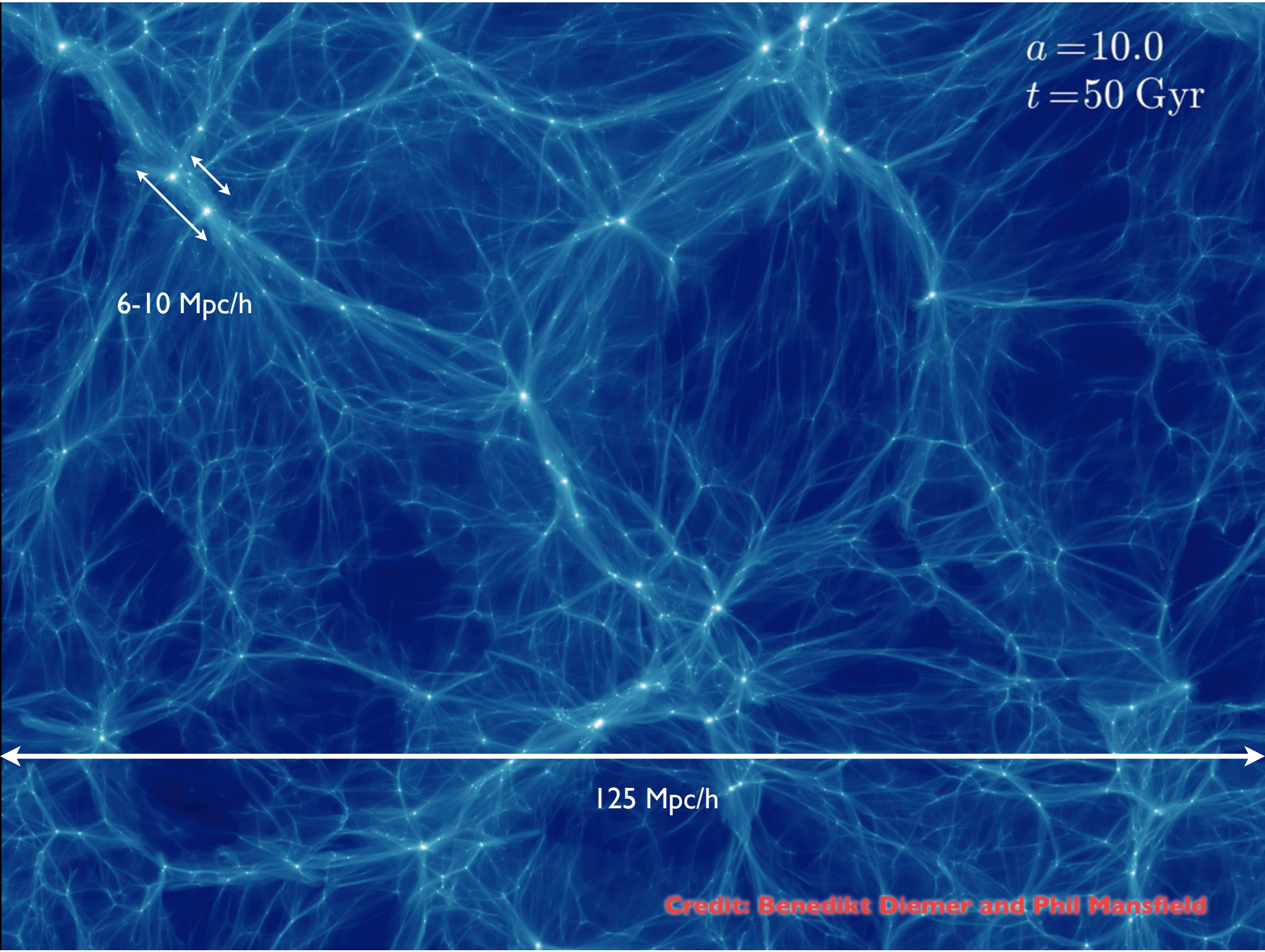
WEIGHING FILAMENTS IN THE COSMIC WEB WITH GRAVITATIONAL LENSING

OR

THE POWER OF LENSING AND SPECTROSCOPY

Mike Hudson - U. Waterloo


$a = 10.0$
$t = 50$ Gyr
6-10 Mpc/h
125 Mpc/h
Credit: Benedikt Diemer and Phil Mansfield

DARK MATTER FILAMENTS

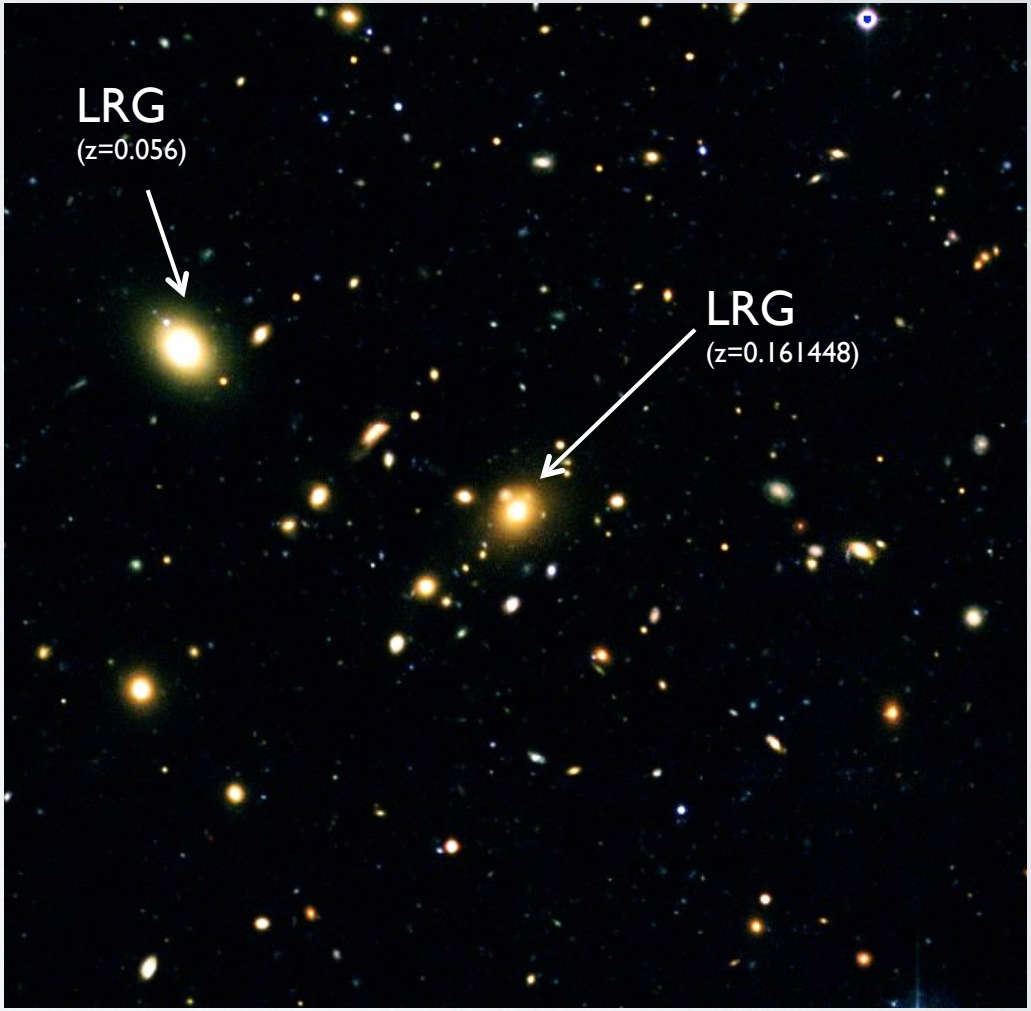
- Low density contrast structures ($\delta \sim$ few): difficult
- Some claims of detection between clusters
- Clampitt et al 4.5 σ detection between SDSS/BOSS
  - But no maps or details of structure

FINDING FILAMENTS

- Look between *physically associated* groups and clusters

  ➤ *need spectra*

- Luminous Red Galaxies (LRGs) live at the centre of rich groups $\sim 10^{13} M_{\odot}$



OBSERVATIONAL DATA

CFHT: Erben *et al.*, 2013; Hildebrandt *et al.*, 2012; Miller *et al.*, 2013; Heymans *et al.*, 2012,2013

SDSS: Eisenstein *et al.*, 2011; Dawson *et al.*, 2012

23,000
Pairs of Luminous Red Galaxies (LRGs)

$$\langle z_\ell \rangle \sim 0.4 \quad \langle \log_{10} M_\star / M_\odot \rangle \sim 11.3$$

ROTATE, RESCALE, SHIFT AND STACK

- 23000 pairs of LRGs were selected between projected separation:

$$6h^{-1}\mathrm{Mpc} \leq R_{\mathrm{sep}} < 10h^{-1}\mathrm{Mpc}$$

$$|\Delta z| < 0.002$$

ROTATE

- 23000 pairs of LRGs were selected between projected separation:

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RESCALE

- 23000 pairs of LRGs were selected between projected separation:

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SHIFT AND STACK

- 23000 pairs of LRGs were selected between projected separation:

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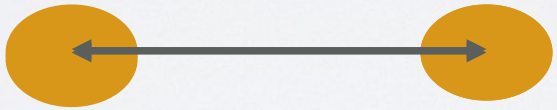
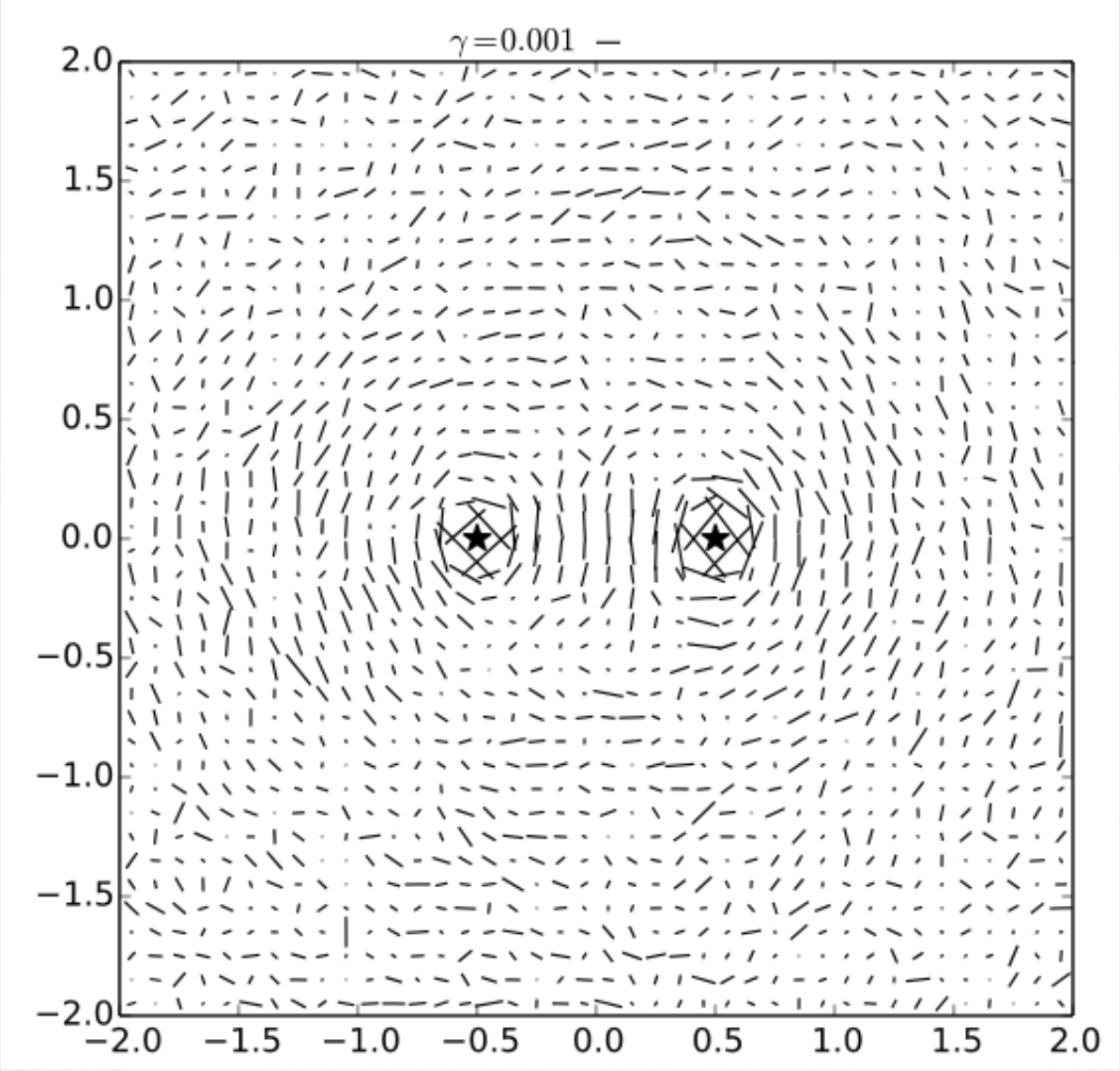
$$|\Delta z| < 0.002$$



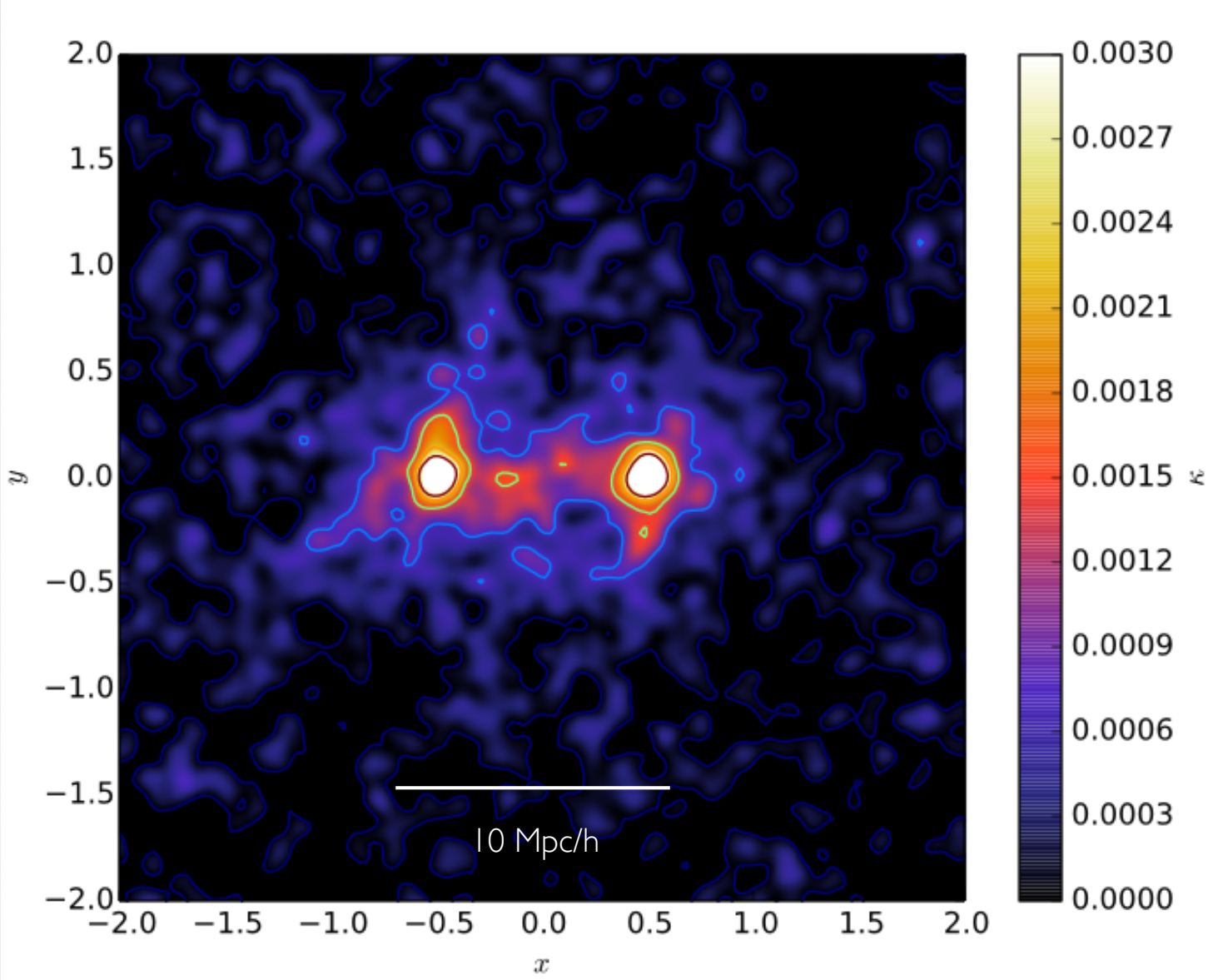
Rotate, rescale shift and stack background galaxies

RESULTING SHEAR MAP



Kaiser & Squires `93 to get convergence (surface mass density) from shears

RESULTING DENSITY MAP



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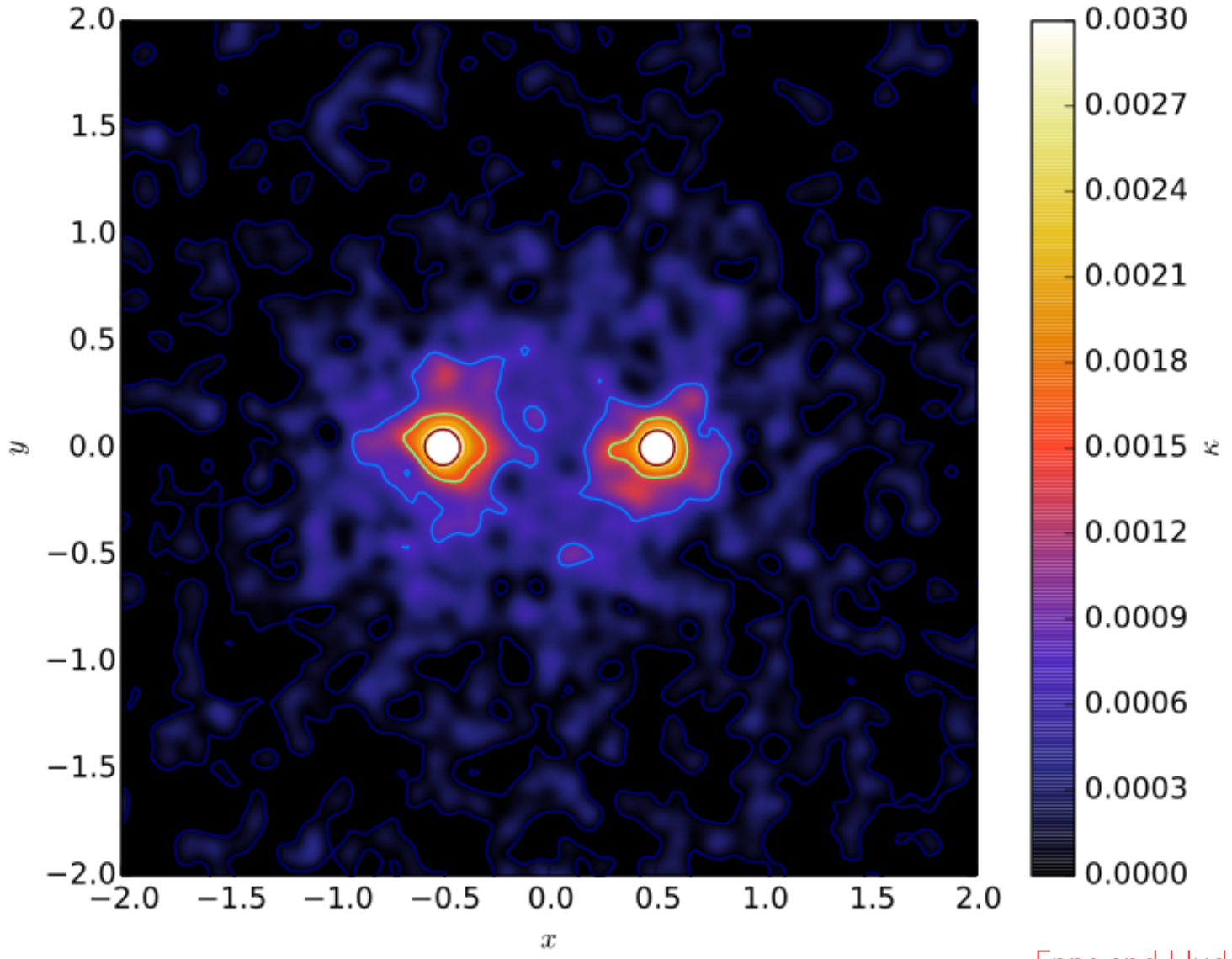
ISOLATING THE FILAMENT

- Compare signal from projected (non-physical pairs) of LRGs
- Get Empirical Estimates of Filament Mass

NON-PHYSICAL PAIRS



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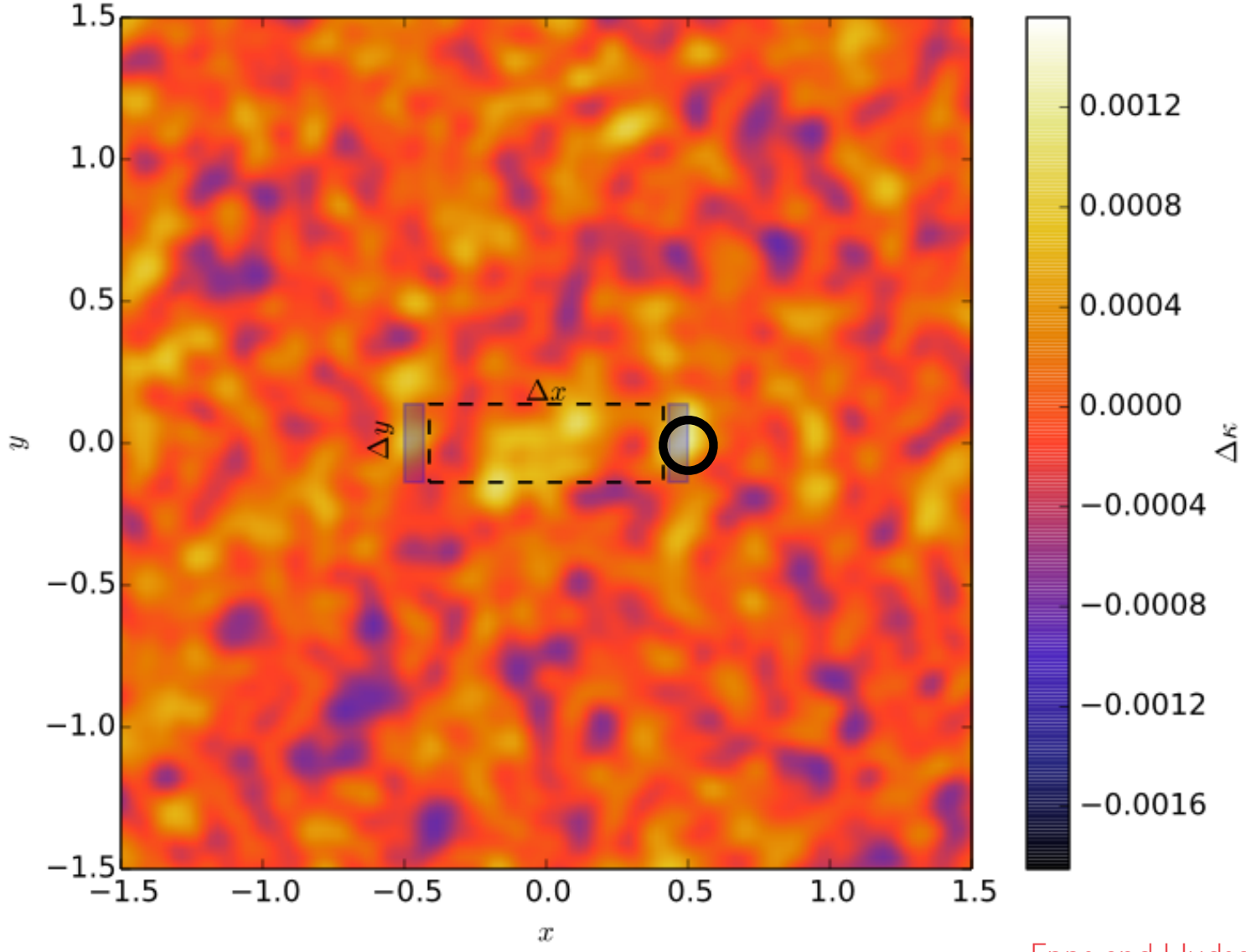
DIFFERENCE MAP



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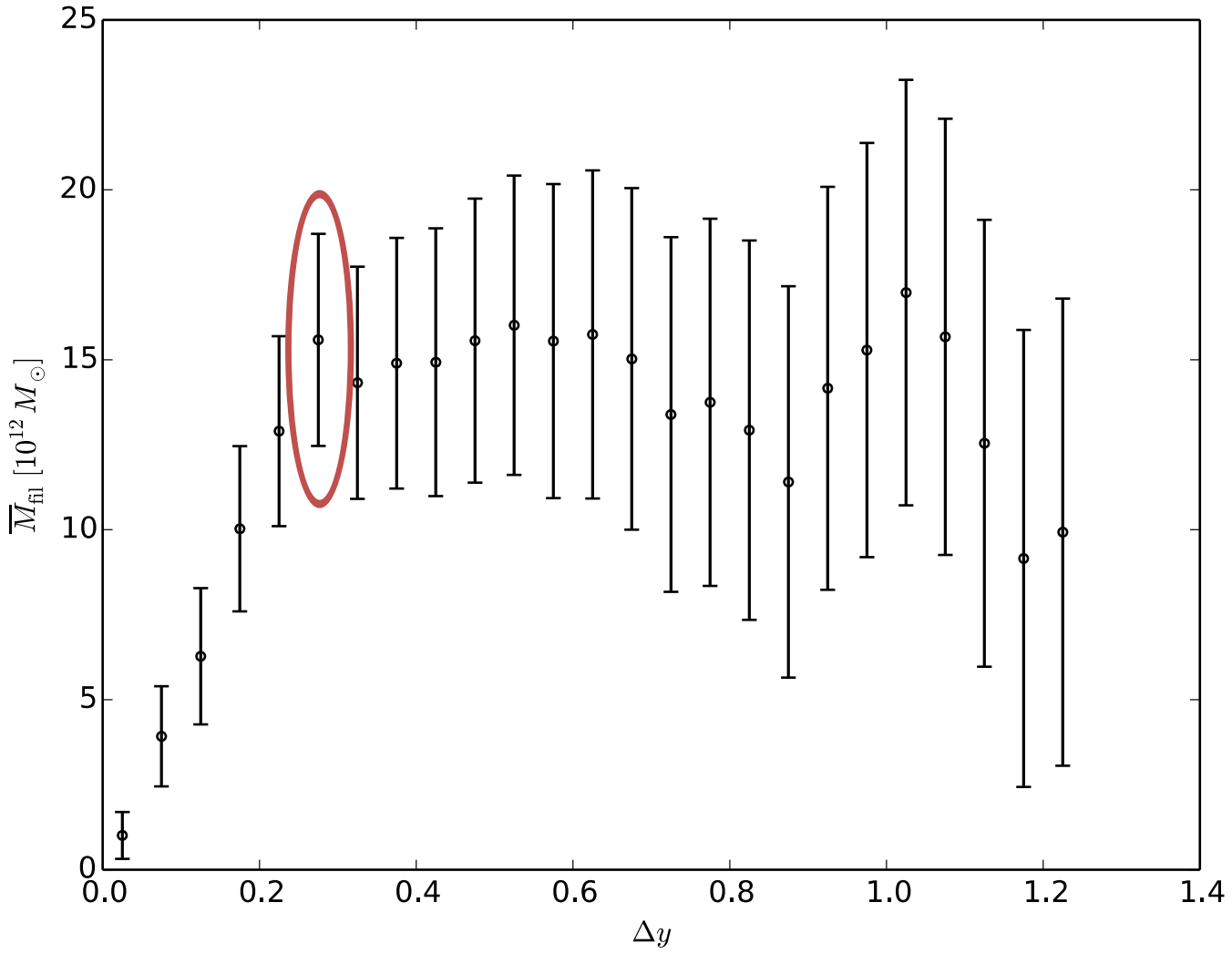
CUMULATIVE MASS ENCLOSED

$$\text{Width} \sim 2.37 h^{-1} \text{Mpc}$$

$$\overline{M}_{\text{fil}} = (1.6 \pm 0.3) \times 10^{13} M_{\odot}$$

Typical overdensity ~ 5



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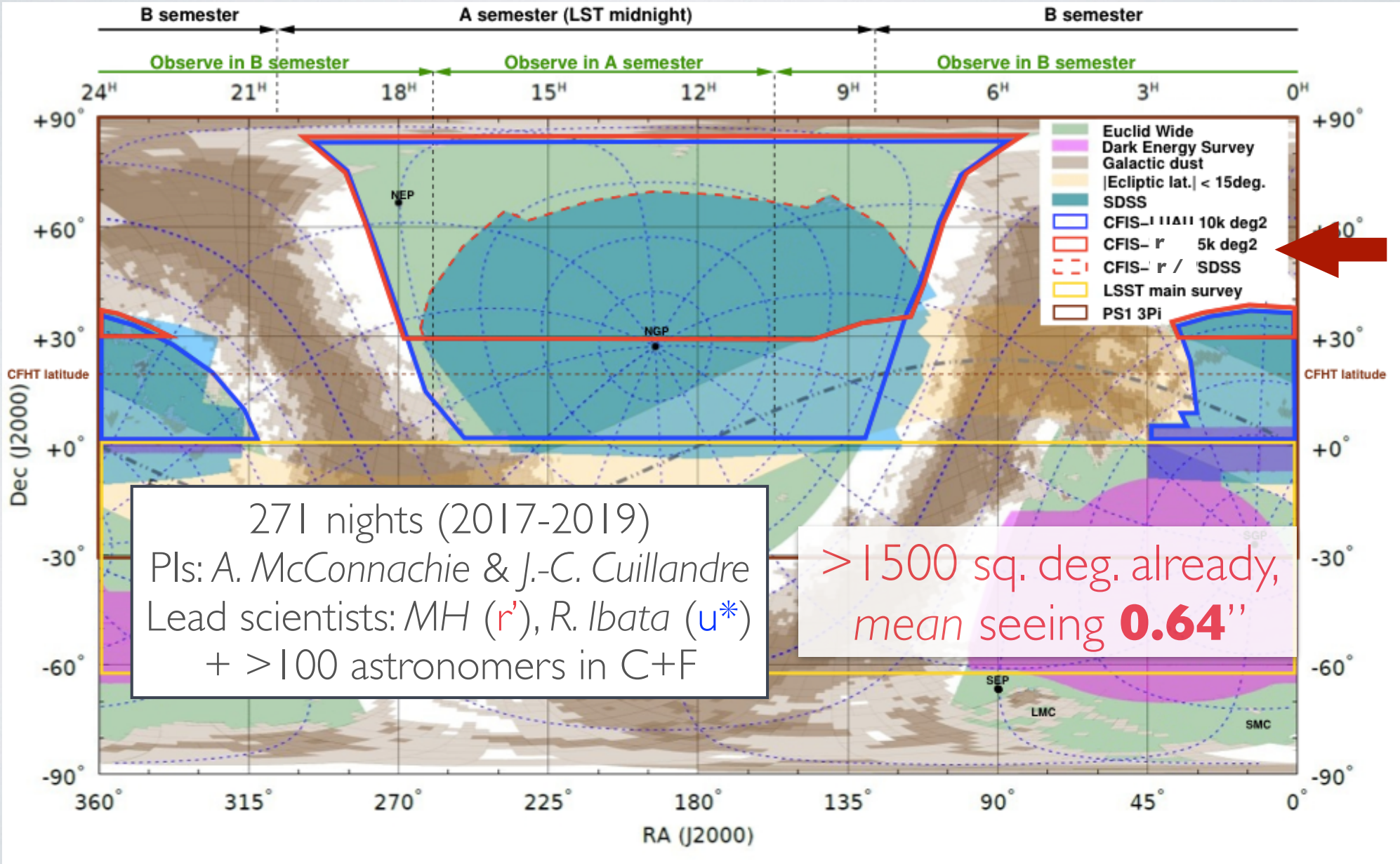
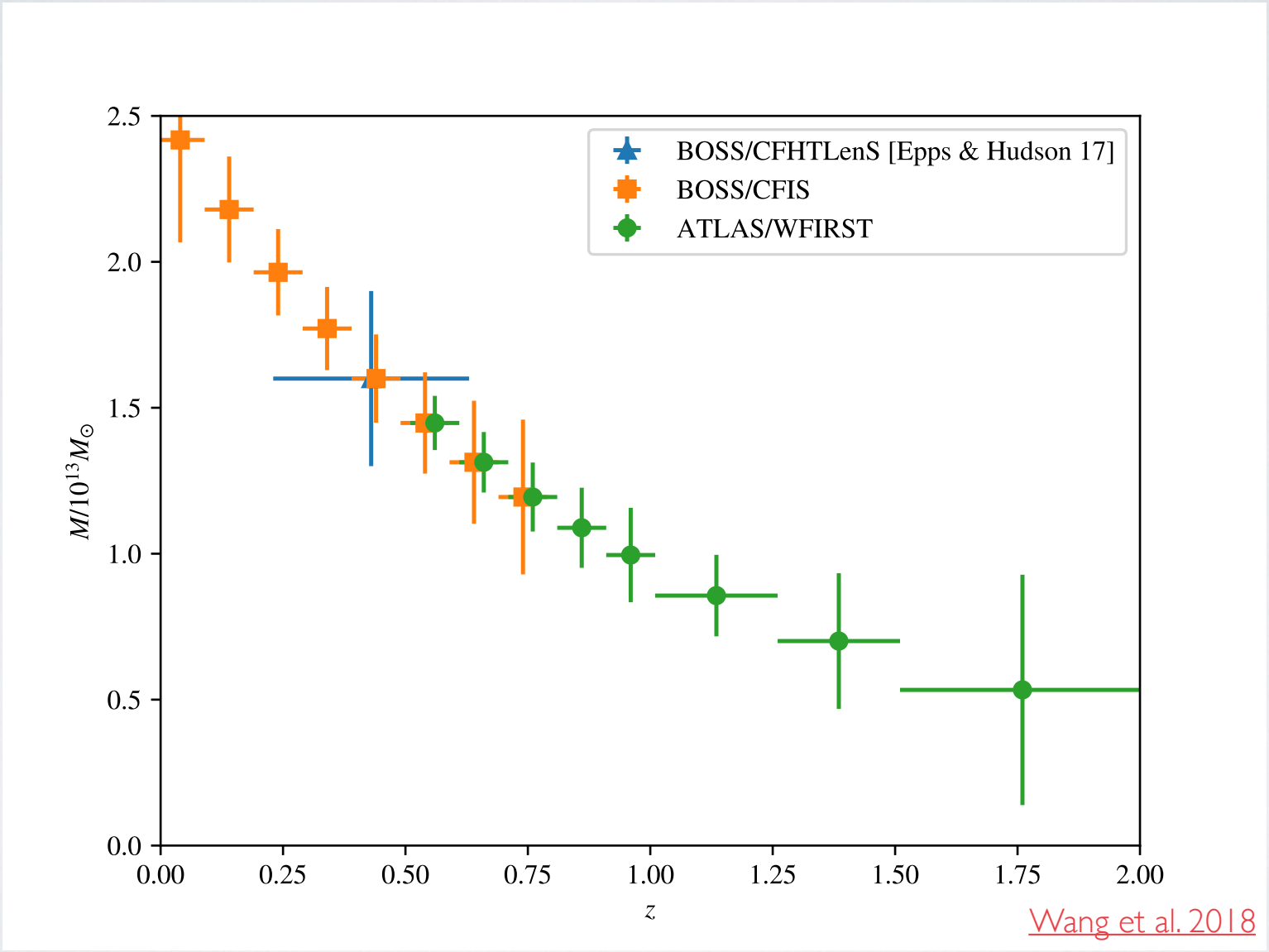
CANADA-FRANCE IMAGING SURVEY (CFIS)



271 nights (2017-2019)
PIs: *A. McConnachie* & *J.-C. Cuillandre*
Lead scientists: *MH* (r'), *R. Ibata* (u*)
+ >100 astronomers in C+F

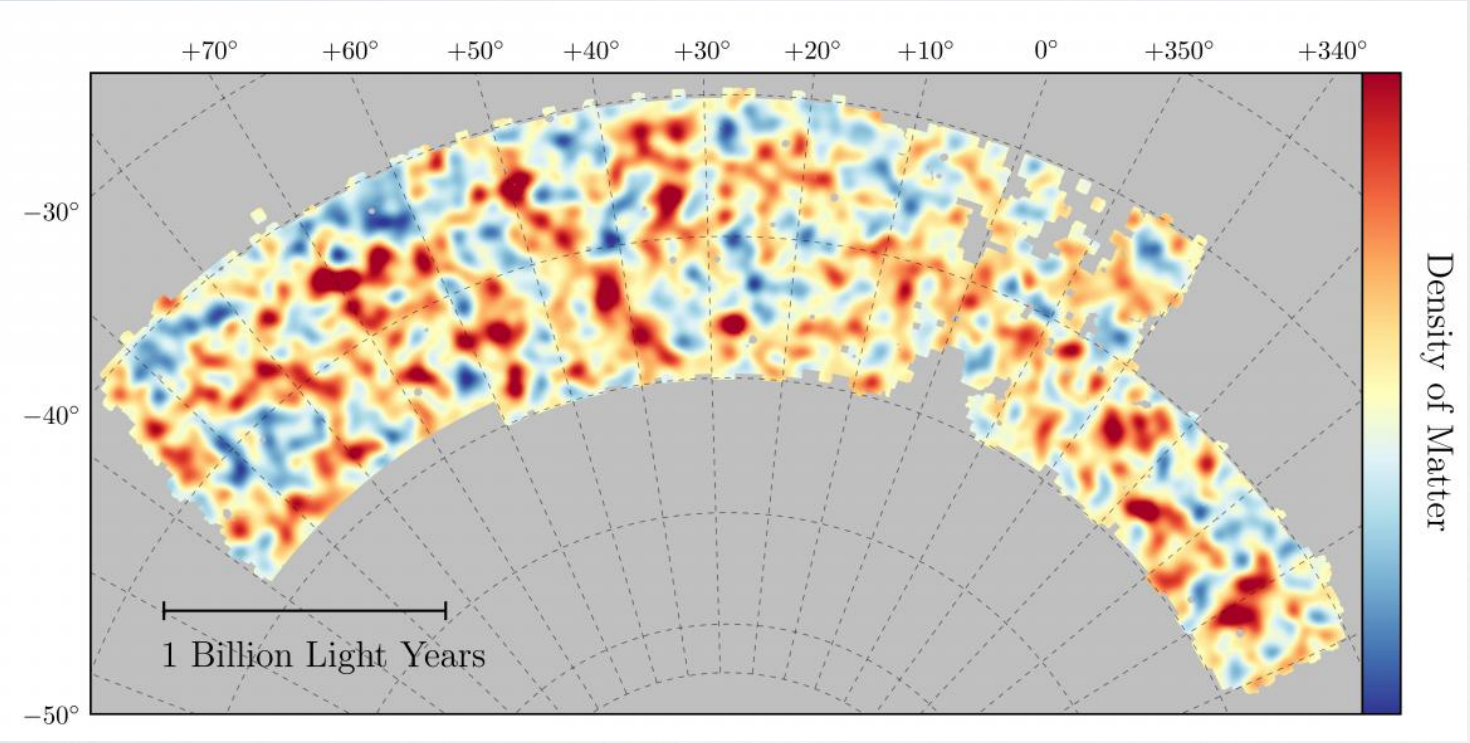
>1500 sq. deg. already,
mean seeing **0.64**''

~~CANADA FRANCE IMAGING SURVEY (CFIS)~~



Wang et al. 2018

LENSING + SPECTROSCOPY

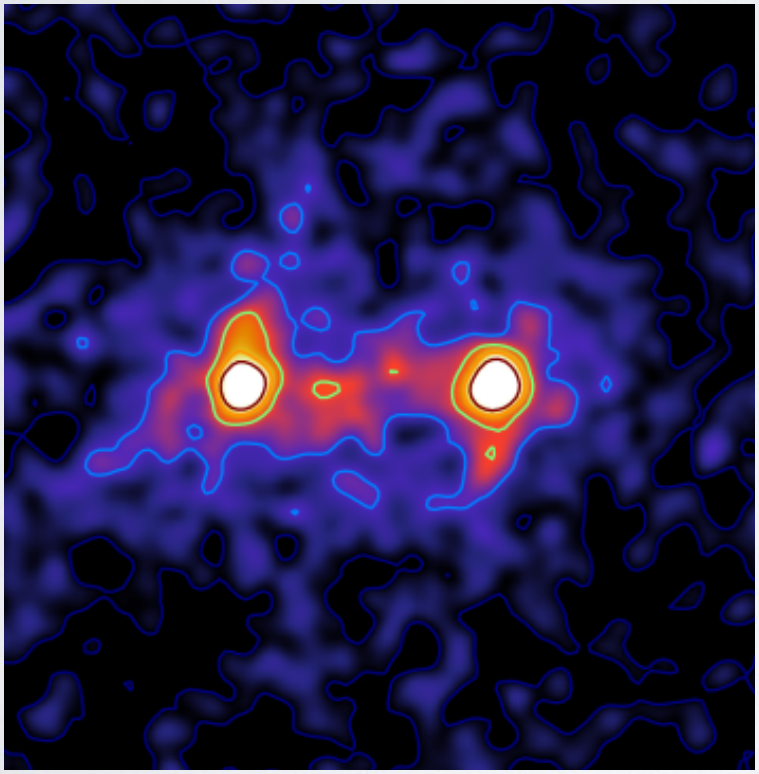


Chang et al. 18 (DES Y1)

- Mapping large-scale structure (in 3D) and cross-correlations
- Cosmic Voids
- Testing General Relativity
- Intrinsic alignments of galaxies and their DM halos with the cosmic web
- Masses and profiles of groups and clusters of galaxies
- Tidal stripping of satellite galaxy DM halos
- Stacking galaxies by their spectroscopic properties (e.g. velocity dispersion)

SUMMARY

New discoveries from combining weak lensing with spectroscopic probes of the environment



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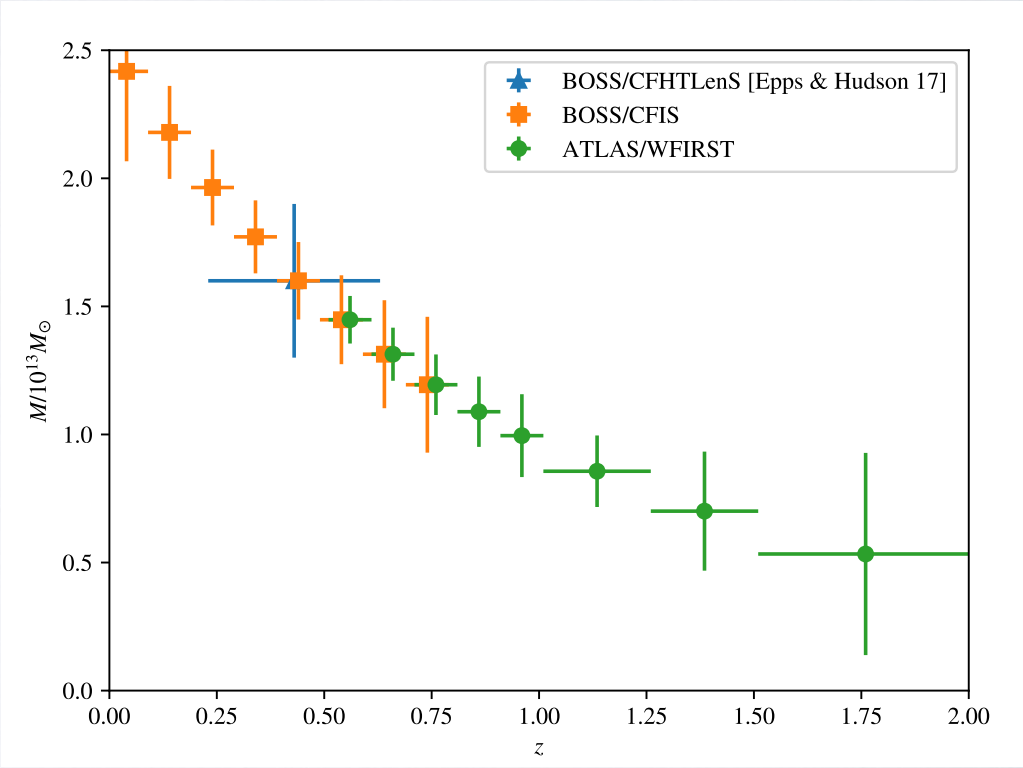

Wang et al. 2018