Cosmic Shear

- High resolution deep imaging
- Multi-band imaging

Object Catalogue


Colours


Galaxies


Stars


P(z)


Shapes


Your Favourite Statistic


Cosmology


Errors/Models


Nuisance


Image Simulations and “null tests”


credit Catherine Heymans


LSS Simulations


Overlapping Spectroscopy


Calibration


Analytical Halo Model


credit Catherine Heymans


Obscuring (Blinding)!
Standard cosmological model

- (flat) LCDM
- Simple: ~ 5 parameters
- Successful in explaining various observations
- But dark!
KiDS: Key Facts

- Weak lensing specific survey
- 1000 deg$^2$ analysed
- 21 million galaxies
- Completed: 1350 deg$^2$
- KiDS+VIKING: 9 photometric bands
**KiDS-1000 core cosmology papers**

**Cosmic Shear Cosmology:** Asgari, Lin, Joachimi et al. (arXiv: 2007.15633)

**3x2pt Cosmology:** Heymans, Tröster et al. (arXiv: 2007.15632)

**Methodology:** Joachimi, Lin, Asgari, Tröster, Heymans et al. (arXiv: 2007.01844)

**Photometric Redshifts:** Hildebrandt, van den Busch, Wright et al. (arXiv: 2007.15635)

**Shear Measurements:** Giblin, Heymans, Asgari et al. (arXiv: 2007.01845)

[Link](#) to other KiDS talks on the KiDS consortium youtube page.
Cosmic Shear

The theoretical model includes:

- Flat $\Lambda$CDM
- Intrinsic Galaxy Alignments
- Baryon Feedback
- Photometric Redshift Calibration Uncertainty
- Shear Calibration Uncertainty (m)
KiDS-1000 Cosmic Shear

Two-Point Correlation Function
Fourier Space

\[ S_8 = \sigma_8 \sqrt{\Omega_m / 0.3} \]

Asgari, Lin, Joachimi et al. 2020
\[ S_8 = \sigma_8 (\Omega_m / 0.3)^{0.5} \]

\[ \Sigma_8 = \sigma_8 (\Omega_m / 0.3)^{\alpha} \]
Asgari, Lin, Joachimi et al. 2020
Comparison with Planck, DES and HSC

1. KiDS-1000 COSEBIs
2. KiDS-1000 band power
3. KiDS-1000 2PCFs
4. KV450 gold (Wright et al. 2020)
5. KV450+DES-Y1 (Asgari et al. 2020)
6. DES-Y1 (Troxel et al. 2018)
7. HSC-Y1 (Hikage et al. 2019)
8. Planck 2018 TT,TE,EE+lowE

\[ S_8 \equiv \sigma_8 \left( \Omega_m / 0.3 \right)^{0.5} \]

Asgari, Lin, Joachimi et al. 2020
Cosmic Shear

Galaxy Galaxy lensing

Clustering

position

position

position

Shape

Shape

Shape
Consistency between Probes and Planck

\[ S_8 = \sigma_8 \sqrt{\Omega_m/0.3} = 0.766^{+0.020}_{-0.014} \]

KiDS-3x2pt and Planck differ in \( S_8 \) with a significance of 3.1\( \sigma \)

Heymans, Tröster et al. 2020
\[ S_8 = \sigma_8 \sqrt{\Omega_m/0.3} = 0.766^{+0.020}_{-0.014} \]

- Same overall precision as Planck for the structure growth parameter \( S_8 \)
- \( S_8 \) from KiDS is 8.3 ± 2.6 % lower than Planck
- “Tension” is driven by differences in \( \sigma_8 \)
Summary of KiDS core cosmology papers

- ~3σ Tension in $S_8$ (assuming flat LCDM)
- From the 3x2pt analysis: tension is driven by $\sigma_8$. The Universe is less “clumpy” than *Planck* predicts.
- This result is validated using
  - mock KiDS and BOSS galaxy surveys
  - KiDS image simulations and null-tests
  - spectroscopic-photometric clustering analysis
  - All identified systematic uncertainties folded through as nuisance parameters
Thanks to KiDS and all our funders
Backup slides
3x2pt: Cosmic Shear +

Band-Powers

Asgari, Lin, Joachimi et al. 2020
Anisotropic Galaxy Clustering: RSD + BAO

Theoretical Predictions includes fully non-linear galaxy bias model
3x2pt: Cosmic Shear + Clustering + Galaxy-Galaxy Lensing

Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020

Heymans, Tröster et al. 2020
KiDS-Planck Tension Metrics

Quantifying $S_8$ only leads to a $\sim 3.1\sigma$ tension.

Including additional parameters, which KiDS is mainly insensitive to, dilutes the overall tension to the $\sim 2\sigma$ level.

Heymans, Tröster et al. 2020
Survey Footprint

Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020
Two point statistics and their scale sensitivity

\[ S_x = \int_0^\infty d\ell \, \ell \, C(\ell) \, W_x(\ell) \]
\[ S_x = \int_0^\infty d\ell \, \ell \, C(\ell) \, W_x(\ell) \]

Correlation functions (2PCFs)

Asgari, Lin, Joachimi et al. 2020
\[ S_x = \int_0^\infty d\ell \, \ell \, C(\ell) \, W_x(\ell) \]

Correlation functions (2PCFs)

COSEBIs

Asgari, Lin, Joachimi et al. 2020
$S_x = \int_0^{\infty} d\ell \, \ell \, C(\ell) \, W_x(\ell)$

Correlation functions (2PCFs)

COSEBIs

Band powers

Asgari, Lin, Joachimi et al. 2020
Reporting Parameter Constraints

The standard marginalised constraint on $S_8$ is typically lower than the global best-fit.

Our fiducial results quote the maximum posterior value and an associated credible interval (PJ-HPD).

Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020
Validating the analytical Covariance Matrix

The analytical covariance has contributions from multiple sources.

We find consistent constraints using mock or analytical covariances.

Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020
Modelling non-linear scales

Baryon feedback (mostly AGN) modifies the small-scale dark matter distribution and is marginalised over.

We blend perturbative and halo-model non-linear modelling for galaxy-galaxy lensing.

Modelling choices affect $S_8$ constraints by less than 0.1σ.

Joachimi, Lin, Asgari, Tröster, Heymans et al. 2020
Impact higher order galaxy bias terms

\[ S_8 \equiv \sigma_8 \sqrt{\Omega_m/0.3} \]
Sampled parameters
Cross-covariance

- From Salmo mocks
- Z-bins: 1 and 5
Mock data analysis: difference between 2pt Stats
Photometric Redshift Calibration with Spectroscopy

Accurate redshift calibration is integral to the interpretation of cosmic shear.

Self-Organising Map: SOM

High-redshift spectra
(DEEP2)

Low-redshift Spectra
(zCOSMOS)

Mid-redshift Spectra
(VVDS)

Wright, Hildebrandt, van den Busch & Heymans 2020
Photometric Redshift Accuracy: mocks

The advantage of the SOM: we trade number density precision for accuracy.

<table>
<thead>
<tr>
<th>KiDS Analysis</th>
<th>Number density per sq arcmin</th>
<th>Uncertainty in the mean redshift range</th>
</tr>
</thead>
<tbody>
<tr>
<td>KV450 (kNN)</td>
<td>7.4</td>
<td>0.011 - 0.039</td>
</tr>
<tr>
<td>KiDS-1000 (SOM)</td>
<td>6.2</td>
<td>0.008 - 0.012</td>
</tr>
</tbody>
</table>
We find no significant offset between the SOM and CZ redshift distributions.

<table>
<thead>
<tr>
<th>bin</th>
<th>$\delta z_{\text{CZ}} \pm \text{comb.}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$-0.001 \pm 0.012$</td>
</tr>
<tr>
<td>2</td>
<td>$0.004 \pm 0.013$</td>
</tr>
<tr>
<td>3</td>
<td>$0.011 \pm 0.020$</td>
</tr>
<tr>
<td>4</td>
<td>$-0.008 \pm 0.013$</td>
</tr>
<tr>
<td>5</td>
<td>$0.003 \pm 0.013$</td>
</tr>
</tbody>
</table>
Shear null tests

- B-modes consistent with pure noise
- Purity of the point-source sample validated with optical-NIR colours
- PSF model accuracy size/shape requirements easily met
- Instrumental defects quantified
- Shear-ratio test passed

Giblin, Heymans, Asgari et al. 2020