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Cosmic Shear Analysis in DECam Local Volume Exploration (DELVE)

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Background

- ΛCDM: 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 and requires six core parameters
- 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

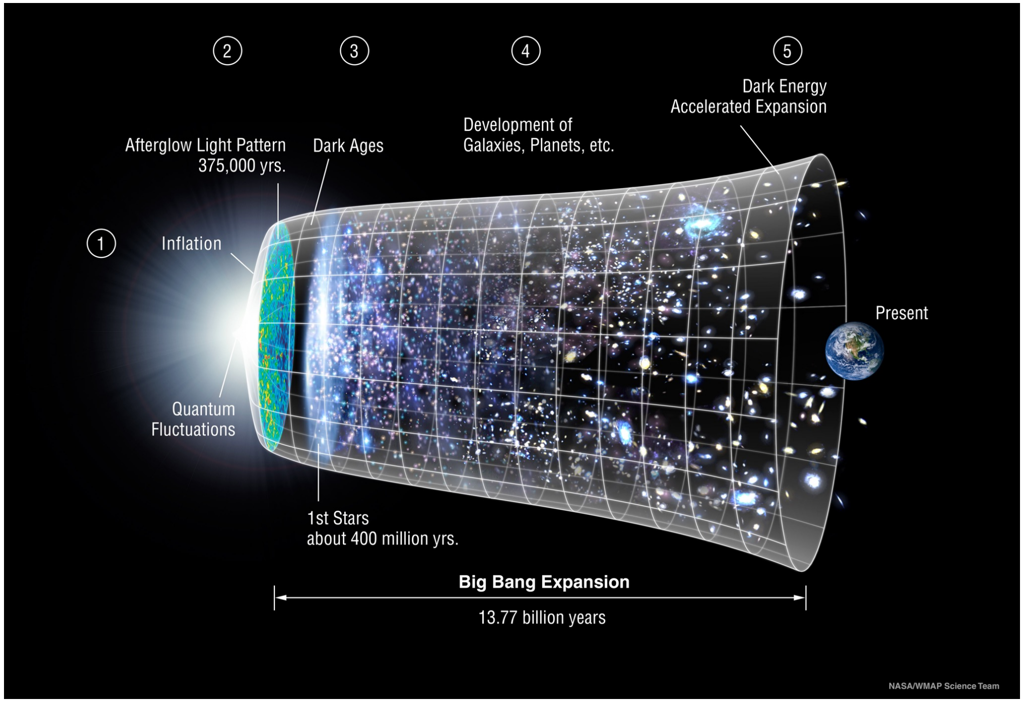
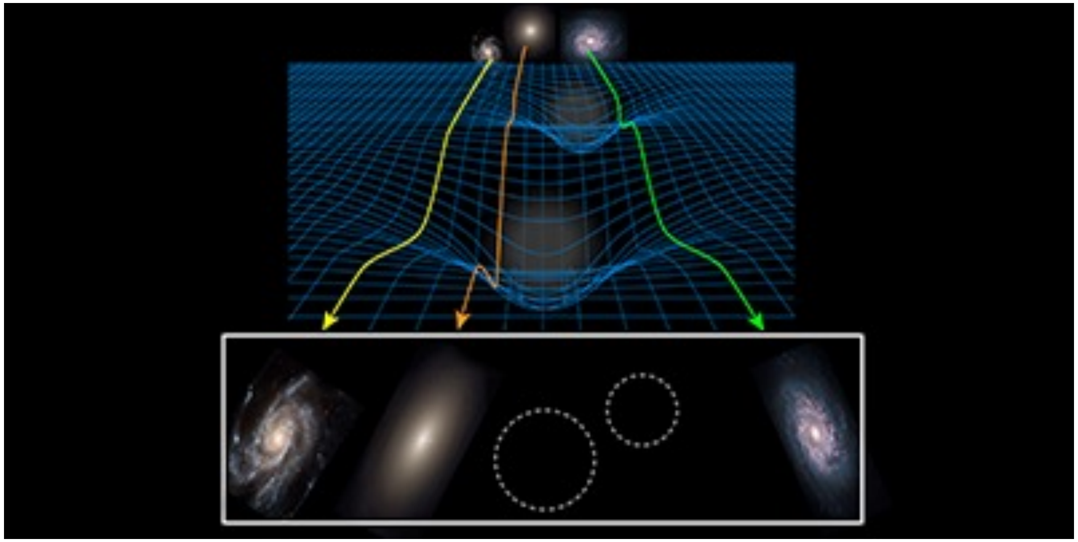


Illustration of the evolution of the Universe, following the ΛCDM model.

Cosmic Shear

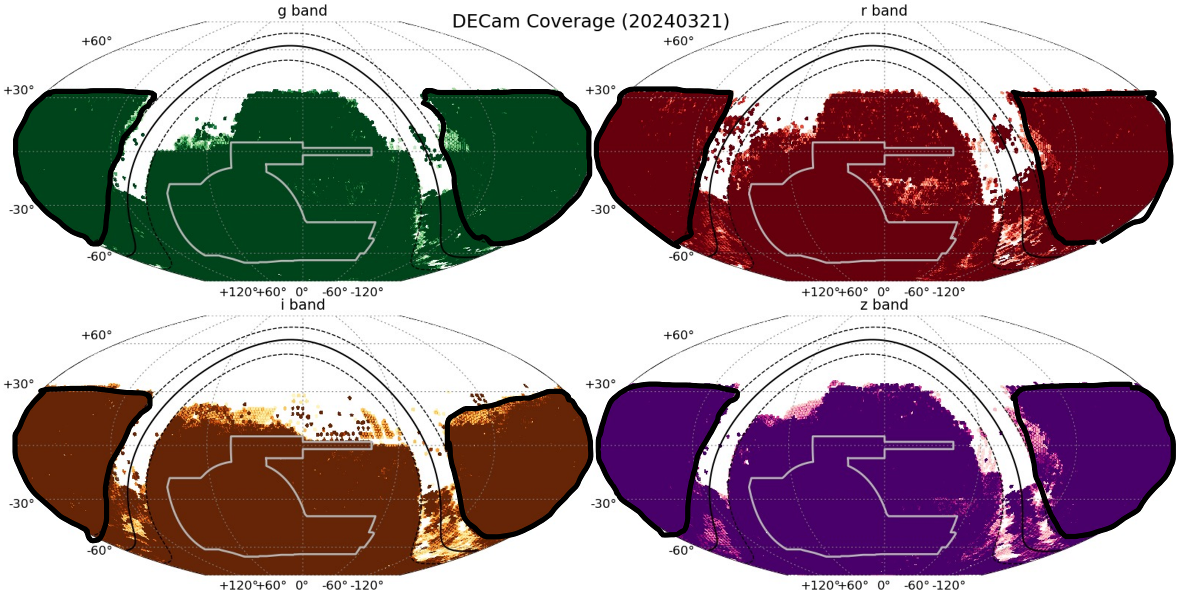
- Weak lensing: Light from background object passes by the gravitational potential wells of foreground masses, creating slightly distorted images. These distortions are statistically averaged over many objects.
- Cosmic shear: Weak lensing signal derived from all of the matter clustered along the line of sight
- Most sensitive to two fundamental cosmological parameters in ΛCDM: the total matter density, Ω_m, and the amplitude of mass fluctuations, σ_8, quoted via $S_8 \equiv \sigma_8 \left(\frac{\Omega_m}{0.3}\right)^{0.5}$
- Testing ΛCDM by evaluating the consistency between measurements of S_8 with low-redshift galaxy surveys and high-redshift CMB measurements



Visualization of the impact of shear on image quality, from APS; galaxy images from STScI/AURA, NASA, ESA, and the Hubble Heritage Team

DECam Local Volume Exploration Survey (DELVE)

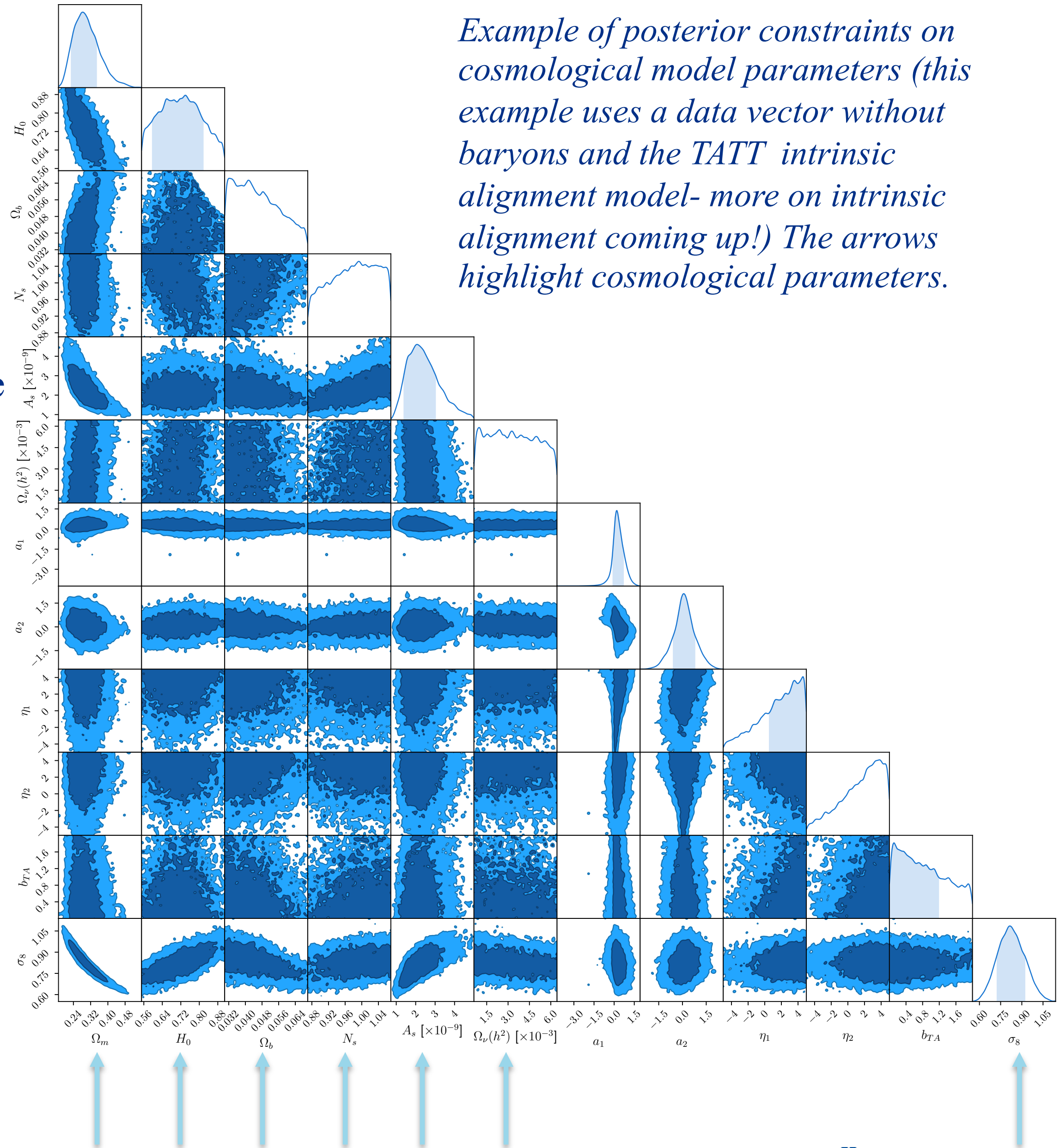
- DELVE: Combines archival and novel DECam data to provide complete coverage of the high-Galactic-latitude southern sky and to understand the faintest, most dark-matter dominated galaxies
- DES: 100M galaxies, 4400 deg^2
- DELVE: 107M galaxies, 5500 deg^2
- DELVE shear catalog will use existing DECam data and DES infrastructure to construct a weak lensing catalog covering 10,000 deg^2
- DELVE cosmic shear analysis will combine with DES analysis



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

Forecast Modeling

- For this project, we use simulated data to develop the pipeline for the cosmic shear analysis of the DELVE shear catalog
- Produce the synthetic data vector by establishing a baseline cosmology and extracting a prediction from the theoretical model for shear correlation functions
- 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

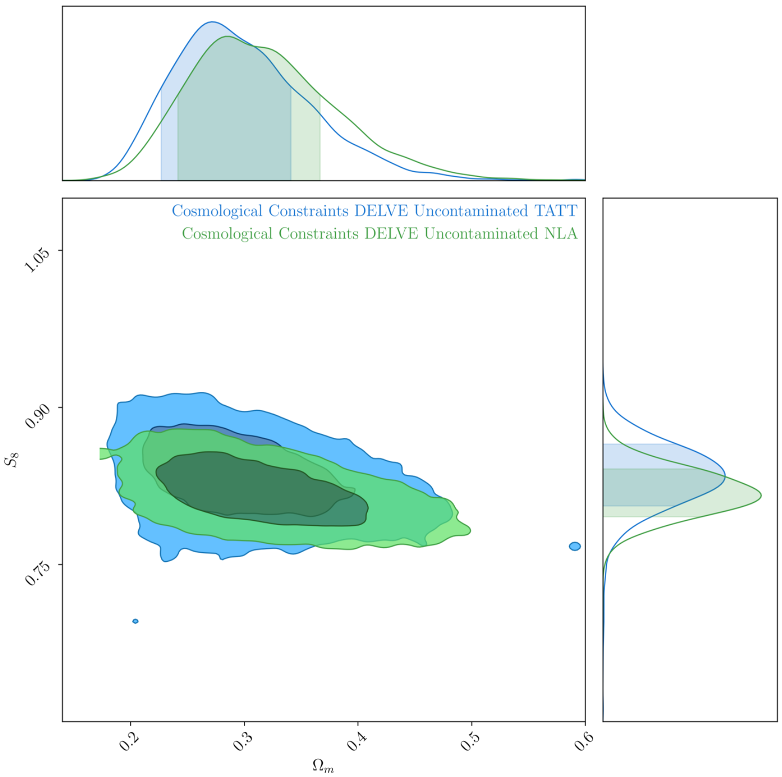


Example of posterior constraints on cosmological model parameters (this example uses a data vector without baryons and the TATT intrinsic alignment model- more on intrinsic alignment coming up!) The arrows highlight cosmological parameters.

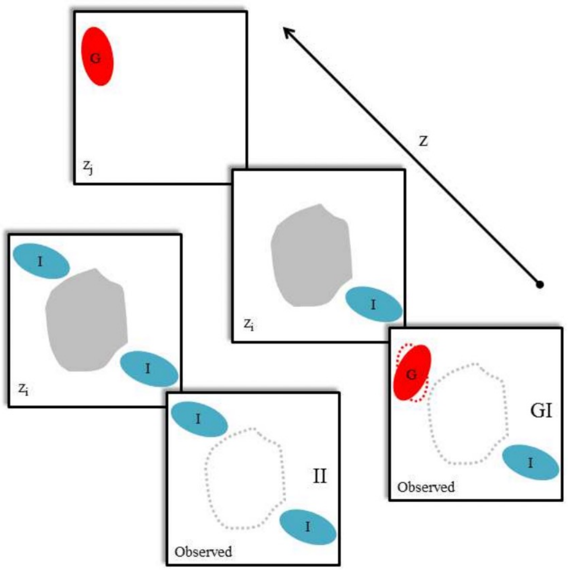
Systematics

Intrinsic Alignment

- Galaxy shapes are affected by local gravitational interactions
- Intrinsic alignments are astrophysical shape correlations that mimic cosmic shear. II alignments (intrinsic shape-intrinsic shape) occur between galaxies that are physically close to each other, and GI alignments (galaxy-intrinsic shape) 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, includes only tidal alignment parameters



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

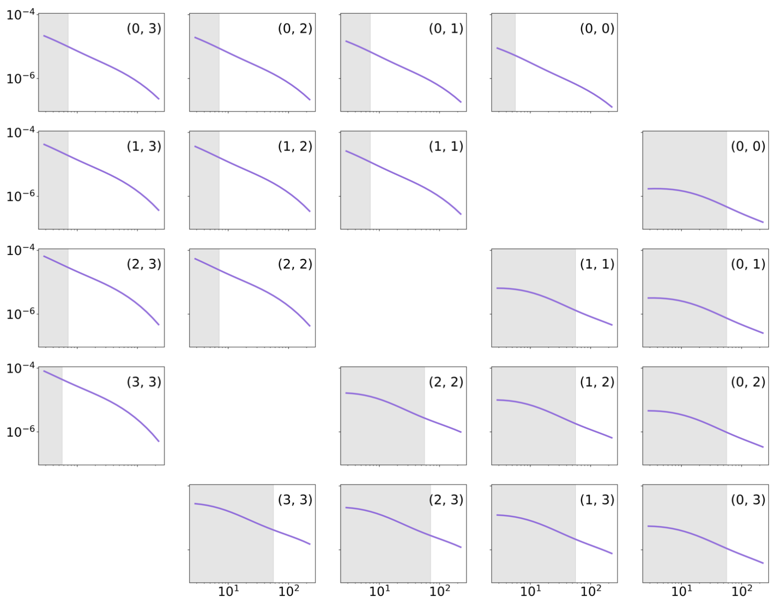


Left: Visualization of 2-point intrinsic alignment correlations GI and II from Troxel et. al (2014). The left series shows the II correlation, where two galaxies are both intrinsically aligned with the tidal field of a structure, creating a correlation between the galaxy shapes. The right series shows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

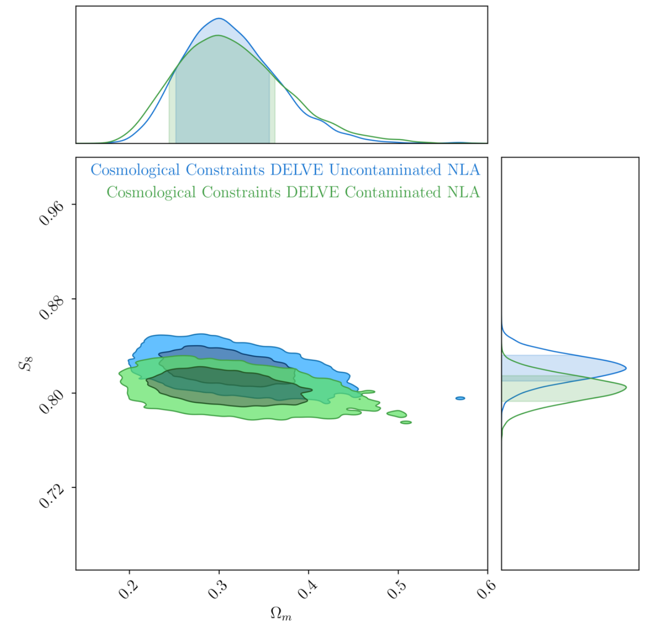
- Impact of baryons on the matter power spectrum at smaller scales is uncertain
- Scale cuts: we avoid this uncertainty by removing parts of the data affected by baryons
- We model baryon contamination by applying the OWLS-AGN matter power spectrum to a simulated cosmic shear data vector
- We define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

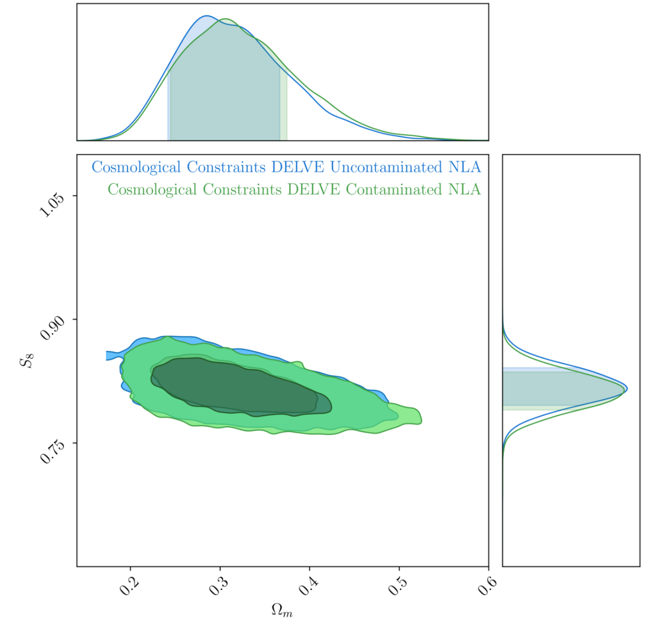


Upper right: Comparison between contaminated and uncontaminated data vector, without applied scale cuts.

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

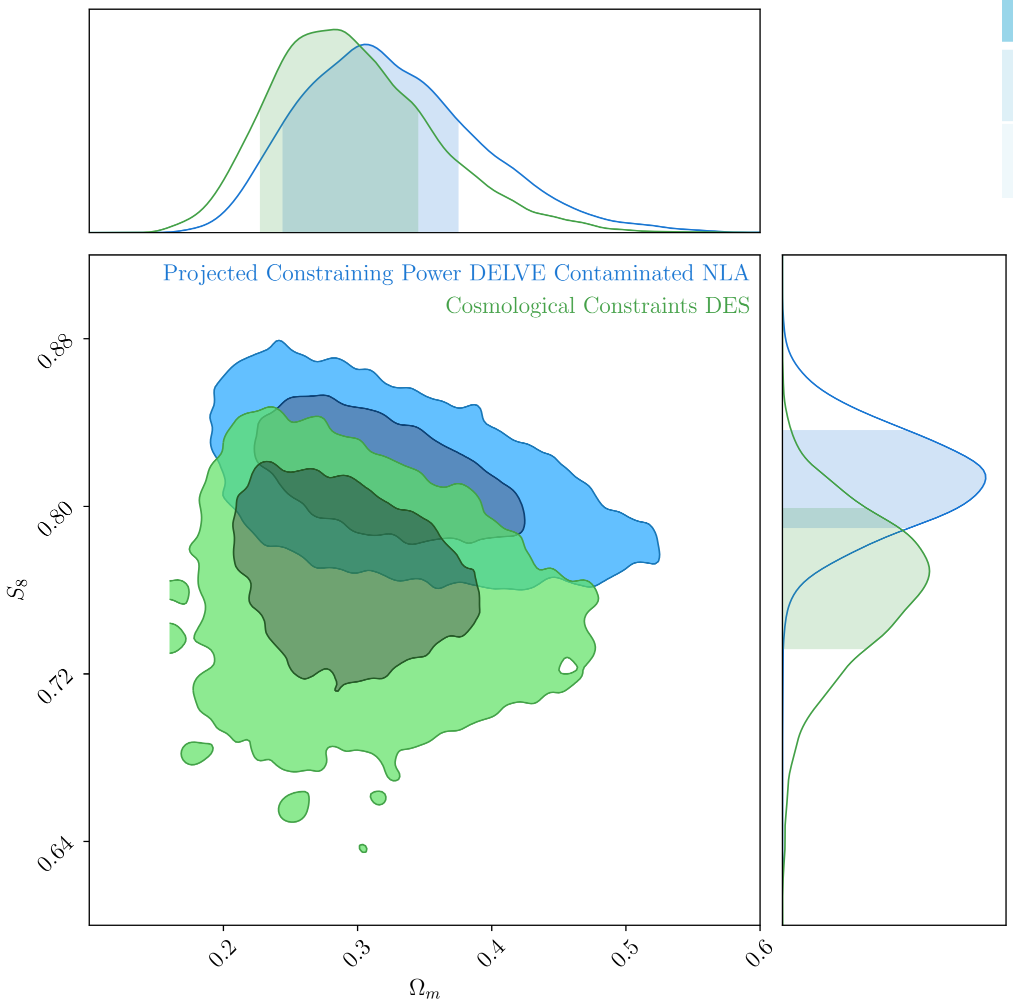
Left: Visualization of applied scale cuts compared to simulated shear data vector. The axes represent the angular scales (arcmin) and the shaded grey blocks represent the regions of affected data. The labels stand for the combination of redshift bins.





Projected DELVE Posterior vs. DES

	DES	DELVE (Contaminated, Scale Cuts)
Ω_m	$0.287^{+0.057}_{-0.060}$	$0.308^{+0.067}_{-0.063}$
S_8	$0.770^{+0.029}_{-0.038}$	$0.816^{+0.020}_{-0.026}$



***PROJECTED** posteriors for Ω_m and S_8 parameters for the contaminated DELVE NLA data vector with applied scale cuts and DES Y3 data vector. Note that the offset is artificial and comes from different input parameters. We focus on comparing the relative size of the contours.*

References

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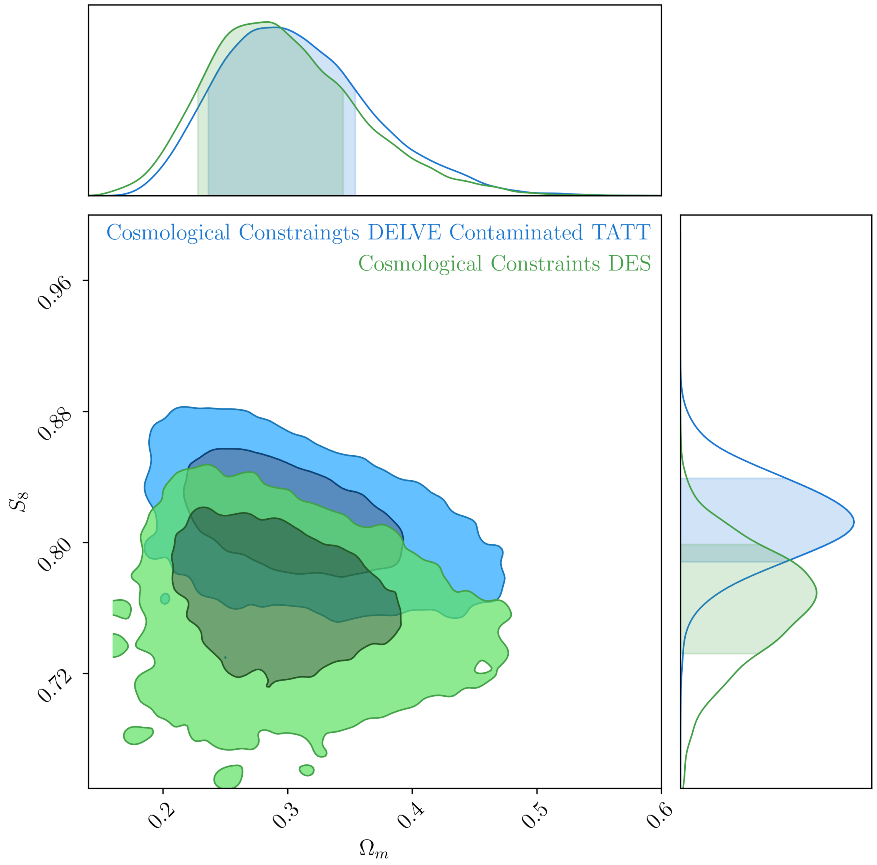
Additional Plots



Posteriors for Ω_m and S_8 parameters for the contaminated DELVE TATT data vector with applied scale cuts and DES Y3 data vector