

Cluster Mass Reconstruction with GRALE: mass distribution within and behind MACS J0416

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GRALE basics

Flexible, free-form: does not rely on mass following light

Adaptive grid: resolution set by local mass density properties

Basis functions: projected Plummer spheres (~ 1000) + mass sheet
final mass maps include
uncertainties from lensing mass degeneracies

Search of mass model space uses a genetic algorithm:

- ✧ does not get stuck in local minima
- ✧ inspired by biological evolution
 - trial mass maps created thru' mutation and cloning
 - fittest mass maps have a higher chance of propagation

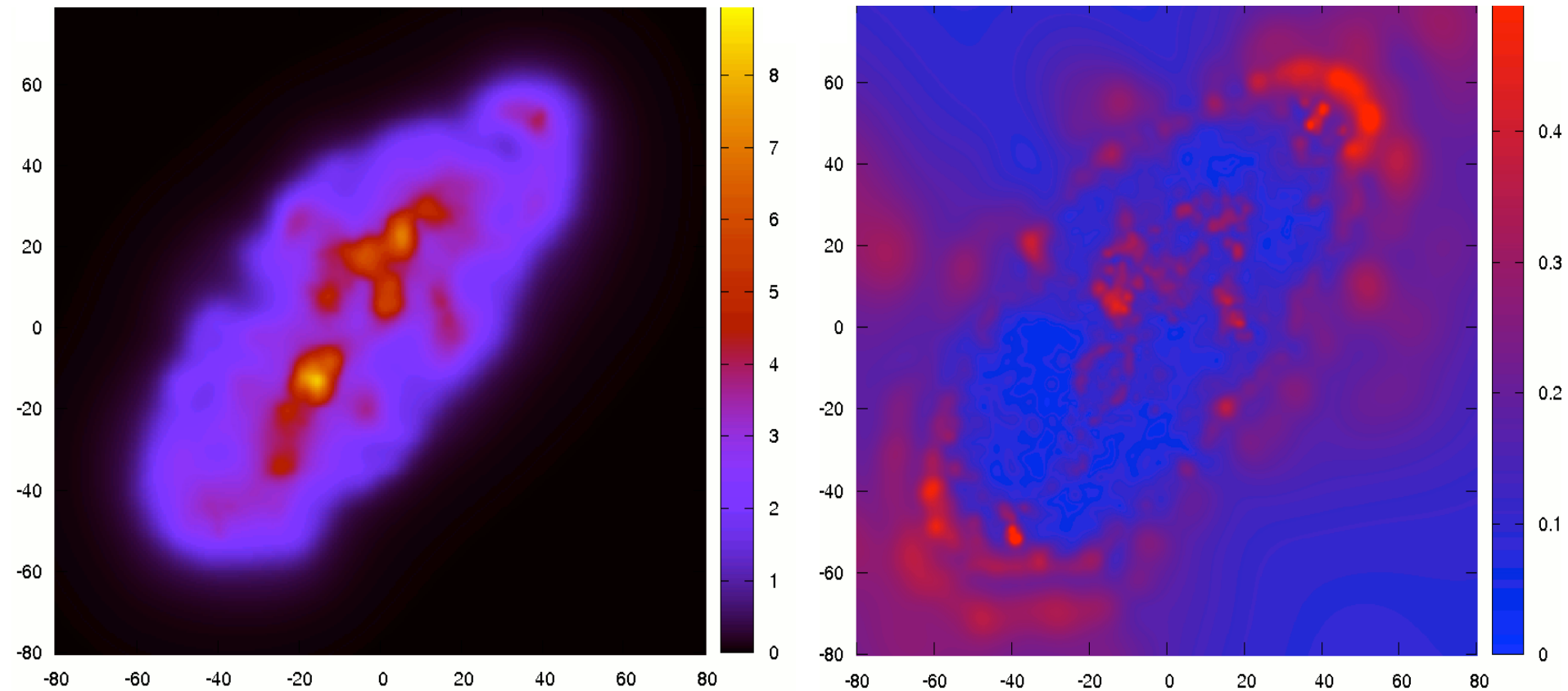
fitness determined by

- fractional overlap of sources in the source plane
not affected by magnification; no over-focusing
- null space: maps with spurious images are less fit
defined for each source separately

MACS J0416: mass reconstruction & uncertainties

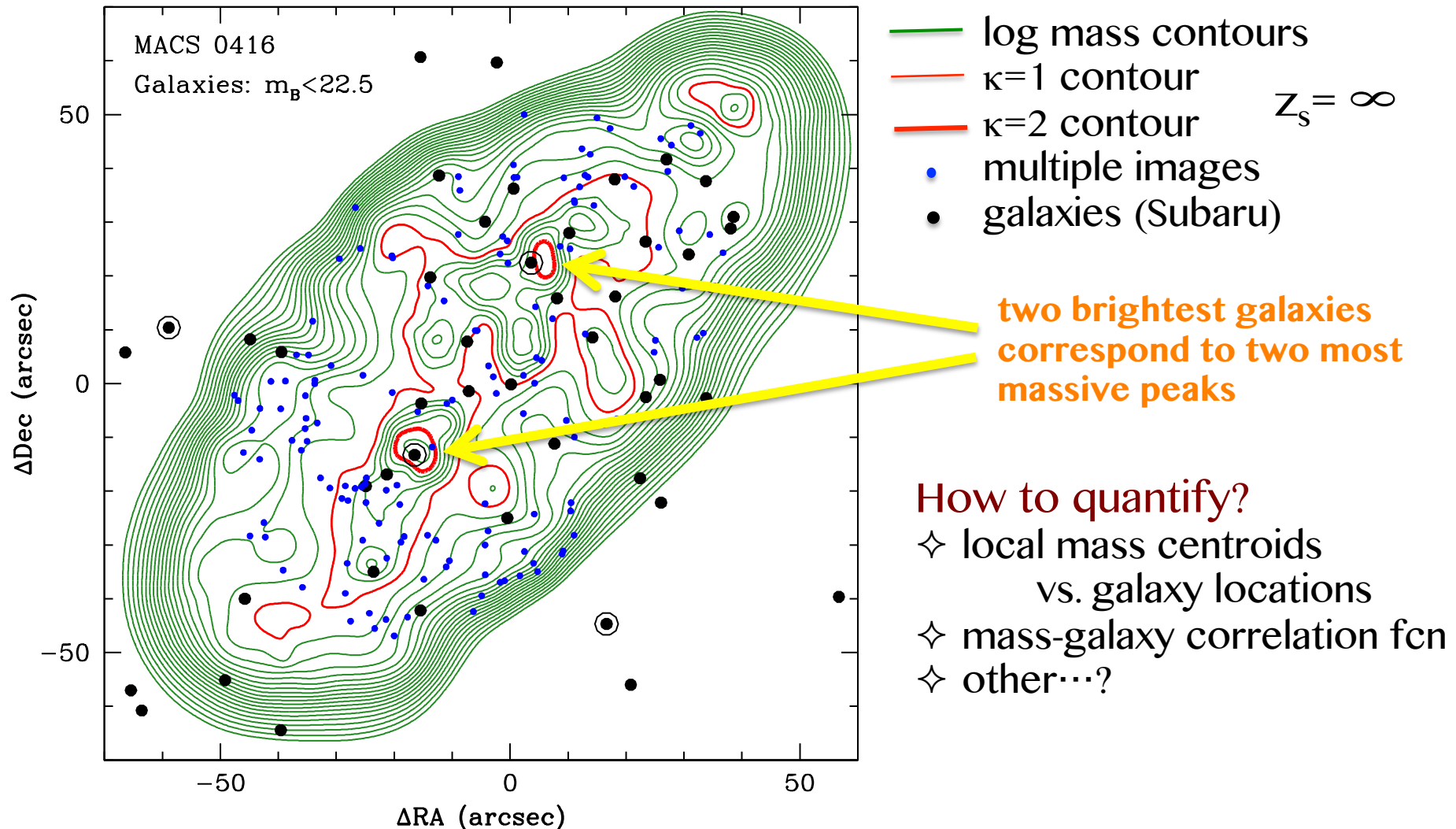
$$\text{fractional rms} = \frac{rms(\vec{x})}{\kappa(\vec{x})}$$

<30 individual reconstructions>

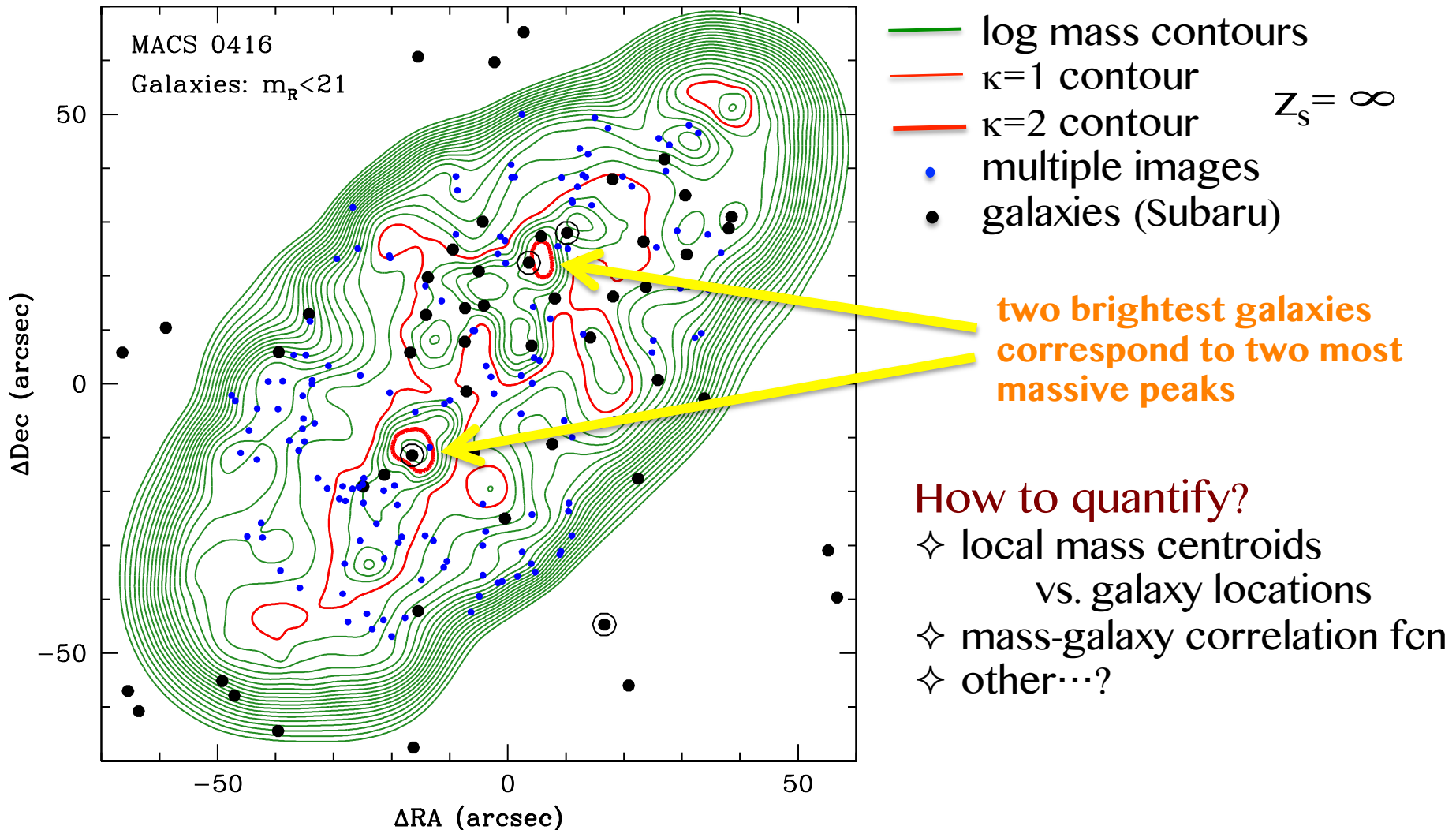


used 149 images from 57 sources (Jauzac+2014; Grillo+2014)

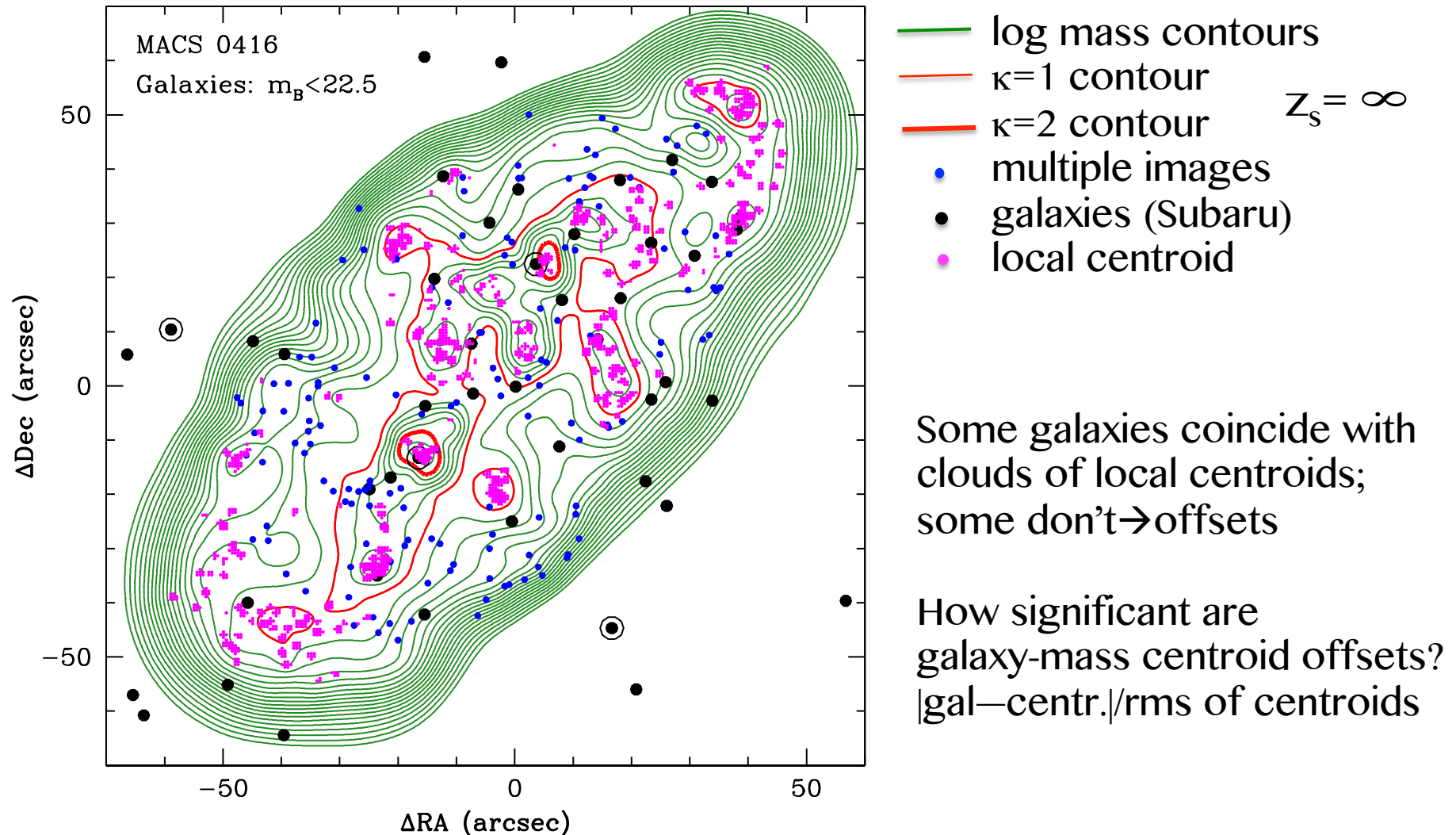
Mass distribution from strong lensing: how well does light follow mass?



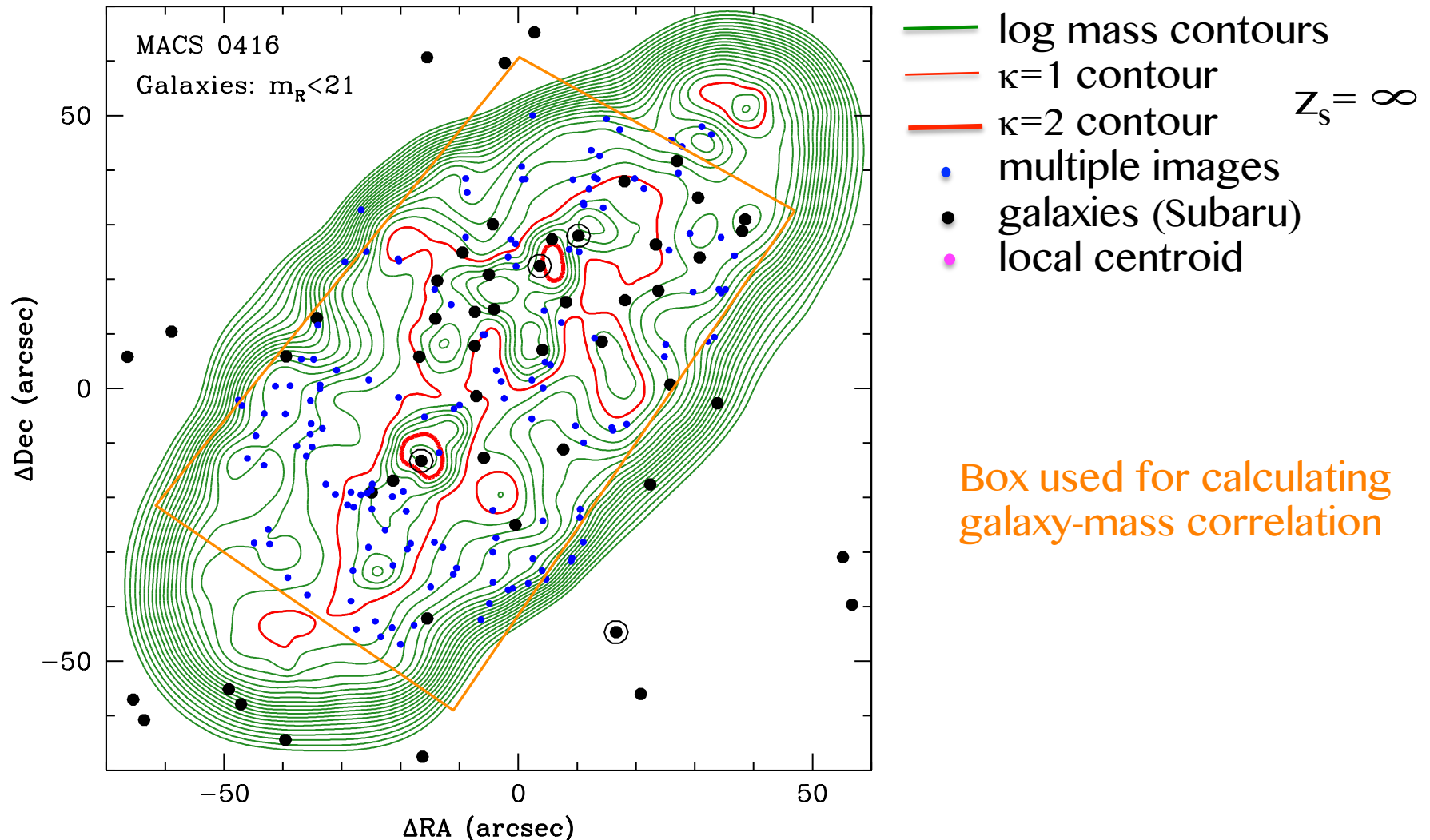
Mass distribution from strong lensing: how well does light follow mass?



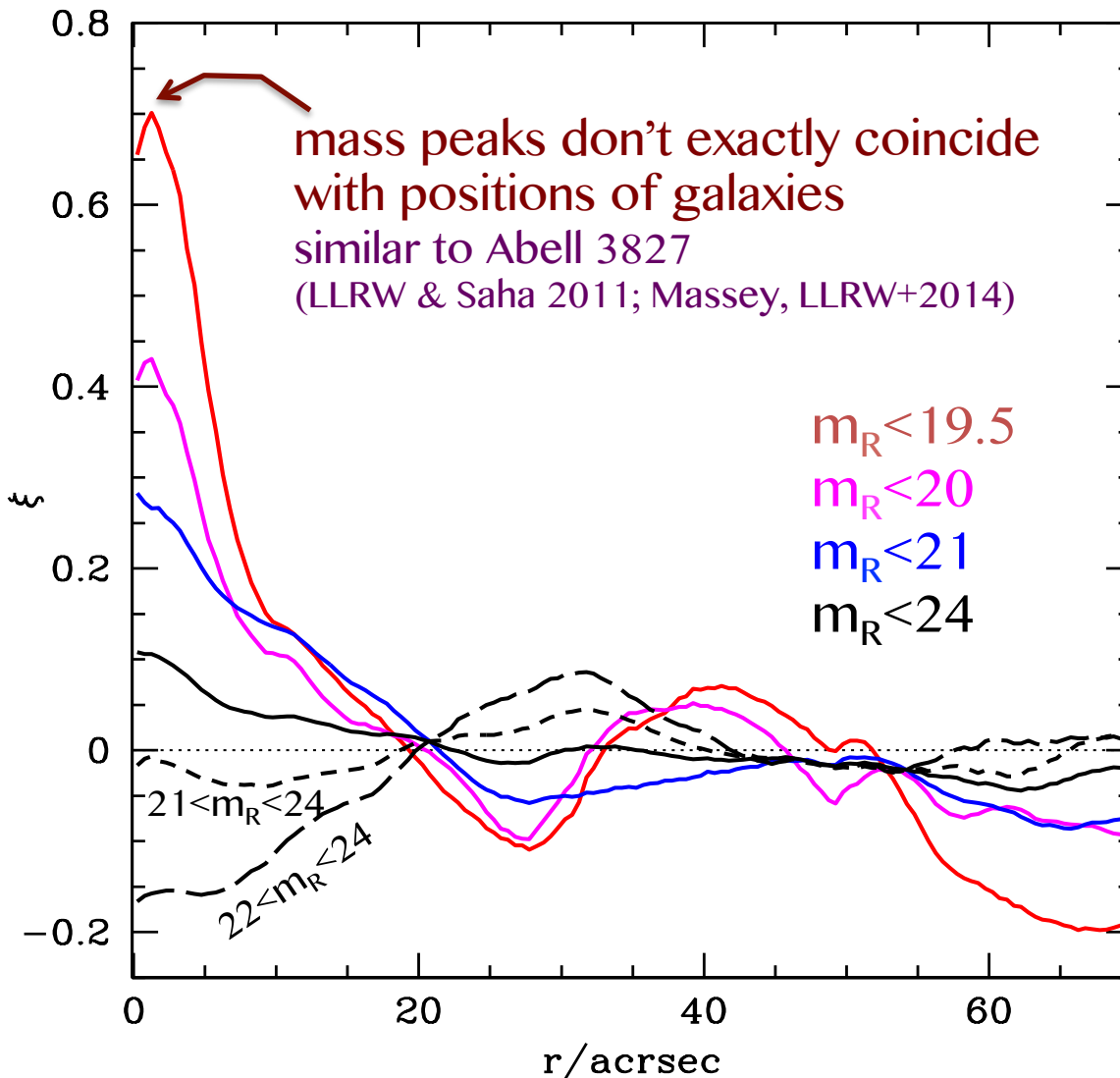
Mass distribution: local mass centroids



Mass distribution: mass-galaxy correlation function box



Mass-Galaxy Correlation



GRALE reconstruction
does not rely on galaxies

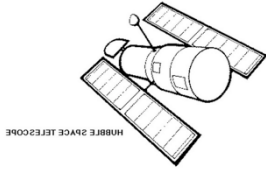
Bright galaxies
correlated with
GRALE-recovered mass

Faint galaxies $21 < m_R < 24$
not correlated with mass

Fainter galaxies $22 < m_R < 24$
anti-correlated with mass:

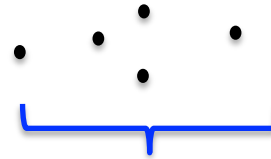
- (1) magnification bias of background galaxies ?
- (2) identification issues of faint cluster galaxies ?

Line of sight structure behind MACS 0416



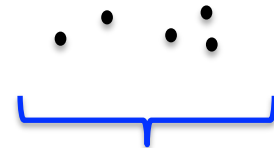
cluster
 $z=0.396$

74 images



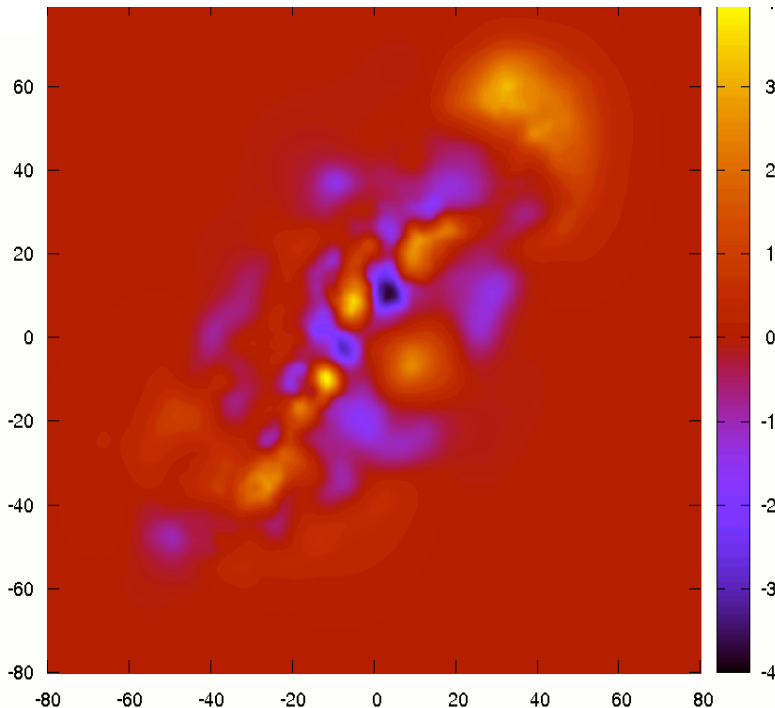
$$\Delta z1 = 1.3 \rightarrow 2.5$$

62 images



$$\Delta z2 = 2.7 \rightarrow 4.7$$

if there were no uncertainties
map values should be 0 or +ve



reconstruction
based on these
sources

reconstruction
based on these
sources

$$K_{\Delta z2} - K_{\Delta z1}$$

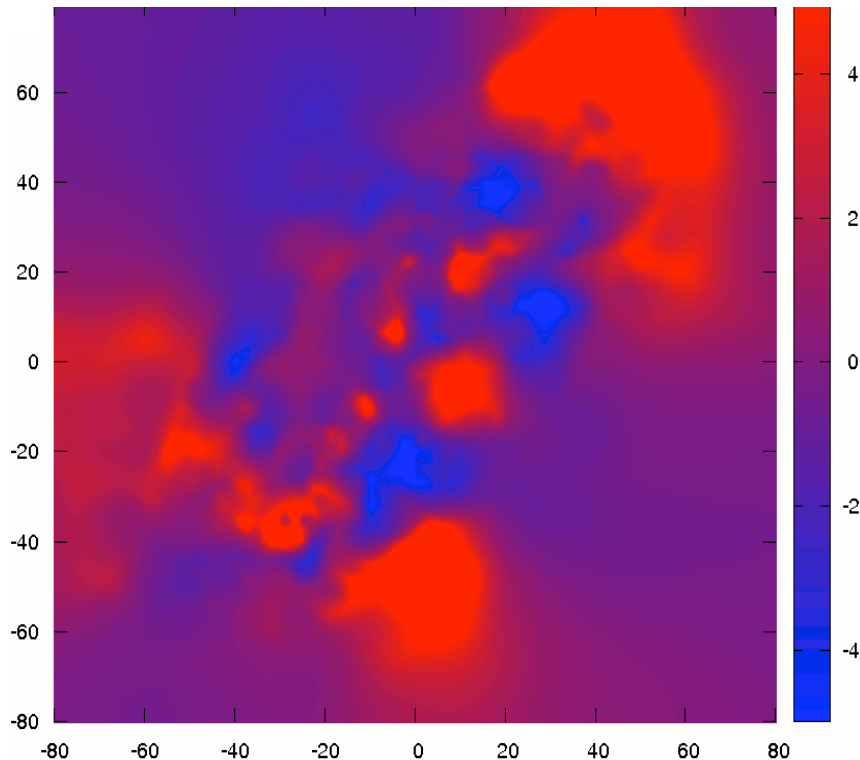


Line of sight structure behind MACS 0416

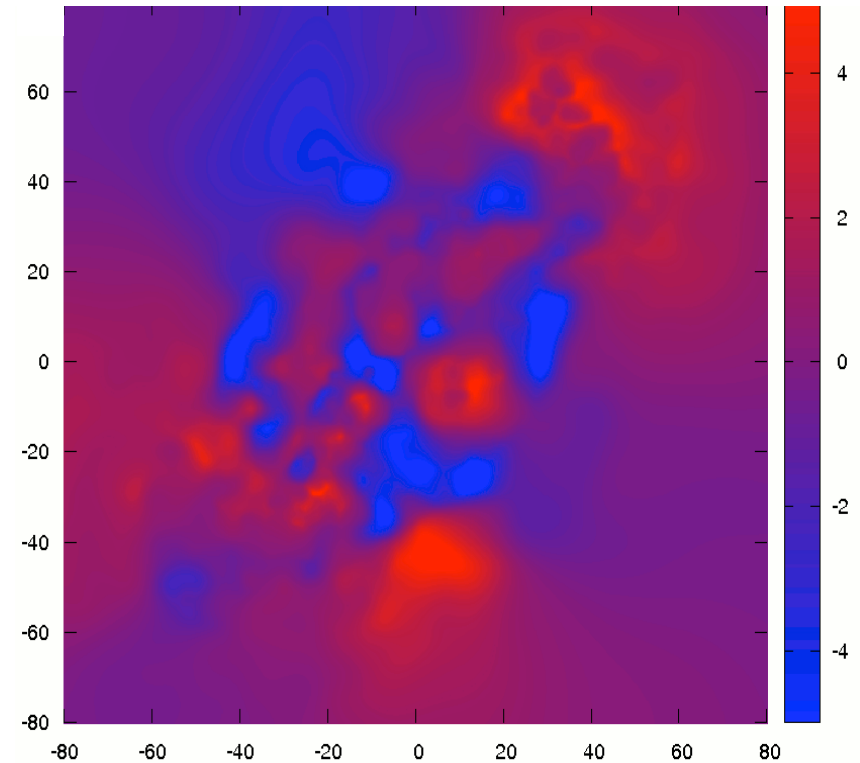
The relevant uncertainties: those associated with using disjoint image sets.

Here we use uncertainties from dispersion between individual maps within each z_{source} interval

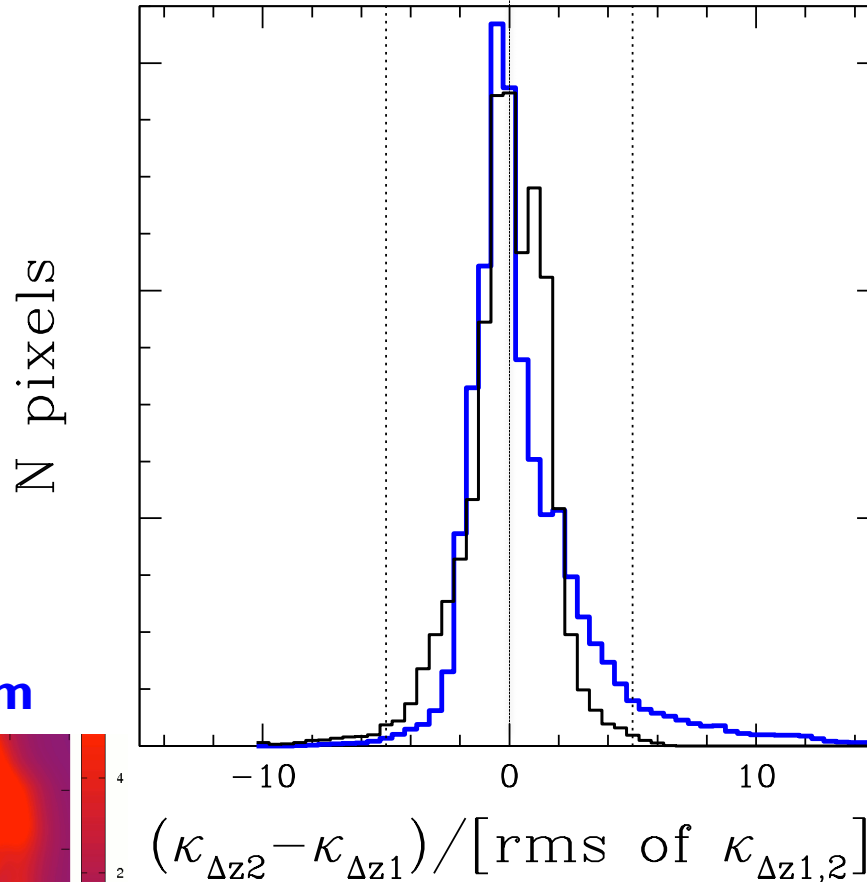
$$\frac{\kappa_{\Delta z2} - \kappa_{\Delta z1}}{\text{rms of } \Delta z1 \text{ maps}}$$



$$\frac{\kappa_{\Delta z2} - \kappa_{\Delta z1}}{\text{rms of } \Delta z2 \text{ maps}}$$

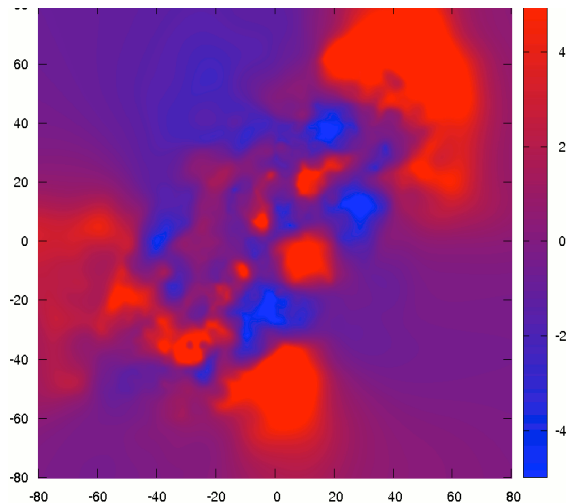


Line of sight structure behind MACS 0416

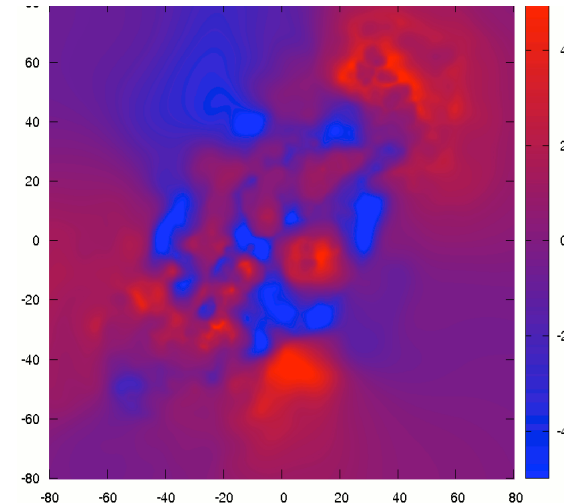


both histograms are
approx. symmetric:
no evidence for
significant los
structures at $z > 2.5$

blue histogram

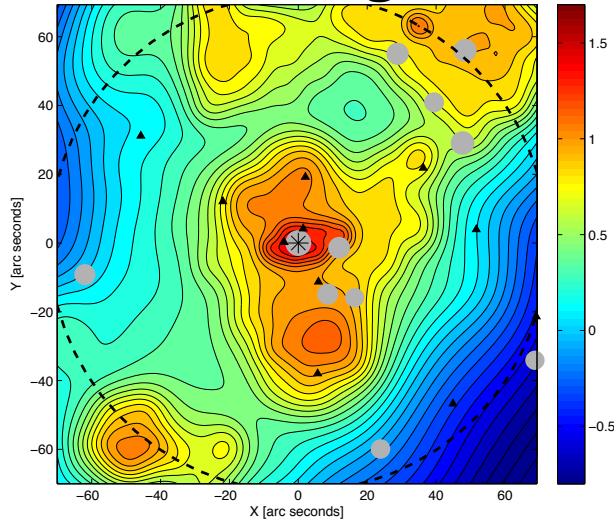


black histogram

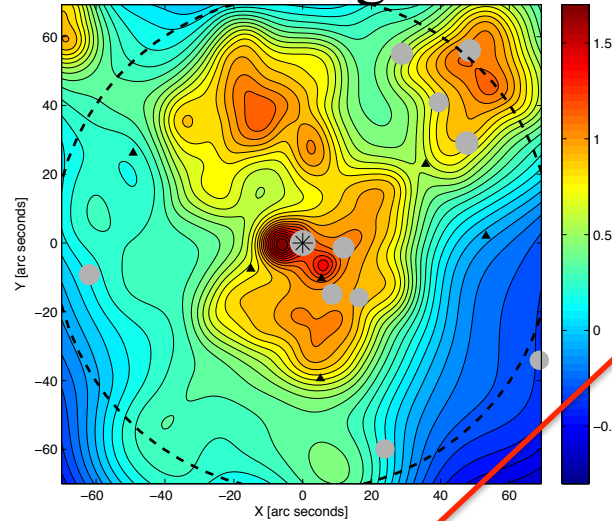


Line of sight structure behind Abell 1689

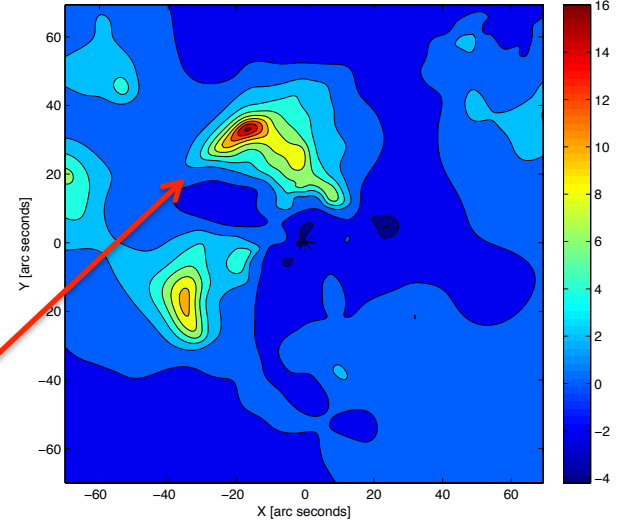
$z_s=2-2.5$
11 images



$z_s=3-4.5$
7 images



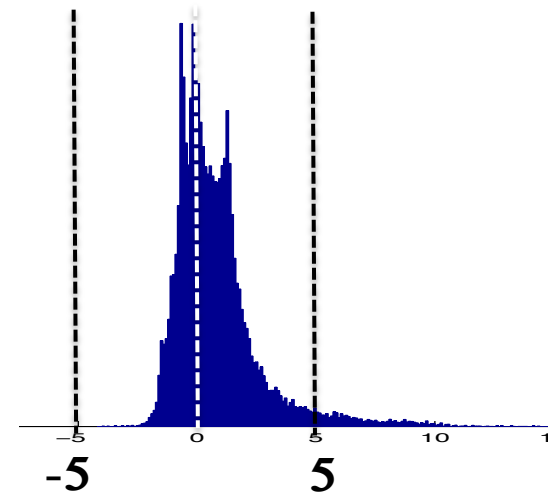
$\frac{\kappa_{\Delta z2} - \kappa_{\Delta z1}}{\text{rms of } \Delta z1 \text{ maps}}$



$z_{\text{lens}}=0.183$

Likely los structure at $z>2.5-3$;
there is nothing this prominent
in the direction of MACS J0416

Mohammed+2014



Conclusions

GRALE:

excellent tool for reconstructing mass distribution in clusters
in a free-form way

MACS0416:

Mass-galaxy correlation: strong correlation with bright galaxies
weaker correlations/anti-correlations with faint/faintest galaxies

No significant los structures behind the cluster

consistent with the fact that other reconstructions of MACS J0416
have very low lens-plane rms: 0.68" (Jauzac+2014); 0.3" (Grillo+2014)
Abell 1689 probably does have a massive los clump at $z > 2.5-3$

Future work:

a more extensive exploration of the los structures and the uncertainties
WL+SL in progress for 6 HST Frontier Field clusters
more distant future: flexion