3-D mass mapping in STAGES using 3-D lensing

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Collaborators:

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Outline

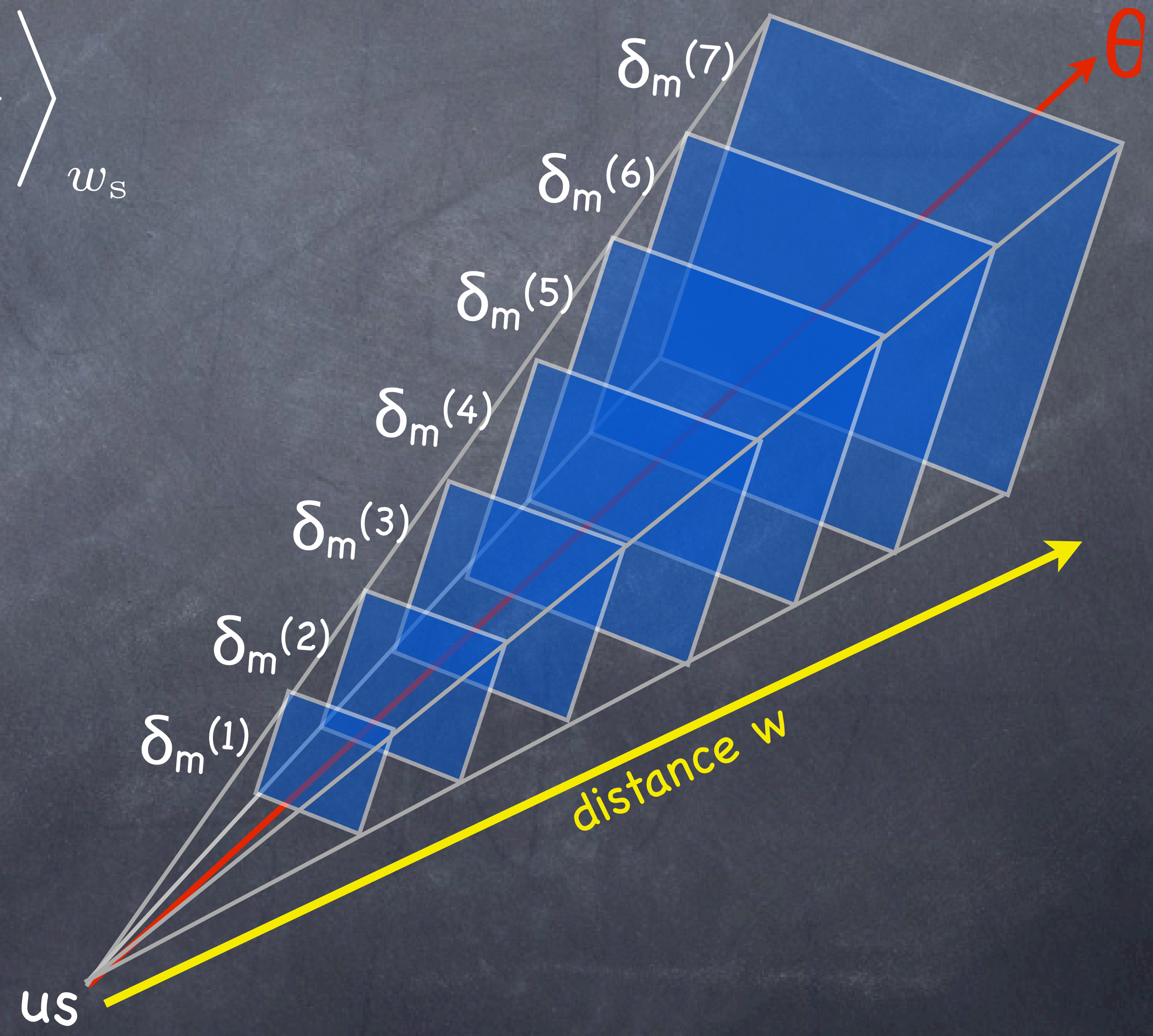
- Modified Wiener filtering of 3-D lensing data
- Radial debiasing and cleaning of map
- Data sample: STAGES
- A mass map vs. light map comparison
- Conclusions

Weak lensing on a grid

- Lensing convergence = projected matter fluctuations

$$\kappa(\theta) = \frac{3H_0^2\Omega_\mathrm{m}}{2c^2}\int_0^\infty \mathrm{d}w\,\frac{W(w)f_\mathrm{k}(w)}{a(w)}\delta_\mathrm{m}(f_\mathrm{k}(w)\theta, w)$$

$$W(w_\mathrm{l}) = \left\langle \frac{f_\mathrm{k}(w_\mathrm{s}-w_\mathrm{l})}{f_\mathrm{k}(w_\mathrm{s})} \right\rangle_{w_\mathrm{s}}$$



Weak lensing on a grid

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- Chop 3-D volume into slices of constant matter density

$$\kappa(\theta) \approx \sum_{i=1}^{N_\mathrm{lp}} Q_i \delta_\mathrm{m}^{(i)}(\theta) \;\;,\;\; Q_i = \frac{3H_0^2\Omega_\mathrm{m}}{2c^2}\int_{w_i}^{w_{i+1}} \mathrm{d}w\,\frac{W(w)f_\mathrm{k}(w)}{a(w)}$$

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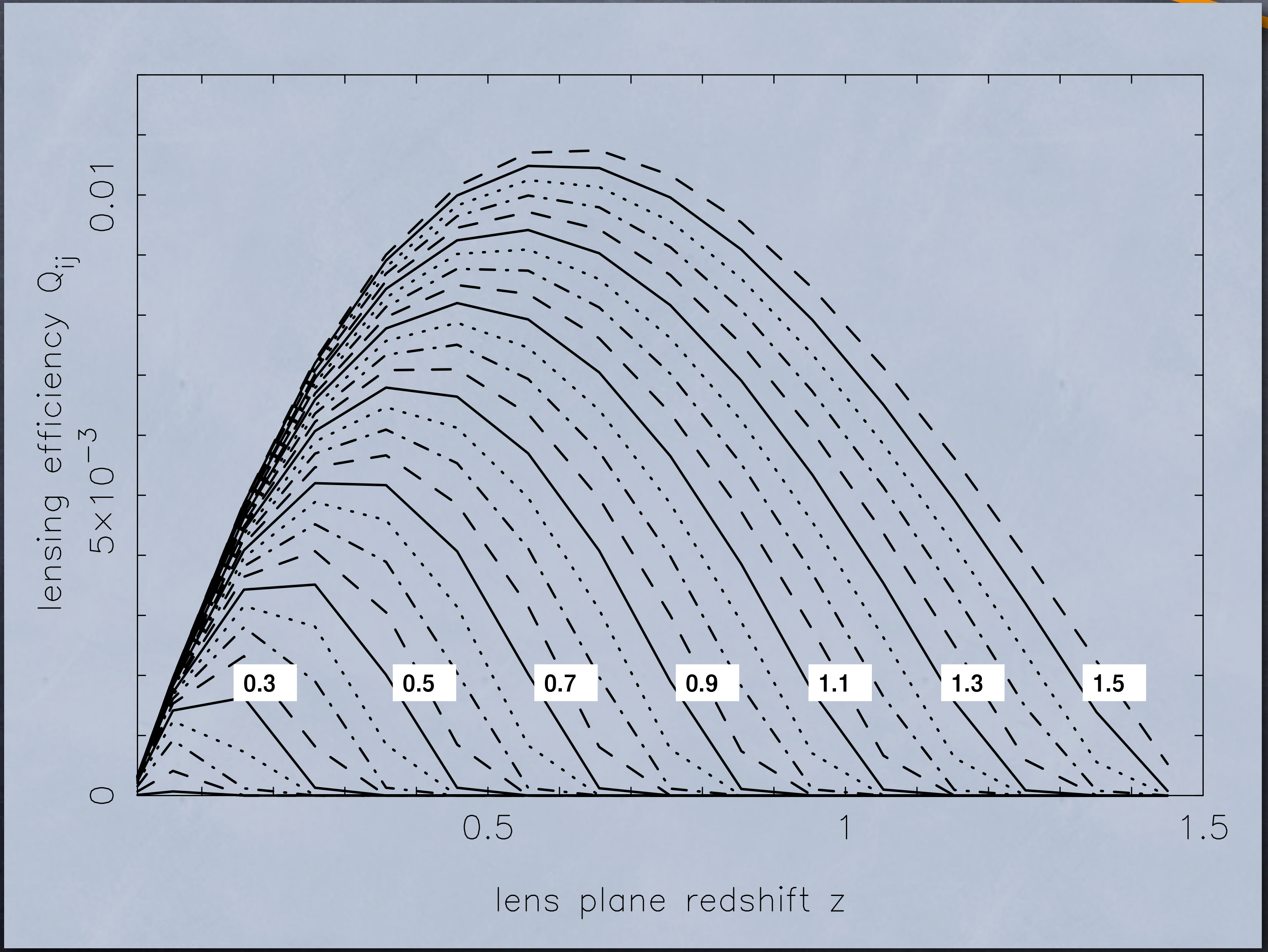
- On a grid we may therefore write

$$\gamma = \mathrm{P}_{\gamma\kappa}\,\kappa = \mathrm{P}_{\gamma\kappa}\mathrm{Q}\,\delta_\mathrm{m}$$

Wiener filter of 3-D lensing data

- Combine all "source redshift bins" into one vector

$$\gamma \equiv \left(\gamma^{(1)}, \gamma^{(2)}, \dots\right) = \mathrm{P}_{\gamma\kappa}\left(\mathrm{Q}^{(1)}, \mathrm{Q}^{(2)}, \dots\right)\delta_{\mathrm{m}} \equiv \mathrm{P}_{\gamma\kappa}\mathrm{Q}\delta_{\mathrm{m}}$$



different z-bins

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- Need to find solution for δ_{m} for given cosmic shear:

$$\epsilon = \mathrm{P}_{\gamma\kappa} \mathrm{Q}\, \delta_{\mathrm{m}} + \mathbf{n}$$

shape noise

Source ellipticities binned on grid

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- Minimum variance solution for δ

$$\delta_{\mathrm{m}}^{\mathrm{mv}} = \mathbf{S}\mathbf{Q}^{\mathrm{t}}\mathbf{P}_{\gamma\kappa}^{\dagger} \left[\mathbf{N}^{-1}\mathbf{P}_{\gamma\kappa}\mathbf{Q}\mathbf{S}\mathbf{Q}^{\mathrm{t}}\mathbf{P}_{\gamma\kappa}^{\dagger} + \alpha \mathbf{1}\right]^{-1} \mathbf{N}^{-1} \epsilon$$

$\mathbf{S} \equiv \langle \delta_{\mathrm{m}} \delta_{\mathrm{m}}^{\mathrm{t}} \rangle$ signal covariance $\mathbf{N} \equiv \langle \mathbf{n}\mathbf{n}^{\dagger} \rangle$ noise covariance

Simon, P., Taylor, A.N., Hartlap, J., 2009, MNRAS, 399, 48

Wiener filter of 3-D lensing data

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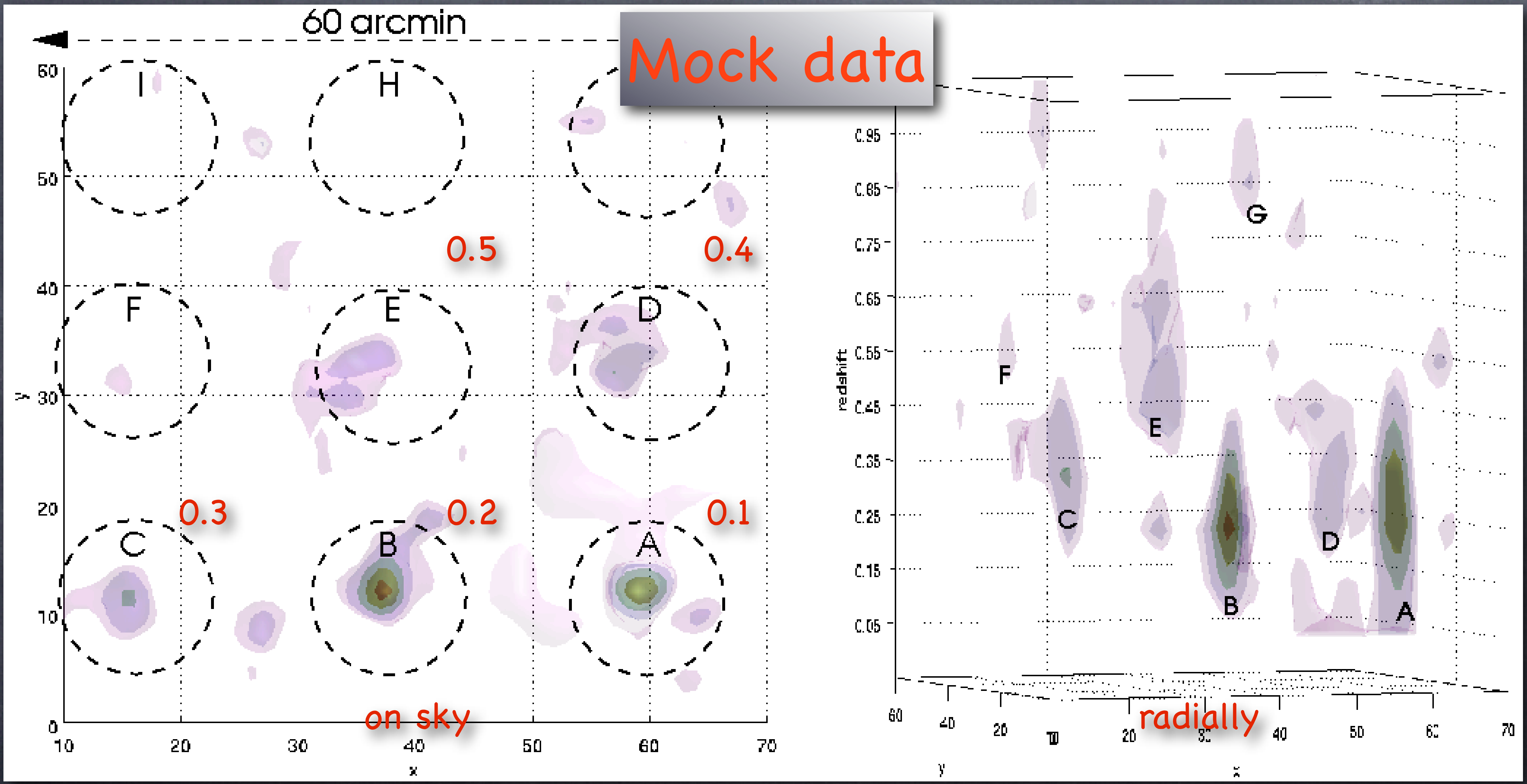
α=1: full Wiener filtering (less noise, biased)
α=0: no prior (plenty noise, unbiased)

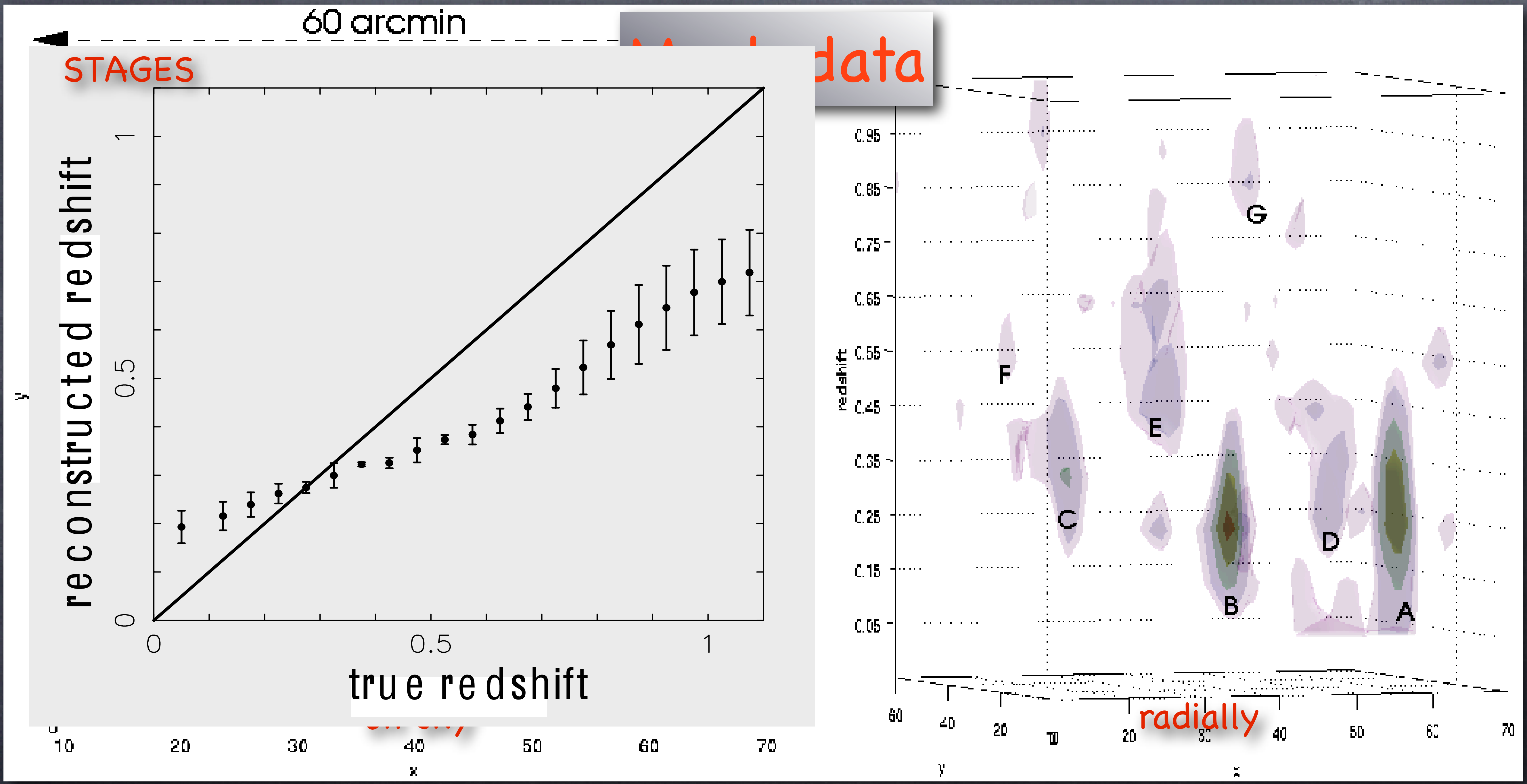
Limitations of technique



z<1.2; 30 z-bins; <z>=0.85; σ_ε=0.3; 30 glx/arcmin^2

10^3 km/s SIS; M_{200} a few $10^{14}h^{-1}$ solar masses

Limitations of technique



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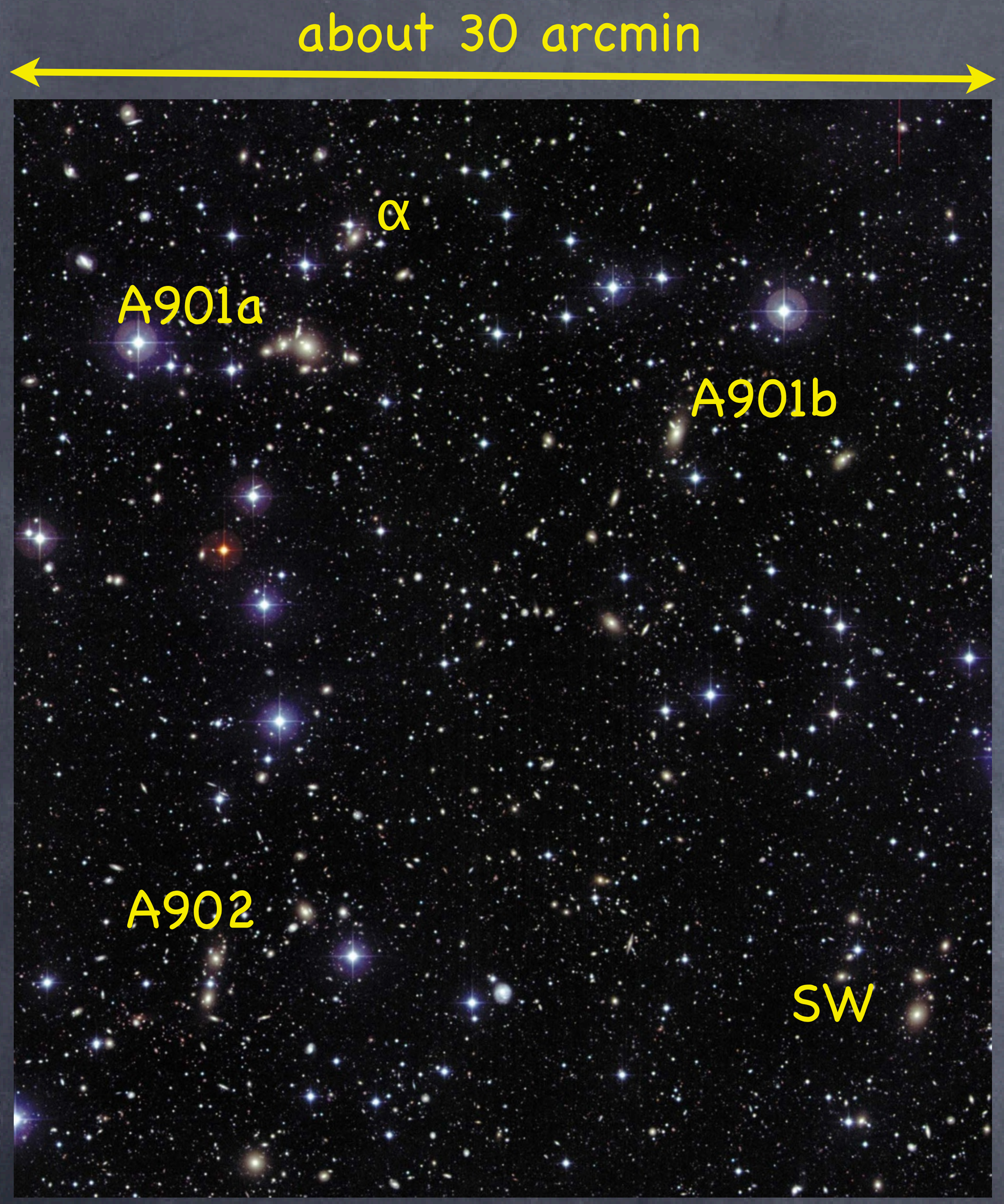
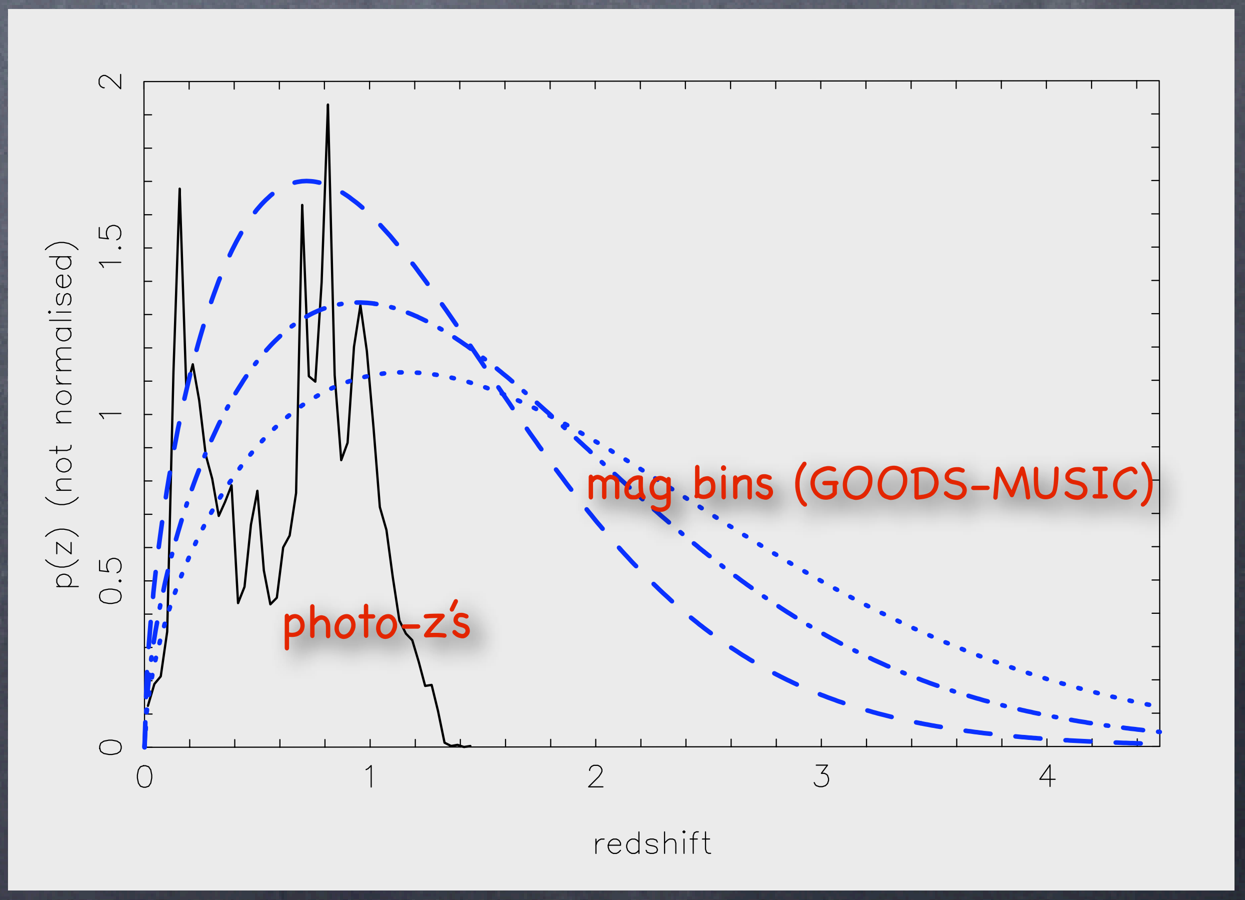
Data sample: STAGES



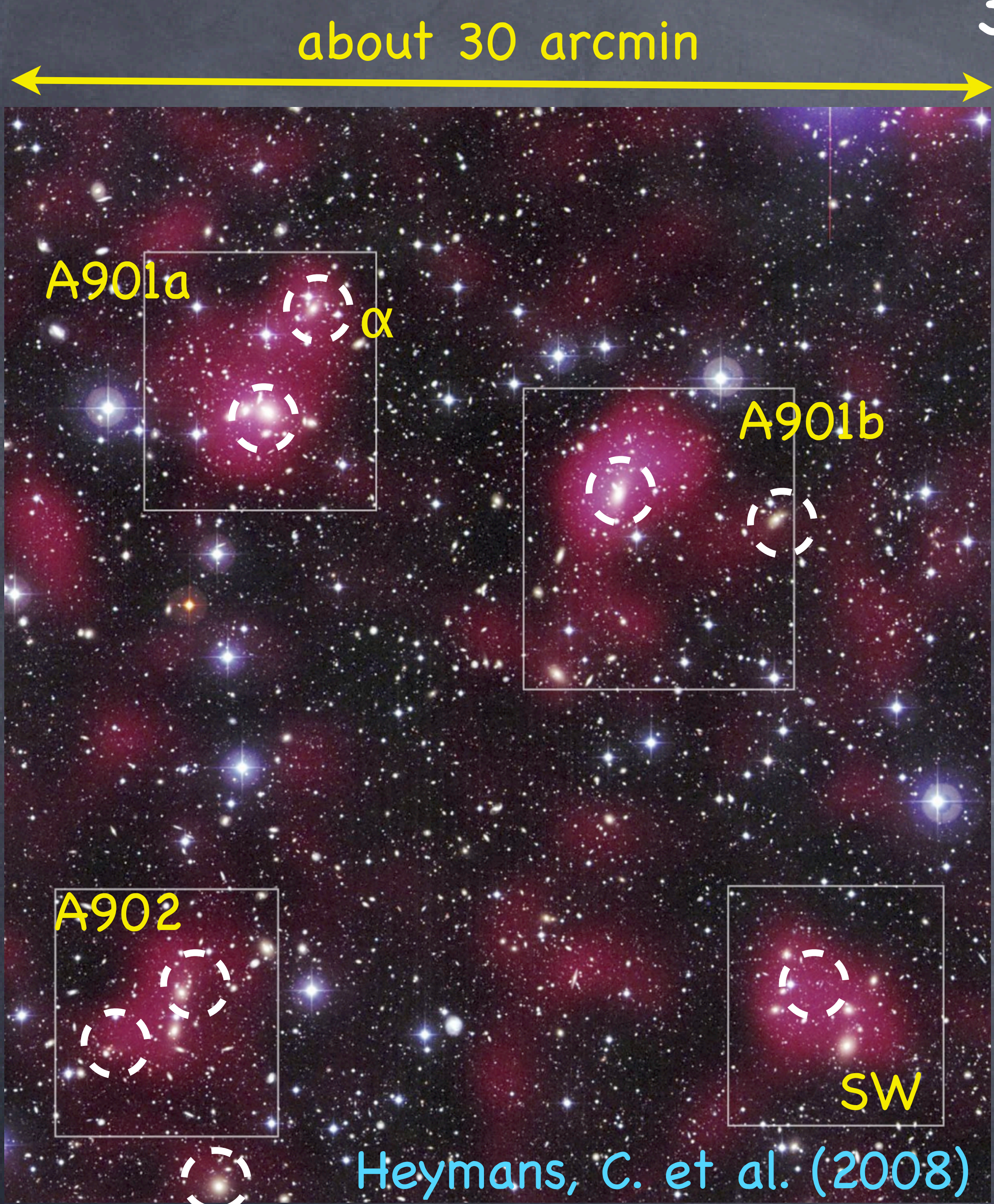
- 21 photo-z slices, z=0...1.3, with 13 sources/arcmin^2 (matched with COMBO-17 survey)
- Three deep mag-bins, m_R=[23,27.45] mag, with 52 sources/arcmin^2
- 22 lens planes, z=0...1.2



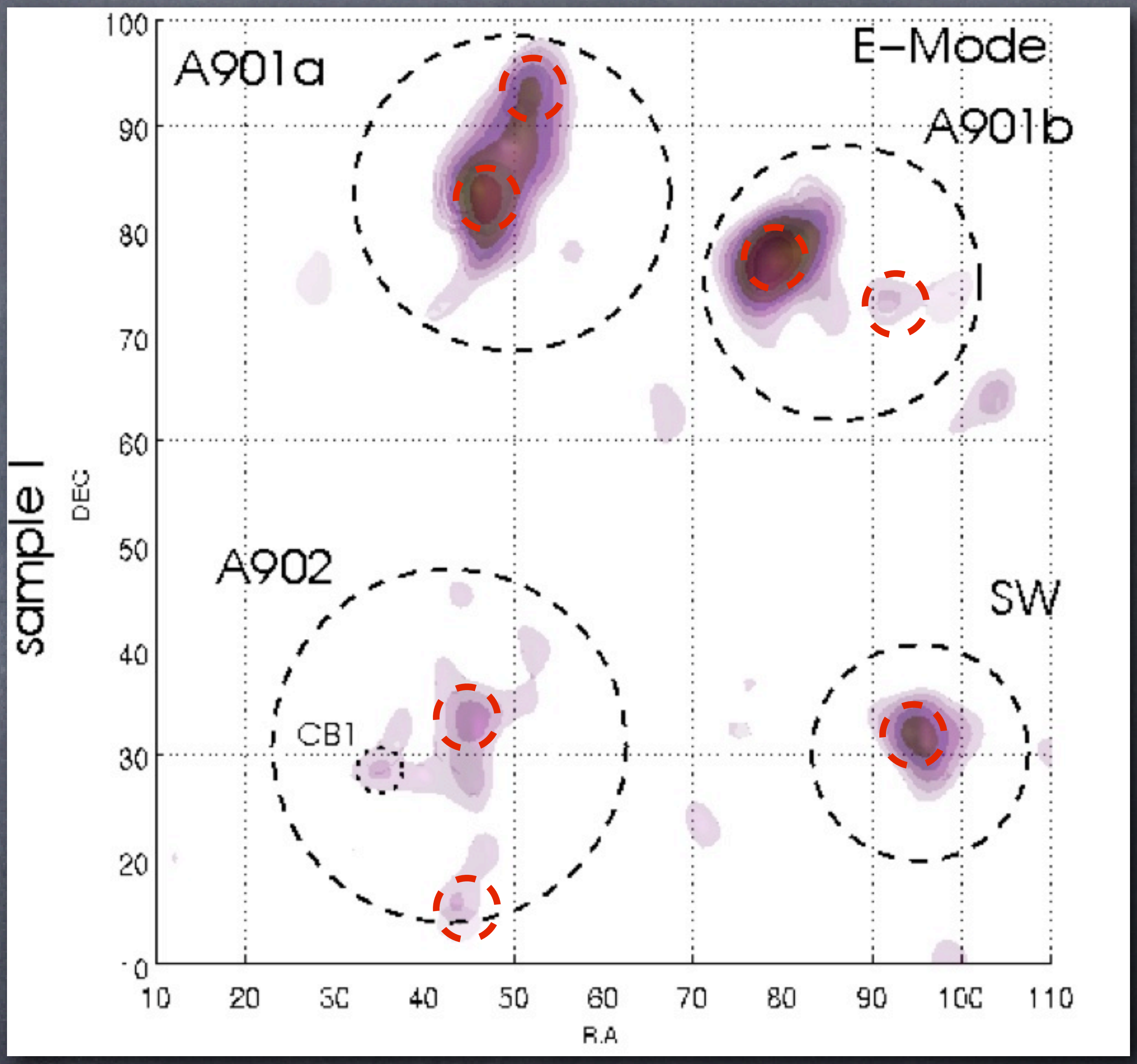
STAGES: Gray et al. (2009)

COMBO-17: Wolf et al. (2004)

Significance of map

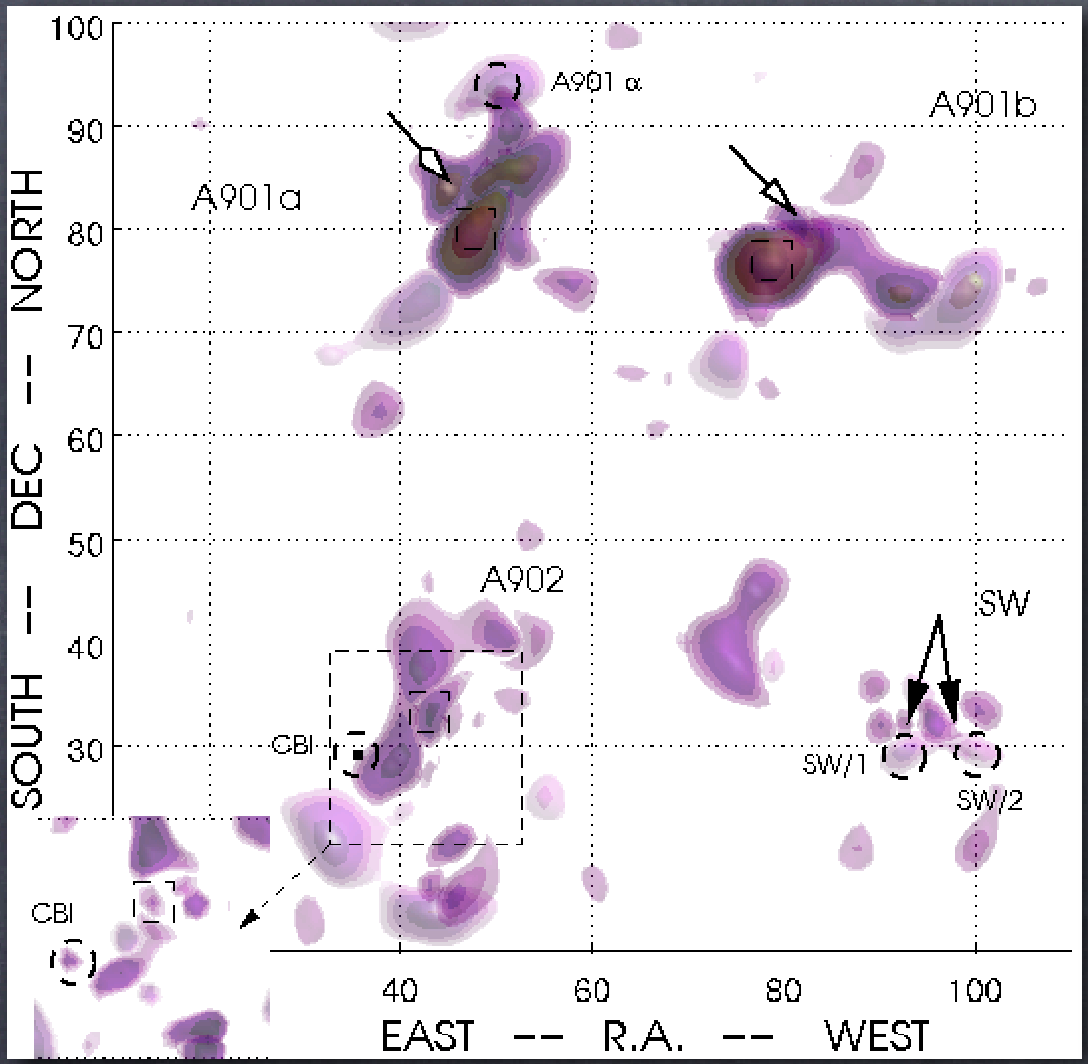


3-D mass map (projected onto sky)

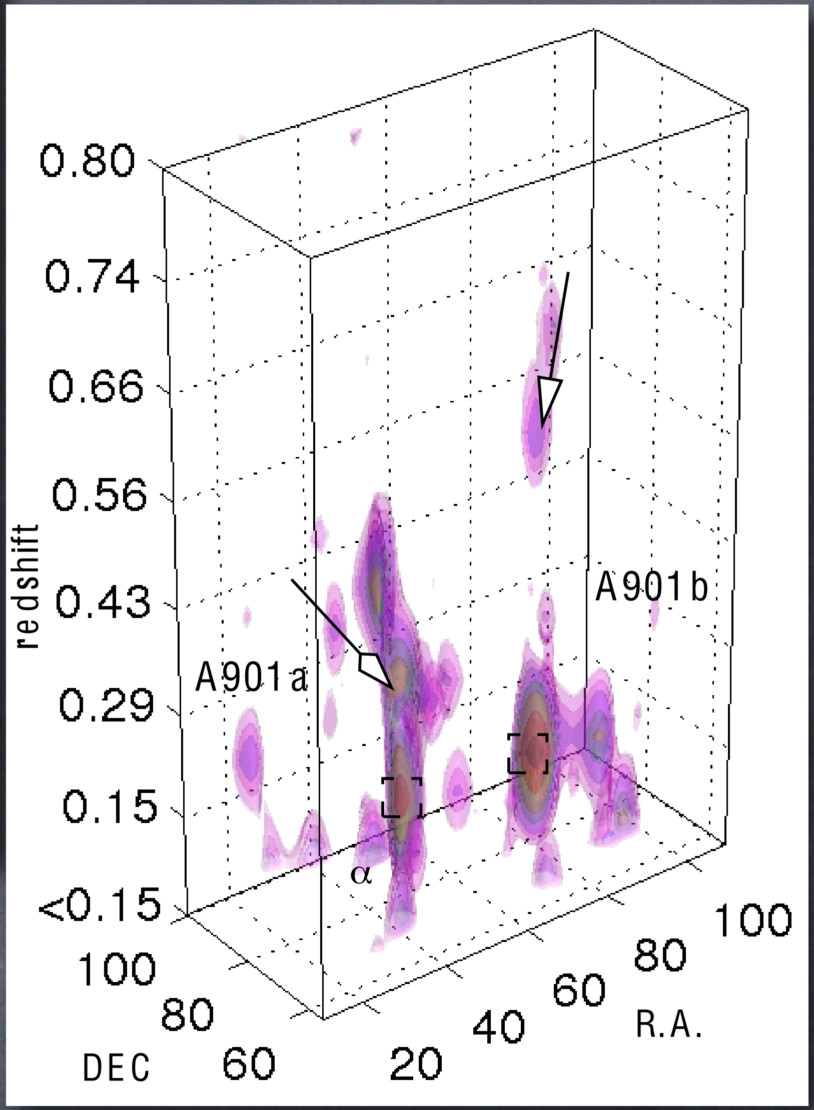


projected S/N surfaces: S/N=2.5,3,3.5...6.0
based on 1000 noise realisations of data

Cleaned and debiased map

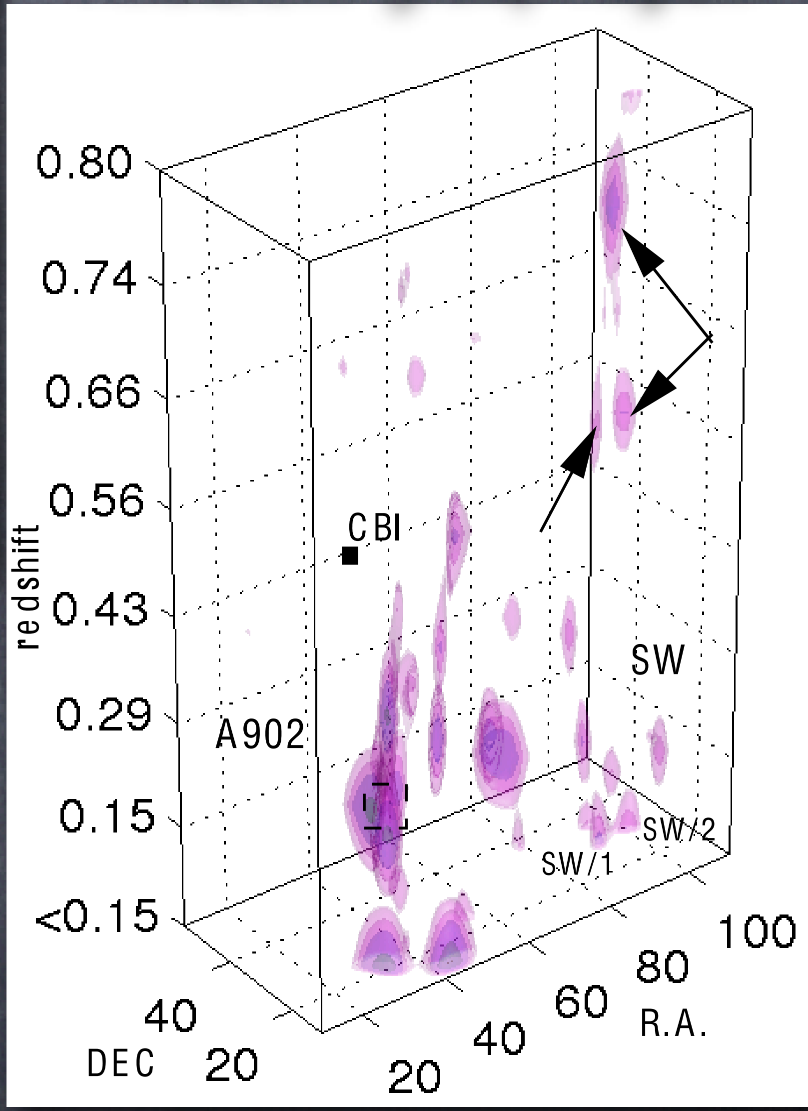


On-sky projection



A901a/A901b region

A902/SW group region

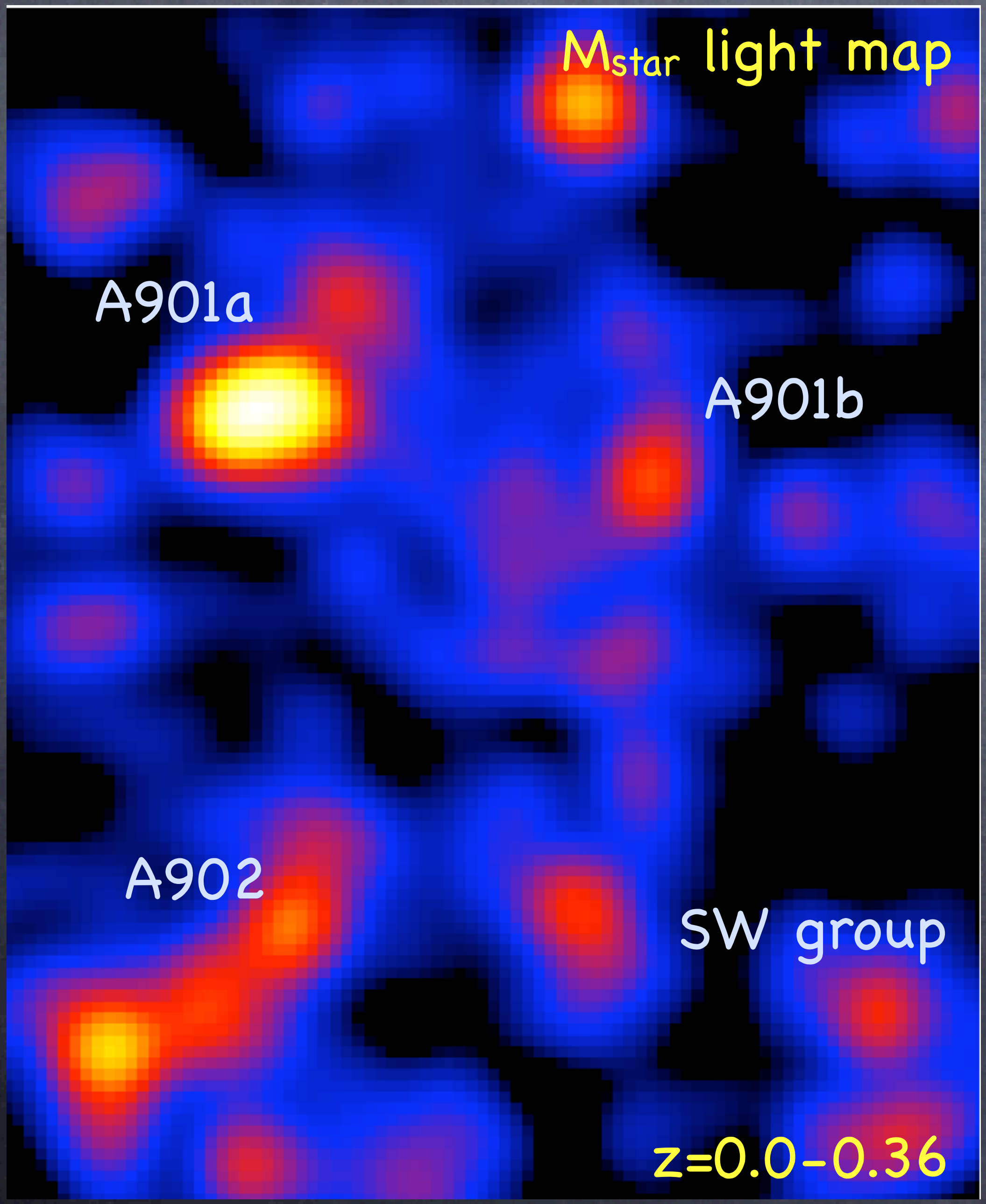


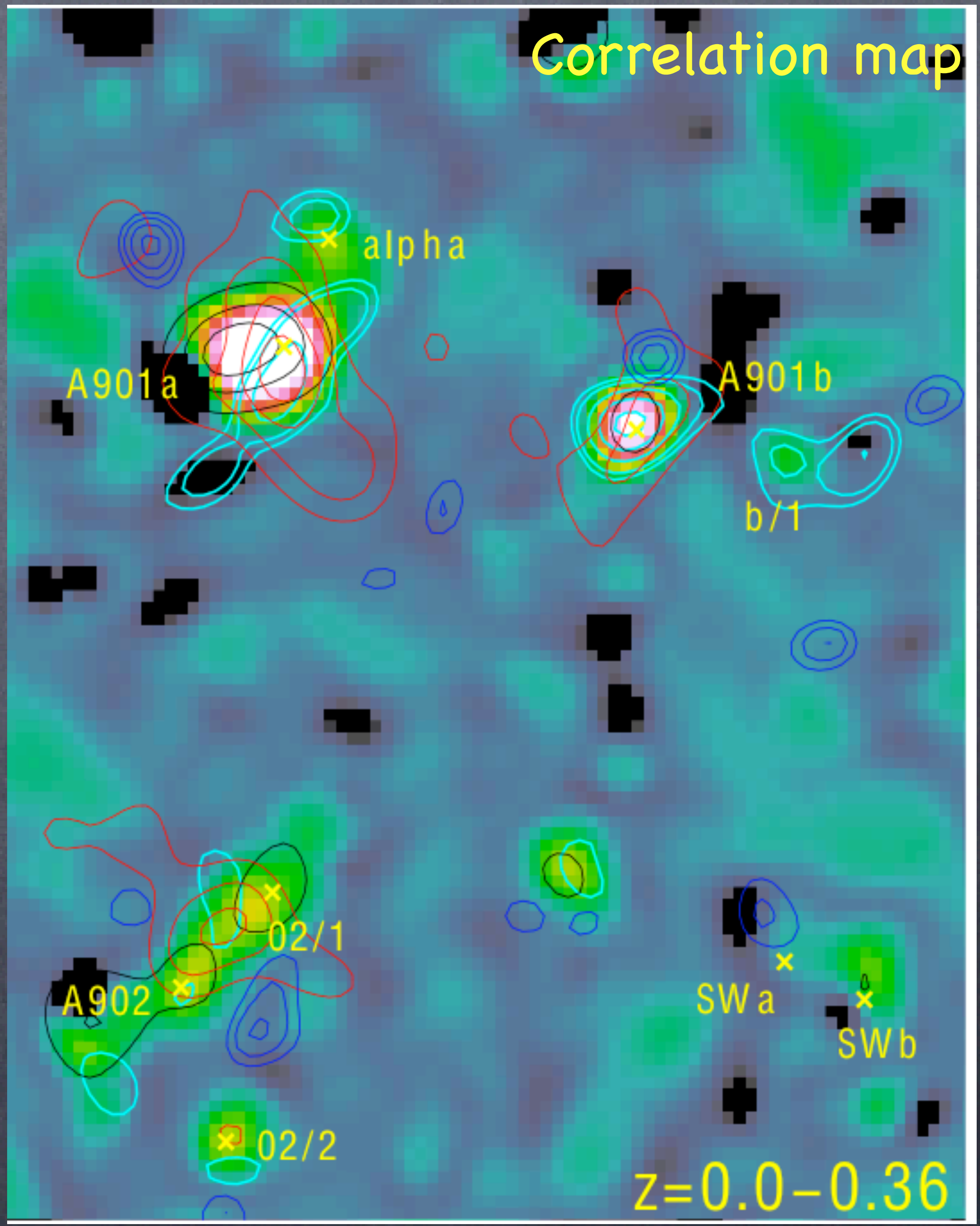
Simon, P., Heymans, C., Schrabback,T., 2010, submitted

Mass vs. light comparison

- Bin galaxy M_{star}-masses (mass in stars) on grid and cross-correlate with lensing mass map:

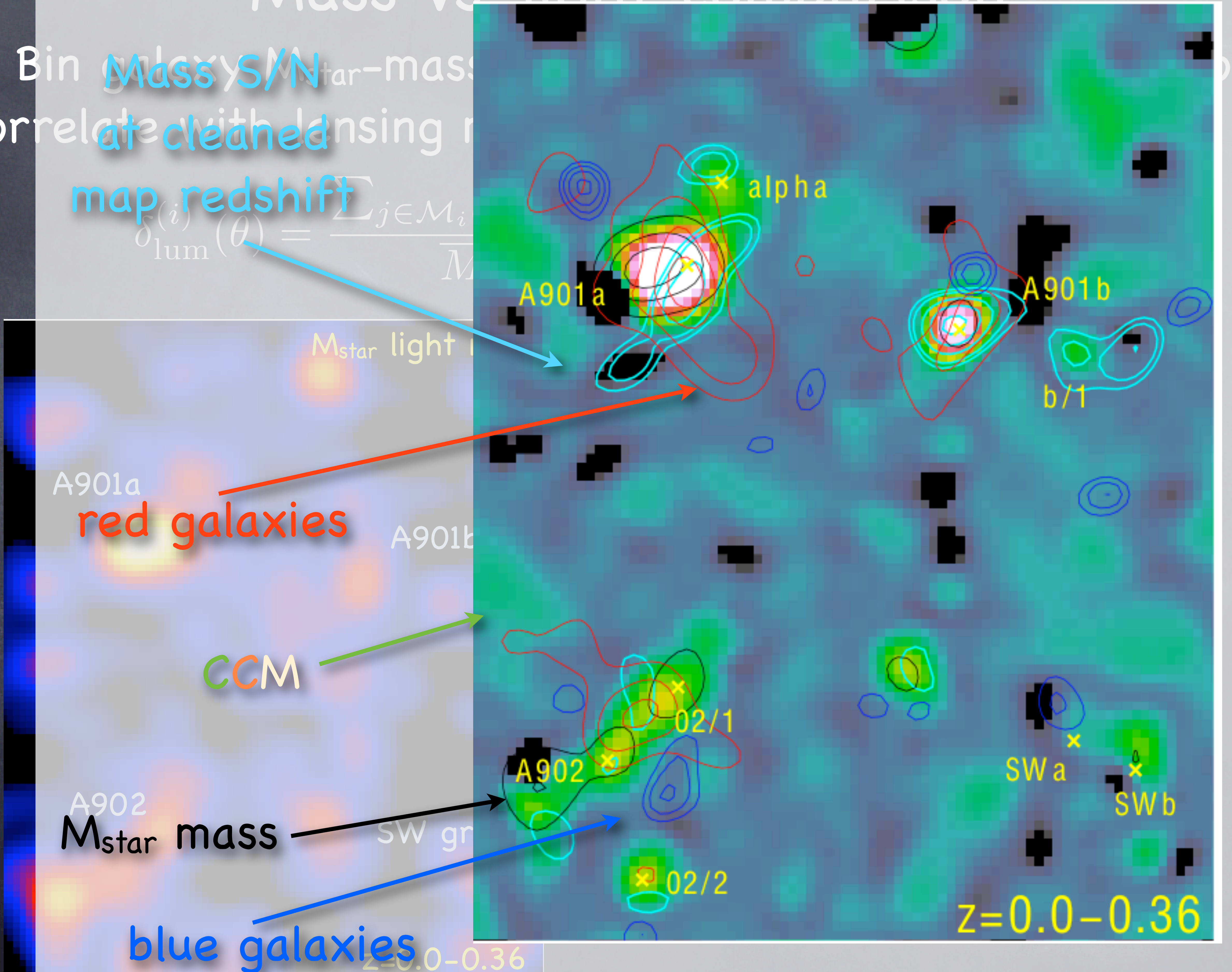
$$\delta_{\rm lum}^{(i)}(\theta) = \frac{\sum_{j\in\mathcal{M}_i(\theta)} M_{*,j}}{\overline{M_*}} - 1\ ;\ {\rm CCM}(\theta) = \frac{\delta_{\rm lum}(\theta)\delta_{\rm m}(\theta)}{\sigma_{\rm lum}\sigma_{\rm m}}$$



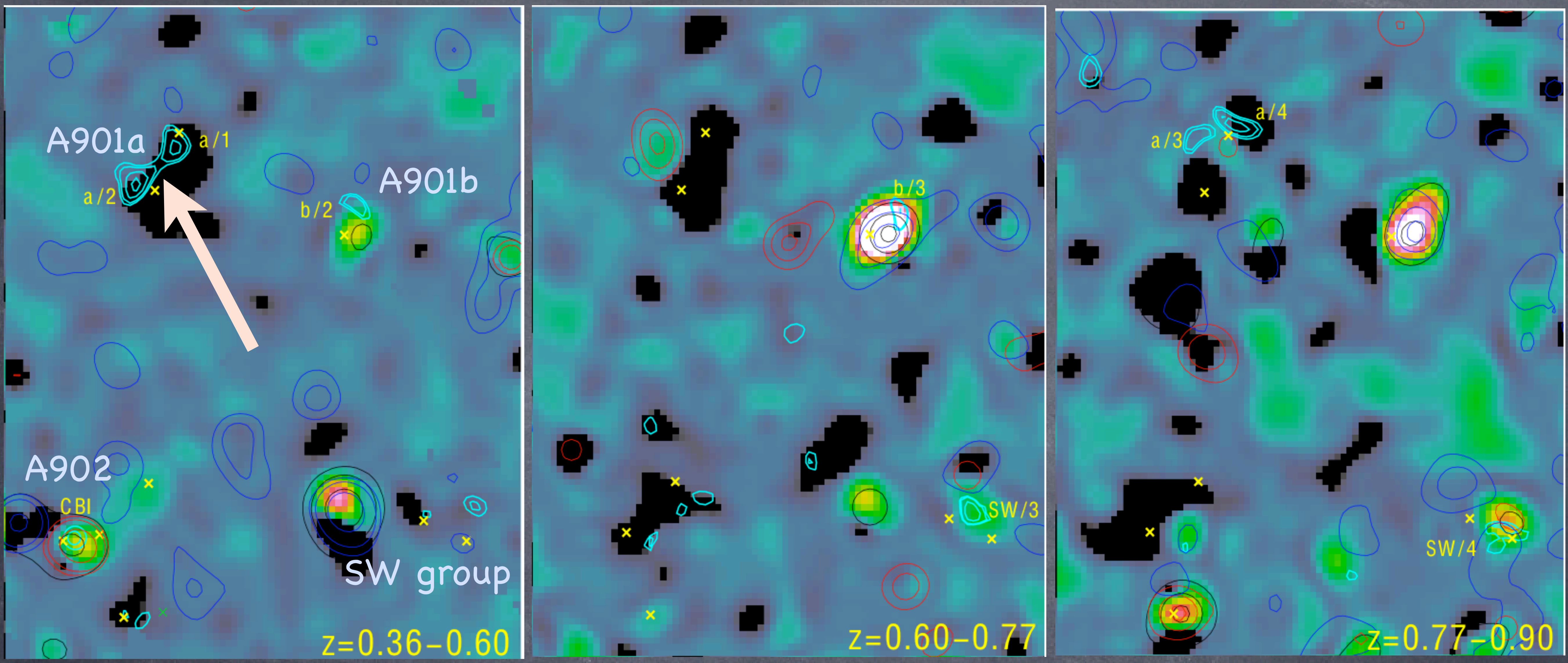


Mass vs. light comparison

- Bin galaxy M_{star}-mass ... oss-correlate with lensing m...



Mass vs. light comparison by eye



- Radial spread of A901a noise artefact?

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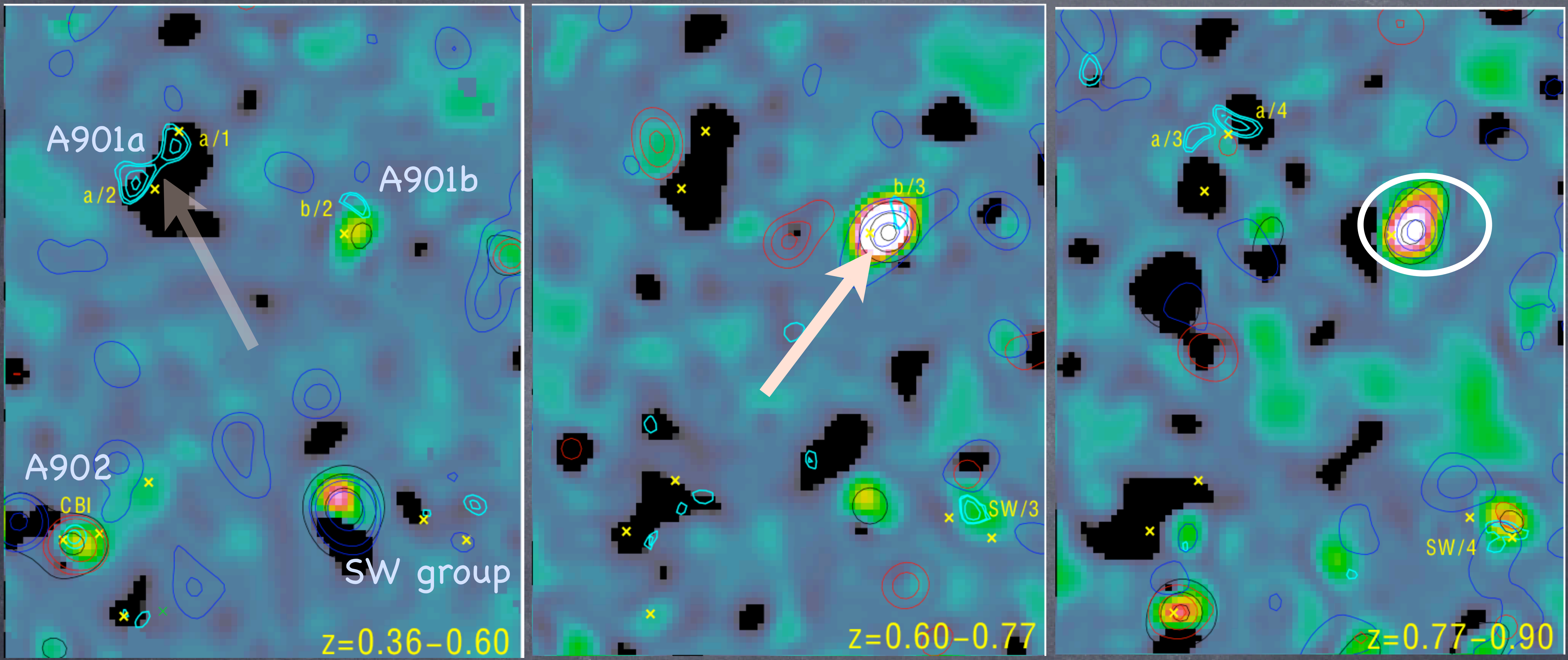

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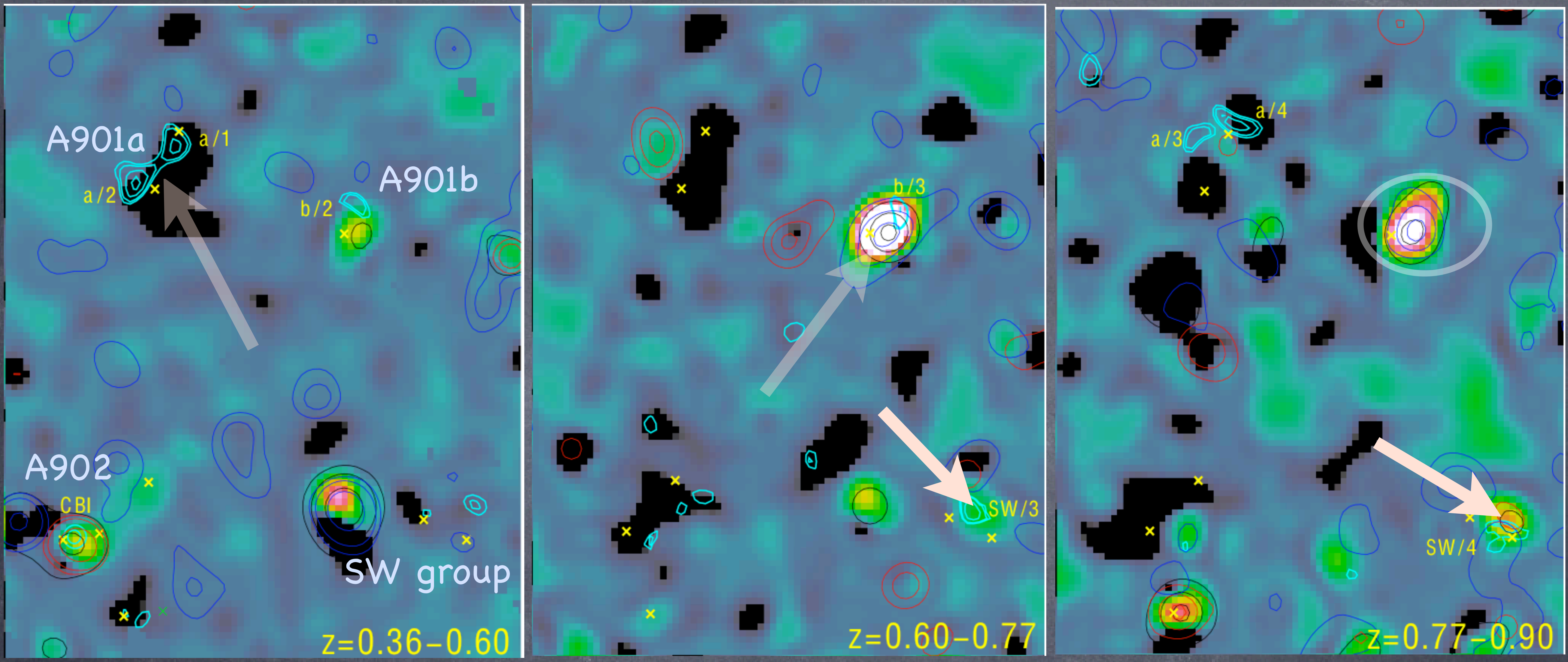
- Light confirms structure behind A901b (z=0.70-0.80)

Mass vs. light comparison by eye



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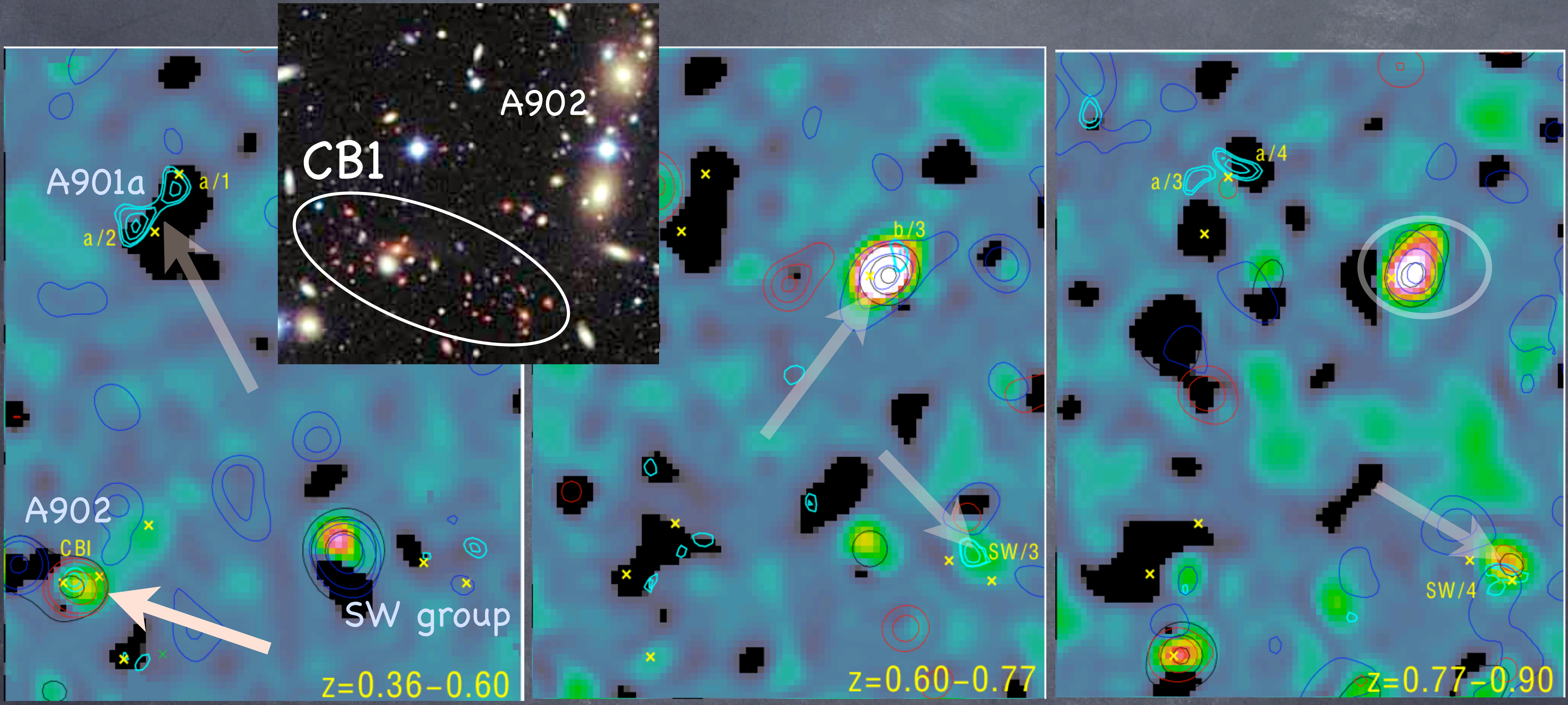
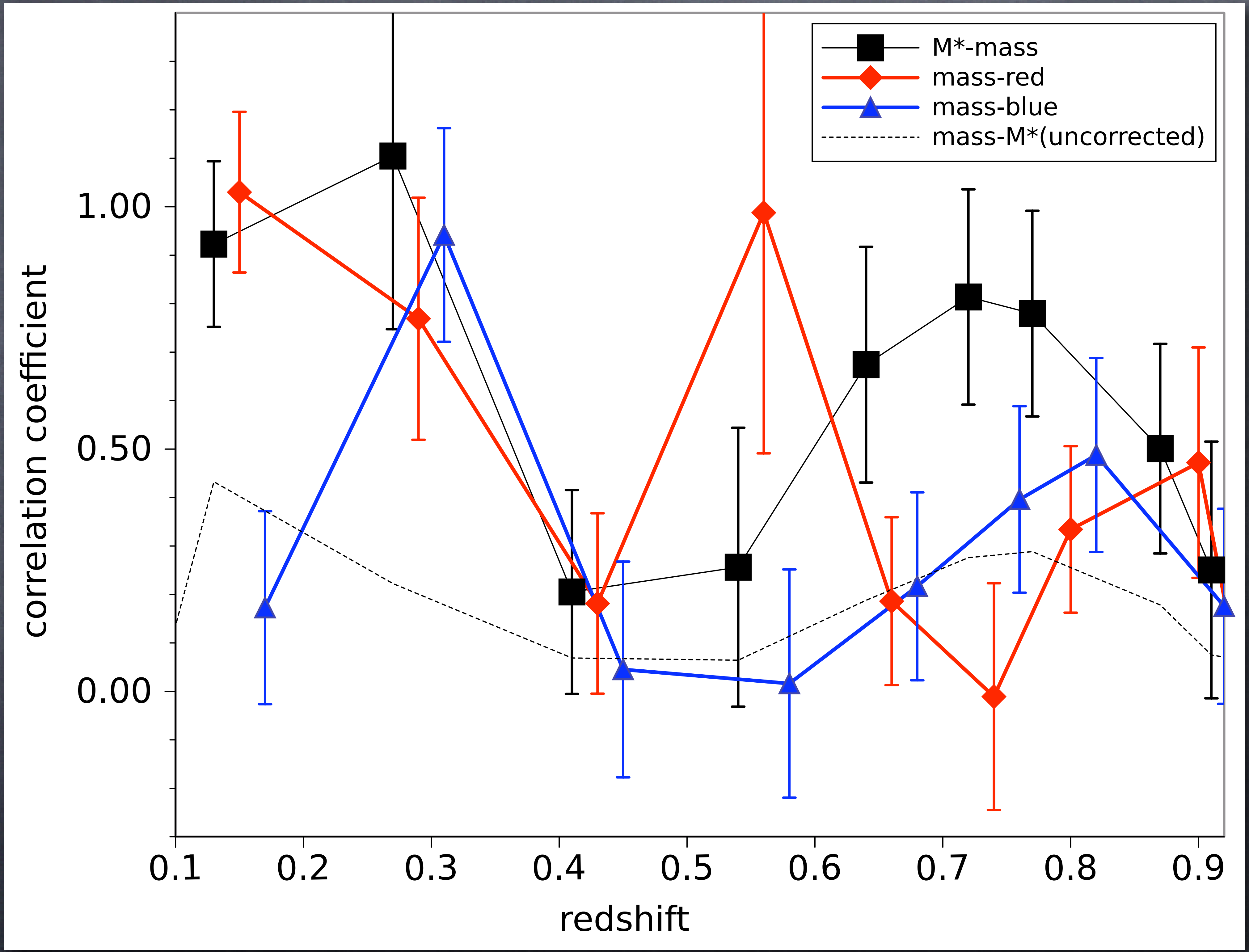
- Light confirms structure behind SW group (z=0.43?,0.80)

Mass vs. light comparison by eye



- Radial spread of A901a noise artefact?
- Light confirms structure behind A901b (z=0.70–0.80)
- Light confirms structure behind SW group (z=0.43?,0.80)
- CB1 reconfirmed (COMBO-17; Taylor et al. 2004: z=0.46)

Light-mass cross-correlation coefficient

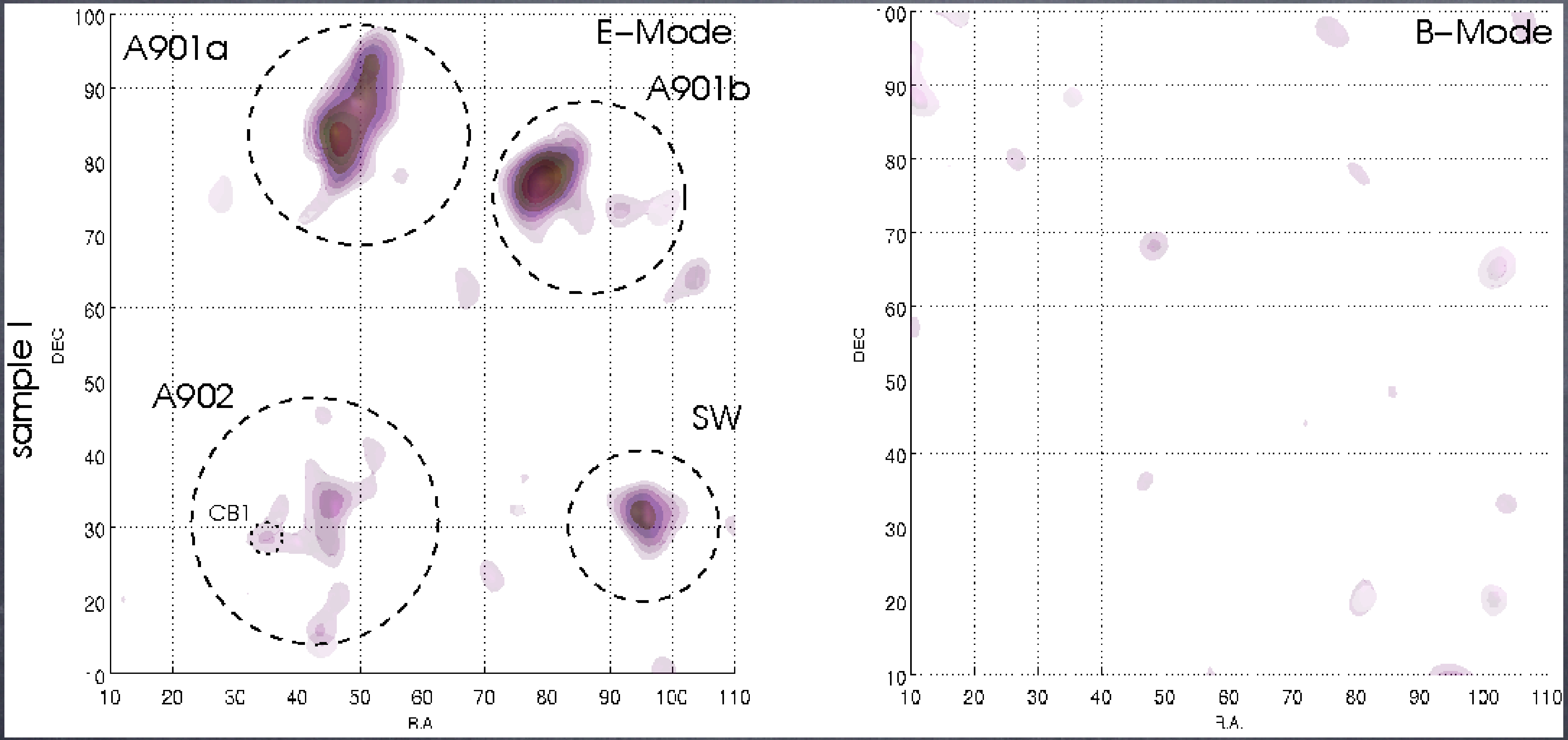


Conclusions

- This work is an application of a new lensing 3-D mass mapping algorithm to real data
- The modified Wiener filter produces a biased image of the true distribution; z-shift bias can be corrected for
- Annoyance of radial cigar-effect inside maps can be partly removed with heuristic cleaning algorithm presented
- 3-D map reveals structure behind A901b and SW-group; may be important for lensing mass modelling
- Good light-mass match at $z<0.3$, declining towards higher z; probably due to incompleteness of mass map

http://www.astro.uni-bonn.de/~psimon/index.php?index=23

Quality control



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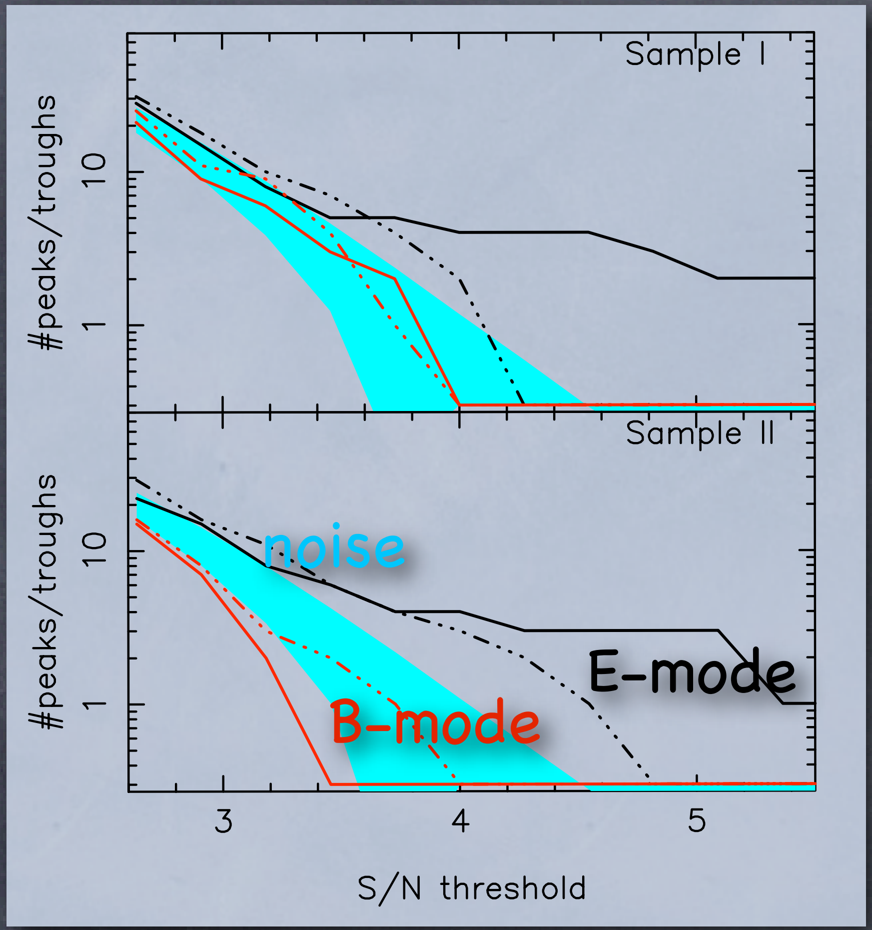
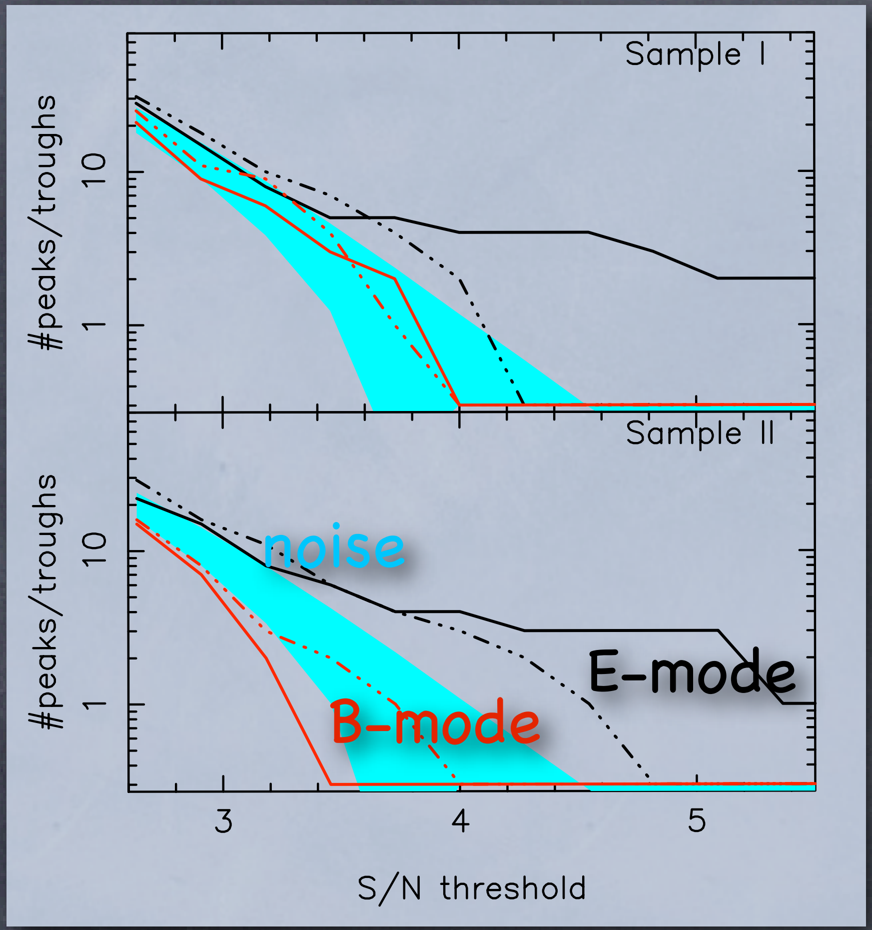


- Frequency statistics of noise peaks

Peaks: pixel larger than all neighbour pixels in transverse&radial direction
Troughs: negative peaks

Noise realisations vs. E/B-mode maps

Quality control



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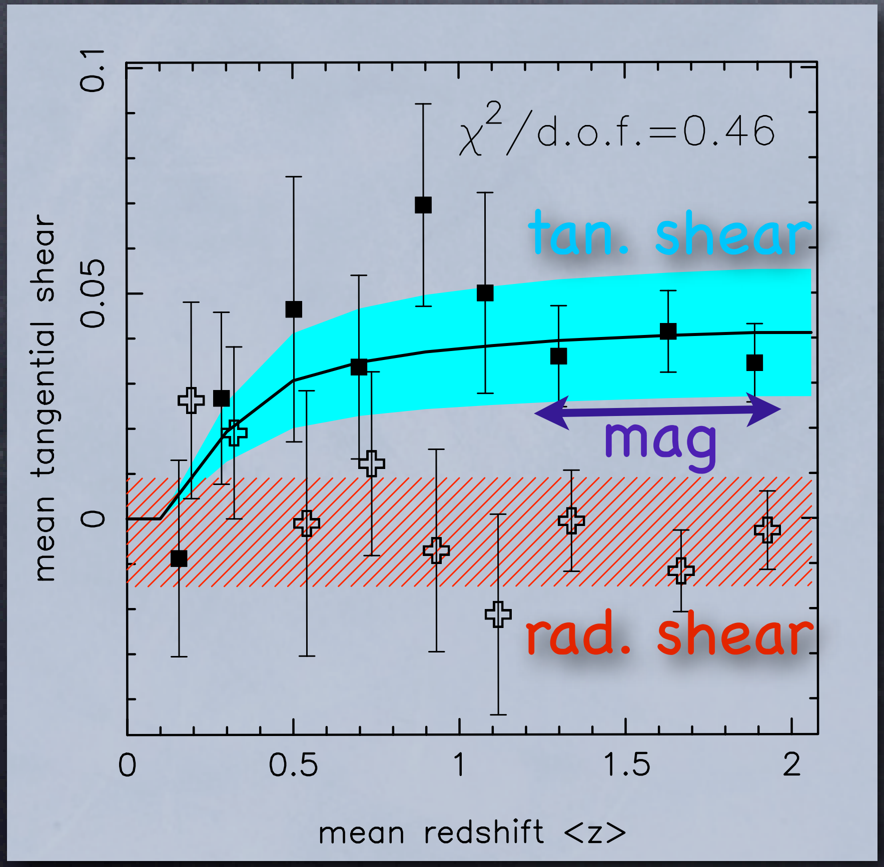
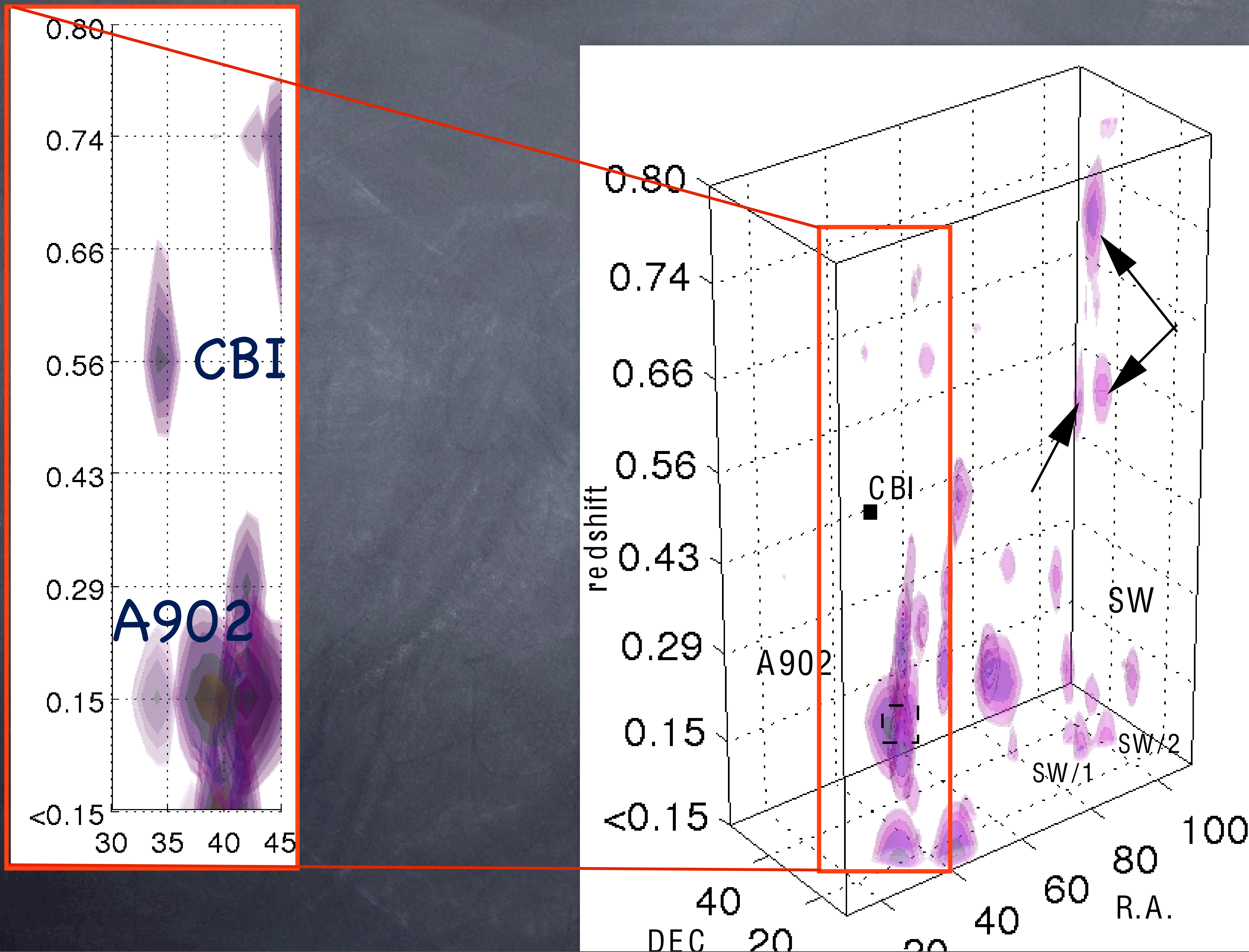


- Z-scaling of tan. shear inside apertures (≈1-2 arcmin radius)

$$\overline{\gamma}_{\rm t}(\theta_{\rm c}, z_{\rm s}) = -\sum_{i\in\mathcal{M}_{\rm s}(z_{\rm s})} \frac{\theta_i^* - \theta_{\rm c}^*}{\theta_i - \theta_{\rm c}}\epsilon_i$$

targets: A901a/b/α, SW and A902

A902 region/less smoothing



Degradation of correlations

- Cross-correlation coefficient between maps:

$$r = \langle \mathrm{CCM}(\theta) \rangle = \frac{\langle \delta \quad (\theta) \delta \quad (\theta) \rangle}{\sigma \quad \sigma} \; ; \quad -1 \leq r \leq +1$$

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- Noise degrades the correlation but can be corrected if signal and noise power are known:

$$r_{\mathrm{true}} = r \times \sqrt{\left(1 + \frac{\langle \mathrm{noise}^2_{\mathrm{lum}} \rangle}{\langle \mathrm{signal}^2_{\mathrm{lum}} \rangle}\right) \left(1 + \frac{\langle \mathrm{noise}^2_{\mathrm{m}} \rangle}{\langle \mathrm{signal}^2_{\mathrm{m}} \rangle}\right)}$$

Noise and signal variances are estimated from noise realisations of mass and light maps;

Map pixel variance = noise variance + signal variance!