Cosmic Shear Analysis in DECam Local Volume Exploration (DELVE)

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Background

- $\Lambda CDM$: spatially flat Universe governed by general relativity that contains baryonic matter, dark matter, and a dark energy component that accelerates the Universe’s expansion
- Sufficient to describe many observed phenomena
- Two of the major components, dark matter and dark energy, are mysterious
- Tension between values of $\Lambda CDM$’s cosmological parameters for low- and high-redshift Universe

Illustration of the evolution of the Universe, following the $\Lambda CDM$ model.
Cosmic Shear

- **Weak lensing:** Light from background object passes by the gravitational potential wells of foreground masses, creating slightly distorted images. These distortions are statistically averaged over many objects.
- **Cosmic shear:** Weak lensing signal derived from the large-scale structure of the Universe.
- Most sensitive to the total matter density, $\Omega_m$, and the amplitude of mass fluctuations, $\sigma_8$, quoted via $S_8 \equiv \sigma_8 \left(\frac{\Omega_m}{0.3}\right)^{0.5}$.
- Testing $\Lambda CDM$ by evaluating the consistency between measurements of $S_8$ with low-redshift galaxy surveys and high-redshift CMB measurements.
DECam Local Volume Exploration Survey (DELVE)

- Combines archival and novel DECam data to provide complete coverage of the high-Galactic-latitude southern sky and to understand the faintest, most dark-matter dominated galaxies
- DELVE shear catalog will use existing DECam data and DES infrastructure to construct a weak lensing catalog covering 10,000 deg² of the night sky with 80 million galaxies
- DELVE cosmic shear analysis will cross-check DES analysis

DELVE area coverage in g, r, i, z photometric bands overlaid on the DES footprint
Forecast Modeling

- Use simulated data to develop the pipeline for the cosmic shear analysis of the DELVE shear catalog
- Compare the impact of different modeling choices on the predicted constraints of cosmological parameters
- Simultaneously model cosmological parameters and systematics such as the shear bias, weak lensing photo-z bias, and intrinsic alignment parameters

Example of posterior constraints on cosmological model parameters (this example uses a data vector without baryons and the TATT intrinsic alignment model)
Systematics

Intrinsic Alignment

- Galaxy shapes are affected by local gravitational interactions
- Intrinsic alignments are astrophysical shape correlations that mimic cosmic shear. II alignments occur between galaxies that are physically close to each other, and GI alignments between galaxies on close lines of sight.
- We forward-model the impact of IA on lensing.
- TATT model includes free parameters for tidal alignment, tidal torquing, and the product of the density and tidal fields. The NLA model, a subset of TATT, only tidal alignment parameters

Right: Impact of TATT vs. NLA intrinsic alignment models on cosmological parameter constraints, without baryonic influence

Left: Visualization of 2-point intrinsic alignment correlations GI and II from Troxel et. al (2014). The left series shows the II correlation, where two galaxies are both intrinsically aligned with the tidal field of a structure, creating a correlation between the galaxy shapes. The right series shows the GI correlation, where a single galaxy is intrinsically aligned by a structure, while a background galaxy is lensed by the same structure.
Systematics

**Baryon Contamination**

- Impact of baryons on the matter power spectrum at smaller scales is uncertain
- Scale cuts: we avoid this uncertainty by removing parts of the data affected by baryons
- We model baryon contamination by applying the OWLS-AGN matter power spectrum to a simulated cosmic shear data vector
- We define scale cuts based on the $\Delta \chi^2$ between cosmic shear vectors with and without the modeled baryon contamination

**Upper right:**
Comparison between contaminated and uncontaminated data vector, without applied scale cuts.

**Lower right:**
Comparison between contaminated and uncontaminated data vectors, with applied scale cuts.

**Left:** Visualization of applied scale cuts compared to simulated shear data vector. The axes represent the angular scales (arcmin) and the shaded grey blocks represent the regions of affected data. The labels stand for the combination of redshift bins.
Comparison to DES Y3

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<th>DES</th>
<th>DELVE (Contaminated, Scale Cuts)</th>
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<tbody>
<tr>
<td>$\Omega_m$</td>
<td>$0.287^{+0.057}_{-0.060}$</td>
<td>$0.308^{+0.067}_{-0.063}$</td>
</tr>
<tr>
<td>$S_8$</td>
<td>$0.770^{+0.029}_{-0.038}$</td>
<td>$0.816^{+0.020}_{-0.026}$</td>
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Posters for $\Omega_m$ and $S_8$ parameters for the contaminated DELVE NLA data vector with applied scale cuts and DES Y3 data vector
References

• Secco, L.F., et al. 2022, Phys Rev. D, 105, 023515
• Zuntz J., et al. 2015, Astronomy and Computing, 12, 45
Additional Plots

*Posterior plots for $\Omega_m$ and $S_8$ parameters for the contaminated DELVE TATT data vector with applied scale cuts and DES Y3 data vector.*