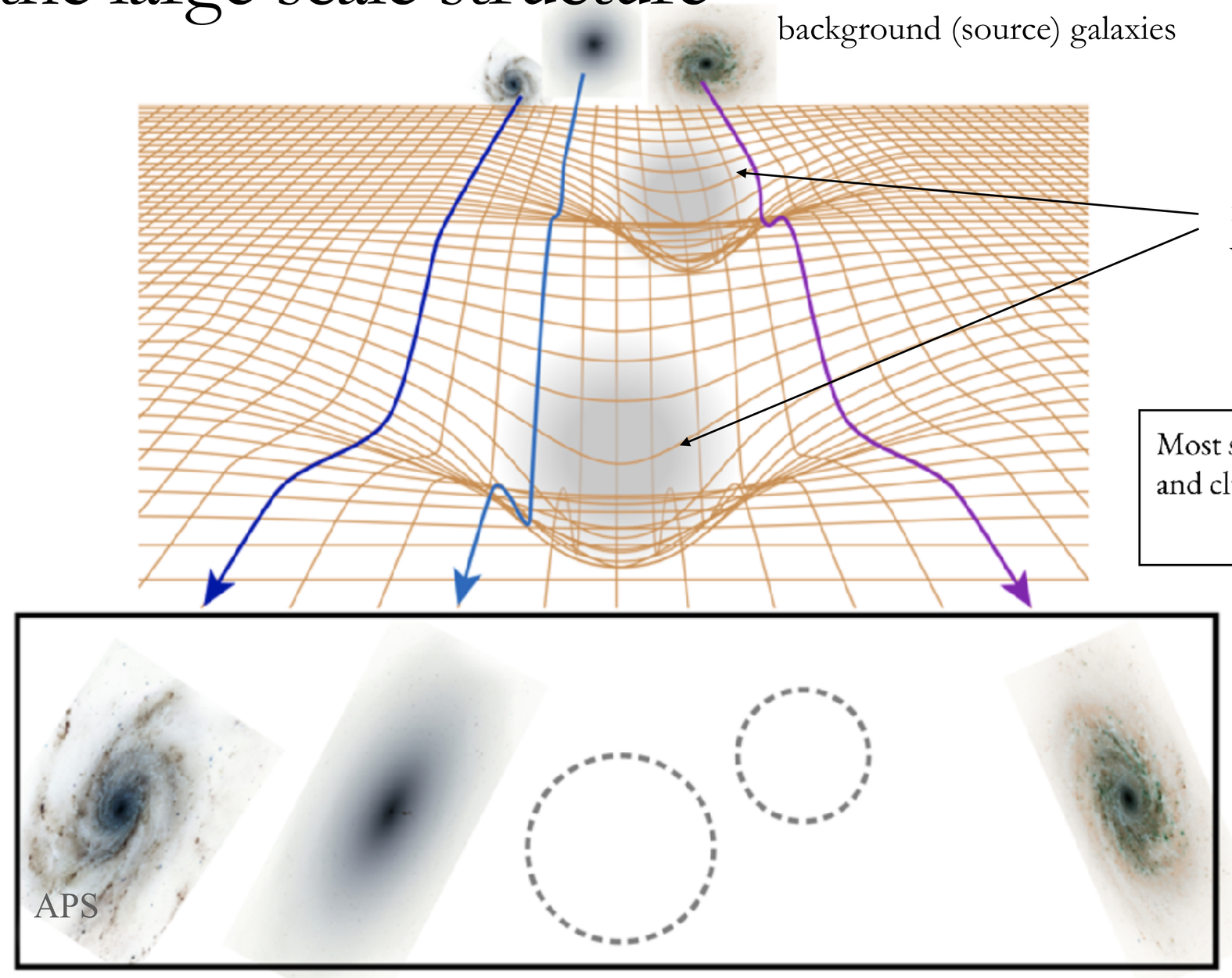
Connecting galaxy formation & cosmology with weak lensing

Dr. Alexandra Amon
Senior Kavli Fellow, Cambridge University

Photo credit: Agnes Ferte

Observing the large scale structure

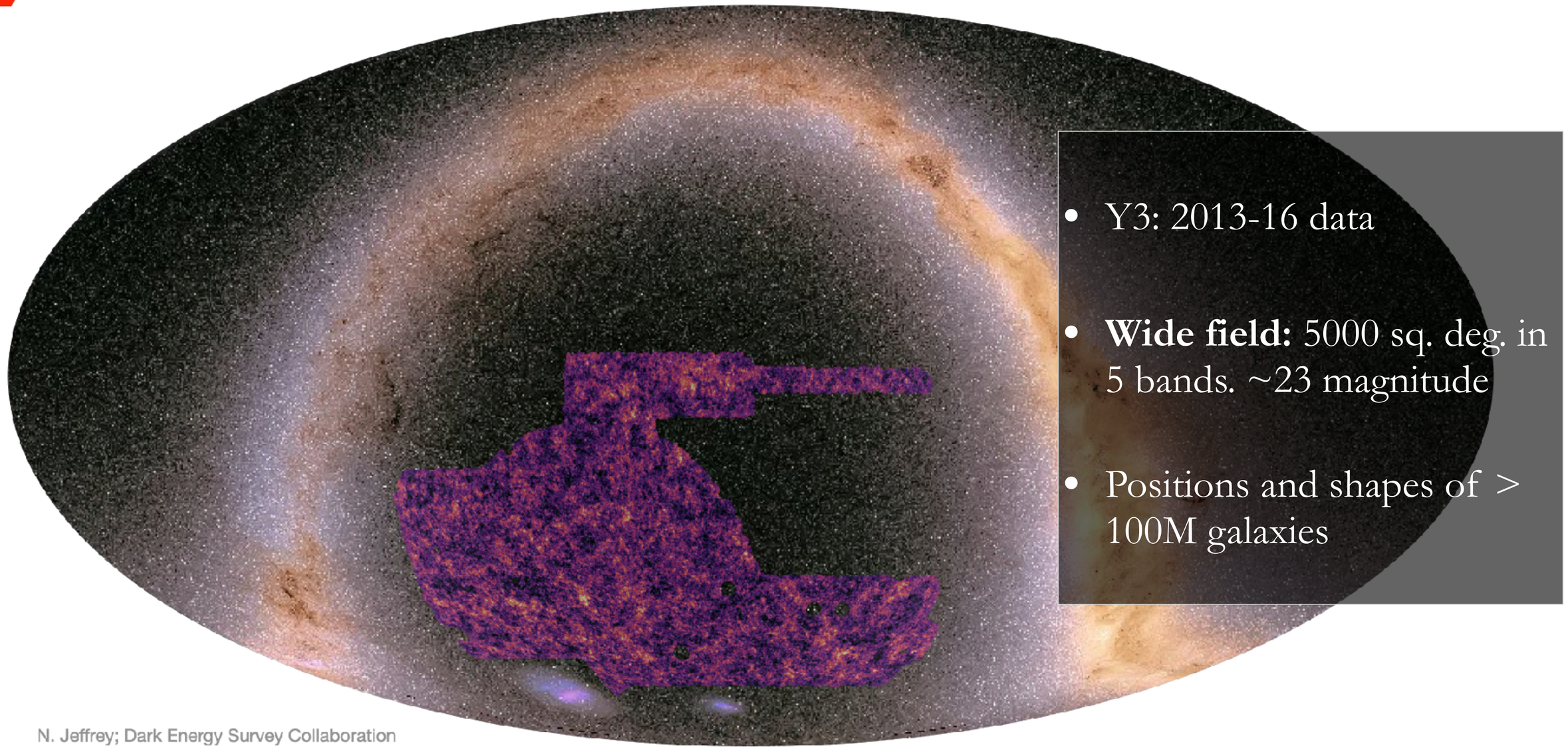
redshift / distance



Most sensitive to the amount, Ω_m and clumpiness of, σ_8, matter.

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

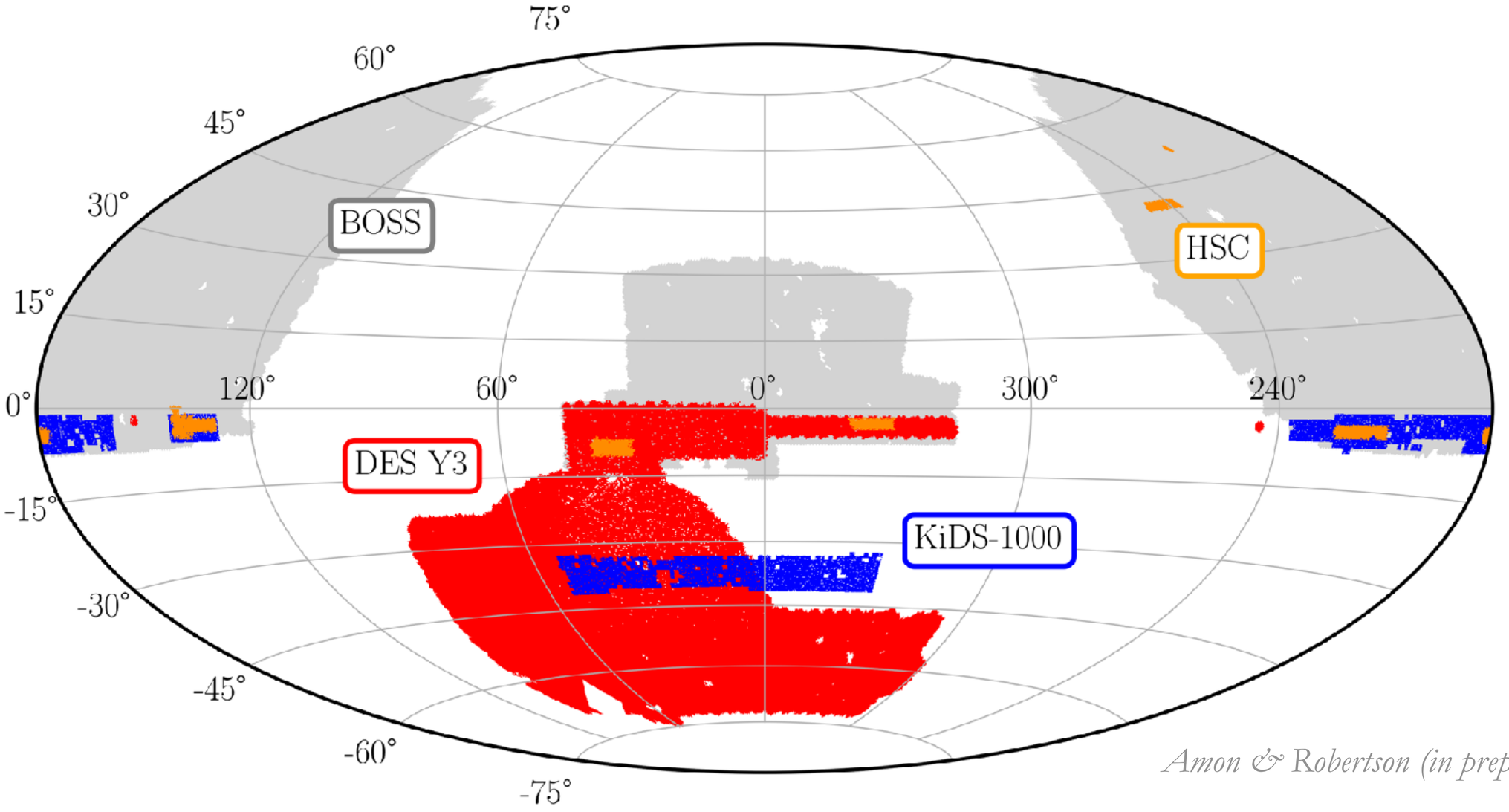
Dark Energy Survey: Y3



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

N. Jeffrey; Dark Energy Survey Collaboration

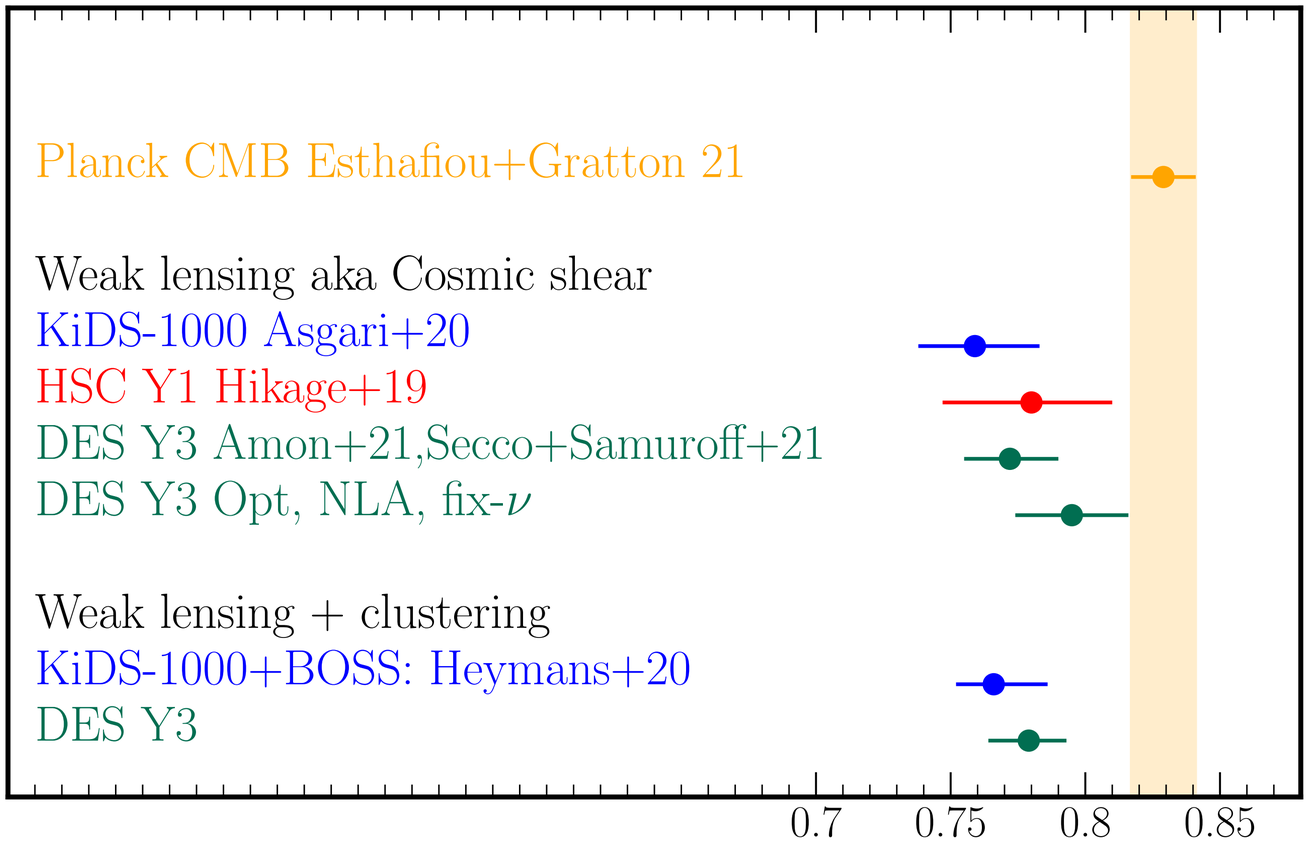
Lensing surveys on sky



Amon & Robertson (in prep.)

Lensing is low

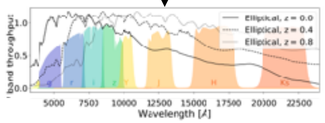
Another tension in cosmology



DES Y3: pixels to cosmology

Wide Field Images

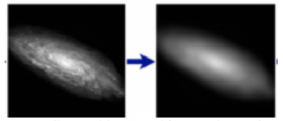
Sevilla, Bechtol +



Deep Field Photometry

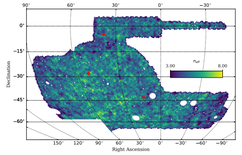
Hartley, Choi, Amon +

Survey selection



Point Spread Function Modelling

Jarvis, Bernstein, ***Amon +***



Shape catalogue

Gatti*, Sheldon,* ***Amon +***

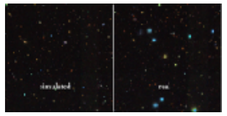
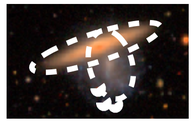
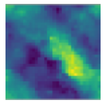


Image simulations

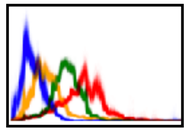


Blending & calibration

MacCrann, Becker, McCullough, Amon+



Redshift calibration



Redshift distributions

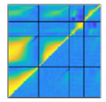
Myles, Alarcon, Amon +
Gatti, Giannini +

The data

Mitigate experimenter bias

Muir +

2-point function measurements



Covariance

Friedrich +

Analysis Methods

Sanchez, Prat +
Cordero, Harrison +
Campos + ; Doux +

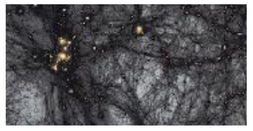
$P(\mathbf{p}|\hat{\mathbf{D}}, M) \propto \mathcal{L}(\hat{\mathbf{D}}|\mathbf{p}, M)P(\mathbf{p}|M)$

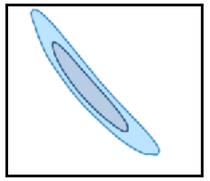
Model choices

Krause +

Mock analysis

de Rose +



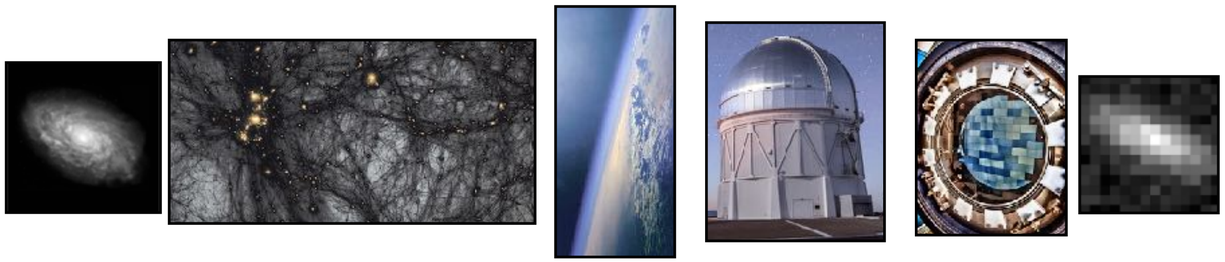


Cosmic shear cosmology

Amon +
Secco, Samuroff +

The model

Leading methods for weak lensing systematics

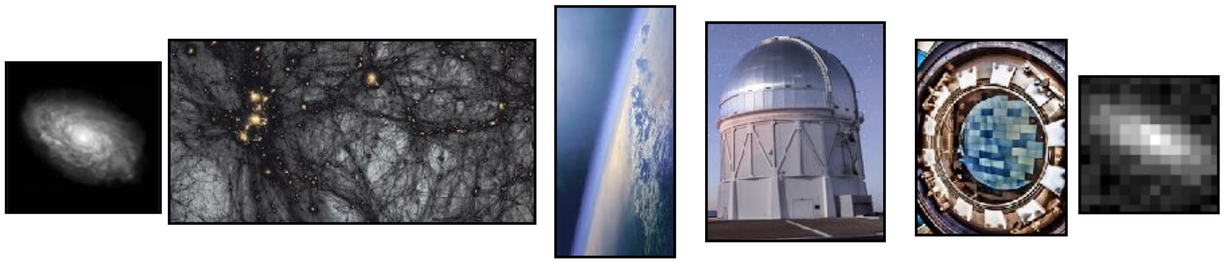


Shape measurement & Point Spread Function (PSF)

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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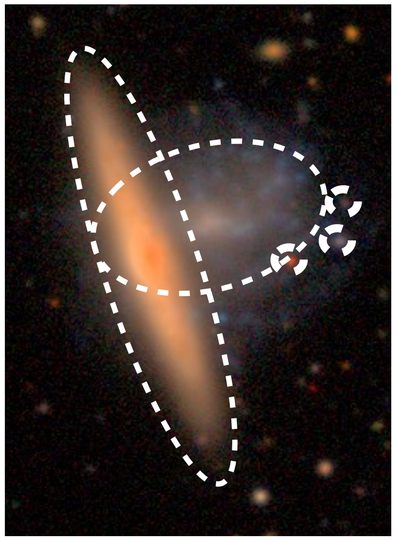
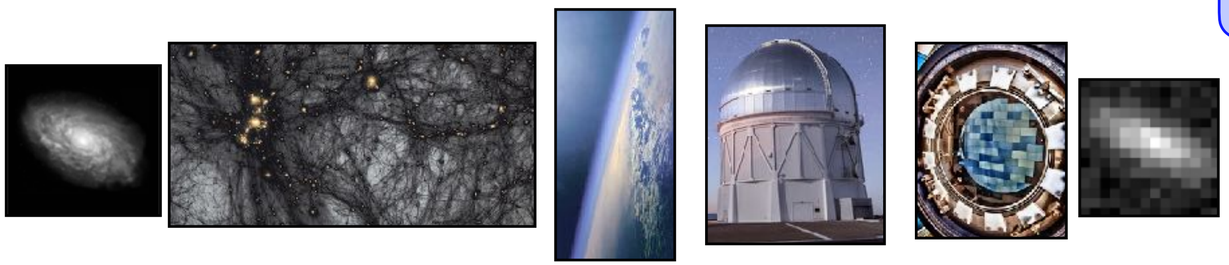


Data Calibration and Blending

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

Jamie McCullough
3rd Yr PhD, Stanford

Leading methods for weak lensing systematics



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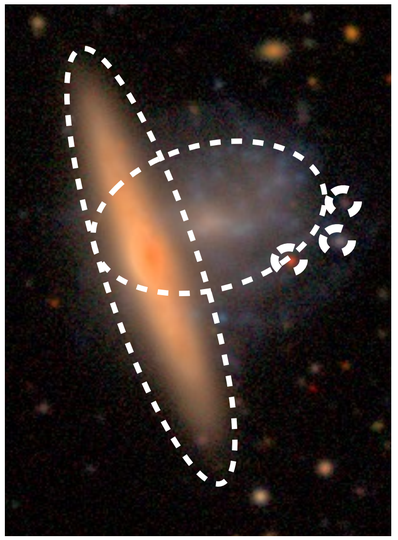

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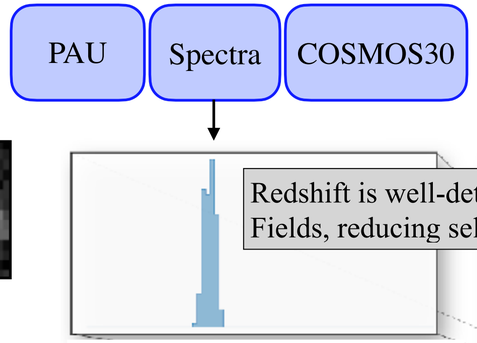
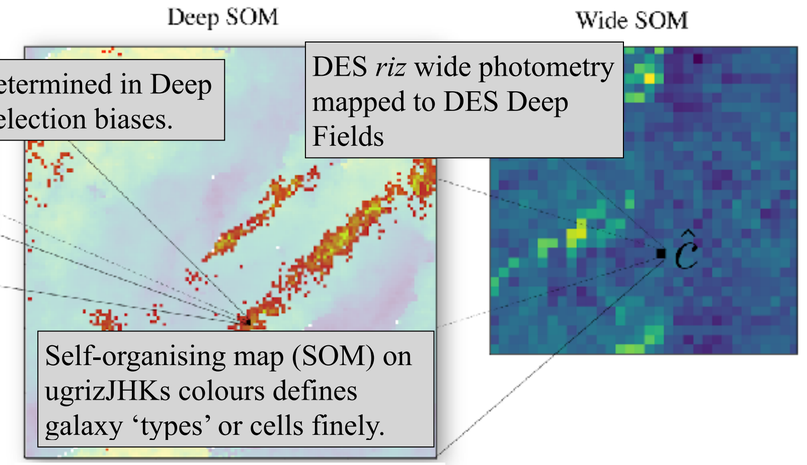


Redshift Calibration

Redshift is well-determined in Deep Fields, reducing selection biases.



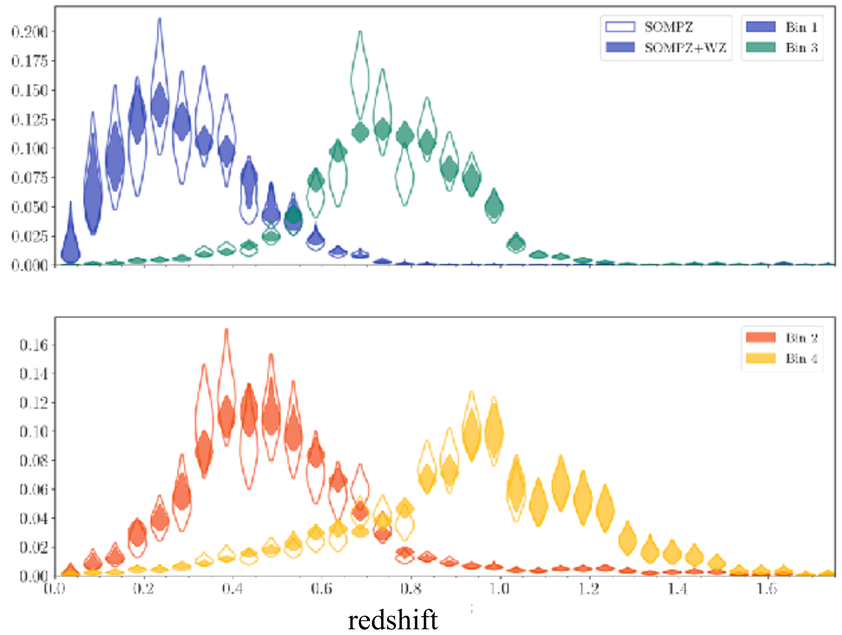
SOMPZ

Justin Myles
4th Yr PhD, Stanford

Clustering

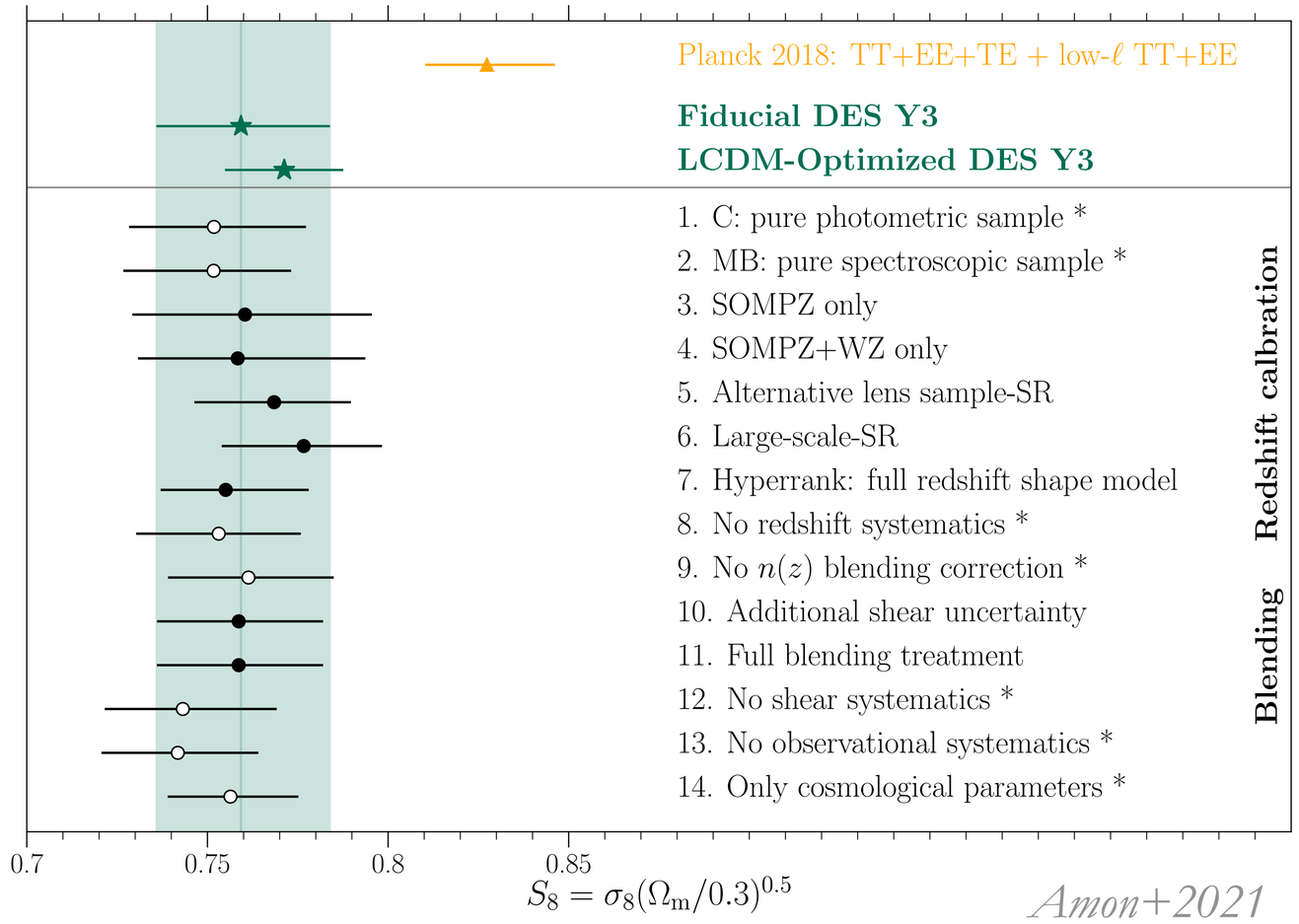
Shear ratio

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

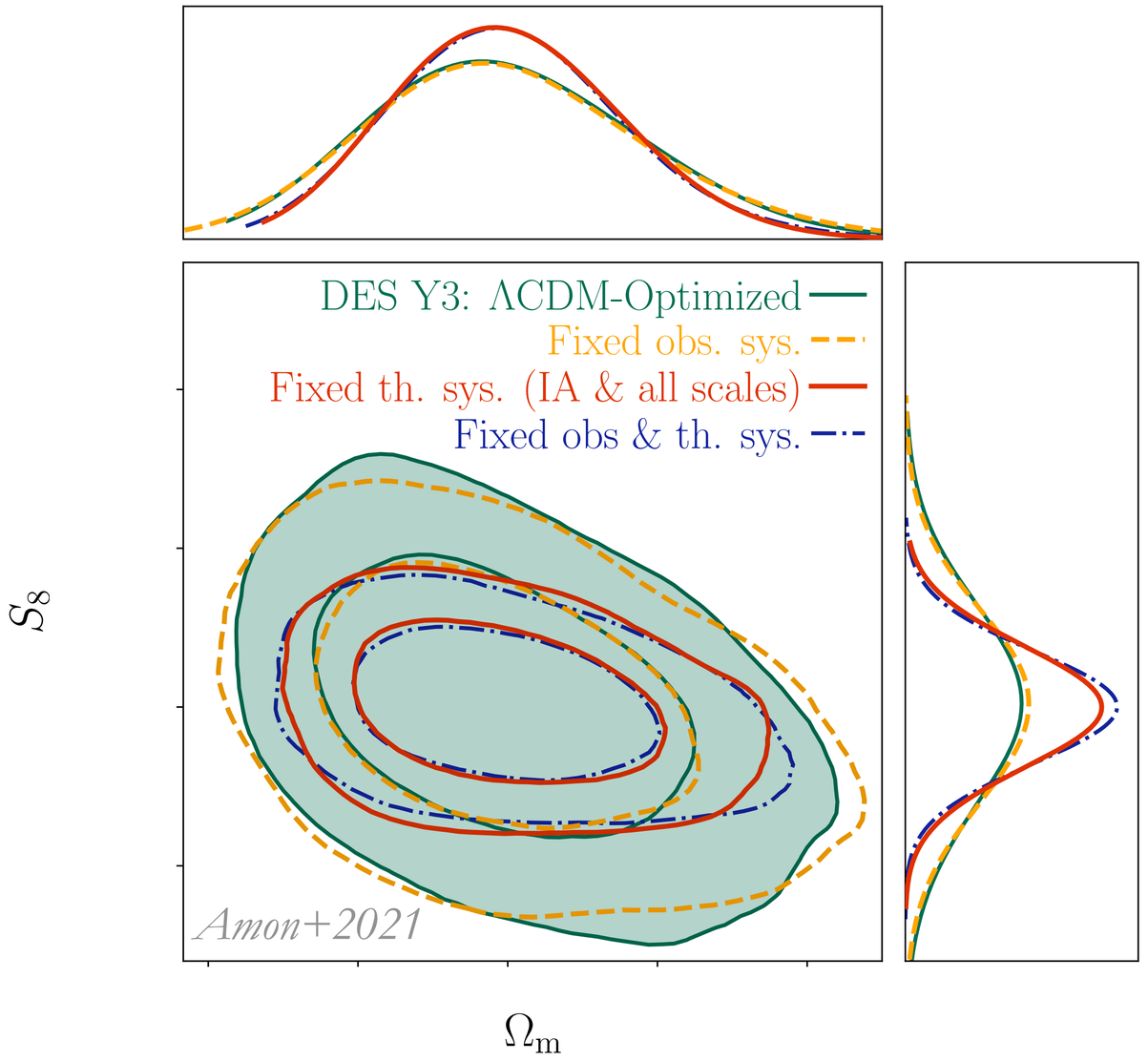


Amplitude of clustering

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!)

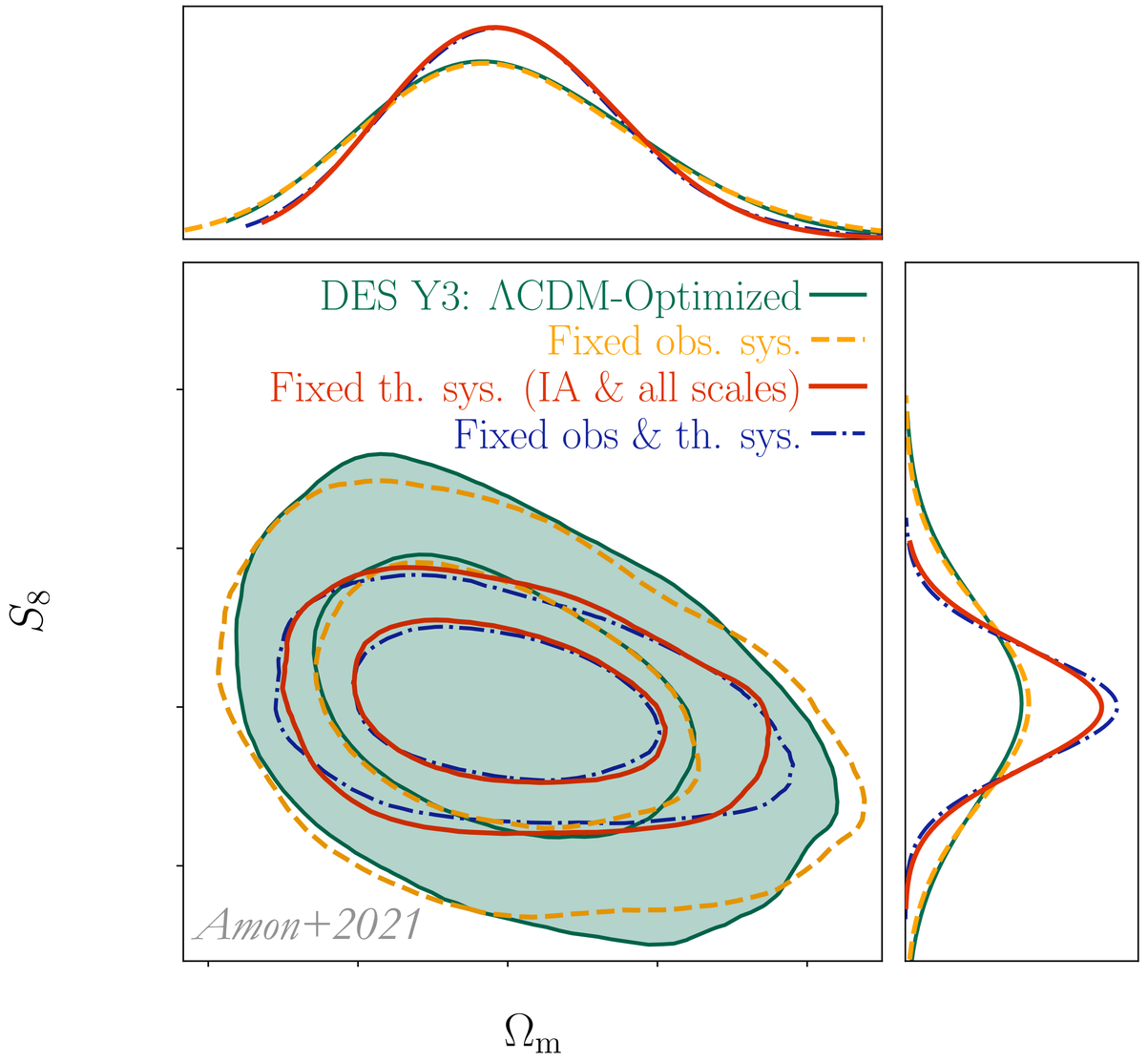


Looking ahead for cosmic shear

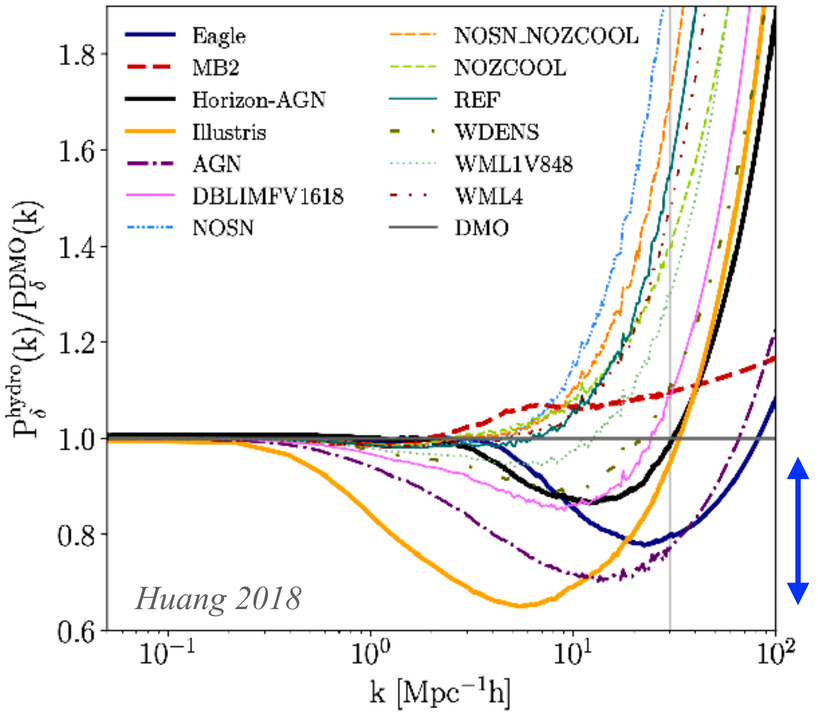
Tested the impact of fixing uncertainties in the analysis to their best fit values:

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

Points to opportunity!

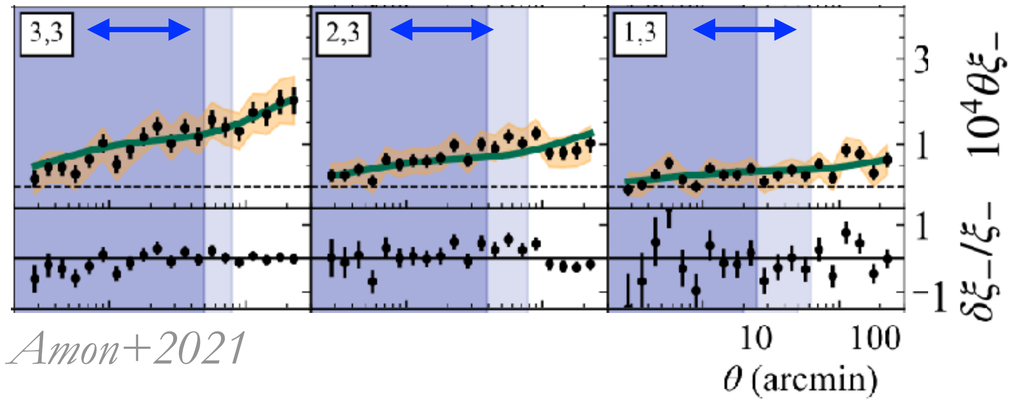


Weak lensing model choices: baryonic feedback



Available hydro-simulations differ by ~20%

This uncertainty necessitates throwing away small-scale information of the DES Y3 measurements.



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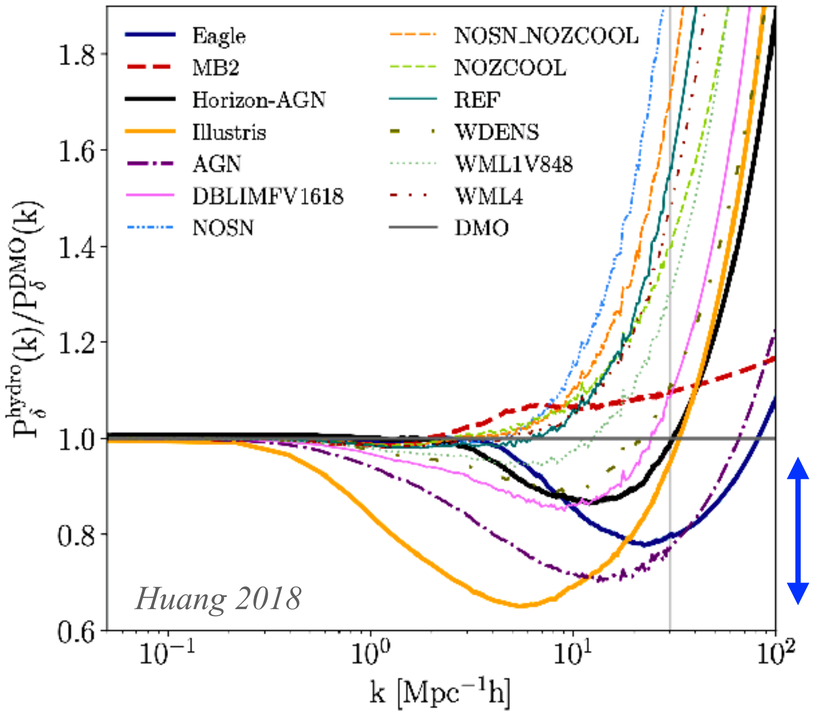

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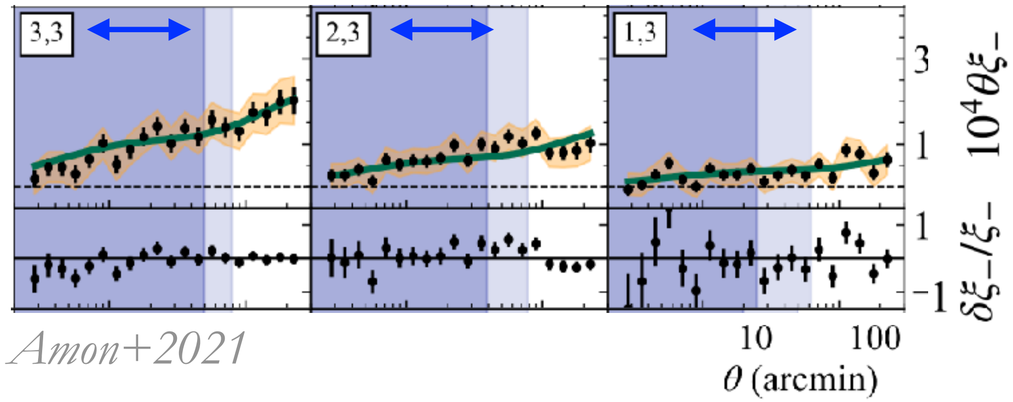
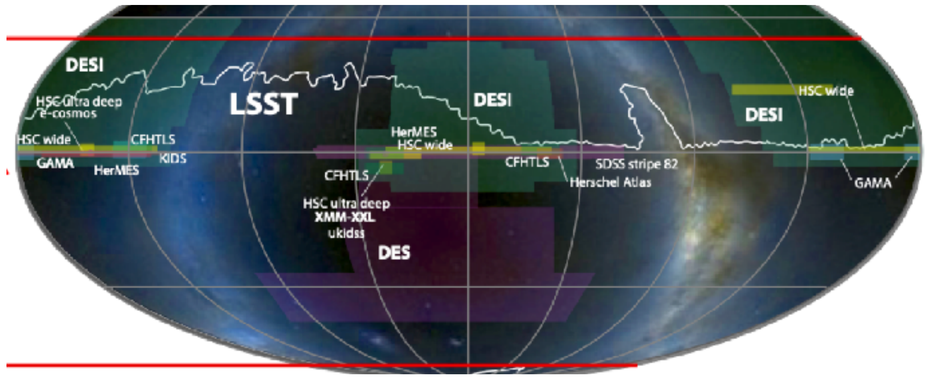
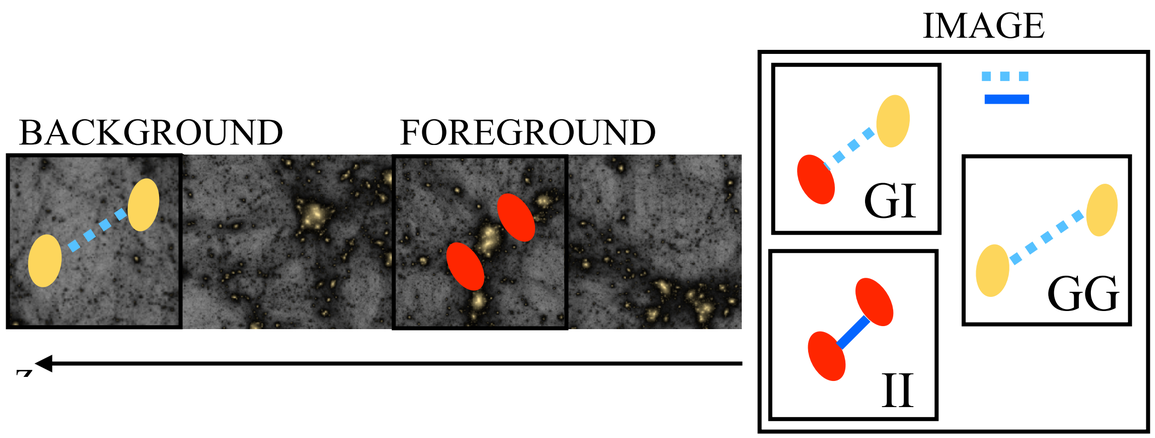


AdvACT / CMB S4



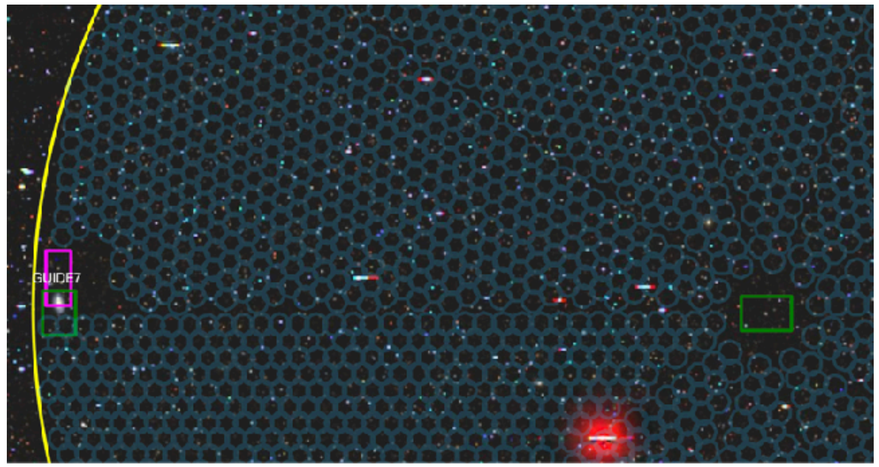
- Use small-scale shear instead to inform the modelling of these galaxy formation effects
- Fold in Sunyaev-Zel'dovich (SZ) information from the CMB using AdvancedACT to map the distribution of gas pressure around dark matter halos.

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?

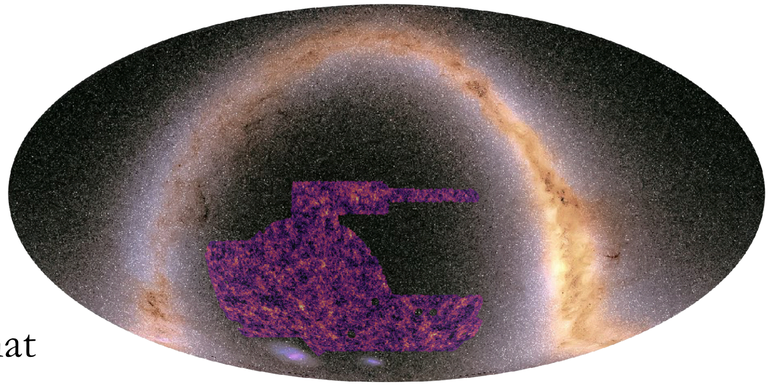
Dark Energy Spectroscopic Instrument

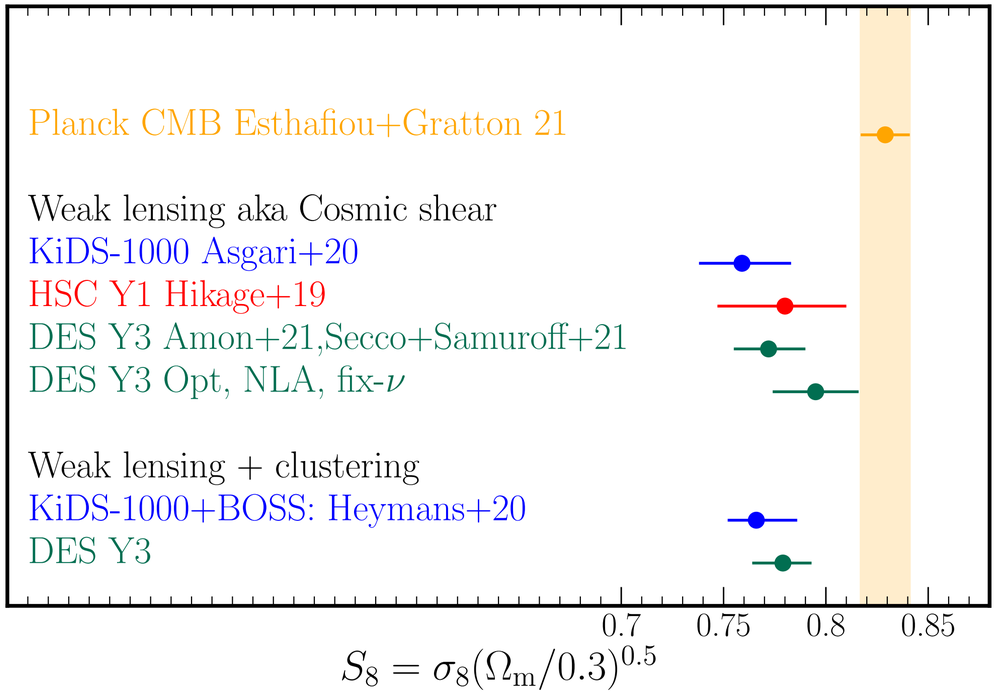


- Using DESI spectroscopic galaxies, directly measure intrinsic alignments and understand which properties they depend on.
- Use that with DES data to construct a data-driven model.

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