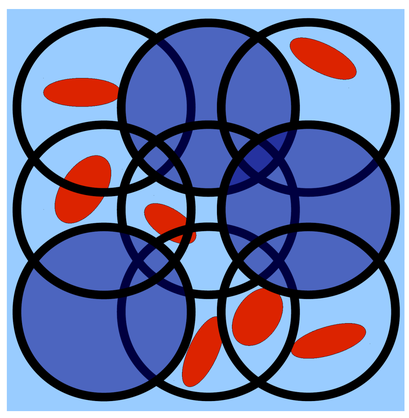
Weak lensing by galaxy troughs in DES Science Verification data

Abstract We measure the weak lensing shear around galaxy troughs, i.e. the radial alignment of background galaxies relative to underdensities in projections of the foreground galaxy field over a wide range of redshift in Science Verification data from the Dark Energy Survey. Our detection of the shear signal is highly significant for troughs with the redshift range $z\in[0.2,0.5]$ of the projected galaxy field and angular diameters of 10'...1°. These measurements probe the connection between the galaxy, matter density, and convergence fields. By assuming galaxies are biased tracers of the matter density with Poissonian noise, we find agreement of our measurements with predictions in a fiducial ΛCDM model. The prediction for the lensing signal on large trough scales is virtually independent of the details of the underlying model for the connection of galaxies and matter. Our comparison of the shear around troughs with the shear around cylinders with large galaxy counts is consistent with a symmetry between galaxy and matter over- and underdensities. The lensing signal of troughs is a promising probe of both ΛCDM and modified gravity models.

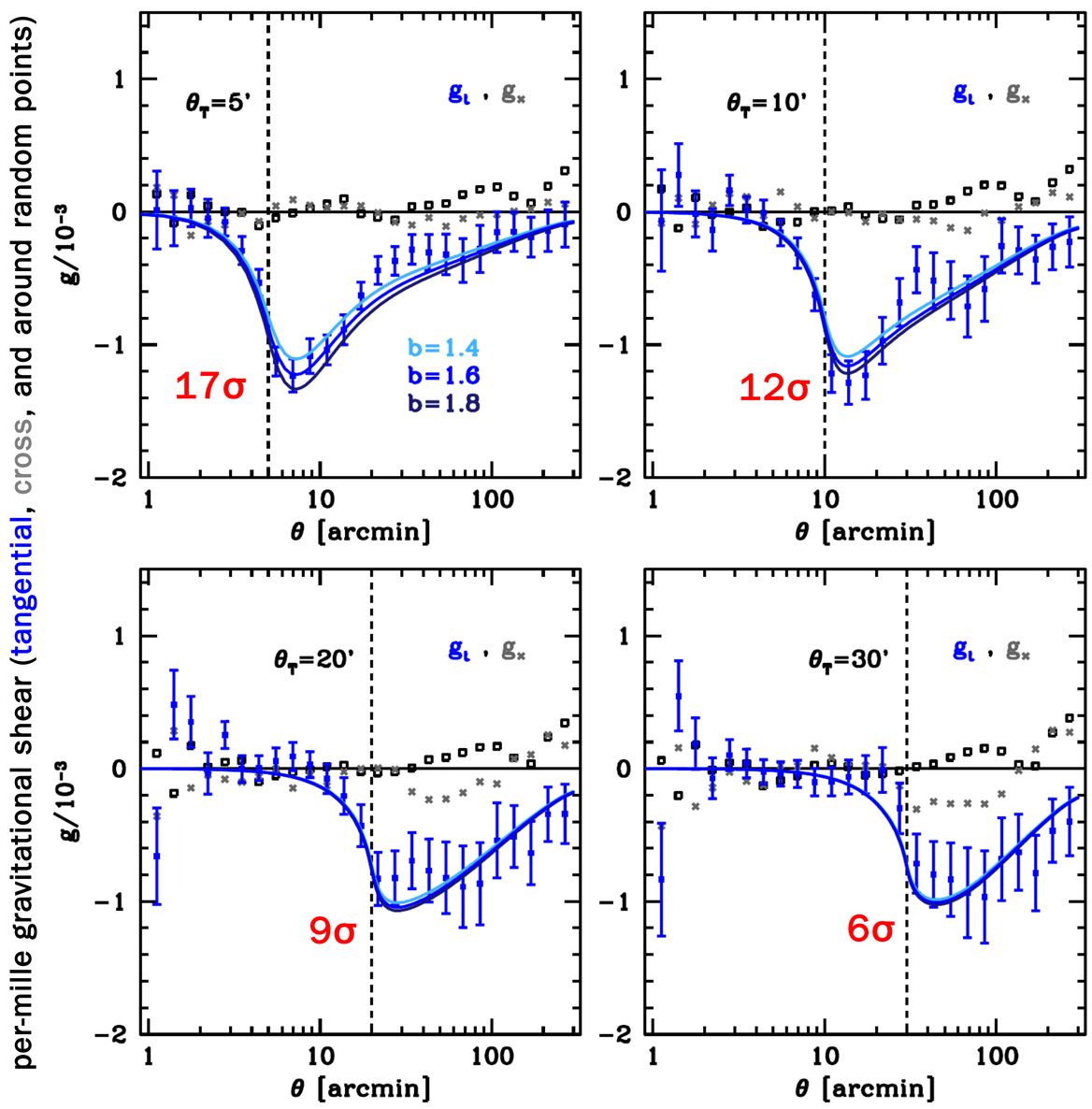
Idea and Measurement

Lensing is sensitive to density fluctuations all along the line of sight from the sources to us. While this means it is hard to measure the shear around 3D underdensities (voids) with high significance, it allows for a high-S/N lensing measurement of the density around **underdensities in the projected galaxy field, which we call troughs**.



We select troughs by projecting the redMaGiC DES galaxy catalog (Rozo+2015) over $z\in[0.2,0.5]$ and counting galaxies in circles of different trough radii. The lower 20th percentile of these is used as trough positions. We then measure the tangential shear of background galaxies around these points (see below) and their angular correlation with galaxies (see paper).

The per-mille radial alignment of background galaxy images is detected with high significance, particularly when compared to recent void lensing studies (Melchior+2014, Clampitt & Jain 2014).



Model

We model the shear signal around troughs by assuming that **galaxies are biased, deterministic tracers** of the matter field **with shot noise**. Using the (cross) power spectra of matter contrast and lensing convergence, we derive the expected shear signal. The predictions are almost independent of the details of the galaxy model on large scales. Our measurements agree with these predictions in concordance ΛCDM (for details see paper).

Galaxy count N in trough

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

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

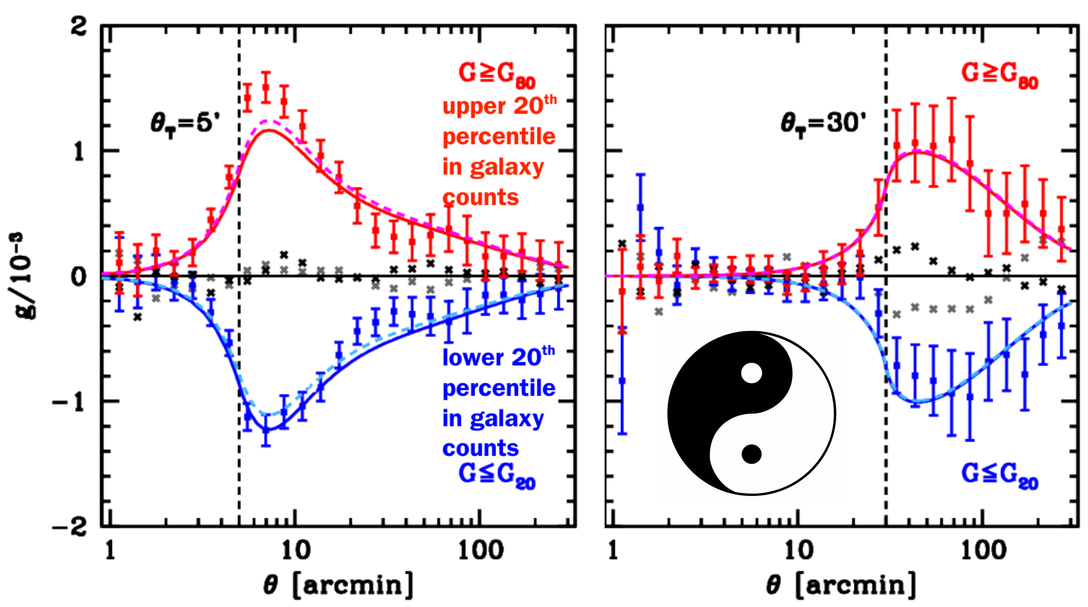
Matter contrast δ_T in trough

$$C_{\kappa,\Sigma}(\ell) = \int_0^{\infty} \mathrm{d}\chi\ \frac{q_\kappa(\chi)\,q_\Sigma(\chi)}{\chi^2}\ P_\delta\left(\frac{\ell}{\chi},\chi\right)$$

Convergence κ / shear γ_t around trough

Symmetry of over- and underdensities

We make the same shear measurements as for the troughs also for the upper 20th percentile of cylinders in galaxy count. In linear structure formation and ΛCDM we expect this to yield the same shear signal with opposite sign, while modified gravity models typically predict enhanced growth of underdensities. Our measurements are consistent with the former.



Daniel Gruen, Oliver Friedrich, and the DES Collaboration – paper on arXiv July 21, 2015