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The Kilo-Degree Survey: Large Scale Structure and Galaxy Haloes

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The Kilo-Degree Survey: large scale structure and galaxy haloes

Konrad Kuijken
Leiden Observatory

and the

KiDS

- KiDS survey overview
- Weak gravitational lensing
- Galaxy groups
- Troughs & ridges
- cosmic shear
- Outlook

- Designed as **weak lensing** + **photometric redshift** survey

- Accurate galaxy shapes
- Good image quality
- Well-controlled PSF
- Wide field
- Deep (median $z \sim 0.7$)

- Multi-band
- u to Ks
- spectroscopic calibration

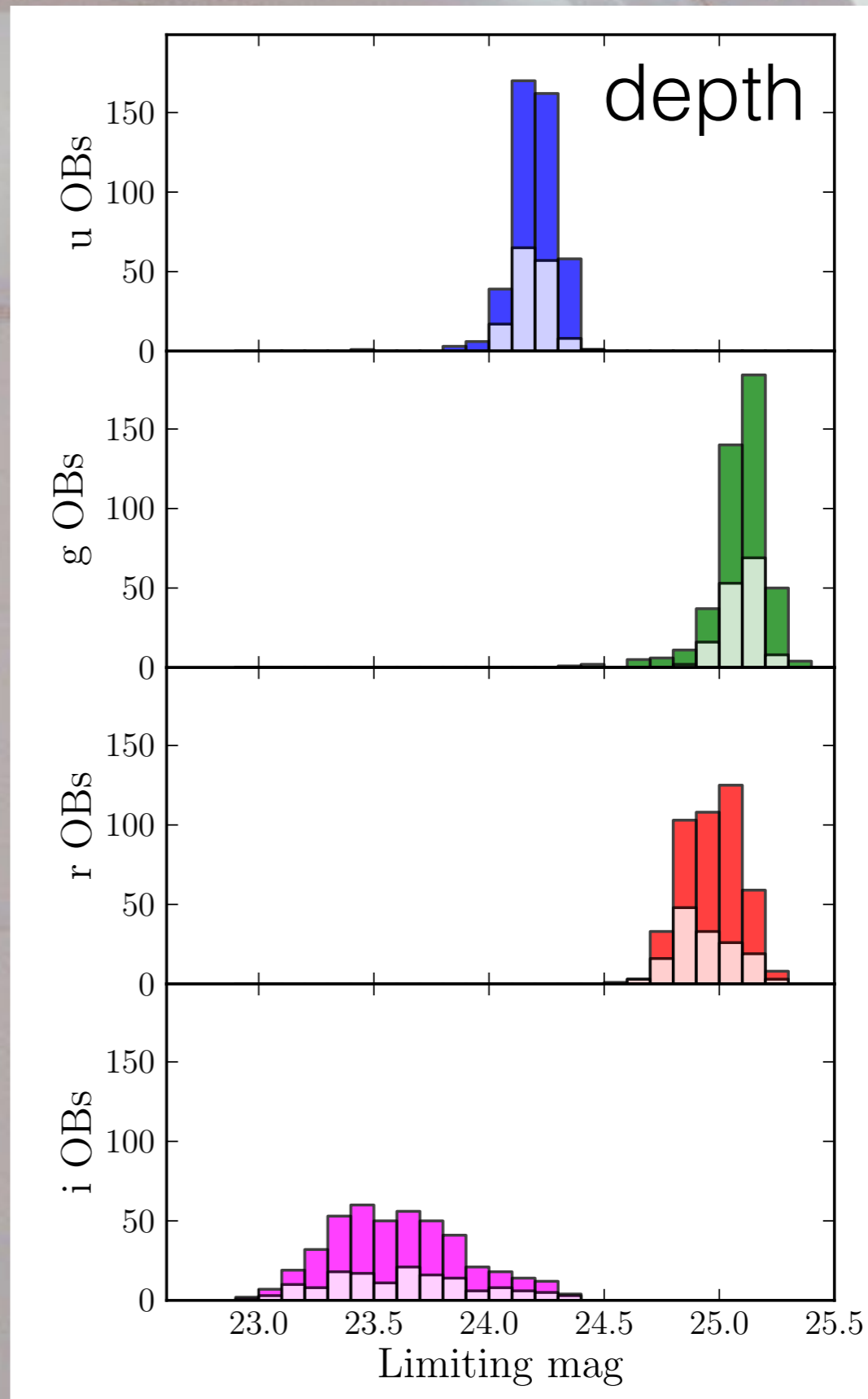
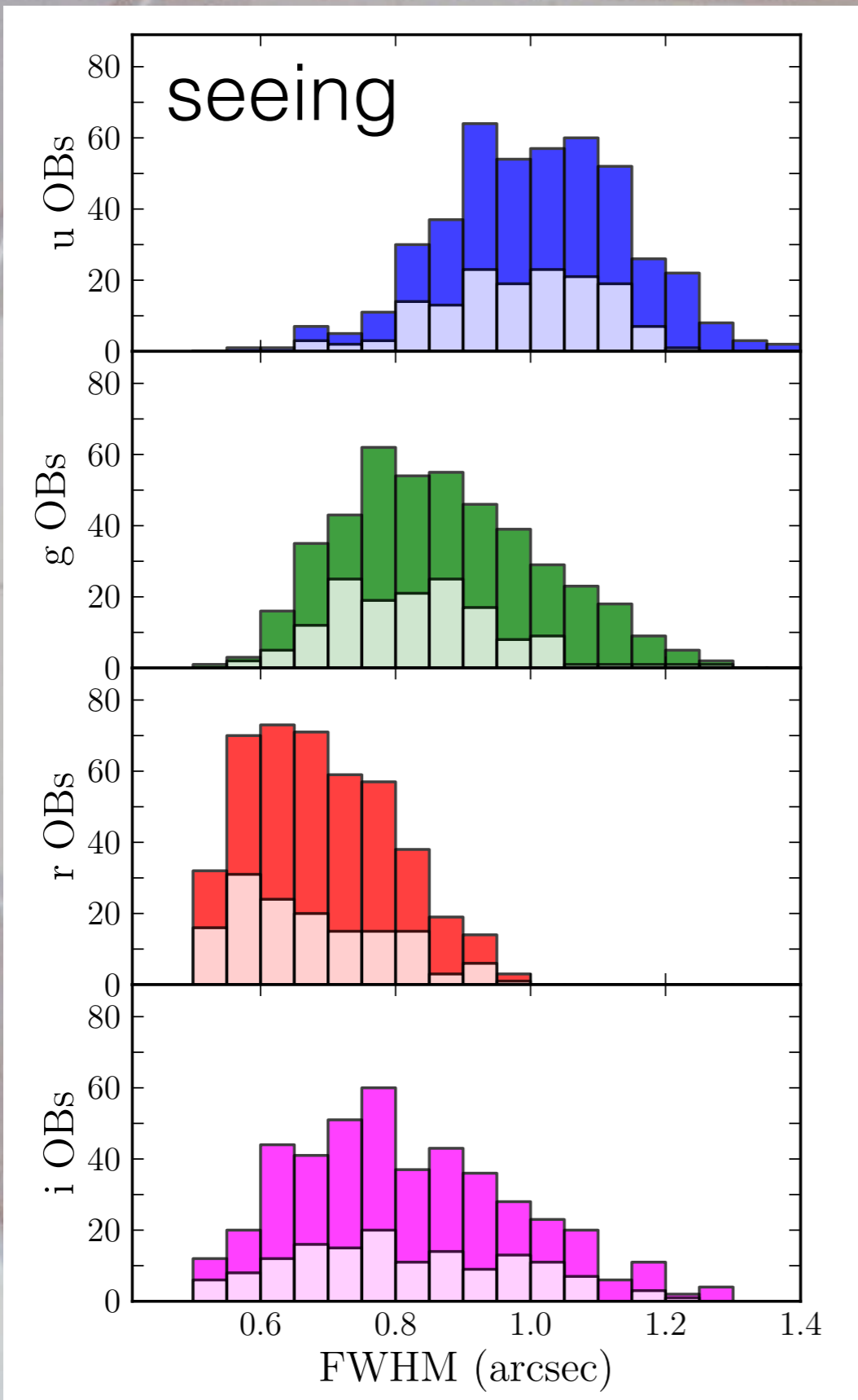
- Excellent match to VST strengths! (+VISTA)

Filters, depths

Filter	Exp Time (s)	Median Seeing (")	5- σ 2" (AB)
u	900	1.0	24.8
g	900	0.8	25.4
r	1800	0.7	25.2
i	1080	0.75	24.2
Z	500	0.8	23.1
Y	400	0.8	22.4
J	400	0.8	22.2
H	300	0.8	21.6
K _s	500	0.8	21.3

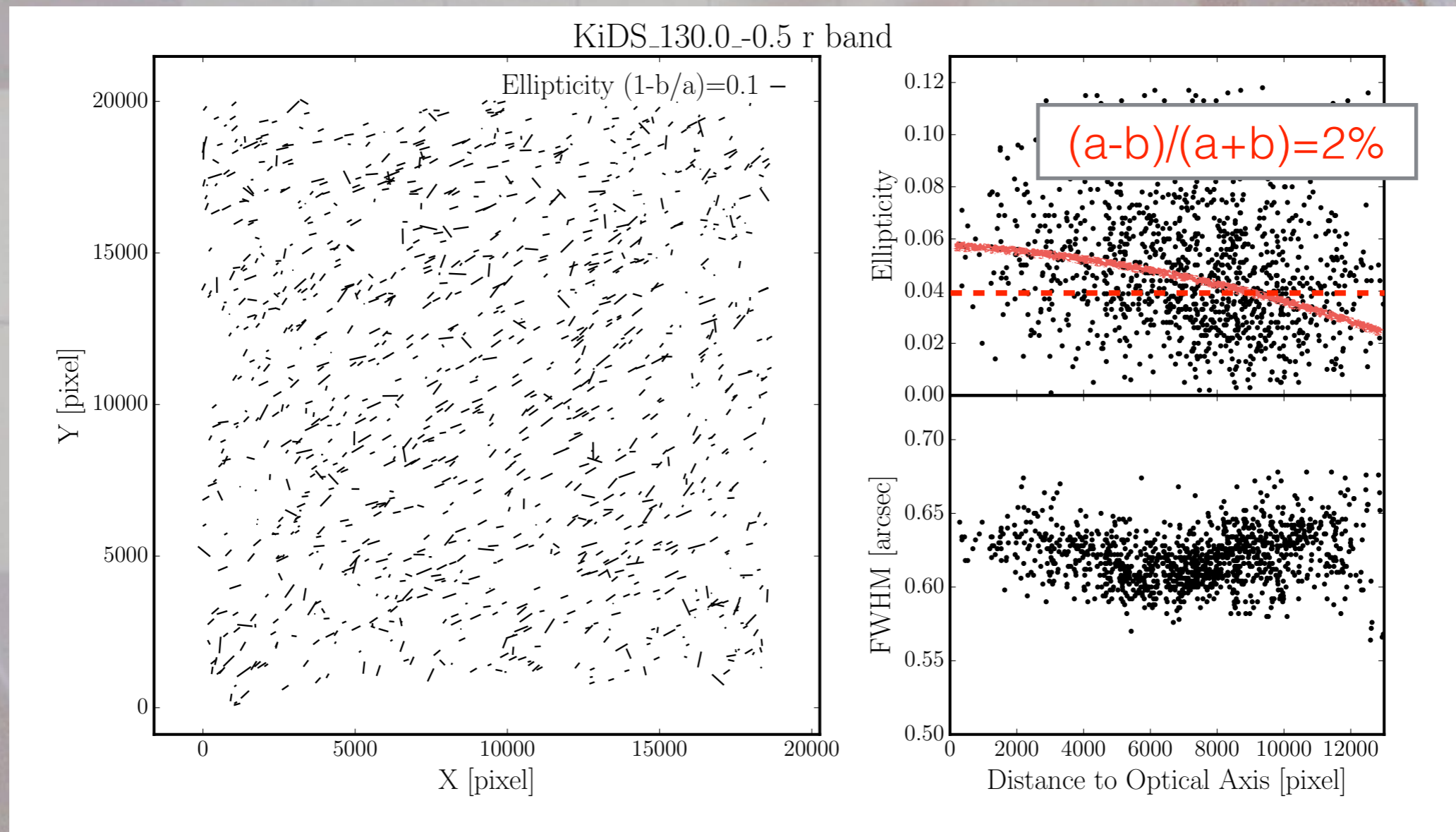
NO Variability!!!

• n



High fidelity imaging

- homogeneous PSF width, low anisotropy, constant plate scale, **median seeing for lensing data 0.7"**

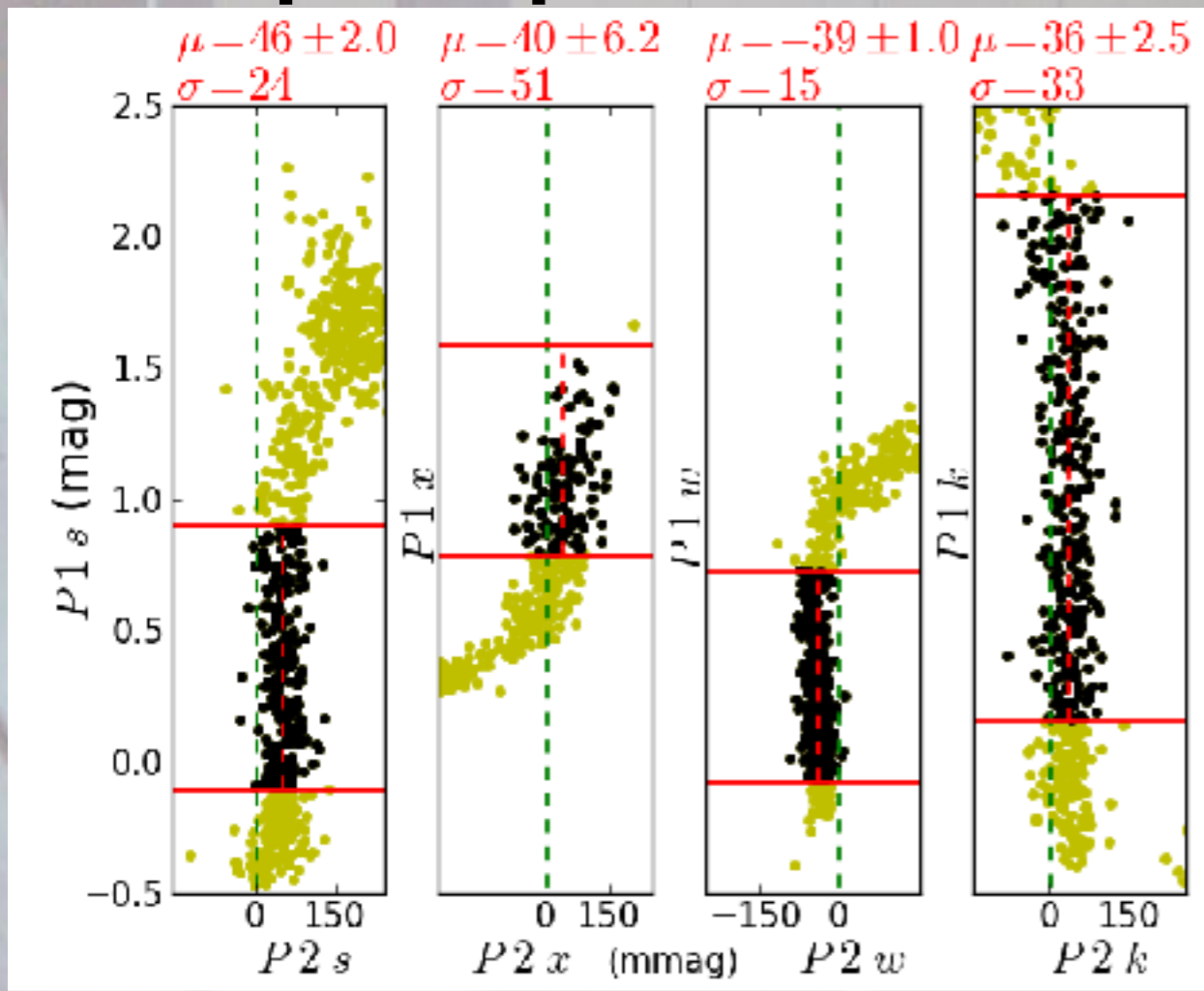


- Advantage of custom-designed f/5.5 Cassegrain telescope over retrofitted Prime Focus camera!

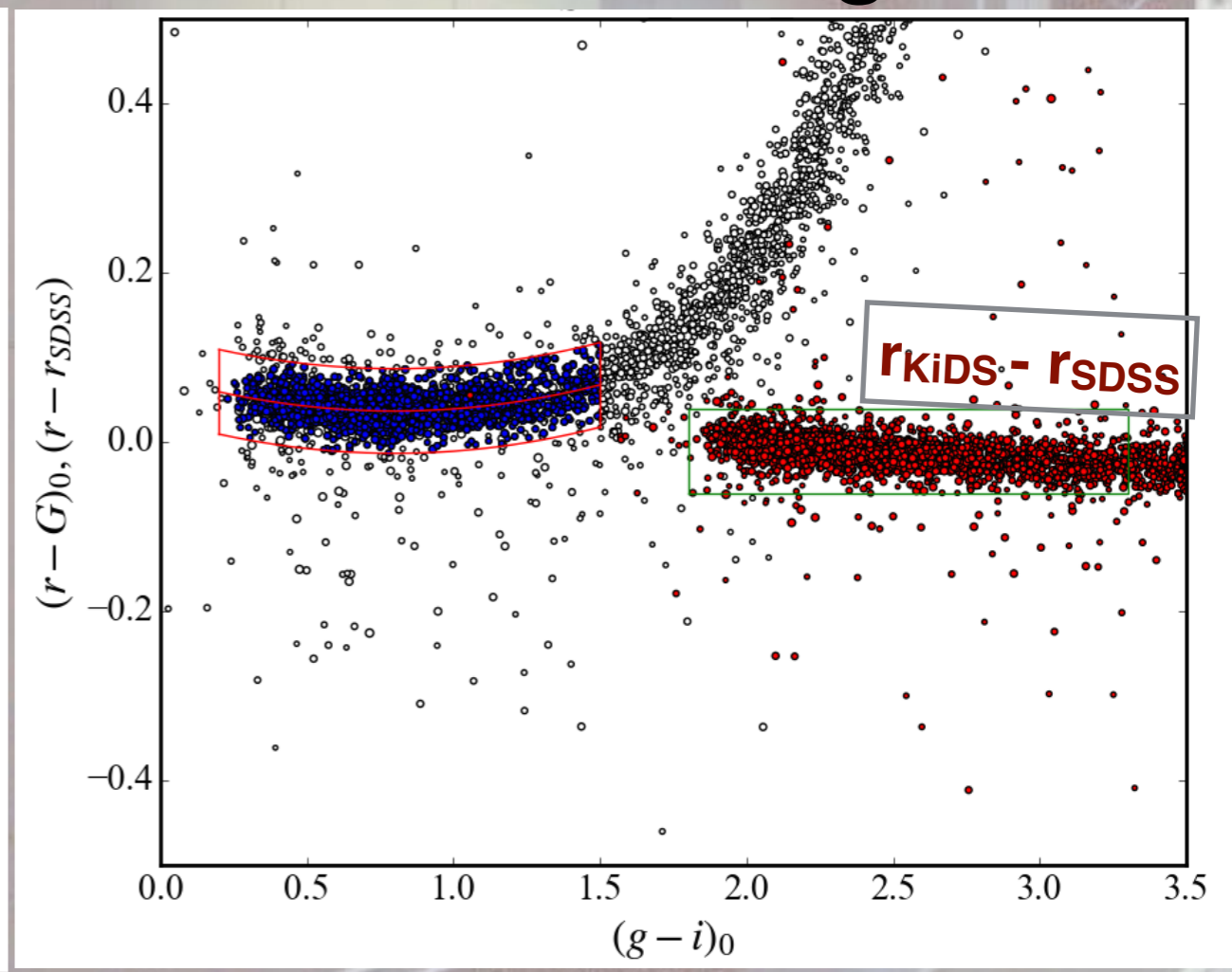
Photometric calibration

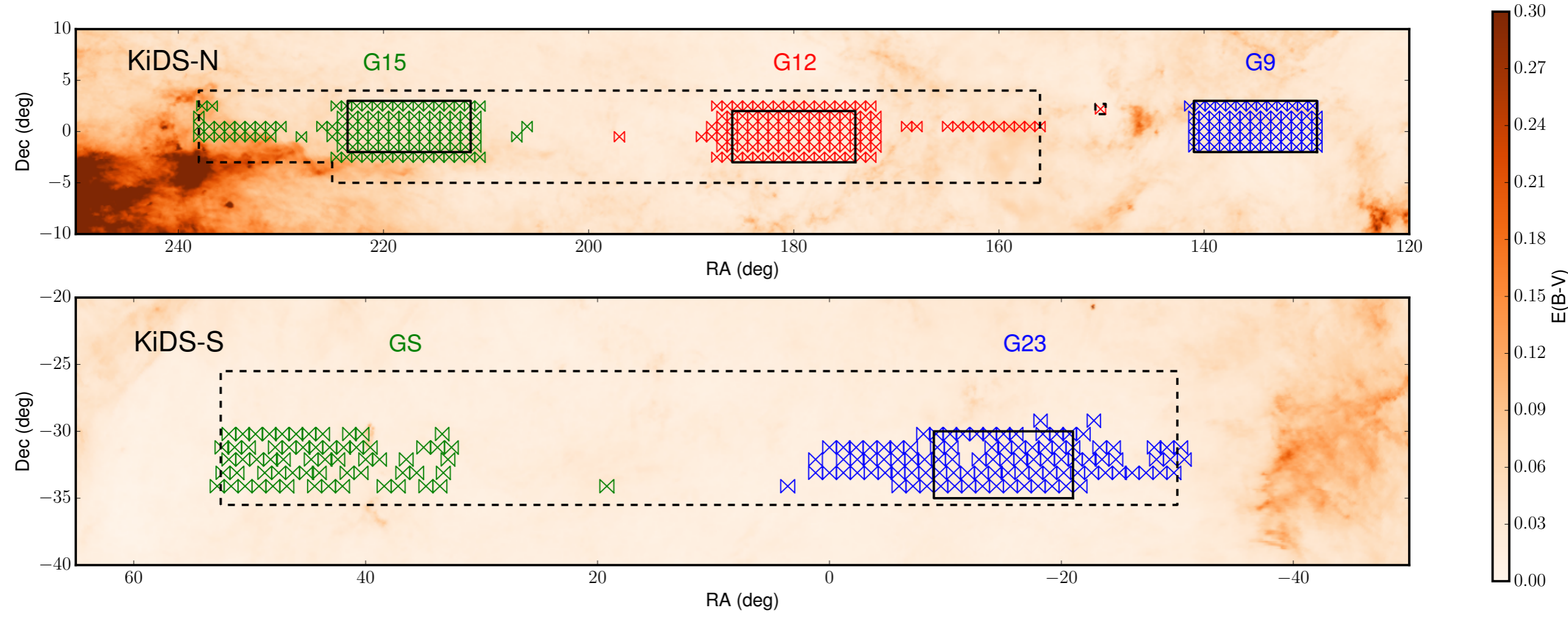
- Combination of stellar locus regression (relative) and cross-match to Gaia G photometry (absolute)

principal colours



Gaia G-r vs. g-i





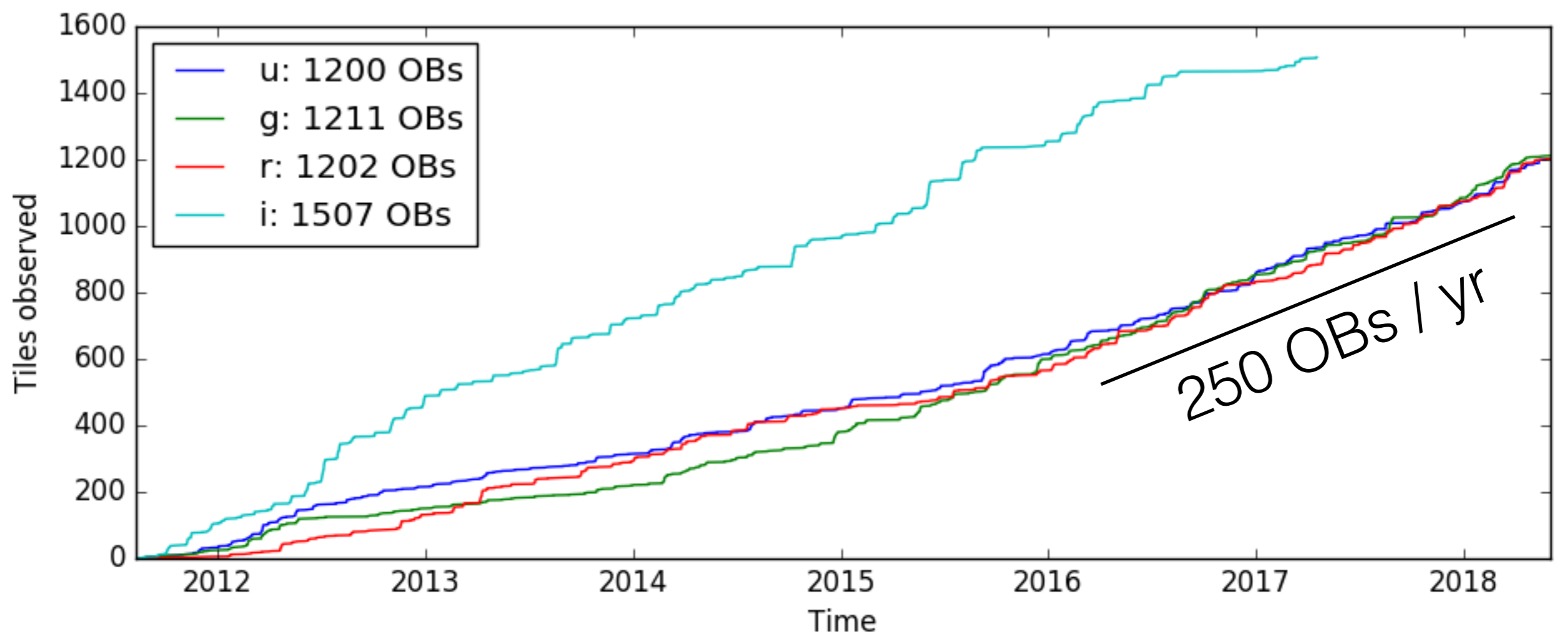
Three on-going weak lensing surveys

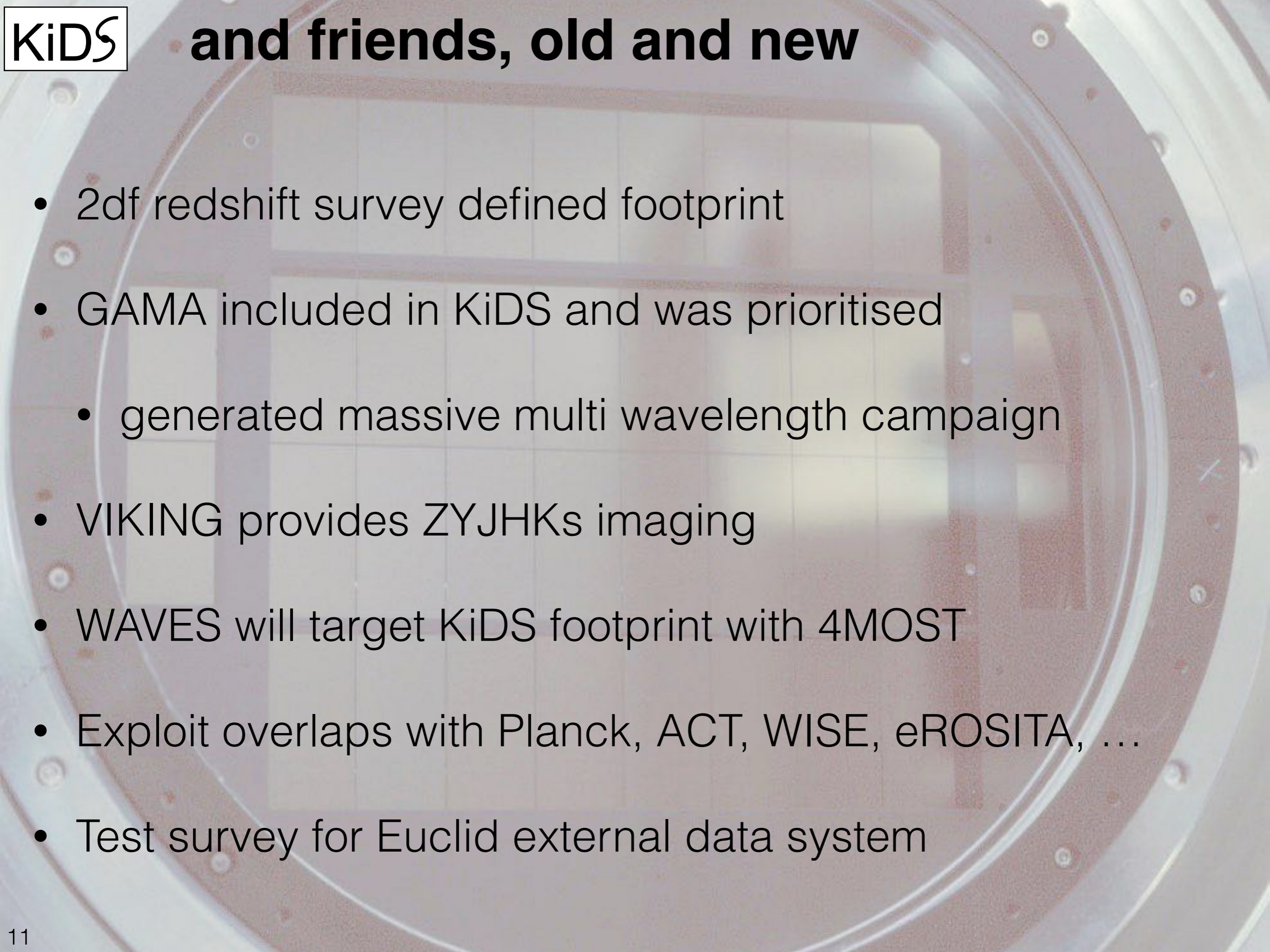
O(500) nights each!

	DES	KiDS	HSC
total area	5000	1500	1400
telescope	4m CTIO	2.6m VST (opt) 3.9m VISTA (IR)	8m SUBARU
image quality	0.9"	0.7"	<0.7"
inverse shear var arcmin ⁻²	65-90	105	>200
bands	grizy	ugriZYJHK	grizy
mean z	0.7	0.77	~0.9
results so far	2000 deg ²	450 deg ²	130 deg ²

KiDS data rate

- Efficient operations since mid-2015 (250 sqdeg/yr)
- Complete early 2019 
- 2nd pass in i band underway
- Survey limited to 1350 sq.deg. VIKING footprint, + spec-z fields

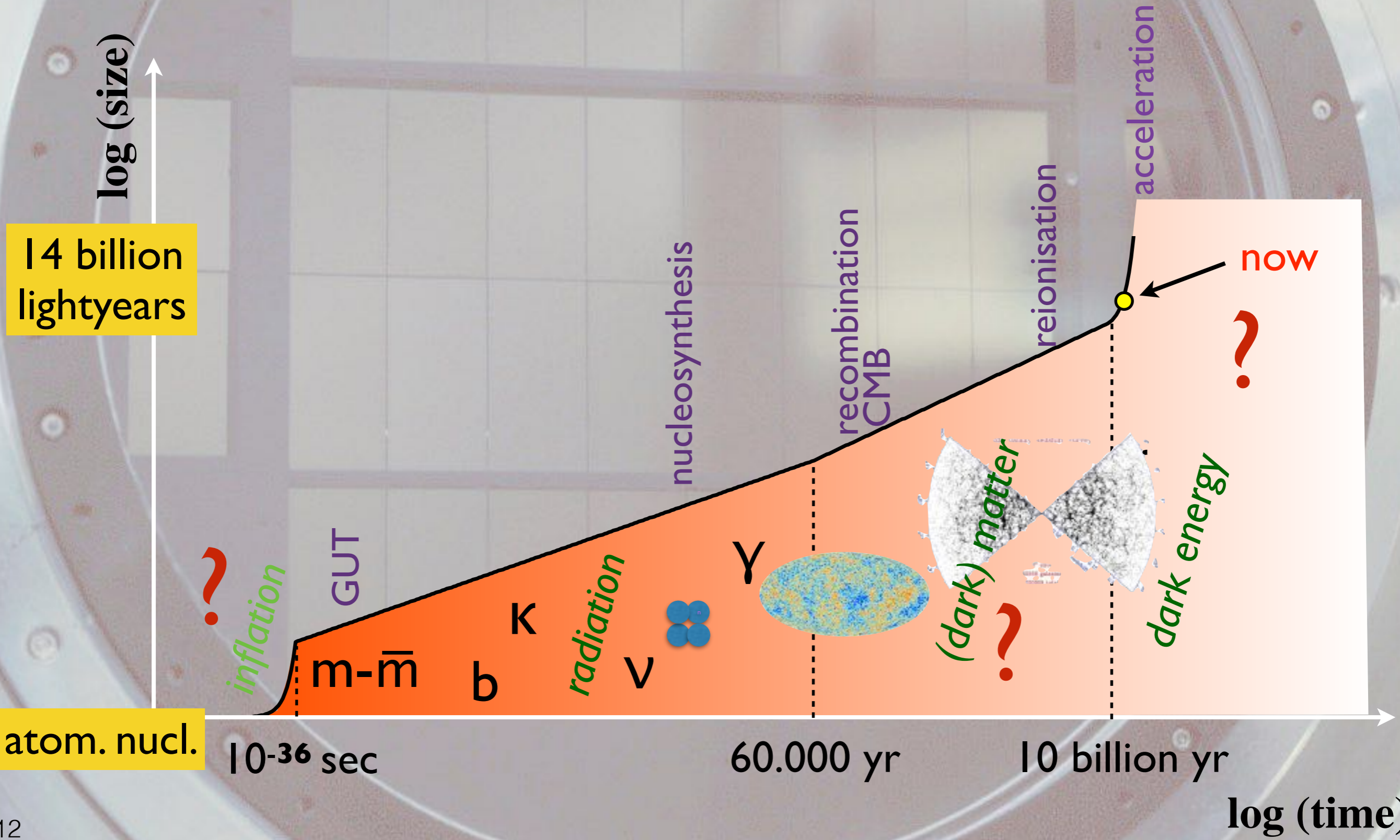




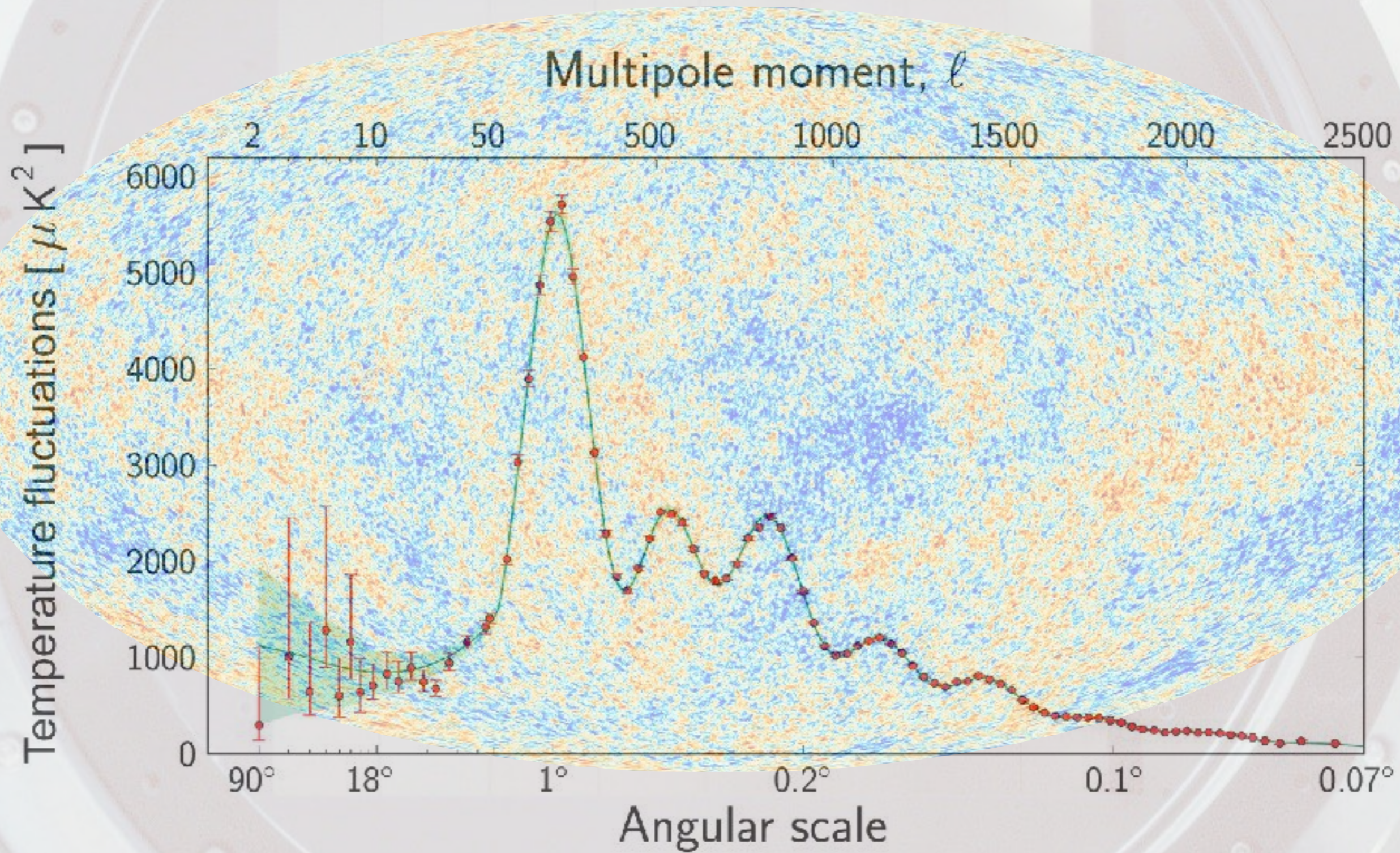
- 2df redshift survey defined footprint
- GAMA included in KiDS and was prioritised
 - generated massive multi wavelength campaign
- VIKING provides ZYJHKs imaging
- WAVES will target KiDS footprint with 4MOST
- Exploit overlaps with Planck, ACT, WISE, eROSITA, ...
- Test survey for Euclid external data system

Testing the Standard Model.....

.....using growth of large-scale structure

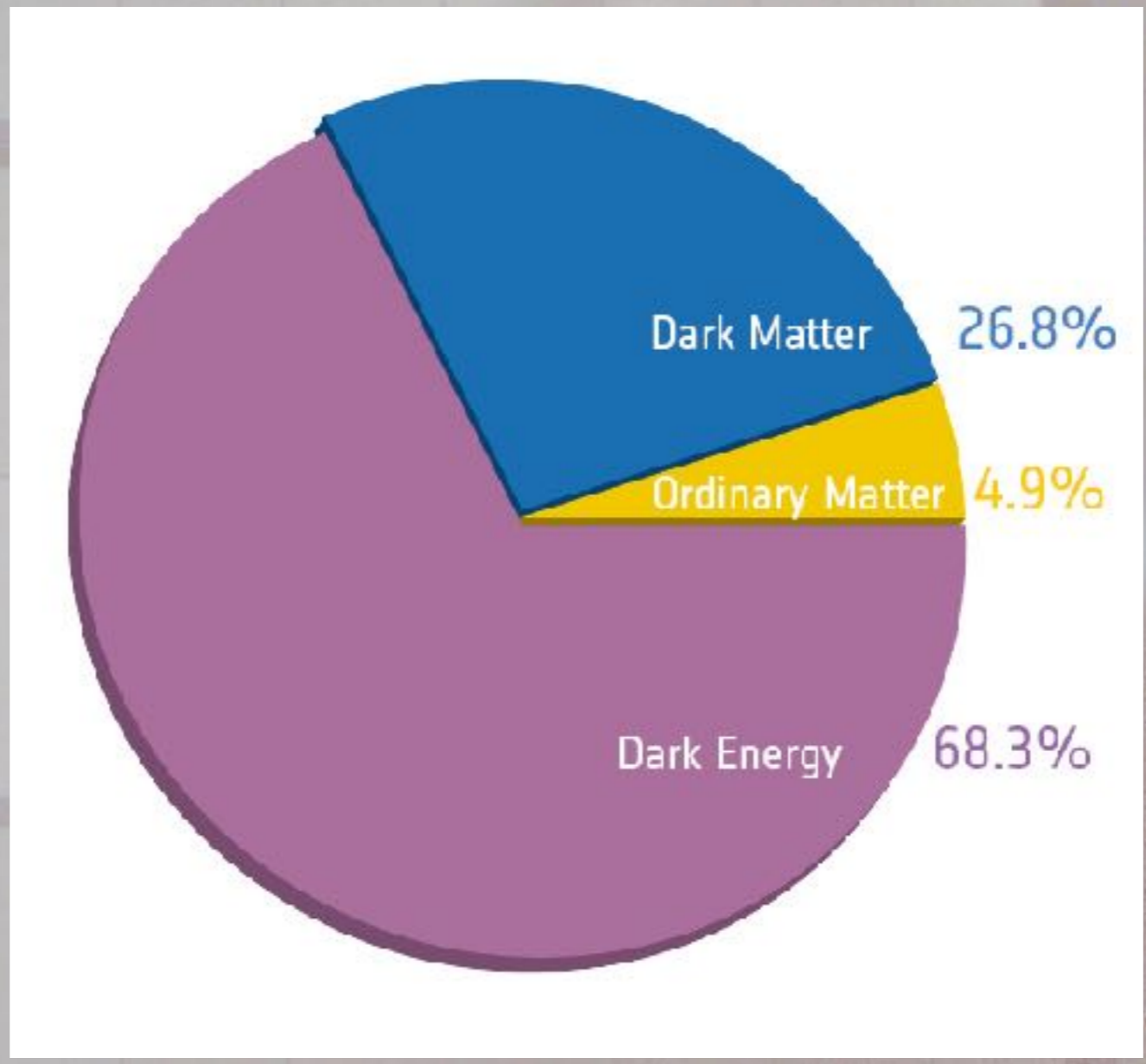


Precision



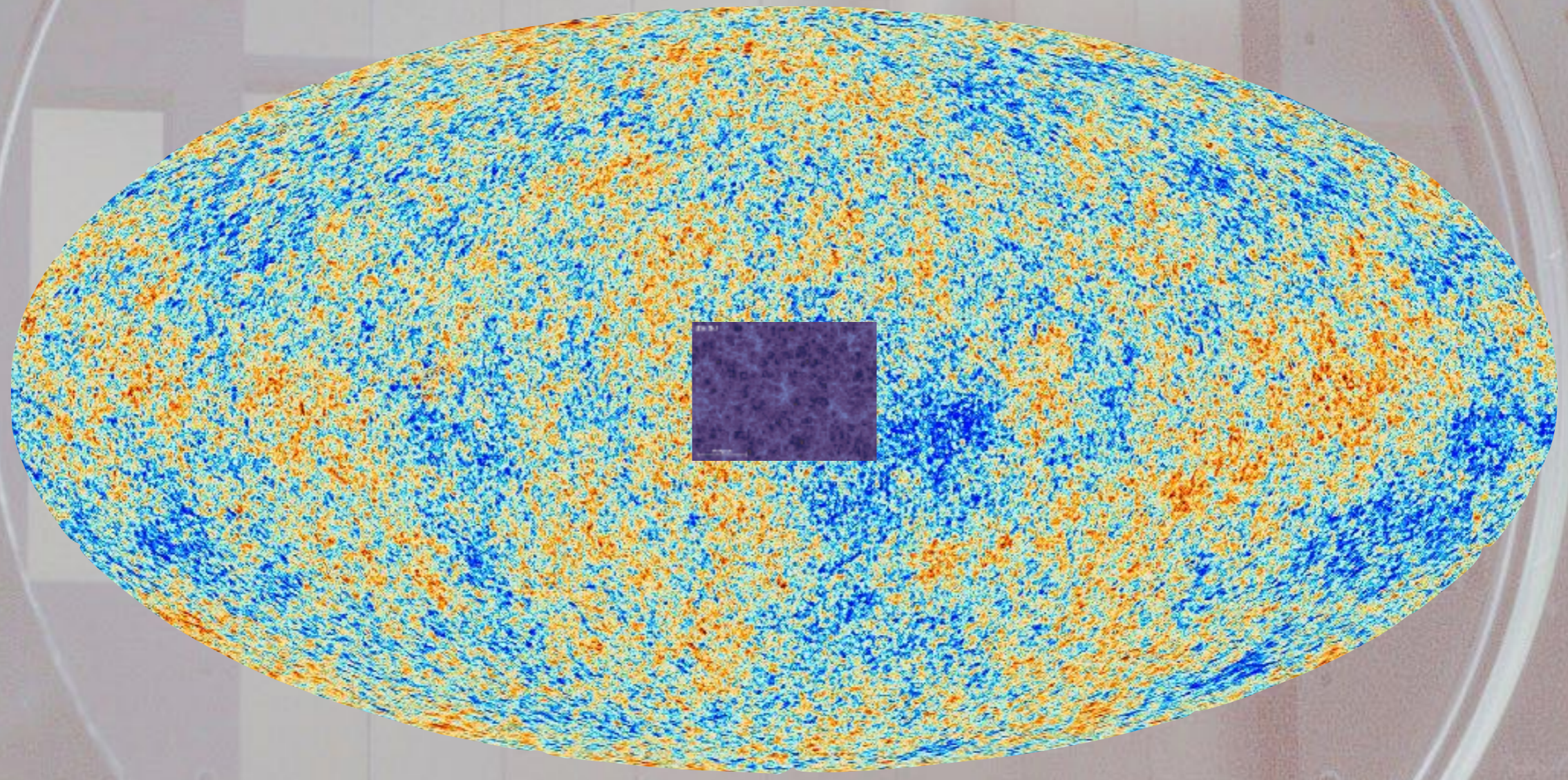
ESA/Planck collaboration

Lemaître parameters



(as measured by Planck collaboration)

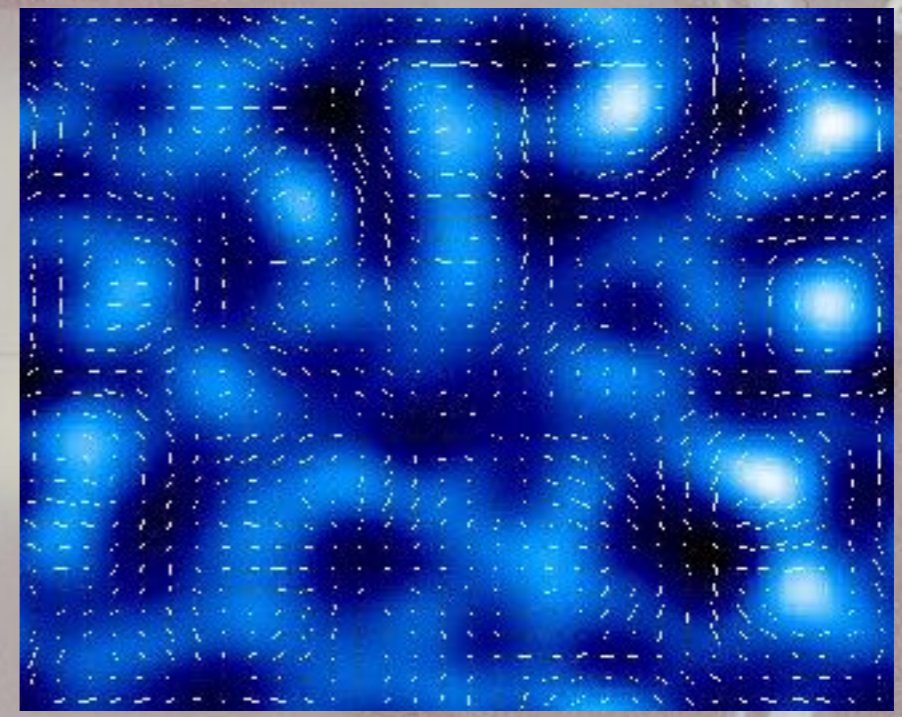
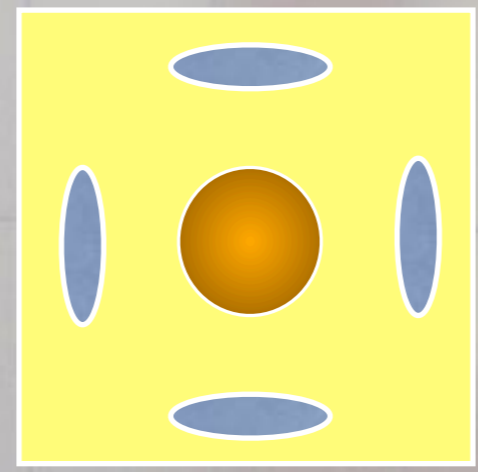
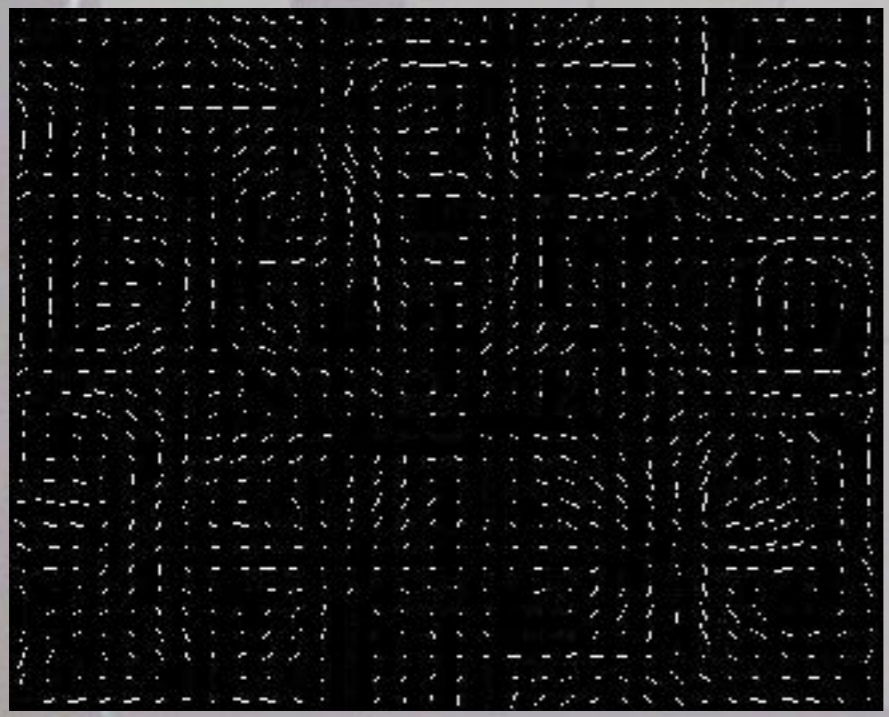
Calculating forward



Weak gravitational lensing

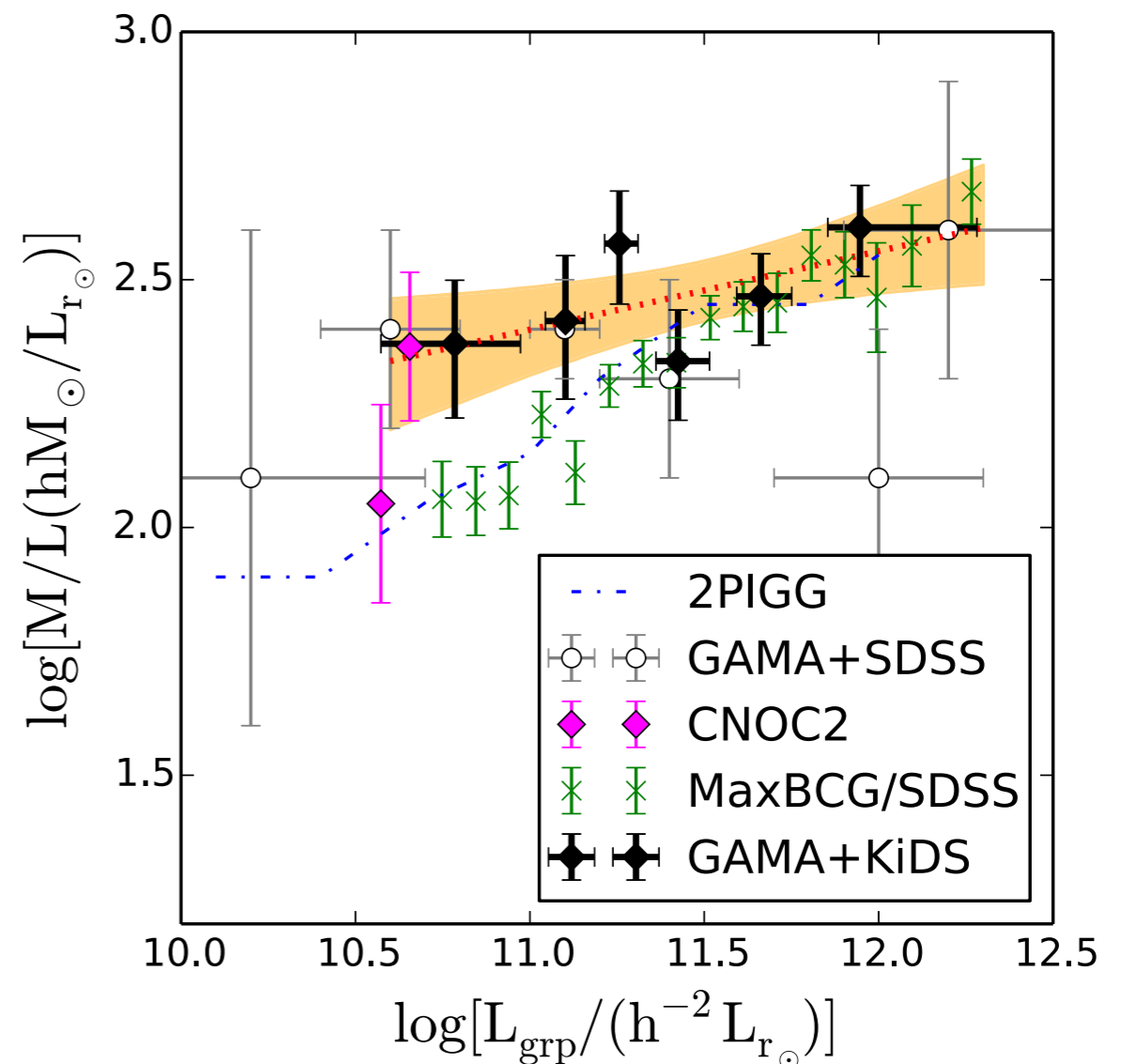
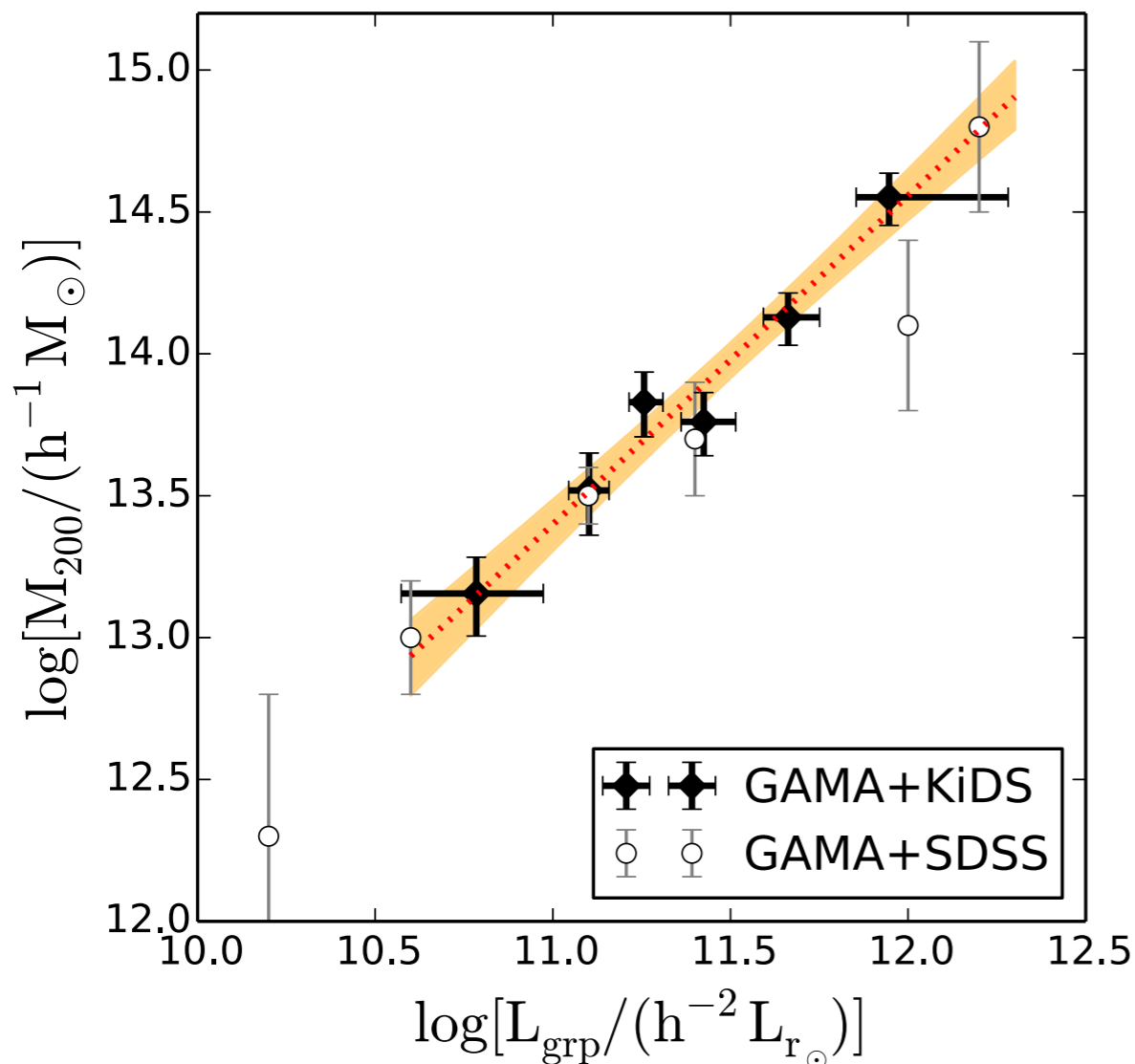
KUIJKEN ET AL 2015, MNRAS 454, 3500

- Light rays are deflected by gravitational fields
- tangential distortion around mass concentrations



- Map out distribution of matter in front of survey galaxies
- Add 3rd dimension through tomography

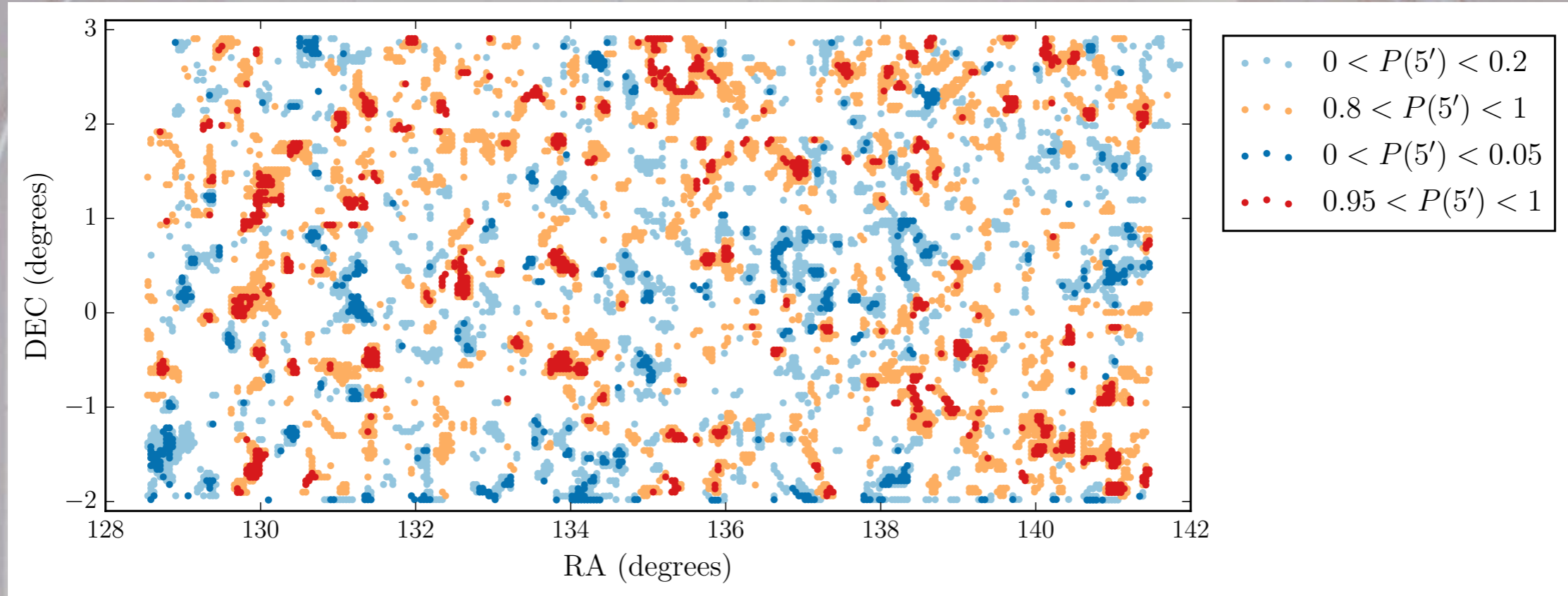
- Use weak lensing effect to measure halos of galaxies, clusters and groups *on Mpc scale!*
- Needs a good catalogue of lenses (stack!)



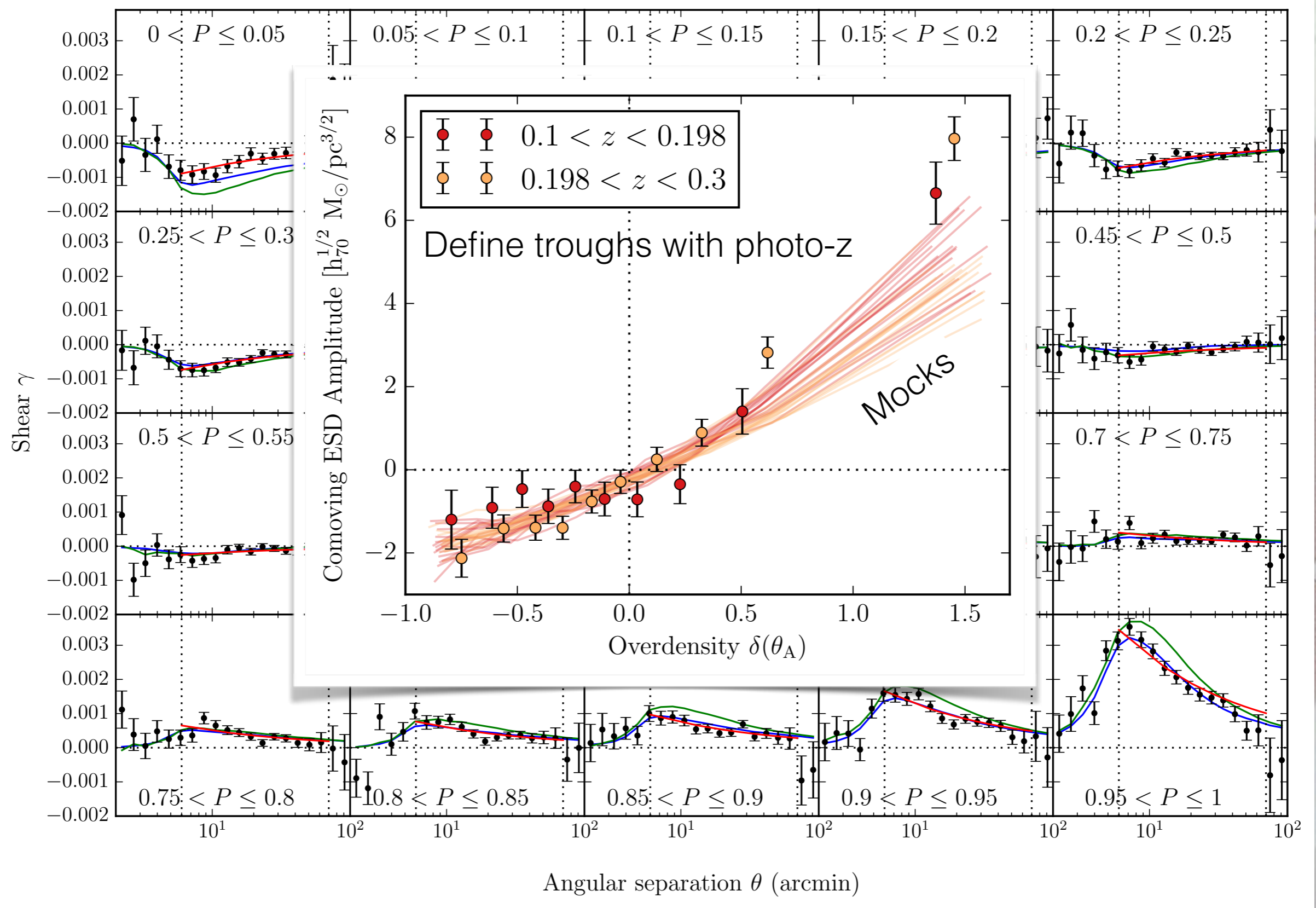
- density profile of voids is ‘clean’ probe of gravity (little baryons), but hard to measure with weak lensing
- Trough = 2D under density of galaxies along line of sight (Grün et al 2016). Easier to measure!
- Weak lensing ‘density split statistics’: split sky by average projected galaxy density in circular apertures and measure mass with lensing

Troughs/ridges in a GAMA patch

BROUWER ET AL 2018, SUBMITTED



- Construct density-defining population, e.g. a simple magnitude limit $r < 20$



Measurements out to 1 deg radius!

HILDEBRANDT ET AL 2017, MNRAS 465, 1454

JOUDAKI ET AL 2017, MNRAS 471, 1259

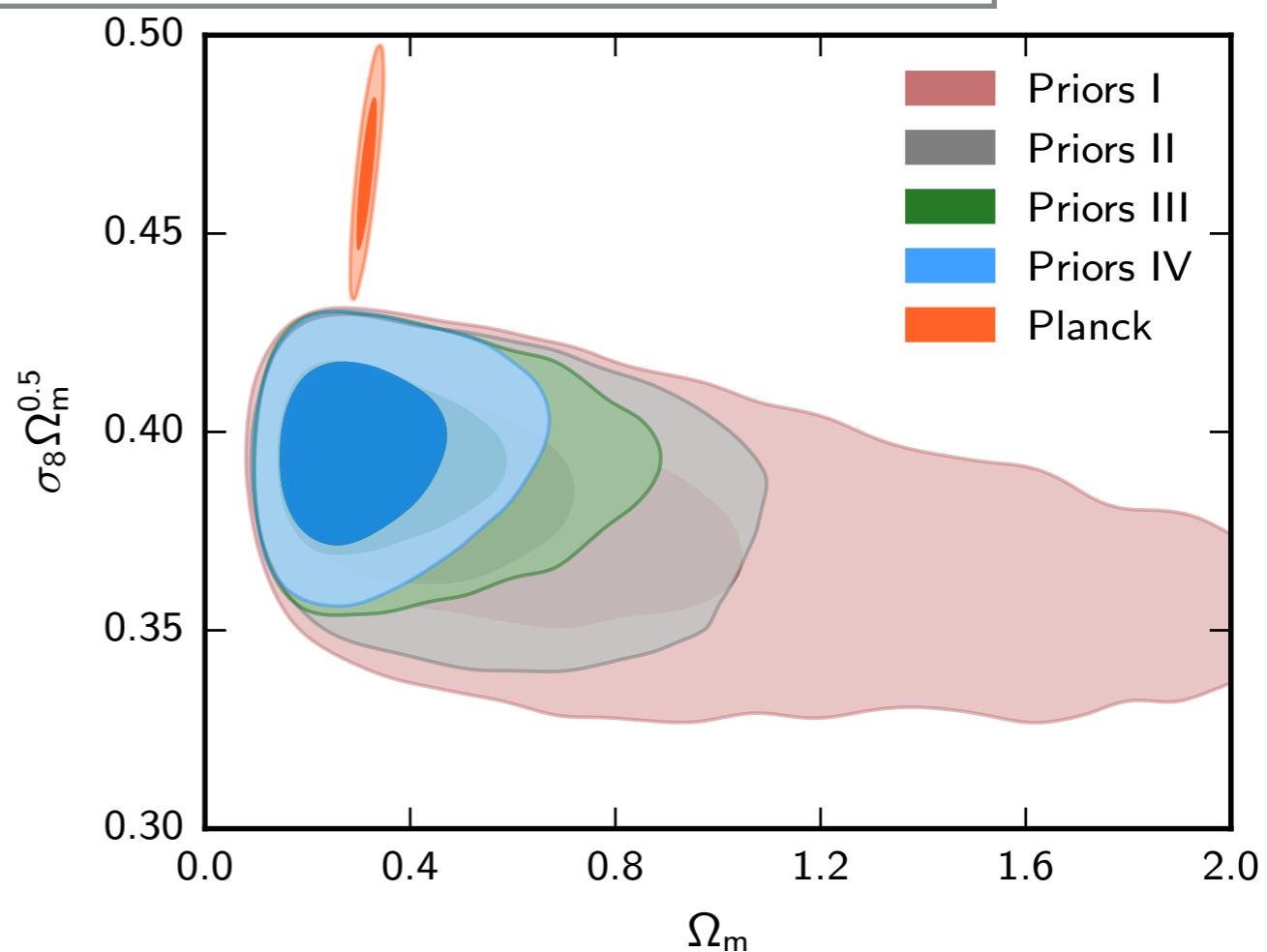
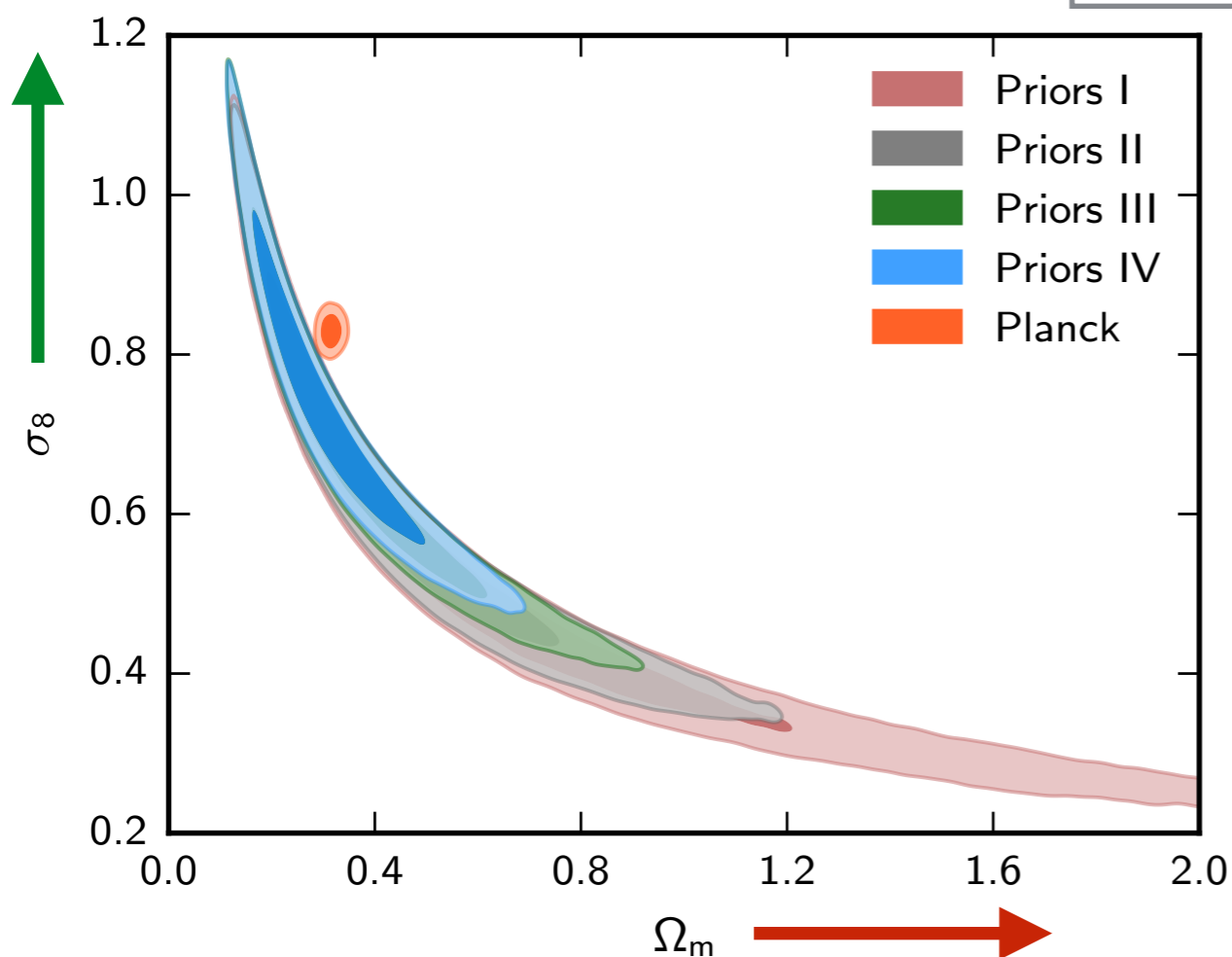
KÖHLINGER ET AL 2017, MNRAS 471, 4412

- 2-point correlation function of galaxy ellipticities, in/ between bins of photometric redshifts
- Independent of where the galaxies are — direct measurement of ‘roughness’ of gravitational potential in front of the survey galaxies (given by power spectrum)
- Calibrate the photometric redshifts via comparison to spectroscopic catalogues
- Sensitive to a amount of clustered matter



Cosmic shear 'banana'

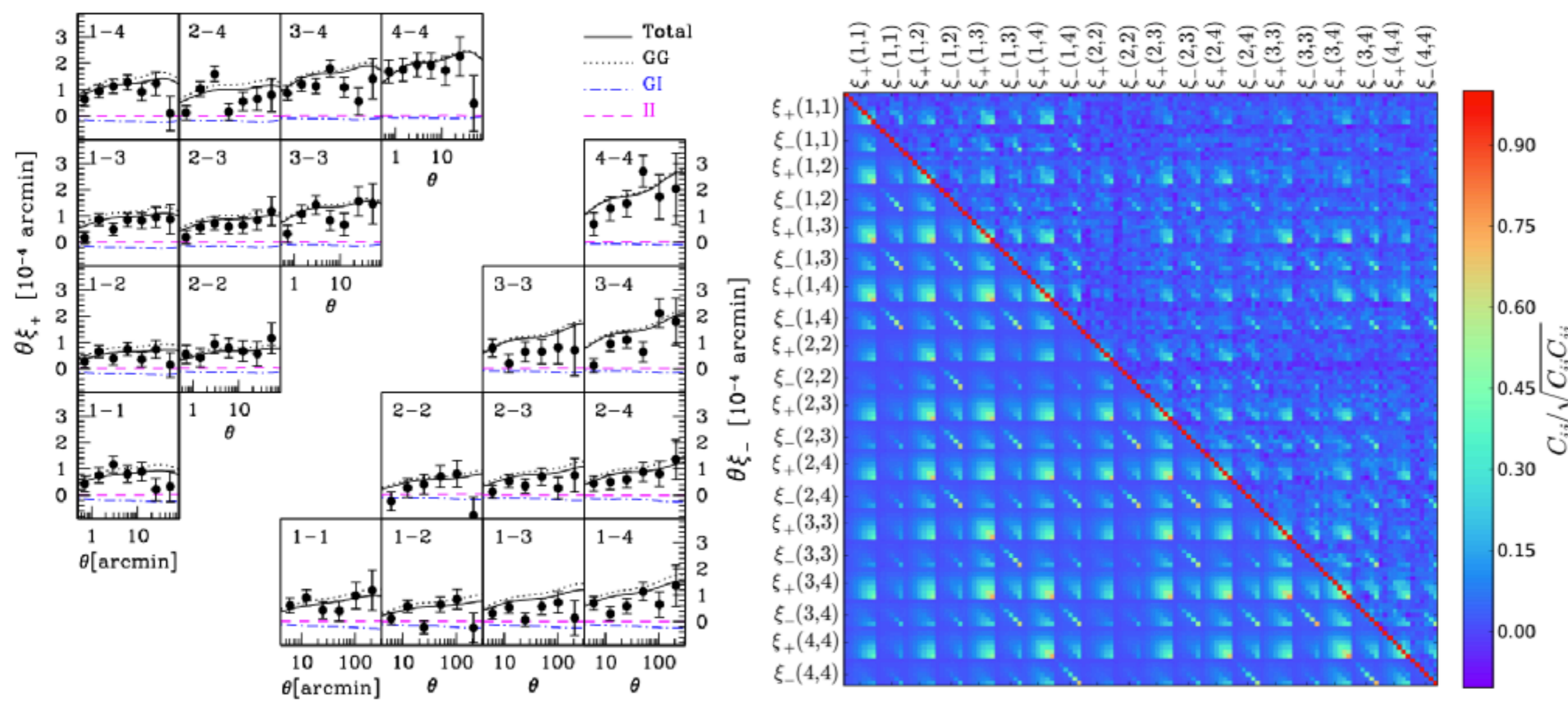
CFHTLenS re-analysis (Joudaki et al 2016)



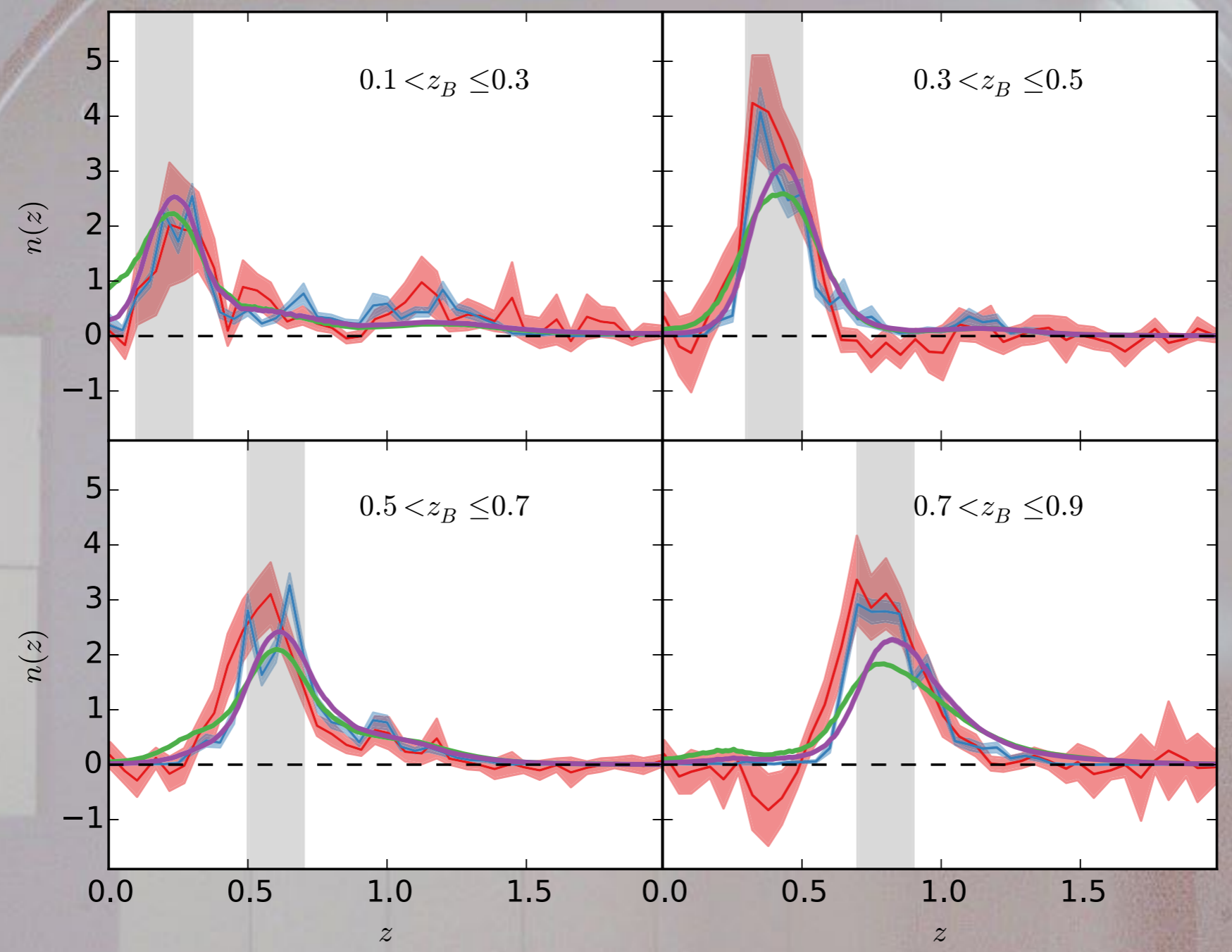
- Measure **amount** of **clustered** matter
- Constraints beyond $S_8 \equiv \sigma_8 \Omega_m^{1/2}$ are sensitive to priors
- Results are in tension with Planck

Tomographic correlation functions

- Data vector and covariance matrix (incl. cosmic variance)
- compare analytical model and mock survey covariance

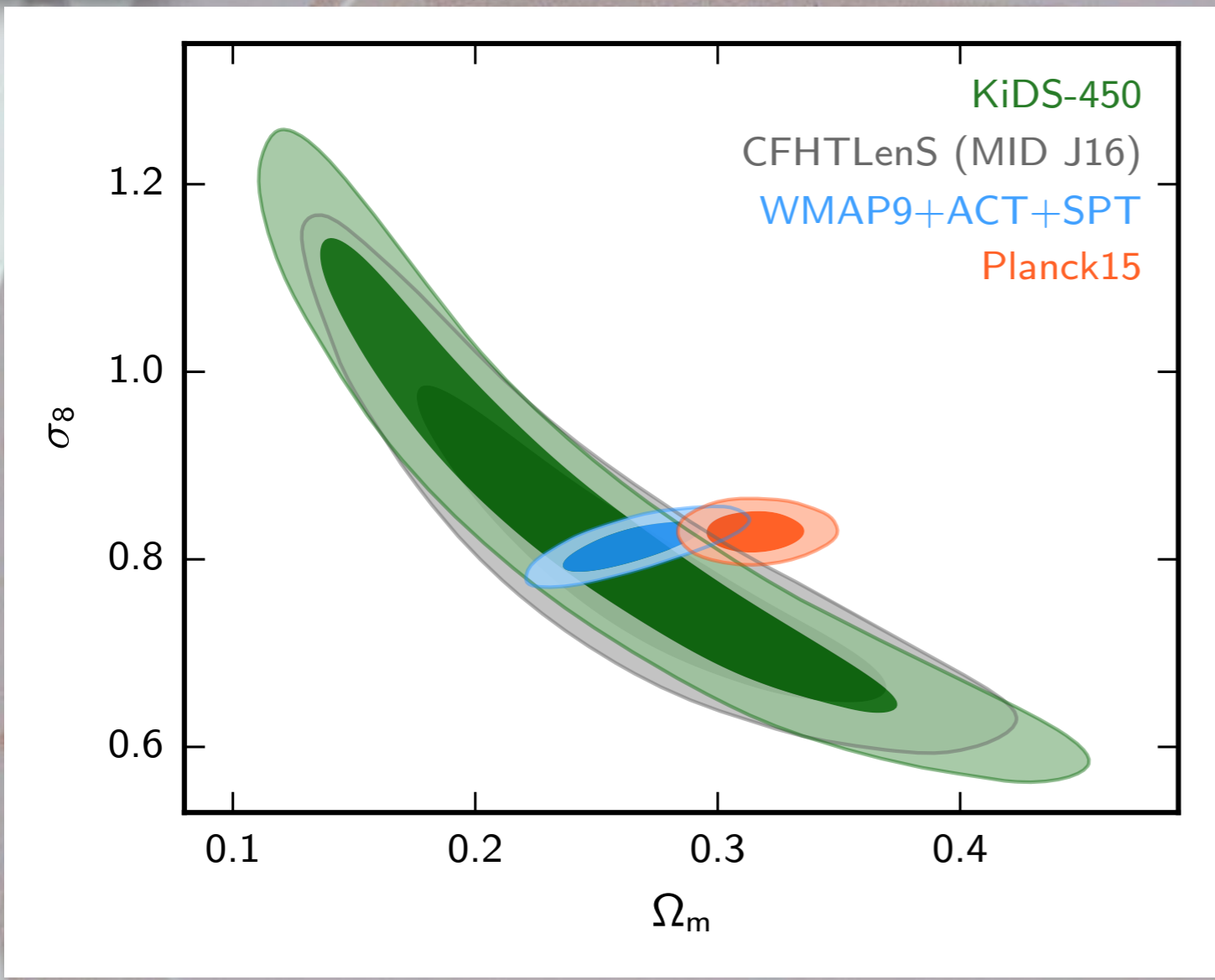


Photometric redshift bins



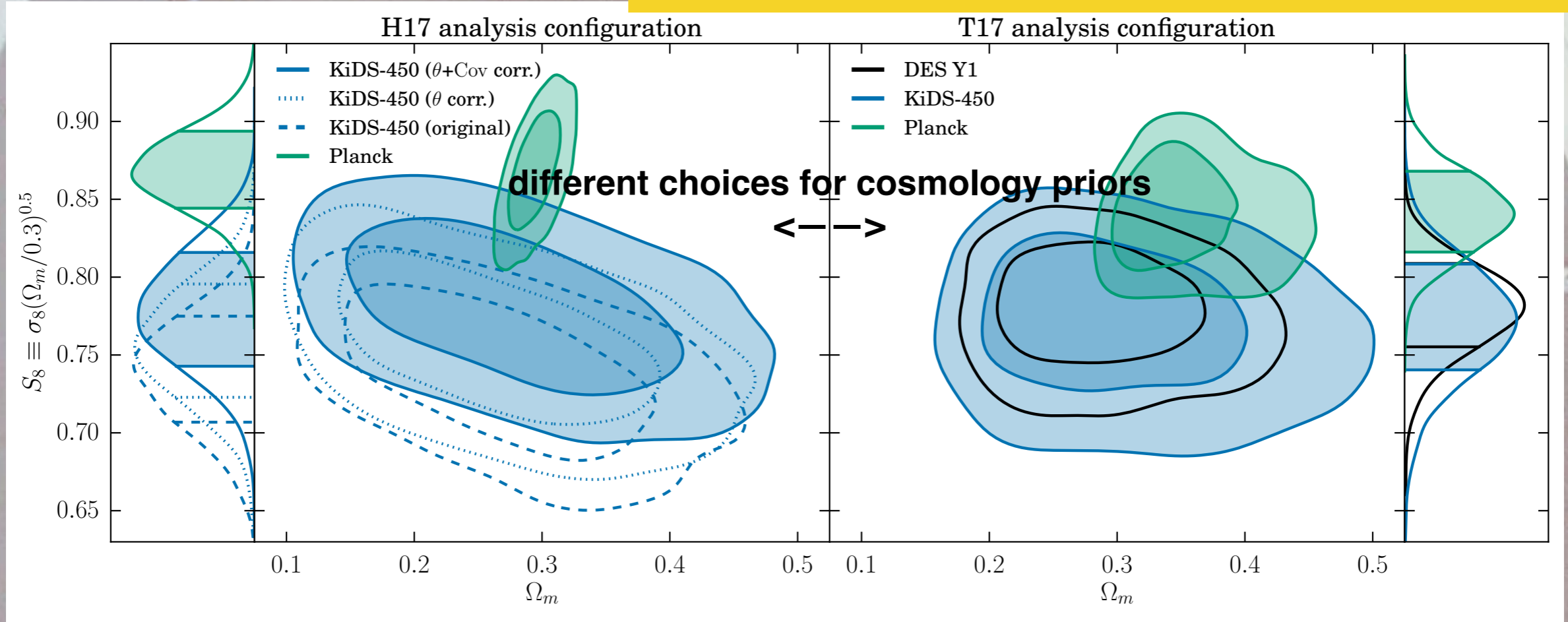
- Group galaxies by maximum-likelihood redshift
- Calibrate ensemble distributions and use those in the modelling

KiDS-450: Result



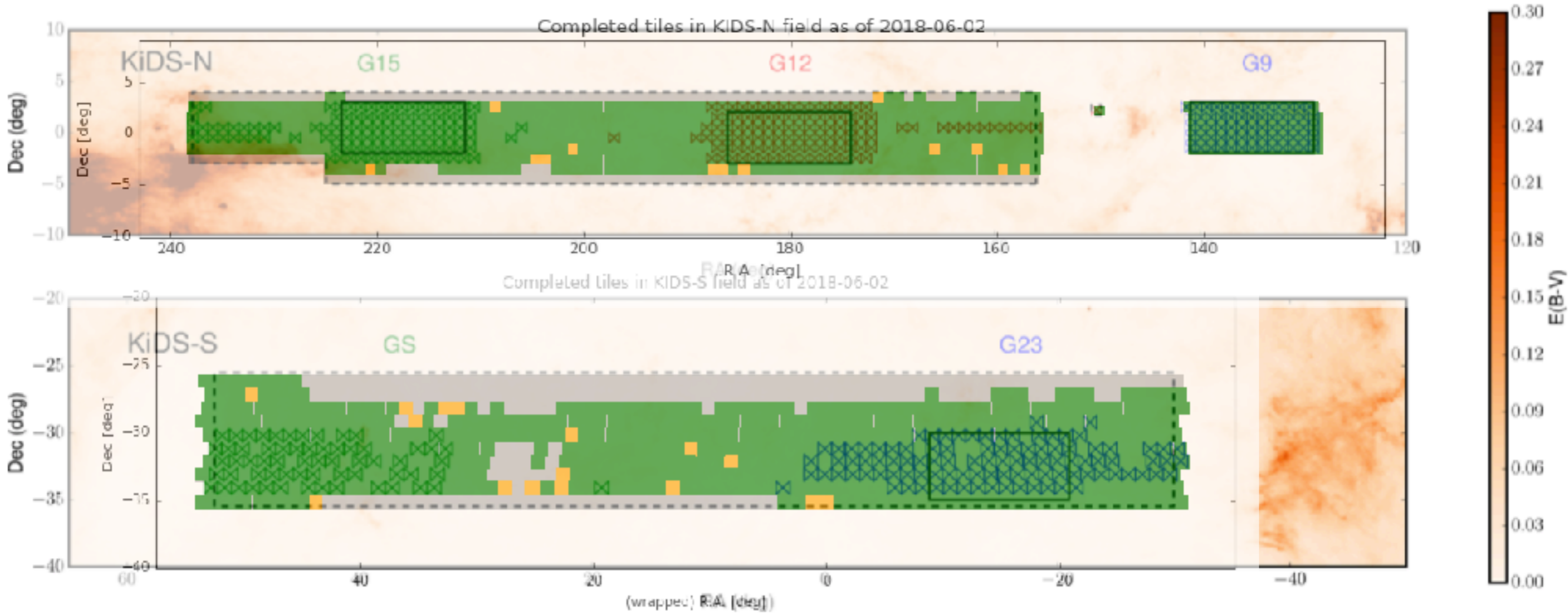
$$\sigma_8 \sqrt{(\Omega_m/0.3)} = 0.745 \pm 0.039$$

- S_8 constraint very similar to CFHTLenS, pre-planck CMB
- Tension with Planck — $2.7\sigma_{\text{KiDS}}$ in S_8 (2.3 σ discrepancy)



- Reanalysis by DES team:
 - Improved covariance estimate 'releases KiDS tension' with Planck slightly
 - DES result *very* consistent with KiDS now!

Next: DR4, "KiDS-900"



- Double area, fewer holes so better correlation functions
- Improved photo-z (incl VIKING)
- Gaia calibration

- “KiDS-900” being produced. Data to ESO this summer.
- New cosmic shear analysis
- First large contiguous field analyses
- VIKING included
- Understand completeness for large-scale clustering measurements —> combined probes of LSS
- And on to survey completion next year!



The KiDS Team

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 Julian Merten

OXFORD

Pedro Lacerdo

MPS LINDAU

Mass maps for KiDS-450

- (hard to analyse but look nice!)

