Connecting galaxy formation & cosmology with weak lensing

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Observing the large scale structure

foreground (lens) galaxies, which are clustered

Most sensitive to the amount, $\Omega_m$ and clumpiness of, $\sigma_8$, matter.

$$S_8 = \sigma_8(\Omega_m/0.3)^{0.5}$$

lensed / sheared image of background galaxies
Dark Energy Survey: Y3

- Y3: 2013-16 data
- **Wide field:** 5000 sq. deg. in 5 bands. ~23 magnitude
- Positions and shapes of > 100M galaxies
Lensing surveys on sky

Amon & Robertson (in prep.)
Lensing is low

*Another* tension in cosmology

\[
S_8 = \sigma_8 (\Omega_m/0.3)^{0.5}
\]

Amplitude of clustering
DES Y3: pixels to cosmology

The data

Wide Field Images
- Sevilla, Bechtol +

Deep Field Photometry
- Hartley, Choi, Amon +

Survey selection

Point Spread Function Modelling
- Jarvis, Bernstein, Amon +

Image simulations
- MacCrann, Becker, McCullough, Amon +

Redshift calibration
- Myles, Alarcon, Amon +
- Gatti, Giannini +

Shape catalogue
- Gatti, Sheldon, Amon +

Blending & calibration
- Mitigate experimenter bias
- Muir +

2-point function measurements
- Model choices
- Krause +

Covariance
- Friedrich +

Analysis Methods
- Sanchez, Prat +
- Cordero, Harrison +
- Campos +; Doux +

Modelling
- Jarvis, Bernstein, Amon +
- Gatti, Sheldon, Amon +

Shape catalogue

Redshift distributions
- Myles, Alarcon, Amon +
- Gatti, Giannini +

Mitigate experimenter bias
- Muir +

Covariance
- Model choices
- Krause +

Mock analysis
- de Rose +

Cosmic shear cosmology
- Amon +
- Secco, Samuroff +

The model

DESY3: pixels to cosmology

The data
Leading methods for weak lensing systematics

Shape measurement & Point Spread Function (PSF)

Coordinated the validation of the DES Y3 shape catalogues of 100 M galaxies [Gatti, Sheldon, Amon+ 2020],

including testing the modelling of the PSF [Jarvis, Bernstein, Amon+ 2020].
Leading methods for weak lensing systematics

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**Data Calibration and Blending**

New modelling of shear calibration biases due to redshift-dependent blending, detected in simulations and propagated to cosmology [MacCrann, Becker, McCullough, Amon+ 2020].
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Data Calibration and Blending

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Built a novel DES Year 3 redshift framework that incorporates a joint photometric & spectroscopic training sample; combines 3 independent calibration methods; and models the full uncertainty [Myles, Alacorn, Amon+ 2020].
Leading methods for weak lensing systematics

Gave cosmic shear cosmology that was stable to all the dials we could turn in the data calibration

Amplitude of clustering

Amplitude of clustering

Amon+2021
Looking ahead for cosmic shear

Tested the impact of fixing uncertainties in the analysis to their best fit values:

Data calibration uncertainties negligible in the Y3 analysis (although maintaining their accuracy is still crucial and challenging for deeper data from DES Year 6 & Rubin!)
Looking ahead for cosmic shear

Tested the impact of fixing uncertainties in the analysis to their best fit values:

Fixing astrophysical/theoretical systematics, both intrinsic alignment modelling and small-scale baryonic effects (by using all scales) improves the S8 constraining power by \( \sim 2 \).

Points to opportunity!
Weak lensing model choices: baryonic feedback

This uncertainty necessitates throwing away small-scale information of the DES Y3 measurements.
Weak lensing model choices: baryonic feedback

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- Use small-scale shear instead to inform the modelling of these galaxy formation effects.
- Fold in Sunyaev-Zel'dovich (SZ) information from the CMB using AdvancedACT to map the distribution of gas pressure around dark matter halos.
Weak lensing model choices: intrinsic alignments

1. Is our modelling flexible enough to encompass our uncertainty in astrophysical effects?
2. Is the IA model suited to late-type galaxies, which dominate lensing samples?

- Using DESI spectroscopic galaxies, directly measure intrinsic alignments and understand which properties they depend on.
- Use that with DES data to construct a data-driven model.

with Daniel Gruen, Benjamin Joachimi
Is weak lensing low?

- **More data:** DES Y6 underway that will require improving calibration techniques further

- **Improve our understanding of baryonic feedback** to robustly use the small-scale lensing measurements in our cosmological analysis

- Tailor our modelling of the intrinsic alignments of galaxies using a data-driven framework