Weak lensing by galaxy troughs in the Dark Energy Survey

Daniel Gruen, Einstein Fellow @ SLAC/KIPAC
with the DES weak lensing working group
The Dark Energy Survey

- **Status:**
  - **SV** (150 sq. deg, full depth):
    data understood, most science done,
catalogs at http://des.ncsa.illinois.edu
  - **Y1** (2000 sq. deg, 40% depth):
data processed, science starting
  - **Y2/3** (5000 sq. deg, 40-50% depth):
data taken, being processed

- **Lensing science, e.g.:**
  - Methods and Systematics (see Mike Jarvis'
and Tomasz Kacprzak's talk, Simon Samuroff's poster)
  - Cosmic shear (see Mike Jarvis' talk)
  - Shear peaks (see Tomasz Kacprzak's talk)
  - CMB lensing (see Pablo Fosalba's talk)
  - Joint probes
    (see Juliana Kwan's talk and Simon Samuroff's poster)
  - Strong lensing (see Thomas Collett's talk)
  - Mass mapping, stacked shear,
**trough lensing** (this talk)

Source: Eric Neilsen
Millennium simulation, \( z=0 \), thick slice

DES SV convergence:
Vikram+2015, Chang+2015
Stacked shear by overdensities: S/N~O(30)

Stacked shear around DES SV optical redMaPPer clusters, *blinded* source: Melchior, DG, McClintock, Varga, Sheldon, Rozo+ in prep.
Stacked shear by underdensities: S/N~O(5)

S/N of void lensing is small:

- Low signal amplitude w/o central ΔΣ 'peak'
- Noise from uncorrelated structure along LOS

source: Sanchez et al. 2016; see also Melchior+2015, Clampitt+2015, Krause+2013
Matter density

\[ \delta(\chi) = \frac{\rho(\chi)}{\langle \rho \rangle} - 1 \]

Galaxy field
- high S/N
- sparse
- modeling issues w.r.t. matter field
- z direction difficult

Convergence \( \kappa \)
- low S/N
- projected only
- simple connection to matter field
- extra gravity test

Millennium galaxies + blur

Millennium dark matter

DES \( \kappa \) map, Vikram+2015
Galaxy troughs

- Trough: (long) cylinder* with galaxy count below some percentile threshold

+ easy to find in photo-z, high S/N of lensing due to suppression of LSS noise,
+ new way of probing structure and gravity in low density regime
+ in the limit of dense tracers, signal is simple to predict and independent of galaxy bias etc.
Theory:
galaxy count to lensing $\kappa$

Galaxy count $N$ in trough

$$p(N|\delta_T) = \frac{1}{N!} \left( \bar{N} \left[ 1 + b\delta_T \right] \right)^N \exp \left( -\bar{N} \left[ 1 + b\delta_T \right] \right)$$

$$\langle \delta_T | N \rangle = \int_{-1}^{\infty} d\delta_T \, \delta_T \, \frac{p(N|\delta_T) \, p(\delta_T)}{P(N)}$$

Matter contrast $\delta_T$ in trough

$$C_{\kappa,\Sigma}(\ell) = \int_{0}^{\infty} dw \, \frac{q_1(w) \, q_2(w)}{w^2} \, P_\delta \left( \frac{\ell}{w}, w \right)$$

Convergence $\kappa$ / shear $g_\ell$ around trough

w/ Oliver Friedrich
Measurement

- DES Science Verification: ~150 sq. deg, grizY, full DES depth
- tracers: Rykoff/Rozo redMaGiC galaxies, 0.2<z<0.5, L>0.5L*, 1/[1000 Mpc^3]
- troughs = lower quintile in galaxy count
- sources:~2x10^6 at z>0.6
**Measurement**

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  1/[1000 Mpc³]

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- Sources: ~2x10⁶ at z>0.6

- S/N ~ 15!

Source: DG+2016
Measurement: trough tomography

$\theta_T = 10'$

trough redshift

$0.4 \leq z_T \leq 0.5$

$0.2 \leq z_T \leq 0.4$

source redshift

low $z_s$ bin

high $z_s$ bin

Source: DG+2016
Measurement:
large-scale SDSS under/overdensity

SDSS troughs x SDSS lensing & Planck CMB lensing, preliminary
with Joseph Clampitt, Bhuvnesh Jain, Erin Sheldon, and Kyle Story
Work in progress for DES Y1+:
Modeling the PDF of $\delta$ & $\kappa$

- Model: cylindrical collapse
  (cf. e.g. Bernardeau+2014, 2015)
- Tested against projected, smoothed $\delta$&$\kappa$ measured in all-sky N-body simulations
- On relevant scales, log-normal fits as well
  (cf. also Clerkin+2016 for DES $\kappa$ PDF)

w/ Oliver Friedrich, Joe DeRose, Stefan Hilbert, Elisabeth Krause, Risa Wechsler
Work in progress for DES Y1+:  
End-to-end analysis in simulations

- Combination of shear around troughs, overdense LOS, and counts-in-cells
- Complementary information from the low-/high density lensing signals at peak scales
- Constraints on bias model from counts-in-cells
- Model is good fit to combined data
- Likelihood contours contain 'truth' within cosmic variance

w/ Oliver Friedrich, Joe DeRose, Stefan Hilbert, Elisabeth Krause, Risa Wechsler
Summary

- Troughs are a probe of projected matter & convergence PDF with high S/N in the low density, large scale regime
- Progress in using trough lensing for cosmology
- DES is on track with a variety of weak lensing science