Continuum Surveys with LOFAR, SKA and its Pathfinders

Chiara Ferrari
A Golden Age for Radioastronomy:
SKA Precursors and pathfinders

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

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

+ JVLA
LWA
eMERLIN
eEVN...

...
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Key Project “Surveys”
Key Project “Magnetism”

GLEAM
(Continuum & Polarization)

WODAN
BEOWULF & FRIGG

EMU
POSSUM

MIGHTEE
(Continuum & Polarization)

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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 Paint 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
Expected flux densities for galaxies at different IR luminosities

Predicted constraints on dark energy equation of state

Expected luminosity function of cluster radio halos
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
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Old!

New!
LOFAR primary beam

Dipole / Tile Beams

Station Beams

LOFAR Surveys

Stappers+ 11
LOFAR PRIMARY BEAM

LOFAR Surveys

Dipole / Tile Beams

Station Beams

Tied-Array Beams

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

MSSS data will be publicly available

> catalog & images <

Heald+ in prep
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 »

Courtesy:
George Heald & MSSS Team

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

Map based on code from this project.
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)**
  - $2\pi$ 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 $\geq 10 \, M_{\text{Sun}}/\text{yr}$ @ $z = 0.5$
  - → SFR $\geq 100 \, M_{\text{Sun}}/\text{yr}$ @ $z = 2.5$

- **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

Images by R. van Weeren
(Toothbrush Galaxy Cluster)

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

Only 30% of available bandwidth!

Courtesy: H. Röttgering & LOFAR Surveys KP
SKA Continuum science

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

CV 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

CV 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 deg² survey @ 0.5” resolution & 40 nJy/beam rms sensitivity

- Wide (weak lensing - galaxy evolution @ z<1)
  5000 deg² survey @ 0.5” resolution & 0.3 uJy/beam rms sensitivity

- All-sky (power spectrum, clusters, magnetism, galactic, legacy)
  31000 deg² survey @ 2” resolution & 2 uJy/beam rms sensitivity

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.
SKA-LOW “Tiger Team”

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

Courtesy: Röttgering

SKA Low confusion limit

SKA1 system baseline design
A big community at work!