The Synergy of Combining the Radio and *and Euclid.

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Overview

- Radio telescopes
- LOFAR
- Radio surveys
- Cosmology
- Legacy science
SKA Phase 1

2 sites (South Africa, Australia);
3 telescopes; one Observatory
Frequency range SKA1: 50 MHz – 3 GHz

Cost-cap: €650M
Construction: 2017 – 2023
Early science: 2020
Phase 2 SKA: 2023 - 2030

SKA-Mid: ~ 190 15m dishes + MeerKAT, RSA
SKA-Low: ~ 250,000 low-freq dipoles, AUS
SKA-Survey: ~ 60 15m dishes + ASKAP, AUS
- ASKAP: 36 x 12m x 36 pixels @ 1.4 GHz
- WSRT/APERTIF: 10 x 25m x 37 @ 1.4 GHz
- Meerkat: 64 x 13m x 1 pixel @ 0.6-15 GHz
LOFAR

10-80 MHz

120-240 MHz
36 LOFAR stations
baselines 100 km
LOFAR Stations Across Europe + three polish stations coming!
Challenges

- Data rates of up to a Tb/s
- Radio interference
- Removal of strong sources: Cygnus A, Tau A, ....
- Timing of the stations clocks
- Ionosphere
- "seeing" performance stations
Note: these images have only 3 arcmin resolution, the NL array has 5 acres resolution…
European baselines

M82 at 150 MHz (Varenius et al. 2014)

Resolution 0.39''x0.24''. RMS noise $\sigma=0.17\,\text{mJy/beam}$. 22 compact sources $>5\sigma$. 

~1 arcsec resolution
M82:
First detection
Carbon radio recombination

Morabito et al.
HBA map:

RMS: 6 mJy/beam

Beam: 19” x 14”

Dyn Range > 13000

Frequency: 140 MHz

NOTES:

• Other strong sources uv-subtracted
• Imaging of the core with standard Clean algorithm
• Imaging of the extended emission with Maximum Entropy (flat prior)

140 MHz, rms 6 mJy/19”x14”

25 MHz, rms 0.6 Jy/85” x 44”
Grothstrip field
\(~6-7 \text{ mJy}\)@\(40-50\ \text{MHz}\)

van Weeren et al. 2014
Grothstrip field
~10 mJy@30-40 MHz
19.5 MHz A2256 field

van Weeren et al.
2014
LOFAR 120-180 MHz

One pointing full FOV
4 x 4 degr

Van Weeren et al. in prep
Overview

- Radio telescopes
  - LOFAR
- **Radio surveys**
- **Cosmology**

Main probes:
- Weak Lensing – Michael Brown
- Baryon Acoustic Oscillations – Phil Bull
- Redshift Space Distortions – Alvise Raccanelli

Selling points
- Large volumes
- Different systematics
- Different redshift distributions
SKA-1: Weak lensing
5000 sq deg with SKA mid

Assumes a two year (on-sky) survey covering 5000 sq. degrees with SKA-MID array.

Different systematics and redshift range

Brown et al. (2014)
Large scale SKA surveys offer exciting and unique opportunities for weak lensing analyses

* rejects spurious instrumental systematic effects:

- In general, the observed ellipticity is composed of the lensing-induced ellipticity, the galaxy’s intrinsic shape and instrumental systematics:

\[
\tilde{\gamma} = \gamma + \gamma^s
\]

- Cross-correlating optical and radio-based shear estimates:

\[
\langle \tilde{\gamma}_o \tilde{\gamma}_r \rangle = \langle \gamma \gamma \rangle + \langle \gamma^s \gamma^s_o \rangle + \langle \gamma^s \gamma^s_r \rangle + \langle \gamma^s_o \gamma^s_r \rangle
\]

Cosmic shear signal

Systematics will be uncorrelated for optical and radio telescopes

Jarvis & Jain (2008); Patel et al. (2010)
Source power spectrum: fluctuation of sources counts on various scales

Different systematics: indeed
Overzier, HR, et al. 2003
Source power spectrum: probing non-gaussianity

Raccanelli et al. 2011
SKA I HI surveys

HI wide

HI deep

$z=0.7$

SKA I: $10^7$ galaxies, SKA II: $10^9$ galaxies
HI - BAO

- SKA-I galaxy survey (10^7 gal) – prepares for Phase II 10^9 gal.
HI - redshift space distortions
Overview

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Fan: WFIRST: ~100 z~8 quasars
10% radio loud?

21 cm forest spectrum
EoR on pc/kpc scales

Carilli et al. 2005

Frequency (MHz)

Flux Density (mJy)
How to feed the monster?

- Cold mode, also named: *quasar mode, radiative mode, fast accretor, high-excitation, strong-lined*
- Hot mode, also named: *radio mode, radiative inefficient, slow accretor, low-excitation, weak-lined*
"Radio AGN feedback: when the little ones were monsters"

How does this depend on the galaxy properties, feeding modes and environment?

Data from cosmos field

Williams and HR, 2015
History of star formation

LOFAR/APERTIF/ASKAP
One pointing full FOV
4 x 4 degr
LOFAR 120-180 MHz
Toothbrush cluster
van Weeren et al.

One pointing full FOV
4 x 4 deg

LOFAR 120-180 MHz
Contours Subaru WL map
Dawson, Jee et al.
Mass: $7 \times 10^{14} \, \text{Mo}$

Red: chandra

Green-blue radio spectral index

2 Mpc shock induced by merging clusters
Shock accelerates particles which then emit synchrotron emission.

Precision cosmology with clusters?
Conclusion

- Competitive cosmology can be done with radio telescopes
- different set of systematics
- Combined legacy science is great