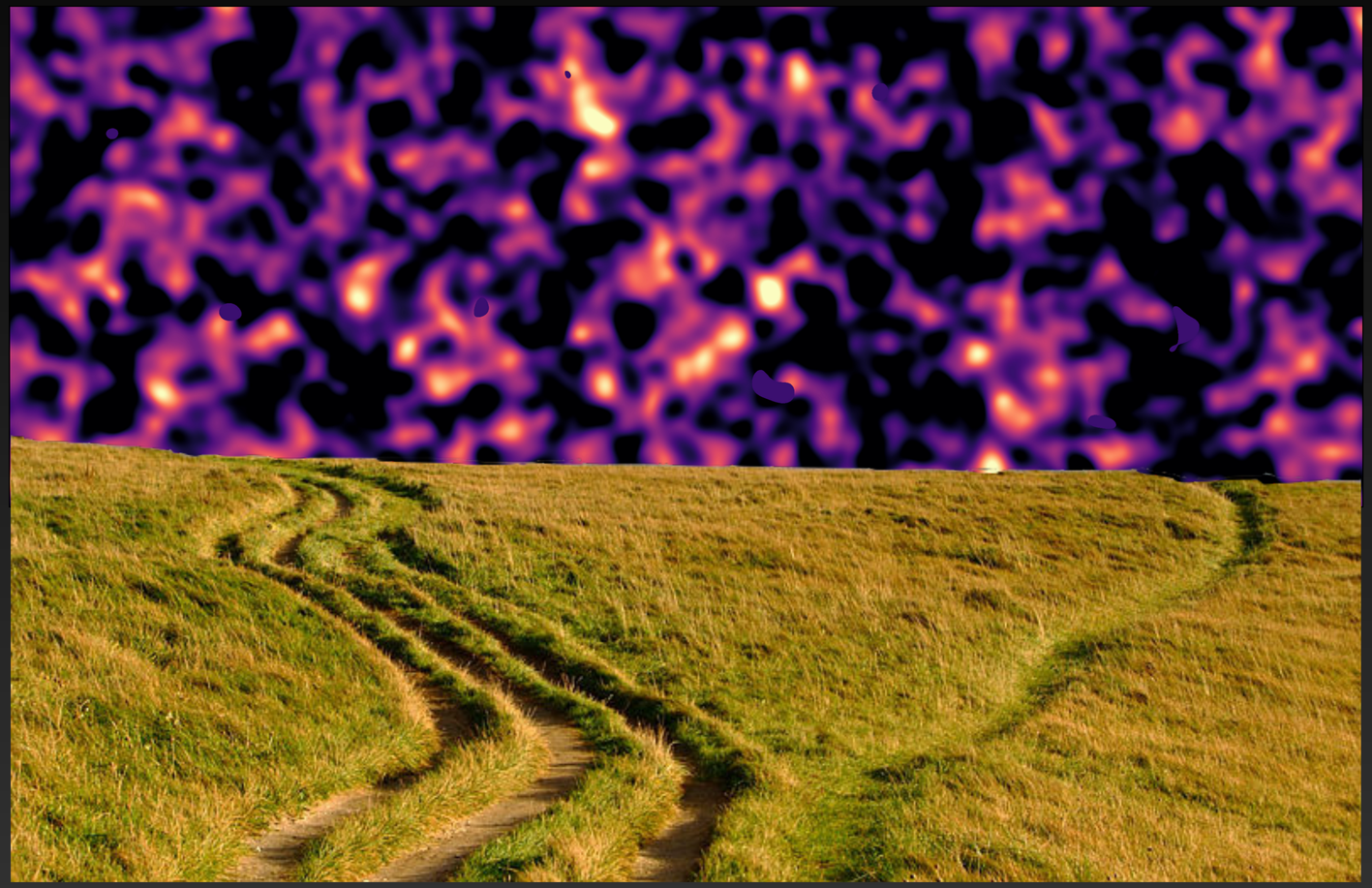

Weak Lensing Cosmology: Taking the Path Less Travelled

Benjamin Giblin,
Yanchuan Cai,
Joachim Harnois-Déraps

Cosmology from Home
July 2021

KiDS

THE UNIVERSITY OF EDINBURGH

ROYAL ASTRONOMICAL SOCIETY
QUICQUID NITET NOTANDUM
1820

What I will be talking about

- Testing the cosmological model with weak lensing (“cosmic shear”)
- Alternative weak lensing statistics:
    - Lensing PDF
    - Clipped shear correlation functions
- Simulated cosmic shear results
- Summary

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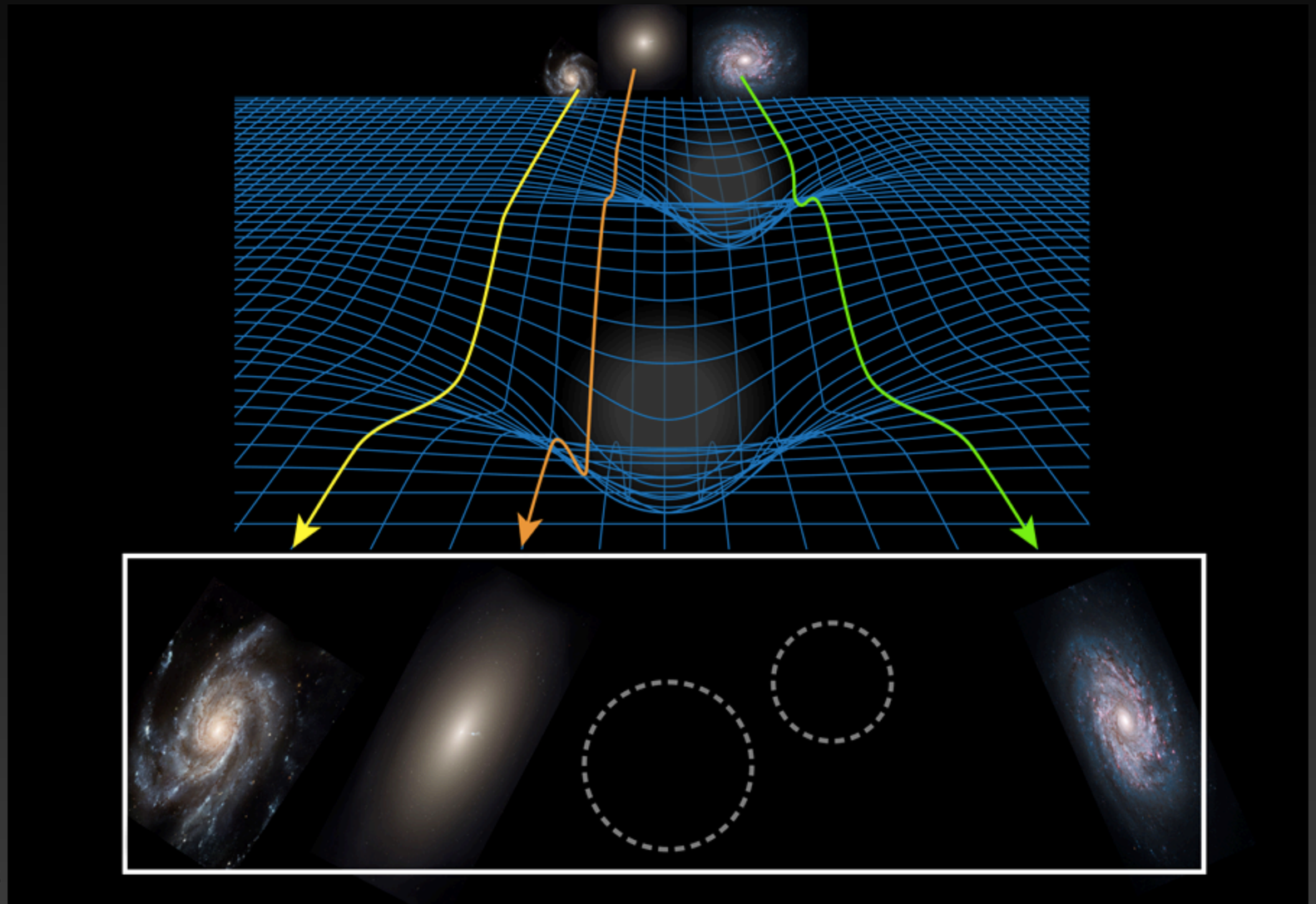
Cosmic shear:

Constraining cosmological parameters with weak lensing



Credit: Stonebreaker, APS

B.Giblin, Cosmology from Home (2021)

Cosmic shear:
Constraining cosmological parameters with weak lensing

The shear correlation function (2PCF) measured from data

The measurement from the data is compared to a theoretical prediction which depends on cosmological parameters (e.g. Ω_m & σ_8)

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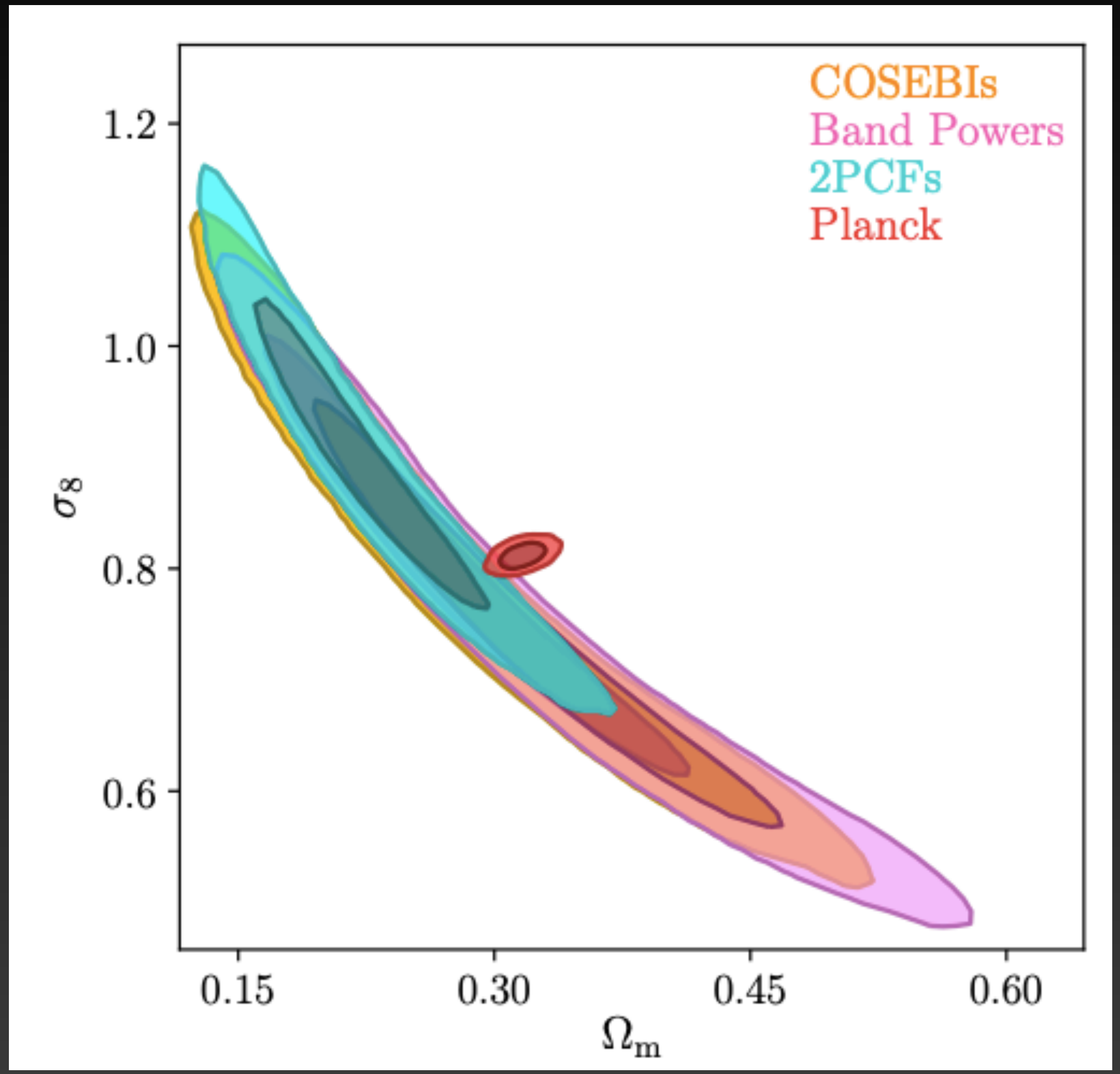

Asgari et al. (2020)

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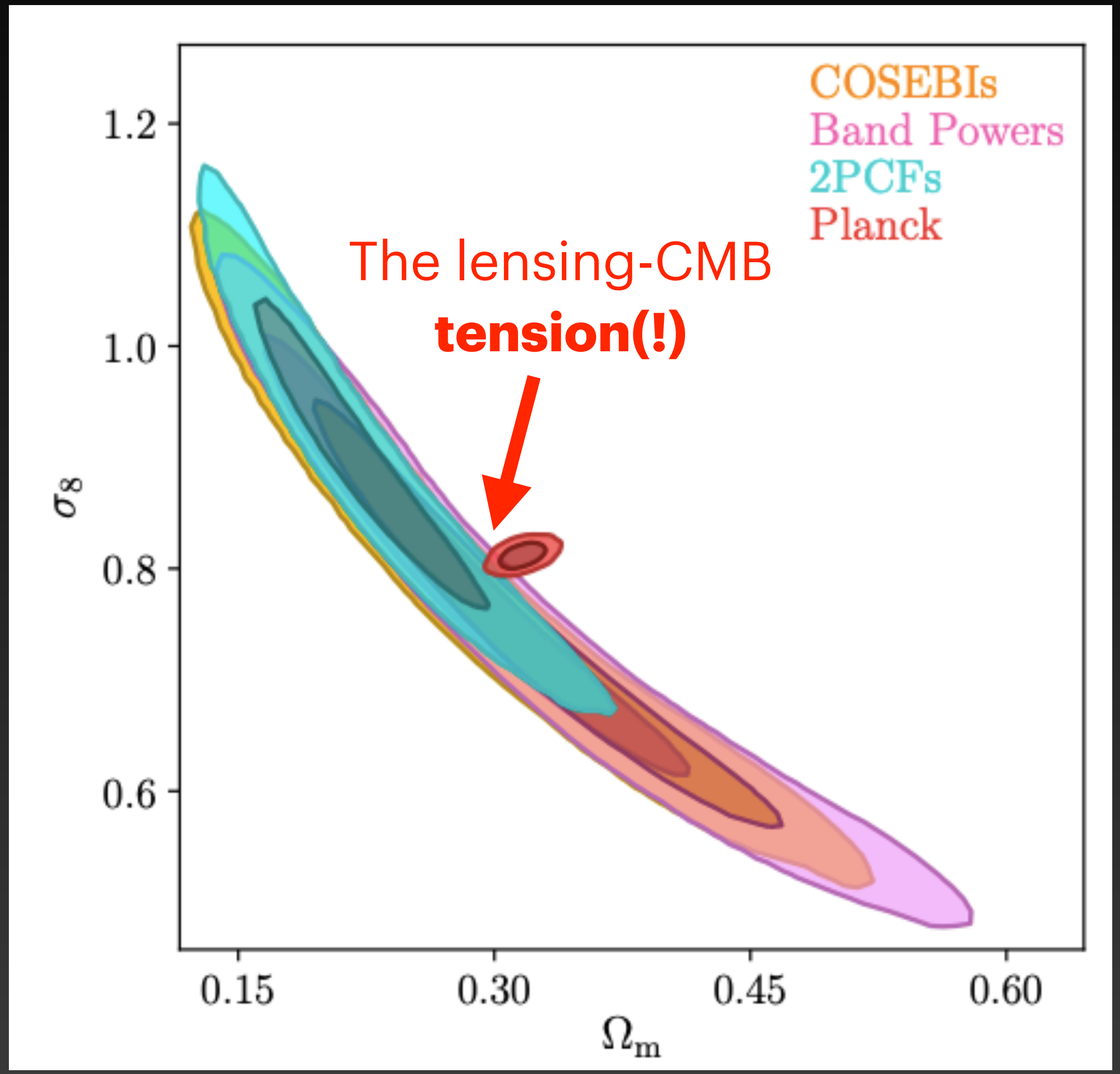


Asgari et al. (2020)

Going beyond the standard shear correlation function

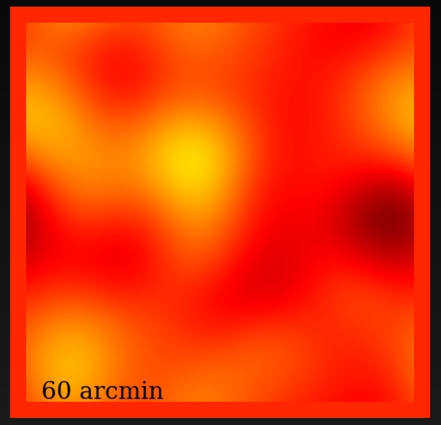
Alternative statistics:

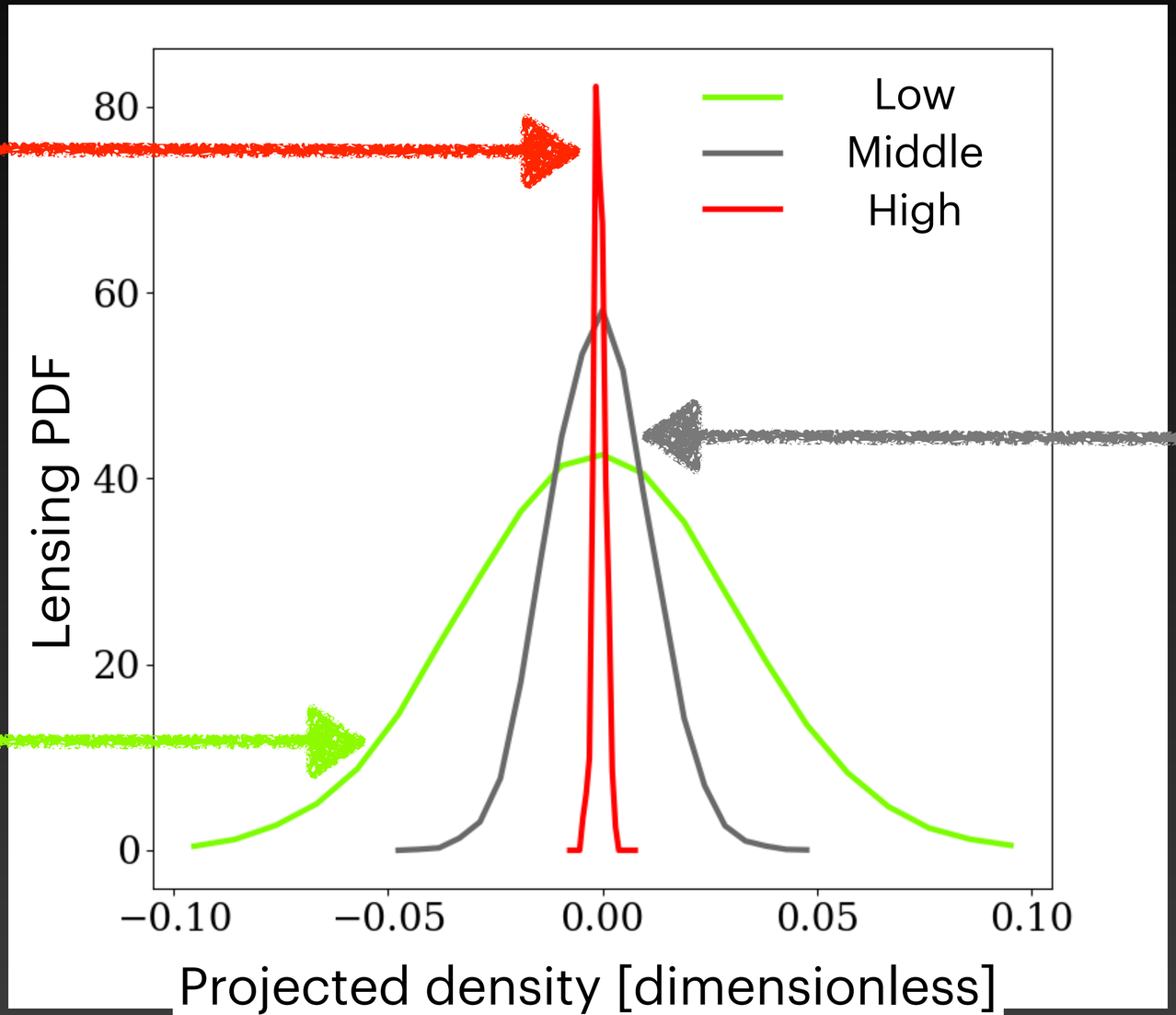
- The lensing probability density function (PDF)[1,2,3]
- “Clipped” shear correlation function[4]

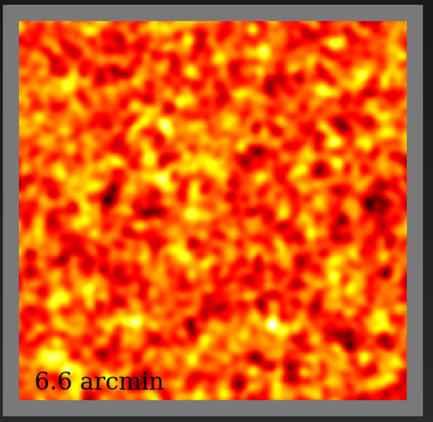
Credit: Kilo-Degree Survey Collaboration

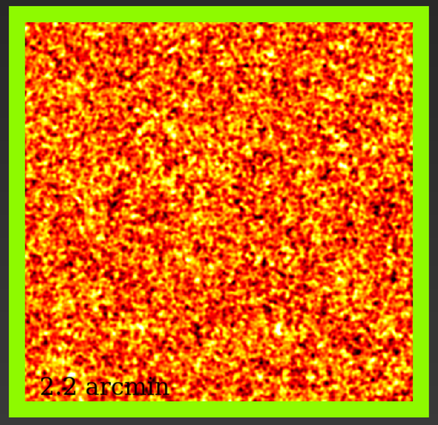
[1] Petri et al. (2015)
[2] Clerkin et al. (2016)
[3] Uhlemann et al. (2019)
[4] Giblin et al. (2018)

Lensing PDF



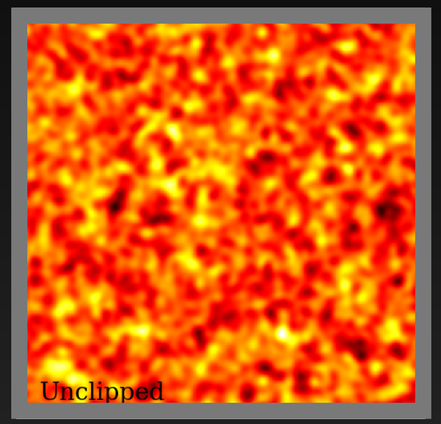


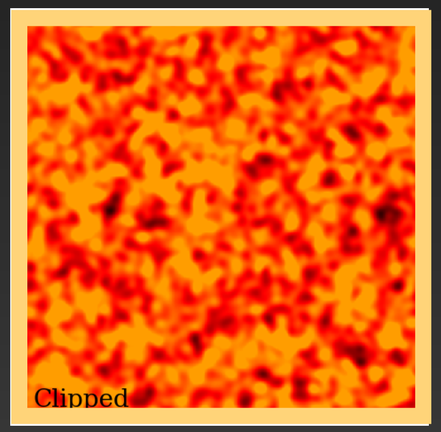


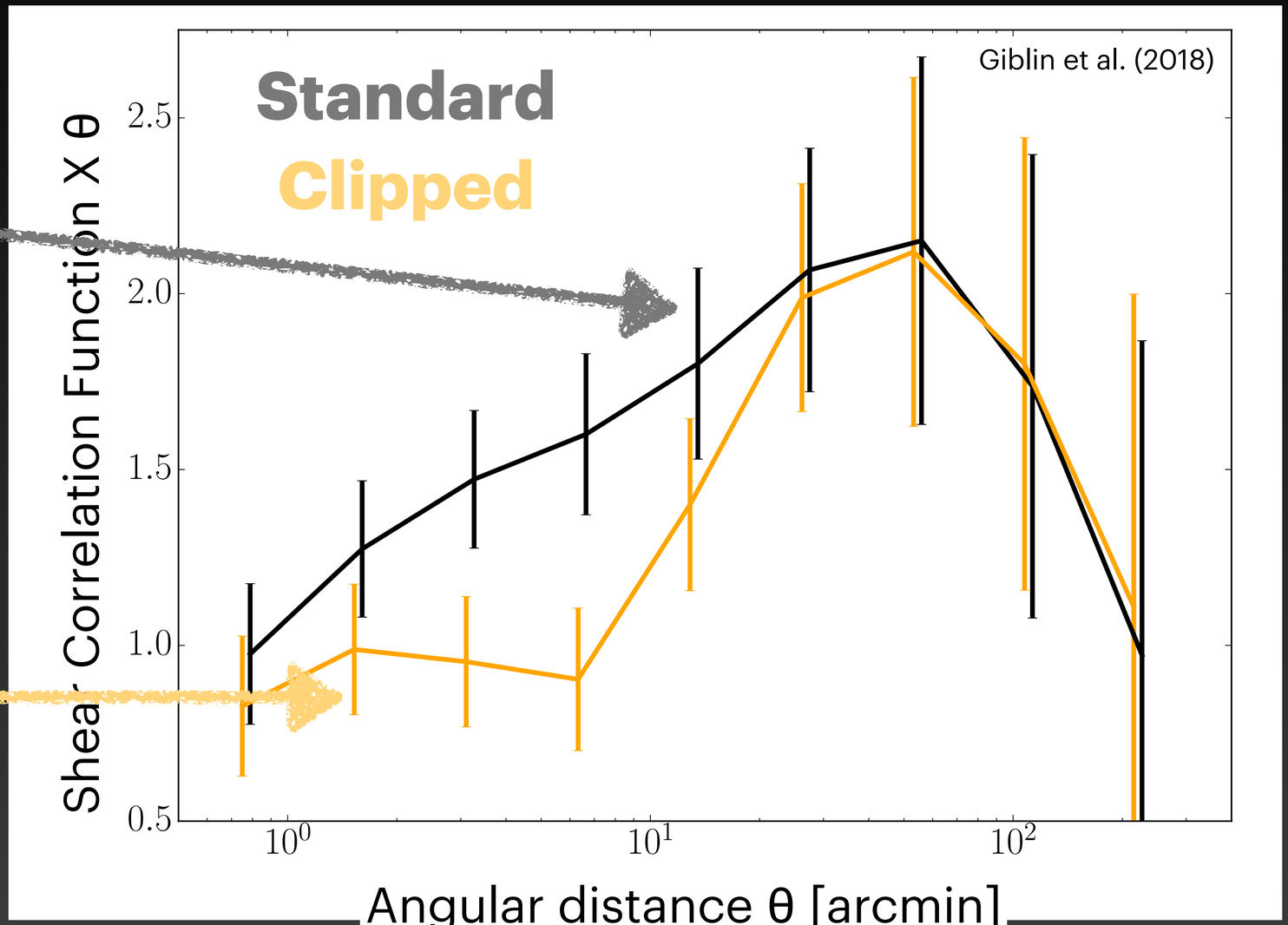


Giblin et al. (in prep.)

Clipped Shear Correlation Function







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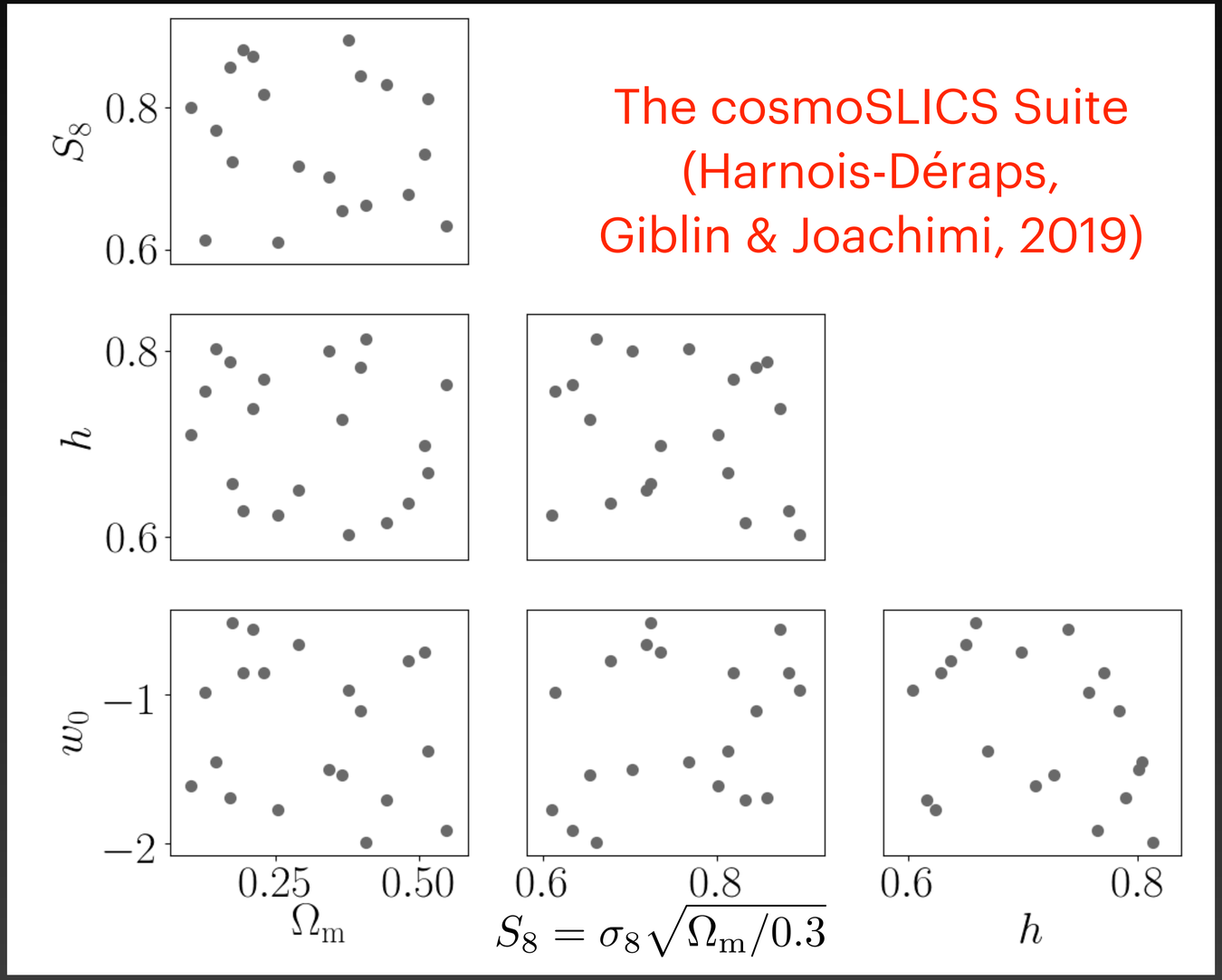
Modelling the cosmological dependence

$$\mathcal{L}(\boldsymbol{d}|\boldsymbol{\pi}) \propto \exp\left(-\frac{1}{2}\left[\boldsymbol{d}-\boldsymbol{m}(\boldsymbol{\pi})\right]^{\intercal}\Sigma^{-1}\left[\boldsymbol{d}-\boldsymbol{m}(\boldsymbol{\pi})\right]\right)$$

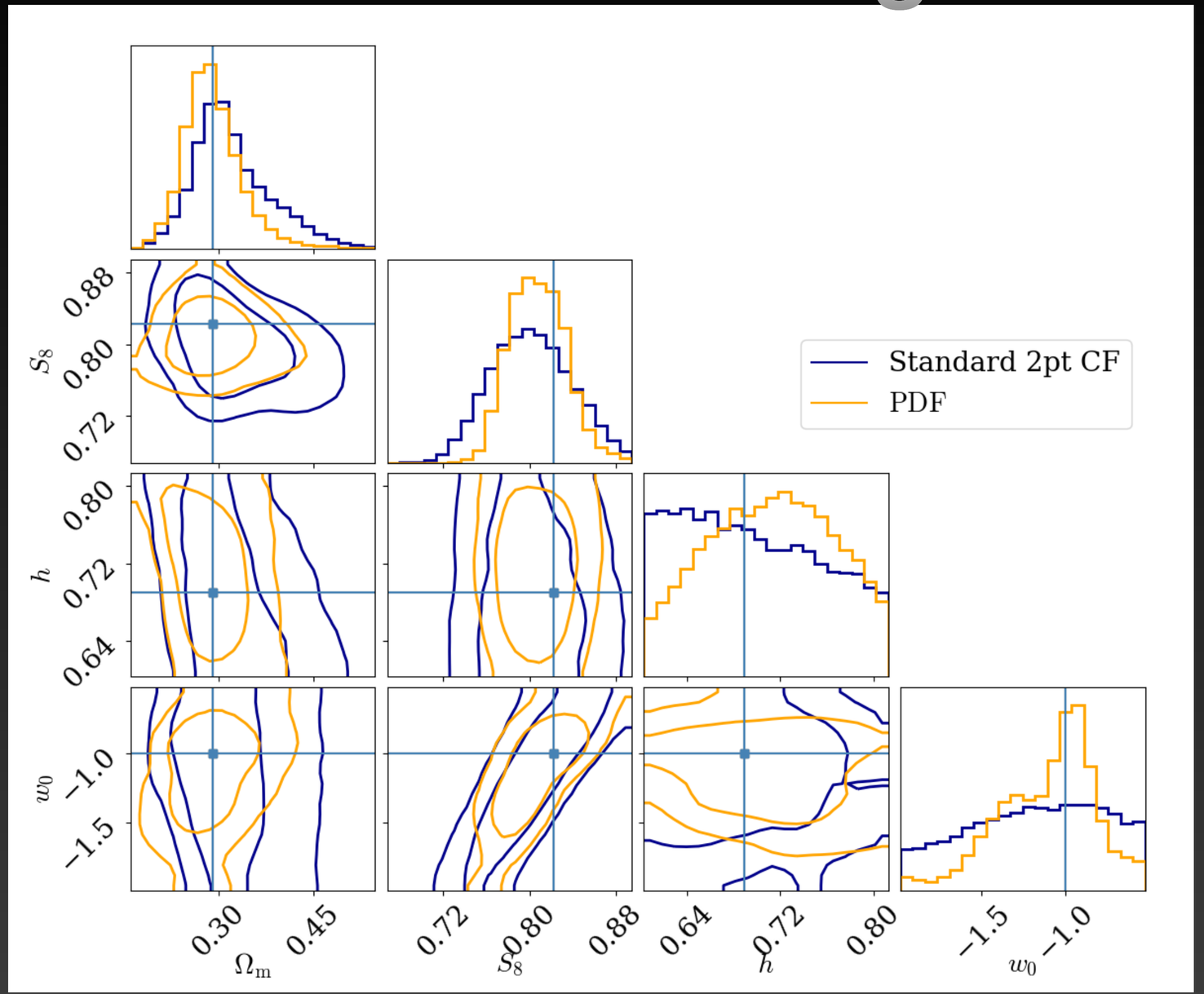
Require a model for
our statistics as a function of
cosmological parameters $\boldsymbol{\pi}$

Modelling the cosmological dependence

Simulations & machine learning to the rescue



Results: The Lensing PDF



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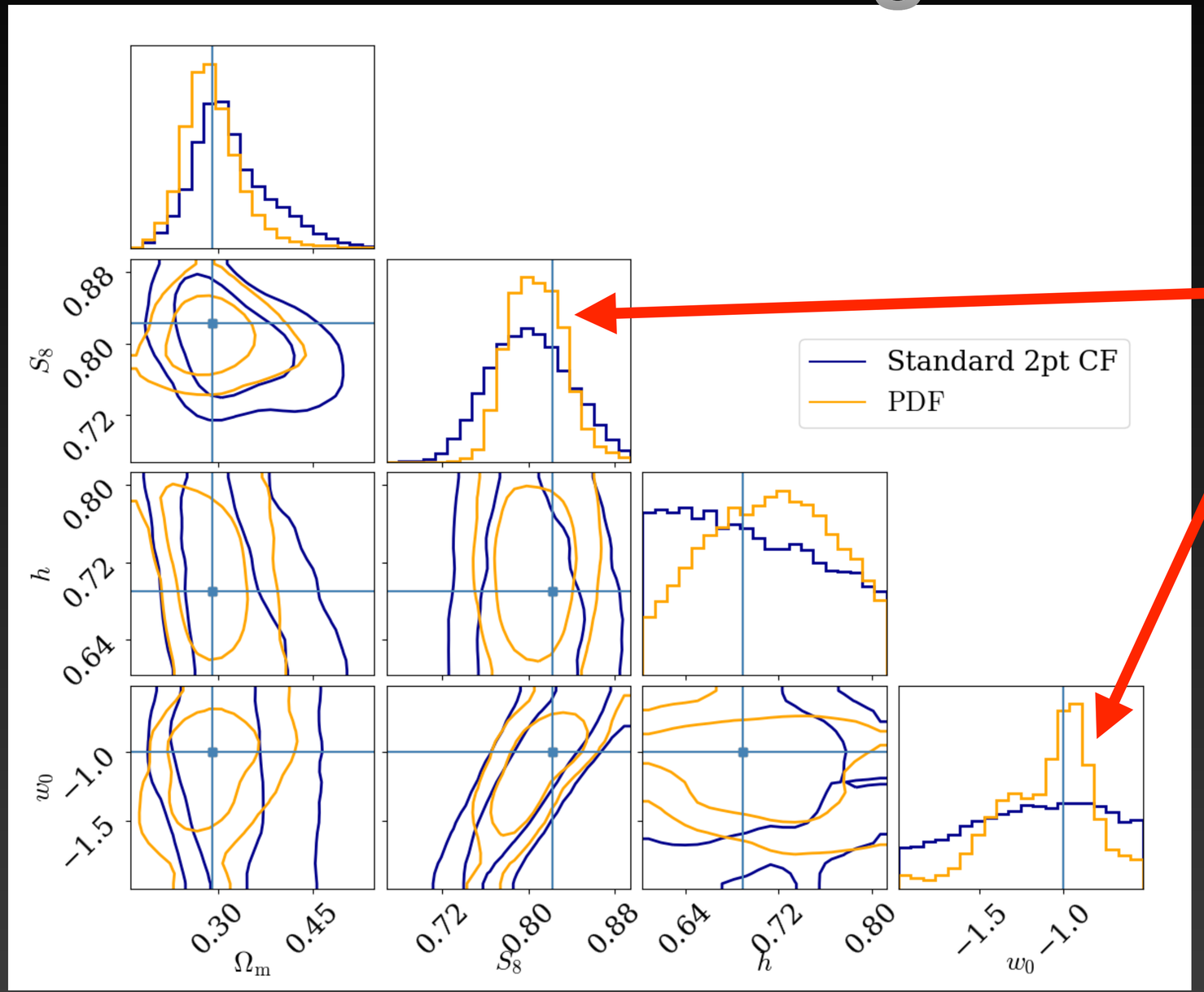
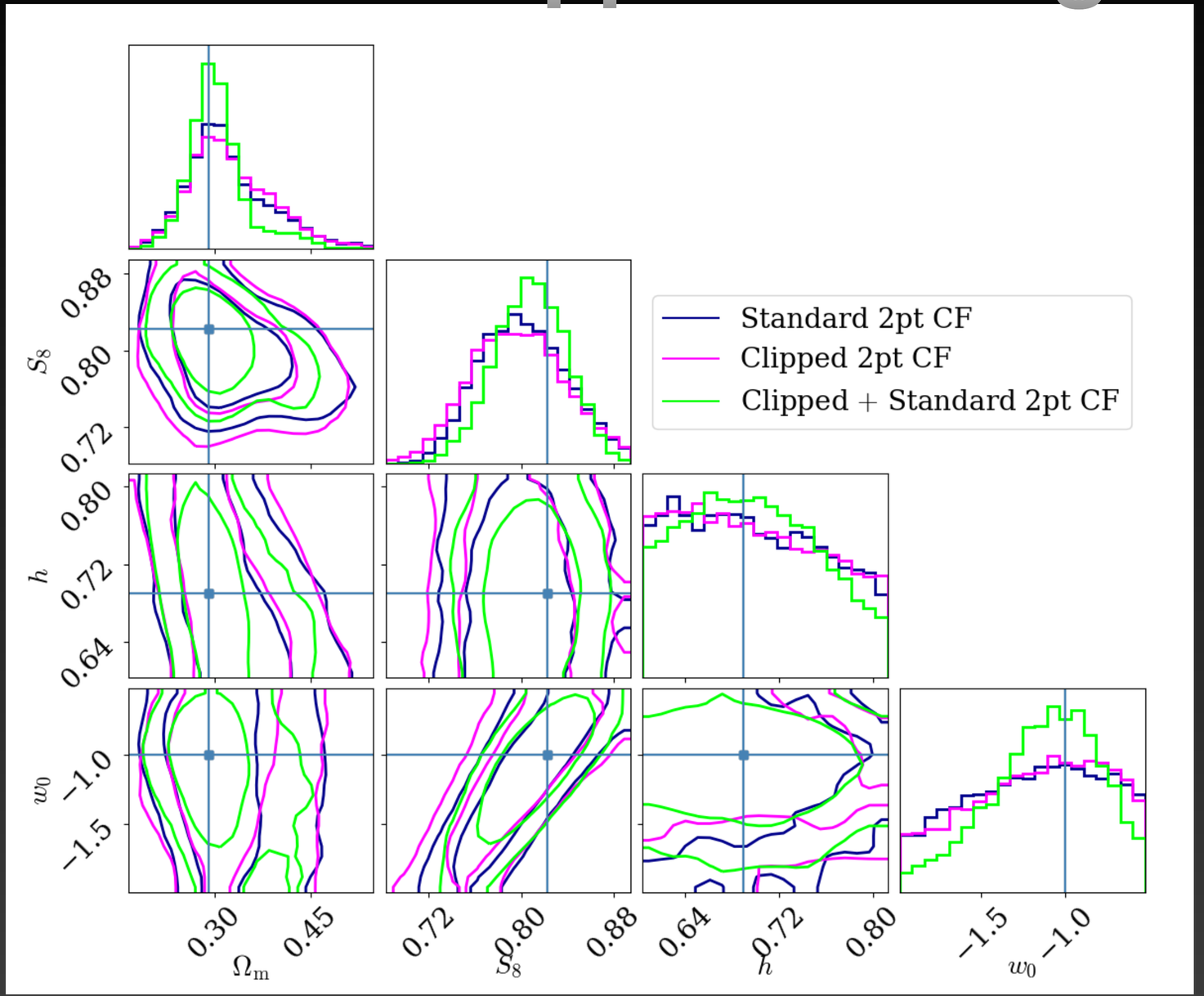


~30% improvement in S_8 and w_0 constraints

Giblin et al. (in prep.)

Results: Clipped Lensing



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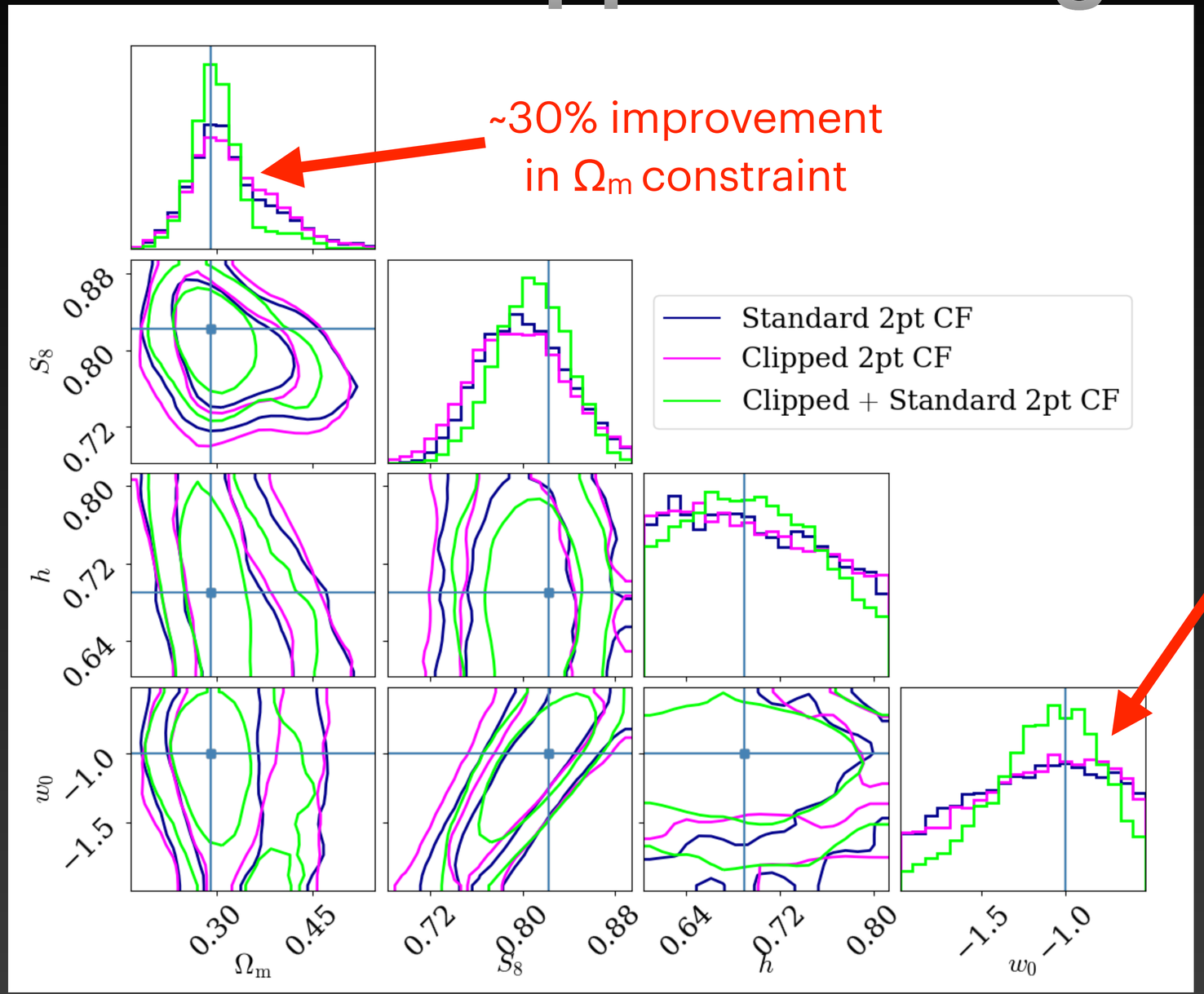


Giblin et al. (in prep.)

Summary

- We have looked an alternative weak lensing lensing statistics - the lensing PDF and clipped shear correlation function.

- These statistics yield 25-30% improvements in Ω_m, $S_8 \sim \sigma_8(\Omega_m)^{0.5}$, and w_0 constraints, relative to the conventional weak lensing correlation functions.

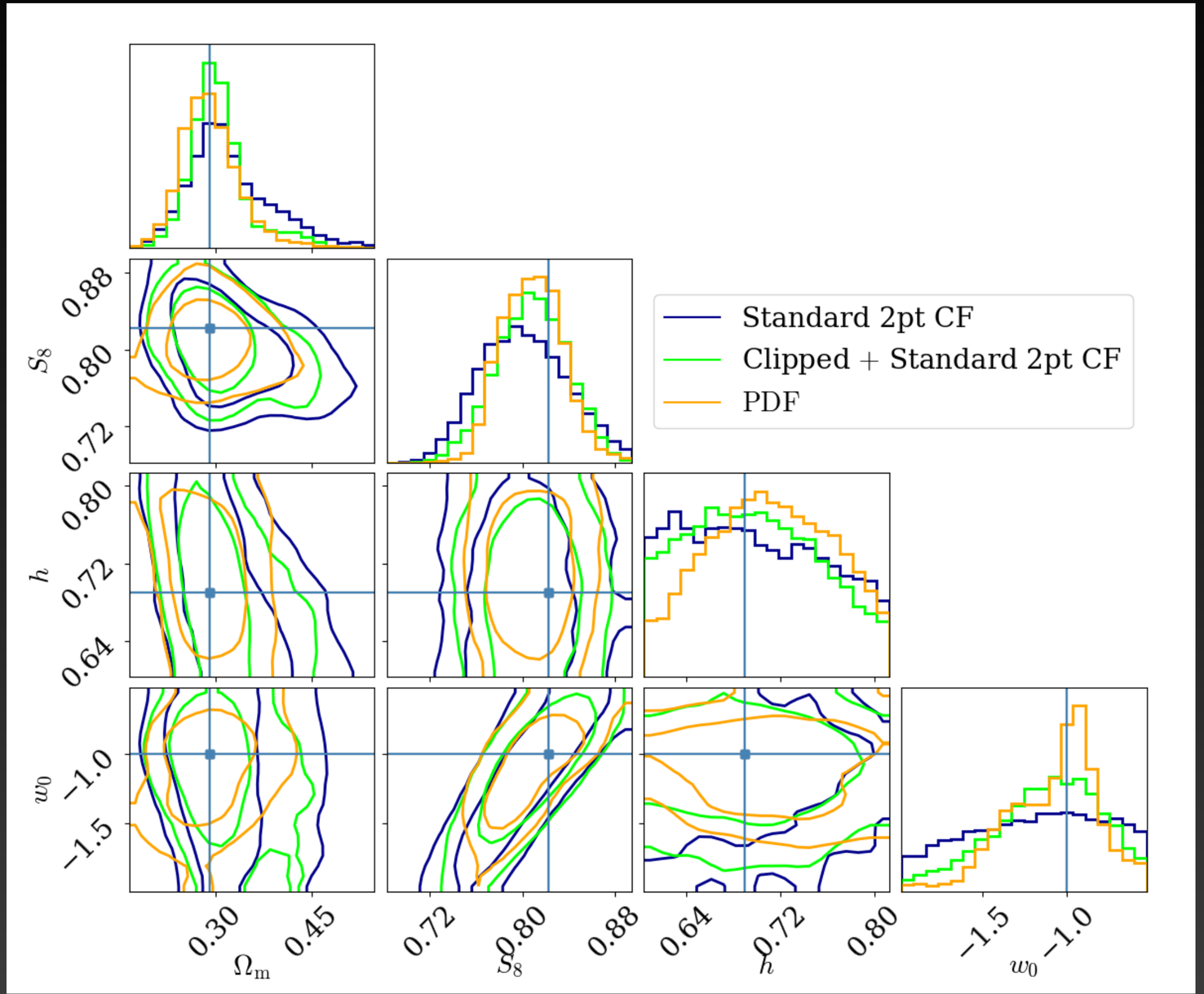
Resources

- The cosmoSLICS weak lensing simulations (available upon request):
    - 26 different cosmologies
    - incl. systematics: baryonic feedback & intrinsic alignments

- My emulator code:
    - https://github.com/benjamingiblin/GPR_Emulator

EXTRA SLIDES

Results: Both



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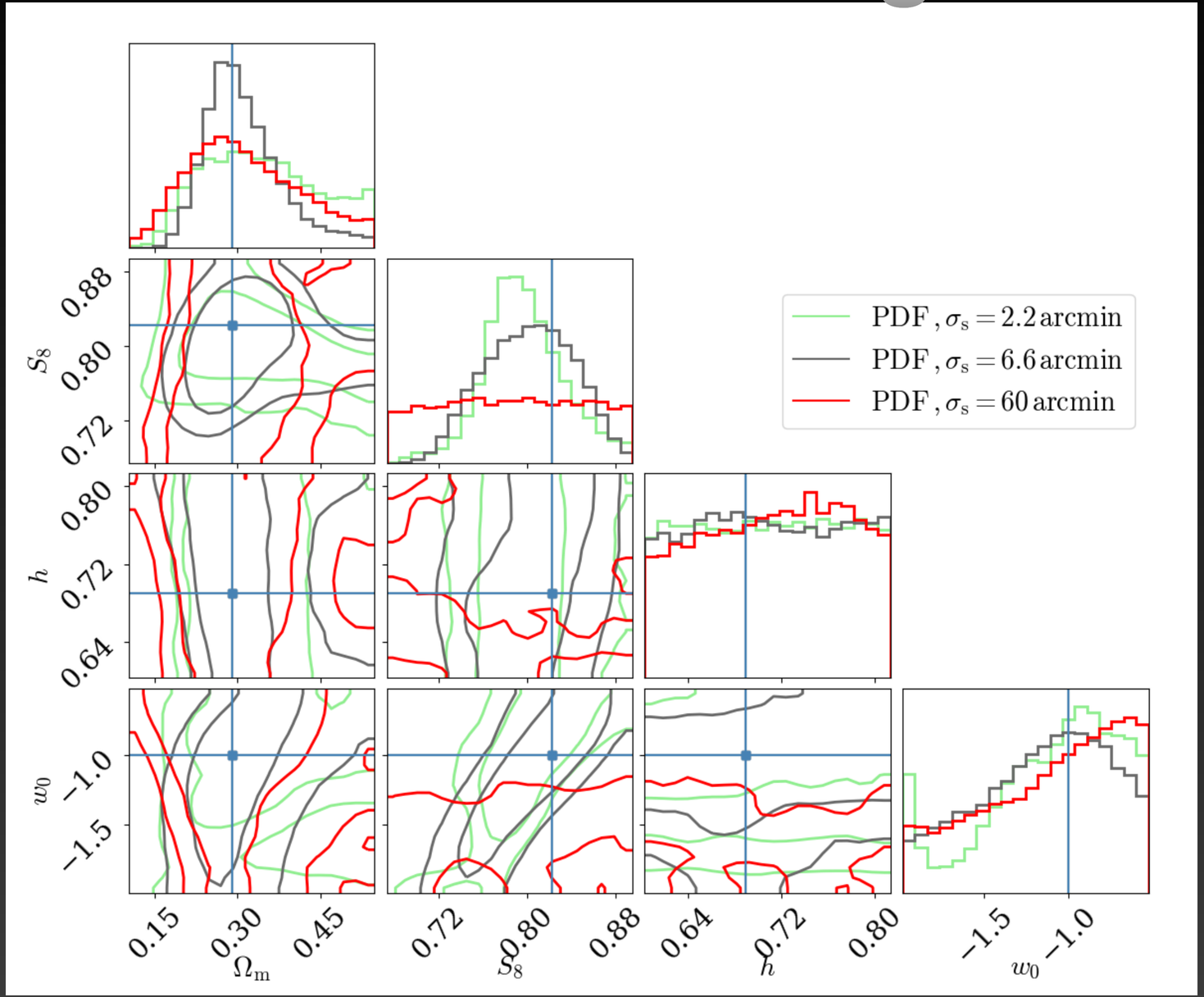
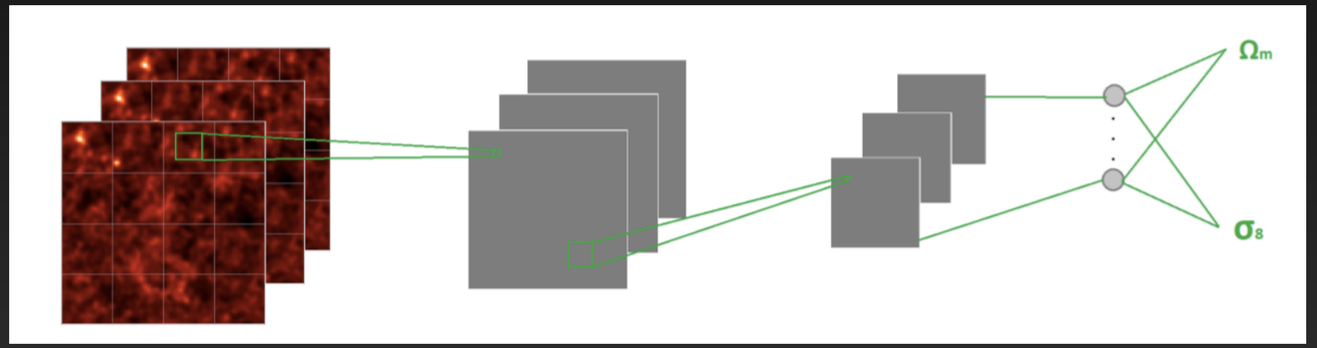
B.Giblin, Cosmology from Home (2021)

Results: The Lensing PDF

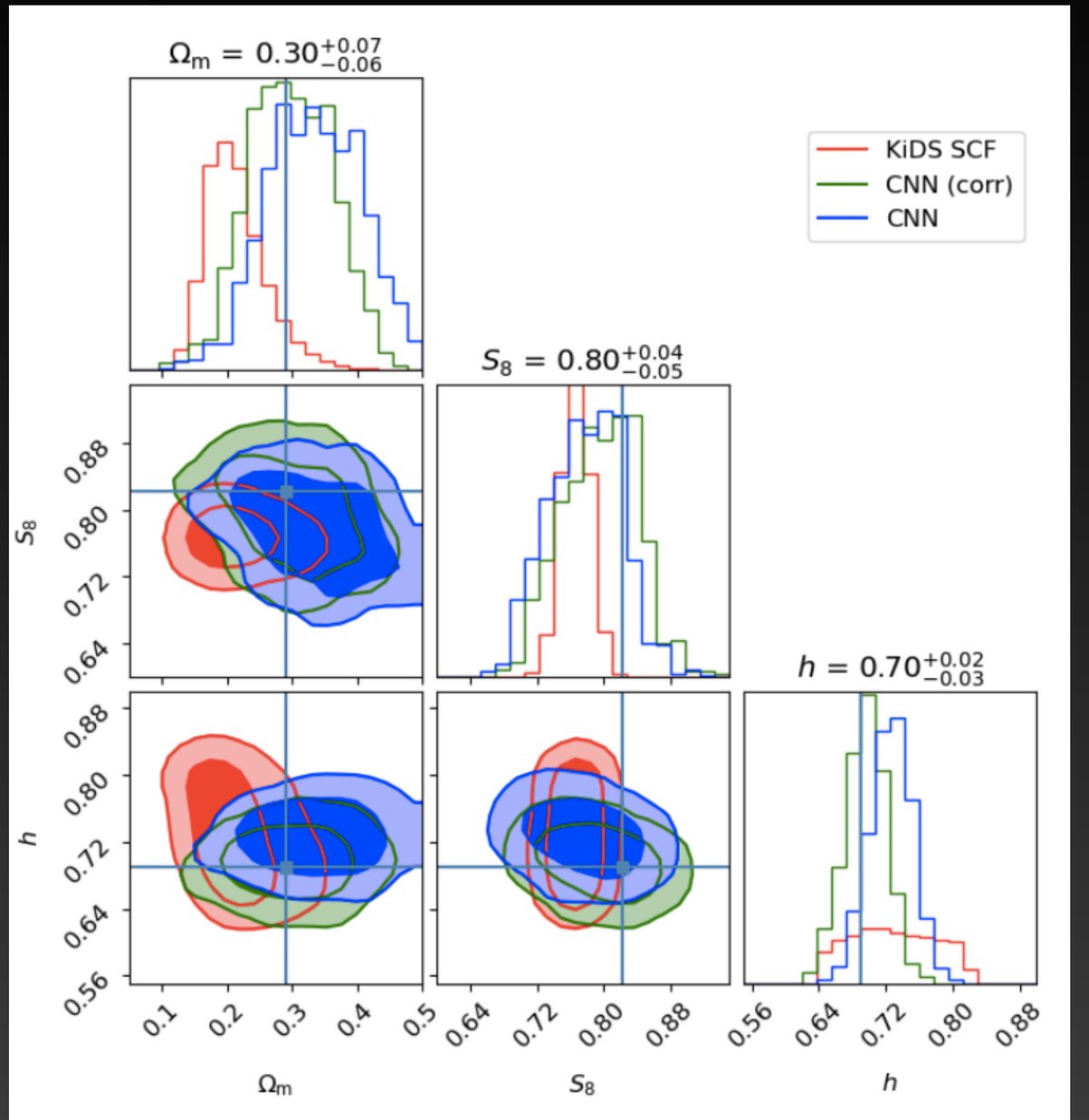


New ways to measure cosmic shear
Deep Learning

Training a convolutional neural network to learn the non-linear relation between weak lensing maps and cosmology:

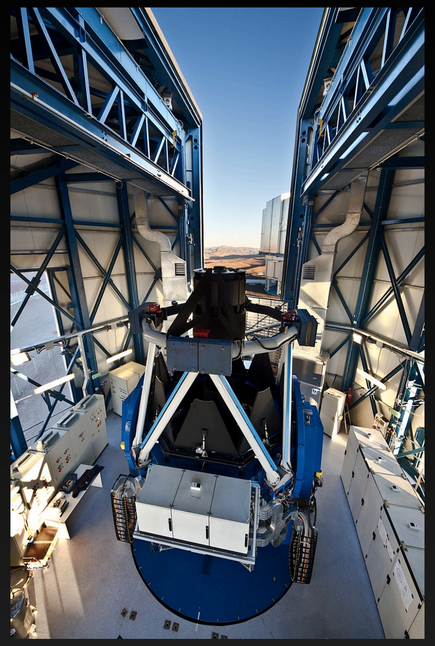


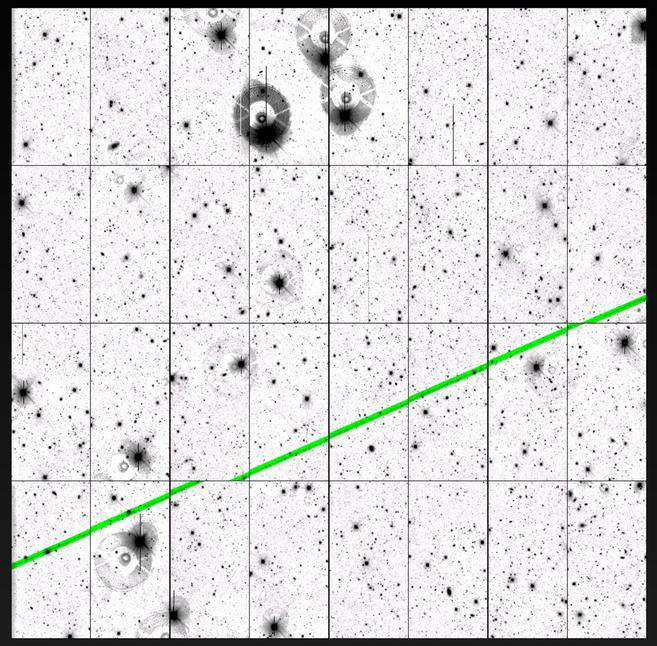
Credit: Rhys Seeburger, PhD student, Heidelberg



The Kilo-Degree Survey (KiDS)

Credit: KiDS Collaboration





KiDS-1000

- 1000deg^2 of sky coverage.
- Images collected at the VLT Survey Telescope (VST).
- 5 dithered exposures in 4 optical bands, *ugri*, each 1deg^2 in size.
- Galaxies also imaged in 5 near-infrared bands with VIKING.
- Shape measurements & redshifts for 21 million galaxies.

Cosmic shear

Probing the standard model with weak lensing

The shear correlation function (2PCF) measured from data

$$\hat{\xi}^{ij}_{\pm}(\theta) = \frac{\sum_{ab} w_a w_b \left[\epsilon^i_{\rm t}(\vec{x}_a)\epsilon^j_{\rm t}(\vec{x}_b) \pm \epsilon^i_{\times}(\vec{x}_a)\epsilon^j_{\times}(\vec{x}_b)\right]}{\sum_{ab} w_a w_b}$$

Galaxy ellipticities measured in your data

The theoretical prediction you compare to

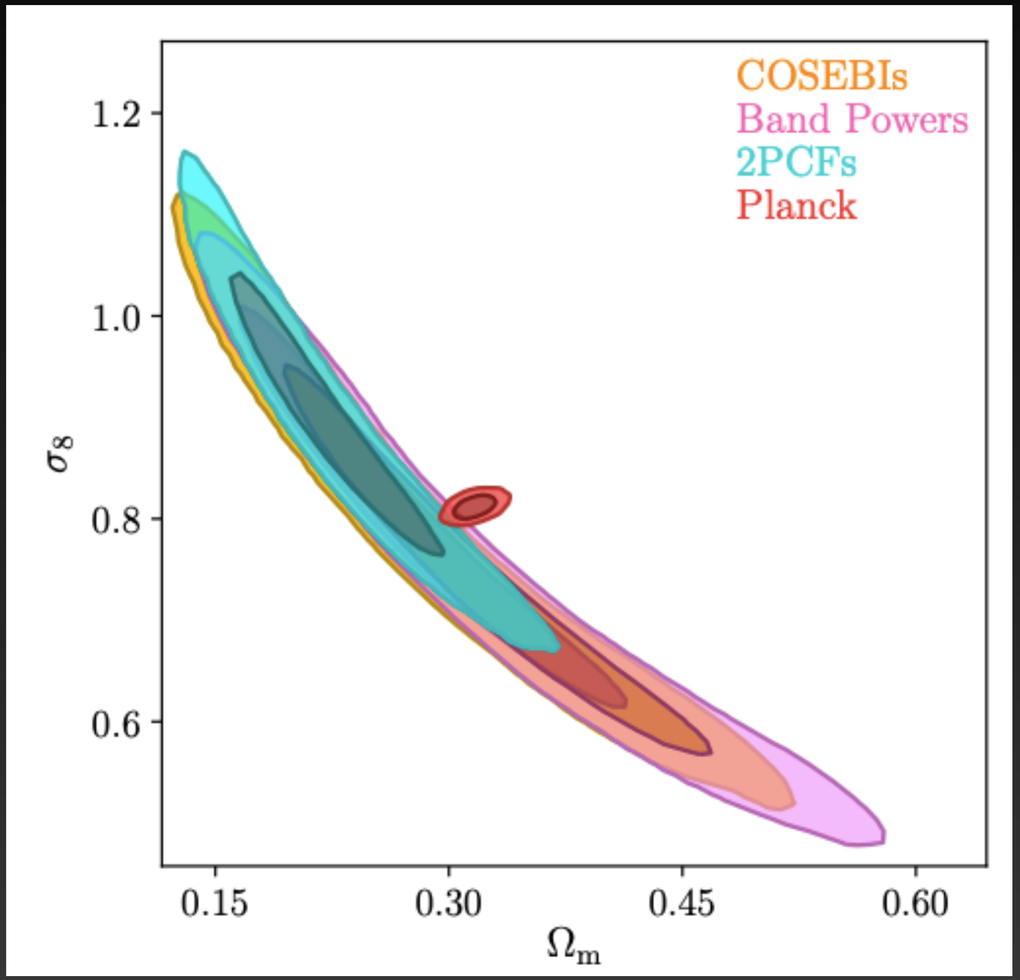
$$\xi^{ij}_{\pm}(\theta) = \frac{1}{2\pi}\int \mathrm{d}\ell\, \ell\, P^{ij}_{\kappa}(\ell)\, J_{0,4}(\ell\theta)\,,$$

$$P^{ij}_{\kappa}(\ell) = \int_0^{\chi_{\rm H}} \mathrm{d}\chi\, \frac{q_i(\chi) q_j(\chi)}{[f_K(\chi)]^2}\, P_{\delta}\left(\frac{\ell}{f_K(\chi)}, \chi\right),$$

Matter power spectrum (depends on Ωm, S8 etc.)

$$q_i(\chi) = \frac{3H_0^2\Omega_{\rm m}}{2c^2}\frac{f_K(\chi)}{a(\chi)}\int_{\chi}^{\chi_{\rm H}} \mathrm{d}\chi'\, n_i(\chi')\frac{f_K(\chi'-\chi)}{f_K(\chi')},$$

Redshift distribution of the lensed galaxies



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