Cosmological constraints from Subaru weak lensing cluster counts

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Takashi Hamana (NAOJ)

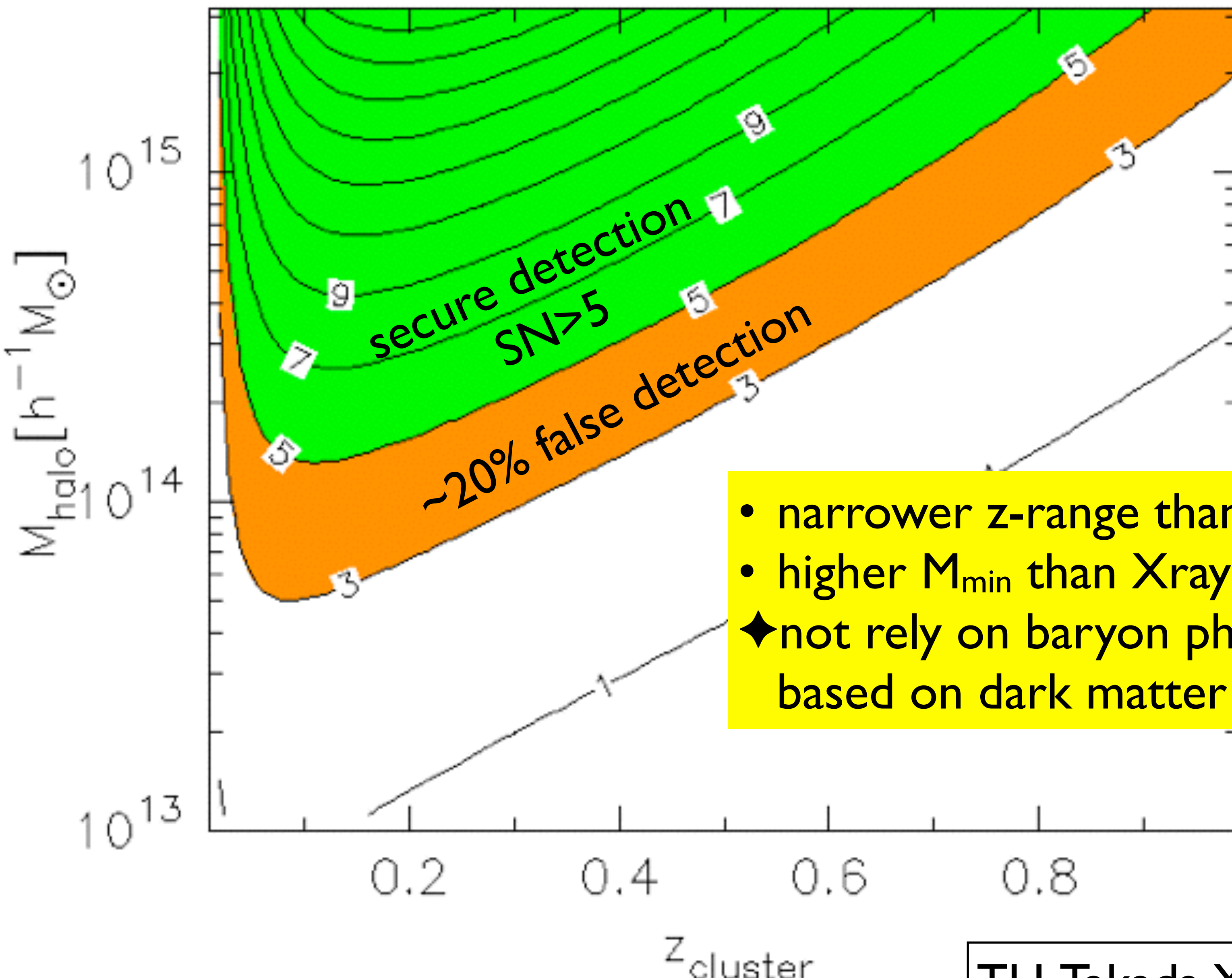
in collaboration with
M. Koike, L. Miller, S. Miyazaki, M. Oguri, J. Sakurai,
M. Sato, M. Shirasaki, M. Takada, N. Yoshida

outline
1. Weak lensing cluster finding
2. Theoretical model of weak lensing cluster counts
3. Data and analysis
4. Results
5. Summary & Future prospects for HSC survey

2015/7/24 LSS conference @Garching

Weak lensing cluster finding

Expected weak lensing SN(M,z) for Subaru weak lensing survey



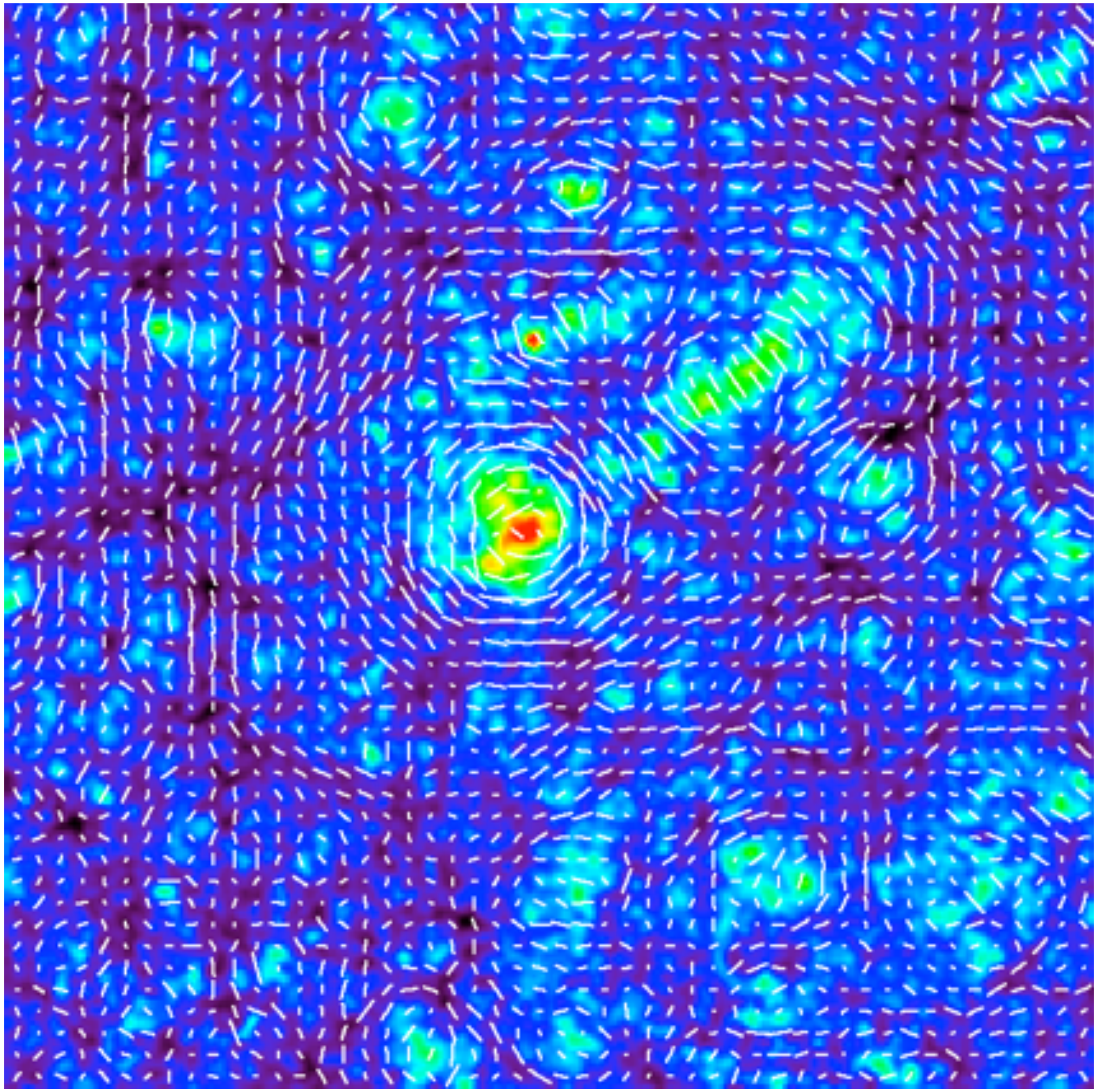
- narrower z-range than SZ
- higher M_{min} than Xray

✦not rely on baryon physics but based on dark matter concentration

TH, Takada, Yoshida (2004)

Weak lensing cluster finding

Searching for peaks in matched filtered weak lensing mass map



Schneider 1996

$$\mathcal{K}(\boldsymbol{\theta}) = \int \mathrm{d}^2\boldsymbol{\phi}\ \kappa(\boldsymbol{\phi} - \boldsymbol{\theta}) U(|\boldsymbol{\phi}|),$$

$$\mathcal{K}(\boldsymbol{\theta}) = \int \mathrm{d}^2\boldsymbol{\phi}\ \gamma_{\mathrm{t}}(\boldsymbol{\phi} : \boldsymbol{\theta}) Q(|\boldsymbol{\phi}|),$$

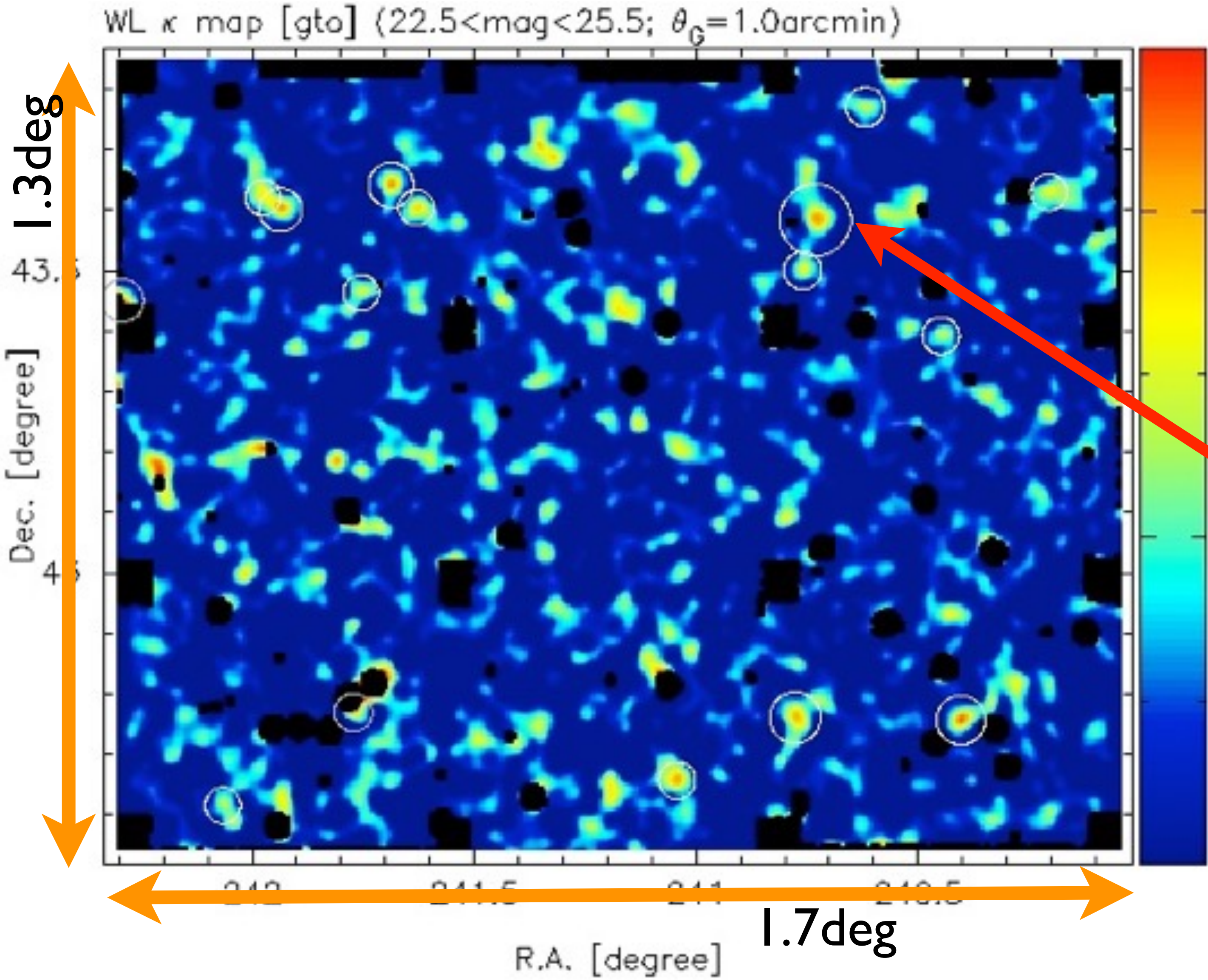
$$Q(\theta) = \int_0^{\theta} \mathrm{d}\theta'\ \theta' U(\theta') - U(\theta).$$

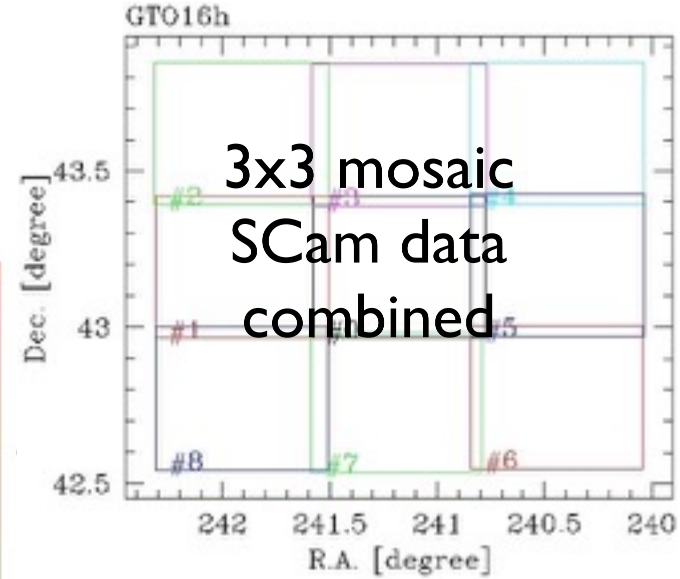
✓Serendipitous finding
- Erben+2000
- Umetsu & Futamase 2000
- Dahel+2003

✓Systematic survey
- Wittman+2001 (CTIO)
- Miyazaki, TH+2001 (Subaru)
- Schirmer+2007 (MPG/ESO)

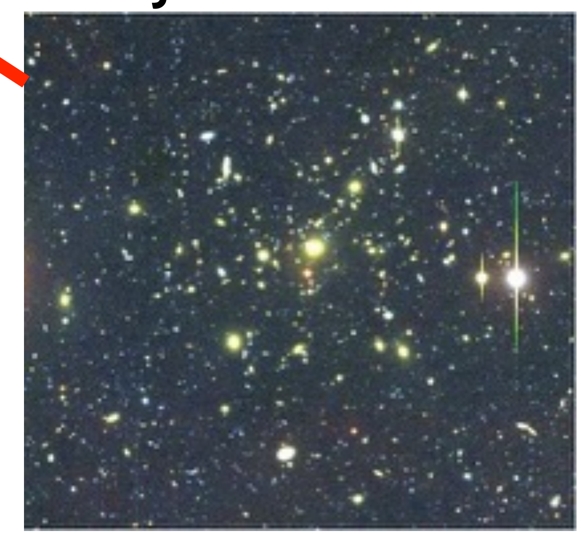
Weak lensing cluster finding

Searching for clusters in weak lensing mass map





SL J1602.8+4335



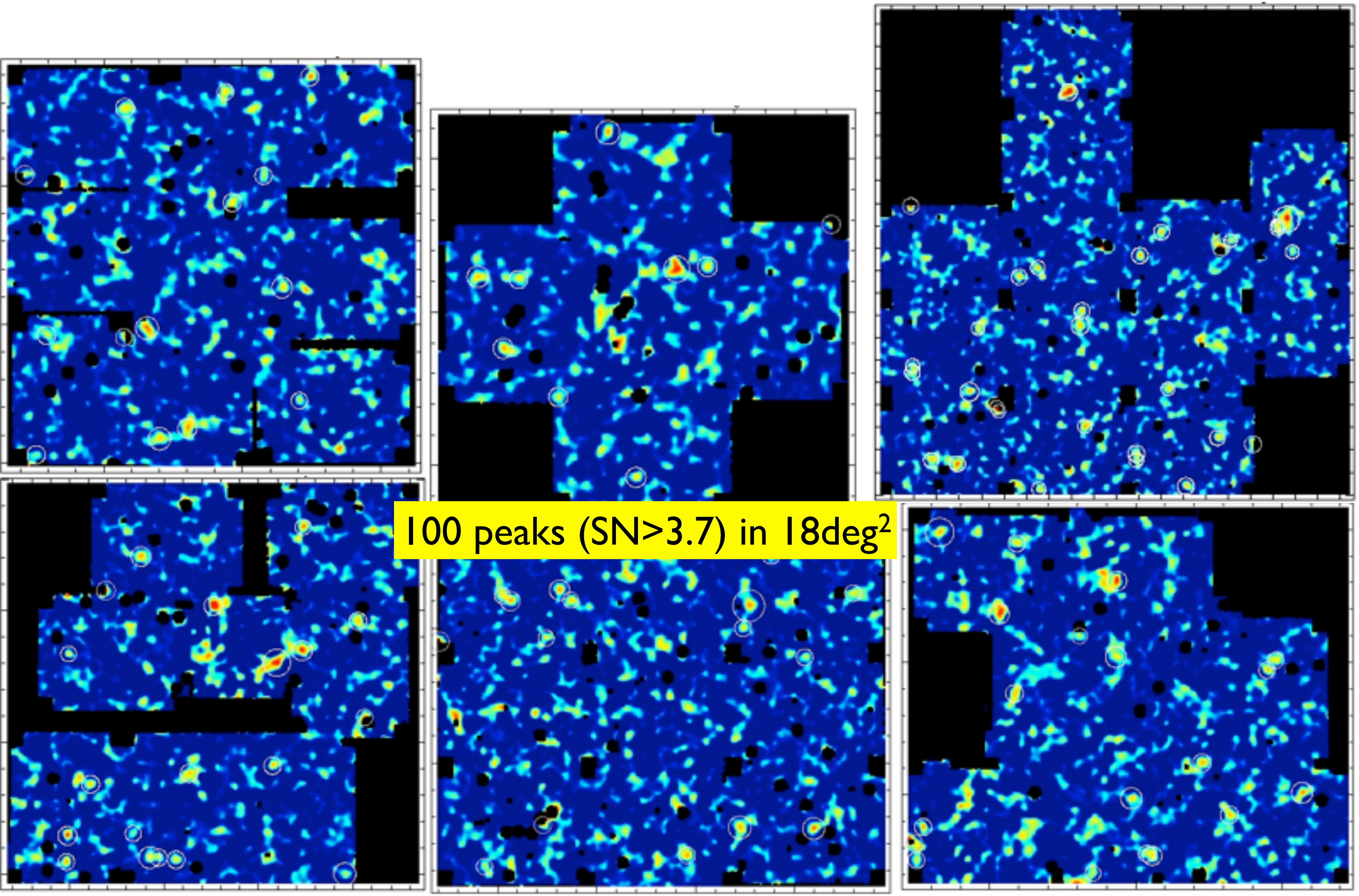
1st weak lensing cluster
z=0.42

Miyazaki, TH+2002 SuprimeCam Rc-band data

Weak lensing cluster finding

We examined capability of weak lensing cluster finding

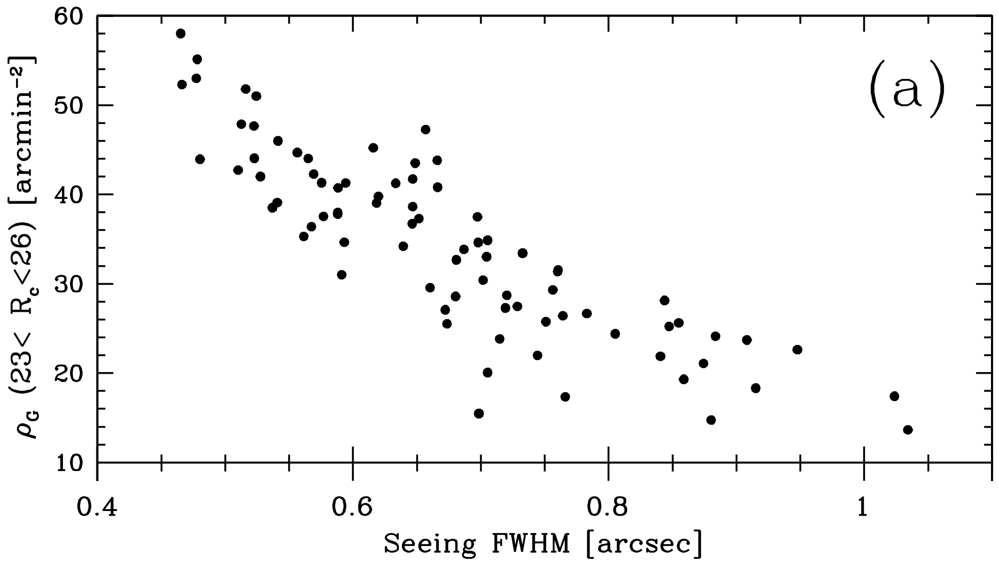
Miyazaki, TH+(2007)



Weak lensing cluster finding

✓cluster detection rate VS observational condition

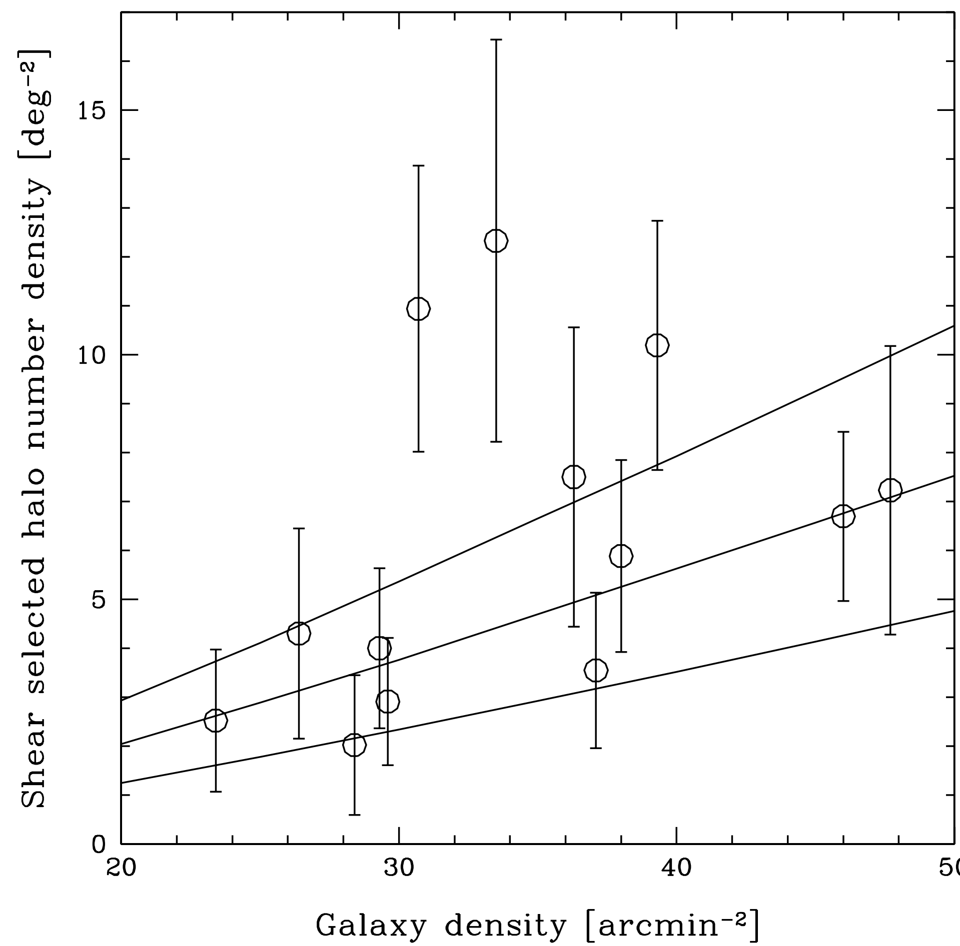
seeing VS lensing-usable galaxy density



$$\text{noise} \propto 1/\sqrt{n_g}$$

Good seeing is key to have more lensing-usable galaxies and to find more clusters

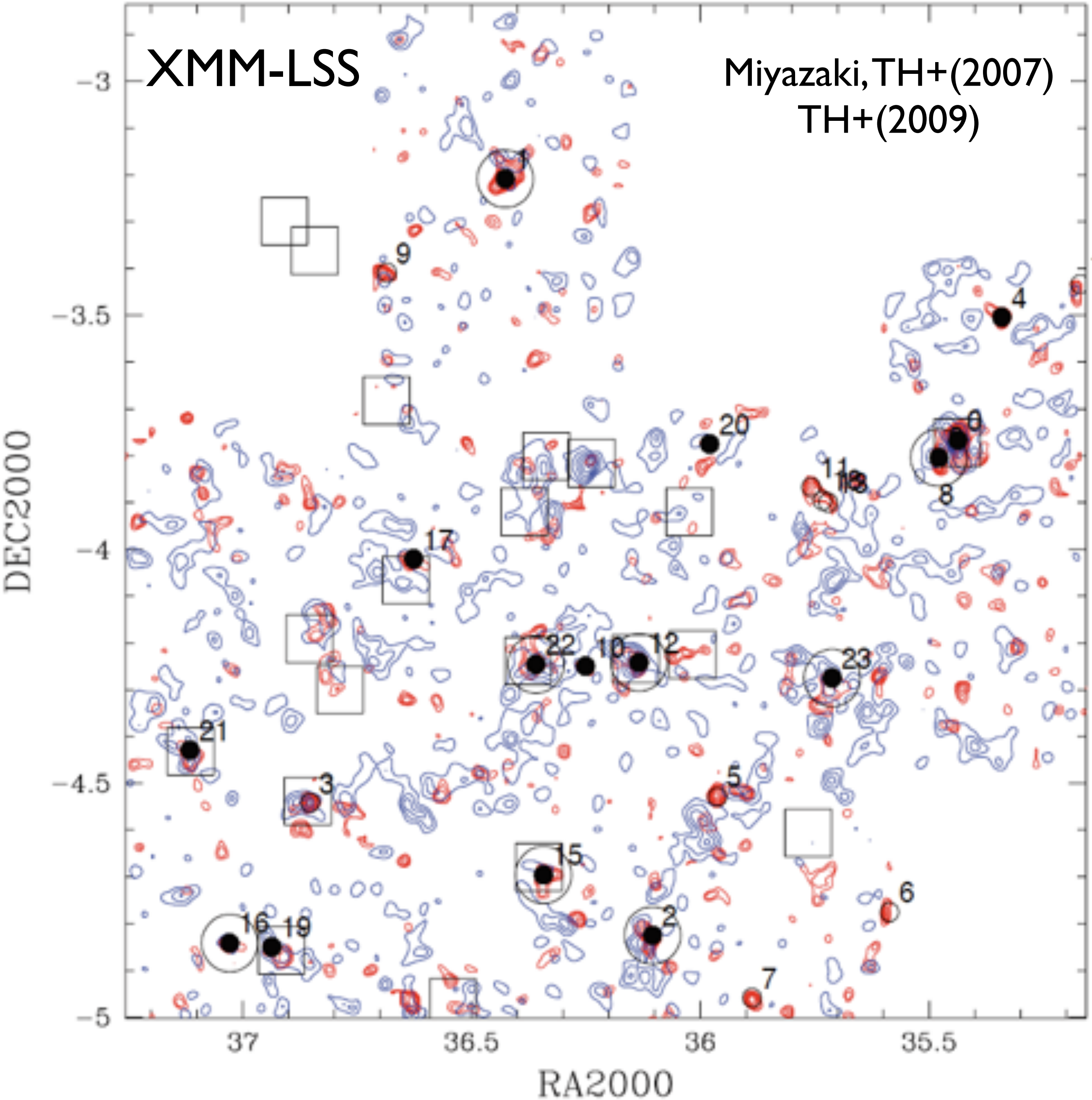
Cluster detection VS galaxy density



Miyazaki, TH+(2007)

Weak lensing cluster finding

✓Purity (contamination rate)



Xray data from XMM-LSS & spectroscopic follow-ups of WL peaks (TH+2007)

➡12/15 WL peaks (SN>3.7) have optical and/or Xray cluster-part

➡~20% false for SN>4 peaks

red cont. : WL-mass

blue cont. : galaxy density

circle : WL-peak

square : Xray cluster

open-circle: z_{spec} cluster

Theoretical model of WL cluster counts

$$n_{\rm halo}(M, z)$$

Signal from each halo

- NFW profile
- M-c relation
- $n_s(z)$

$$\gamma_t(M, z)$$

$$\mathcal{K}(\boldsymbol{\theta}) = \int \mathrm{d}^2\boldsymbol{\phi}\ \gamma_{\rm t}(\boldsymbol{\phi} : \boldsymbol{\theta}) Q(|\boldsymbol{\phi}|),$$

Bartelmann+(2001)
TH, Takada, Yashida (2004)
TH, Oguri, Shirasaki, Sato (2012)

Noise from intrinsic galaxy shape noise

$$\sigma_{\rm shape} = \frac{\sigma_e}{2n_g} \int d^2\theta\ Q^2(\theta)$$

$$SN = \mathcal{K}/\sigma_{\rm shape}$$

$$n_{\rm peak}(SN)$$

Theoretical model of WL cluster counts

✓modeling various effects

- galaxy intrinsic shape (TH+2004, Tang&Fan2010, Liu+2014, Shirasaki+2015)
- large-scale structures (TH+2004,2012,Marian+2010)
- diversity of halo properties
  - tri-axiality & orientation (TH+2012, Tang&Fan2005)
  - scatter in M-c relation (Cardone+2014, Manini&Romano2014)
- spatial variation of observational condition (TH+2015)
- lensing magnification effect (Schmidt&Rozo2011)
- baryon effect (Osato+2015)

✓optimization of window function

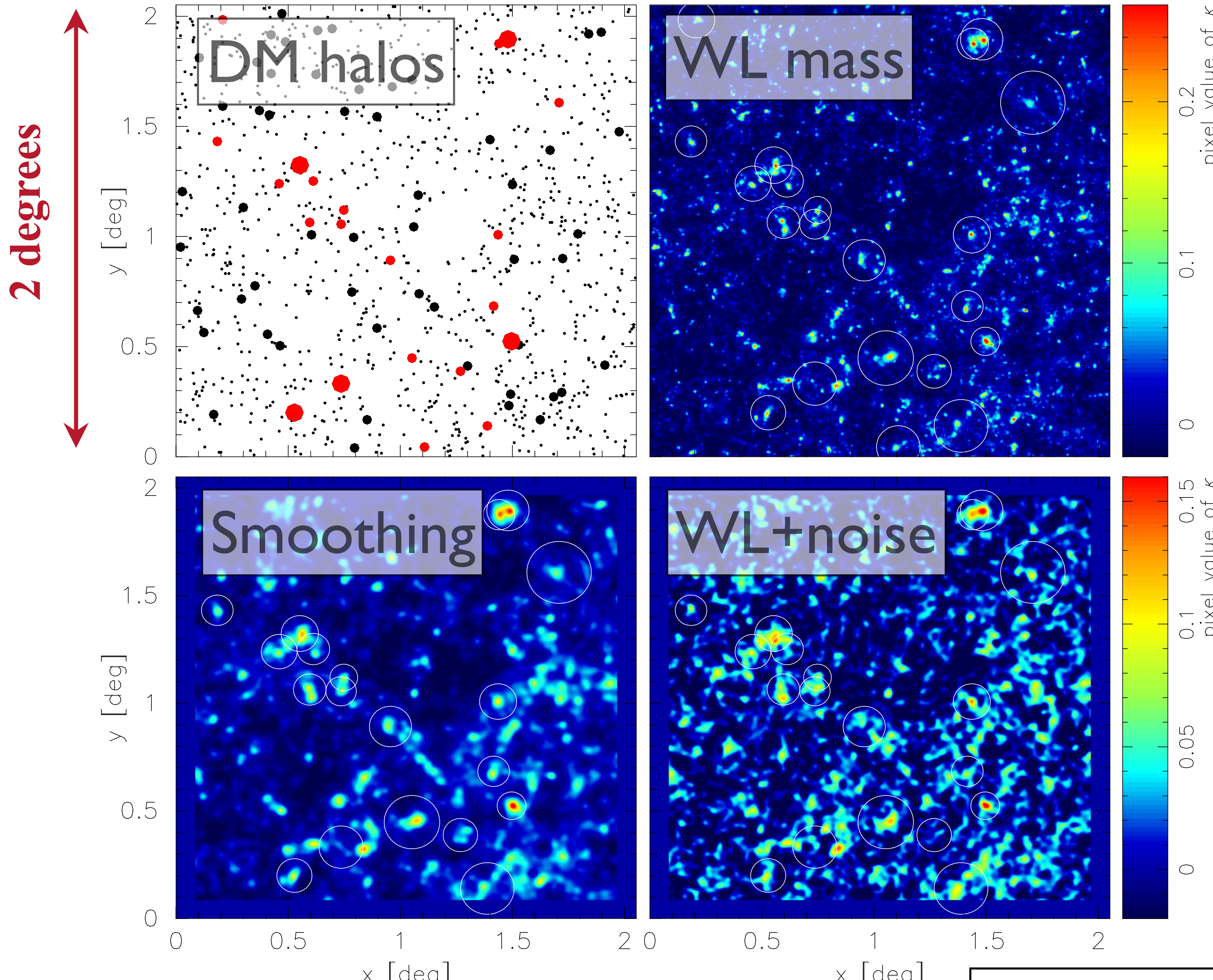
- get higher SN with a matched filter
- reduce the dilution effect by member galaxies

(TH+2012, Hennawai&Spergel 2005, Maturi+2005, Schmidt&Rozo2011)

see Chieh-An Lin's poster for an alternative approach

Theoretical model of WL cluster counts

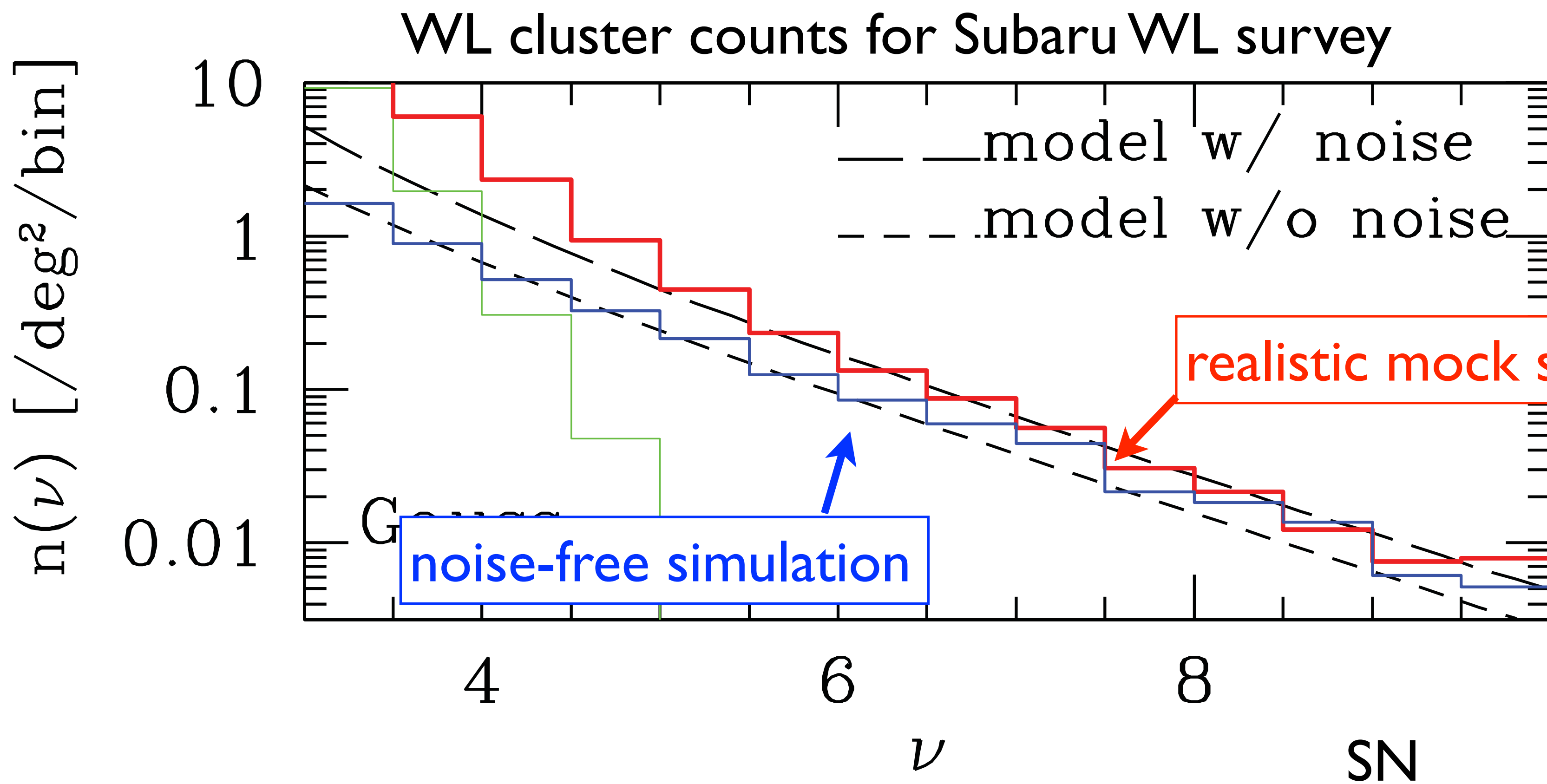
✓ tested against mock numerical simulation of weak lensing survey



TH, Takada, Yoshida (2004)

Theoretical model of WL cluster counts

✓ tested against mock numerical simulation of weak lensing survey



TH+ (2012)

Theoretical model of WL cluster counts

- Good agreement with the mock simulation result
- N_{peak}(SN>5)～0.5cluster/deg^2 for a Subaru-like data (n_g~25/arcmin^2)

➡Sensitive to n_g — N_{peak}(SN>5)<0.1/deg^2 for n_g~15/arcmin^2

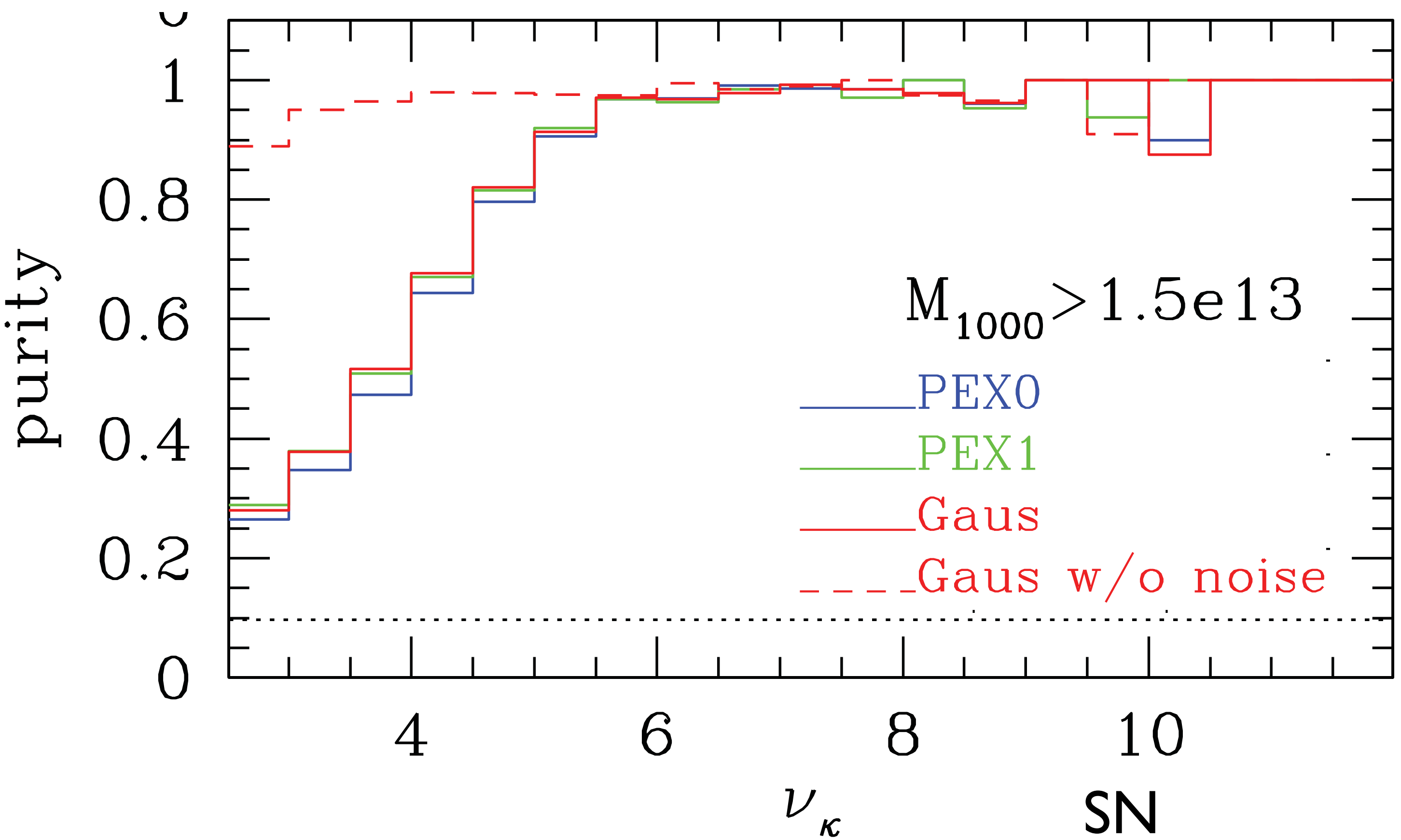
➡Need n_g>20/arcmin^2 to have "moderate mass cluster sample"

Theoretical model of WL cluster counts

✓ purity (1-contamination)

- ~90% for SN=5
- >98% for SN>6 (due to LOS projections)
- <50% for SN<4

TH+2012

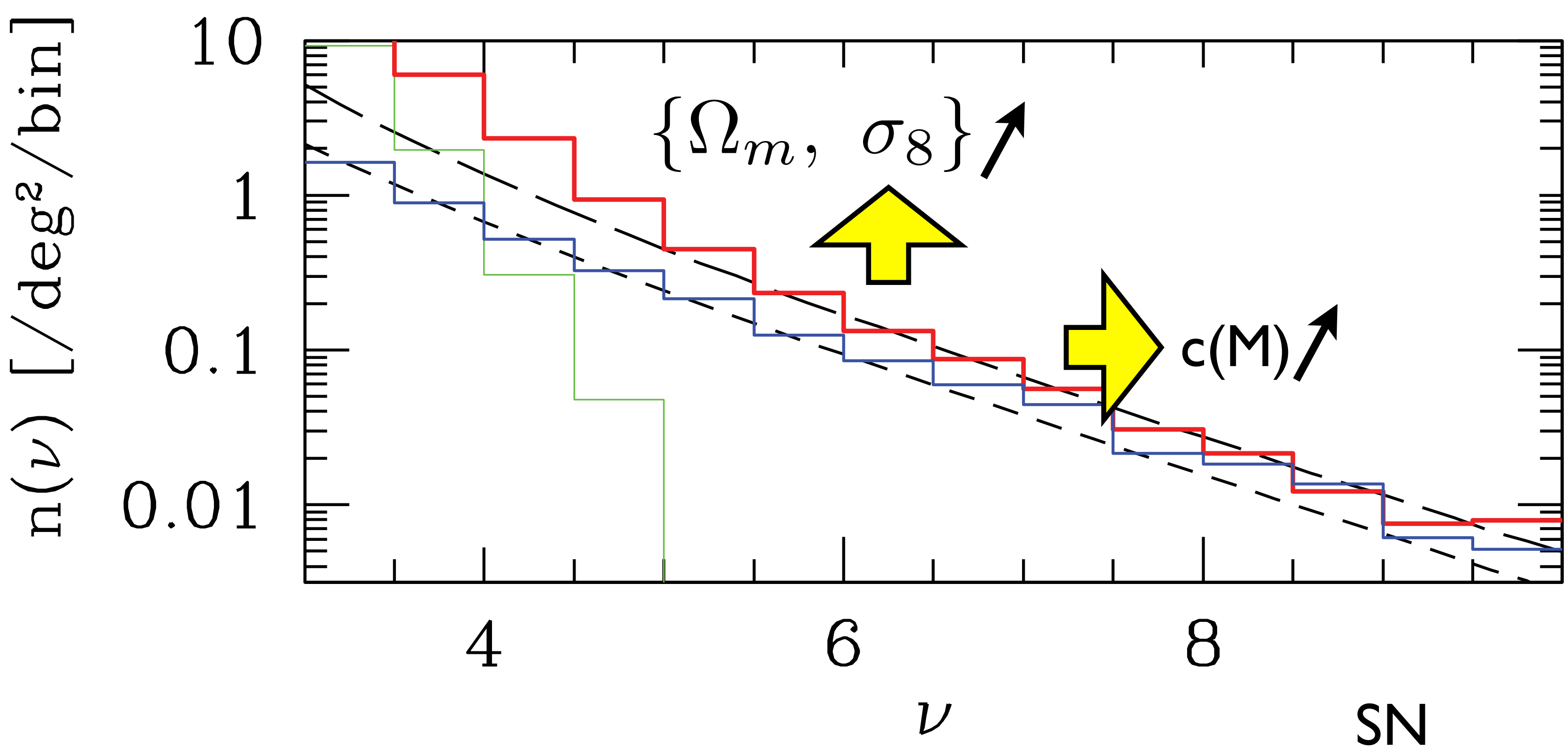


Theoretical model of WL cluster counts

✓Dependence on the cosmology & M-c relation

$\{\Omega_m,\ \sigma_8\} \nearrow \Rightarrow N_{\mathrm{halo}} \nearrow \Rightarrow N_{\mathrm{peak}} \nearrow$

$c(M) \nearrow \Rightarrow \text{peak height} \nearrow \Rightarrow N_{\mathrm{peak}} \nearrow$



TH+ (2012)

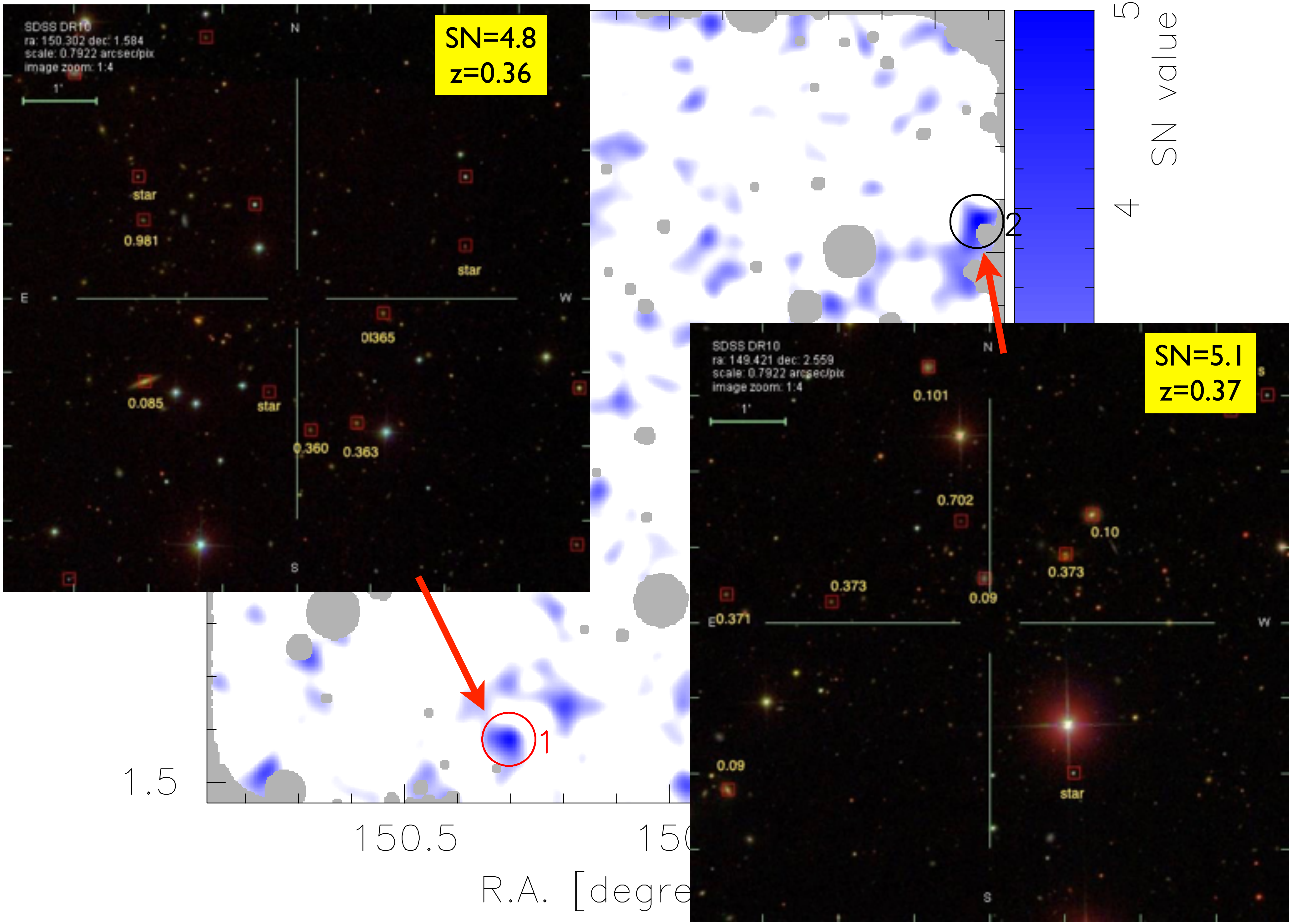
Data & Analysis

✓SuprimeCam i-band data from archive
- Texp > 40min (i_{lim}>25.5)
- seeing FWHM < 0.7”
- contiguous region > 2 deg^2

✓data reduction → *hscPipe* developed by Princeton-NAOJ-IPMU
✓object detection → *sextractor* (22<i<25 AB-mag)
✓shear measurement → *lensfit* tuned for SuprimeCam data

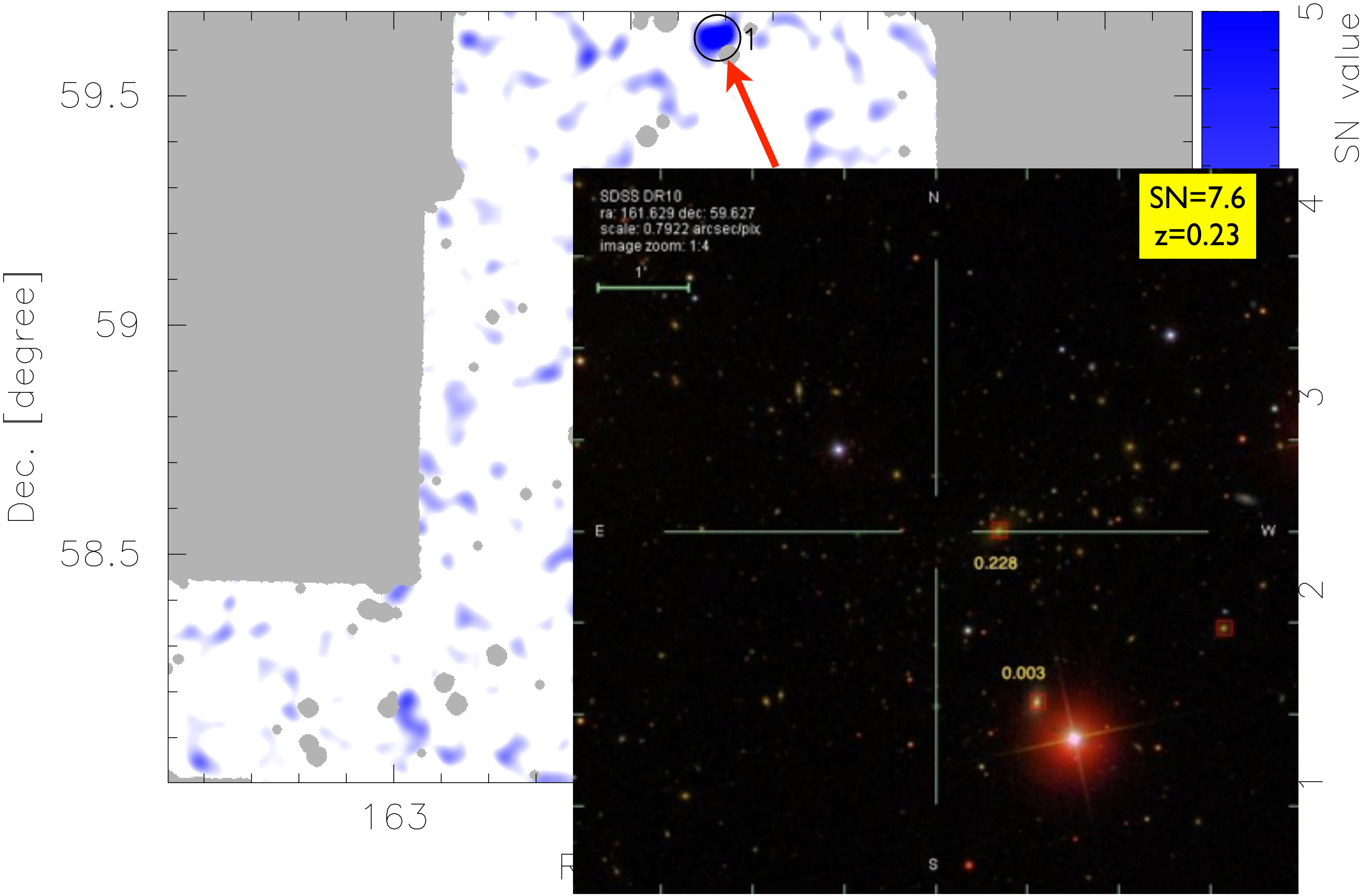
	area/$area^{eff}$ [deg^2]	n_g / n_g^{eff} [$arcmin^{-2}$]
XMM-LSS	3.6/2.8	24/21
COSMOS	2.1/1.6	29/26
Lockman-hole	2.1/1.6	26/24
ELAIS-N1	3.6/2.8	25/22
total	11.4/9.0	

Results COSMOS

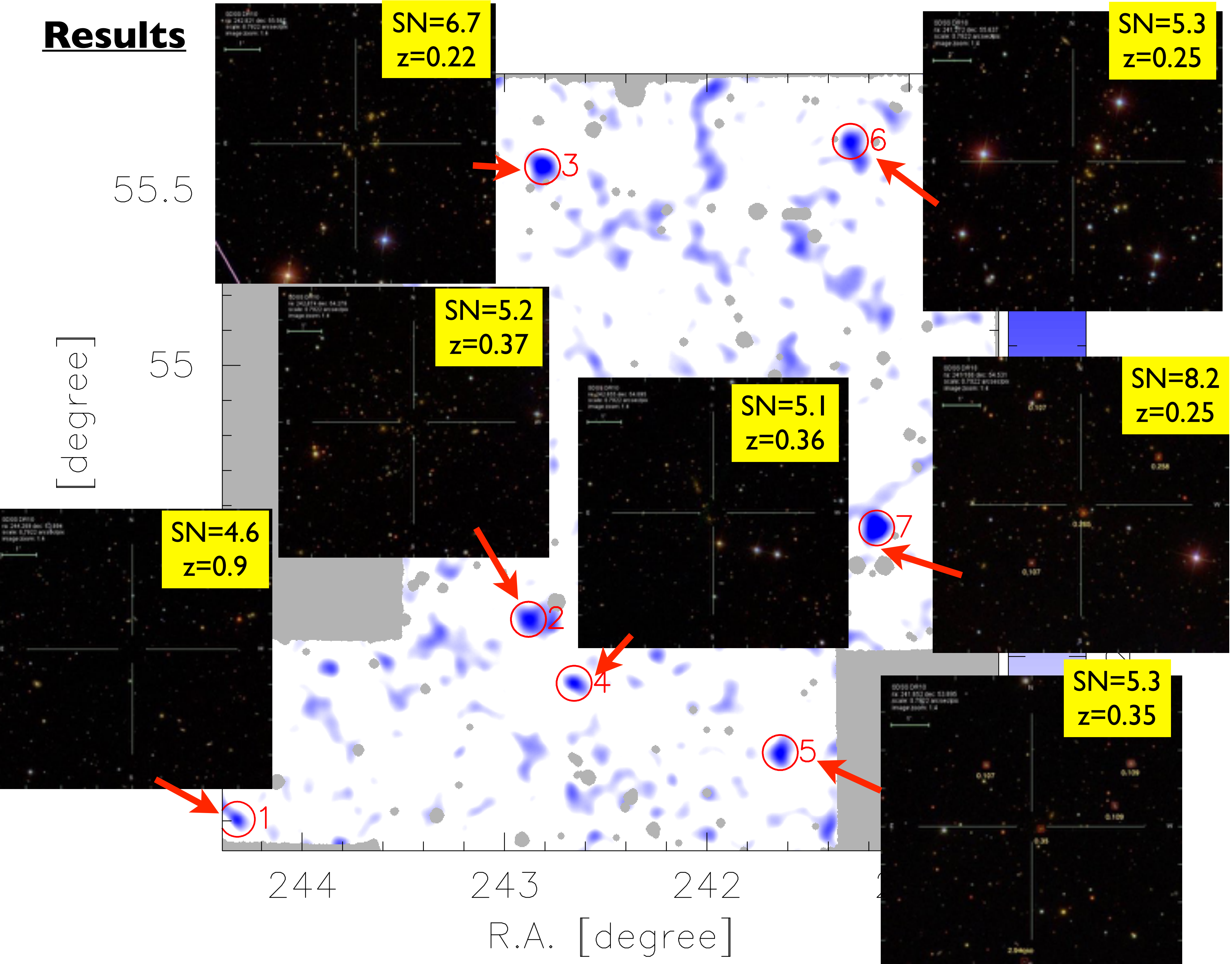


Results

Lockman-hole



Results


SN=6.7
z=0.22
SN=5.3
z=0.25
SN=5.2
z=0.37
SN=5.1
z=0.36
SN=8.2
z=0.25
SN=4.6
z=0.9
SN=5.3
z=0.35
1
2
3
4
5
6
7
55.5
55
[degree]
244
243
242
R.A. [degree]

Results

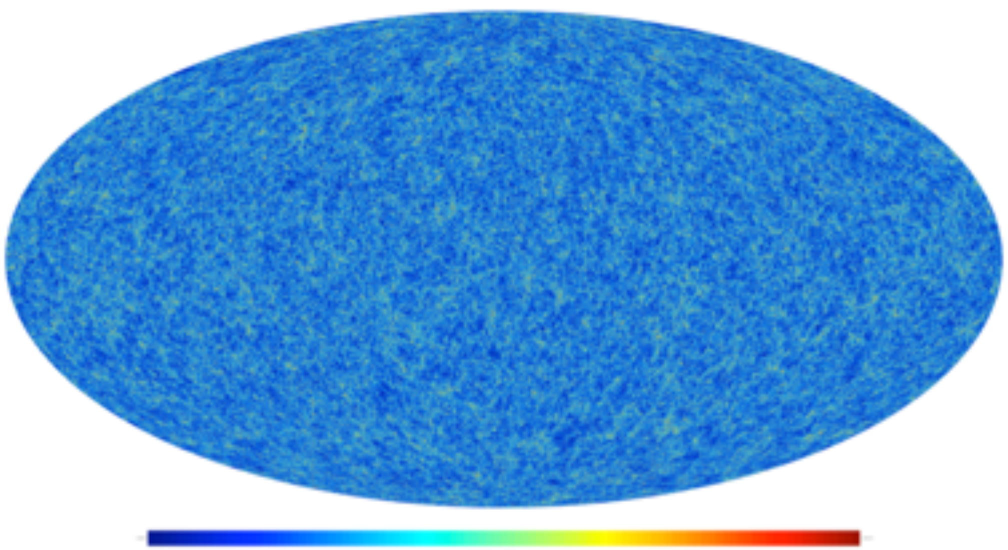
Sample (cosmic & Poisson) variance

- evaluated using mock survey data from full sky ray-tracing sim

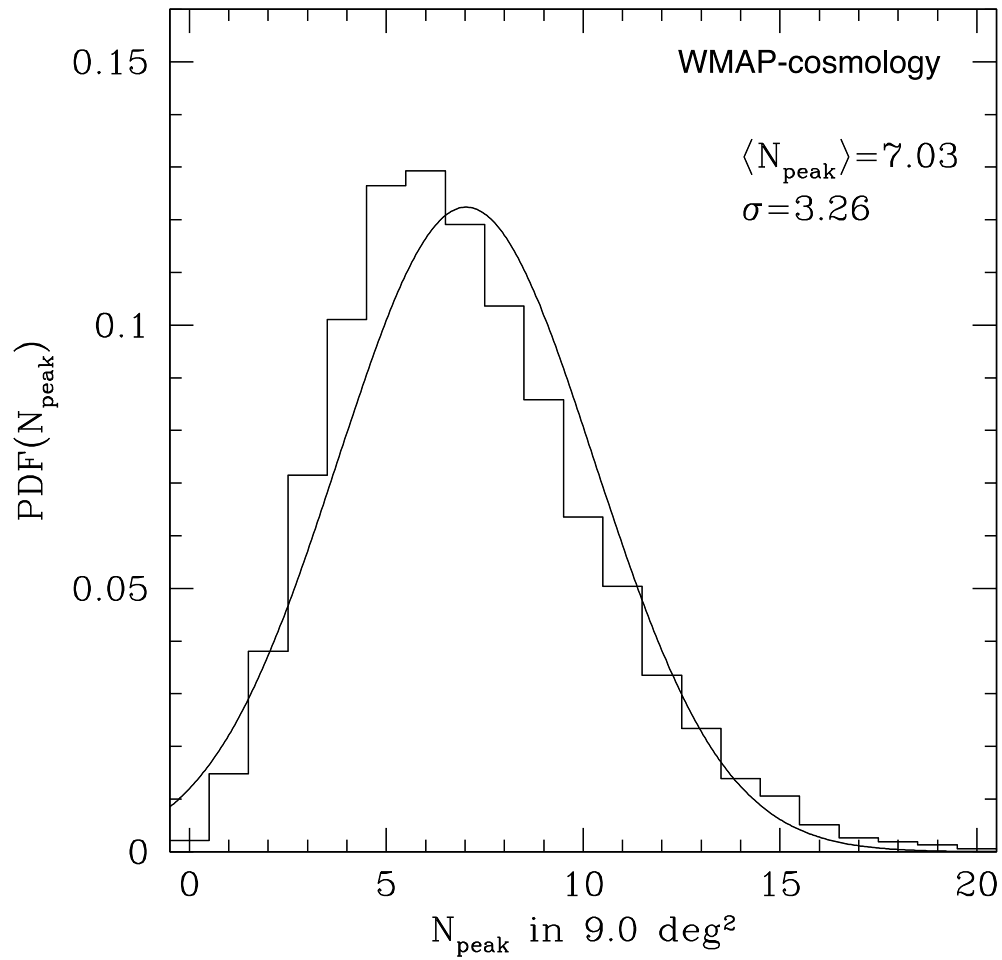
$$N_{peak}(SN > 5) = 6 \pm 3.1 \text{ in } 8.96\text{deg}^2$$

$$Var(N_{peak}) \simeq \text{Poisson} + CV^2$$

$$\rightarrow CV \simeq 1.9$$



Full-sky weak lensing sim.
by TH, Shirasaki, Takahashi
(see also Shirasaki+2015)

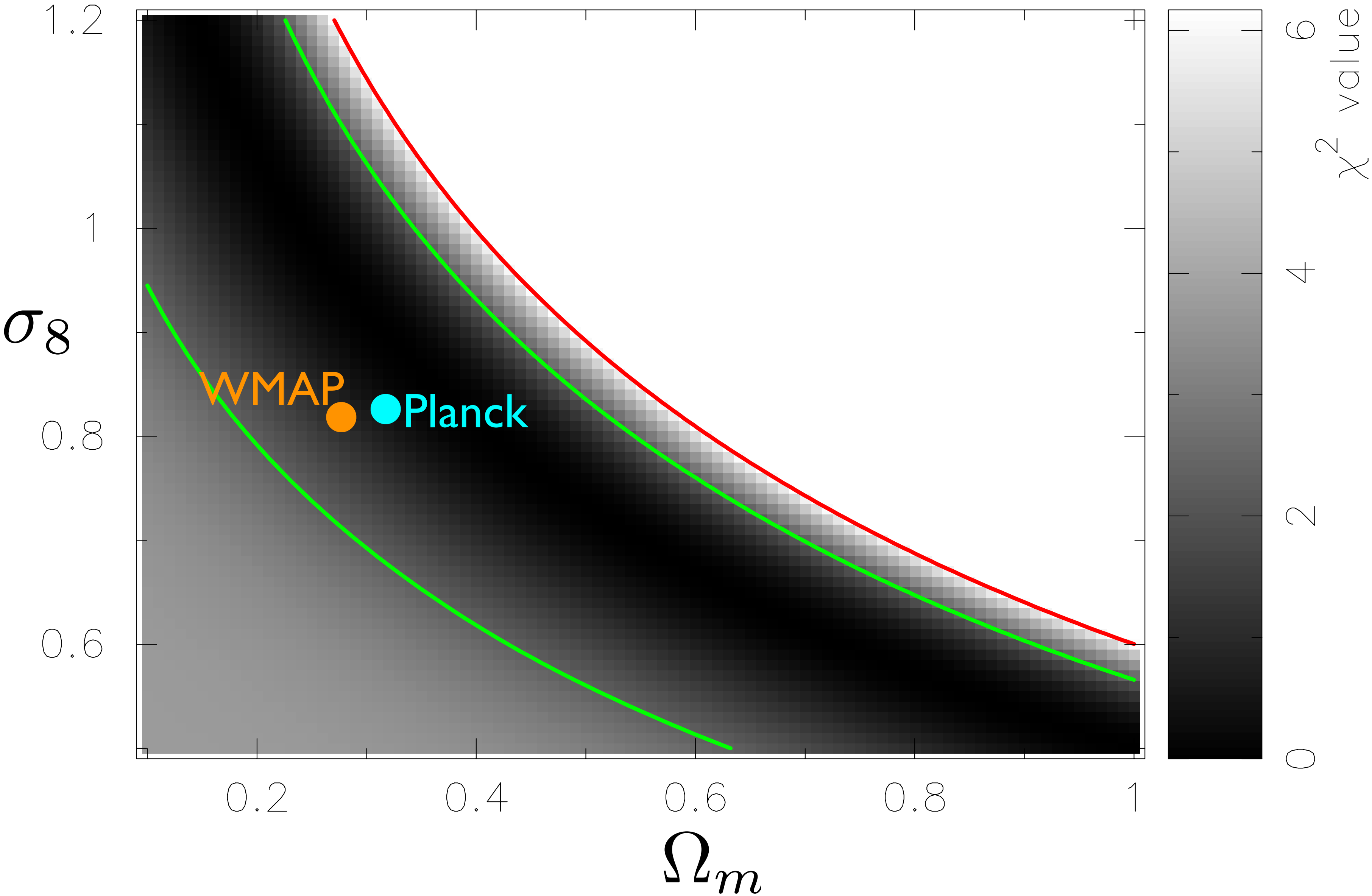


Results

$N_{peak}(SN>5) = 6 \pm 3.1$ in 8.96deg^2

$$c(M,z) = 9.6\left(\frac{M_{vir}}{10^{12}h^{-}1M}\right)^{-0.075}(1+z)^{-0.7}$$

M-c relation by Klypin+2011 was assumed

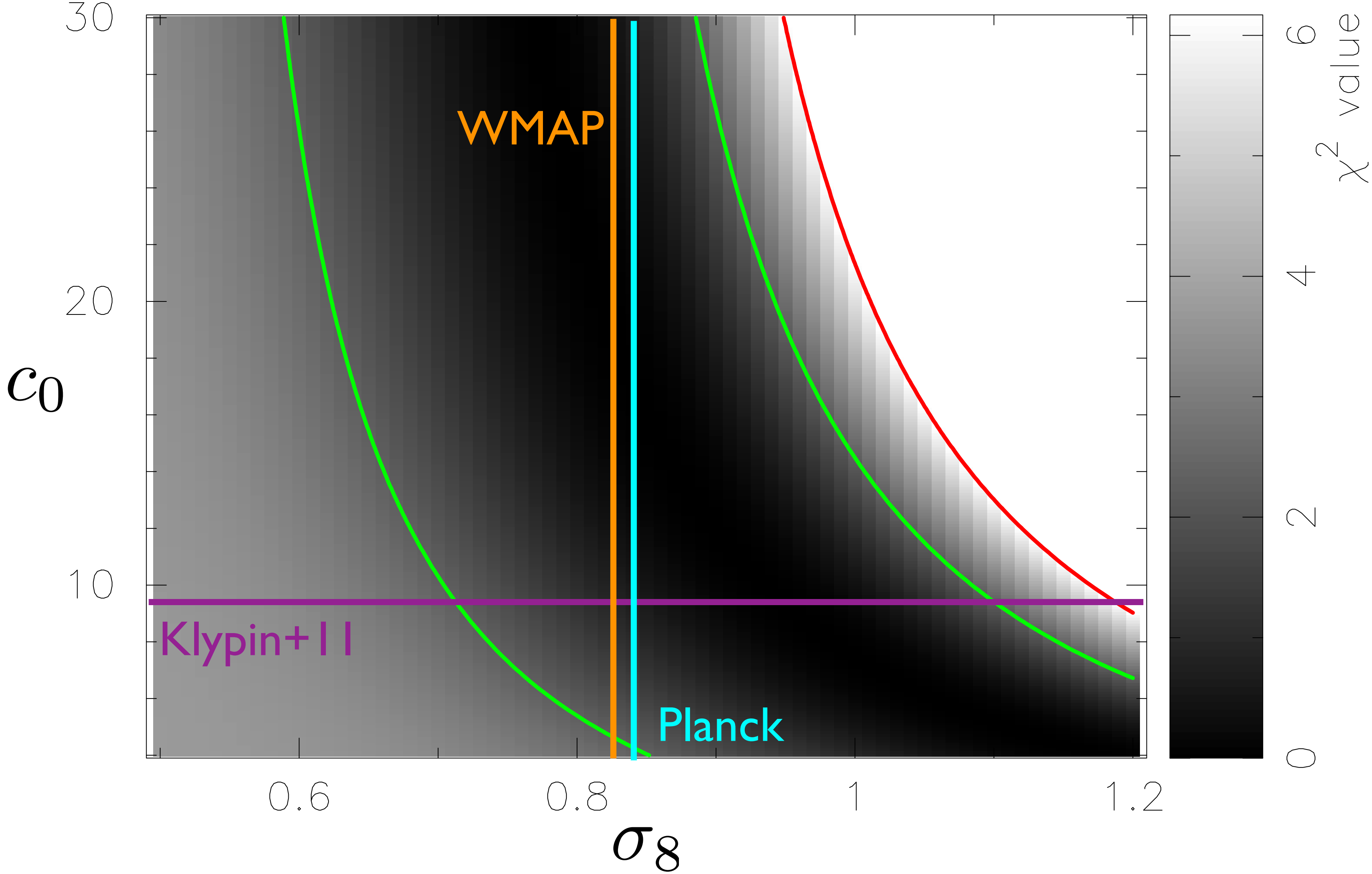


Results

$N_{peak}(SN > 5) = 6 \pm 3.1$ in 8.96deg^2

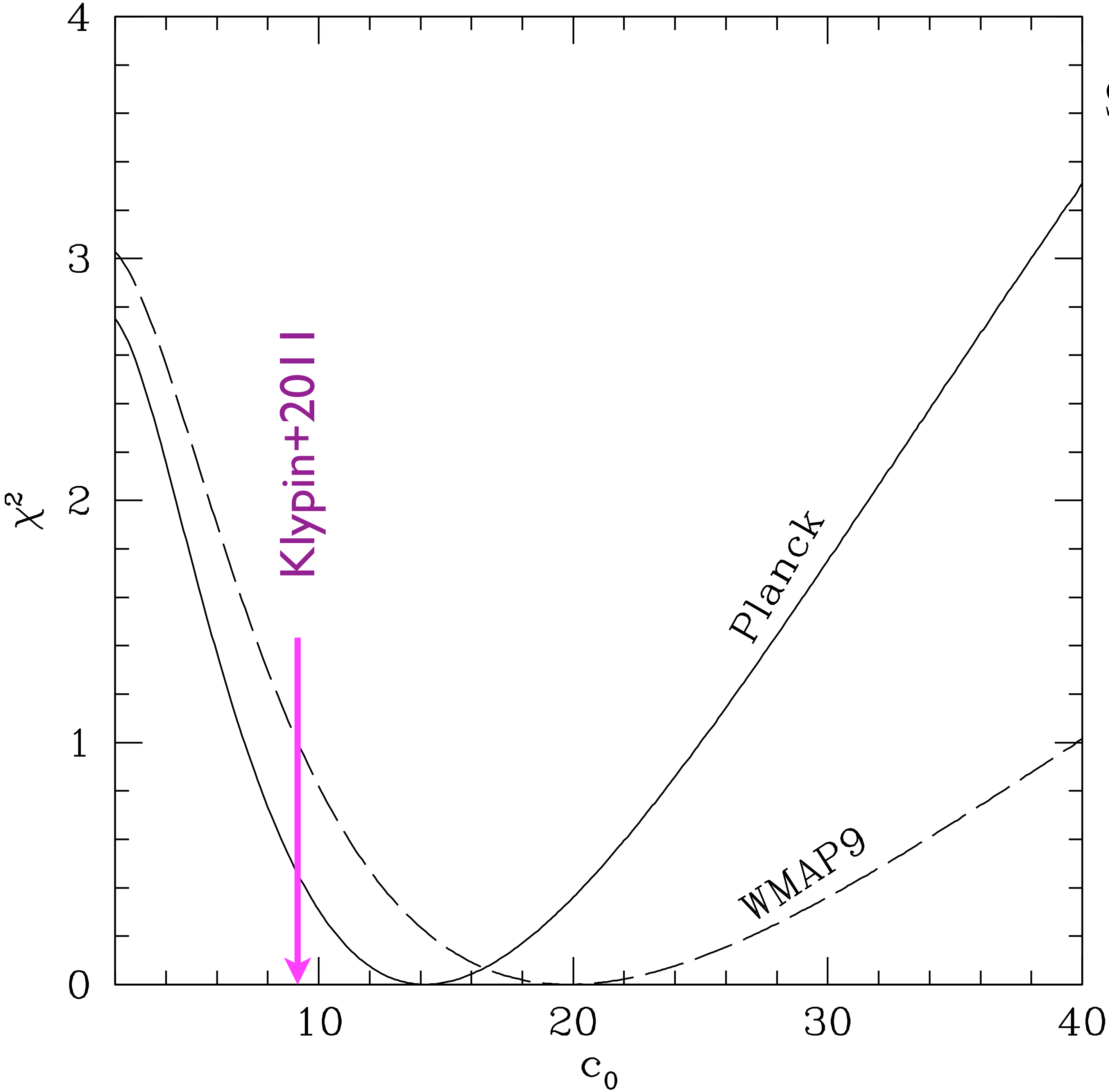
$$c(M, z) = c_0 \left(\frac{M_{vir}}{10^{12} h^{-1} M} \right)^{-0.075} (1 + z)^{-0.7}$$

$\Omega_m = 0.278$



Results

$N_{peak}(SN > 5) = 6 \pm 3.1$ in 8.96deg²

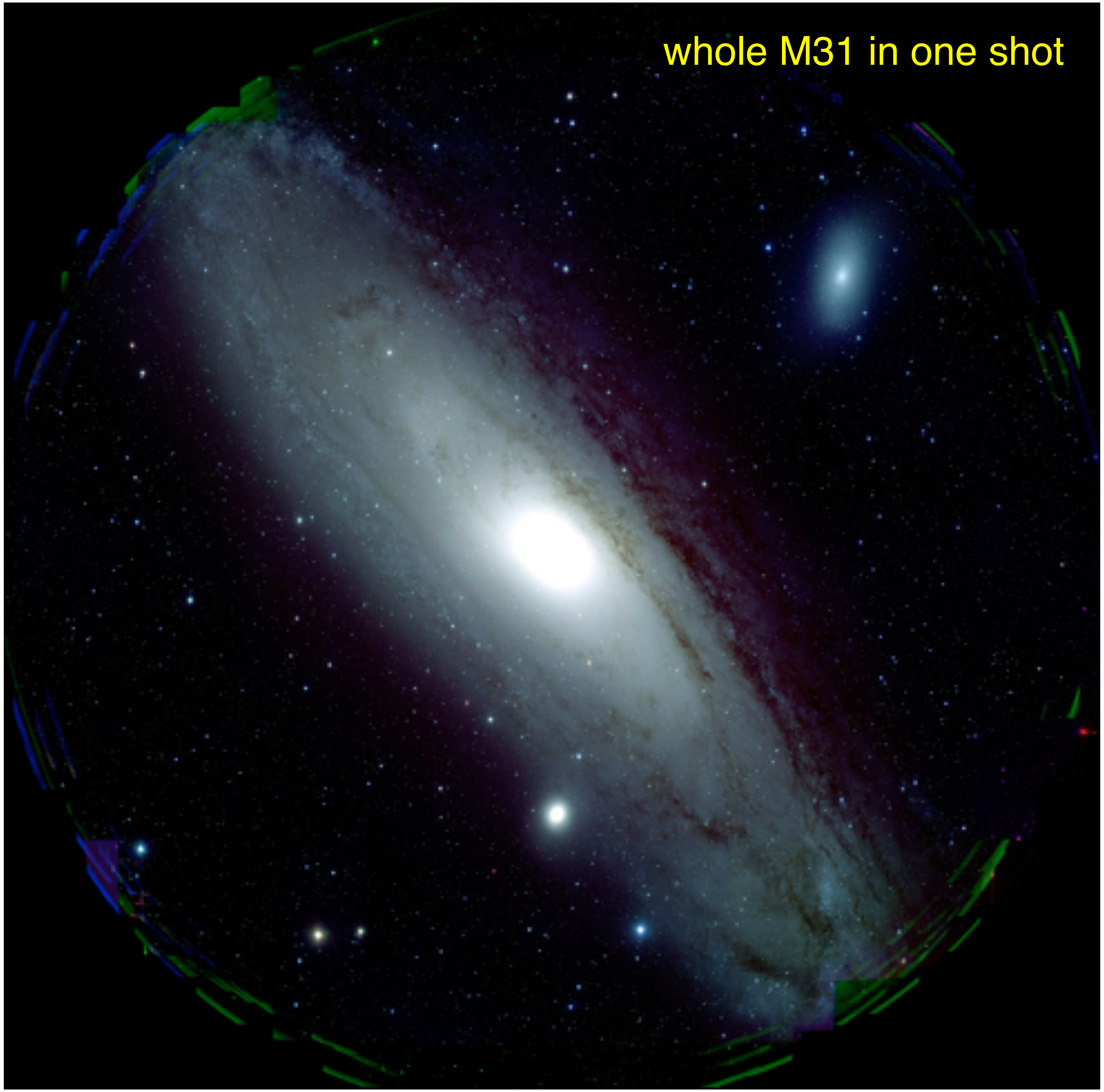


$$\Omega_m = 0.278$$

$$\sigma_8 = \begin{cases} \text{Planck} \\ \text{WMAP9} \end{cases}$$

Hyper SuprimeCam survey

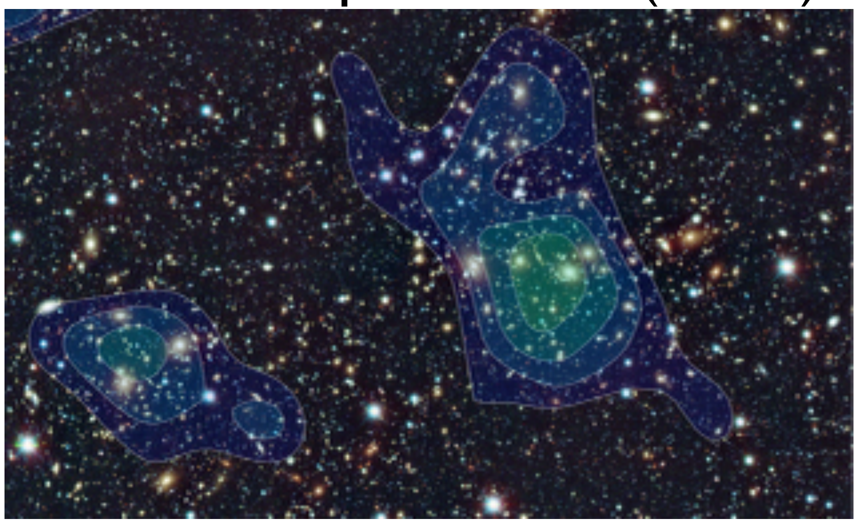
- Hyper SuprimeCam — 1.7deg^2 FoV ~ 7xSuprimeCam
- r_{AB}=26mag with 10min exposure



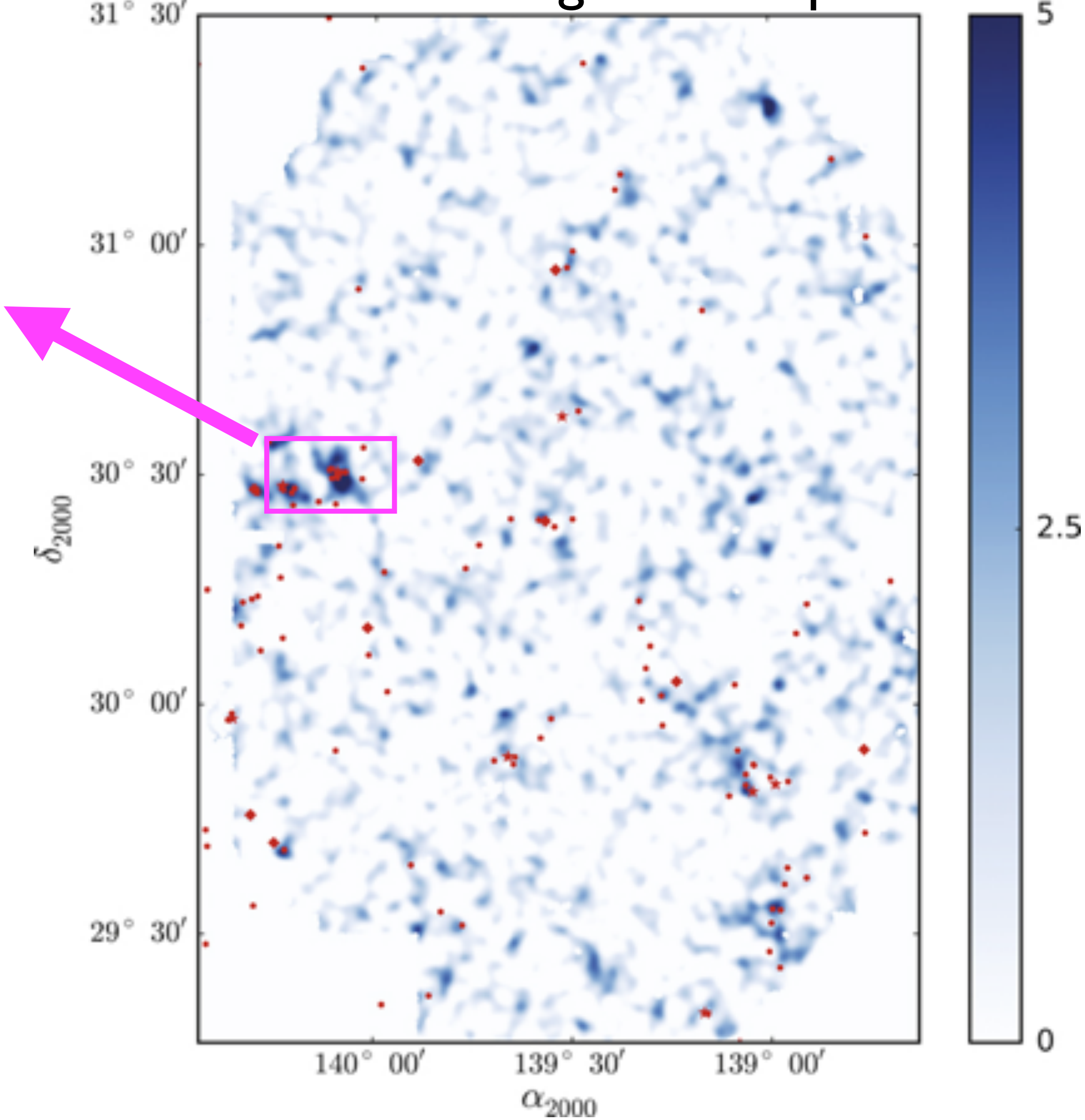
Hyper SuprimeCam survey

- Good image quality confirmed by engineering data (Miyazaki+TH+2015)

Abell 781 super cluster (z=0.3)

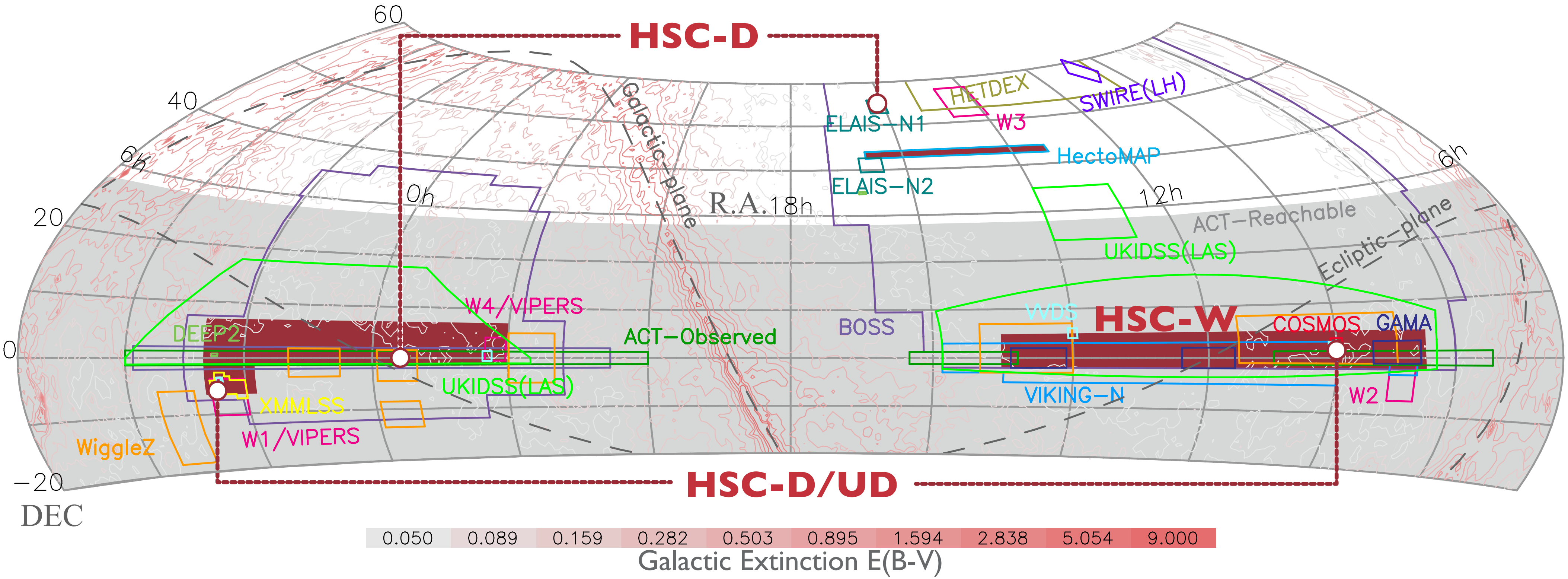


weak lensing mass map



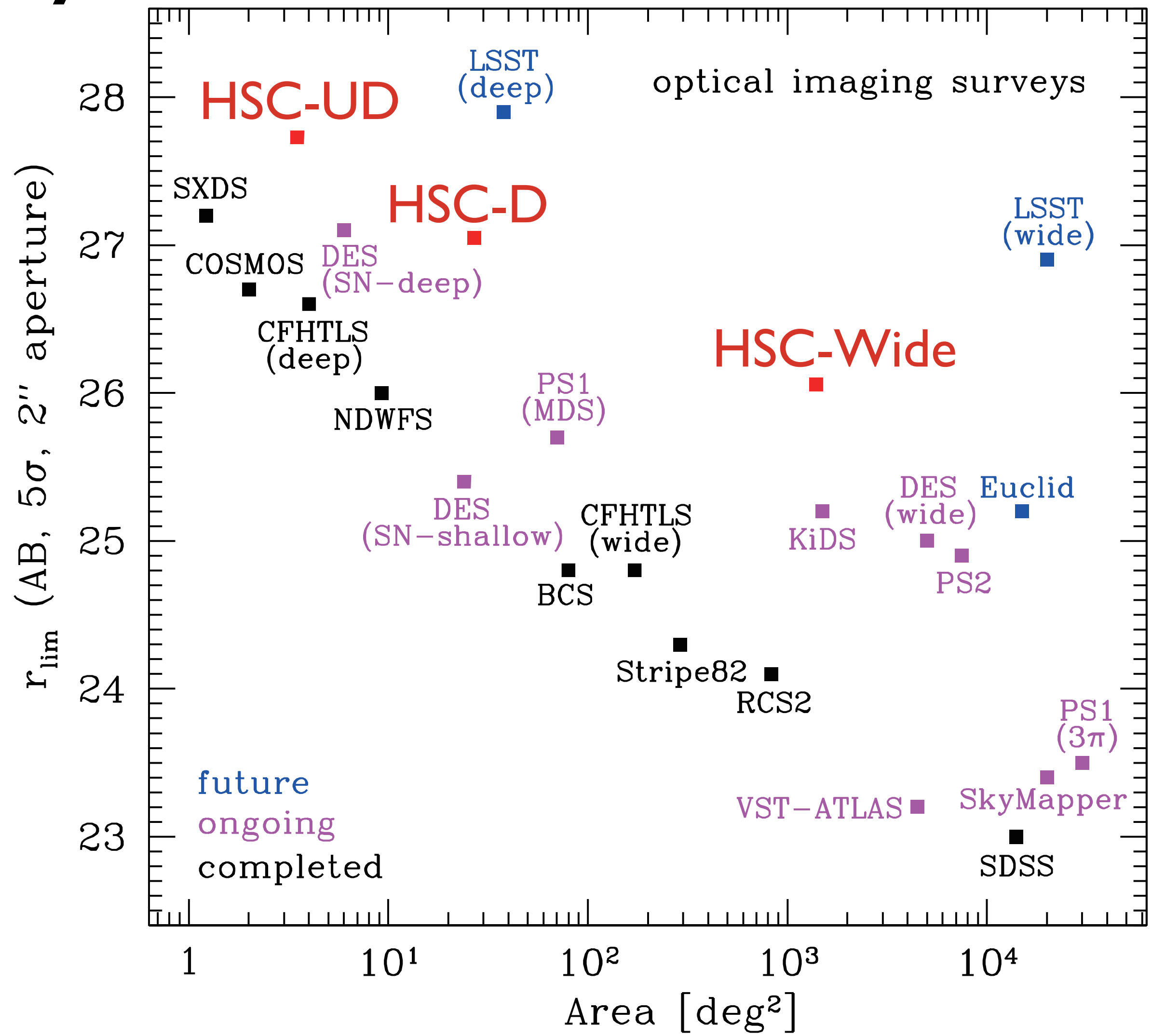
Hyper SuprimeCam survey

- Japan-Princeton-Taiwan project
- ~5 years from 2014
- 3 layers
  - UltraDeep — 3.5deg^2
  - Deep — 27deg^2
  - Wide — 1400deg^2

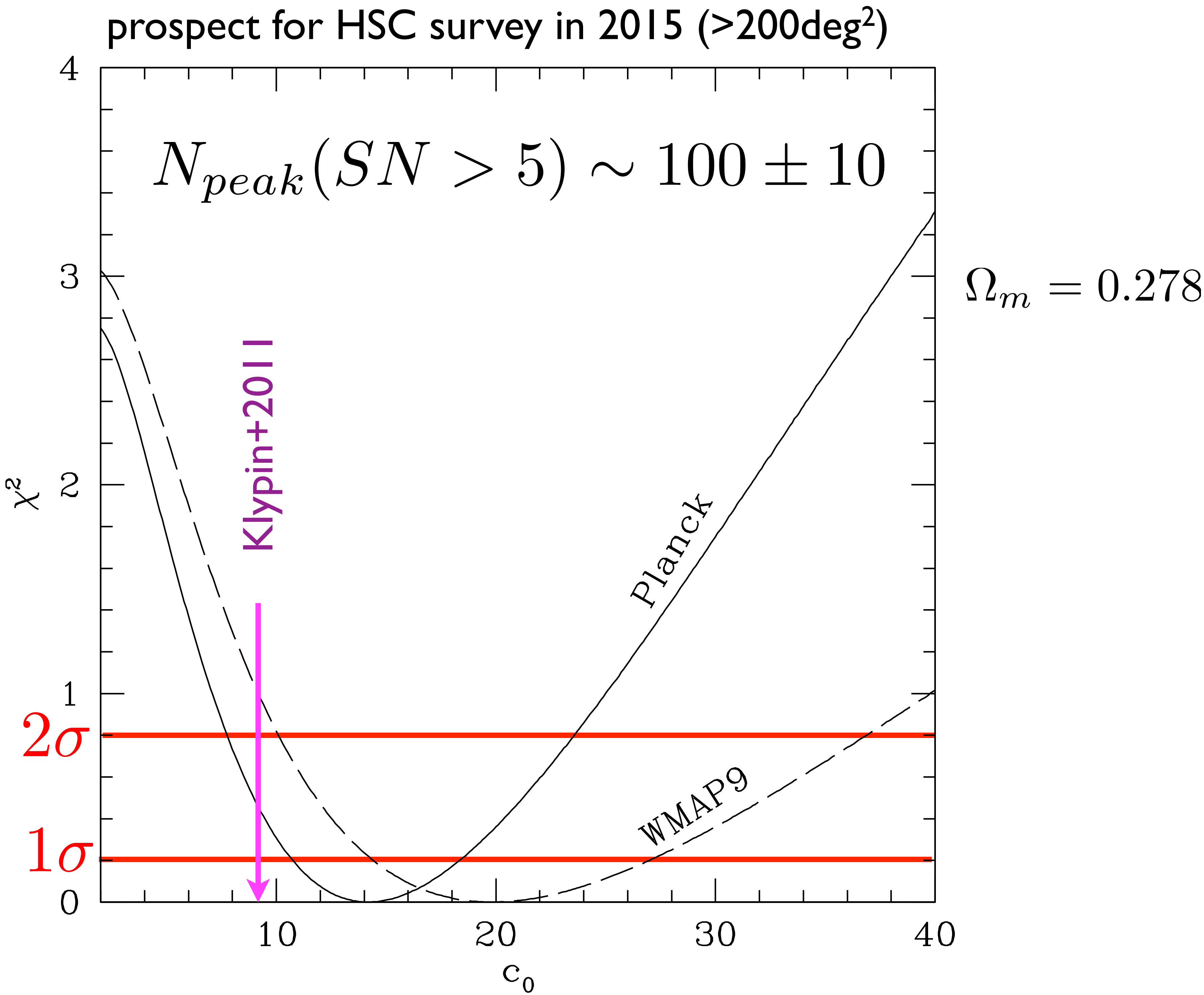


Hyper SuprimeCam survey

- Japan-Princeton-Taiwan
- ~5 years from 2014
- 3 layers
  - UltraDeep — 3.5deg^2
  - Deep — 27deg^2
  - Wide — 1400deg^2
- i-band data for lensing shape measurement, thus good seeing time for it



Summary & Future prospects



Summary & Future prospects

1.weak lensing cluster finding in11deg^2 SuprimeCam i-band data

- 6 peaks with SN>5 (in clean area)
    - all the peaks having optical/Xray counter-part
    - *First constraints on M-c & cosmological parameters* from WL cluster counts, though the constraints are very broad
    - c_0 consistent with LCDM simulations

2.prospect for HSC survey

- >200deg^2 by end of 2015
    - ➡~100 WL clusters (sample variance ~10%)
    - ➡may place useful constraints

✓more accurate theoretical model may be needed

see Shirasaki's poster for comprehensive study on future prospects