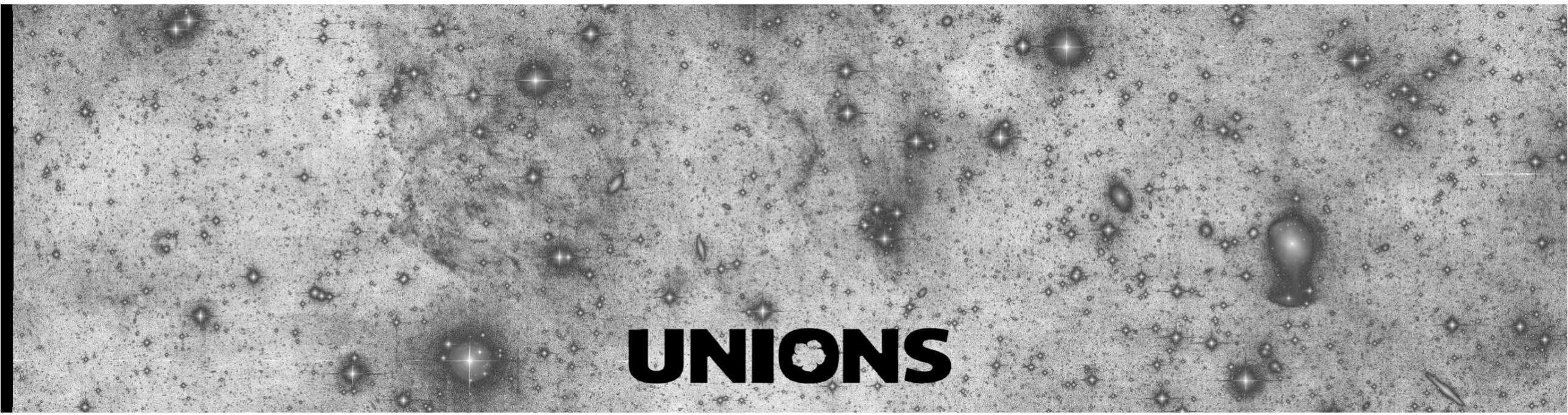
WEAK LENSING SCIENCE FROM



Ludovic Van Waerbeke

on behalf of the UNIONS Weak Lensing Team

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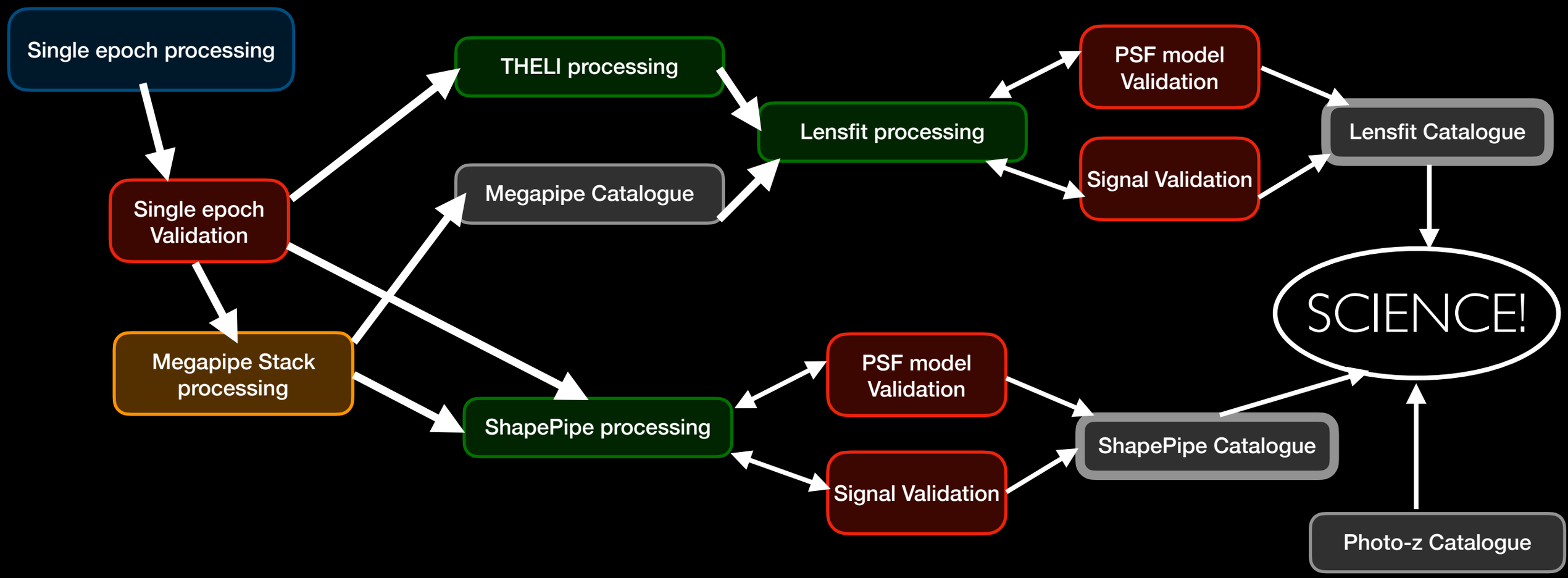
I- WHAT IS OUR SCIENCE STRATEGY?

- Run two independent shape measurement pipelines (ShapePipe/MegaPipe and Lensfit/THELI)
- Perform PSF correction diagnostics using state of the art tools (developed for CFHTLenS, KiDS, DES) to freeze the PSF model
- Use PSF diagnostics combined with signal diagnostic tools (e.g. E,B modes, COSEBI) to construct two gold sample shape catalogues
- Write science papers following a quality requirement agenda (less demanding science comes first)
- The photometric redshift effort is made in parallel in a **blinded way**

Weak Lensing pipelines



ShapePipe:

- Open source code on GitHub (Farines, Guinot et al. 2022)
- Based on MegaPipe processing
- Relies on metacalibration in combination of multi-epochs model fitting
- First analysis in Guinot et al. 2022

Lensfit:

- Image partly reprocessed by THELI
- Bayesian multi-epochs model fitting
- Previously used for CFHTLenS (Miller et al. 2013) and KiDS (Giblin et al. 2020)

Where are we now?

Lensfit

- Effective area: 2138
- Number of galaxies: 109 025 910
- Weighted galaxy density: 10.78
- Shape noise: 0.29

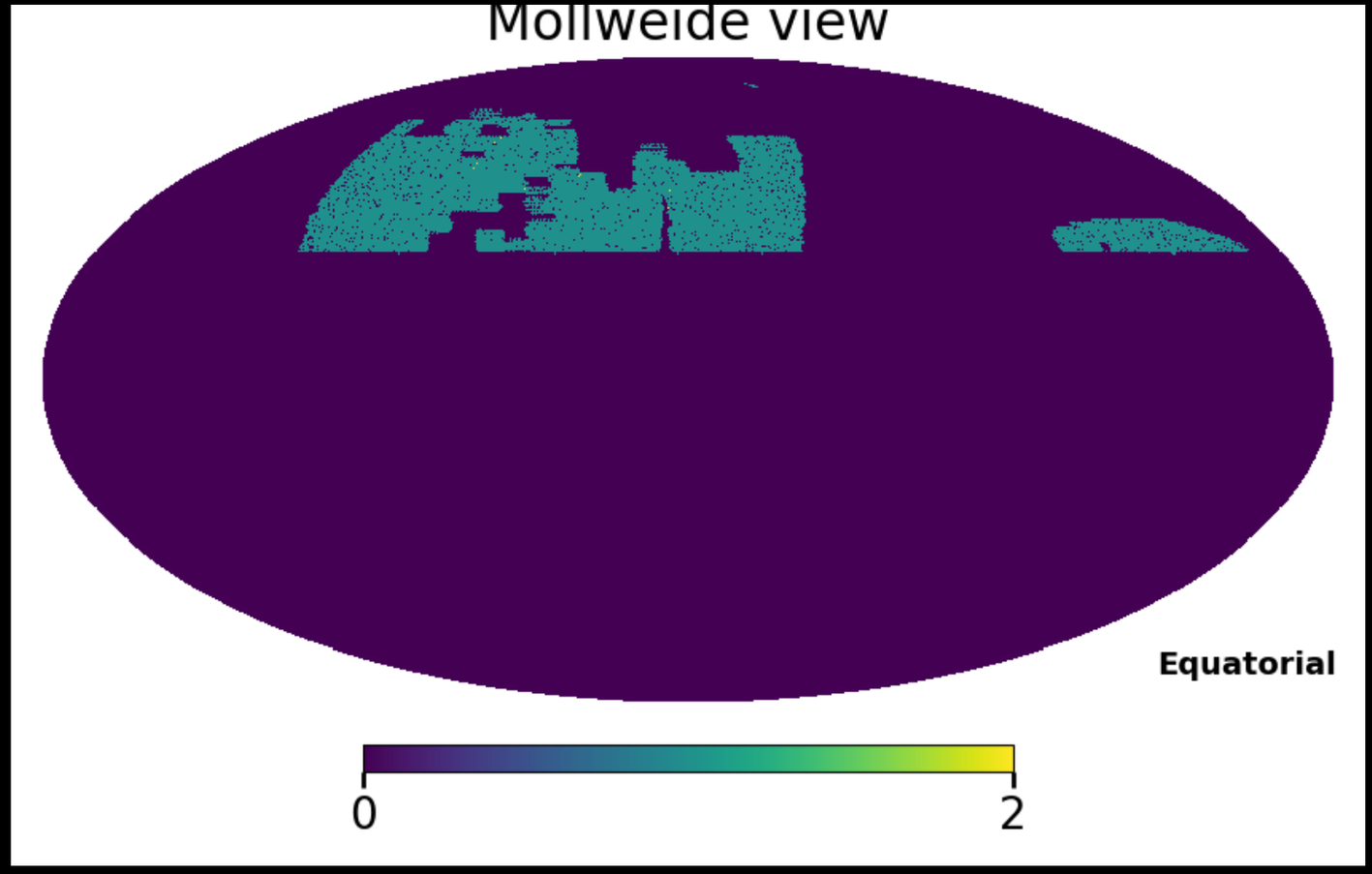
ShapePipe

- Effective area: 2897
- Number of galaxies: 97 239 250
- Weighted galaxy density: 8.43
- Shape noise: 0.34

New data to be added in the coming 1-2 months:

effective area > 3000 sq.deg.

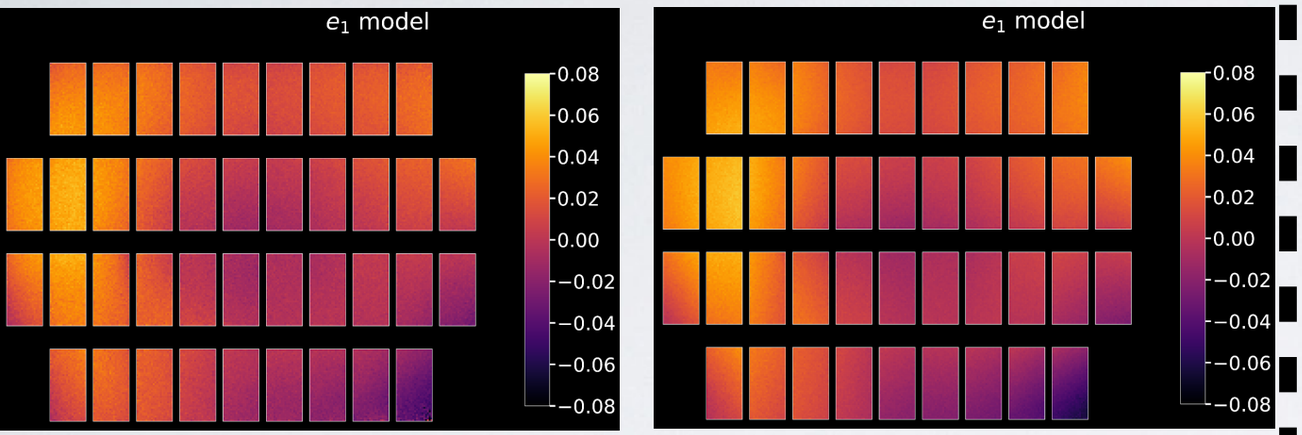
Incremental additions are possible

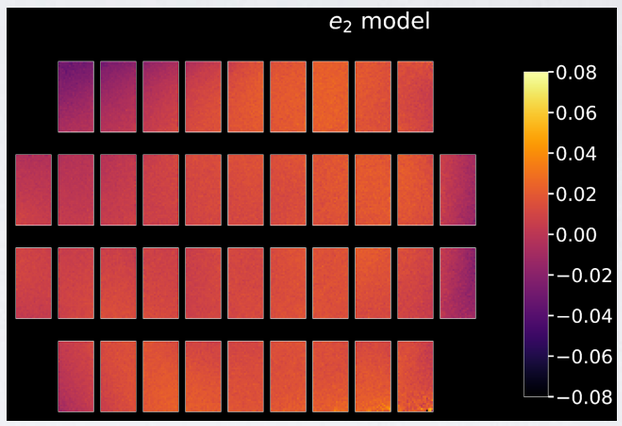


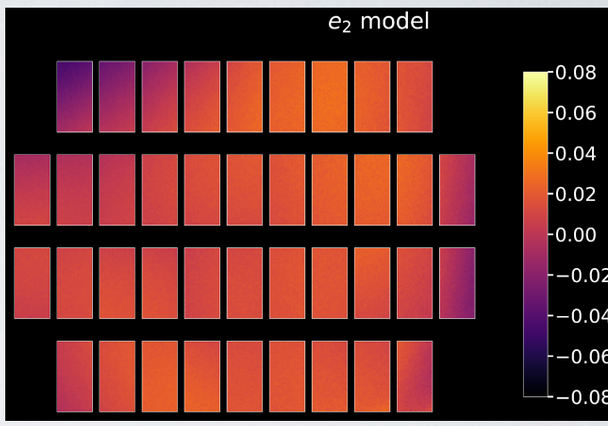
PSF ellipticity residuals on the focal plane

ShapePipe | Lensfit | ShapePipe | Lensfit

e_1 | e_2

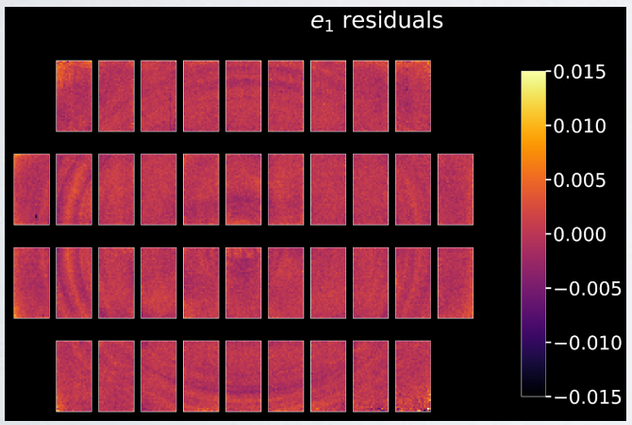


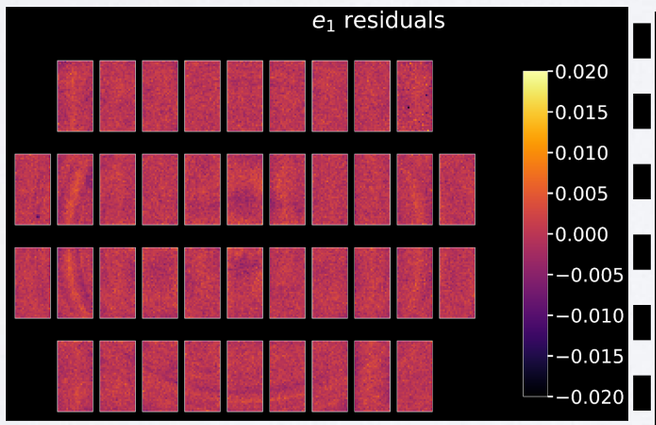


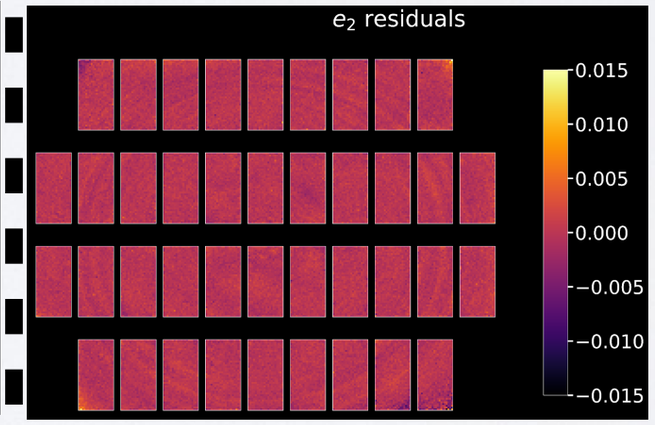


Before | Before

e_1 | e_2





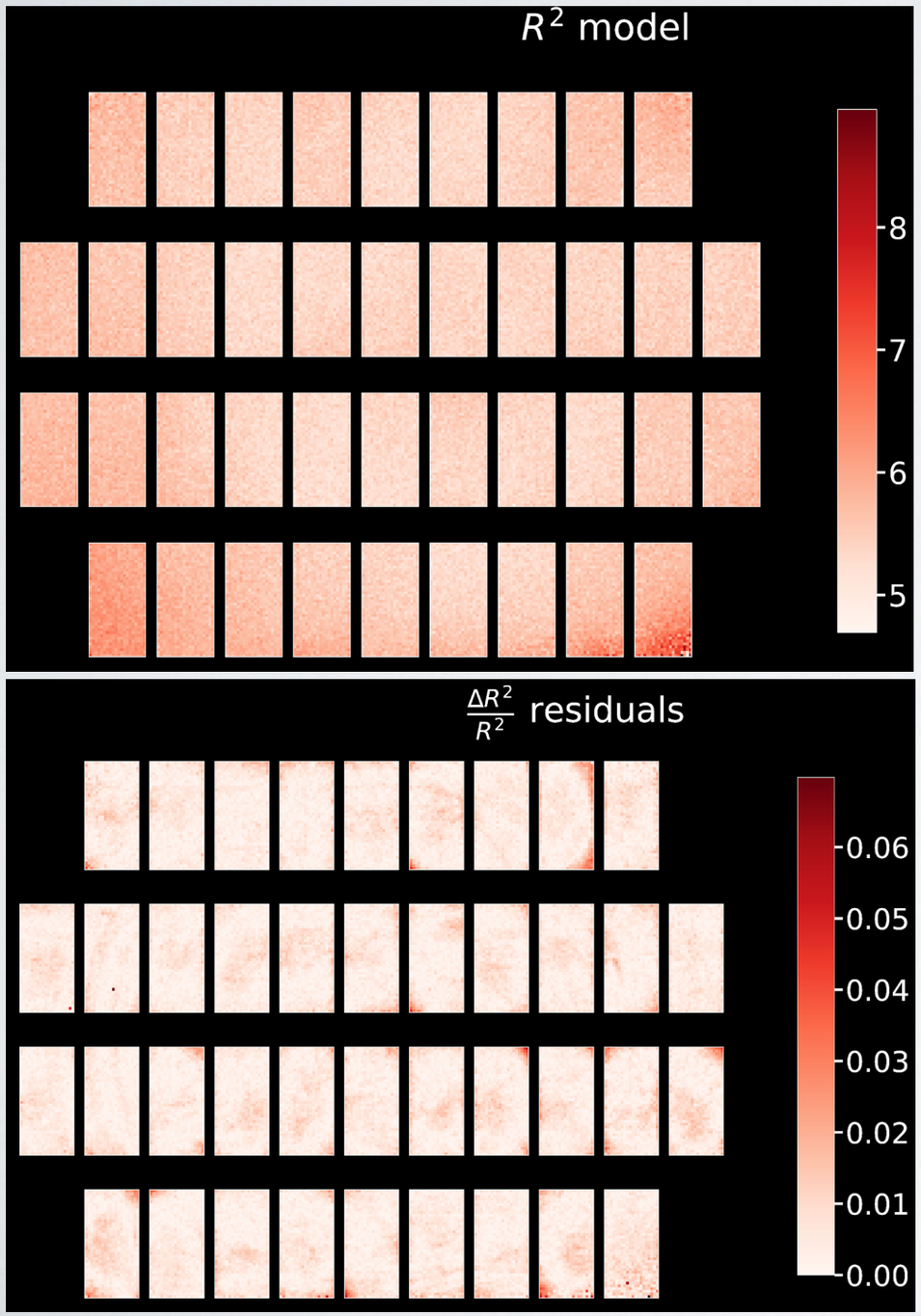


After | After

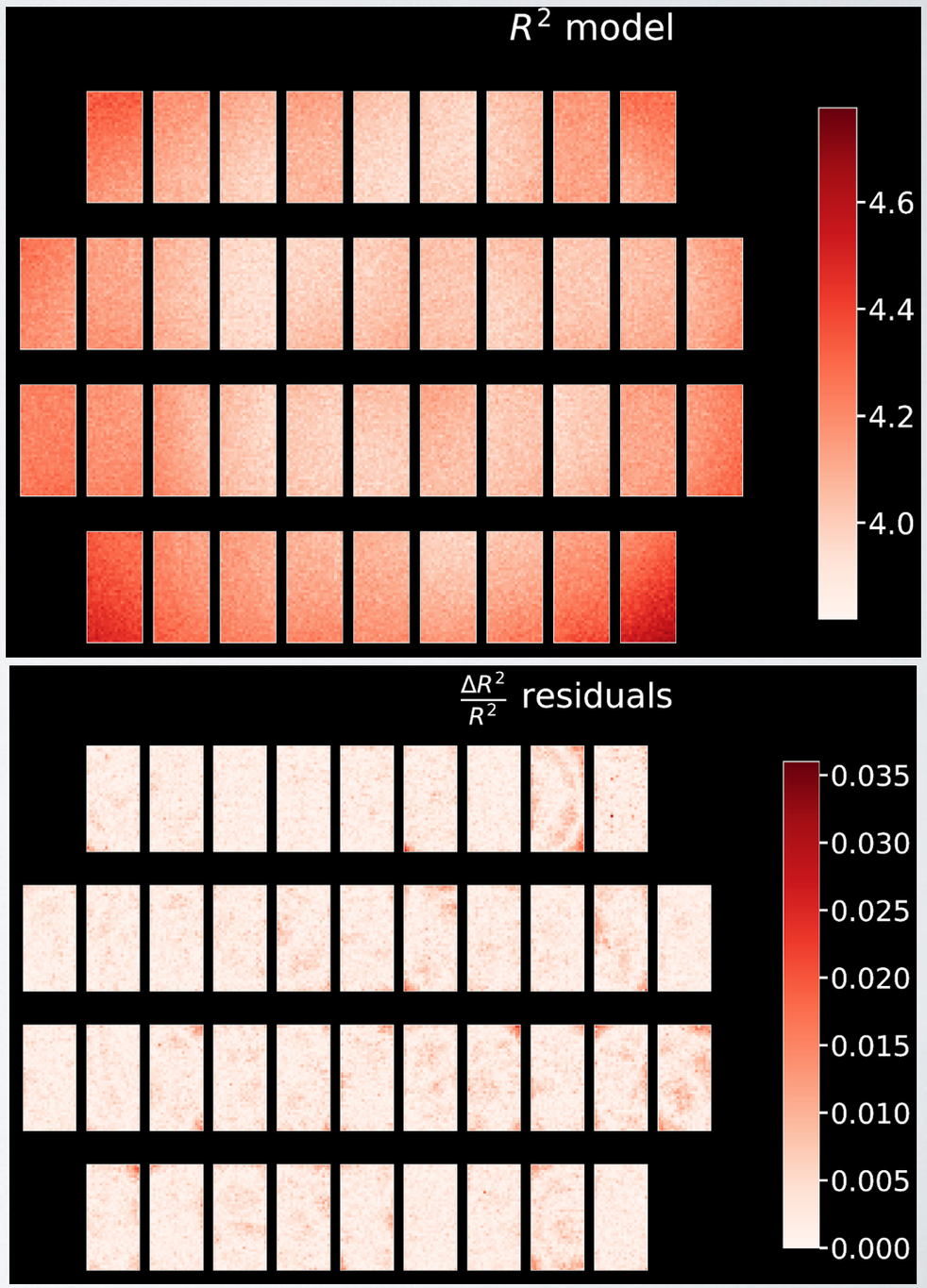
PSF size residuals on the focal plane

PSF size R^2

ShapePipe



Lensfit



Gain 1:100

Sophisticated PSF residual analysis on the way

Extension on rho-stats (from DES Y3)

For more details see Sec. 5.3 here.

$$\boldsymbol{\gamma}^{\mathbf{est}} = \boldsymbol{\gamma} + \delta\boldsymbol{e}^{\mathrm{sys}}_{\mathrm{PSF}} + \delta\boldsymbol{e}^{\mathrm{noise}} \longrightarrow \langle \delta\boldsymbol{e}^{\mathrm{noise}} \rangle = 0$$

$$\delta\boldsymbol{e}^{\mathrm{sys}}_{\mathrm{model}} = \alpha \mathbf{e}_{\mathrm{model}} + \beta\left(\mathbf{e}_* - \mathbf{e}_{\mathrm{model}}\right) + \eta\left(\mathbf{e}_* \frac{T_* - T_{\mathrm{model}}}{T_*}\right)$$

$$\delta\boldsymbol{e}^{\mathrm{model}}_{\mathrm{PSF}} = \alpha\boldsymbol{p} + \beta\boldsymbol{q} + \eta\boldsymbol{w} \qquad \boldsymbol{p} \equiv \mathbf{e}_{\mathrm{model}},\ \boldsymbol{q} \equiv \boldsymbol{e}_* - \boldsymbol{e}_{\mathrm{model}},\ \text{and}\ \boldsymbol{w} \equiv \boldsymbol{e}_* \left(T_* - T_{\mathrm{model}}\right)/T_*$$

$$\begin{aligned}
\langle \boldsymbol{\gamma}^{\mathbf{est}} \boldsymbol{p} \rangle &= \alpha \langle \boldsymbol{p}\boldsymbol{p} \rangle + \beta \langle \boldsymbol{q}\boldsymbol{p} \rangle + \eta \langle \boldsymbol{w}\boldsymbol{p} \rangle, \\
\langle \boldsymbol{\gamma}^{\mathbf{est}} \boldsymbol{q} \rangle &= \alpha \langle \boldsymbol{p}\boldsymbol{q} \rangle + \beta \langle \boldsymbol{q}\boldsymbol{q} \rangle + \eta \langle \boldsymbol{w}\boldsymbol{q} \rangle, \\
\langle \boldsymbol{\gamma}^{\mathbf{est}} \boldsymbol{w} \rangle &= \alpha \langle \boldsymbol{p}\boldsymbol{w} \rangle + \beta \langle \boldsymbol{q}\boldsymbol{w} \rangle + \eta \langle \boldsymbol{w}\boldsymbol{w} \rangle .
\end{aligned}$$

$$\rho_0 = \langle \boldsymbol{p}\boldsymbol{p} \rangle,\ \rho_1 = \langle \boldsymbol{q}\boldsymbol{q} \rangle,\ \rho_2 = \langle \boldsymbol{q}\boldsymbol{p} \rangle$$
$$\rho_3 = \langle \boldsymbol{w}\boldsymbol{w} \rangle,\ \rho_4 = \langle \boldsymbol{q}\boldsymbol{w} \rangle,\ \text{and}\ \rho_5 = \langle \boldsymbol{p}\boldsymbol{w} \rangle$$
$$\tau_0 = \langle \boldsymbol{\gamma}^{\mathbf{est}} \boldsymbol{p} \rangle,\ \tau_2 = \langle \boldsymbol{\gamma}^{\mathbf{est}} \boldsymbol{q} \rangle,\ \text{and}\ \tau_5 = \langle \boldsymbol{\gamma}^{\mathbf{est}} \boldsymbol{w} \rangle$$

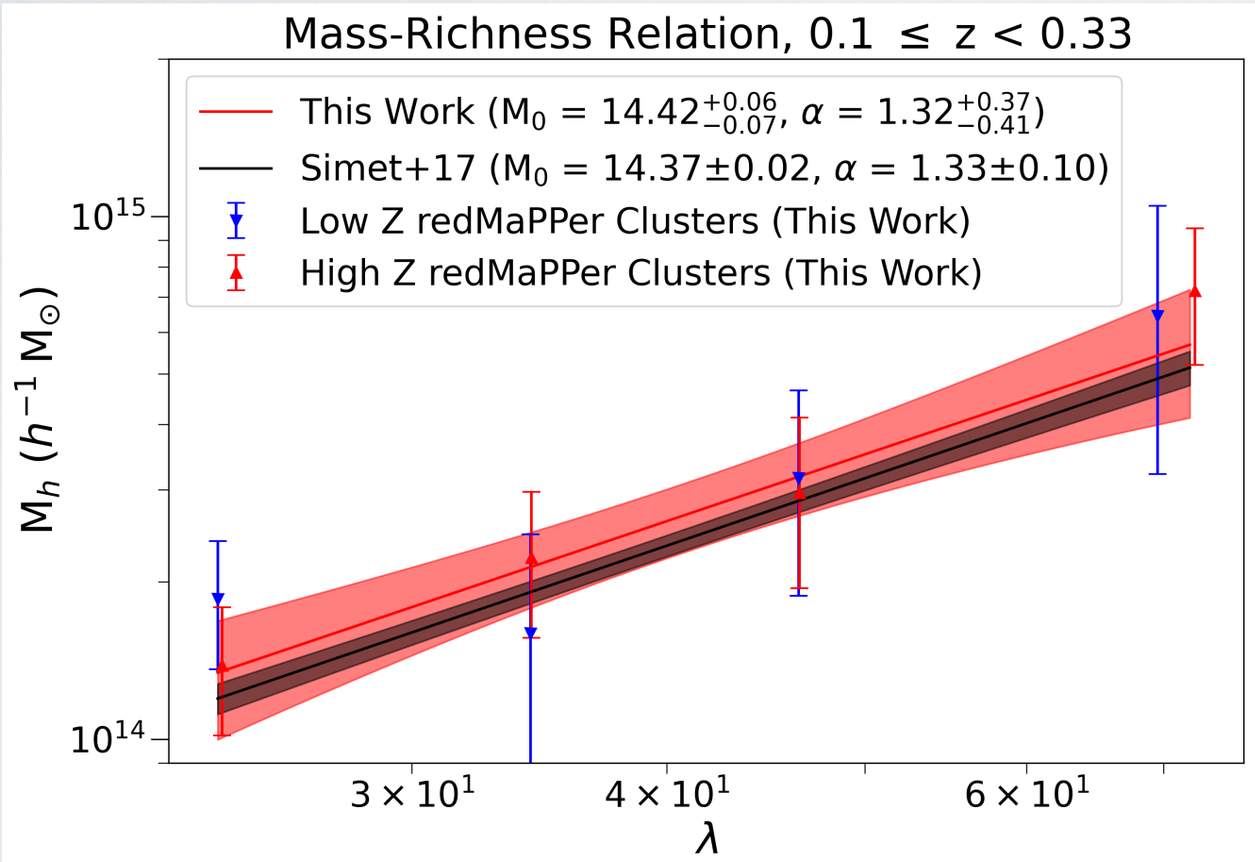
$$\begin{aligned}
\tau_0 &= \alpha\rho_0 + \beta\rho_2 + \eta\rho_5, \\
\tau_2 &= \alpha\rho_2 + \beta\rho_1 + \eta\rho_4, \\
\tau_5 &= \alpha\rho_5 + \beta\rho_4 + \eta\rho_3 .
\end{aligned}$$

II- EARLY WEAK LENSING SCIENCE (WORK IN PROGRESS)

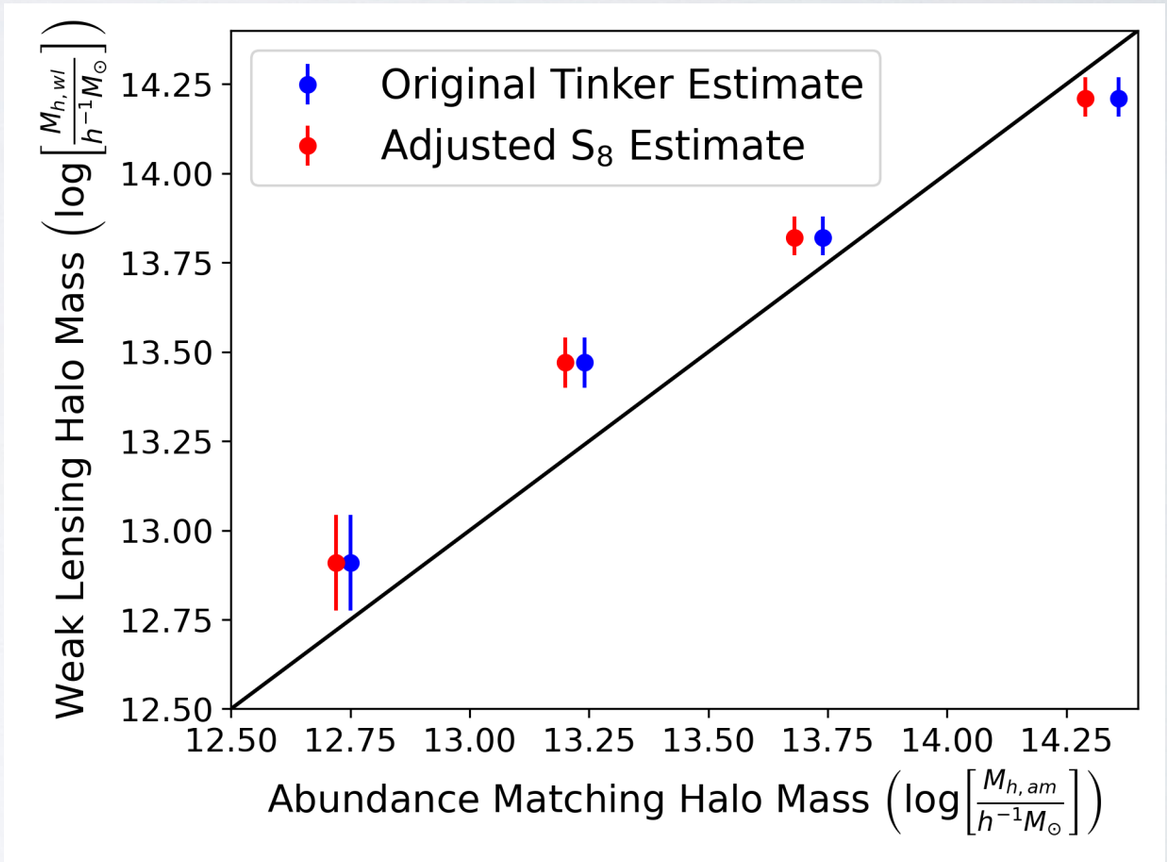
- Masses of groups and clusters
- Shapes of dark matter haloes
- Mass and light on large scales
- Anti-lensing by cosmic voids

WEAK LENSING MASSES OF GROUPS AND CLUSTERS

redMaPPer Clusters



Tinker (2021) Groups



Agreement with Simet+ 2017 (SDSS)

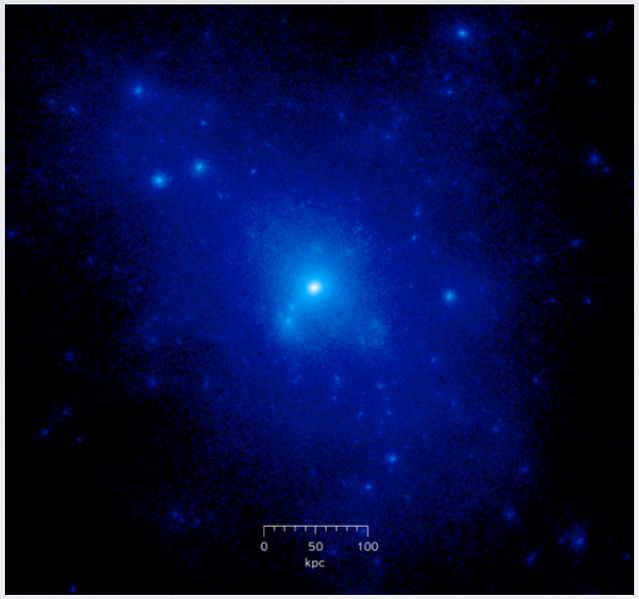
WL vs. Abundance Matching

- disagrees with high $S_8 \equiv \sigma_8(\Omega_m/0.3)^{0.5} = 0.83$
- agrees better with low $S_8 = 0.77 \pm 0.06$

Spitzer et al. 22, submitted

ELLIPTICITY OF DM HALOES

Theory/simulations predict that DM haloes are triaxial: elliptical in 2D projection



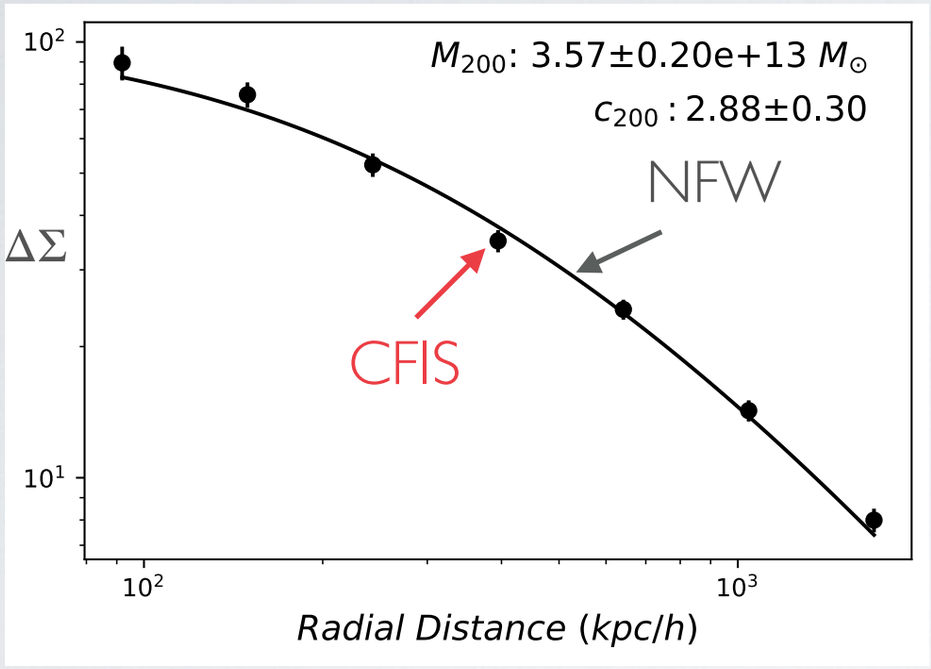
How to measure this effect?

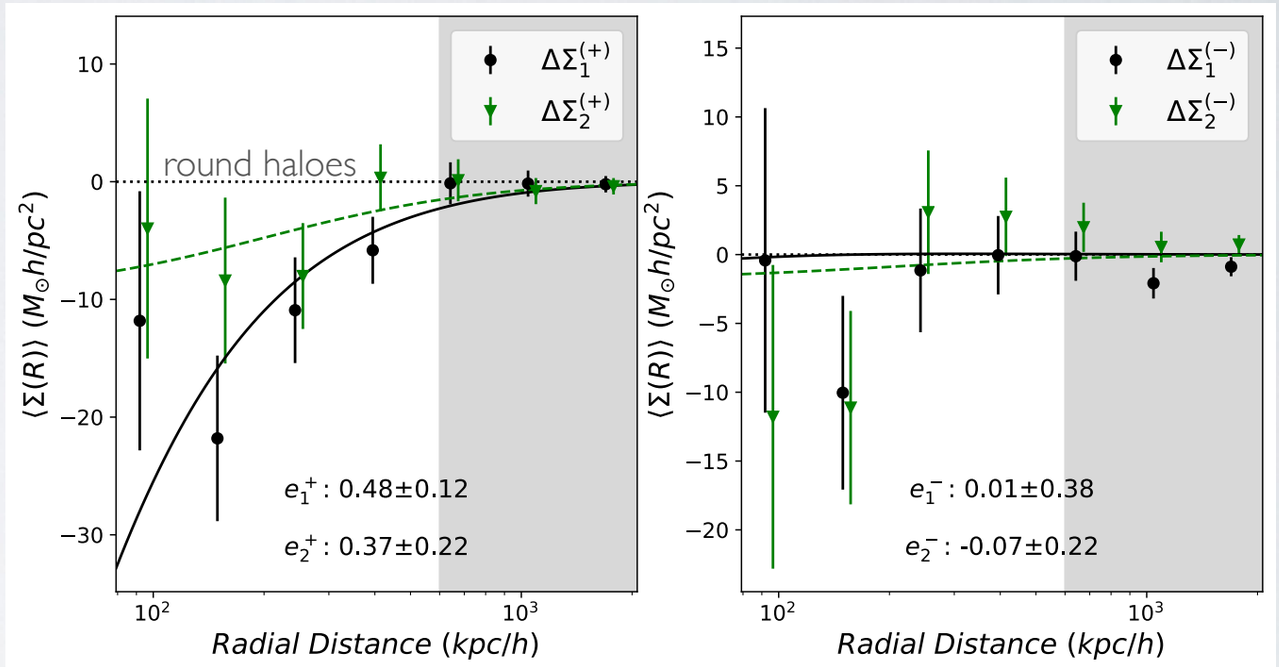
- Assume halo ellipticity is correlated with ellipticity of the light

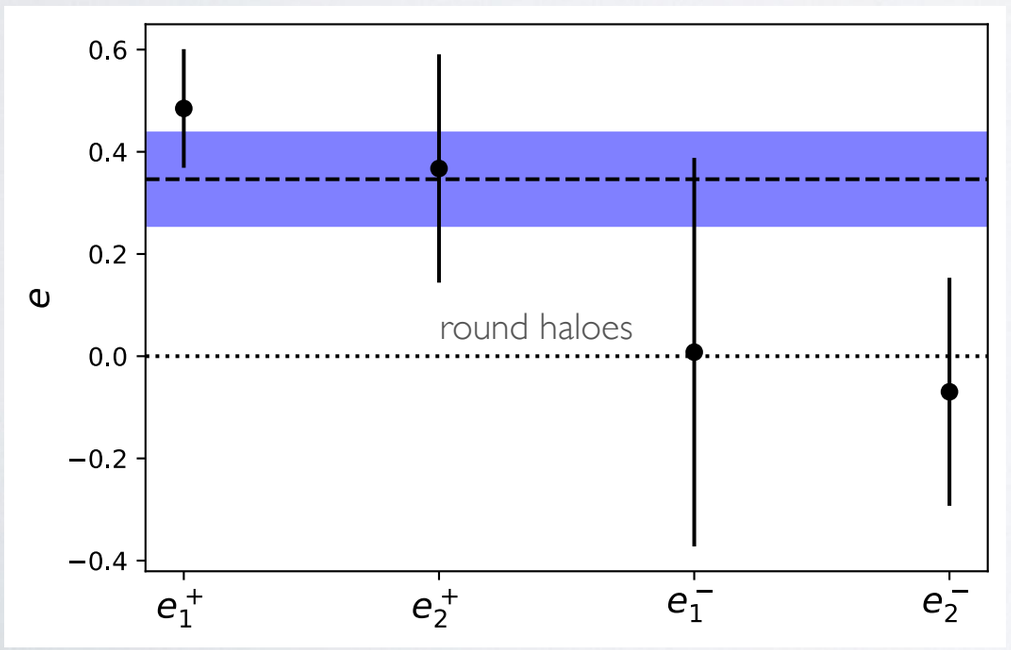
- **Stack** 18,000 SDSS DR7 Luminous Red Galaxies (LRGs) at z ~ 0.2 with halo mass ~3.5 x 10^{13} solar masses.

- Measure the **quadrupole** of the shear

ELLIPTICITY OF DM HALOES







DM haloes are elliptical

e = 0.35±0.09

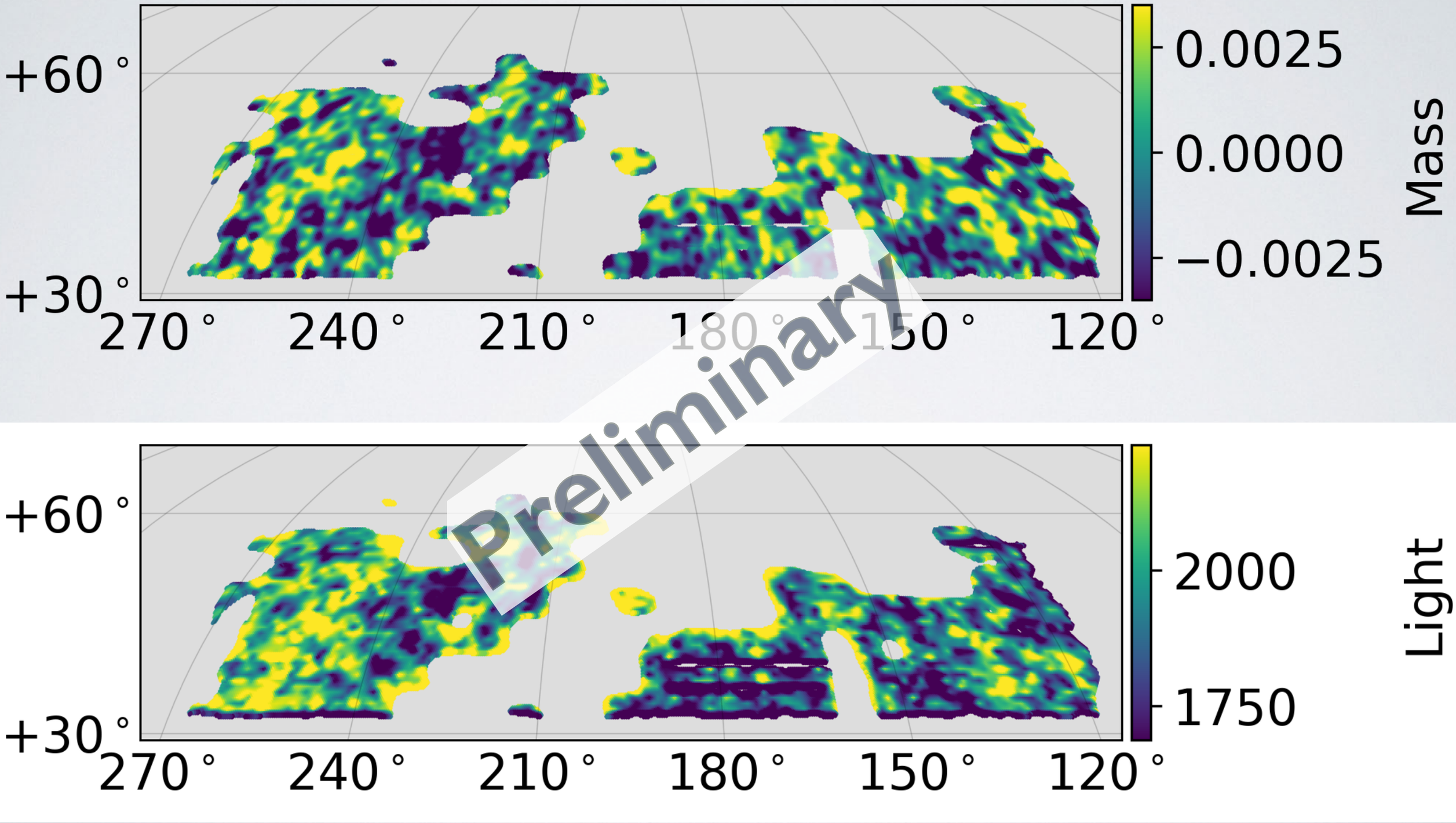
corresponding to

a triaxial ellipsoid

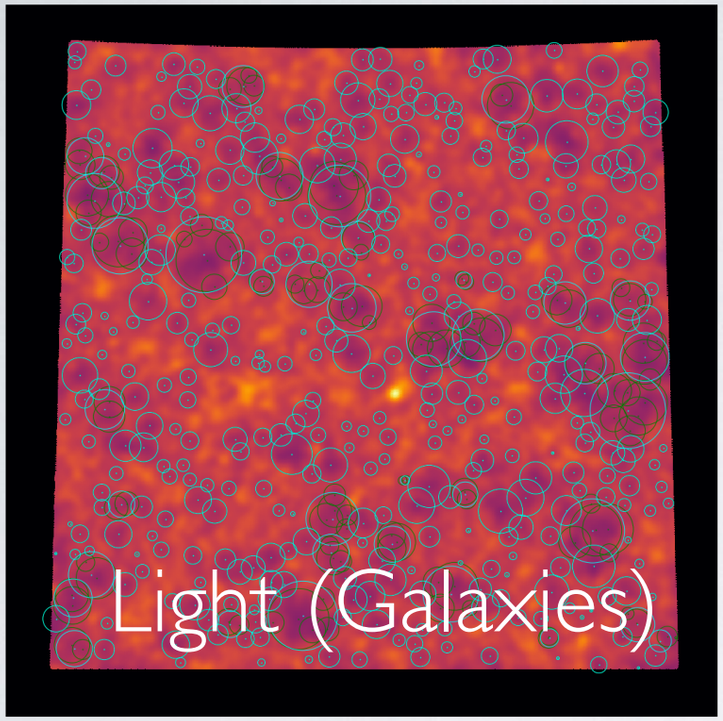
1 : 0.75 : 0.6

Robison et al. 22, submitted

DARK MATTER MASS MAPS

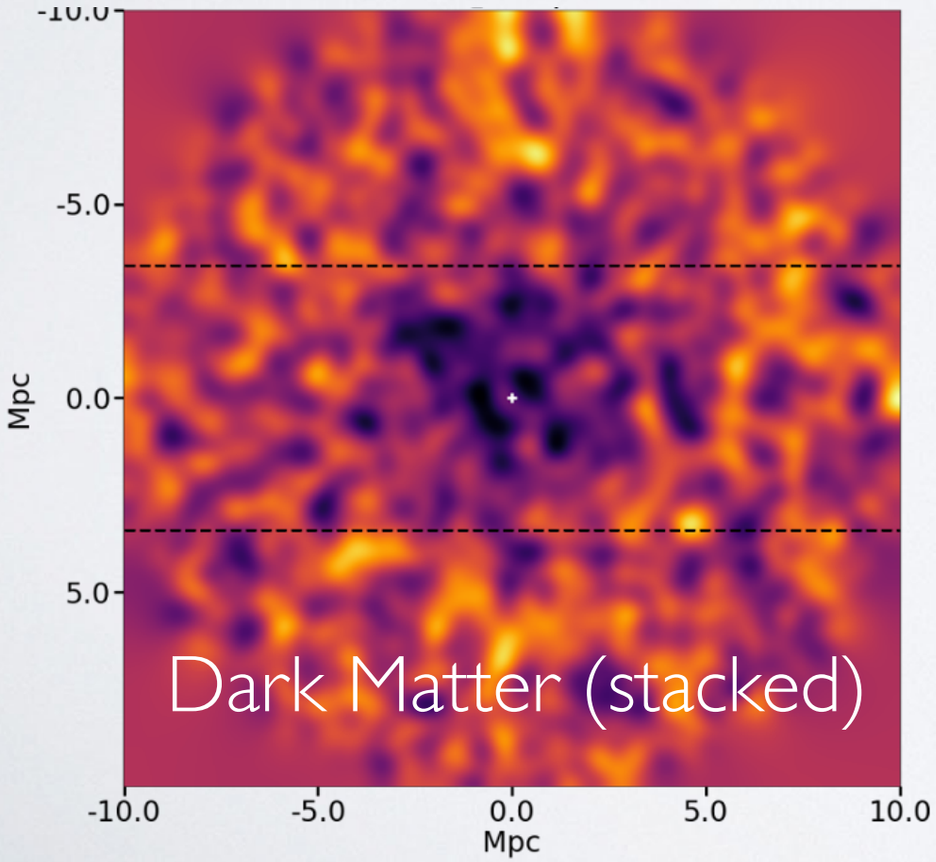


(ANTI-)LENSING BY COSMIC VOIDS



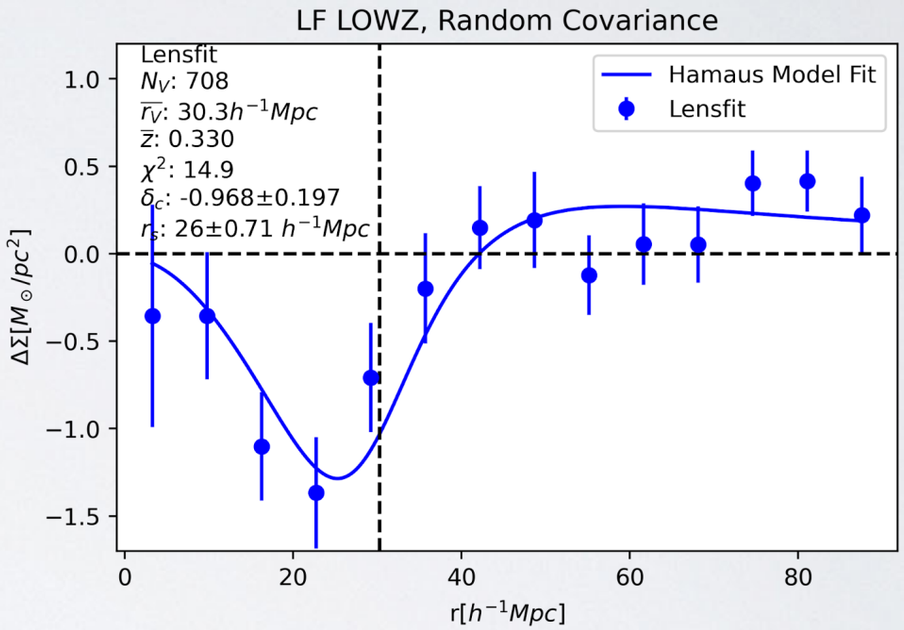
2D Voids
("Troughs")

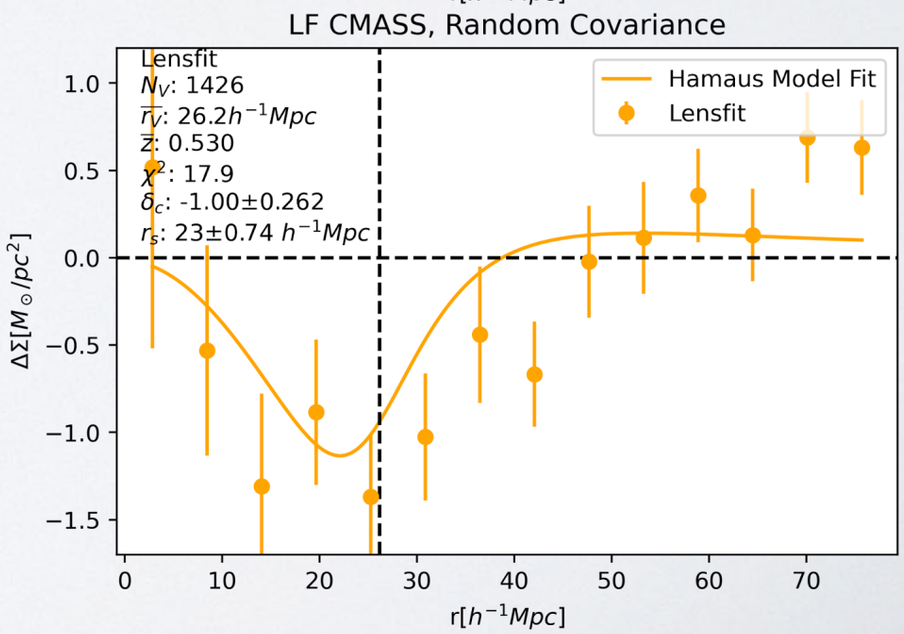
Axel Guinot
et al., in prep



3D Voids from BOSS

Hunter Martin et al.,
in prep



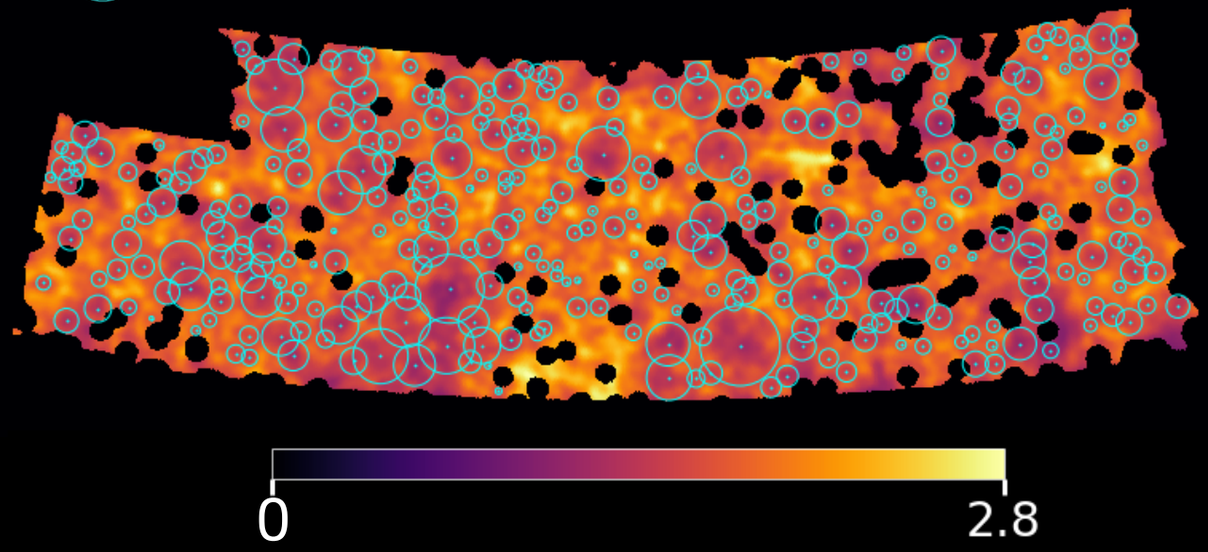


TROUGH LENSING

Axel Guinot et al., in prep

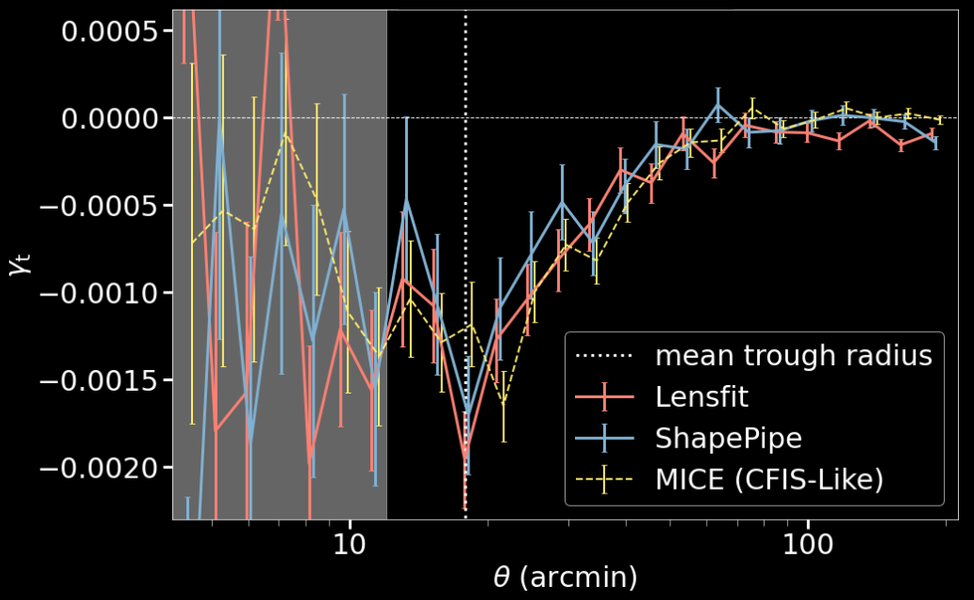
: Trough

Density

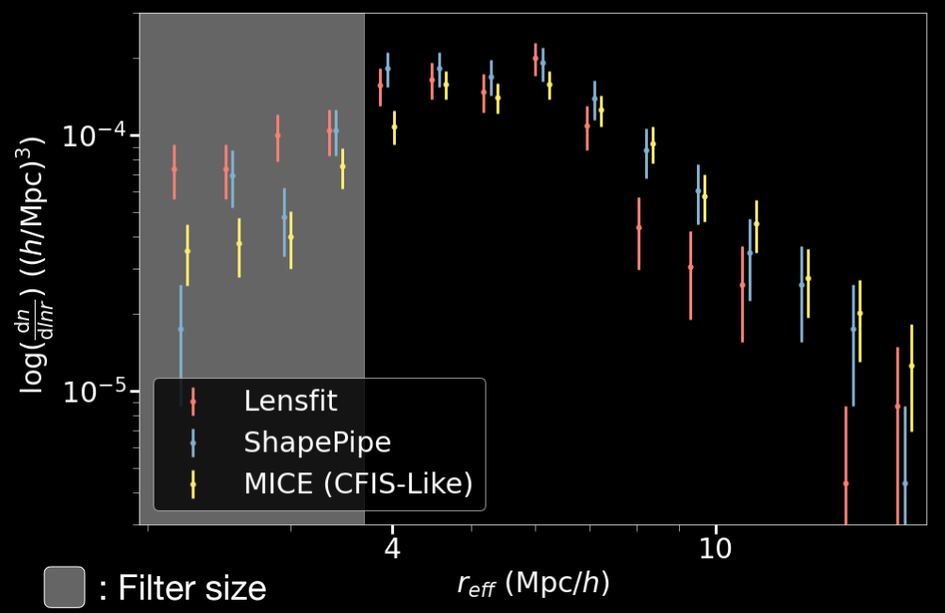


Tangential Alignement

Lensing by



Abundances



: Filter size

III- COMING UP (2023)

- 2D cosmic shear paper (unblinding)
- 2D cosmic shear paper with other low-z probes
- Shape measurements comparison paper
- Tomographic cosmic shear
- Multi-probes paper with shear tomography

IV - WEAK LENSING SCIENCE

- **Galaxies**
  - dependence on mass, redshift and environment
  - tidal stripping of DM haloes of satellites
  - assembly bias
  - ultra-diffuse galaxies (UDGs)
- Masses of **clusters** of galaxies
  - redMapper, Planck, XMM, eBOSS
- Filaments of the **cosmic web**
- *The weight of emptiness*: negative masses of **cosmic voids**
- **Large-scale structure:** DM mass maps
  - Cross-correlations between mass and CMB, tSZ,…
  - Galaxy density (eBOSS/DESI)
  - Peaks and higher order statistics
- Testing **General Relativity**: UNIONS vs. eBOSS
- **Cosmic shear** and S_8

IV - CONCLUSION

- Internal release of 2 independent catalogues (v1.0)
- Accurate, blinded n(z) for preliminary science applications
- First set of PSF validation tests are promising
- Preliminary science projects under way

- Full calibration using simulation (work in progress)
- Continue validation with new tests
- Measure of S8 with the current data (no tomography)

- New analysis using the multi-band information
- Implementation of MetaDetection
- Full 3x2pts analysis with tomography
- Plus a lot more!

IV - CONCLUSION

What is the question we want to address with UNIONS compared to its precedessors?

S_8 tension with Planck is 3σ with KiDS and 1.5σ with DES

UNIONS: 5000 sq.deg. ugriz
DES: 5000 sq.deg. griz
KiDS: 1350 sq.deg. ugriZYJHK

UNIONS will be a decisive factor in the characterisation of the S_8 tension

DES and KiDS are stage 3 surveys

Euclid and Rubin are stage 4 surveys

UNIONS is clearly a stage 3.5 survey with a strong science potential