Radio Weak Lensing with 3 GHz
JVLA COSMOS Observations

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Previous relevant talks:
Dan Thomas: Overview & Radio Shape Measurement
Ian Harrison: SuperCLASS
Contents

1. Introduction
   i. Radio Weak Lensing Timeline
   ii. The COSMOS Field

2. 3 GHz JVLA Catalogue
   i. Observations
   ii. Source Selection: Principal Component Analysis

3. Cross-Matching Radio & Optical
   i. Position Angles
   ii. Cross-Power Spectra

}\ Main Science Output
Radio Weak Lensing Timeline

1. Forecasts ✓
   SKA Weak Lensing I, II & III papers (arXiv:1601.03947; 1601.03948; 1606.03451)

2. Pathfinding
   JVLA COSMOS
   SuperCLASS

3. Cosmological constraints
   SKA Weak Lensing ~2030

Credit: Dr Ian Harrison
COSMOS Field

Surveys:
- Chandra (X-ray)
- Hubble Space Telescope (optical)
- GALEX (UV)
- CFHT (optical)
- JVLA (radio)

Credit: Dr Ian Harrison
**3 GHz JVLA Observations**

- **192 pointings:**
  - 64 separated by 10′ in RA and DEC
  - 64 +5′ in RA and DEC
  - 64 -5′ in RA and DEC

  ⇒ uniform rms noise

**384 hours:**
- 324 hours in A-Configuration (longer baselines)
- 60 hours in C-Configuration (shorter baselines)

**Bandwidth of 2048 MHz centred on 3 GHz**

Smolčić et al. (2017), arXiv:1703.09713v1
Source Selection: Initial Issues

10,830 sources in catalogue

- Star-Forming Galaxies ✓
- AGN ✗
- Unresolved Objects ✗

Shapes from real-space image using im3shape (1st talk from Dan)

Low $|\varepsilon|$ excess
⇒ many small circular unresolved objects?

Singular parameter cuts on source catalogue don’t work
⇒ Need composite cuts: Principal Component Analysis

Size $\geq 1 \times$ PSF ($\geq 0.75''$)

Size $\geq 1.5 \times$ PSF ($\geq 1.125''$)
Source Selection: Principal Component Analysis

Size cut:

- \( |\varepsilon| > 0.05 \rightarrow 2,080 \) sources
- \( |\varepsilon| \leq 0.05 \rightarrow 1,679 \) sources

Details:

10,830 sources

\[ PC_i = (p_i^x_0 \times x0) + (p_i^y_0 \times y0) + (p_i^{\text{radius}} \times \text{radius}) + (p_i^{\text{ra}} \times \text{ra}) + (p_i^{\text{dec}} \times \text{dec}) + (p_i^{\text{flux}} \times \text{flux}) + (p_i^{\text{rms}} \times \text{rms}) \]

Graphs:

- PCA weights
- Explained variance ratio vs. component number
Source Selection: PCA-Output Catalogue

- Size cut $\geq 1 \times \text{PSF}$
- $|\varepsilon| > 0.05$ for 2,080 sources
- $|\varepsilon| \leq 0.05$ for 1,679 sources
- PCA
- Remove everything with PC1 $\geq -44$ & PC2 $\leq 0.9$

- 10,830 sources
- 3,759 sources
- 2,028 sources

Mainly neglected $|\varepsilon| \leq 0.05$ sources, but included some.
Mainly included $|\varepsilon| > 0.05$ sources, but neglected some.

~35% larger than using singular cuts (1,539 sources).
### Source Selection: COSMOS Catalogues

<table>
<thead>
<tr>
<th>WL Source Density</th>
<th>Optical</th>
<th>Radio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>34 gal arcmin$^{-2}$</td>
<td>0.3 gal arcmin$^{-2}$</td>
</tr>
</tbody>
</table>

![Optical Source Map](image1.png)

![Radio Source Map](image2.png)
Cross-Matching Optical and Radio

Pearson’s Correlation Coefficient, $R_a$

<table>
<thead>
<tr>
<th></th>
<th>$R_a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>This work (2018)</td>
<td>0.14</td>
</tr>
<tr>
<td>VLA 3 GHz COSMOS</td>
<td></td>
</tr>
<tr>
<td>Perfect Correlation</td>
<td>1</td>
</tr>
<tr>
<td>No Correlation</td>
<td>0</td>
</tr>
<tr>
<td>Negative Correlation</td>
<td>-1</td>
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<tr>
<td>Patel et al. (2010)</td>
<td>0.097</td>
</tr>
<tr>
<td>VLA MERLIN Hubble Deep Field North</td>
<td></td>
</tr>
<tr>
<td>Tunbridge et al. (2016)</td>
<td>0.028</td>
</tr>
</tbody>
</table>
Cross-Matching
Optical and Radio
Cross-Matching Optical and Radio

Need a more statistical measure between radio and optical signals
⇒ Power Spectra

\[ R_\alpha = 0.14 \]
Power Spectra

\[ \langle \gamma_i \gamma_j \rangle (\theta) \]

c.f. CMB polarisation power spectra


Publicly available at [https://bitbucket.org/fkoehlin/qe_public](https://bitbucket.org/fkoehlin/qe_public)

z1 \times z2 \rightarrow \text{Radio} \times \text{Optical}
Power Spectra: Gaussian Random Fields

100 Realisations
- Each 2 deg²
- Scatter, $\sigma_\varepsilon = 0.3$

Source Density
- Optical
  - 30 gal arcmin⁻²
- Radio
  - 0.3 gal arcmin⁻²

$$D = \sqrt{\sum_{\ell} \left( \frac{\hat{C}_\ell^{EE}}{\sigma'_\ell} \right)^2}$$

Detection Significance, $D$
- Optical-Optical: 7.7
- Radio-Optical: 1.4
- Radio-Radio: 0.1
Conclusions

• PCA applied to source selection works, although needs refining to remove e.g. AGN

• **Cross-Matching Radio & Optical**
  • Position Angle-matching shows a good correlation between radio and optical catalogues: improvement on previous results

  ![Graph](image)

  \[ R_\alpha = 0.14 \]

• Significant cross-power spectrum possible with current data:
  \[ D = 1.4 \]