Cosmological results from the Kilo Degree Survey

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Mellier (1999)
Cosmic shear

Observables:
• Ellipticities
• Photo-z

Need to be calibrated extremely well!

$\Rightarrow$
tomographic 2pt shear corr. fct.
Cosmological constraints

Kilbinger et al. (2013)

- Measure amount of **clustered** matter
- \( S_8 = \sigma_8 \left( \Omega_m/0.3 \right)^{0.5} \)
$S_8$ results over the years

Kilbinger (2015)
• 1350 sq. deg. survey
• VLT Survey Telescope (VST)
• Four bands: $ugri$ (photo-z)
• Shapes down to $r \sim 24$
• $\sim 8$ gal/arcmin$^2$
• Overlap with VIKING (ZYJHKs)
Cosmic shear with KiDS-450

- **450 deg$^2$** (observations up to July 2015).

- Tomographic analysis: 4 photo-z slices
  - $0.1 < z_{\text{phot}} < 0.3$, 
  - $0.3 < z_{\text{phot}} < 0.5$, 
  - $0.5 < z_{\text{phot}} < 0.7$, 
  - $0.7 < z_{\text{phot}} < 0.9$

Hildebrandt, Viola et al. (2017)
Systematic error control

- Shapes measurement systematics:
  - Telescope/camera design
  - Observing conditions

- Photo-z systematics:
  - Survey design (shallow and wide)
  - 3 redundant techniques to calibrate redshift distribution

- Theoretical systematics:
  - Careful selection of radial range
  - Redundancy

- Psychological systematics:
  - Blinding
KiDS-450: Results (blind-1)

- $S_8 = 0.745 \pm 0.039$  
  2.3$\sigma$ discrepancy with Planck

Hildebrandt, Viola et al. (2017)
KiDS-450: Results (blind-2)

- $S_8 = 0.720 \pm 0.039 \quad 2.8\sigma$ discrepancy with Planck

Hildebrandt, Viola et al. (2017)
KiDS-450: Results (blind-3)

- $S_8 = 0.772 \pm 0.039$

1.7σ discrepancy with Planck

Hildebrandt, Viola et al. (2017)
In summary, we find that the four possible choices for

- S_8 constraint very similar to CFHTLenS, pre-planck CMB
- Tension with Planck — 2.7σ_{KiDS} in S_8
  (2.3σ discrepancy in full parameter space)
$S_8$ results over the years

Kilbinger (2015; updated)
Extended cosmologies

• Massive neutrinos.
• Non-zero curvature.
• Evolving dark energy.
• Modified gravity.
• Running spectral index.

Joudaki et al. (2017)
Evolving dark energy

- Resolves tension between KiDS and Planck.
- Only extensions that is moderately favoured by the data.
- 3-σ deviation from a cosmological constant.
- Resolves tension between Riess et al. (2016) and Planck.
Figure 10. Constraints on $\Omega_m - \sigma_8^8$ and $\Omega_m - S_8^8$ from this work for different combinations of power spectra. Also shown are the fiducial results for KiDS-450 (H+17; Hildebrandt et al. 2017) and Planck (P+16; Planck Collaboration et al. 2016).

Figure 11. Reduced $\chi^2$ values of the best-fitting models, corresponding $p$-values of the fit, and constraints on the amplitude of the intrinsic alignment model $A_{IA}$ and effective biases of the two foreground samples, $b_{z1}$ and $b_{z2}$, for the different combinations of power spectra. The lower points show the results of the conservative run, where we excluded the lowest $\ell$ bin from $P_E(c_1)$ and the highest $\ell$ bin from $P_{gm}$ and $P_{gg}(c_2)$ in the fit. The red, vertical dashed line in the second panel indicates a $p$-value of 0.05, the 2$\sigma$ discrepancy line.

Constrained in the combined fit, with $A_{IA} = 1.30 \pm 0.40$. Most of the constraining power on $A_{IA}$ comes from $P_{gm}$, as the redshift distributions of the foreground samples and the shape samples partly overlap; fitting only $P_E$, $A_{IA} = 0.89 \pm 0.79 - 0.59$ and is therefore only inconclusively detected. In an analysis of cosmic shear data from CFHTLenS combined with WMAP7 results, Heymans et al. (2013) reported $A_{IA} = -1.18 \pm 0.96 - 1.17$. Joudaki et al. (2017) analysed CFHTLenS data and found $A_{IA} = -3.6 \pm 1.6$, while the correlation function analysis of KiDS (Hildebrandt et al. 2017) reported $A_{IA} = 1.10 \pm 0.64$. Hence, similar to Hildebrandt et al. (2017), our results prefer a positive intrinsic alignment amplitude, but we detect it with a larger significance. The preference for negative values in CFHTLenS but positive values in KiDS suggests that $A_{IA}$ is not simply a measure of the amount of intrinsic alignment of galaxies, but that in fact it accounts for systematic effects that might differ between surveys. Further evidence for this scenario is that the amplitude we obtain is larger than what is expected based on results from previous dedicated intrinsic alignment studies; although intrinsic alignments have been detected for luminous red galaxies (e.g. Joachimi et al. 2011; Singh et al. 2015), the constraints for less luminous red galaxies and blue galaxies are consistent with zero (Mandelbaum et al. 2006; Hirata et al. 2007; Mandelbaum et al. 2011). We provide evidence that $A_{IA}$ effectively accounts for uncertainty in the redshift distributions in Sect. 4.3.
VIKING@VISTA

- Same footprint as KiDS.
- Already finished (1350deg²).
- ZYJHKs images.
- 5σ depths of 21.2 (Ks) to 23.1 (Z).
Photometric redshifts

**KiDS**

- Objects with $Z_L > 0.9$:
  - NMAD = 0.123
  - $\eta_{0.15} = 29.2\%$

- All objects:
  - NMAD = 0.089
  - $\eta_{0.15} = 26.7\%$

**KiDS + VIKING**

- Objects with $Z_L > 0.9$:
  - NMAD = 0.099
  - $\eta_{0.15} = 25.4\%$

- Usable with optical data only:
  - Usable with optical+NIR data:

- All objects:
  - NMAD = 0.070
  - $\eta_{0.15} = 17.8\%$
Summary & Outlook

• KiDS-450 measures $S_8$ with ~5% error (1/2 syst., 1/2 stat.).

• Tension Planck versus lensing persists (~2.3σ).

• Emphasis on robustness, redundancy, blind analysis.

• All data public: http://kids.strw.leidenuniv.nl/cosmicshear2016.php

• Cosmic shear result tested further from different angles.

• ~900deg$^2$ now, 1350deg$^2$ by end 2018 => factor >2 improvement to robustly test ΛCDM and prepare for Euclid.