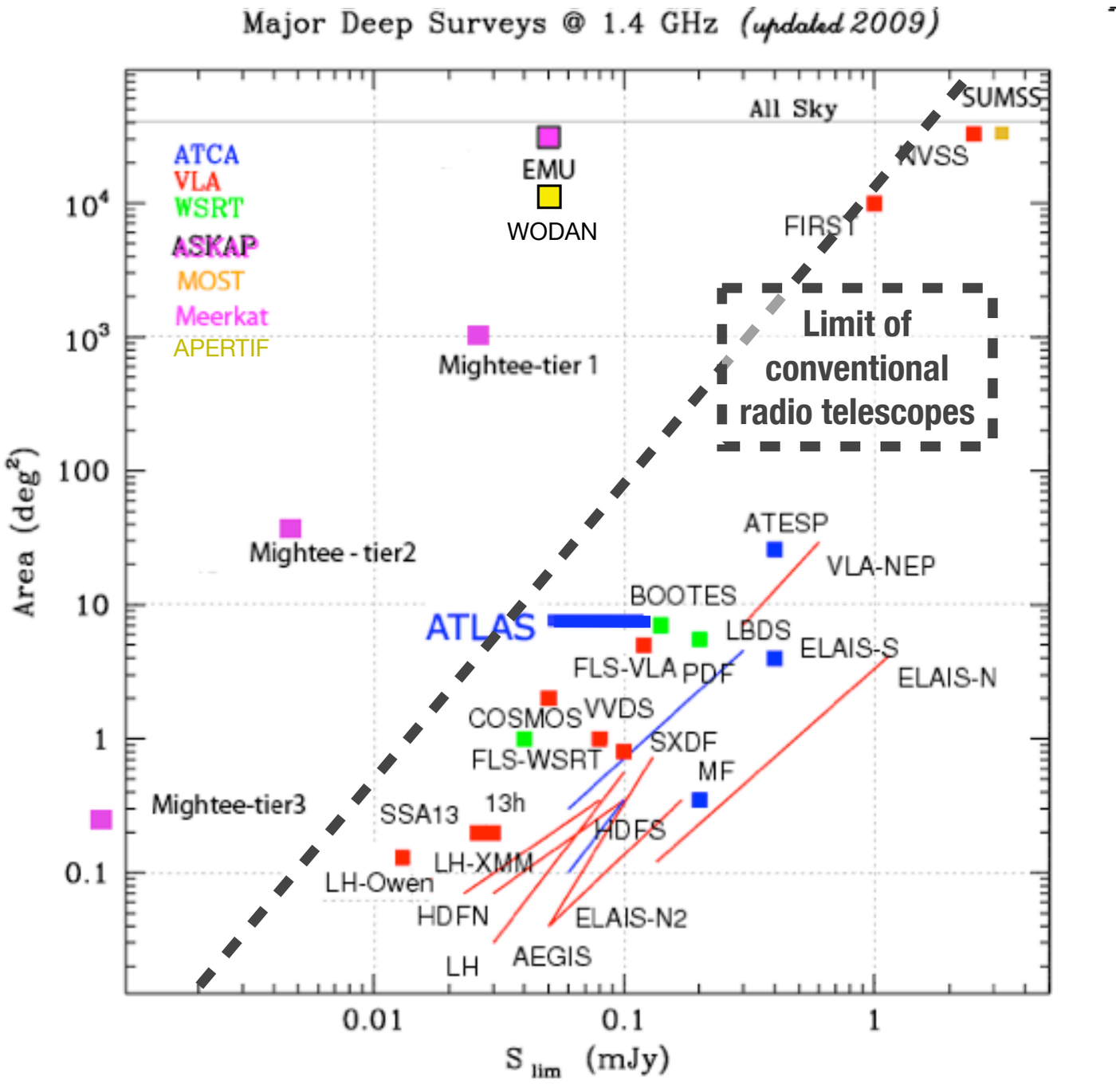
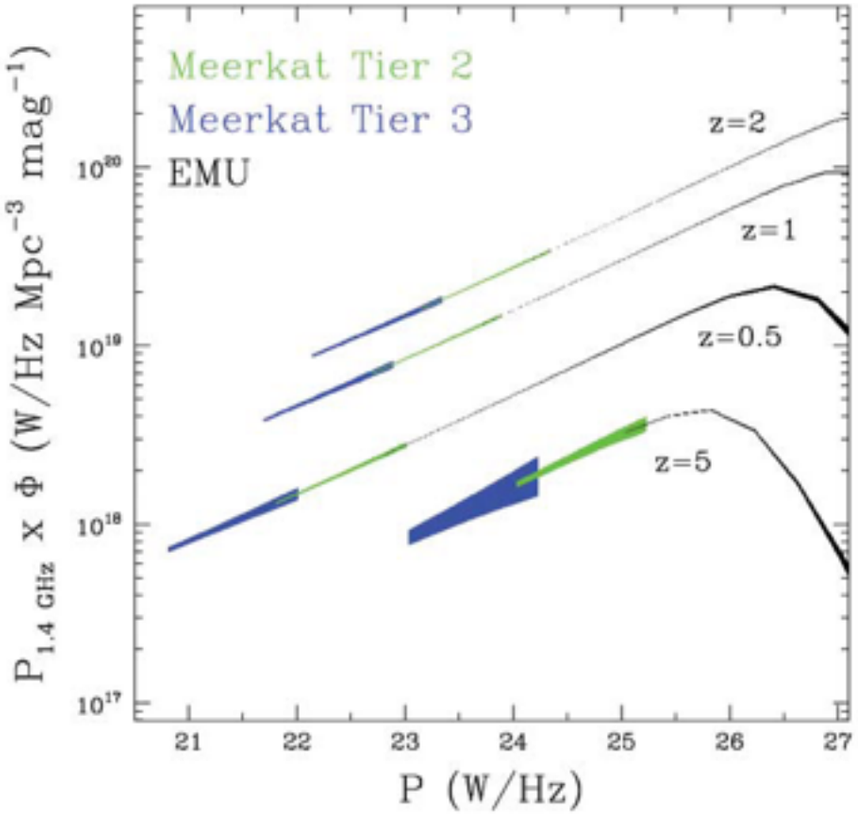
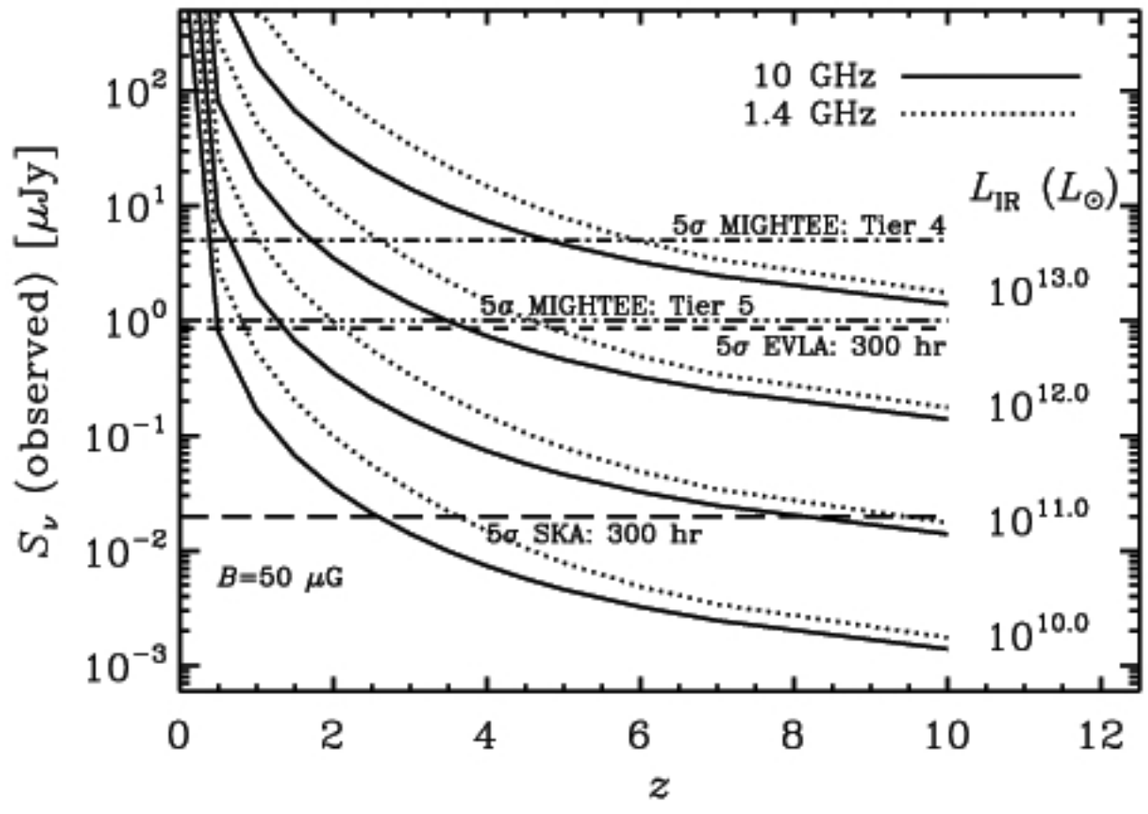


Diagram courtesy: Isabella Prandoni - see Norris+ 12

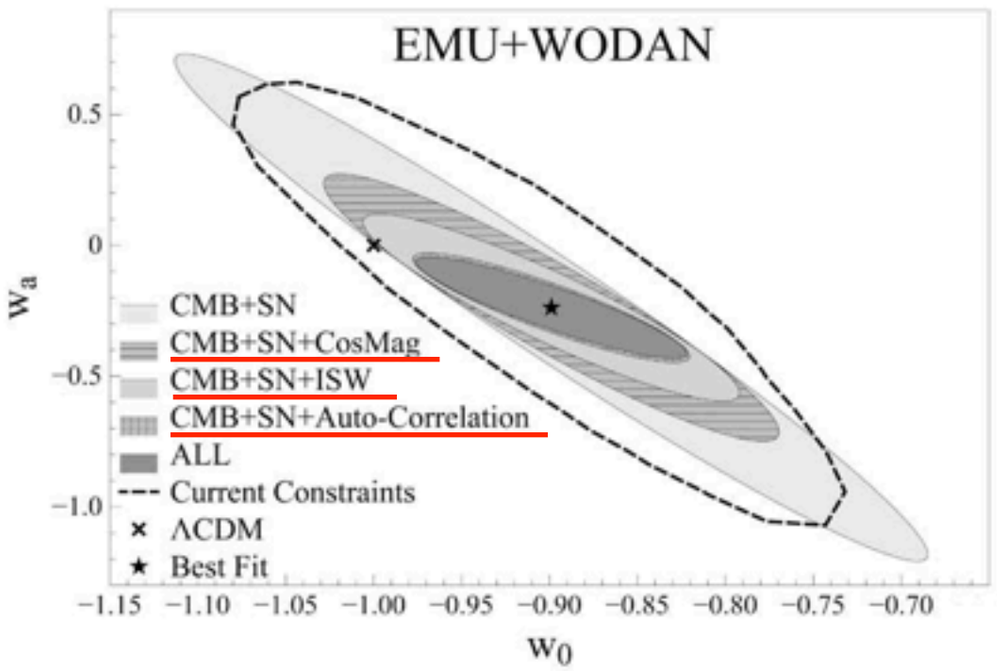
AGN luminosity function



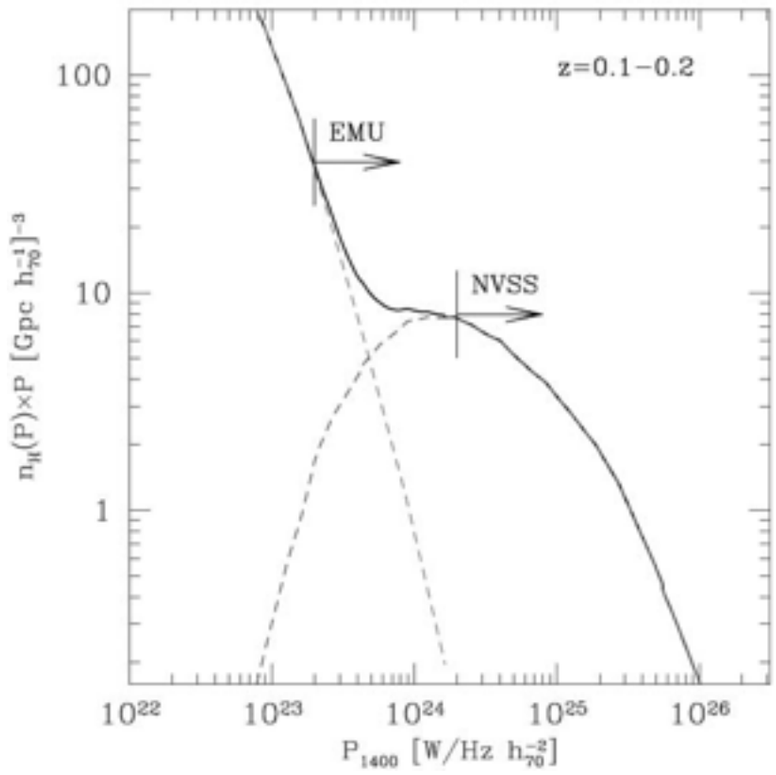
Expected flux densities for galaxies at different IR luminosities



Predicted constraints on dark energy equation of state



Expected luminosity function of cluster radio halos



Norris+ 12

Main science goals

- **Galaxy evolution**
  star-formation vs. AGN, environment, z

  → ***see talk by M. Lehnert***

- **Large scale structures**
  galaxy clusters, super-clusters, filaments

  → ***see talks by A. Bonafede & F. Vazza***

- **Cosmology**
  Int. Sachs-Wolfe eff., power spectrum, cosmic magnification

  → ***see talk by B. Wandelt***

- **Magnetism**
  magnetic fields from the Milky Way to intra-cluster filaments

  → ***see talk by Katia Ferrière***

- **Galactic Science**
  radio sources within our MW

  → ***see talks by P. Zarka & J. Girard***

- **Rare/Legacy**
  new objects, serendipity, legacy value

+ Importance of multi-wavelength synergies !!!
(see talks by F. Combes, G. Pratt, M. Langer, H. Sol)

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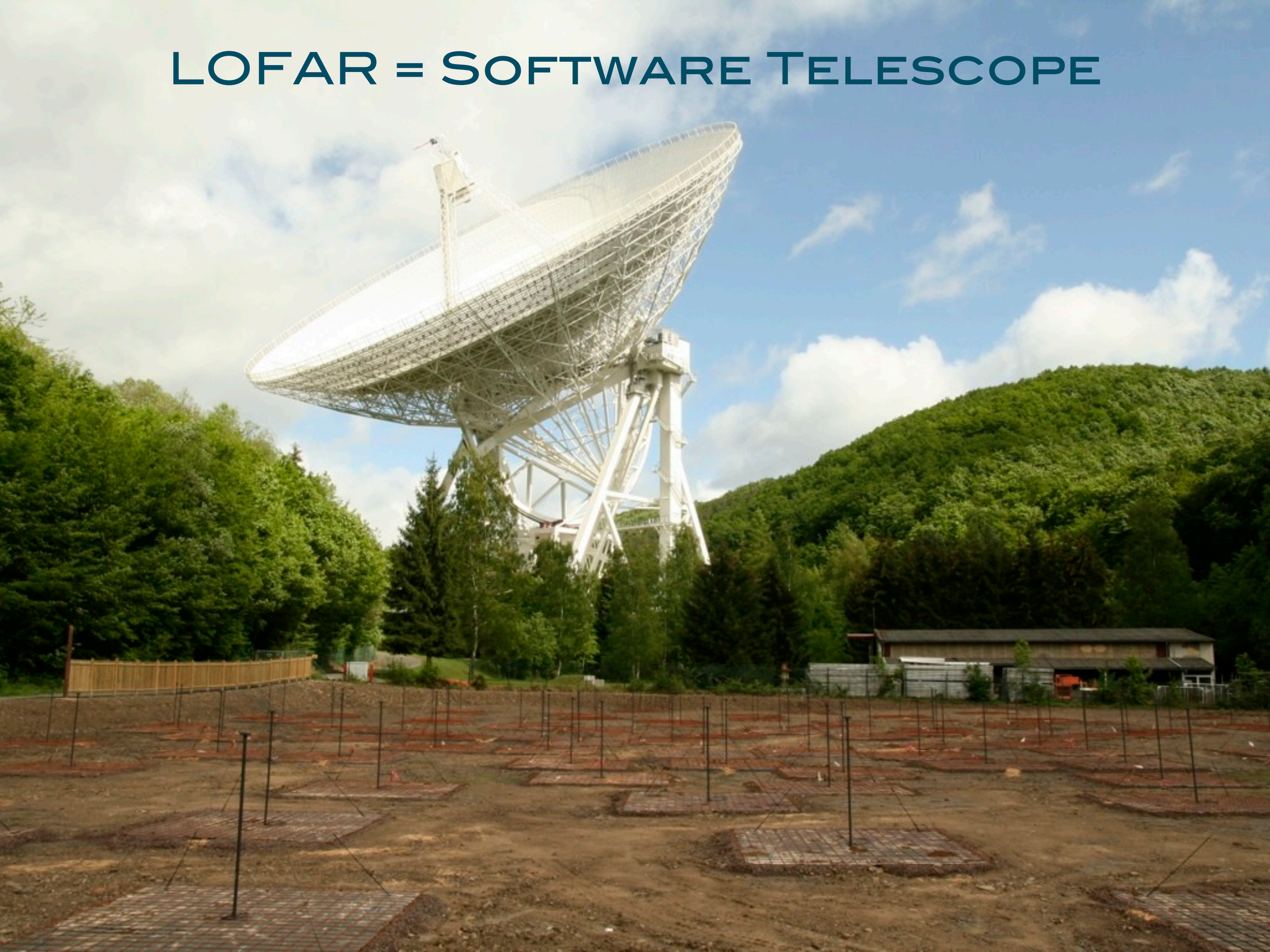
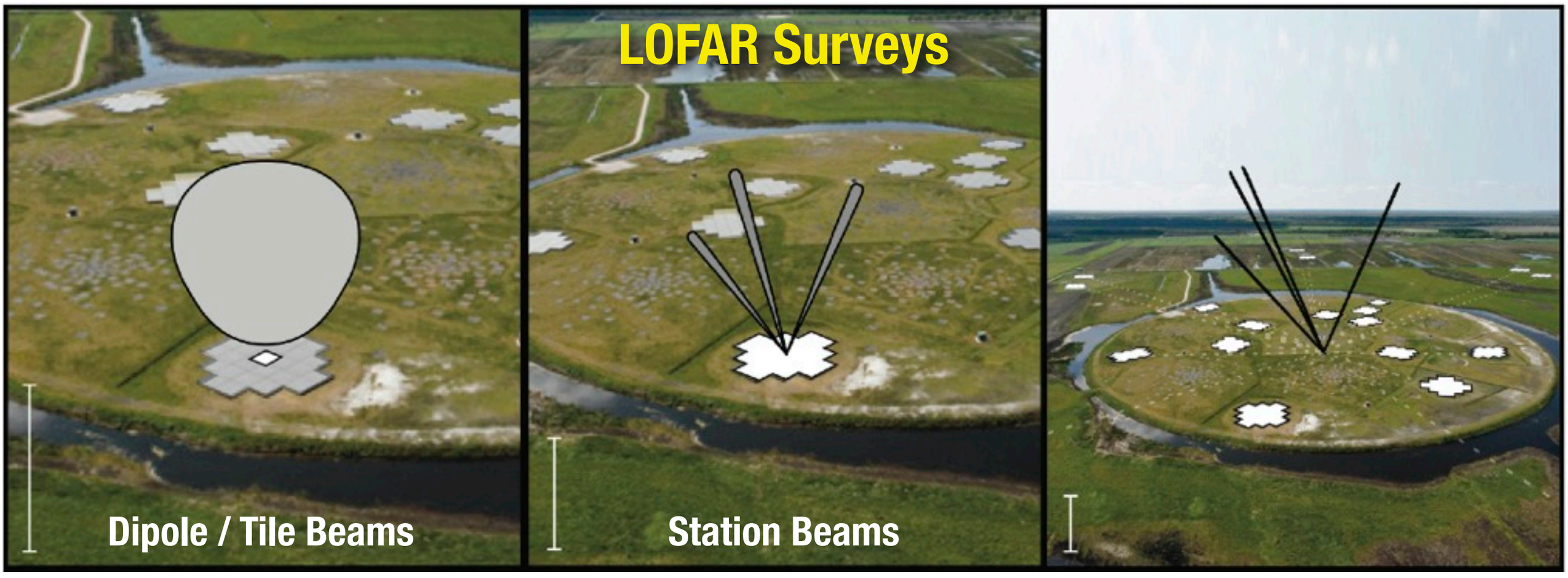
LOFAR = Software Telescope

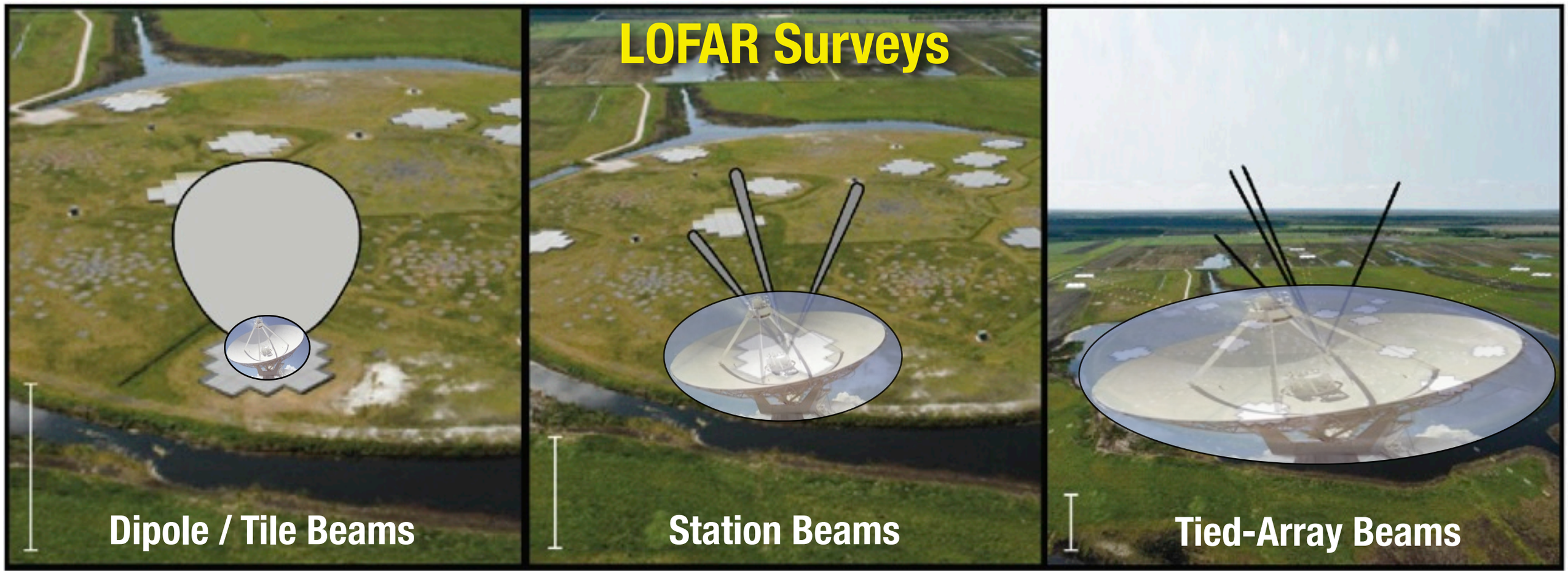


LOFAR = Software Telescope

LOFAR PRIMARY BEAM



LOFAR PRIMARY BEAM

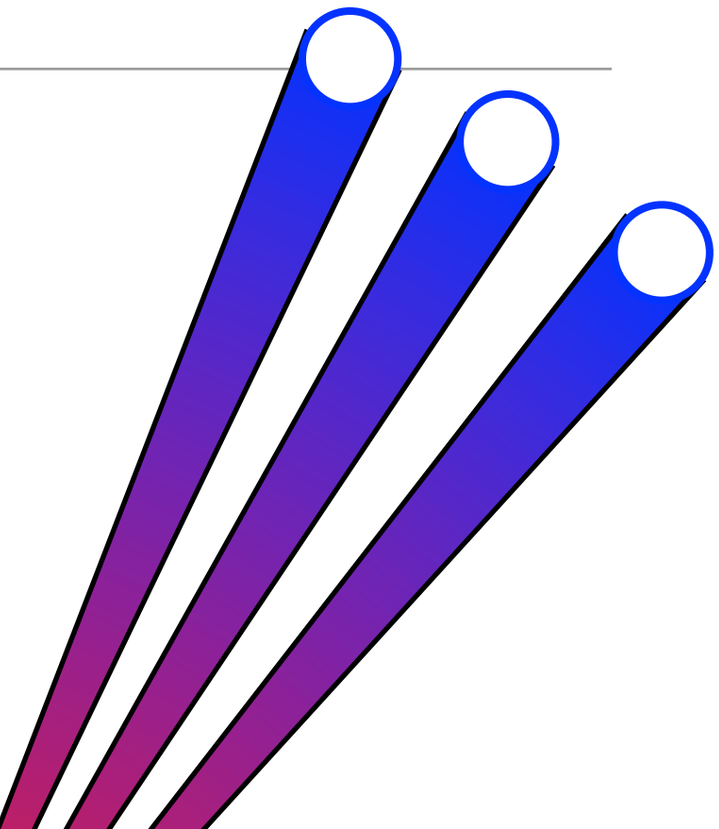


Stappers+ 11

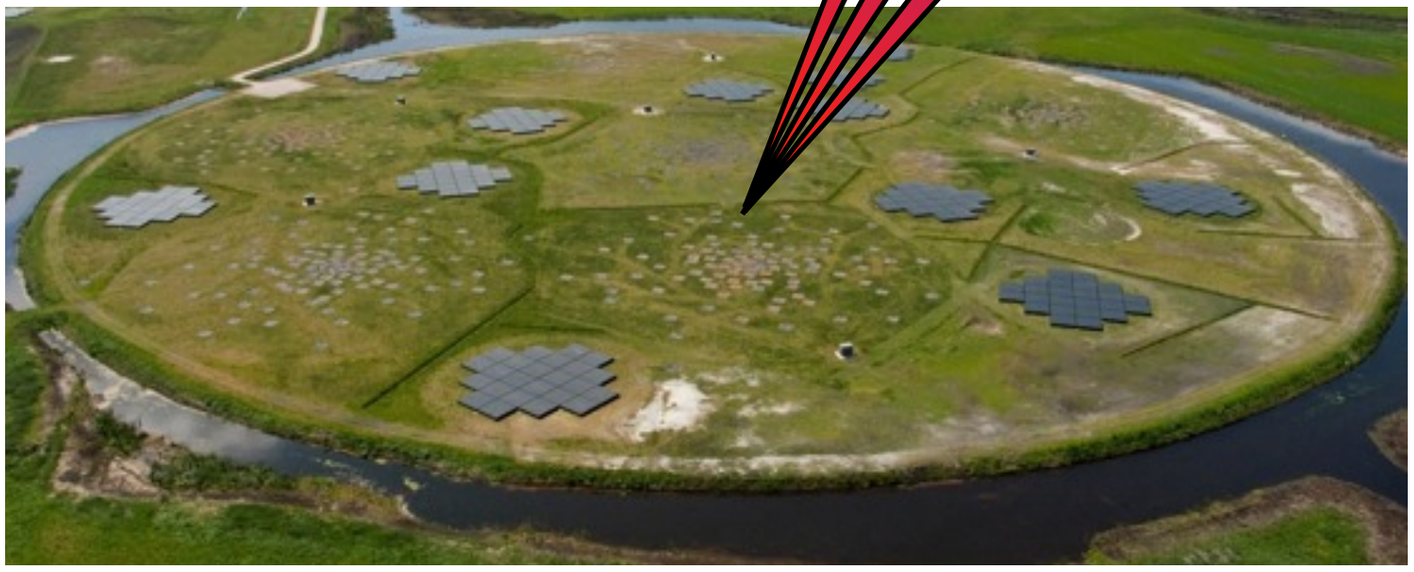
MSSS: FIRST LOFAR IMAGING SURVEY

LOFAR MSSS: Multifrequency Snapshot Sky Survey

- Multifrequency: 16 2-MHz bands from 30-180 MHz
- Snapshot: Multi-epoch short observation mode
- Sky: Quickly cover entire northern sky
- Survey: First large LOFAR imaging program

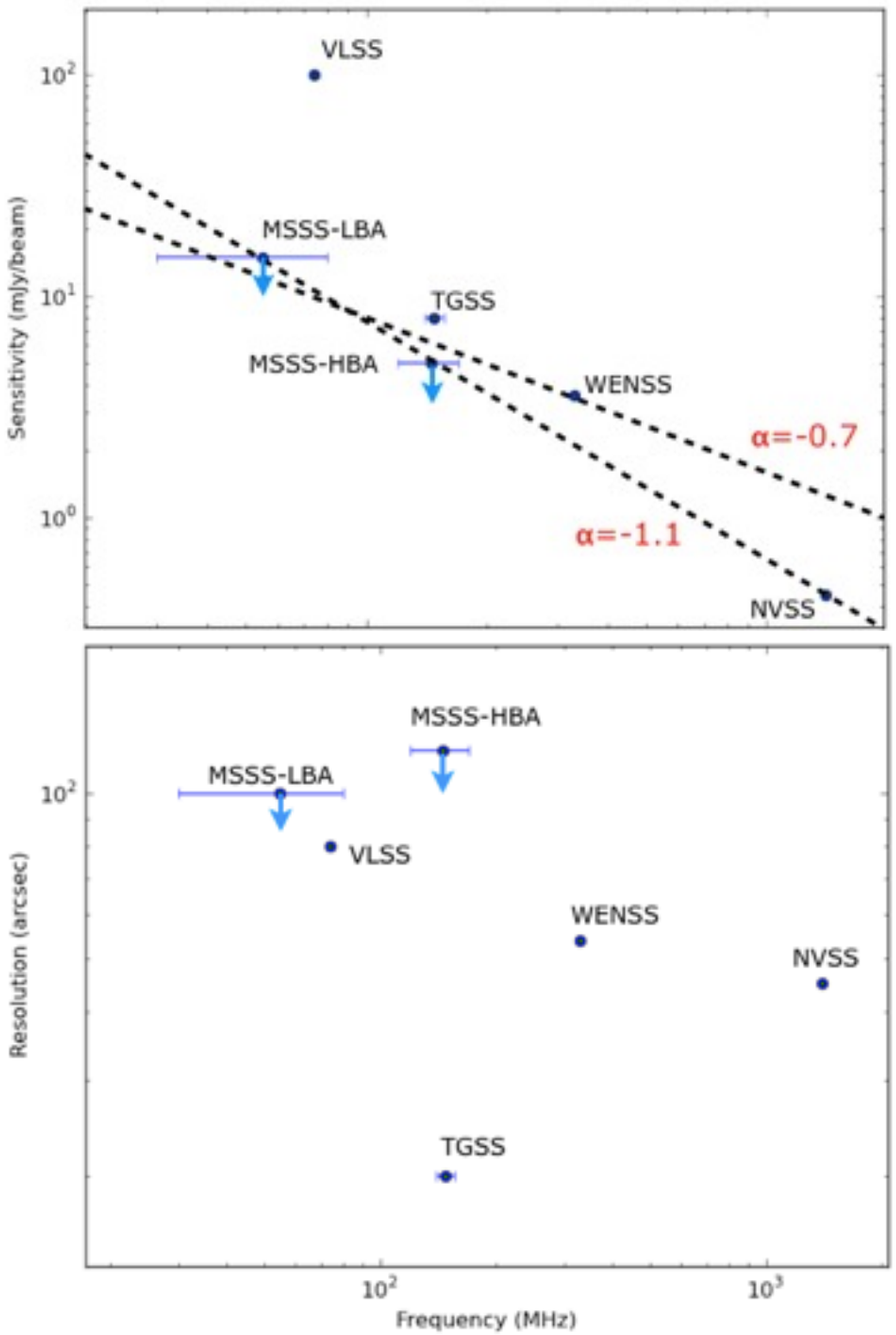


MSSS uses
3 simultaneous
***broadband** beams*



***Heald** & MSSS Team*

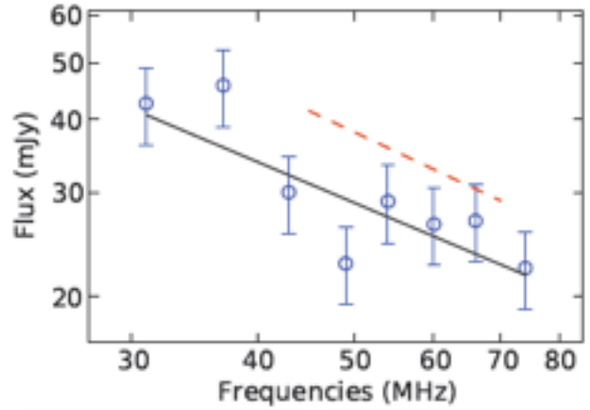
MSSS: EXCELLENT COMPARISON WITH EXISTING SURVEYS



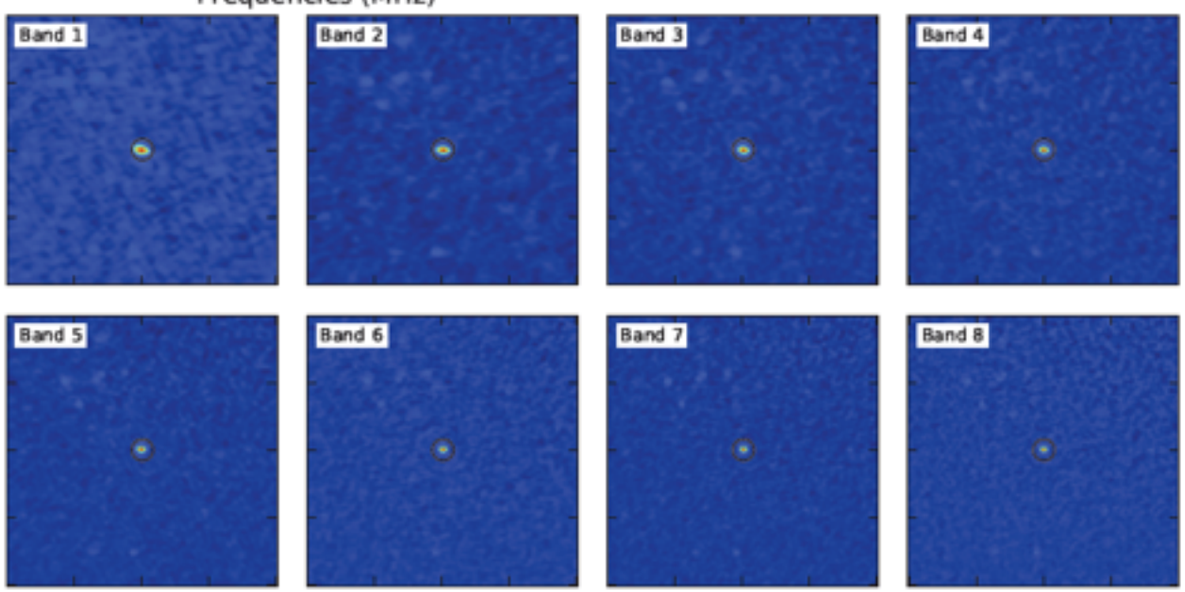
Heald+ in prep

MSSS data will be publicly available

> catalog & images <



Field: L070+69 ID: 001
RA: 04:34:27.0291 Dec: 72:29:11.2712
Distance center: 3.301°
Number of detections: 8 [1 2 3 4 5 6 7 8]
Spectral index: -0.72 ± 0.21
χ^2 =6.96 (6 d.o.f)
Catalogue detection: 0434.4+7229



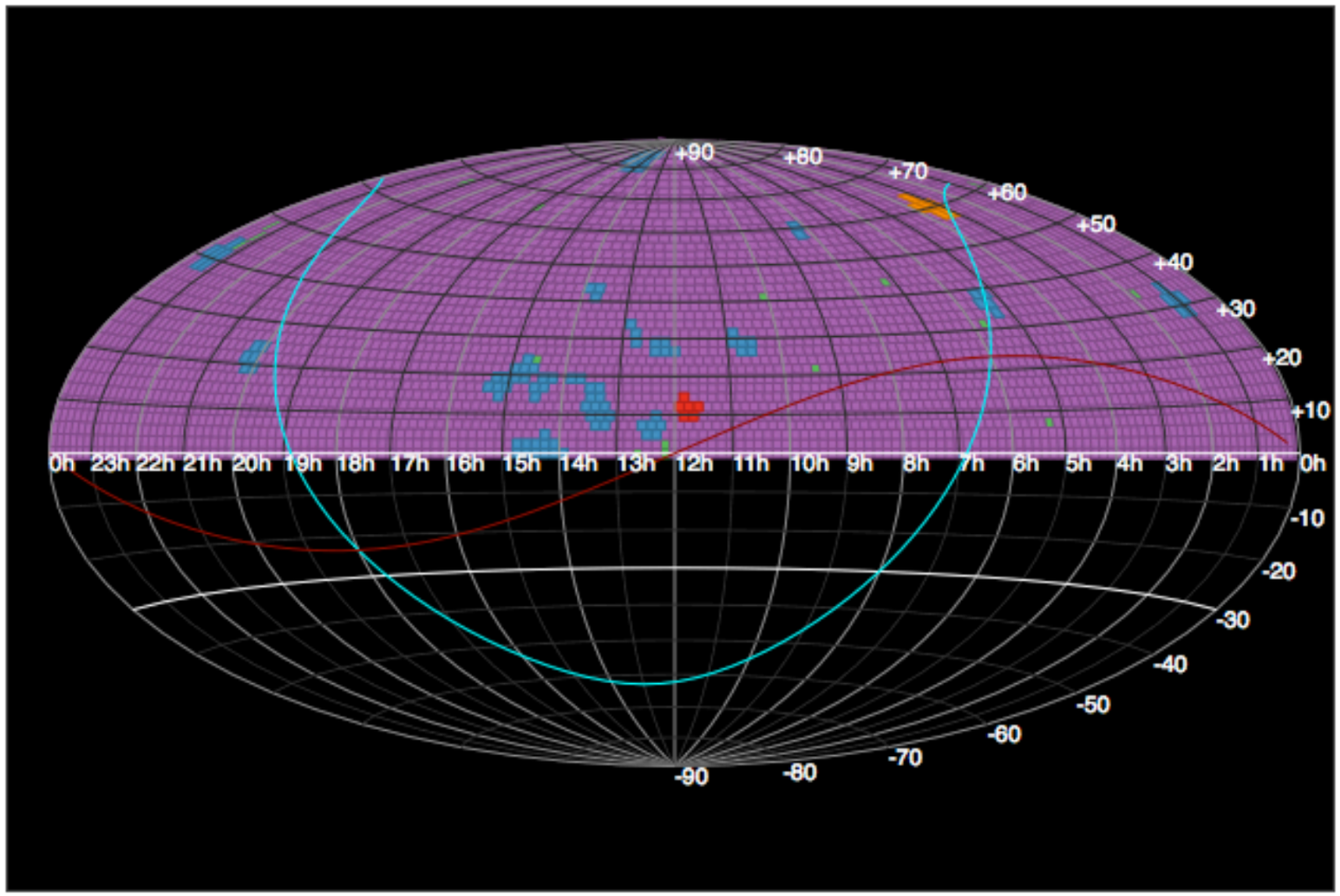
MSSS IN GOOD SHAPE !

LOFAR Observation Database

MSSS HBA

Number of Targets	3616
Number of Calibrators	8
Start Date	8 Feb. 2013
Stop Date	27 Jan. 2014
Completed Fields	3514 (97.2%)
Information collected	5 Feb. 2014

Show me the data »



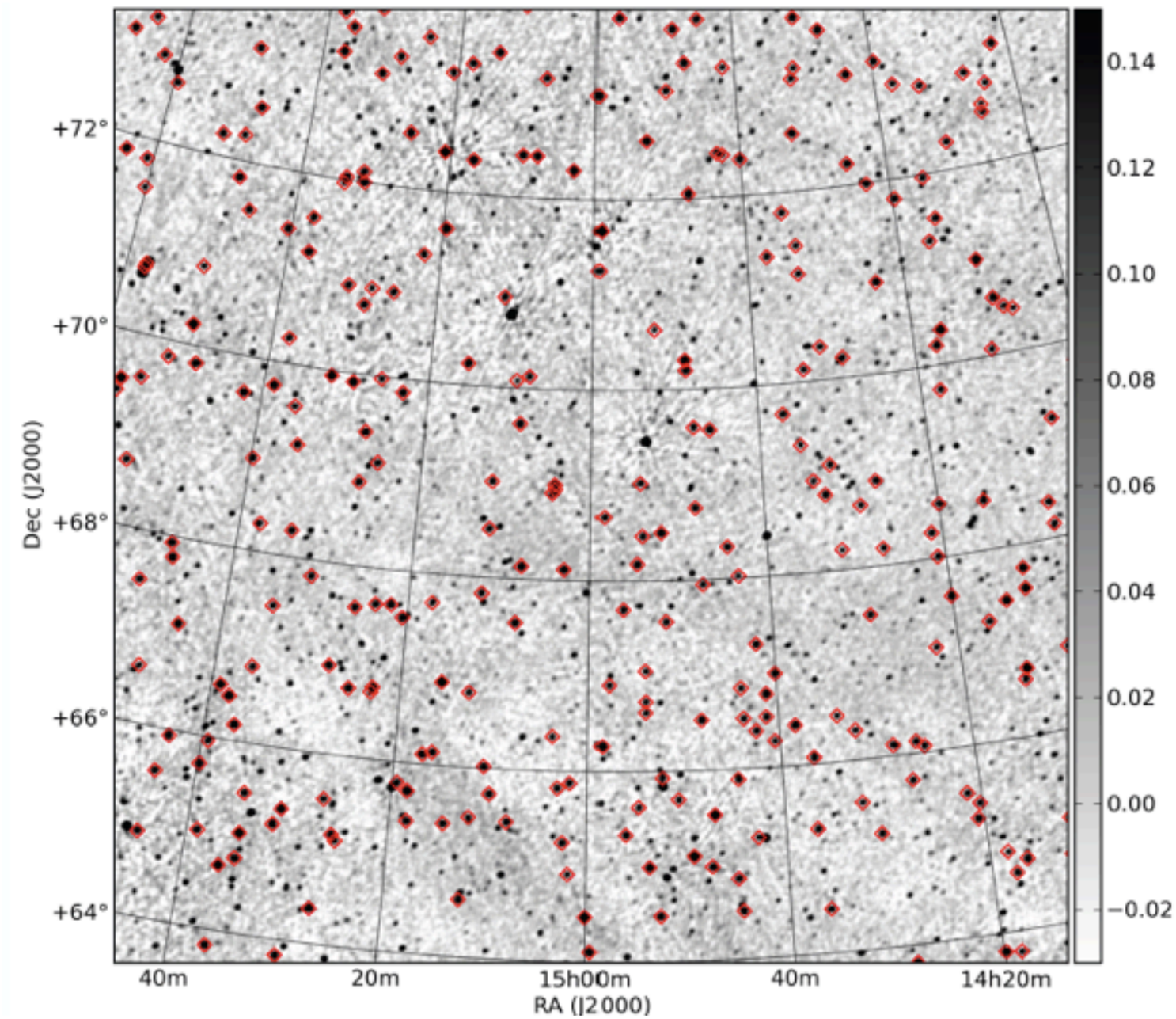
Hammer Projection

Map based on code from this project.

Data available on CEP (0.4%)
Data archived (96.5%)
Partial data available (2.7%)
Data missing (0.2%)
Not yet observed (0.2%)

Courtesy:
George Heald & MSSS Team

MSSS: VERIFICATION FIELD



Courtesy: Heald & MSSS Team

Heald+ in prep.

LOFAR Key Science Projects

- Epoch of Reionisation
- **Deep extragalactic surveys**
- Transient sources
- Ultra high energy cosmic rays
- Solar science and space weather
- Cosmic magnetism

LOFAR Key Project Surveys

- ***Large Area Survey (Tier 1)***

  2π ster. @ 15, 30, 60, 120 MHz

  783 deg^2@ 200 MHz

  → **100 galaxy clusters @ z > 0.6**

  → **200 radio-galaxies @ z > 7**

- ***Deep Area Survey (Tier 2)***

  Several hundreds deg^2 @ 30, 60, 120, 200 MHz

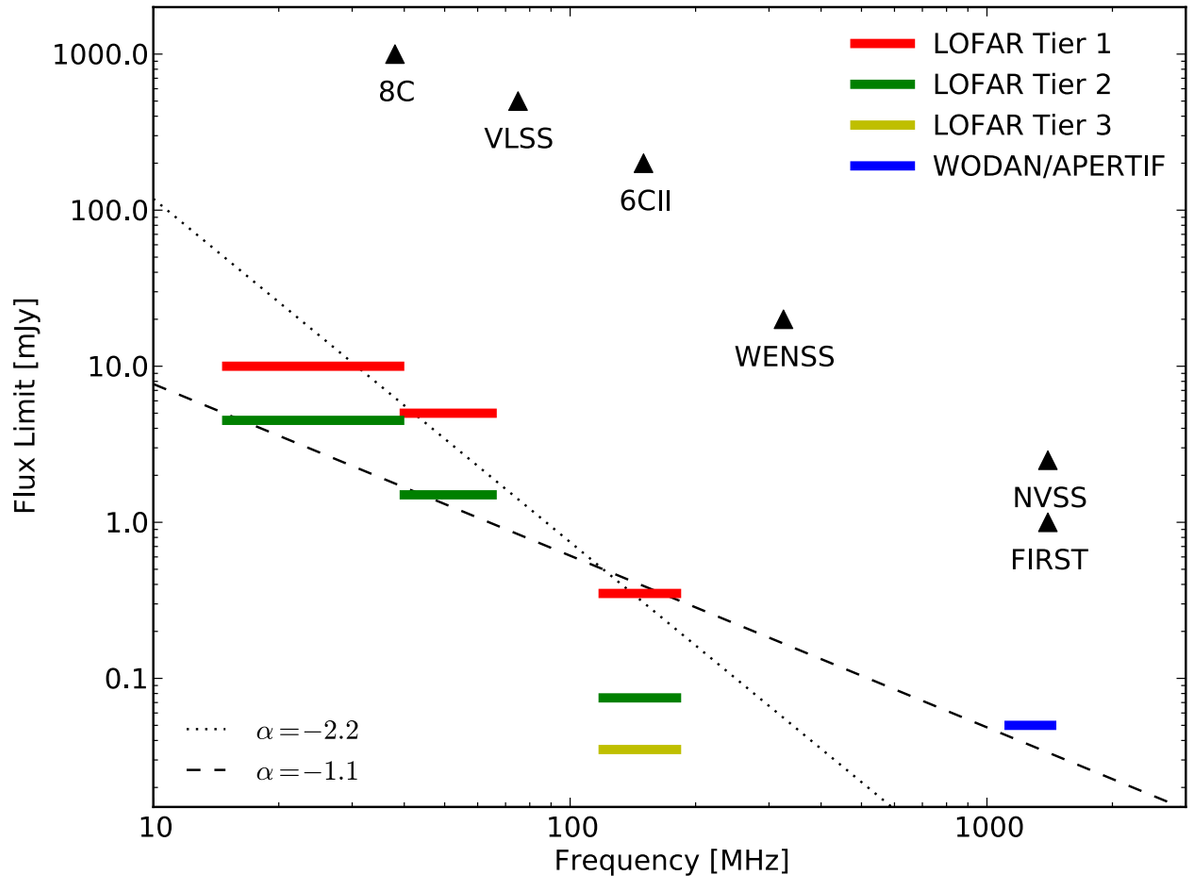
  → **SFR ≥ 10 M_{Sun}/yr @ z = 0.5**

  → **SFR ≥ 100 M_{Sun}/yr @ z = 2.5**

- ***Ultra-Deep Area Survey (Tier 3)***

  ~70 deg^2 @ 150 MHz

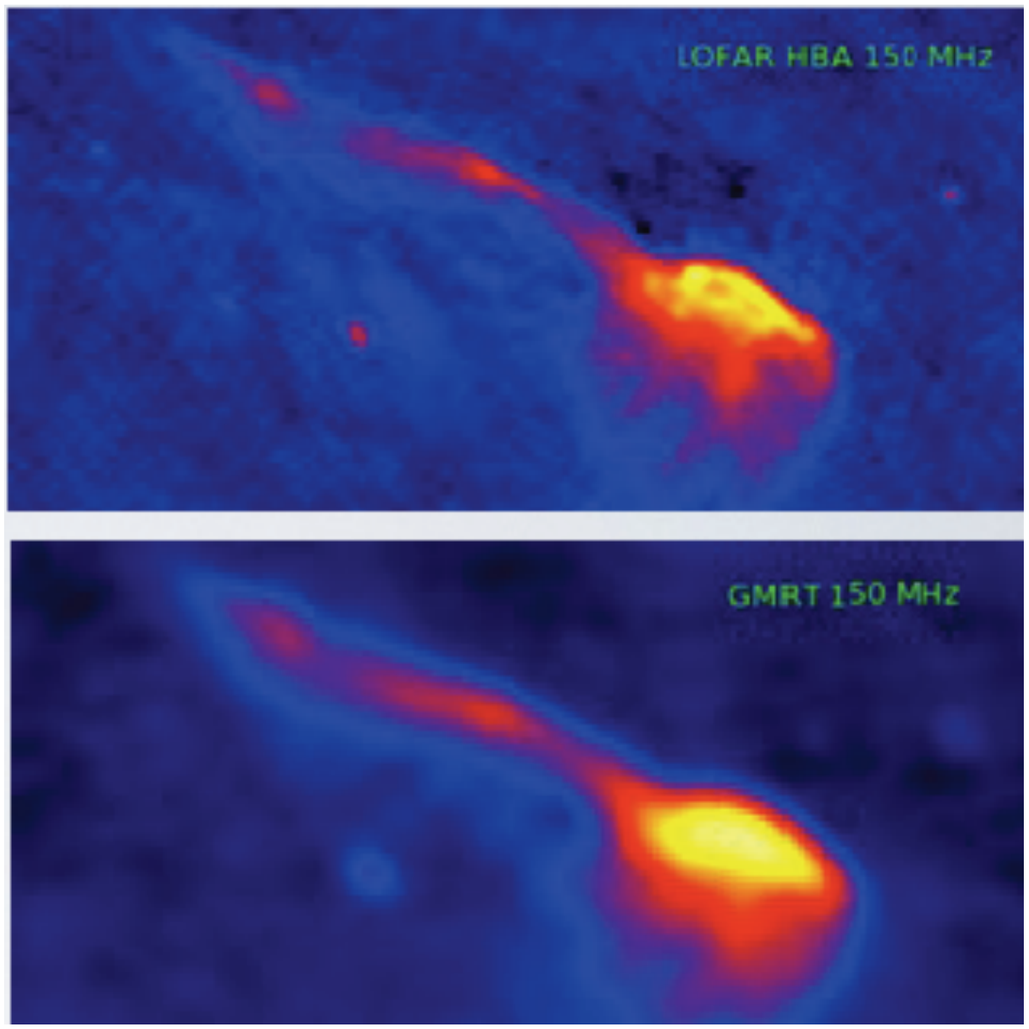
  → **20 proto-clusters @ z > 2**



Courtesy: H. Röttgering

On-going LOFAR Surveys

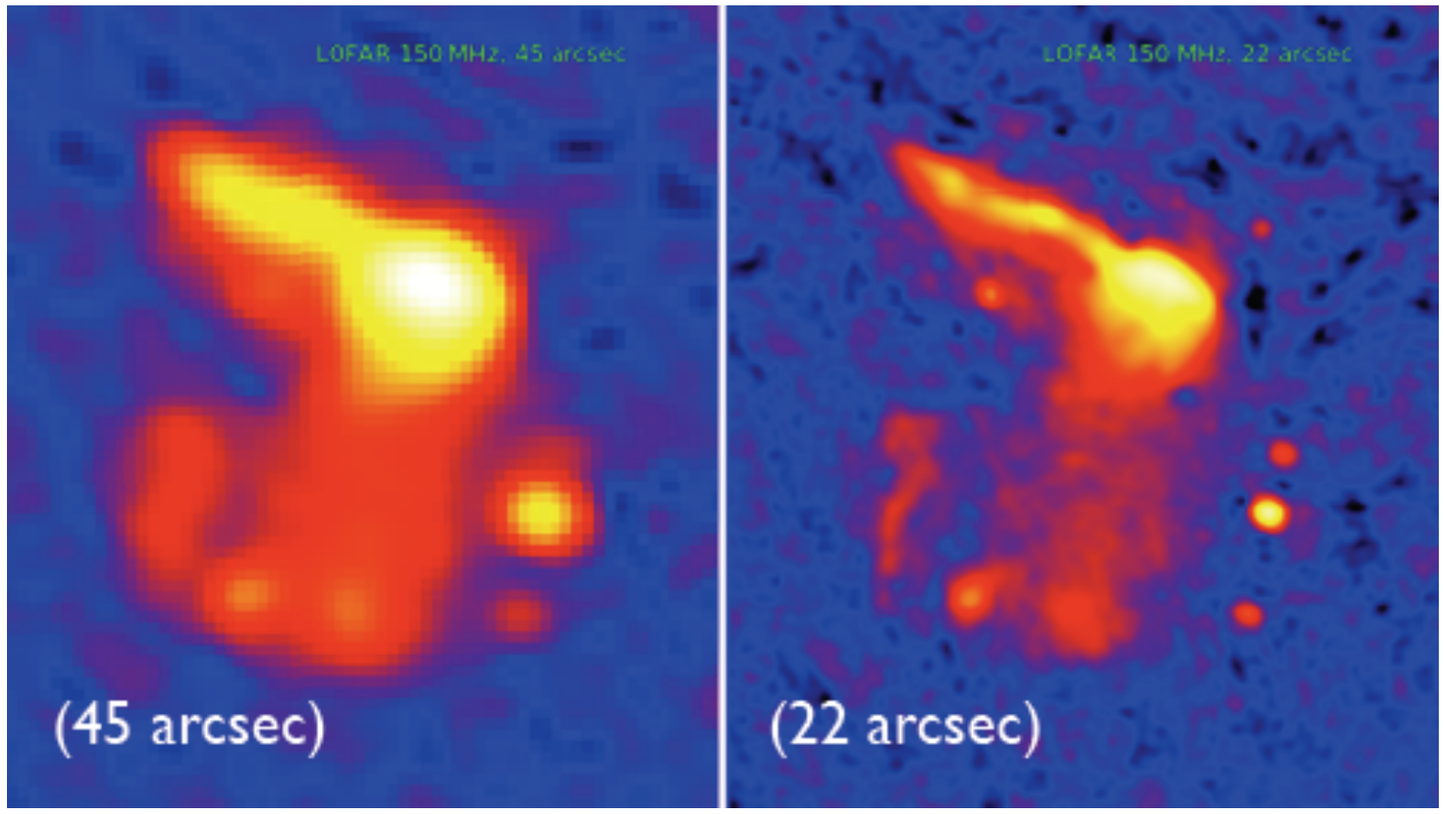
LOFAR Cycles 0-1



Full resolution (5x7 arcsec), 140-160 MHz
close to thermal noise (190-250 microJy/beam)

Only 30% of available bandwidth !

Images by R. van Weeren
(Toothbrush Galaxy Cluster)



Courtesy: H. Röttgering & LOFAR Surveys KP

SKA Continuum science

Inputs

- SKA Continuum Science Team: Monthly Telecons
- Science Assessment Workshop: 9-11 Sept. 2013 at SKAO
- Team + Experts + SKA Office

Scopes

- Identify critical science driven technical requirements for SKA1
- Discuss possible SKA1 Baseline Design changes required by key science cases
- Make recommendations and prioritize change requirements, if needed
- Indicate pathway to SKA2

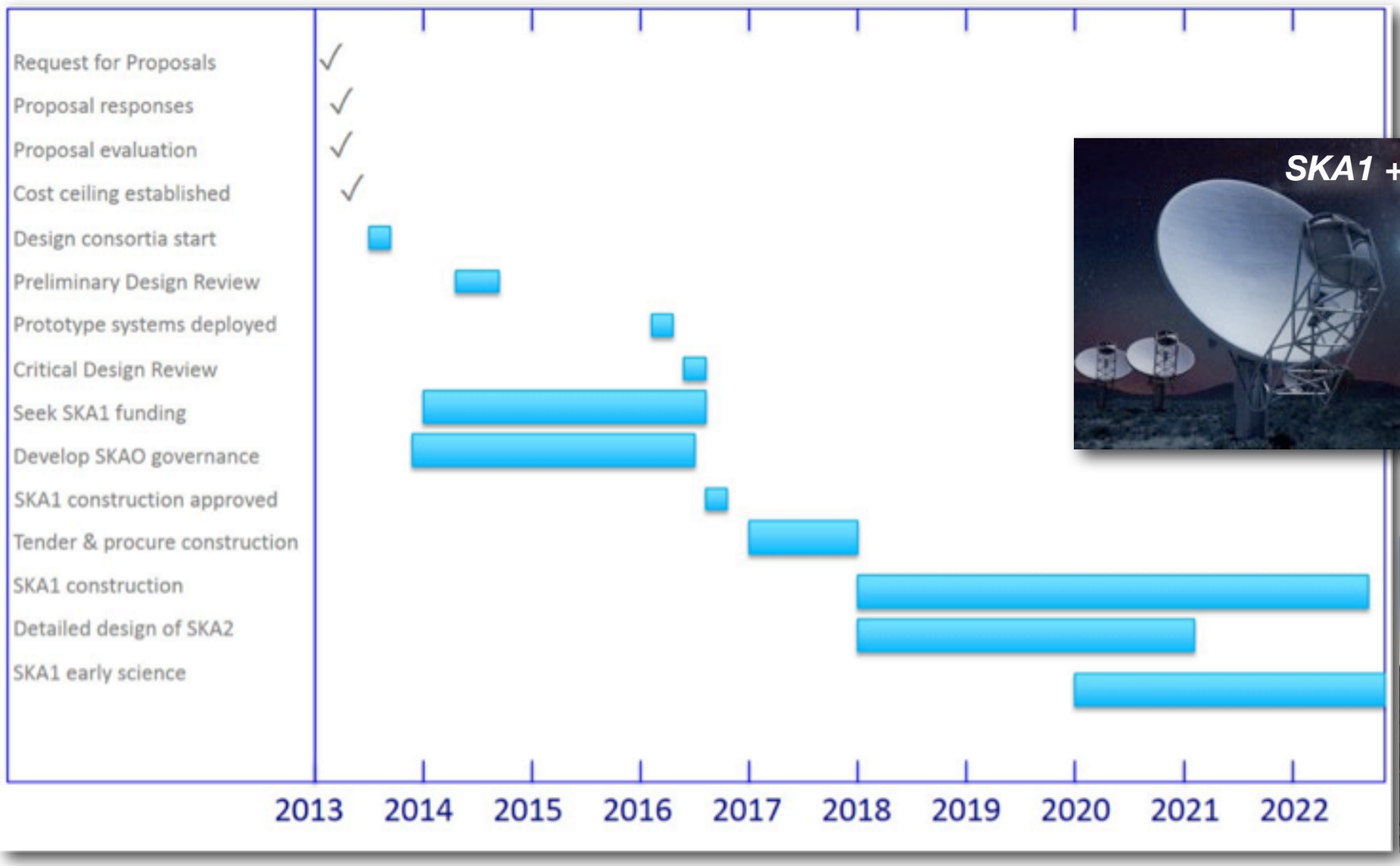
Caveat

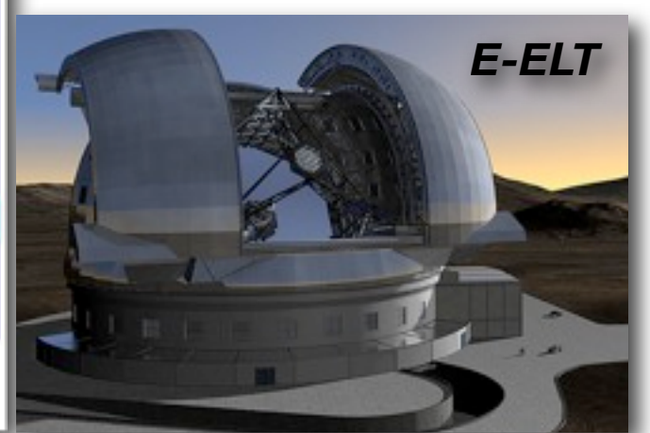
on-going work

variety of science areas addressed by continuum surveys - need to focus
…..BUT can attract large communities (not only radio)

*SKA Engineering meeting - Courtesy: **I. Prandoni, N. Seymour** & Continuum Science WG*

SKA Working Groups & Surveys





See also talk by Françoise Combes

Three major continuum surveys

- Deep (galaxy evolution @ z>1 - deep fields - lensing clusters)
  30 deg^2 survey @ 0.5” resolution & 40 nJy/beam rms sensitivity
- Wide (weak lensing - galaxy evolution @ z<1)
  5000 deg^2 survey @ 0.5” resolution & 0.3 uJy/beam rms sensitivity
- All-sky (power spectrum, clusters, magnetism, galactic, legacy)
  31000 deg^2 survey @ 2” resolution & 2 uJy/beam rms sensitivity

→ SKA1 @ ~ 1-2 GHz

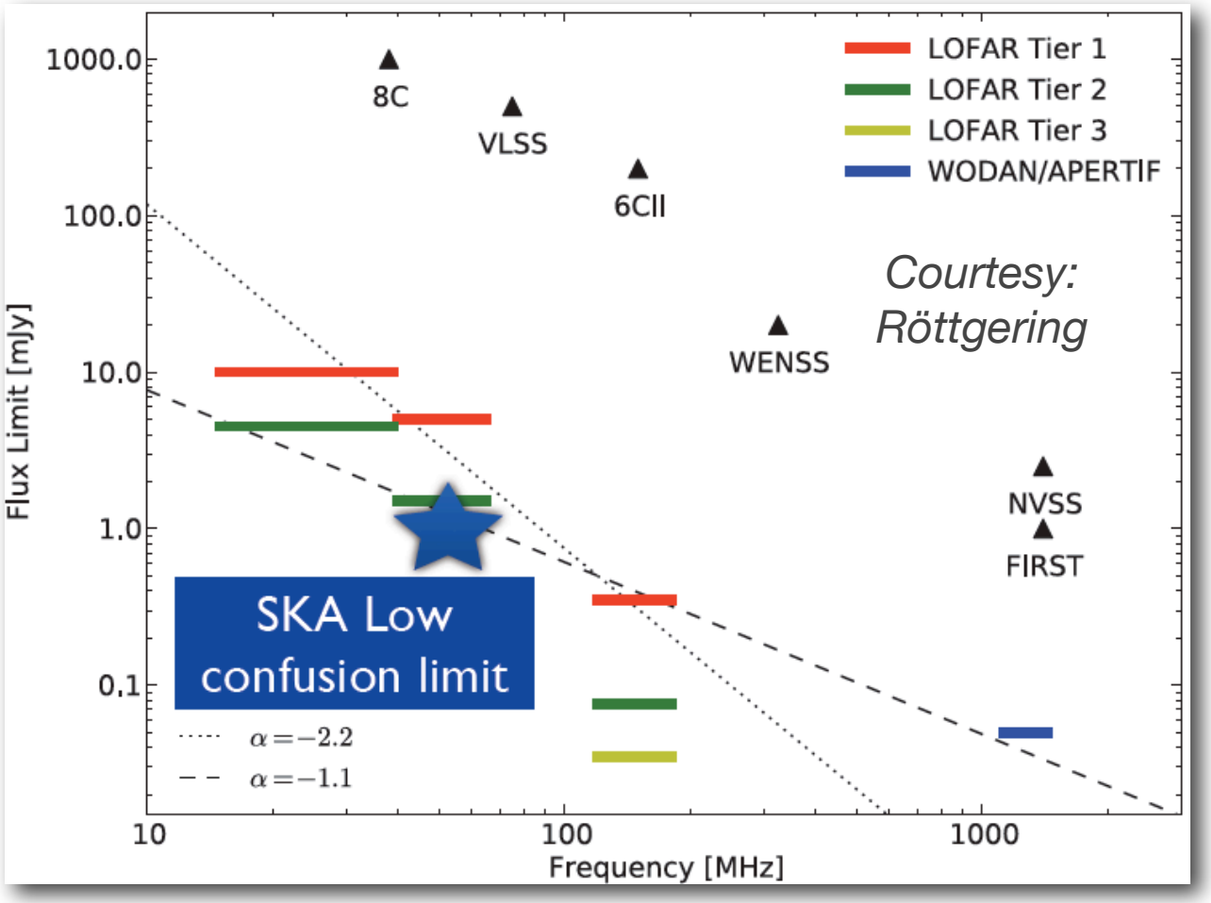
- Path to SKA2 (mid frequencies):
  - <0.1” resolution at 1 GHz

    resolving SF in high-z galaxies SF/AGN interplay, weak/strong lensing
  - >10 GHz capability (up to 20-30 GHz?)

    thermal emission in SFG at very high z, radio-FIR rest frame colors, synergy with ALMA (>30 GHz), spatially resolved (AU-scale) studies of proto-planetary disks, etc..

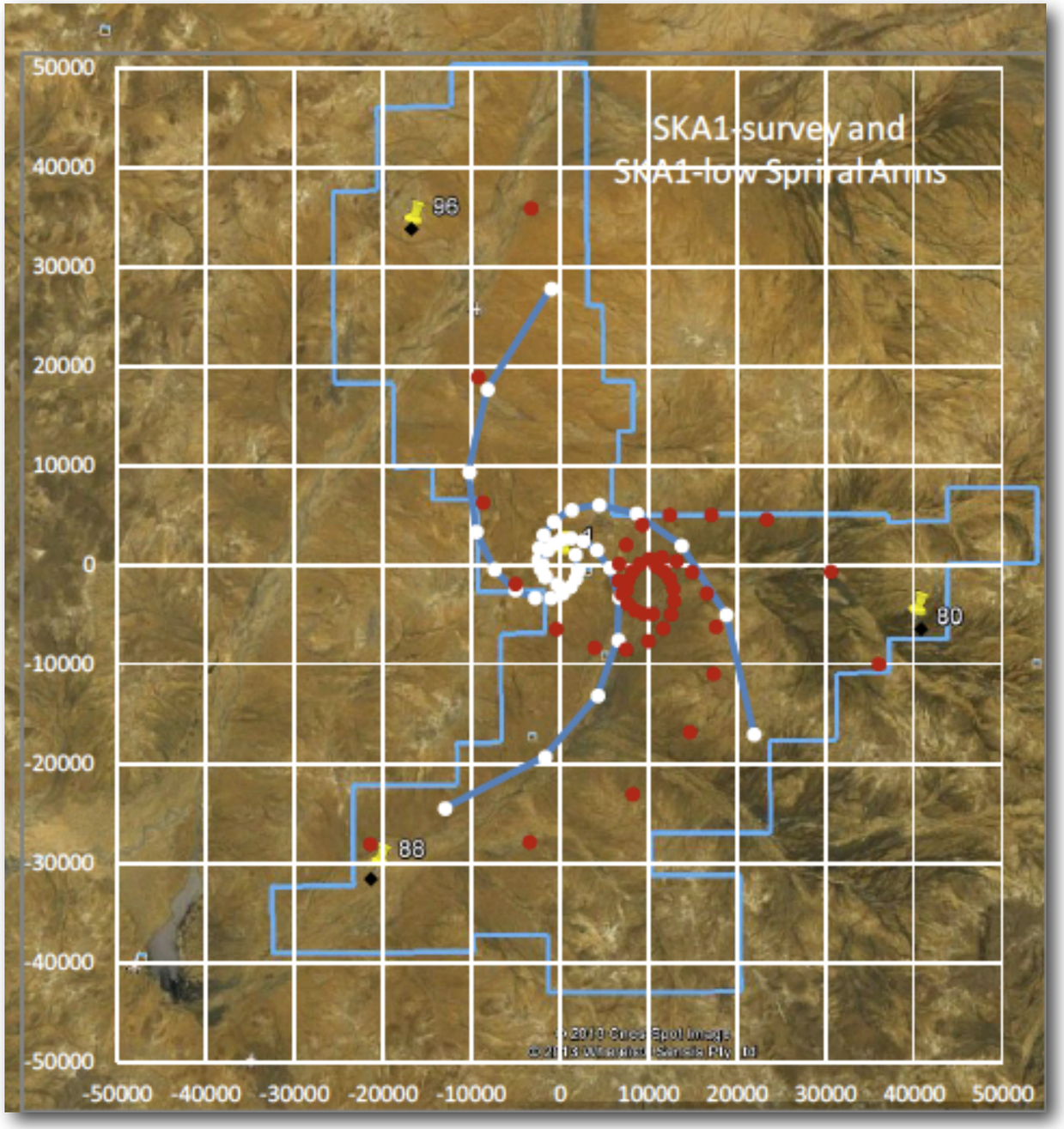
*Continuum Science Assessment Workshop Summary - Courtesy: **I. Prandoni, N. Seymour** & Continuum Science WG*

SKA-LOW "Tiger Team"



Courtesy: Röttgering

Are we missing extremely interesting science cases?
Which kind of modifications would be required?
→ ***see talk by Franco Vazza***



SKA1 system baseline design

A big community at work !

“SKA Pathfinders Radio Continuum Surveys” 2013 meeting, UK