#GR21

DENSITY PROFILES OF GALAXY CLUSTERS IN THE CFHT STRIPE 82 SURVEY FROM WEAK GRAVITATIONAL LENSING

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OUTLINE

- INTRODUCTION AND MOTIVATION
  - MATTER DISTRIBUTION THROUGH WEAK LENSING
  - PRECISE MASS MEASUREMENTS
- OVERVIEW OF THE DATA
  - CS82 SURVEY AND DR7 SDSS STRIPE 82 COADD
  - LENS CATALOG FROM REDMAPPER
  - SOURCE CATALOG FROM LENSFIT
- WL MEASUREMENTS
  - AVERAGE TANGENTIAL PROFILES
- SUMMARY AND PERSPECTIVES

INTRODUCTION

- ΛCDM model makes a number of predictions about the galaxy clusters

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  Dark matter distribution, NFW profile, halo mass function
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- From observations: difficult to measure the cluster mass

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  Physical assumptions, need of mass-observable relations
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- Weak gravitational lensing: well-suited for studying mass profile

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  Sensitive to all mass associated with the cluster, probe dark matter
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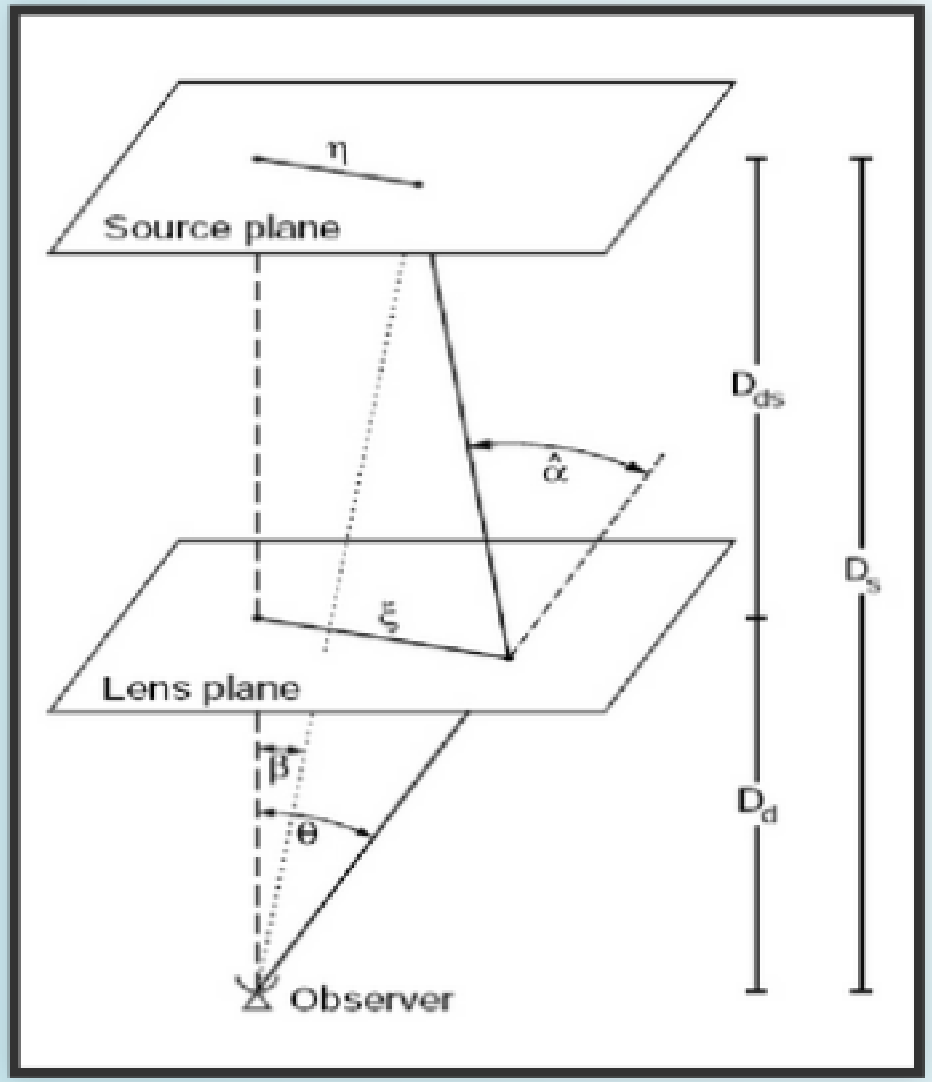
INTRODUCTION

The gravitational lensing effect: bending of the light by a matter distribution.



Sketch of a gravitational lens system (Bartelman & Schneider, 2001).

$$\vec{\beta} = \vec{\theta} - \vec{\alpha}$$

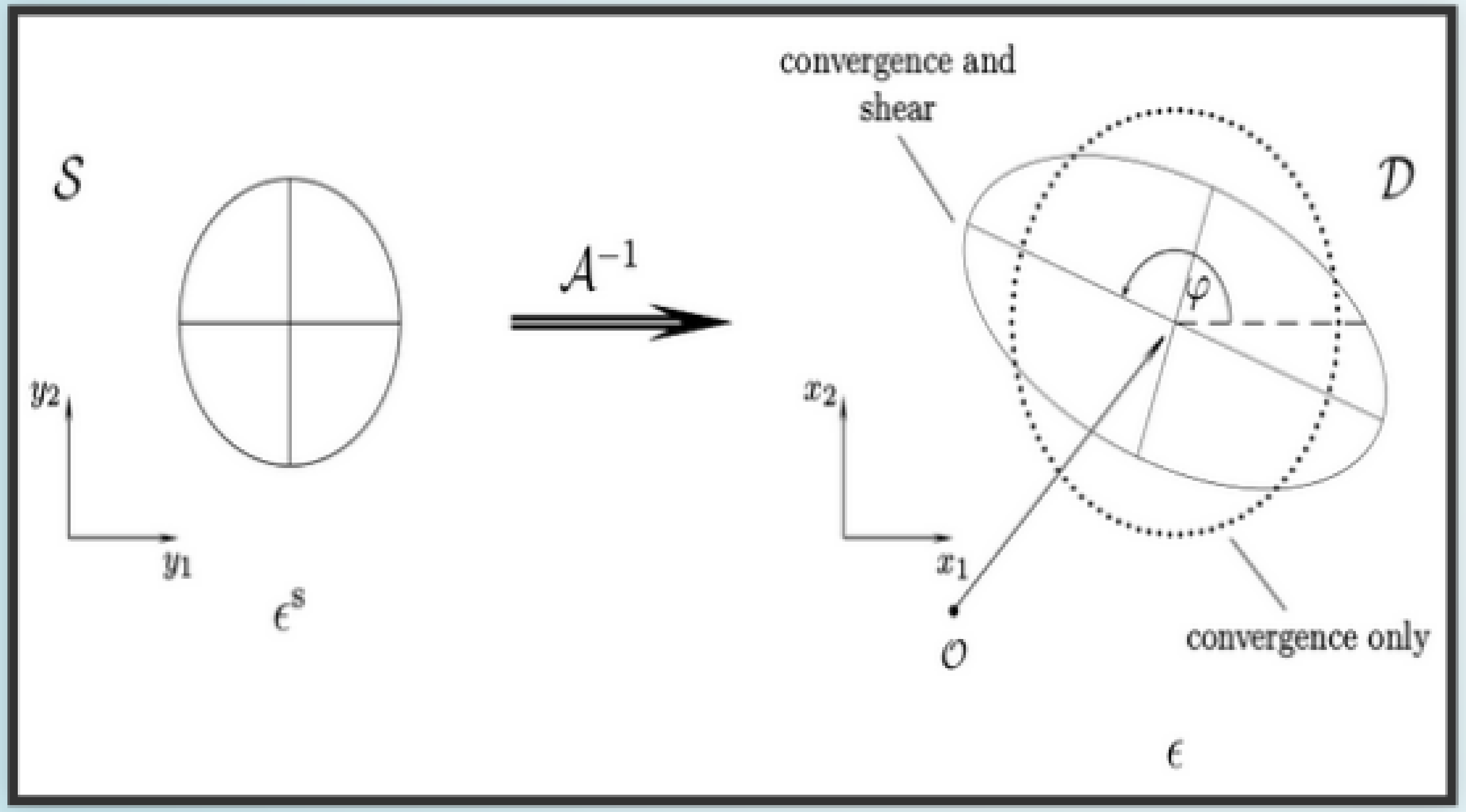
$$\vec{\alpha}(\vec{\theta}) = \nabla_\theta \Psi(\vec{\theta})$$

$$\Psi(\vec{\theta}) = \frac{1}{\pi}\int_{\mathbb{R}^2} d^2\theta' \kappa(\vec{\theta'}) \ln|\vec{\theta} - \vec{\theta'}|$$

$$\kappa(\vec{\theta}) = \frac{1}{2}\nabla_\theta \cdot \alpha(\vec{\theta})$$

INTRODUCTION

The gravitational lensing observables: shear, convergence and magnification.



Example of a circular source that transforms into ellipse under influence of shear and convergence (Narayan & Bartelmann, 1997).

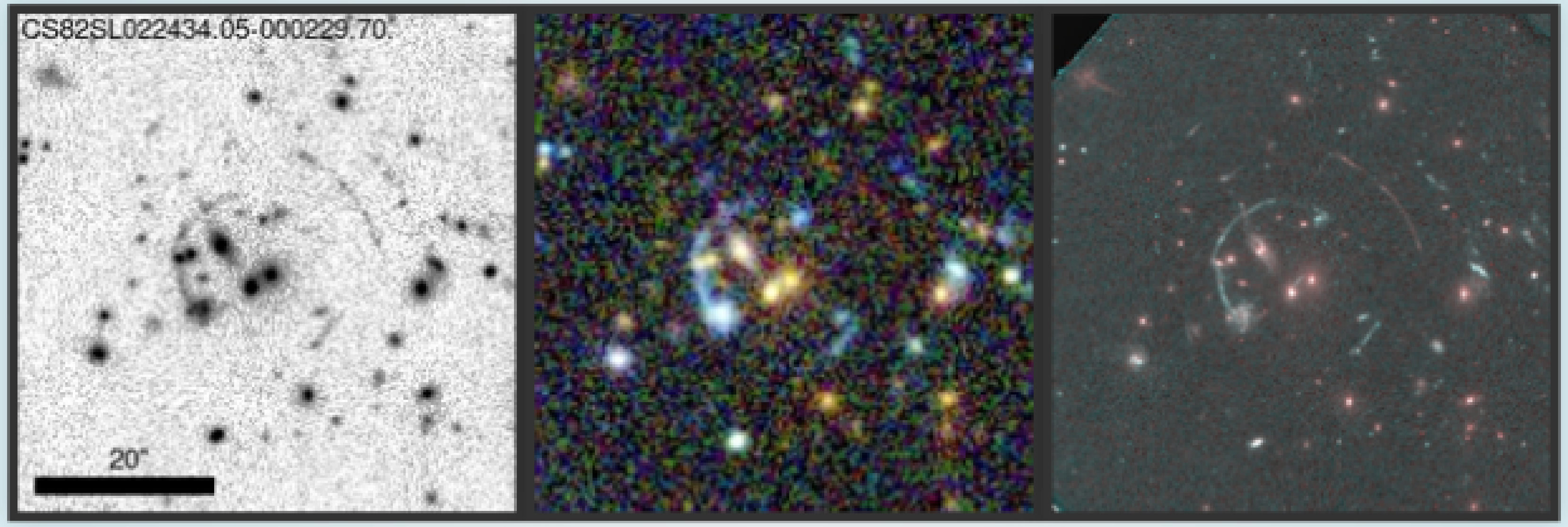
$$\kappa(\vec{\theta}) = \frac{\Sigma(D_d\vec{\theta})}{\Sigma_{crit}}$$

$$\begin{aligned} \gamma_1 &= \frac{1}{2}(\Psi_{,11} - \Psi_{,22}) \\ \gamma_2 &= \Psi_{,12} \end{aligned}$$

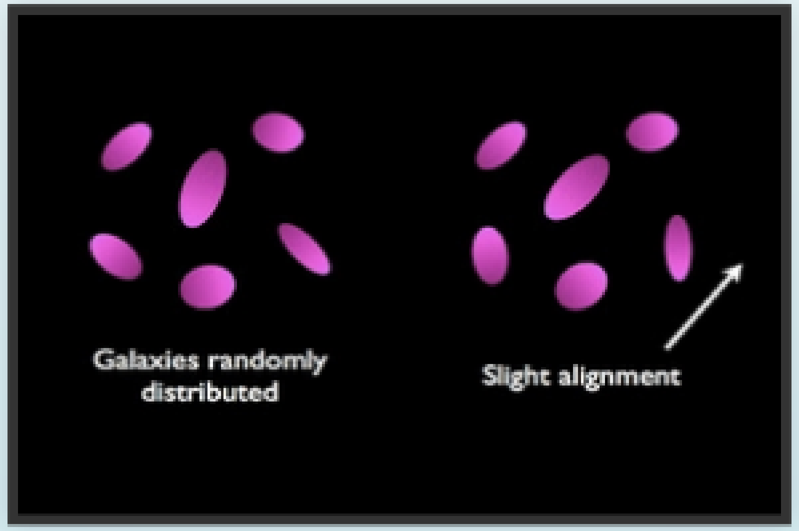
$$\mu = \frac{1}{(1-\kappa)^2 - |\gamma|^2}$$

INTRODUCTION

The gravitational lensing regimes: strong and weak.



Strong lensing: strong distortions, multiple images and arcs. Image: G. Caminha.



Weak lensing: slight distortions in a preferential direction. Image: E. Grocutt.

MOTIVATION

- Challenges:

  Galaxy clusters detection → several cluster finders

  Galaxy shapes measurements → seeing, optical effects

  Accurate mass estimation → weak lensing systematics

- Objectives:

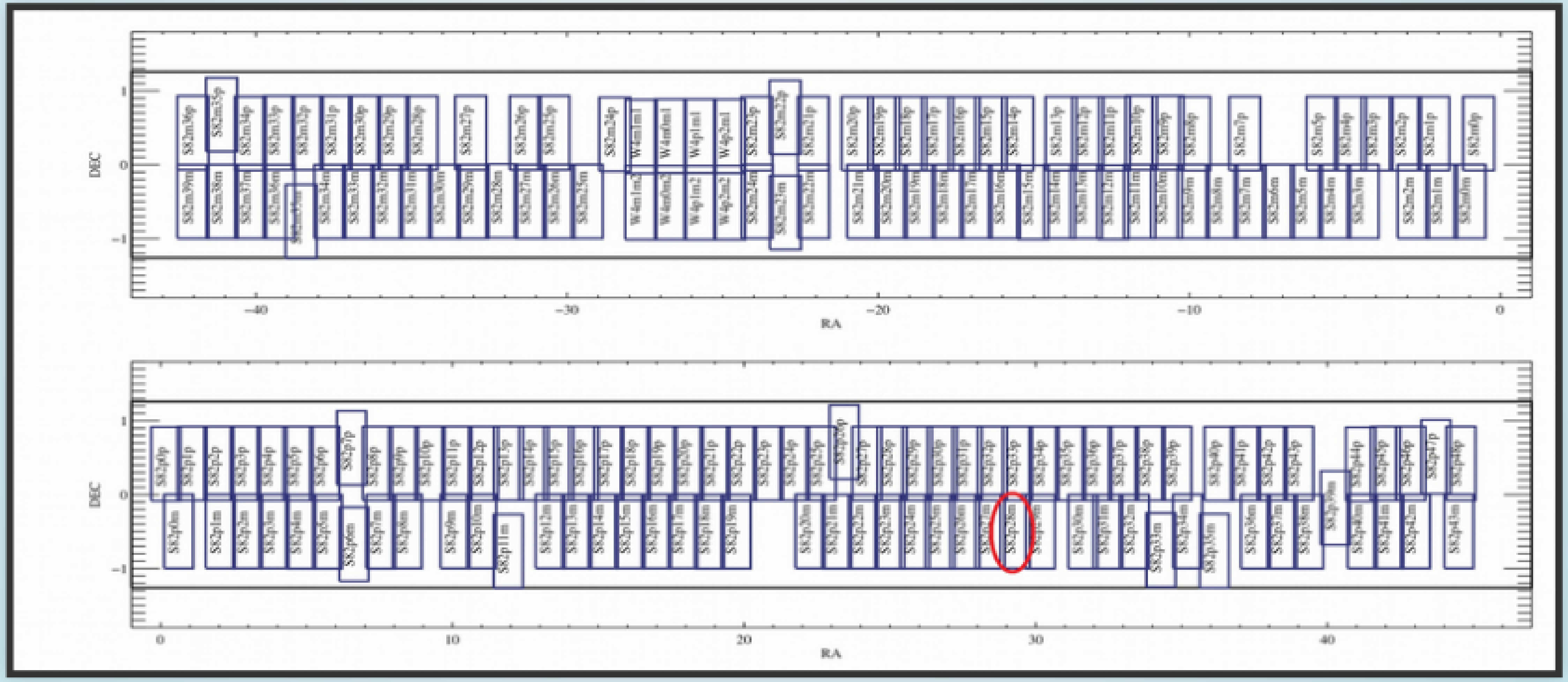
  Measure the weak lensing signal from CS82 galaxy clusters

  Test the weak lensing systematics: miscentering, point mass, etc.

  Estimate the mass and concentration

CFHT STRIPE 82 SURVEY

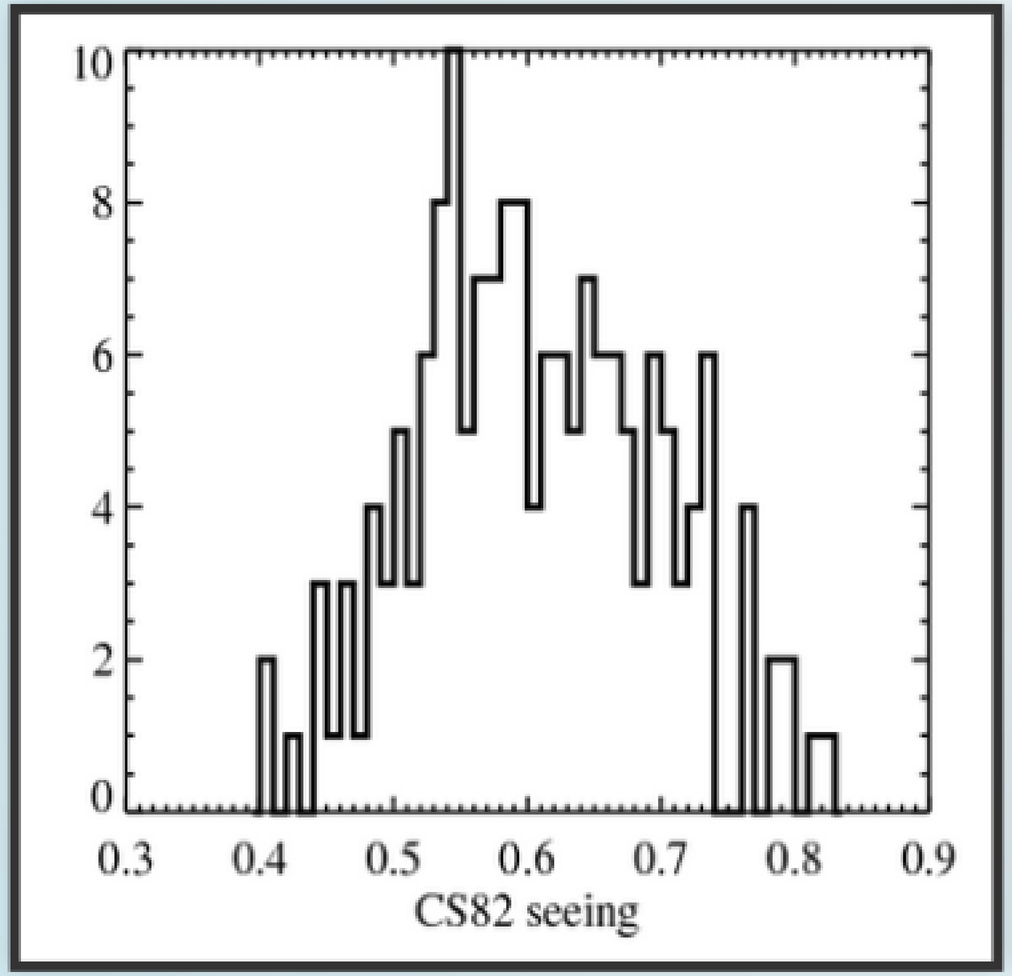
- Focus on weak lensing, 170 deg^2 on Stripe 82 region
- i-band (optical), i~23.5, mean seeing 0.6$''$

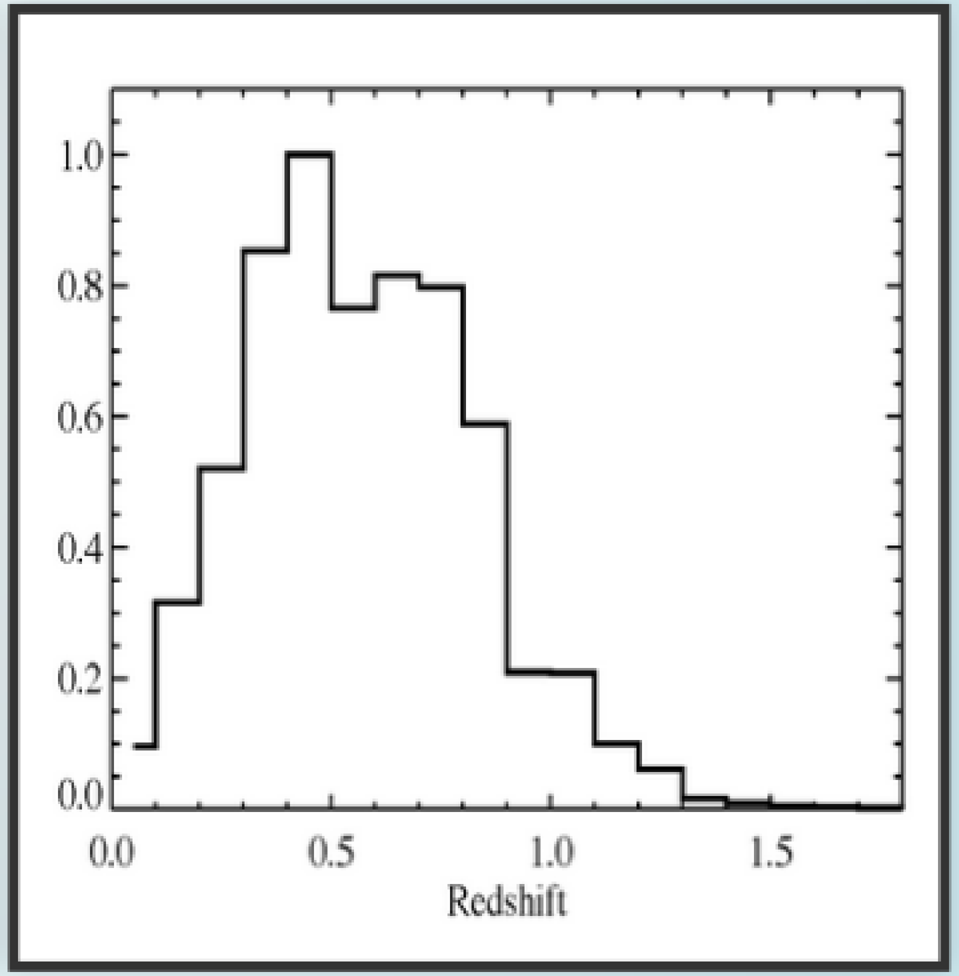


CS82 footprint: 176 tiles, equatorial region, avoiding bright stars. Image: A. Leauthaud.

CFHT STRIPE 82 SURVEY

- Excellent image quality for the shape measurements of the faint sources
- Stripe 82 also is covered by different multiwavelenght surveys





CS82 footprint: 176 tiles, equatorial region, avoiding bright stars. Image: A. Leauthaud.

REDMAPPER LENS CATALOG

- red sequence Matched-filter Probabilistic Percolation (redMaPPer) - Rykoff et al., 2013

- The richness λ is the number of red sequence galaxies brighter than $0.2L_*$ at the redshift of the cluster within a scaled aperture
- Cluster centering is done with a probabilistic algorithm ($P_{cen}>0.9$, well centering clusters)
- Richness values are corrected for the survey masked area
- CS82 redMaPPer clusters:
  - redshift range $0.1 < z < 0.7$
  - $\lambda > 20$
  - Total of 838 clusters

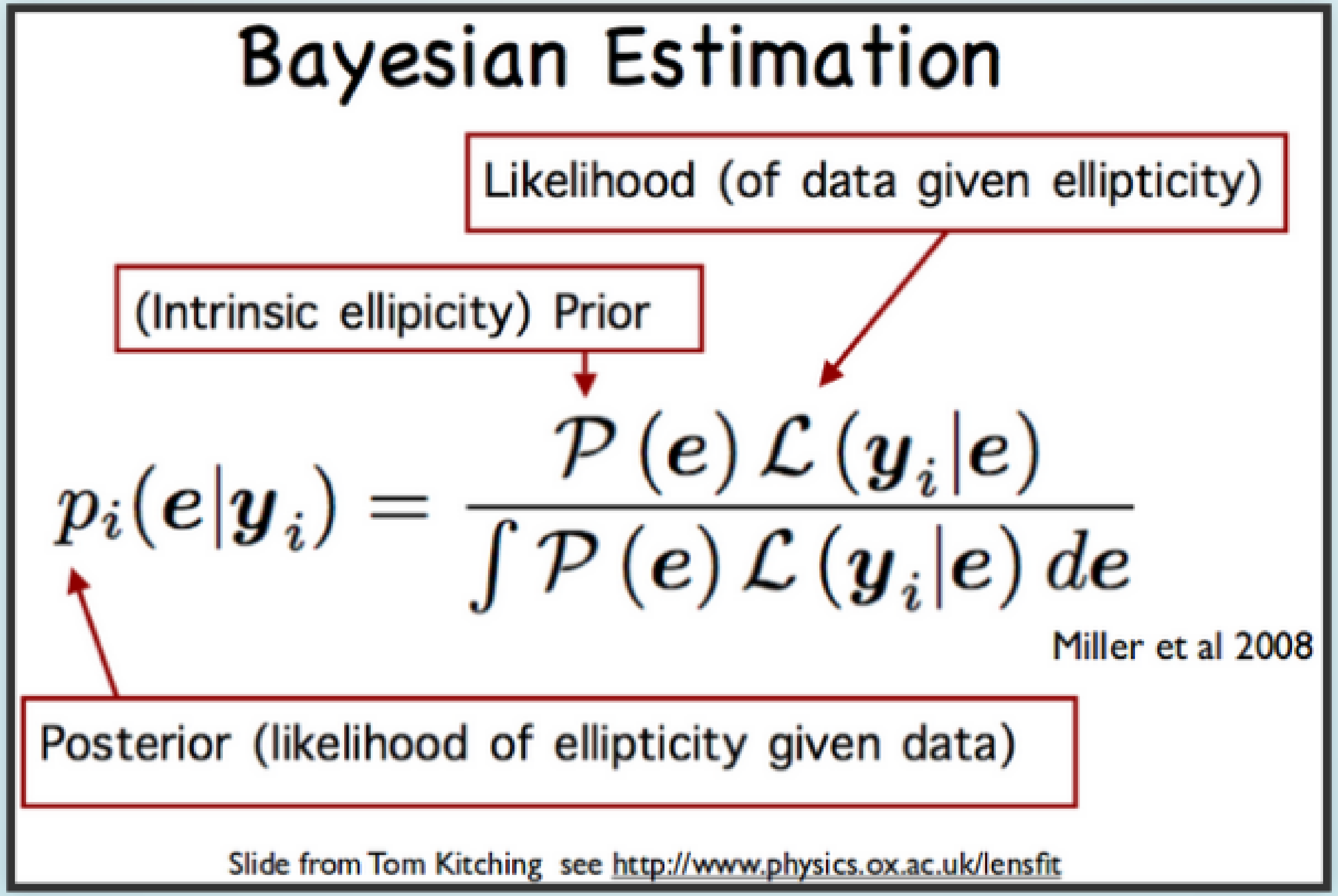
LENSFIT SOURCE CATALOG

- Lensfit (Miller et al., 2007): Bayesian method to measure the shape of galaxies by a model-fitting
- Models: exponential and de Vaucouleurs
- PSF modelling: from the stars in the field, pixelized PSF model to polynomial fit in the image
- Distortion correction: from the astrometric calibration, relationship between pixel and celestial coordinates as a function of position across the field

Lensfit process overview: measure PSF → create a model → convolve with PSF and correct distortion → determine the likelihood of the fit

LENSFIT SOURCE CATALOG

1 - Lensfit computes the posteriori likelihood to the ellipticities by:



LENSFIT SOURCE CATALOG

2 - Shear using the prior and the likelihood:

$$\langle \mathbf{e} \rangle = \frac{1}{N} \sum_i \int \mathbf{e} p_i(\mathbf{e}|\boldsymbol{y}_i) \mathrm{d}\mathbf{e}$$

$$\hat{g_\mu} \equiv \frac{\sum_i^N w_i \langle e_\mu \rangle_i}{\sum_i^N w_i \partial \langle e_\mu \rangle_i / \partial g_\mu}$$

$$\frac{\partial \langle e_\mu \rangle}{\partial g_\mu} \simeq 1 - \left[\frac{\int \left(\langle \mathbf{e} \rangle - \mathbf{e} \right) \mathcal{L}(\mathbf{e}) \frac{\partial \mathcal{P}}{\partial e_\mu} \mathrm{d}\mathbf{e}}{\int \mathcal{P}(\mathbf{e}) \mathcal{L}(\mathbf{e}) \mathrm{d}\mathbf{e}} \right]$$

3 - Lensfit catalog provides: RA, DEC, γ_1, γ_2, weights, m, etc.

Lensfit outputs + BPZ photo z's → ~4.400.000 sources

WL MEASUREMENT THEORY

- γ_1, γ_2 to tangential and cross shear components:

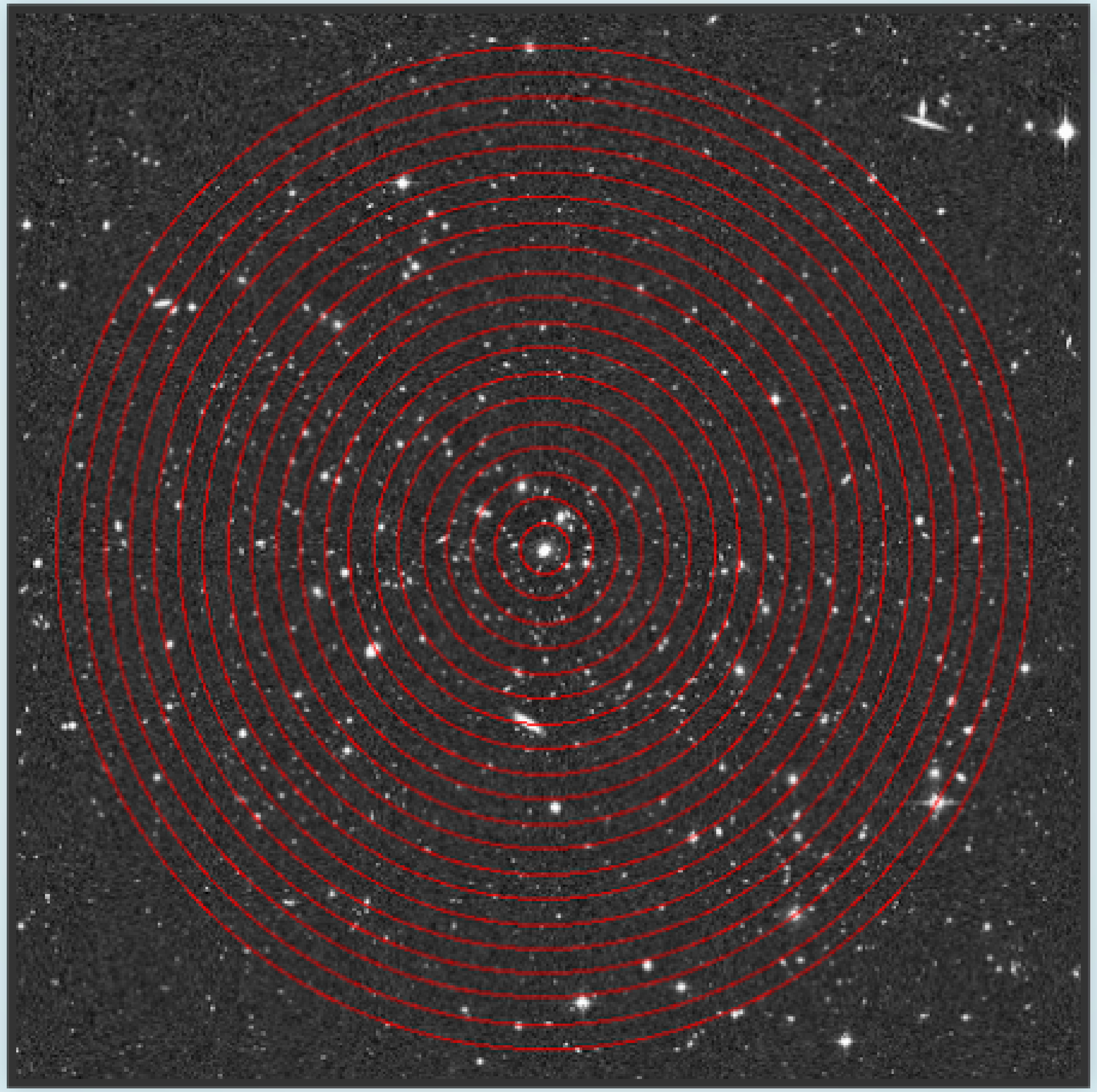
$$\gamma_t = -\gamma_1 \cos(2\phi) - \gamma_2 \,\mathrm{sen}(2\phi) \qquad \gamma_\times = \gamma_1 \,\mathrm{sen}(2\phi) - \gamma_2 \cos(2\phi)$$

- Average tangential shear, γ_t, in annulus of radius R:

$$\gamma_t(R) = \frac{\Delta\Sigma}{\Sigma_{crit}} \equiv \frac{\overline{\Sigma}(< R) - \langle\Sigma(R)\rangle}{\Sigma_{crit}}$$

$$\Sigma_{\mathrm{crit}} = \frac{c^2}{4\pi G}\frac{D_s}{D_l D_{ls}}$$

WL MEASUREMENTS IN PRACTICE



- Binning in z or λ and compute ΔΣ with xshear code (E. Sheldon, on Github)

- Stacking the signal of the clusters in the sample

WL MEASUREMENTS IN PRACTICE

- The $\Delta\Sigma$ is computed, in the concentric rings, by:

$$\Delta\Sigma(R) = \frac{\sum_{ls} w_{ls} \gamma_t^{ls} \Sigma_{\rm crit}}{\sum_{ls} w_{ls}}$$

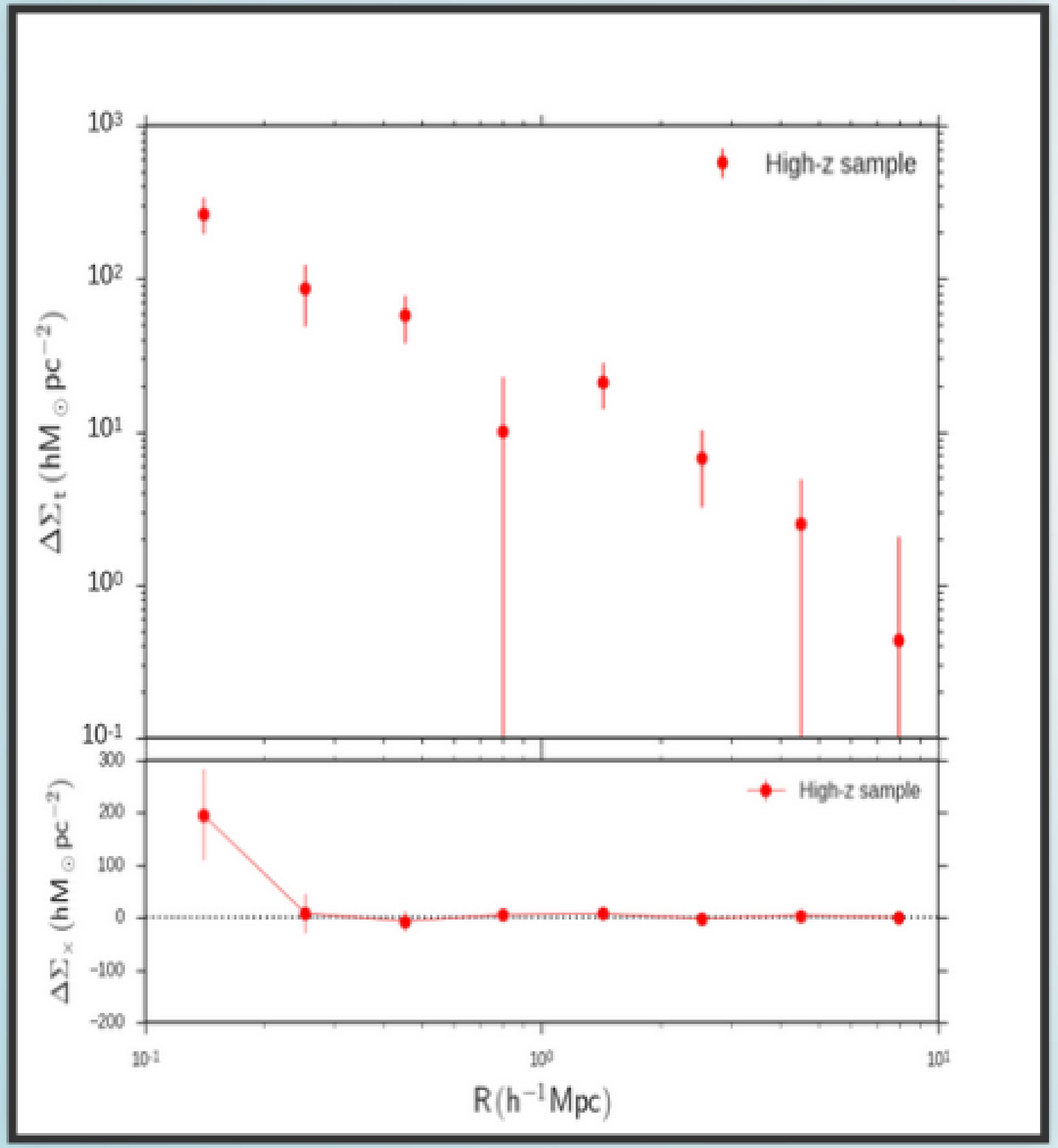
where w is the weight for each source:

$$w_{ls} = w_n \Sigma_{\rm crit}^{-2}$$

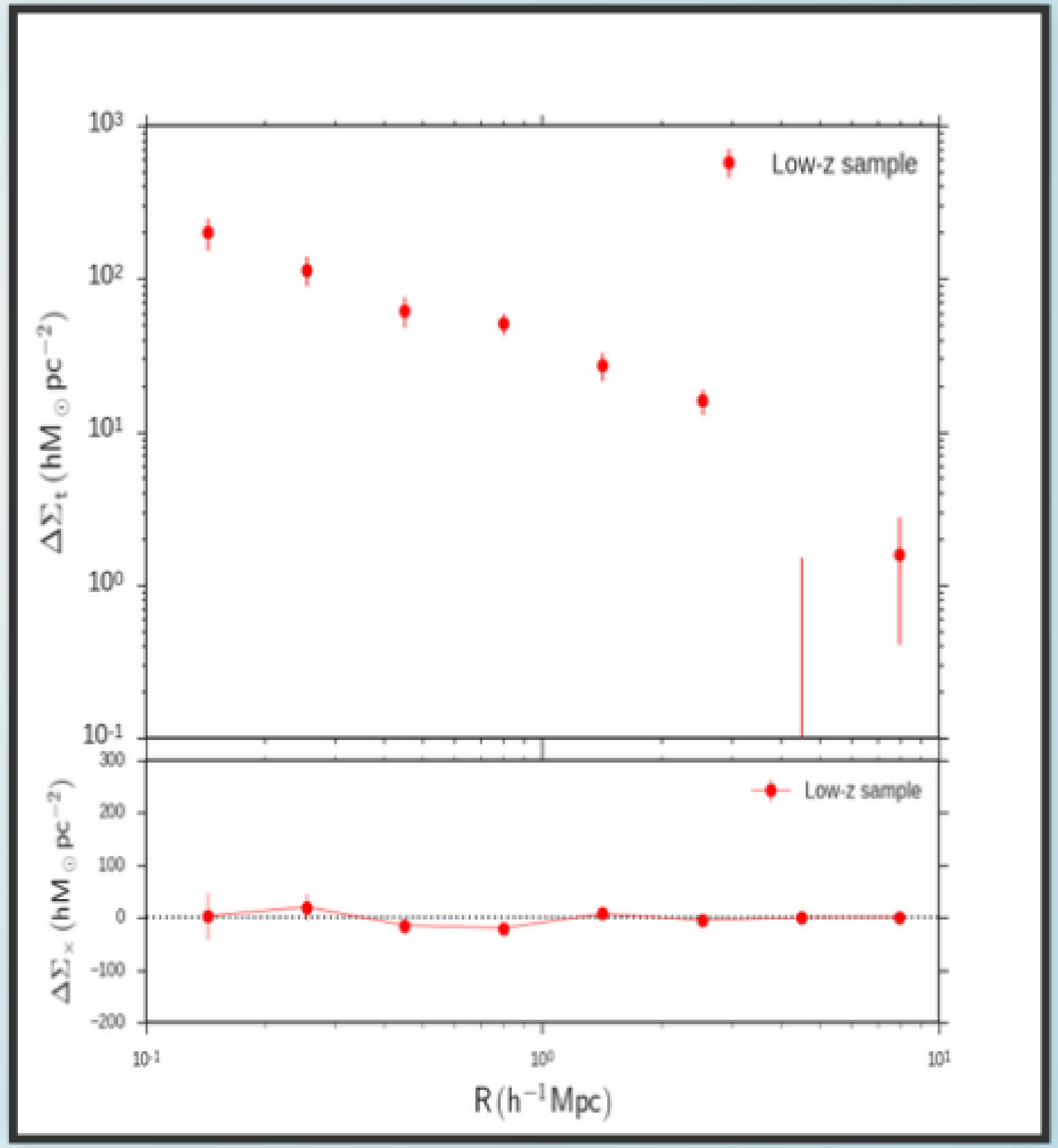
- Binning of the the samples in redshift: low-z (0.2 to 0.4) and high-z (0.4 to 0.6)
- Cuts on CS82 masked catalog to get the Lensfit-sources
- H0 = 67.8, Ωm = 0.307, clustercentric radius from 0.1h^-1 to 10h^-1 Mpc

WL SIGNAL FROM STACKING

High z sample

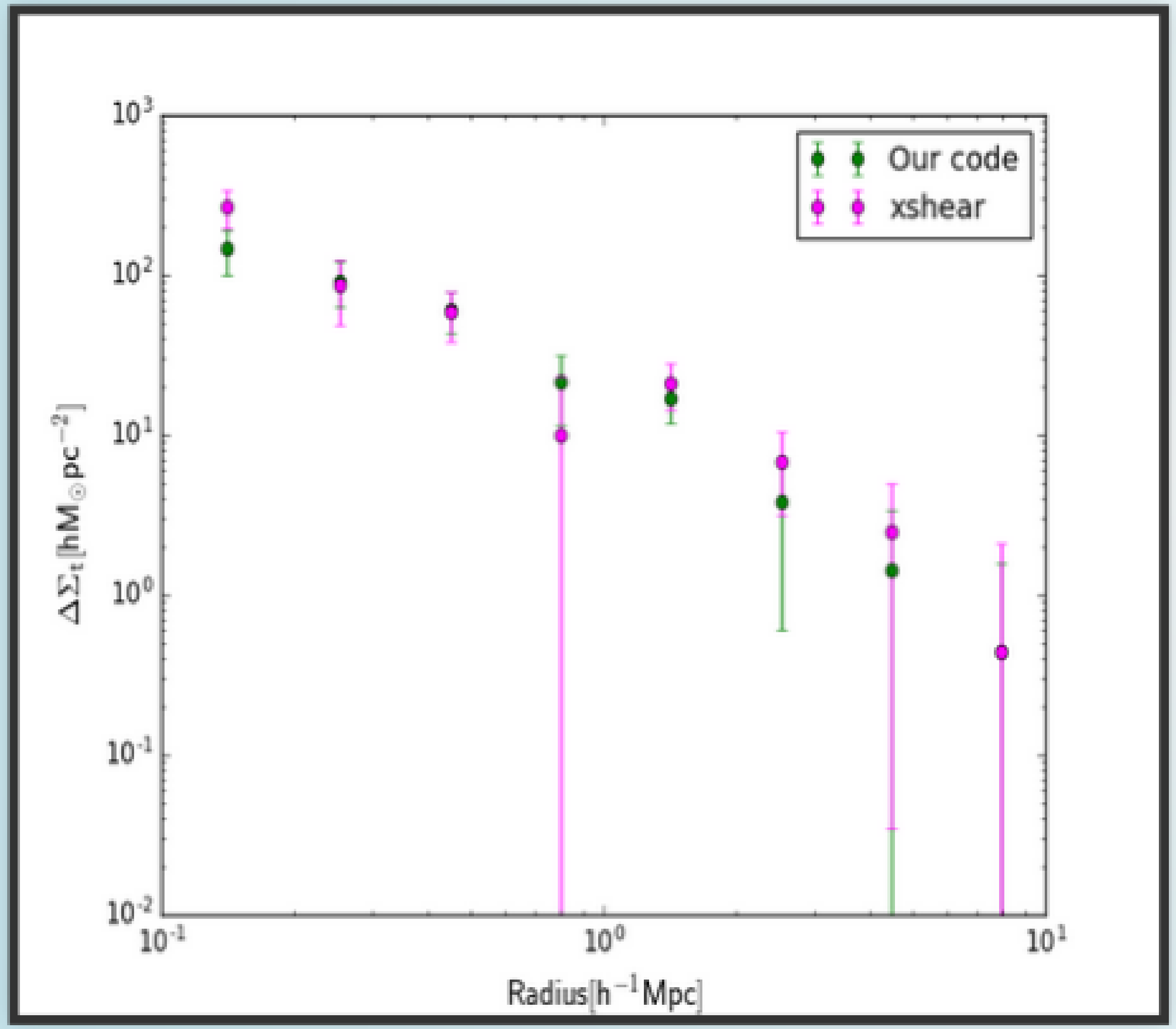


Low z sample

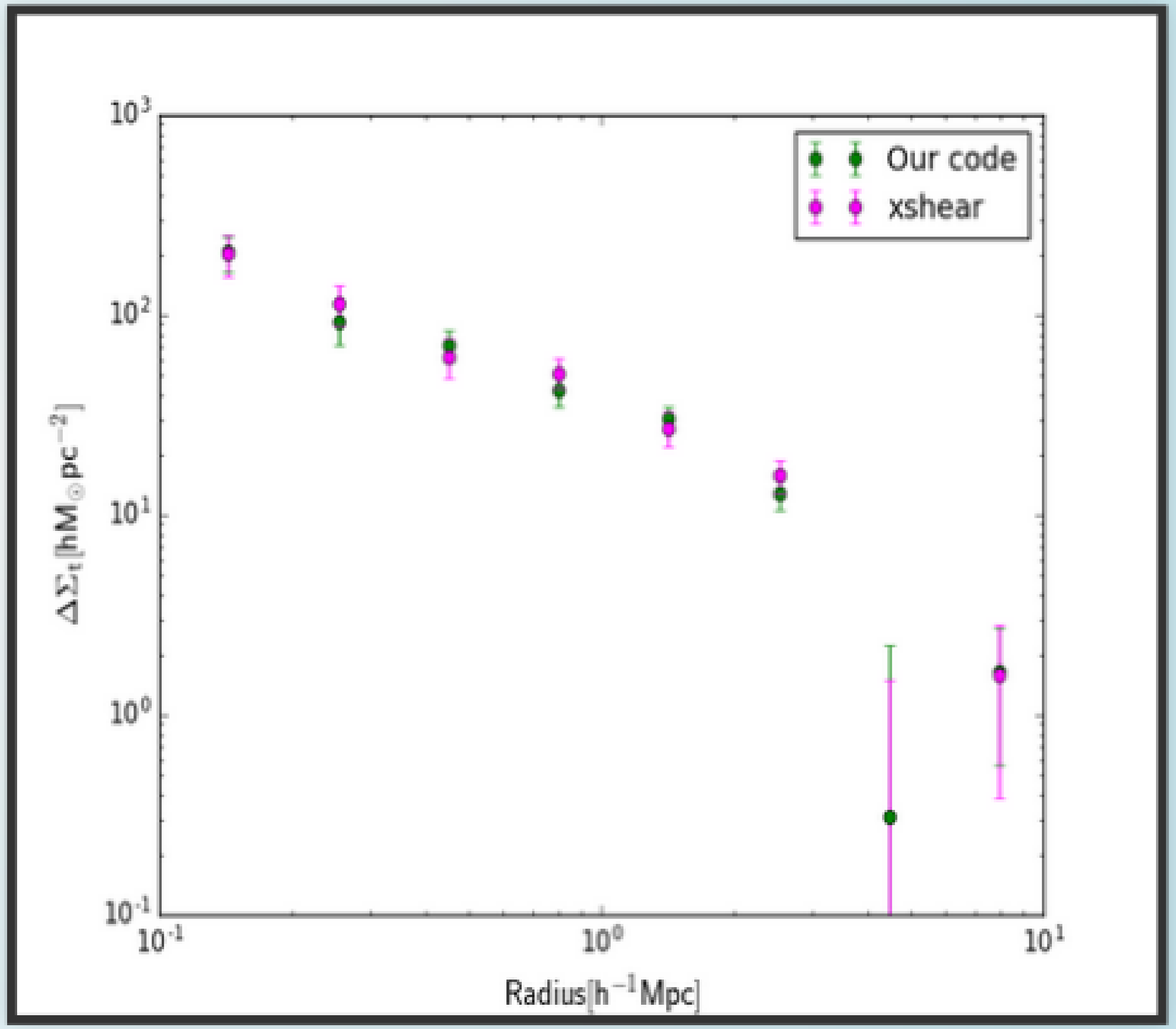


WL SIGNAL FROM STACKING

High z sample



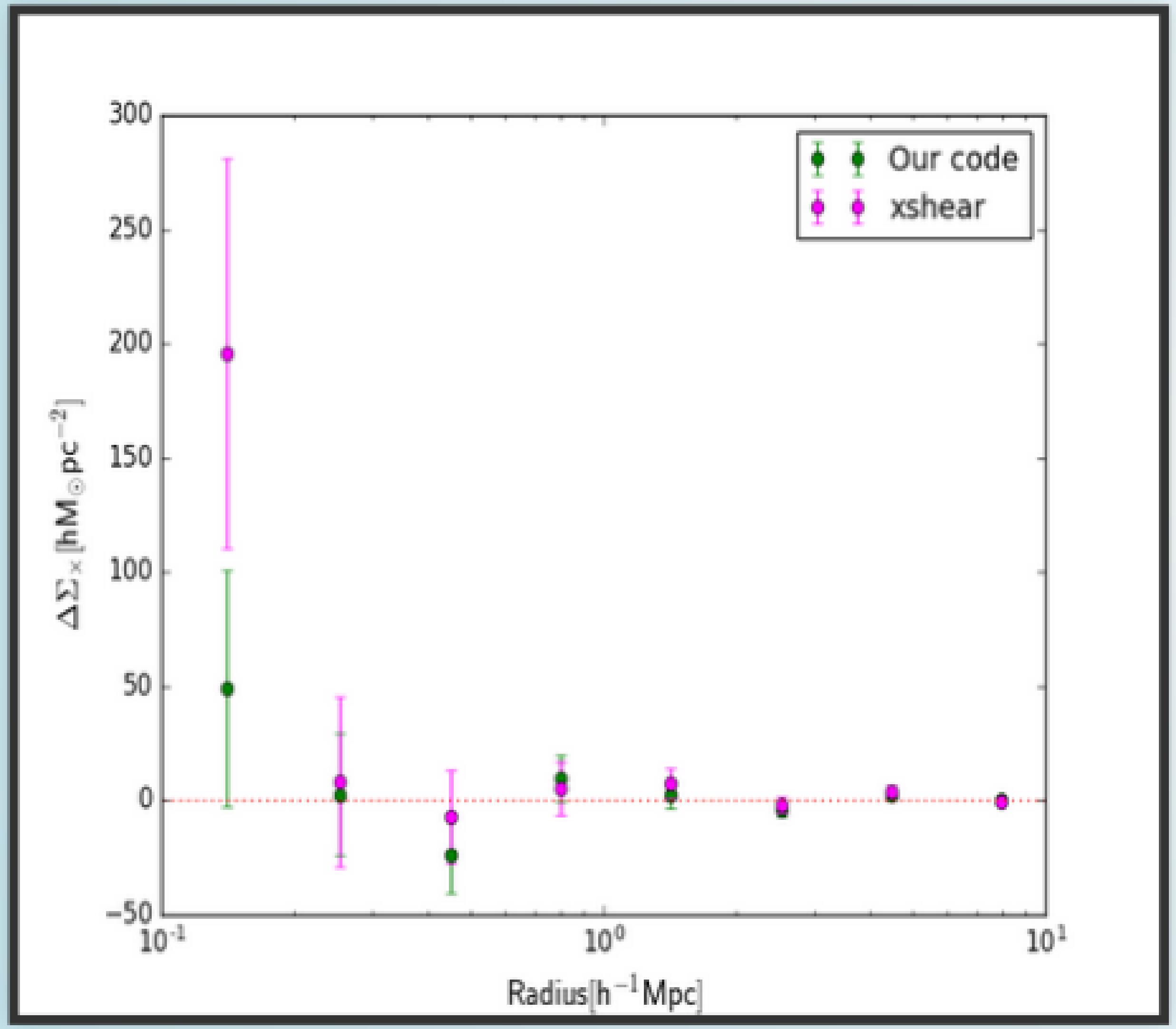
Low z sample



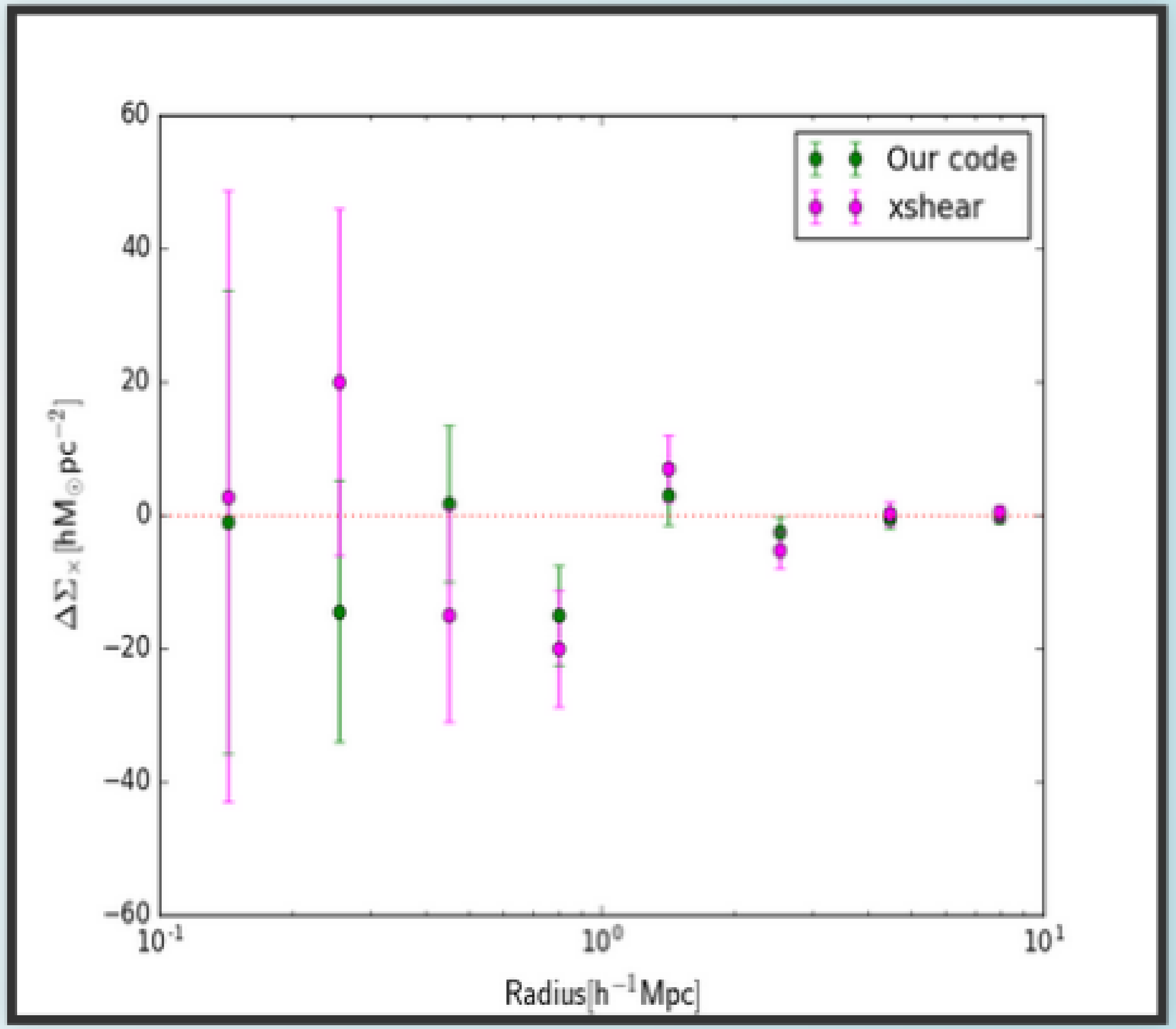
- Comparison of the xshear results with an independent code

WL SIGNAL FROM STACKING

High z sample



Low z sample



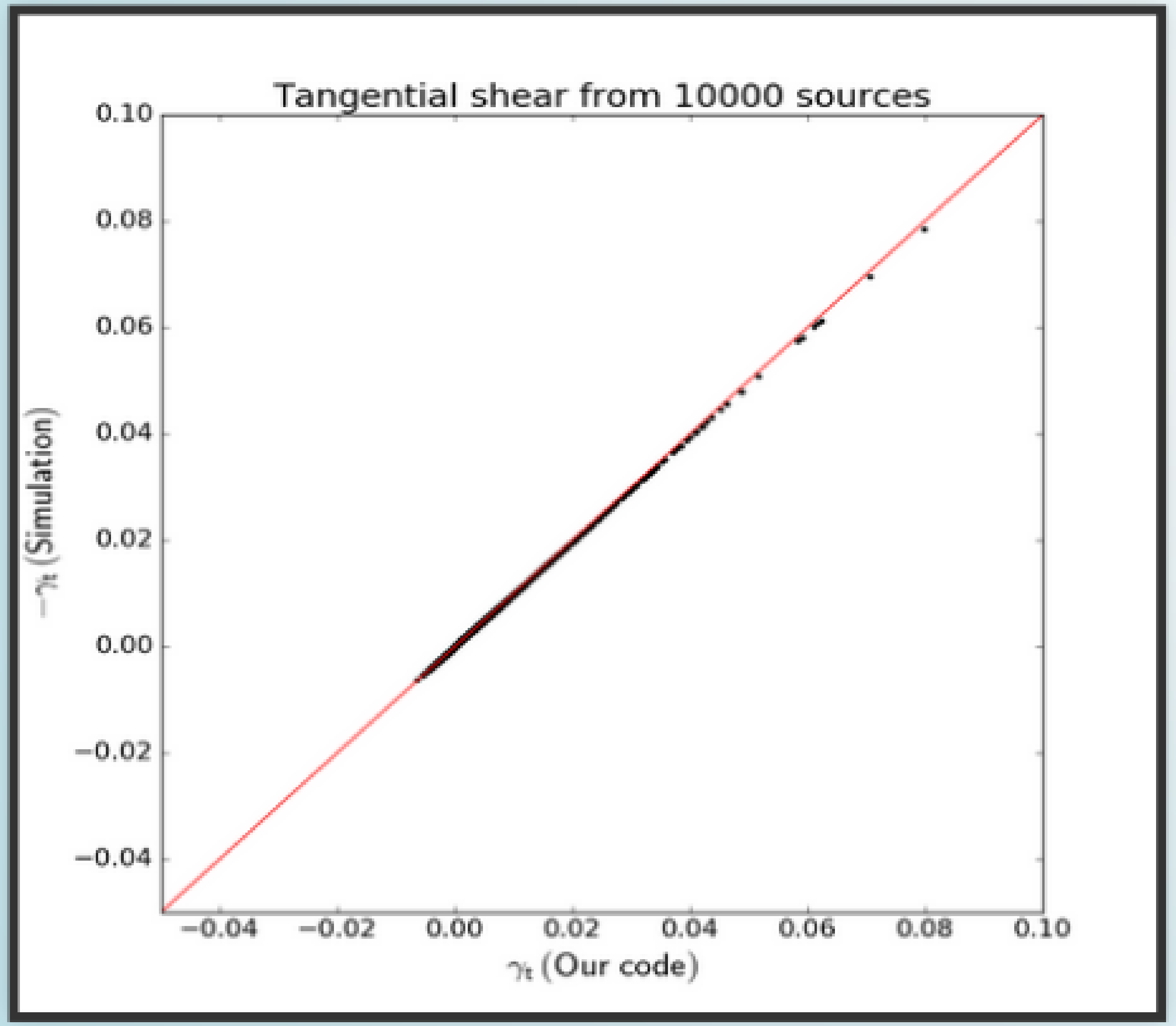
- Comparison of the xshear results with an independent code

TESTING THE WL CODES

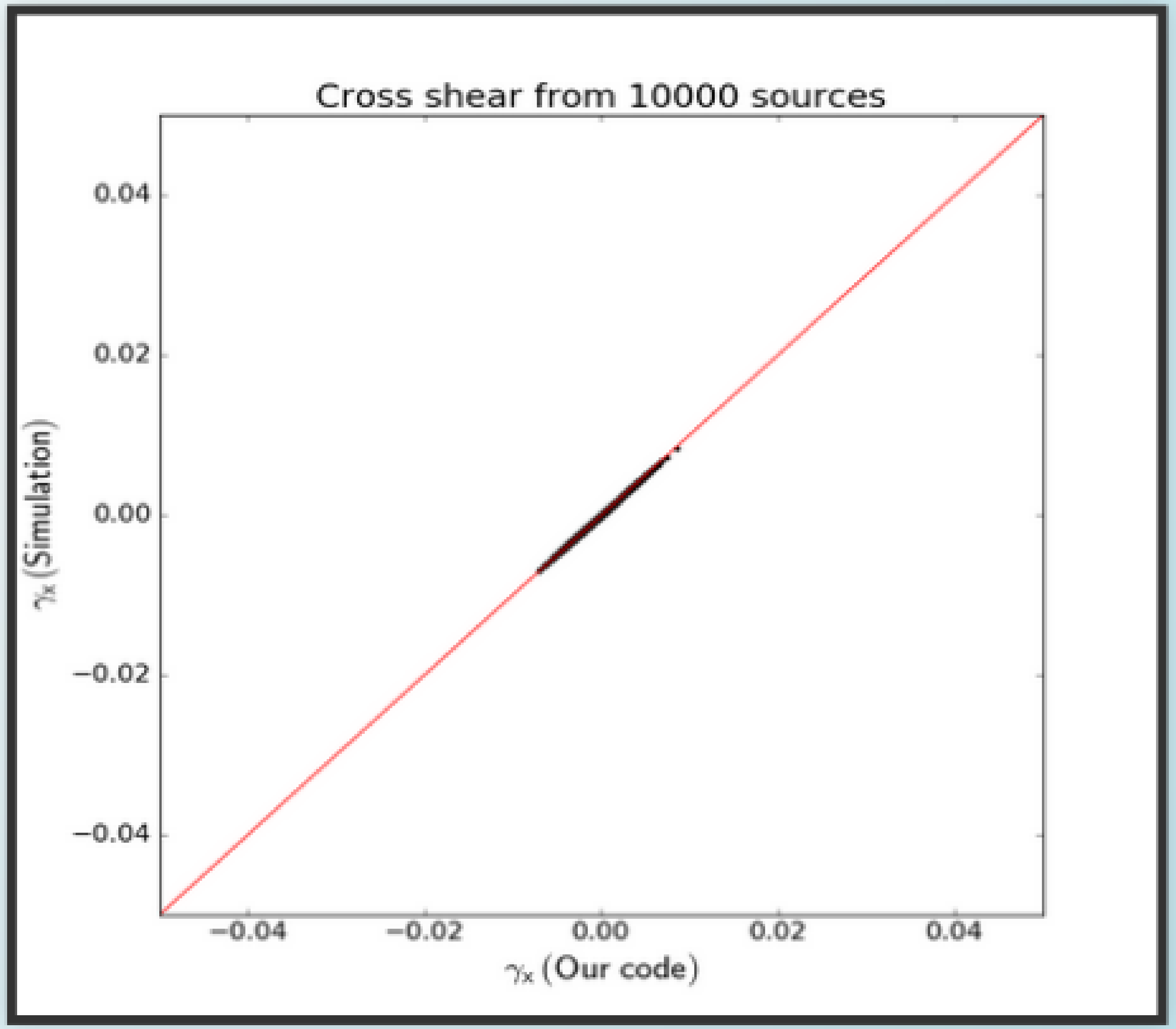
- Better way to test: simulations
- NFWsim (H. Lin): code to simulate the tangential shear according to a Navarro-Frenk-White (NFW) profile with mass M200 + gaussian noise
- NFWsim outputs: shear components (γ_1, γ_2) and tangential and cross components of the shear (γ_t, γ_x)
- Testing: $(\gamma_1, \gamma_2) \rightarrow (\gamma_t, \gamma_x) \rightarrow (\gamma_t, \gamma_x) \times \Sigma_{crit} = \Delta\Sigma$

TESTING THE WL SIGNAL FROM THE CODES

Tangential shear

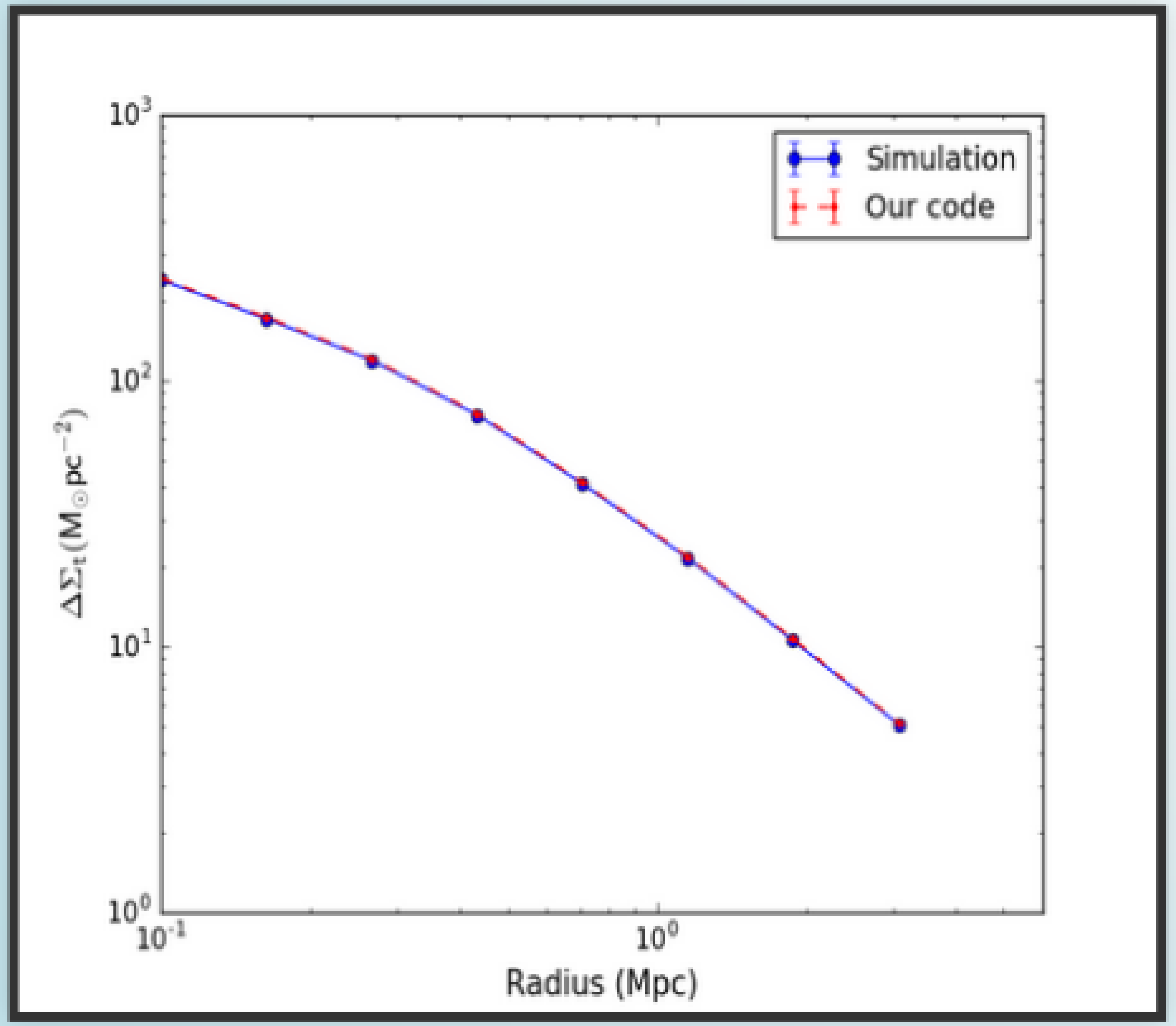


Cross shear

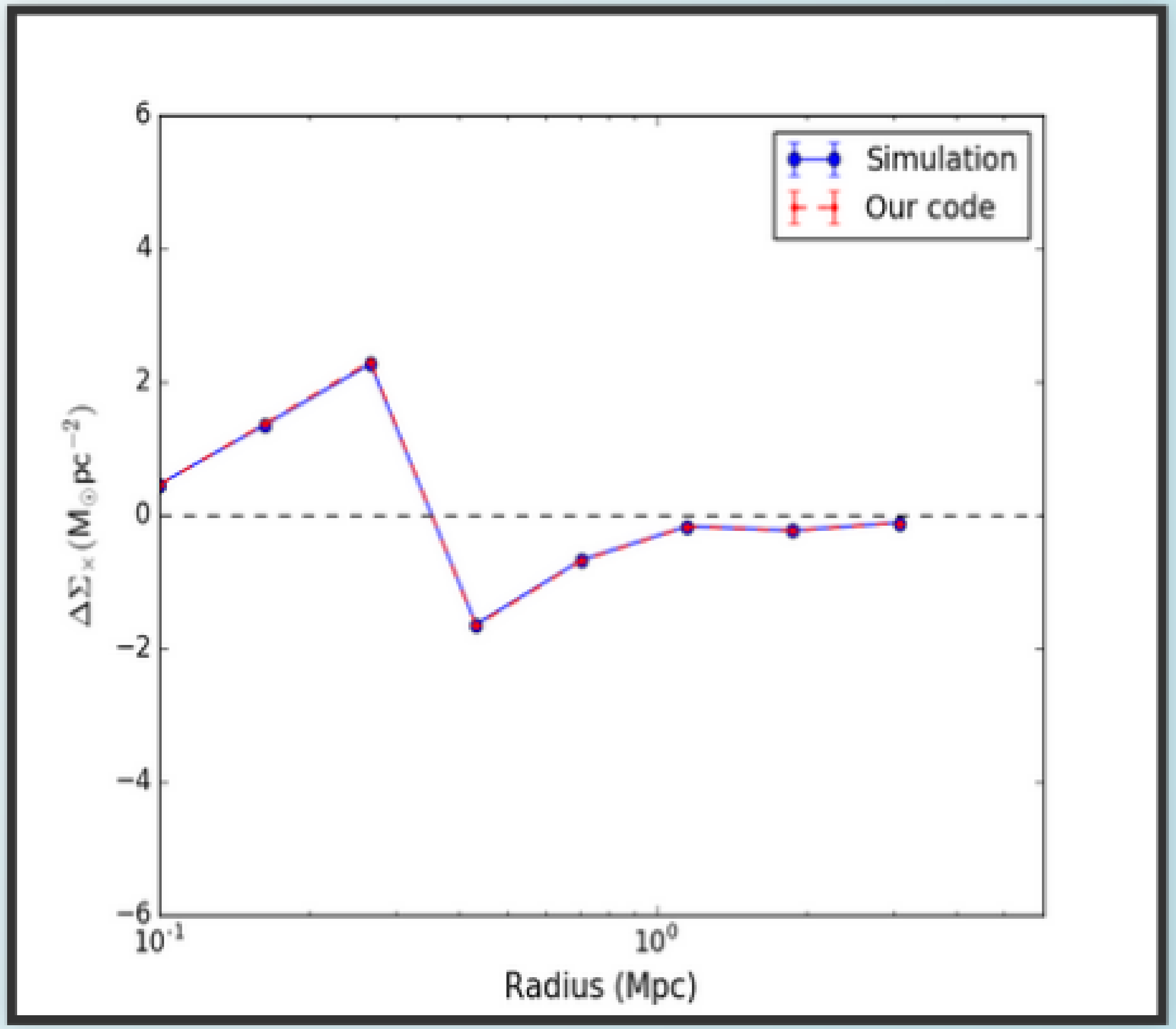


TESTING THE WL SIGNAL FROM THE CODES

ΔΣ cross



ΔΣ tangential



SUMMARY AND PERSPECTIVES

- We measured the average shear profile of two samples of galaxy clusters in low (0.2 to 0.4) and high (0.4 to 0.6) redshift using the CS82 imaging data
- We tested our codes against a set of simulations: results are encouraging!
- Next steps:
  - Detailed study of systematic effects such as miscentering, photo-z uncertainties
  - Bayesian profile fitting to determine the mass vs. richness relation
  - Test of different profiles: Einasto, BMO, etc.

THANK YOU!

QUESTIONS?

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