Gravitational lensing with Subaru Hyper Suprime-Cam survey

Survey webpage: http://hsc.mtk.nao.ac.jp/ssp/
Public data release: https://hsc-release.mtk.nao.ac.jp/doc/

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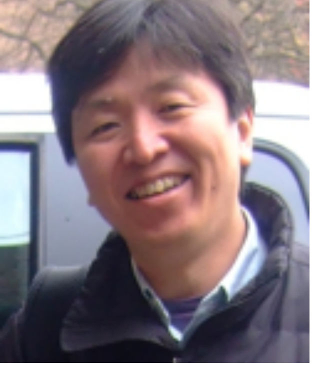
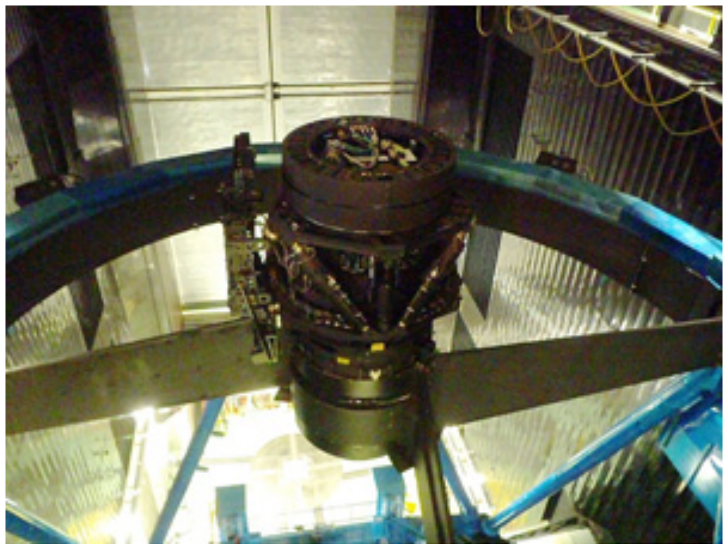
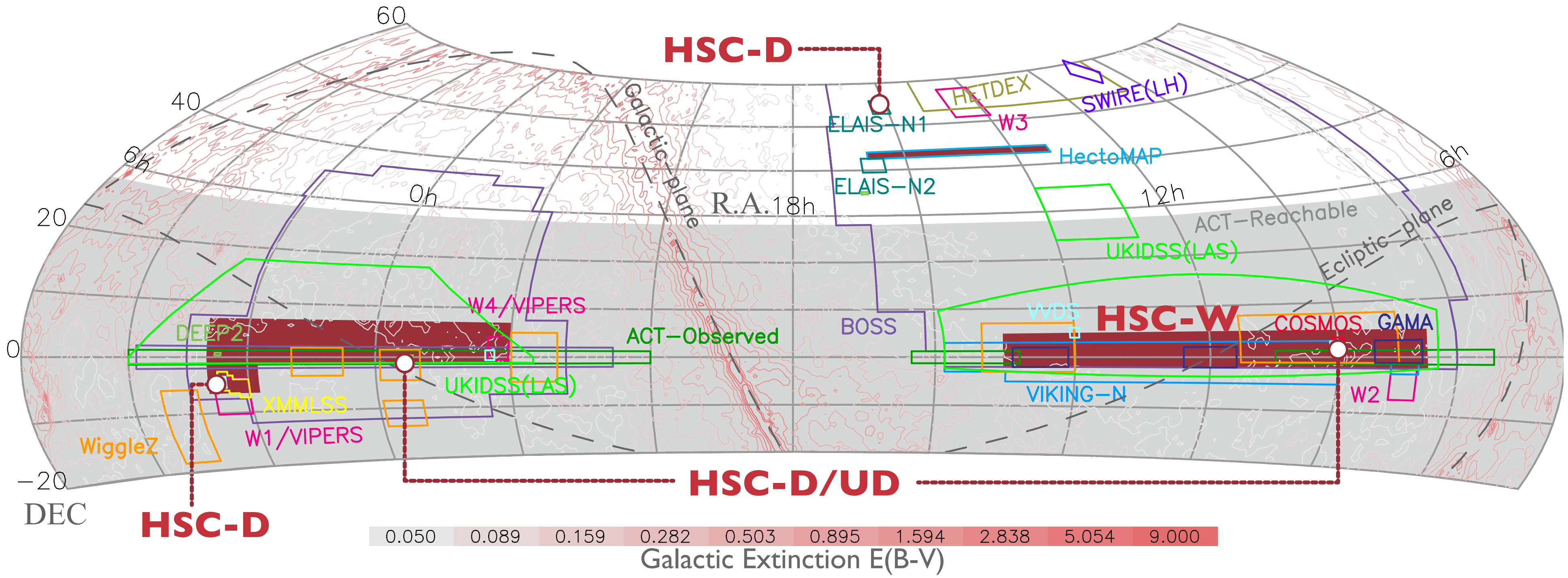


PI: Satoshi Miyazaki (NAOJ)

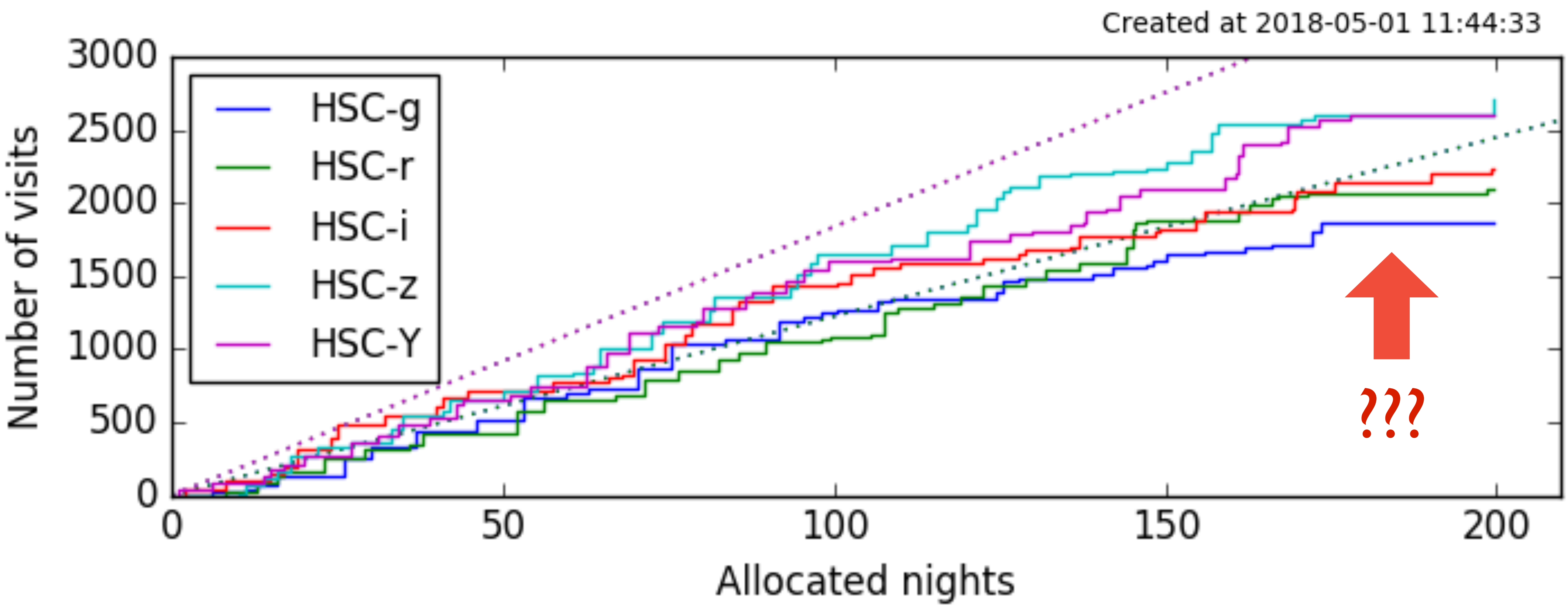
Hyper Suprime-Cam (HSC)





- new wide-field (1.7 deg^2) camera at Subaru telescope
- 3-layer survey (2014-2019?)
  - Wide (1400 deg^2, r_{lim} ~ 26, grizy)
  - Deep (27 deg^2, r_{lim} ~ 27, grizy+3NBs)
  - Ultra-Deep (3.5 deg^2, r_{lim} ~ 28, grizy+3NBs)

HSC survey progress



- 2/3 of nights already allocated

First year shear catalog

- first-year shear catalog from ~1/5 of total data
- shape measurements w/ re-Gaussianization method (Hirata & Seljak 2003)

Astronomical Society of Japan

Publ. Astron. Soc. Japan (2018) 70 (SP1), S25 (1–43)
doi: 10.1093/pasj/psx130
Advance Access Publication Date: 2017 December 23

The first-year shear catalog of the Subaru Hyper Suprime-Cam Subaru Strategic Program Survey

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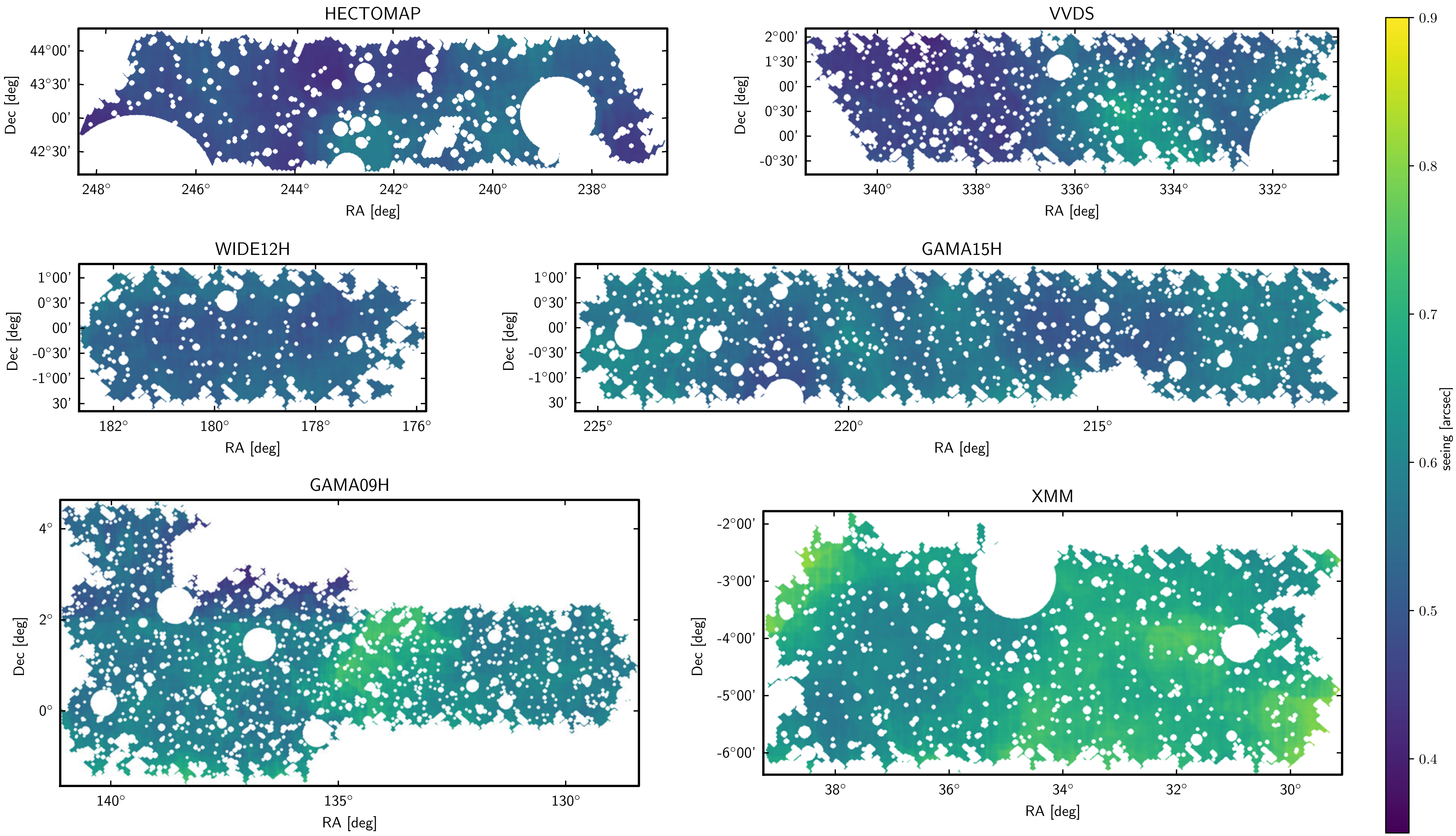
Mandelbaum, Miyatake+ PASJ **70**(2018)S25



- total area of ~137 deg^2 after bright star mask
- mean seeing of 0.58″, n_{eff} ~ 22 arcmin^{-2}

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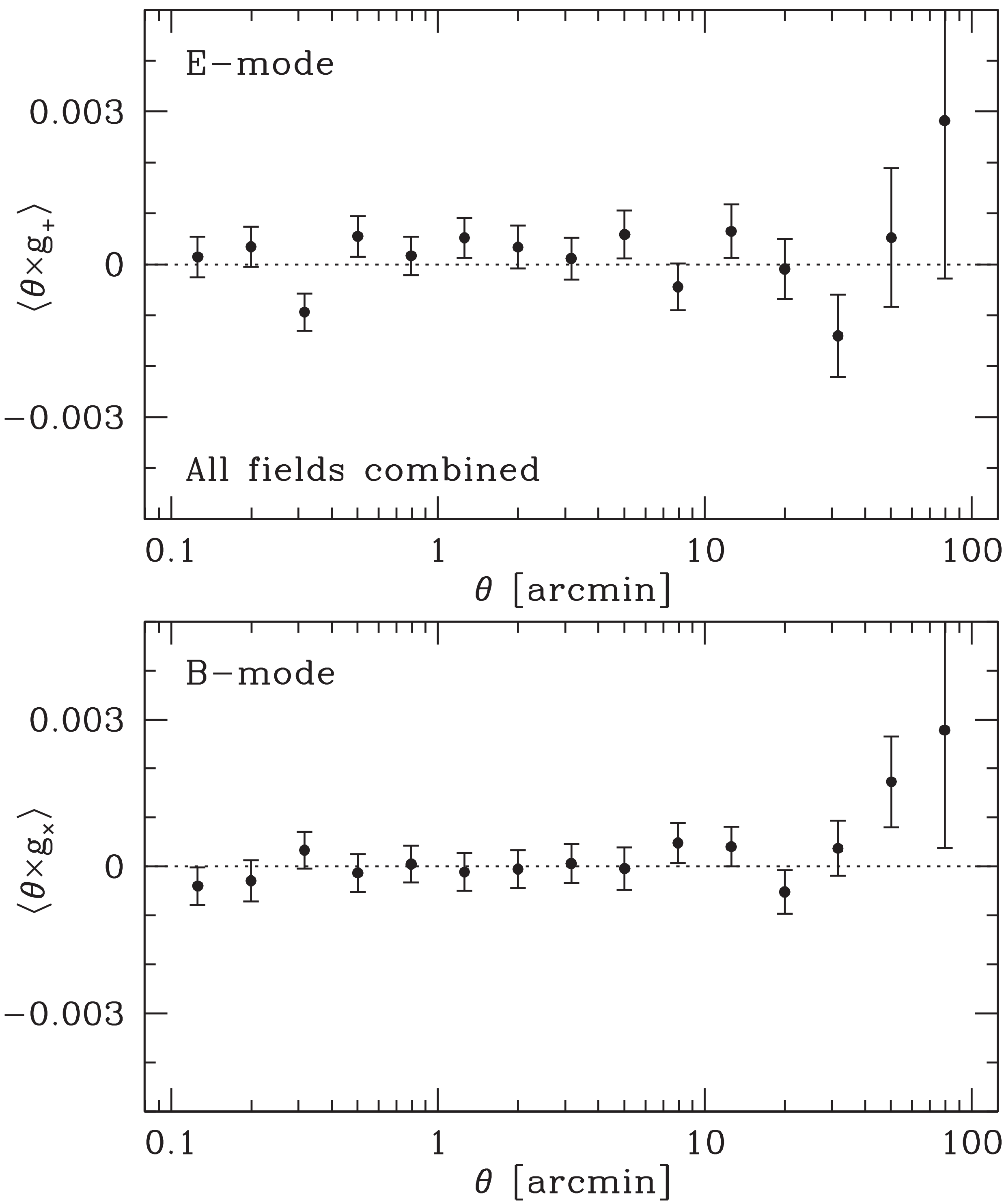
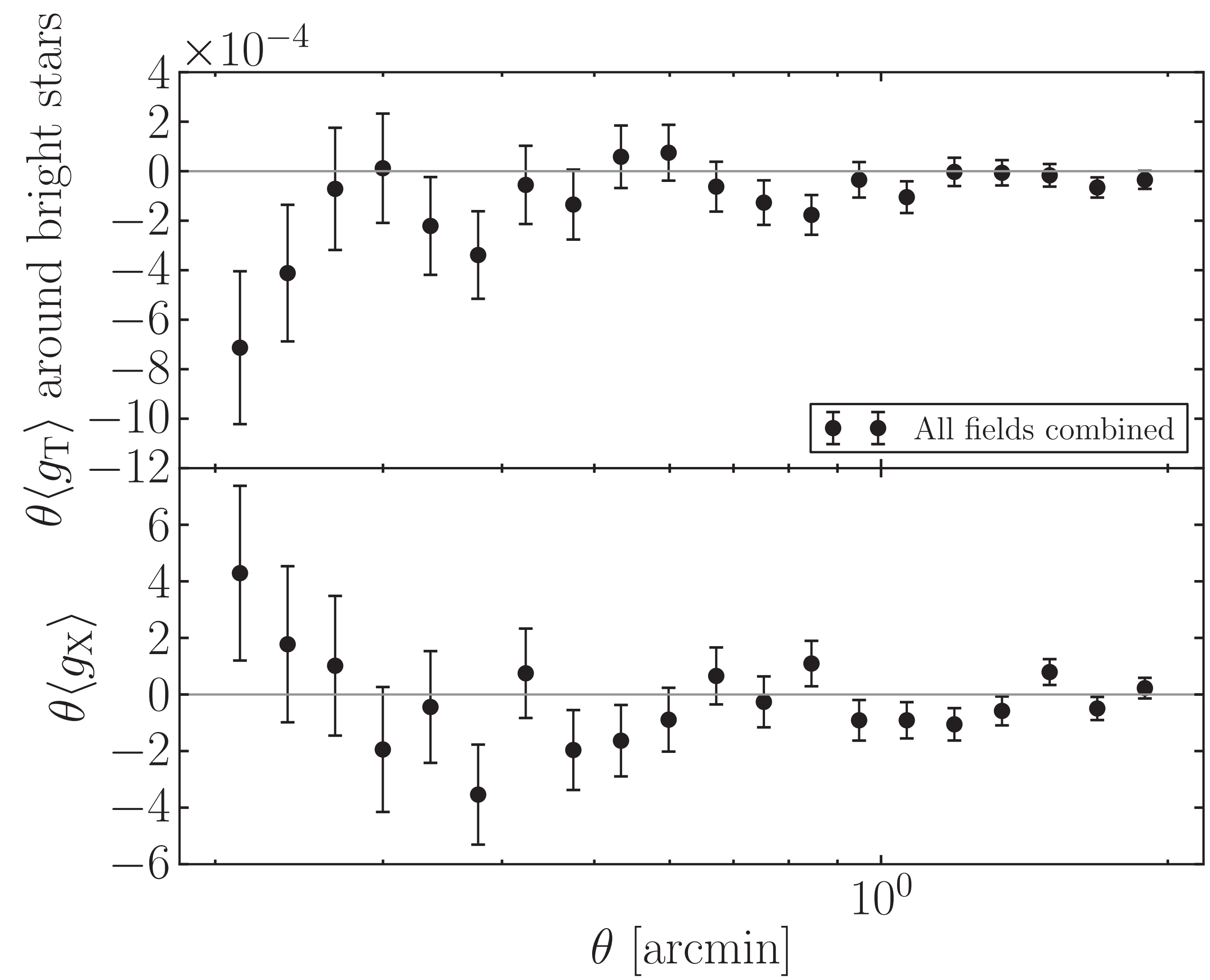
Null tests





↑ tangential and cross shear around bright stars

← tangential and cross shear around random points

Weak lensing mass reconstruction

- we want to know convergence κ (DM dist.) from shear γ (observed galaxy shape)
  - systematics tests from B-mode maps
  - find clusters, voids, troughs, …
  - cross-correlations with other maps

$$\hat{\gamma}(\vec{\ell}) = \frac{1}{\pi}\hat{\kappa}(\vec{\ell})\hat{D}(\vec{\ell}) \qquad \hat{D}(\vec{\ell}) = \pi\frac{\ell_1^2 - \ell_2^2 + 2i\ell_1\ell_2}{|\vec{\ell}|^2}$$

$$\rightarrow \boxed{\kappa(\vec{\theta}) - \kappa_0 = \frac{1}{\pi}\int d\vec{\theta}'\gamma(\vec{\theta}')D^*(\vec{\theta} - \vec{\theta}')}$$

(Kaiser & Squires 1993)

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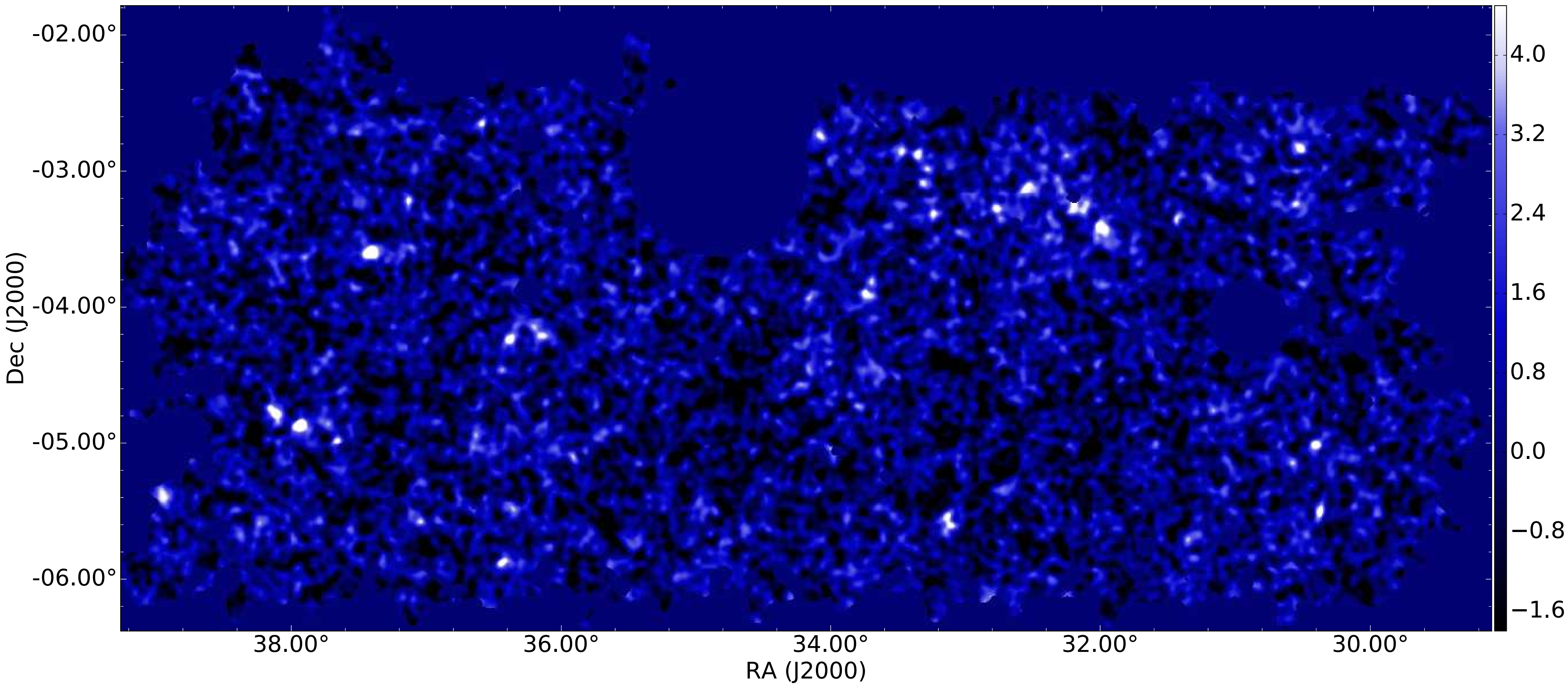
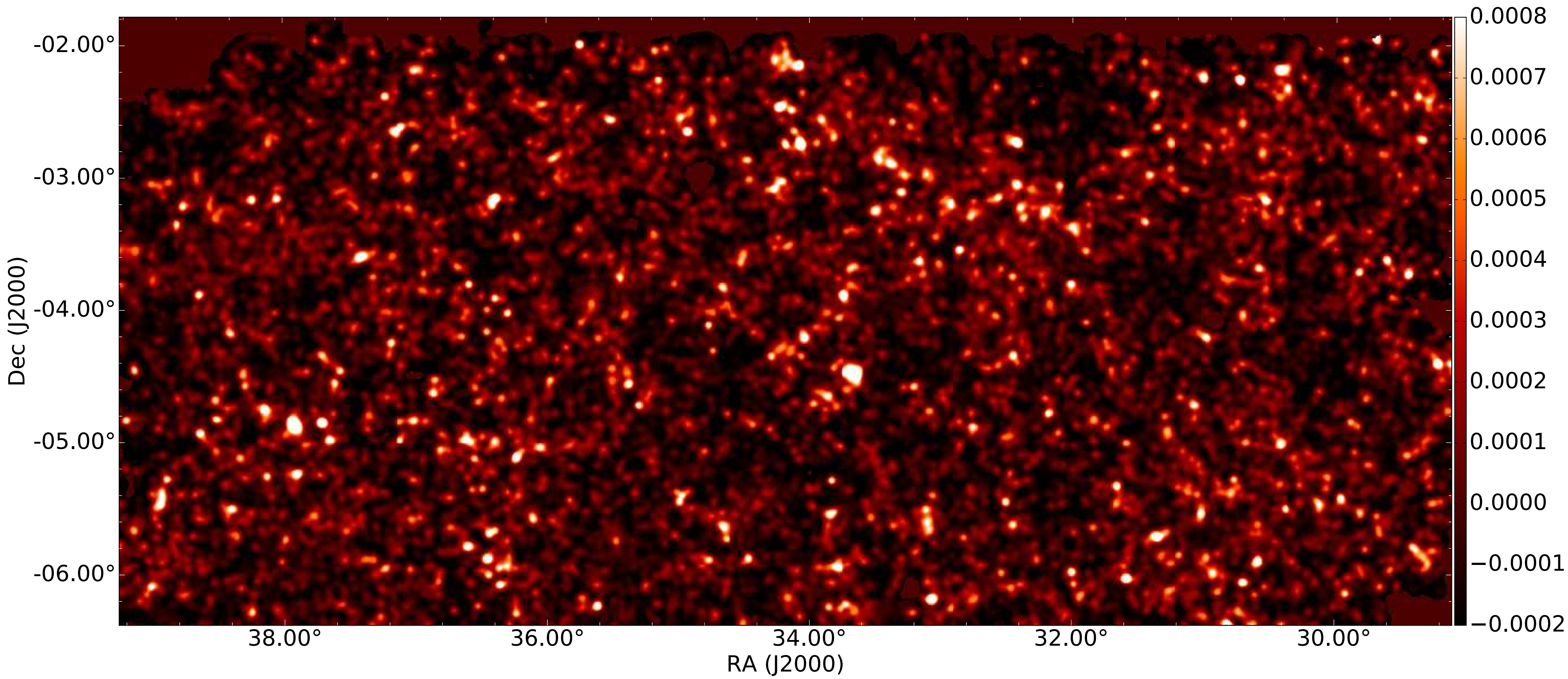


WL mass map



galaxy mass map

XMM

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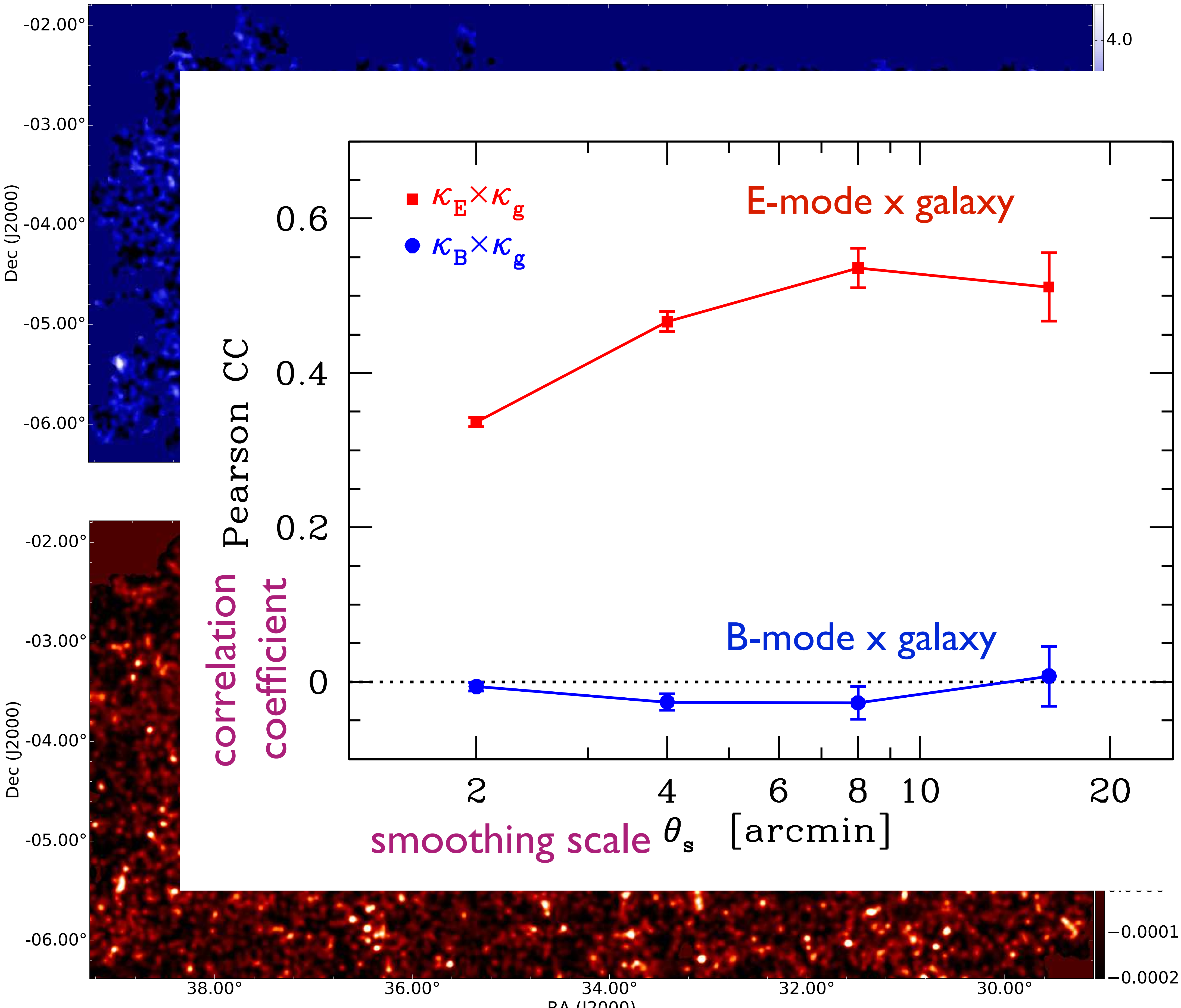

WL
mass
map

galaxy
mass
map

XMM

3D mass reconstruction

- by using photometric redshifts, we can derive WL mass maps for different source redshifts z_s

- then 3D mass reconstruction is essentially a linear inversion problem

$$\kappa(\boldsymbol{\theta}, z_{s,i}) = \sum_j R(z_{s,i}, z_{l,j})\rho(\boldsymbol{\theta}, z_{l,j}) \Rightarrow \rho(\boldsymbol{\theta}, z_{l,j}) = \sum_i \left[R^{-1}\right]_{ij} \kappa(\boldsymbol{\theta}, z_{s,i})$$

2D projected mass dist.

3D mass dist.

- 3D mass reconstruction is very noisy, thus needs efficient filtering using e.g., Wiener filter (e.g., Hu & Keeton 2003)

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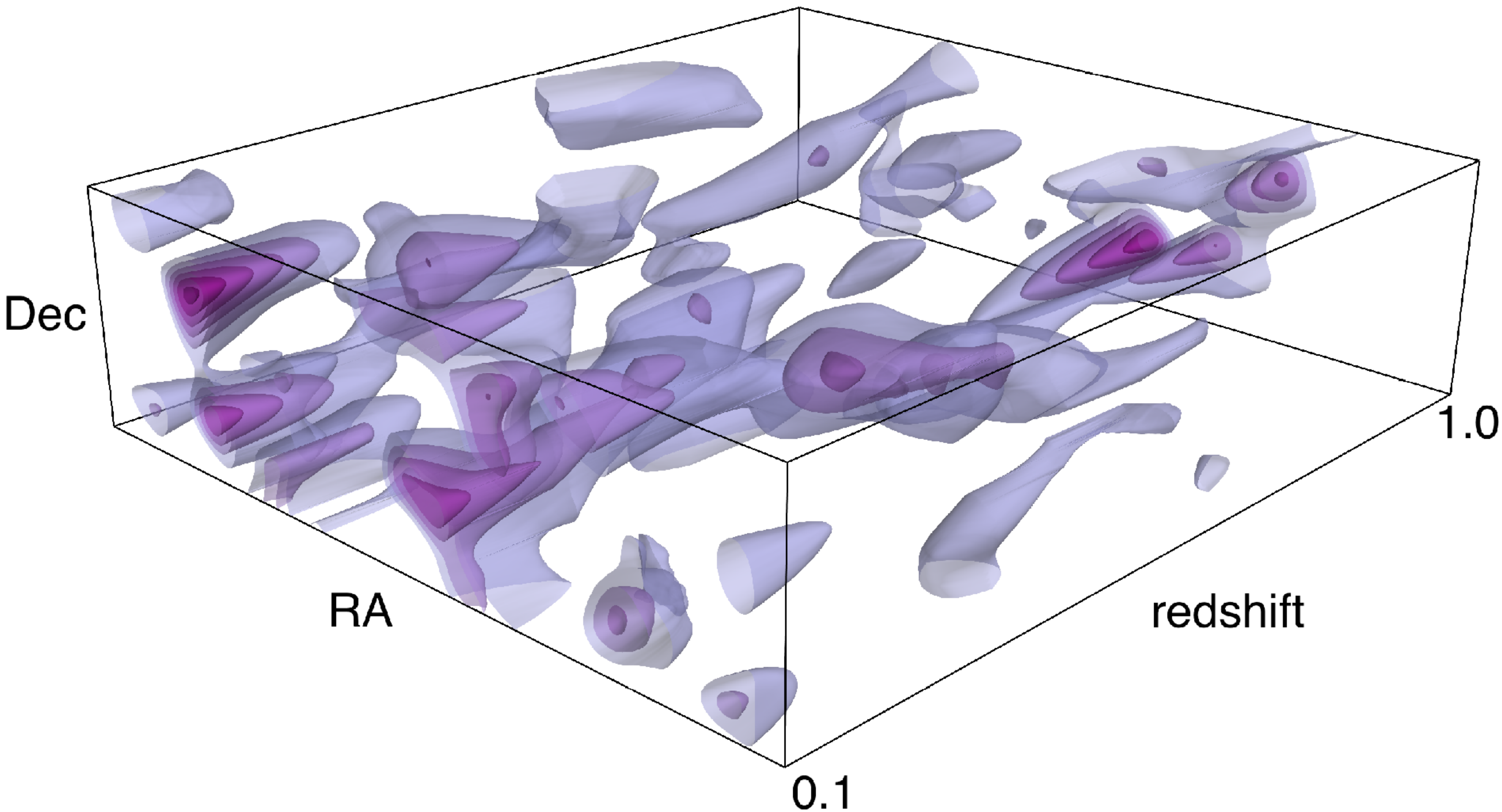
Largest 3D mass map ever created



see also Subaru press release: https://www.naoj.org/Pressrelease/2018/02/26/

Application of mass map: peaks

- high S/N peaks of mass maps corresponds to massive clusters of galaxies
- provide a unique means of constructing a shear (mass) selected cluster sample (e.g., Wittman+2001, Miyazaki+2002, Schirmer+2007, …)
- however it was difficult to construct a large sample of mass selected clusters because it requires both wide and deep imaging

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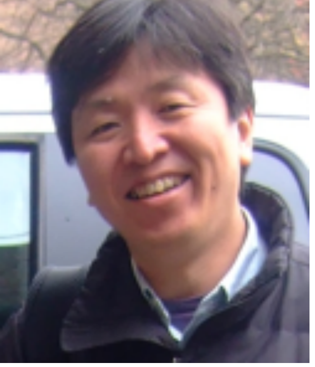
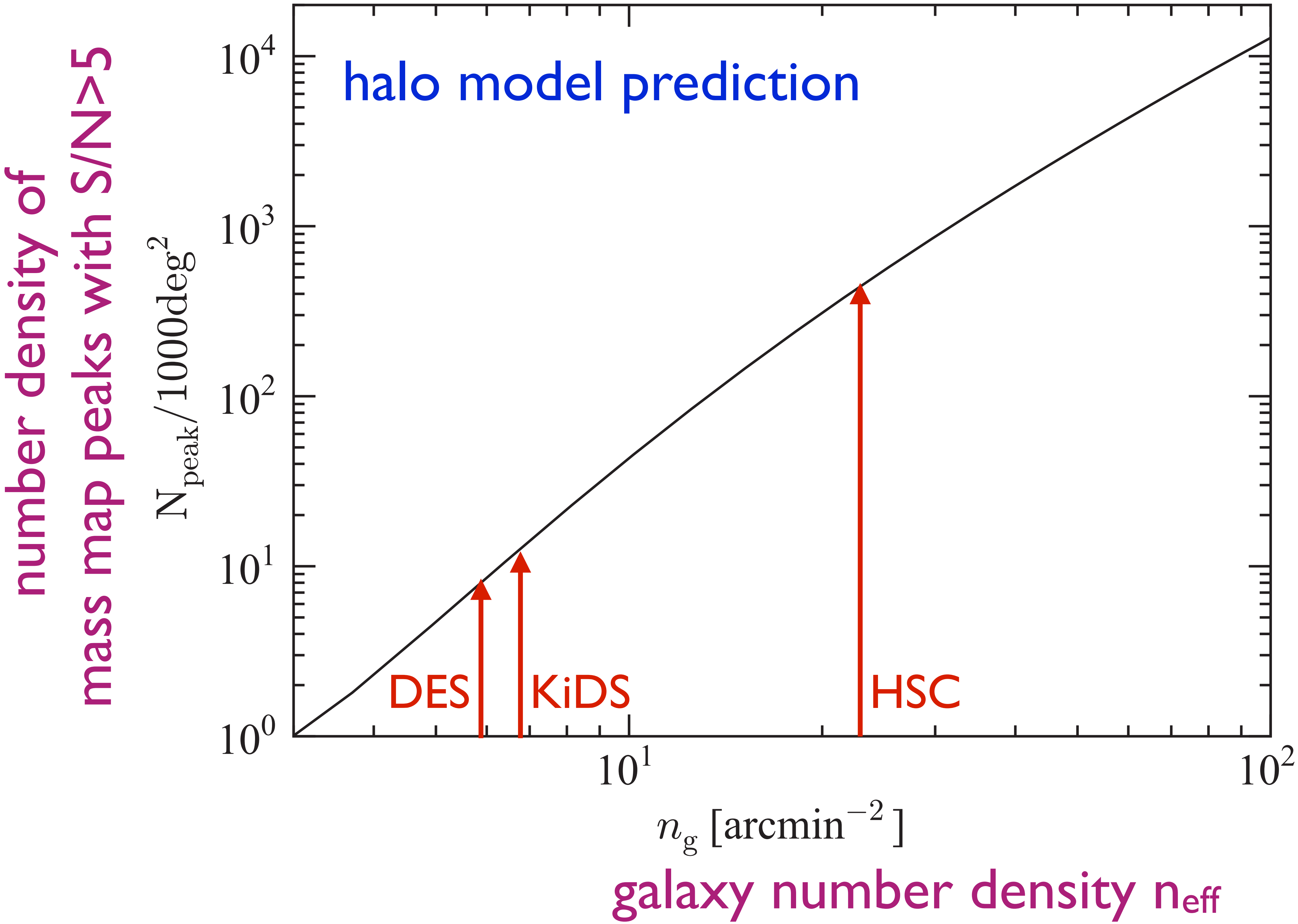
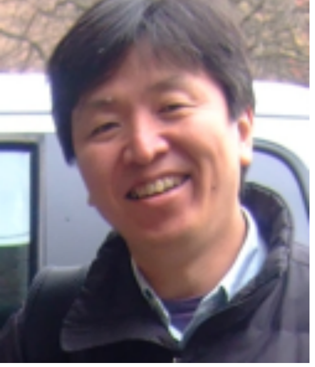


Importance of high n_{eff}





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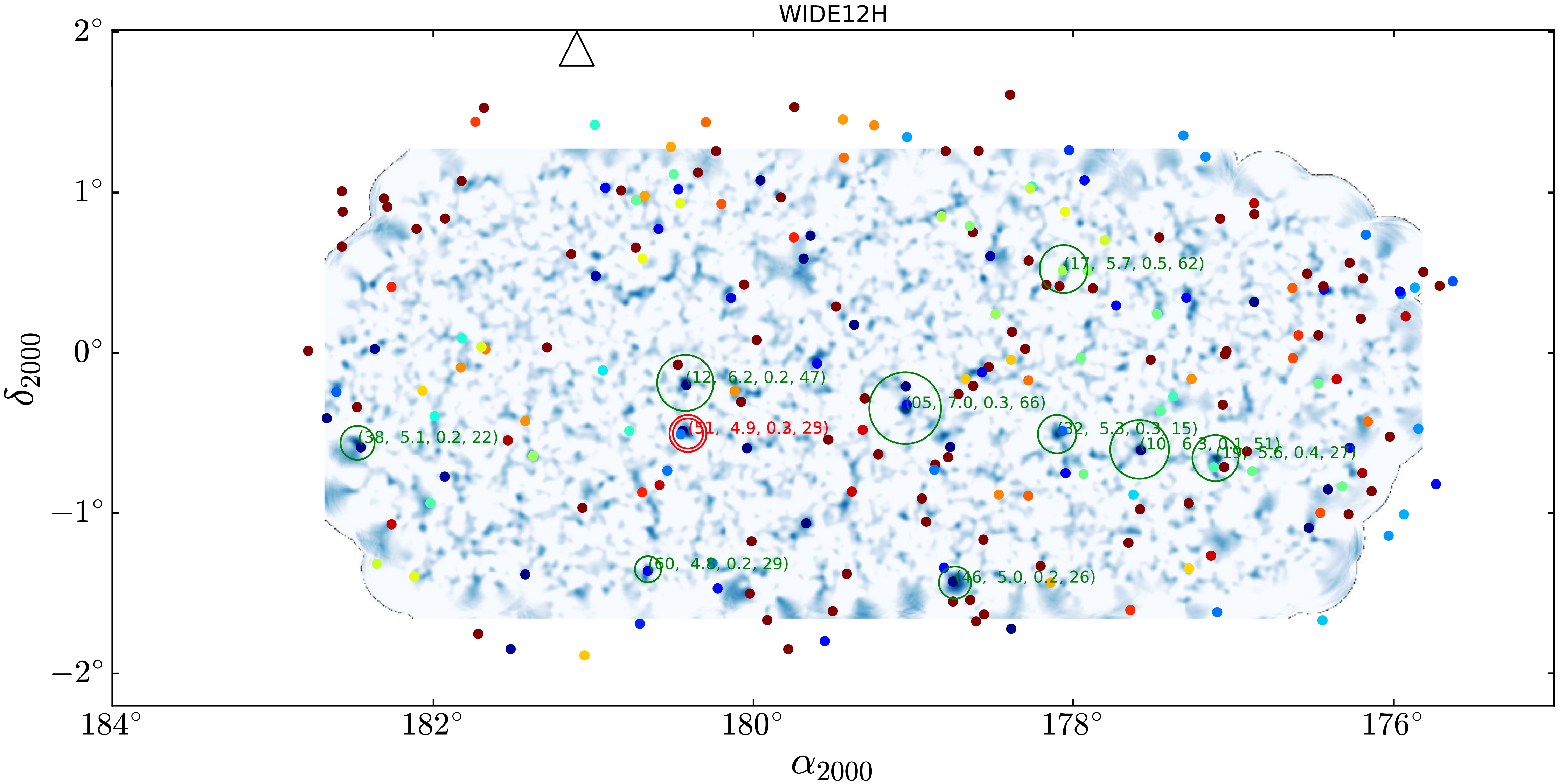
Shear selected cluster sample



open circles: mass map peaks

filled circles: optical (CAMIRA) clusters

- 65 mass map peaks with S/N>4.7 (by far the largest shear-selected cluster sample)
- almost all of them match optical clusters

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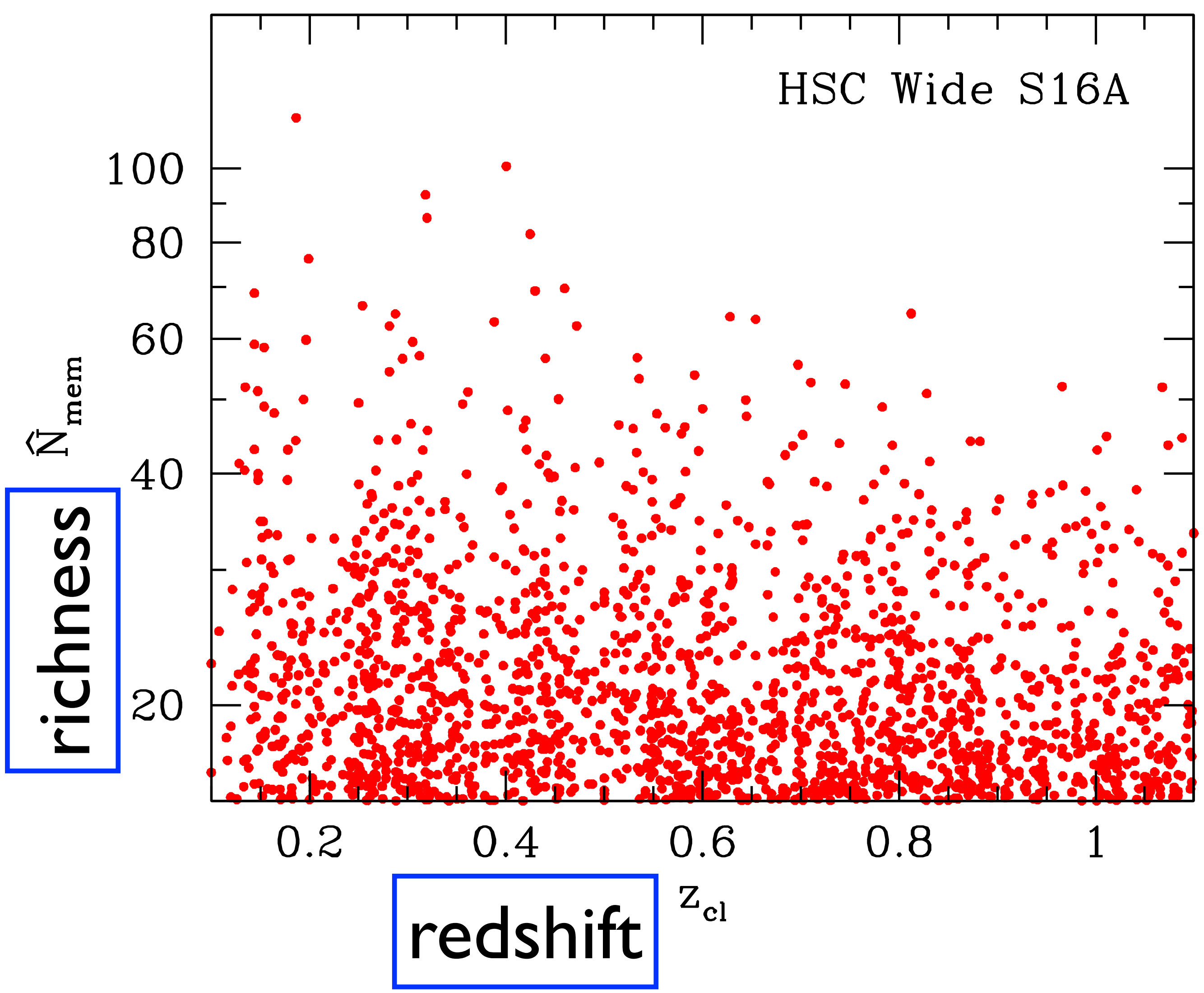
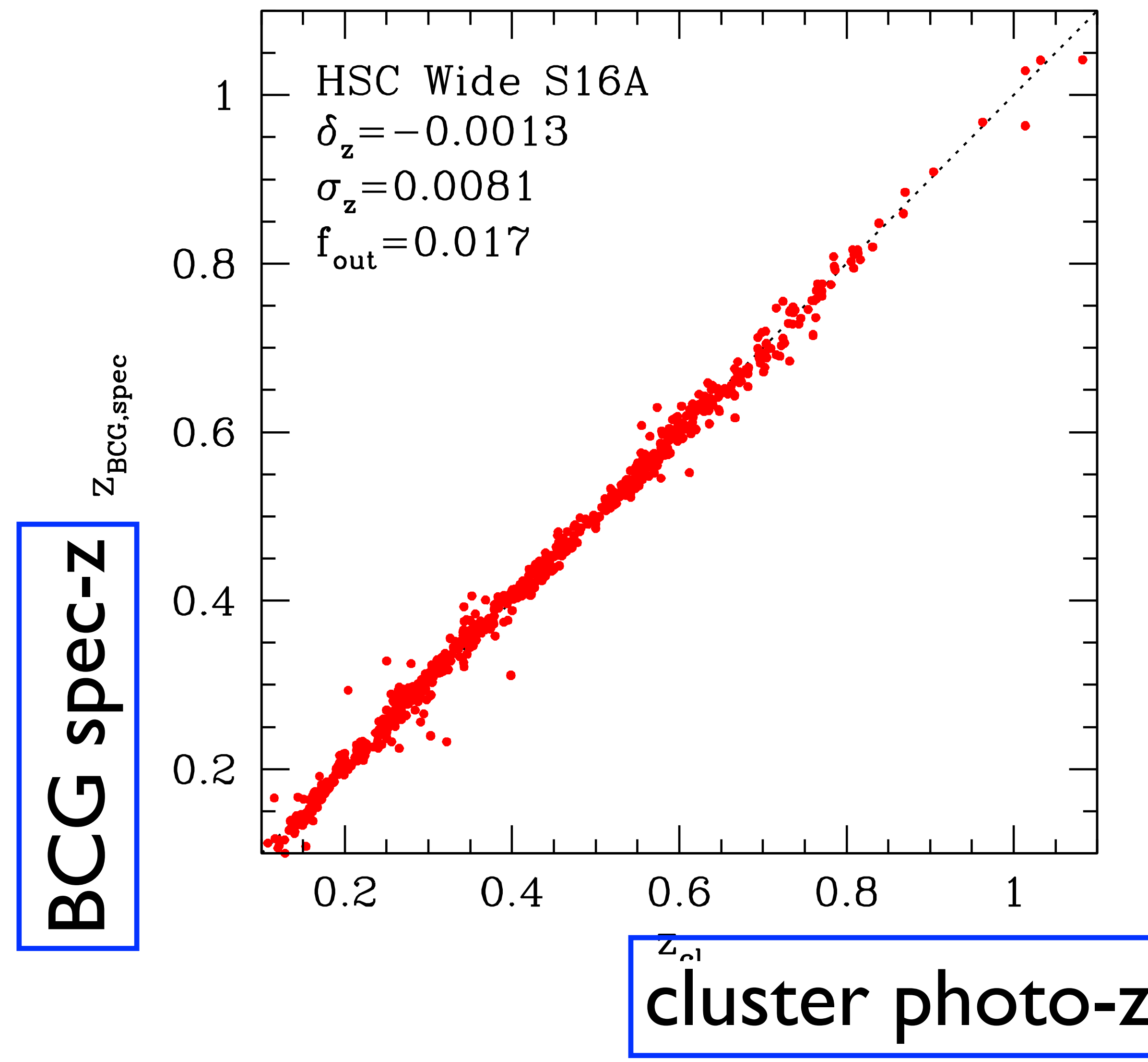
CAMIRA HSC cluster catalogue

- red-sequence cluster finder CAMIRA (MO 2014) applied to HSC survey data
- uniform cluster catalog out to z=1.1!





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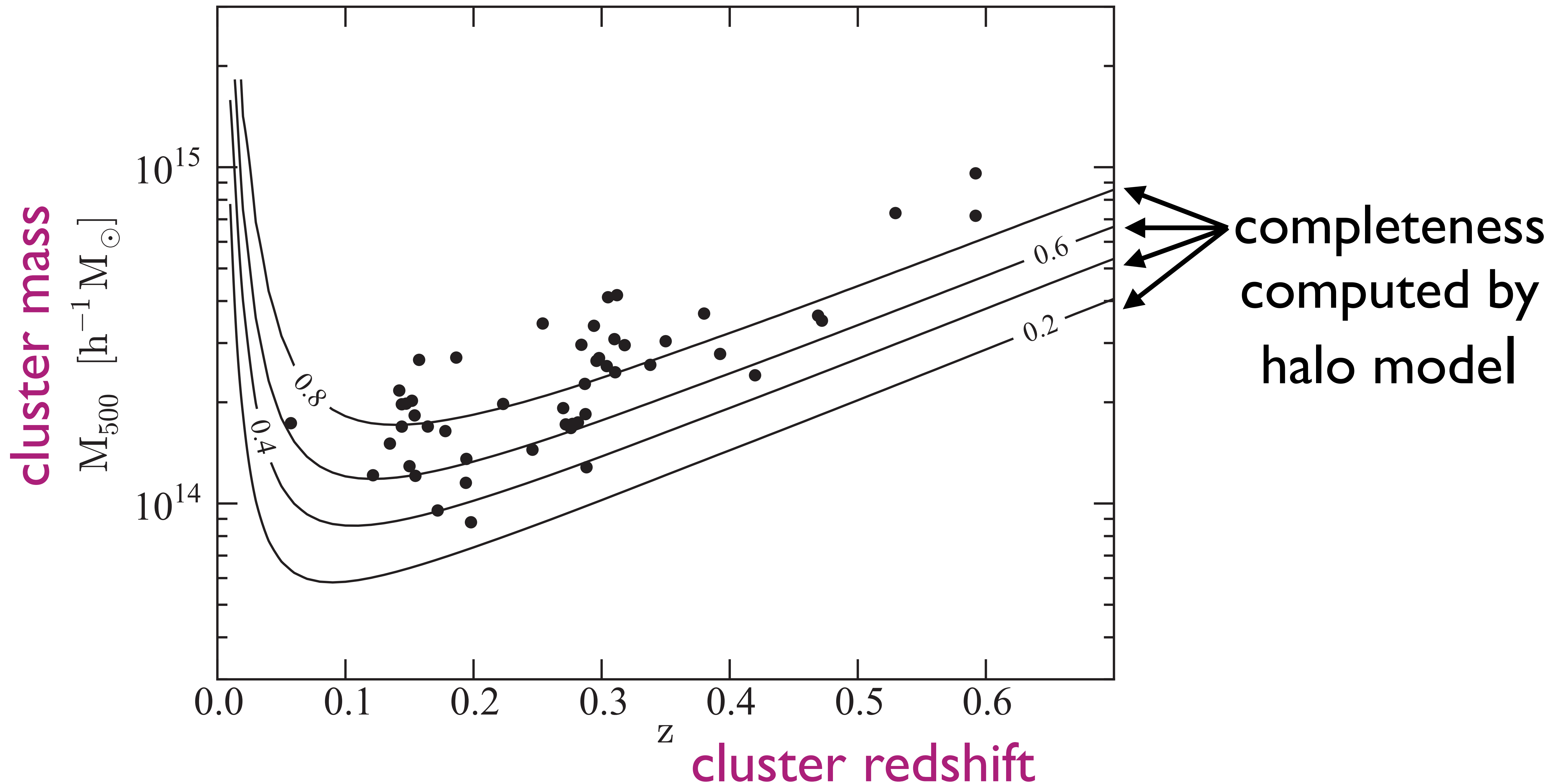
Shear selected clusters



- well-defined selection function is advantage!

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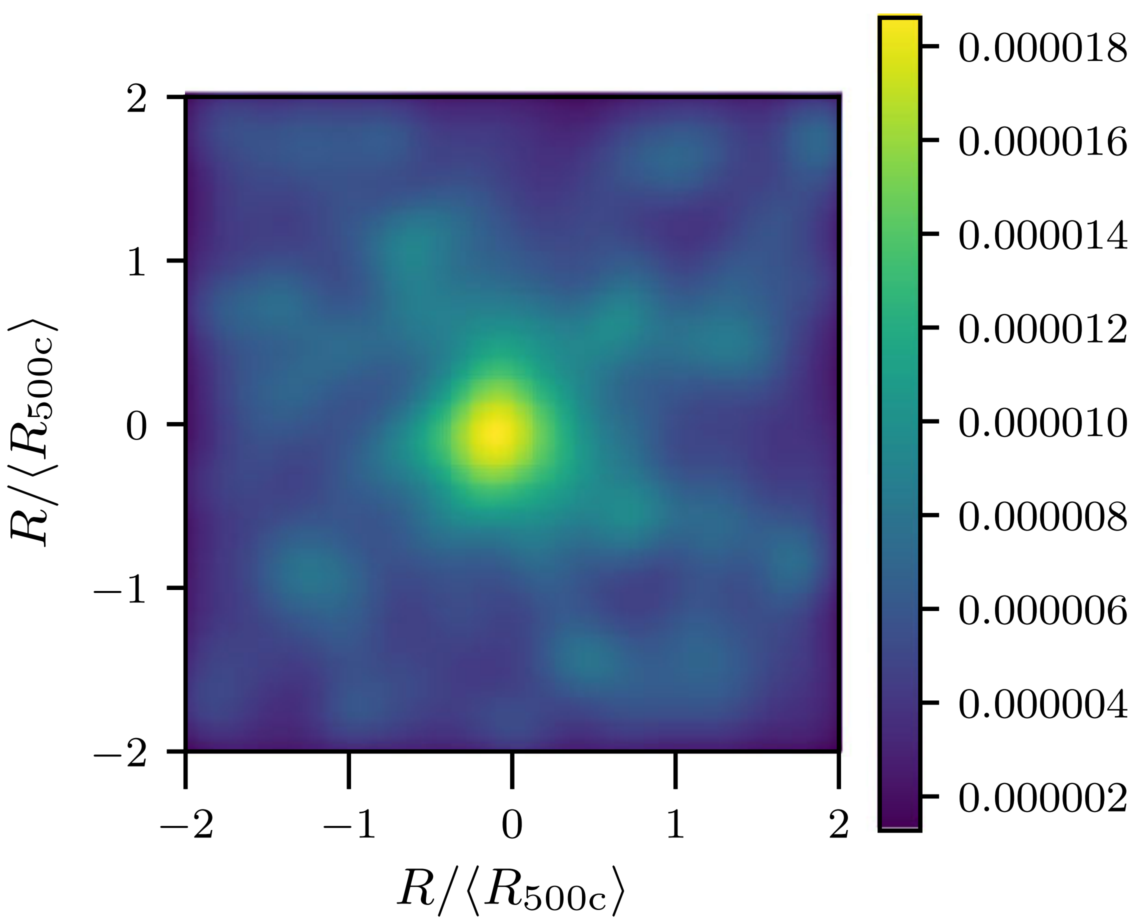
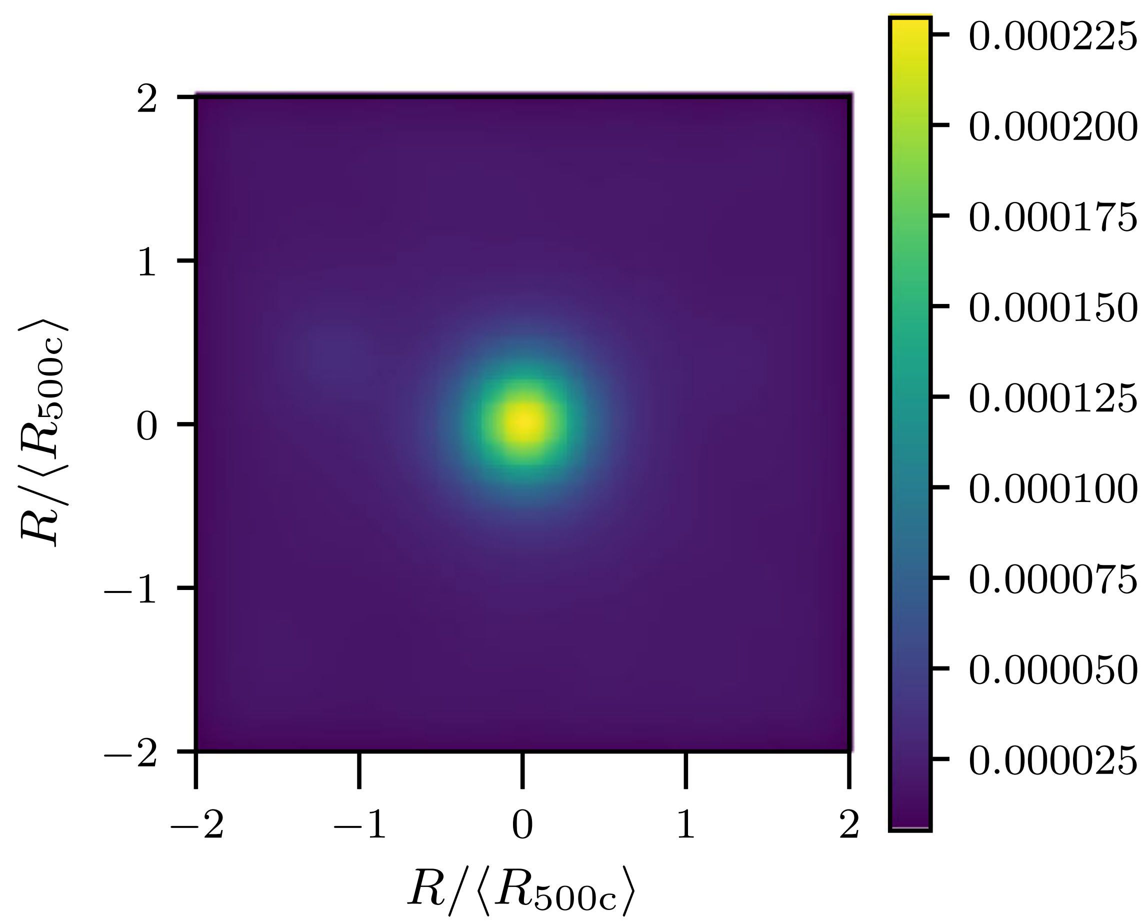
X-ray underluminous?

- stacked RASS X-ray images of shear selected clusters versus X-ray clusters w/ similar masses
- factor of 2 difference in average X-ray luminosity!



shear-selected clusters



X-ray clusters

Other HSC lensing results

- weak lensing mass measurements of SZ clusters to calibrate hydrostatic mass bias
  (Medezinski+2018, Miyatake+2018)
  [see Hironao Miyatake's talk on Wednesday!]
- discovery of many strong lenses
  (Tanaka+2016, Chan+2016, More+2017, Sonnenfeld+2018a)
- combining weak and strong lensing analysis
  (Sonnenfeld+2018b)
  [see Alessandro Sonnenfeld's talk on Friday!]

Hikage, MO+ in prep.

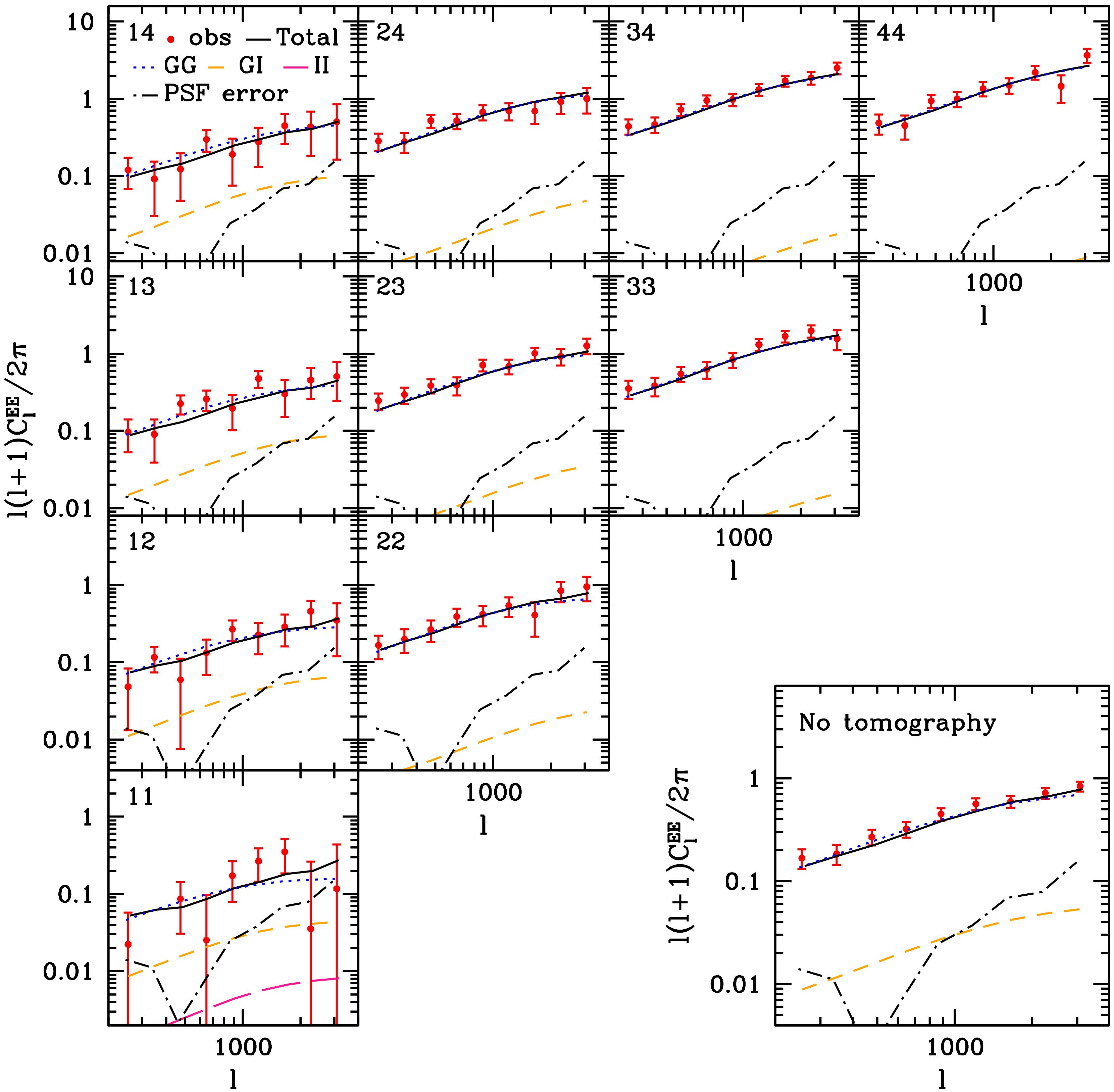
Coming soon: cosmic shear

- analysis in Fourier space w/ pseudo-C_l method
  (see Hikage+2011, Hikage & MO 2016)
- cosmology-dependent covariance
- accuracy of C_l measurement and covariance tested against realistic mock shear catalogs
- B-model C_l consistent with zero, and best-fit χ^2 of E-mode C_l fully acceptable
- analysis blinded both catalog and analysis level

Hikage, MO+ in prep.

Coming soon: cosmic shear

(normalization blinded)



4-bin tomography

marginalize over photo-z error, IA, PSF residual error

4% constraint on $S_8=\sigma_8(\Omega_m/0.3)^{0.45}$

Summary

- HSC survey is an ideal survey for lensing!
- its high galaxy number density allows us to reconstruct high-resolution mass maps, crucial for finding clusters by lensing
- a large sample of purely mass selected cluster sample sheds new light on clusters
- cosmological constraints coming soon!