Cosmic Shear Covariances for DES SV and internal Covariance Estimation

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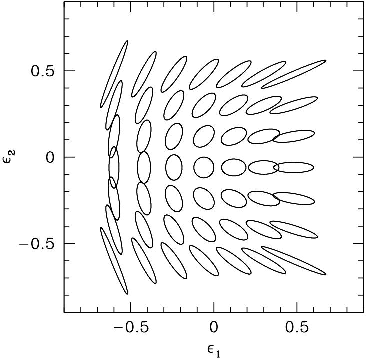
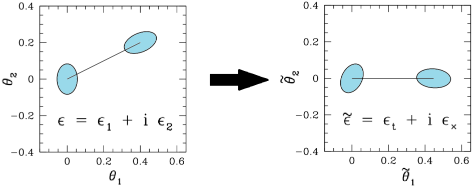
DARK ENERGY SURVEY

Cosmic Shear in a Nutshell



⇐ Characterize ellipticities by complex number:

$$\boldsymbol{\epsilon} = \epsilon_1 + i\epsilon_2$$
$$= \epsilon \cdot e^{2i\phi}$$



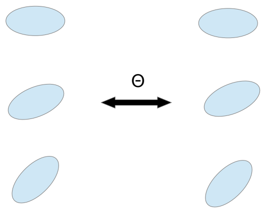
⇐ For each galaxy pair define tangential and cross component ϵ_t and $\epsilon_\times$.

Cosmic Shear in a Nutshell

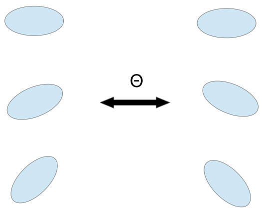
- The Cosmic Shear 2-pt. functions $\xi_\pm(\theta)$ can be measured by:

$$\hat{\xi}_\pm(\theta) = \frac{\sum_{ij}(\epsilon_{i,t}\epsilon_{j,t} \pm \epsilon_{i,\times}\epsilon_{j,\times})}{N_{\text{pair}}(\theta)} \ .$$

- largest contributions to $\xi_+(\theta)$ from parallel alignment of galaxy shapes:



- largest contributions to $\xi_-(\theta)$ from galaxies aligned mirror symmetric to their connection line:



Covariance Matrices for Cosmic Shear

- measure the data vector $\hat{\boldsymbol{\xi}} = \left[\hat{\xi}_{\pm}(\theta_1), \ldots, \hat{\xi}_{\pm}(\theta_d)\right]$.

Covariance Matrices for Cosmic Shear

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$$C(\theta_1, \theta_2) = \langle [\hat{\xi}(\theta_1) - \xi(\theta_1)] \cdot [\hat{\xi}(\theta_2) - \xi(\theta_2)] \rangle \ ,$$

  to constrain cosmological models.

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- Ways to get the covariance matrix:
  - > Modelling
  - > Estimating from simulations
  - > Estimating from data

Covariances from Becker et al. 2015

Cosmic Shear Measurements with DES Science Verification Data

- M. R. Becker, M. A. Troxel, N. MacCrann, E. Krause, T. F. Eifler, O. Friedrich, A. Nicola + DES Collaboration
- arxiv:1507.05598

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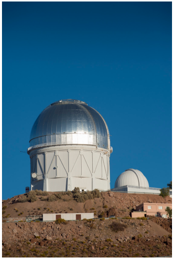
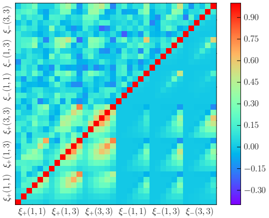
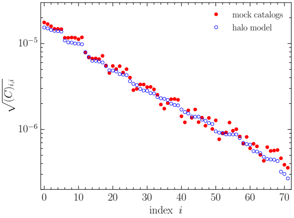


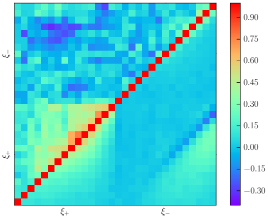
Covariances from Becker et al. 2015

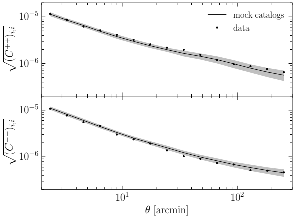
tomographic covariance from halo-model and mock catalogs:





jackknife covariance from data and mock catalogs:

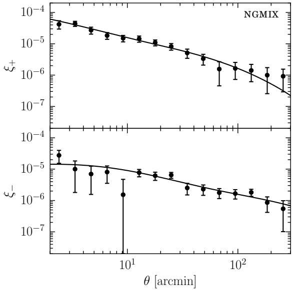


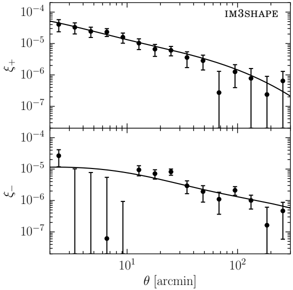


Covariances from Becker et al. 2015

- Modelling:
  - halo-model covariance from CosmoLIKE (Eifler et al. 2014b, Krause et al. 2015):
    including Gaussian contributions, convergence trispectrum and finite volume effects
- Simulations:
  - 7 × 3 N-body light cones patched together along line of sight
  - box size $= 1050h^{-1}Mpc$, $2600h^{-1}Mpc$, $4000h^{-1}Mpc$ resp.
  - particles $= 1400^3$, 2048^3 , 2048^3 resp.
- Jackknife:
  - Jackknife estimation as in Friedrich et al. 2015.
  - computed for both data and mocks to check for field-to-field systematics

Covariances from Becker et al. 2015





Conclusions:

- Covariance from mocks and halo-model give consistent constraints on $\sigma_8(\Omega_m/0.3)^{0.5}$.
- Our mock catalogs have the same size as the data, i.e. no area rescaling.
- Ready to do science! See also DES Collaboration (2015) for first DES cosmic shear cosmology results!

Friedrich et al. 2015, Performance of internal Covariance Estimators for Cosmic Shear Correlation Functions

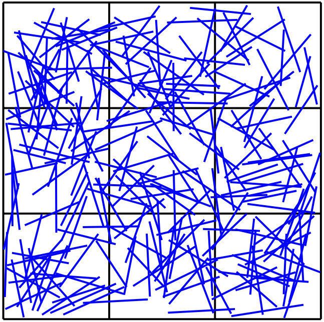
> O. Friedrich, S. Seitz, T. F. Eifler, D. Gruen

> use log-normal simulations of the convergence field to test covariance estimation from the data

> Hilbert et al. (2011) approximate the covariance matrix in case of log-normal convergence as

$$C^{ss}_{\pm\pm}(\theta_1, \theta_2) = \text{Gaussian Covariance} + \frac{8\pi}{\kappa_0^2 A}\, \xi_\pm(\theta_1)\xi_\pm(\theta_2) \int_0^{\theta_\mathrm{A}} \mathrm{d}\theta\ \theta\ \xi_\kappa(\theta)\ .$$

Internal Covariance Estimation



Measure $\hat{\boldsymbol{\xi}}^{\alpha}$ in sub-patches $\alpha = 1, \ldots, N_{\mathrm{S}}$.

Main idea:

- measure covariance of sub-patches
- (hope to) rescale it to the total survey area:

$$\hat{\boldsymbol{\xi}} \approx \frac{1}{N_{\mathrm{S}}} \sum_{\alpha} \hat{\boldsymbol{\xi}}^{\alpha}$$

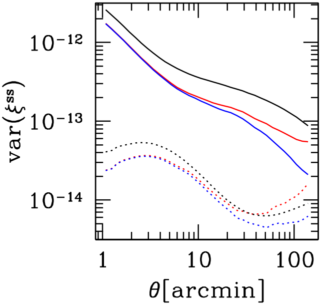
$$C_{\mathrm{tot}} \approx \frac{1}{N_{\mathrm{S}}} \cdot C_{\mathrm{S}}$$

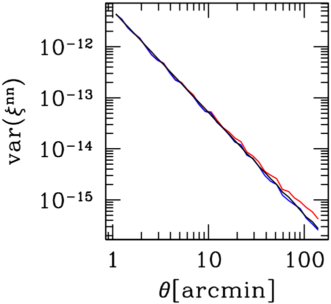
- other methods: jackknife, bootstrap (almost identical, especially on small scales)

Problems in internal Covariance Estimation

- What about galaxy pairs that cross between subregions?
- Subregions are correlated!
- How many subregions are needed to get stable covariance estimates?

Finite Area Effect

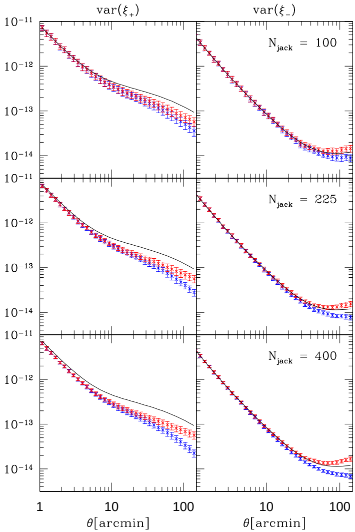




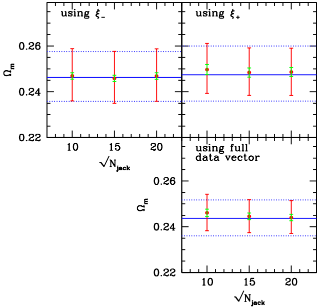
- Example: survey of $5000\,\mathrm{deg}^2$, 400 sub-regions
- C is NOT proportional to $1/A$! Recall:

$$C^{ss}_{\pm\pm}(\theta_1, \theta_2) \quad = \quad \text{Gaussian Covariance} \ + \frac{8\pi}{\kappa_0^2 A}\ \xi_\pm(\theta_1)\xi_\pm(\theta_2) \int_0^{\theta_A} \mathrm{d}\theta\ \theta\ \xi_\kappa(\theta)\ .$$

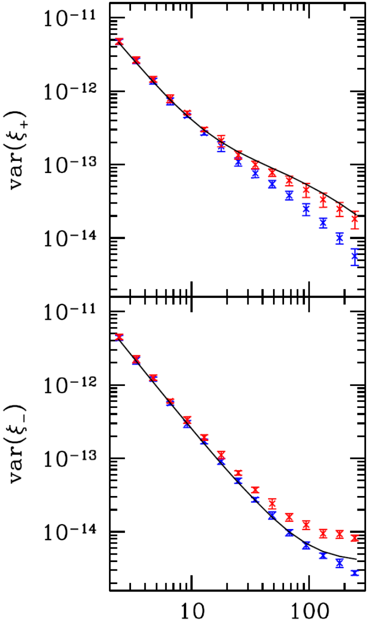
Cosmological Parameters from Jackknife?



- marginalisation over σ_8, fixing other parameters
- inversion of the covariance estimate using Hartlap-Kaufmann factor

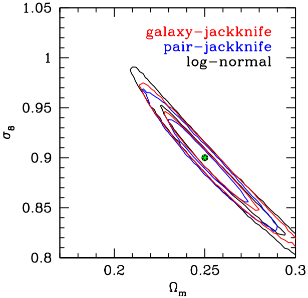


Forecast for DES Y5



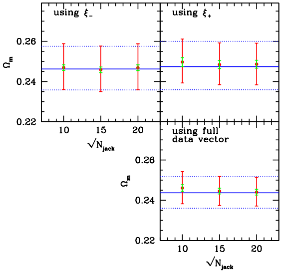
- measuring $\xi_\pm$ from $2'$ to $300'$
- compute likelihood in $\Omega_m - \sigma_8$ plane using CosmoLIKE

  (Eifler et. al 2014)



(10 of these plots in the paper)

Conclusions



- reconstruct $\gtrsim 80\%$ of the likelihood contours in 2D, $\gtrsim 90\%$ in 1D
- basic limitations: systematic under estimation of the uncertainties
- code will be public within 2 weeks, i.e. when paper is on arxiv.