Cosmology with the VLASS

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Predictions based on current knowledge

\[ \nu = 1.4 \text{ GHz} \]

\[ \log \left( \frac{S^{5/2}}{n} \right) \text{ (Jy}^{3/2} \text{ sr}^{-1}) \]

\[ \log [S(Jy)] \]

- Owen & Morrison (2008)
- This paper
- Wilman et al. (2008)
- Condon (1984)

Condon et al. 2012
Predictions based on current knowledge

Wilman et al. 2008, 2010, SKADS simulations provide redshift distributions etc, split by type
Radio Continuum

Log (Radio Flux Density)

Log (Frequency)
Radio Continuum

No redshift information!
Radio Continuum

\[ \log(\text{Radio Flux Density}) \]

\[ 1 + z \]

\[ \log(\text{Frequency}) \]

No redshift information!

\[ \Delta z \sim 0.05(1+z) \]
Integrated Sachs-Wolfe (ISW) effect

CMB photons gain energy entering a deep gravitational potential well

Universe undergoes accelerated expansion

Photons lose less energy upon exit

Test: Cross-correlation of large structures with CMB

All-sky could help, but main limitation is the depth – LOFAR, EMU and WODAN will outperform VLASS-all-sky for this science case
The importance of continuum deep fields for cosmology

- Depth and breadth enables Halo Occupation Distribution modelling at $0.5 < z < 4$
  - The link to the dark matter distribution

Matsuoko et al. 2011
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Hatfield et al. in prep.
The importance of continuum deep fields for cosmology

Lindsay et al., PhD thesis
Halo Occupation and link to DM distribution

Lindsay, Jarvis, Santos et al. 2014

Lindsay, Jarvis & McAlpine 2014
Xcorrelation with CMB lensing

Allison et al. 2015, arXiv.1502.06456
Weak Lensing with VLASS
Radio surveys offer exciting and unique opportunities for weak lensing analyses.

- Measuring galaxy shapes in overlapping optical & radio surveys...

- 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 shear estimates:

\[ \langle \tilde{\gamma} \tilde{\gamma} \rangle = \langle \gamma \gamma \rangle + \langle \gamma \gamma^s \rangle + \langle \gamma^s \gamma^s \rangle \]
Radio surveys offer exciting and unique opportunities for weak lensing analyses
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Radio 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:
    \[
    \langle \tilde{\gamma}_o \tilde{\gamma}_r \rangle = \langle \gamma \gamma \rangle + \langle \gamma \gamma^s_o \rangle + \langle \gamma \gamma^s_r \rangle + \langle \gamma^s_o \gamma^s_r \rangle
    \]
Radio surveys offer exciting and unique opportunities for weak lensing analyses

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

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

\[ \langle \tilde{\gamma}_o \tilde{\gamma}_r \rangle = \langle \gamma \gamma \rangle + \langle \gamma^s \rangle^o + \langle \gamma^s \rangle^r + \langle \gamma^s o \gamma^s r \rangle \]

Cosmic shear signal

Systematics will be uncorrelated for optical and radio telescopes

Jarvis & Jain (2008); Patel et al. (2010)
Radio weak lensing

- Very different systematics to optical surveys.
- Precise redshift information from HI measurements.
- Extend reach of weak lensing to higher redshifts.
- Unique to JVLA until SKA1 (>2022). VLASS would be the key survey.
Other advantages, techniques and science applications:

- Accurate calibration of colour gradient effects with radio telescopes.

- Cluster lensing and galaxy-galaxy lensing using optical- and radio-selected samples.
Lensing Magnification

Background sources (high-z) lensed by massive foreground (low-z) sources:

- Background area appears stretched
  $\rightarrow$ decreased surface density

- Fainter background sources appear brighter
  $\rightarrow$ increased surface density

Test: Cross-correlation of foreground and background objects

Optical surveys suffer from dust obscuration – gives a false magnification signal.

Radio continuum surveys do not suffer from this!
The importance of continuum deep fields for cosmology

• Need accurate redshift distributions:
  • Requires very complete spec- or photo-z’s – only possible over deep fields, but large enough to overcome sample/cosmic variance
• Need to understand the relation to the underlying DM distribution, halo-models
• Beneficial to do this as a function of radio source type to obtain z-distribution and galaxy bias as a function of type
• Depth needs to be high enough to provide enough radio sources to measure lensing signal (~5 per arcmin²)
Summary

• Tremendous amount of unique cosmology with VLASS
• Maximising source density drives surveys to lowest frequency whilst retaining reasonable resolution
• A lot of “large-scale” continuum cosmology can be done with >2 arcsec resolution (above confusion noise – cf LOFAR/EMU/WODAN/MeerKAT)
• Additional information about source morphology underpins some uniquely powerful science cases, thus resolution is critical;
• Maximum source density, and morphological classification drives the surveys to low-frequency with reasonable resolution (~0.8arcsec).
• Calibration with deep field data also very important for future all-sky experiments with WODAN/EMU/LOFAR etc