# KiDS survey: first lensing results

Konrad Kuijken
Leiden Observatory

300-Mpix CCD mosaic camera
OmegaCAM@VST

KiDS

# “The other surveys”

- Dark Energy Survey  5000 sqdeg, $i_{AB}$=24
- Kilo-Degree Survey  1500 sqdeg, $r_{AB}$=24.9
- HyperSuprimeCam  1375 sqdeg, $i_{AB}$=26
- soon: PAU, J-PASS  8500 sqdeg narrow-band $m_{AB}$~22.5

- Each targets large-scale structure/cosmology
- KiDS focus is on *high-fidelity* lensing / tomography

# KiDS Lensing team

Konrad Kuijken
Massimo Viola
Henk Hoekstra
Marcello Cacciato
Maciek Bilicki
Ricardo Herbonnet
Margot Brouwer
Cristobal Sifon
Jelte de Jong
Ewout Helmich
Nancy Irrisari

**LEIDEN**

Catherine Heymans
Ami Choi

**EDINBURGH**

Edo van Uitert
Benjamin Joachimi
Tom Kitching

**UC LONDON**

Lance Miller

**OXFORD**

Hendrik Hildebrandt
Patrick Simon
Thomas Erben
Axel Buddendiek
Alexandru Tudorica
Reiko Nakajima
Peter Schneider

**BONN**

Mario Radovich

**PADUA**

Ludovic van Waerbeke
Joachim Harnois-Deraps

**U BRITISH COLUMBIA**

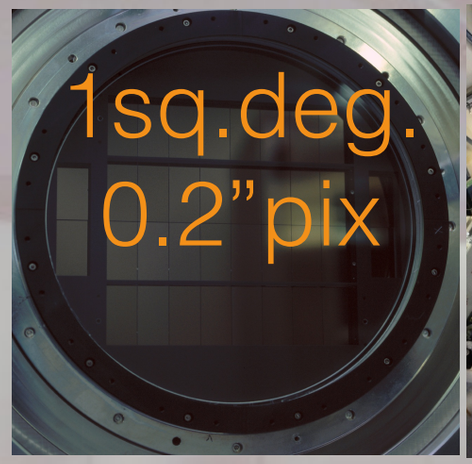
Edwin Valentijn
Gijs Verdoes Kleijn
John McFarland
Hugo Buddelmeijer
Gert Sikkema

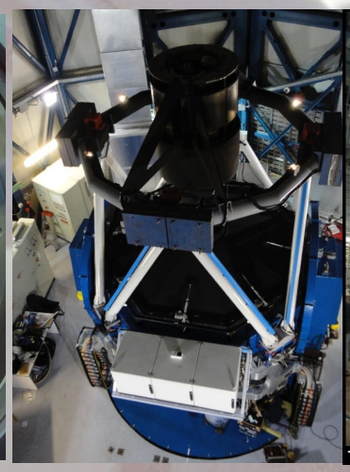
**GRONINGEN**

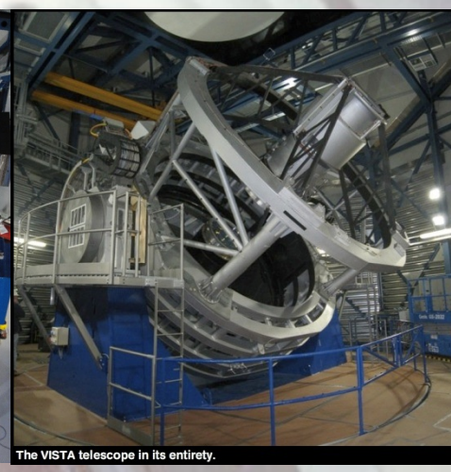
Chris Blake

**SWINBURN**

# KiDS in a nutshell



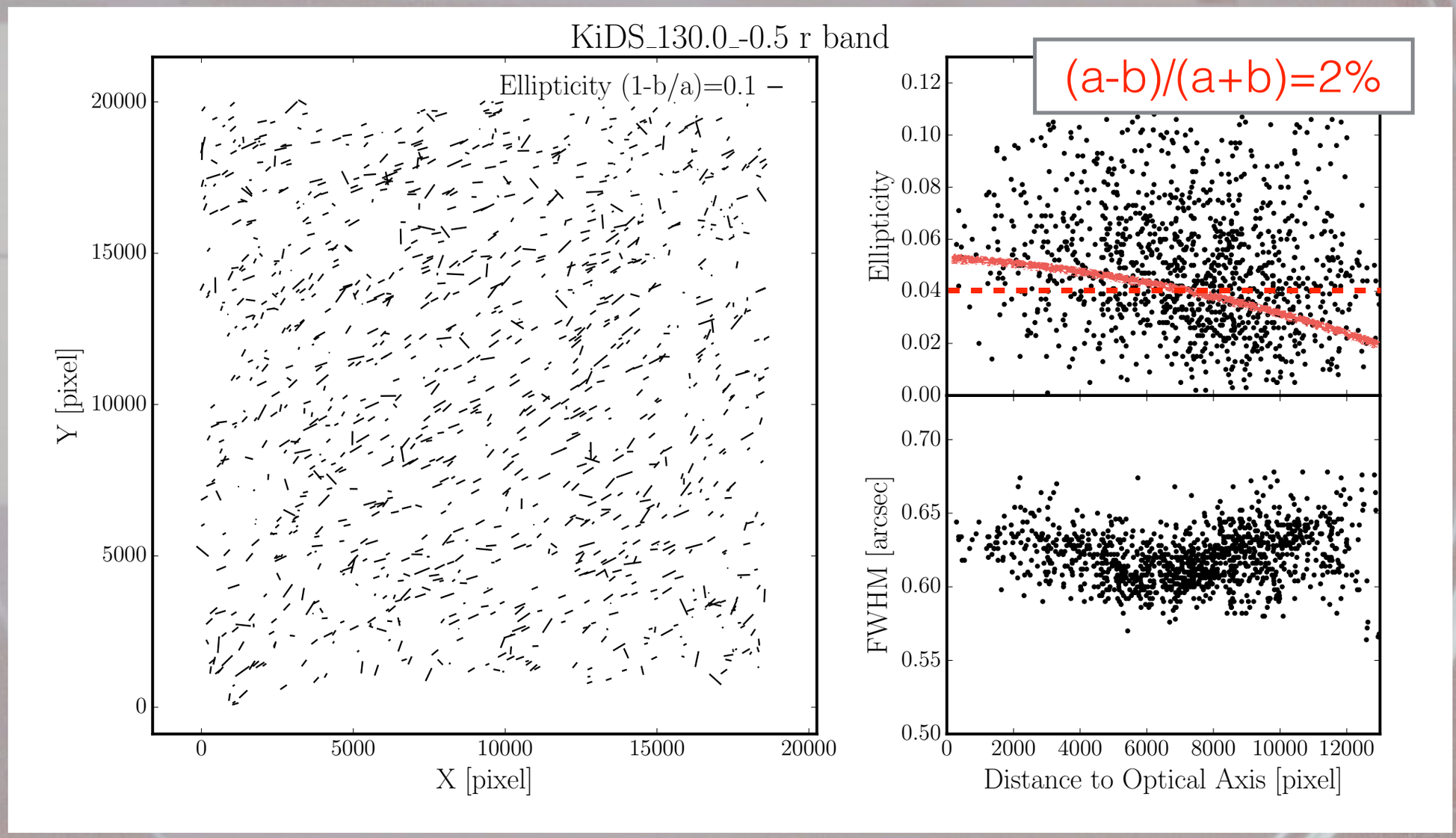






- 9-band survey u-K with VST/ OmegaCAM and VISTA
- 1500 square degrees
- 2mag deeper than SDSS, 2x sharper
- weak lensing + photoz optimized: **DARK M&E**
- started Oct 15 2011
- 500 sqdeg observed

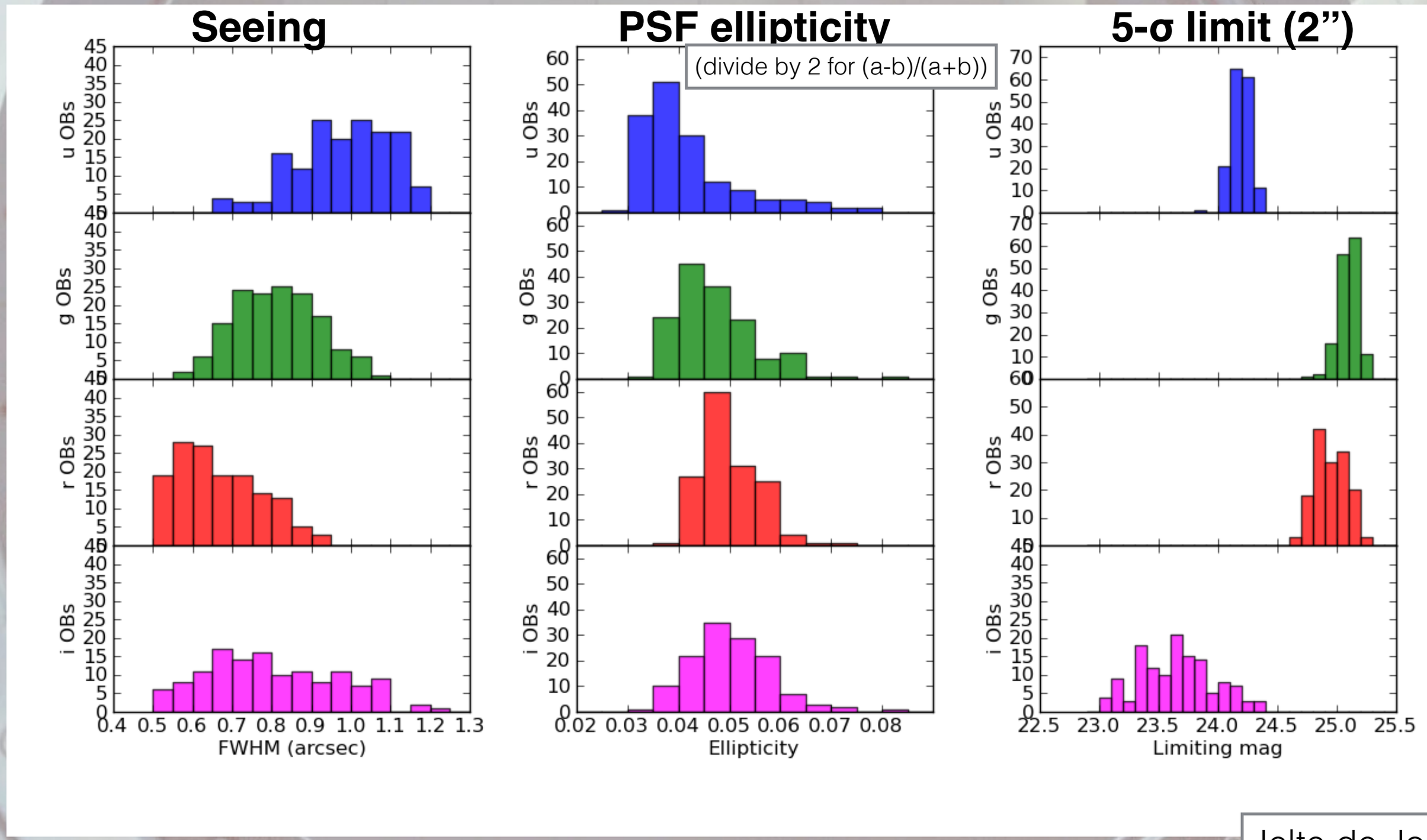
# High-fidelity

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



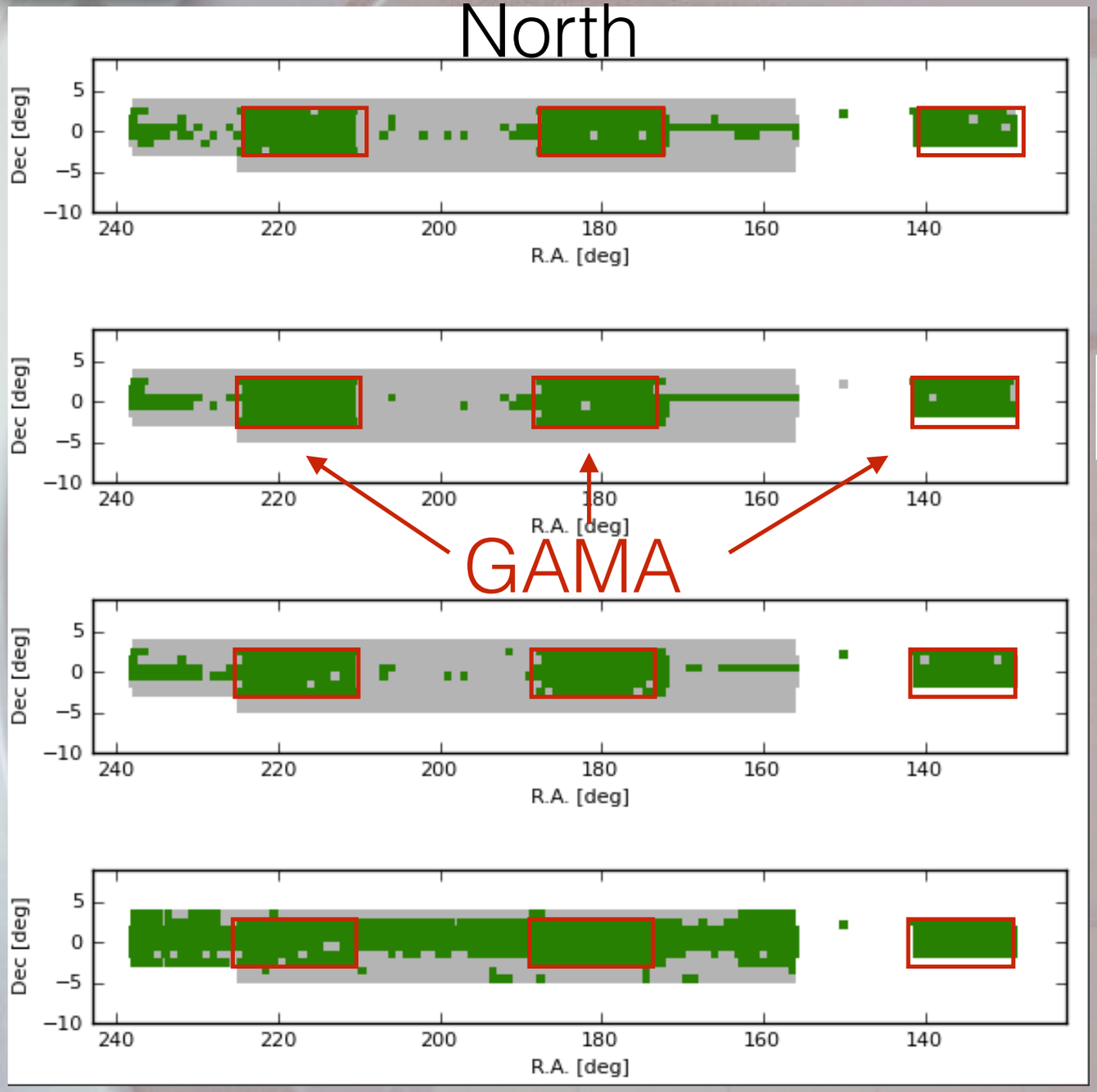

- 9-band photometry for photo-z ugriZYJHK

# Data quality (first 148 sq.deg.)




Jelte de Jong

# Observation status

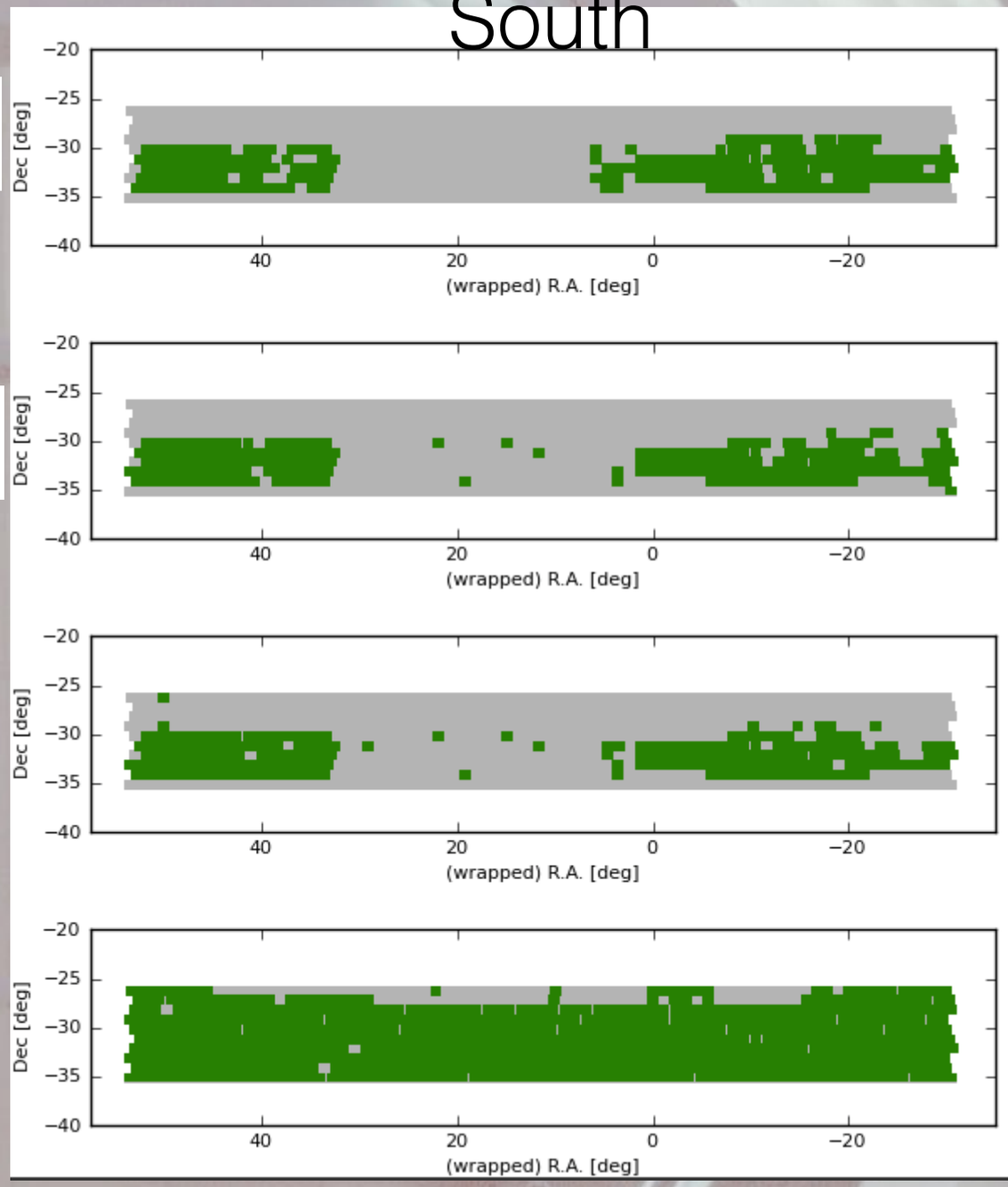



u

g

r

i




~500 out of 1500 square degrees observed (ugri).

Seeing (r<g<u) + moon (i) dictate schedule.

Observations go to full depth (5 dithers) at once.

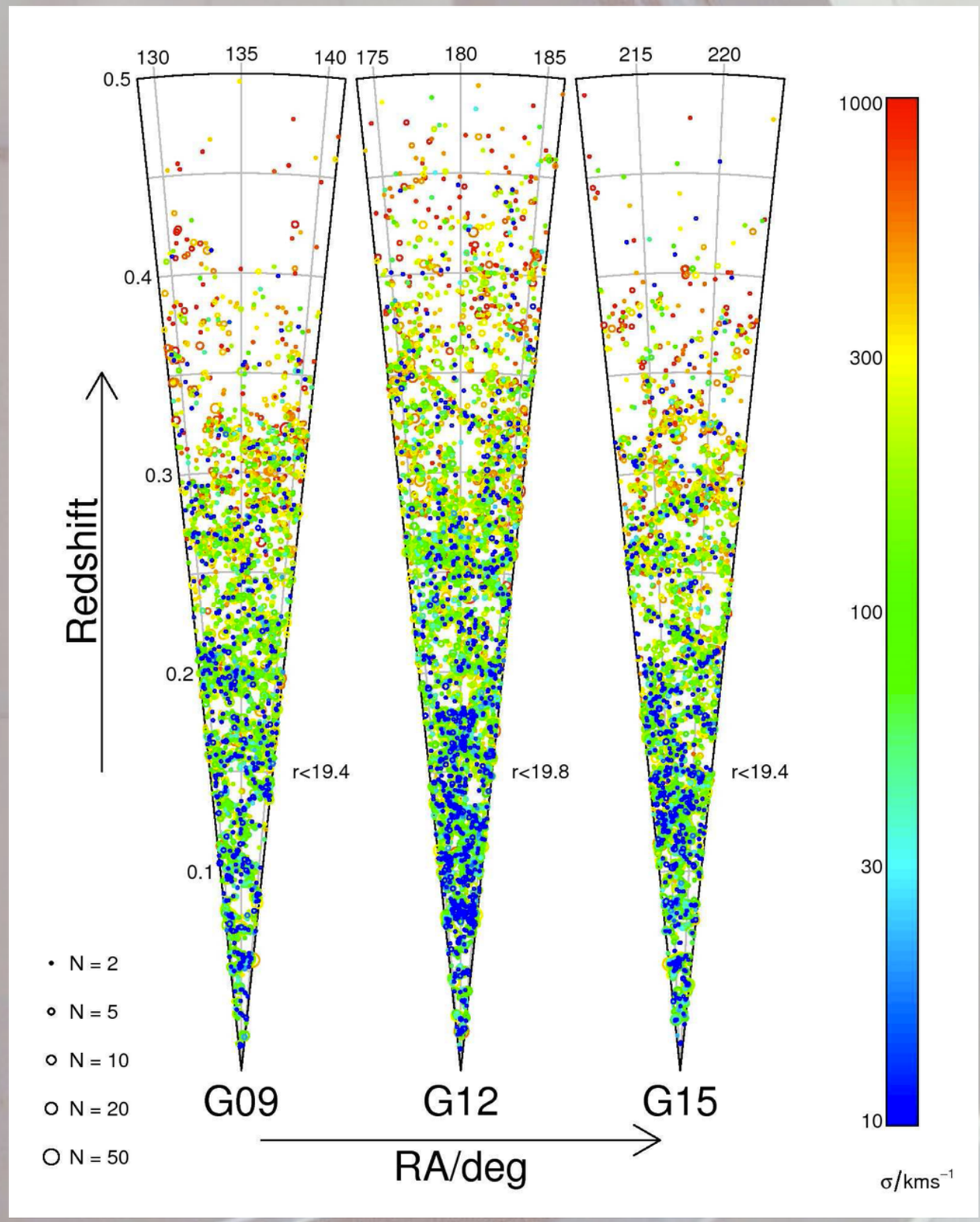
No variability

# GAMA: Galaxy And Mass Assembly

Driver++ 2012, Liske ++2015

- 250,000 redshifts from AAT
- flux-limited (r<19.8)
- **complete in dense regions**
- deep, so efficient lenses
- Group catalogue

Robotham 2011



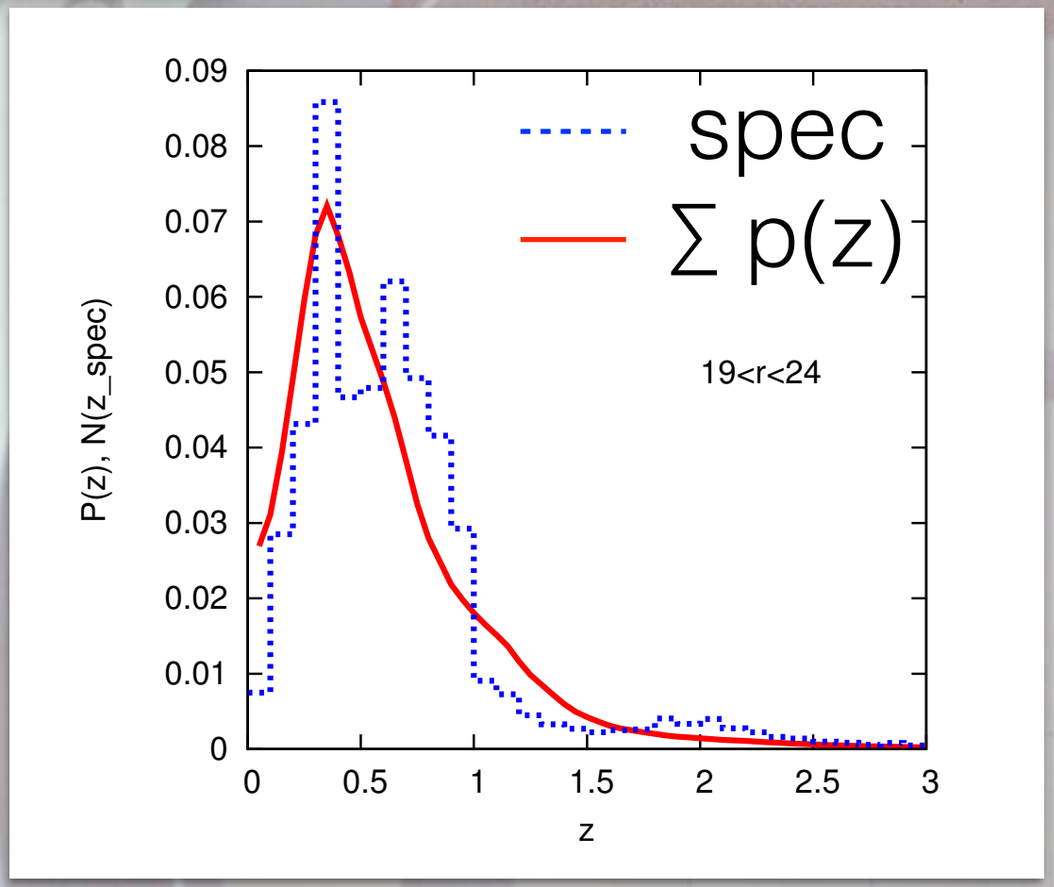
# Data processing

- Two parallel pipelines. Significant CFHTLenS heritage
  - Shapes: THELI + *lens*fit (r band)

    Thomas Erben, Lance Miller, Catherine Heymans
    - single-exposure model fitting, no pixel resampling
    - Bayesian treatment of size and ellipticity priors
    - calibrated with simulations
    - catalogues ***blinded*** - analyse 3 sabotaged data sets + the real one.
  - Photometric redshifts: GAaP + BPZ (u,g,r,i band)

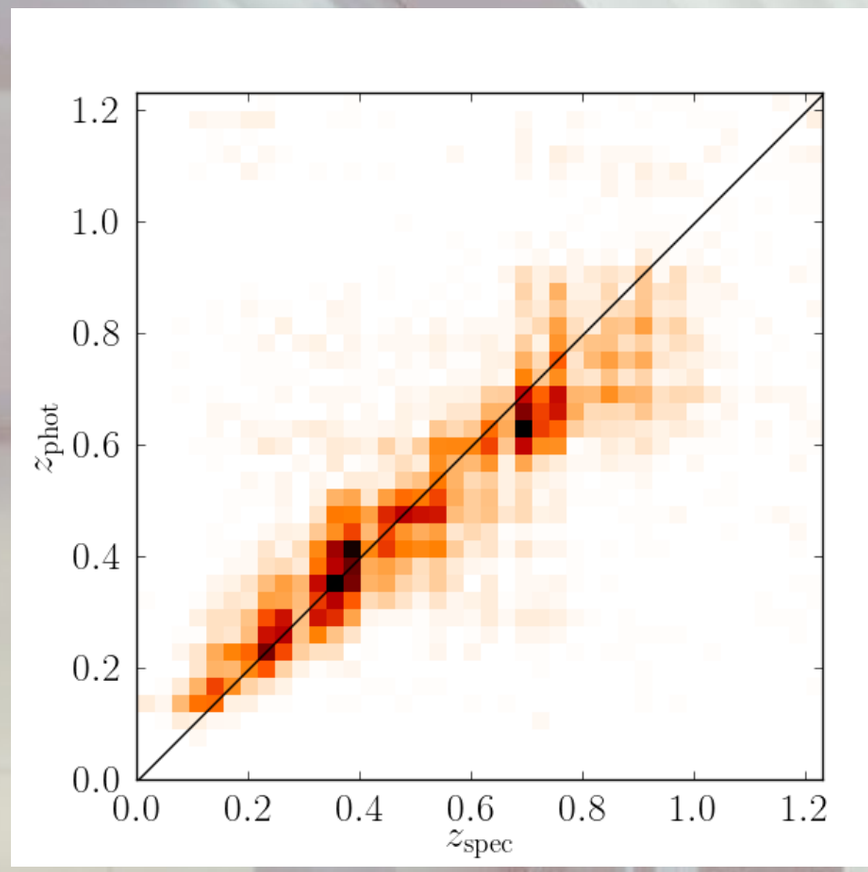
    KK, Hendrik Hildebrandt
    - stacked images
    - PSF Gaussianization + matched-aperture photometry
    - BPZ (Benitez 2000)

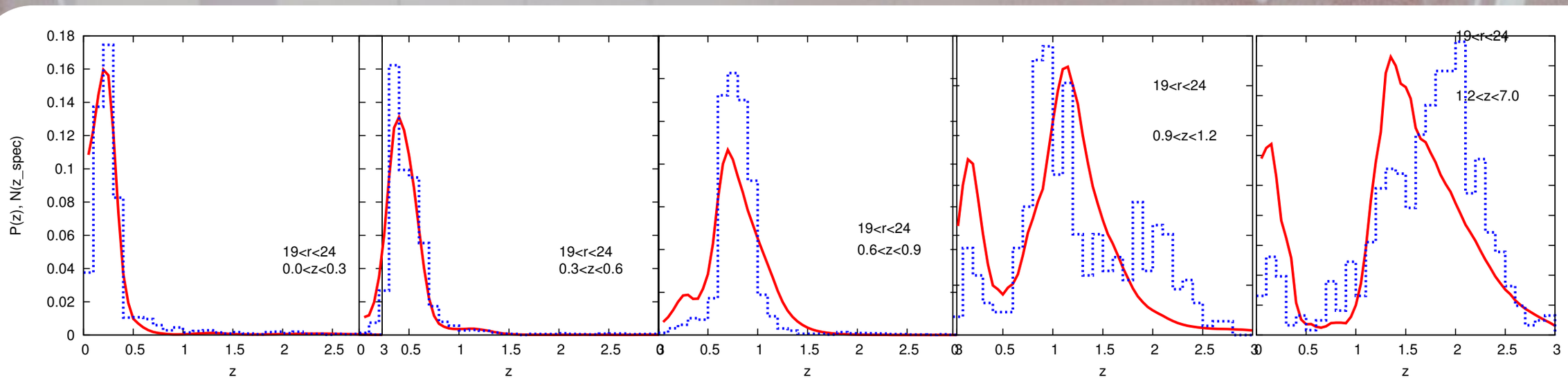
# Photometric redshifts (*ugri*)



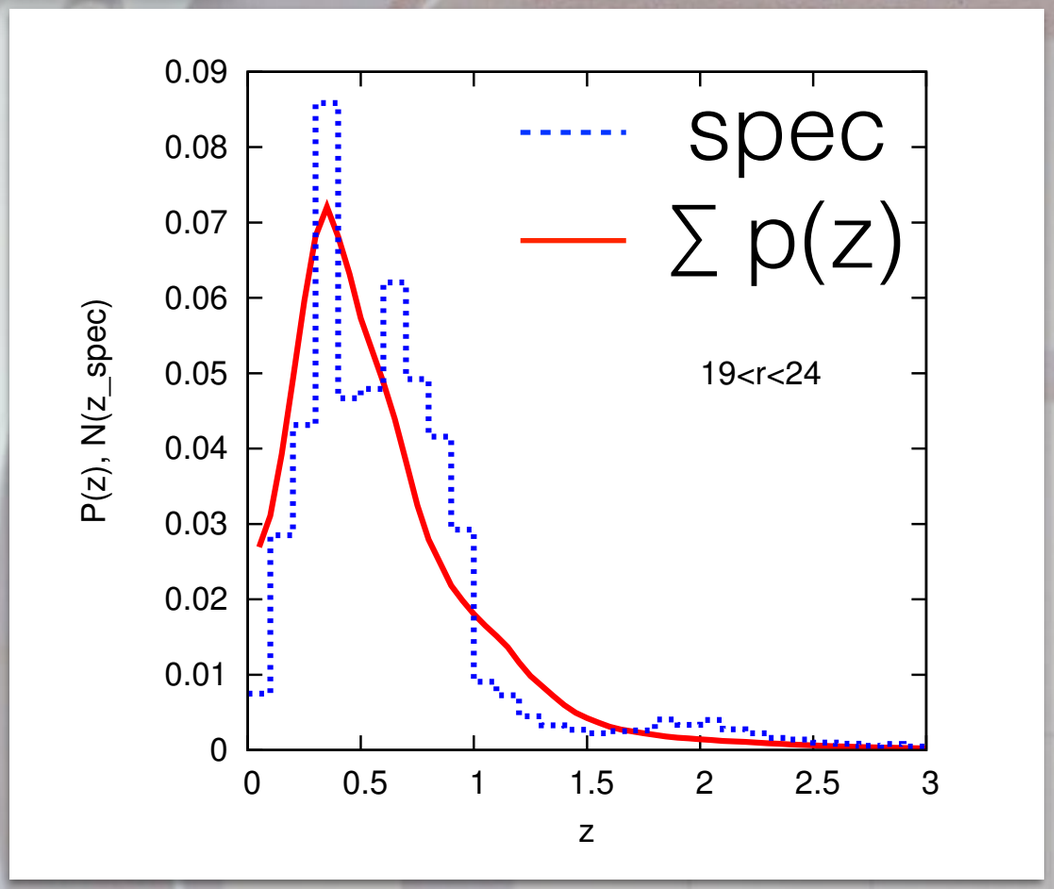

COSMOS
CDFS

(VST data from VOICE programme —thanks!)



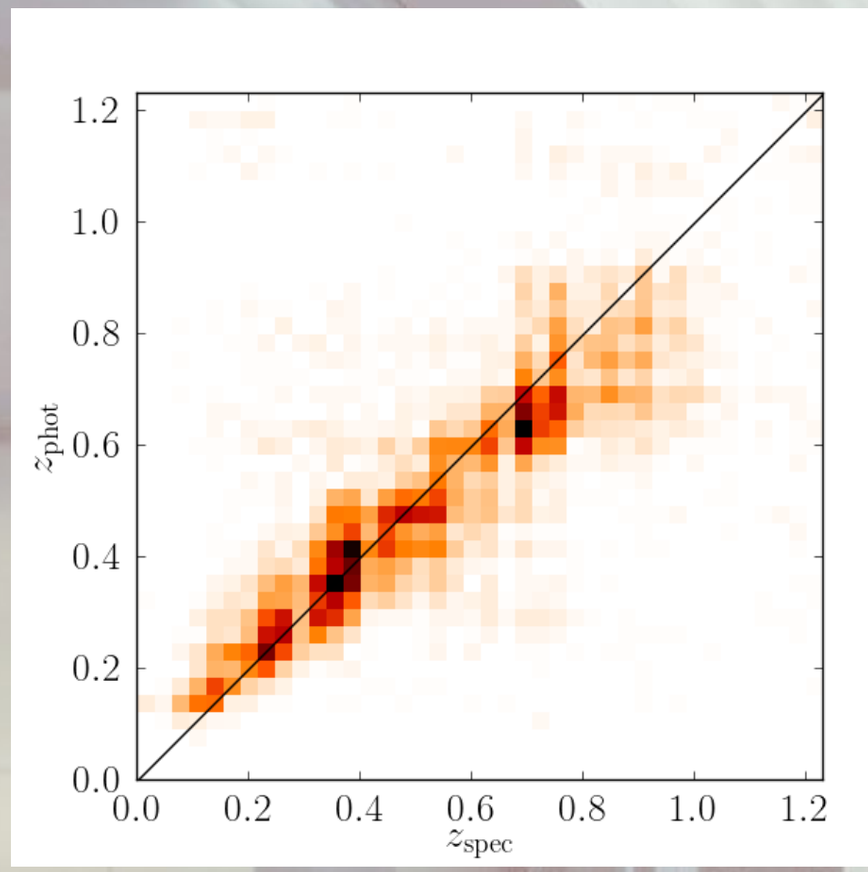



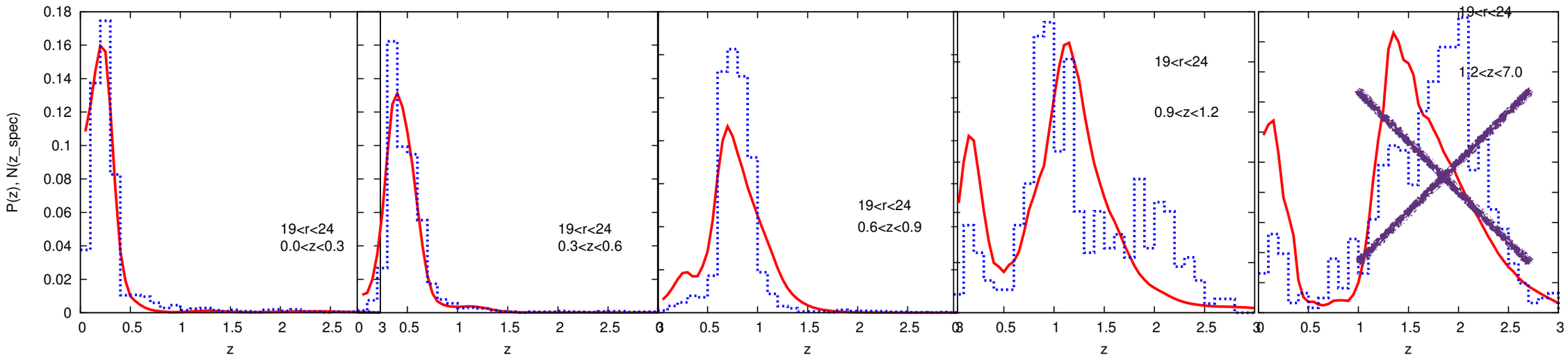
# Photometric redshifts (*ugri*)




COSMOS
CDFS

(VST data from VOICE programme —thanks!)



# First KiDS papers!

# First KiDS papers!

ArXiv 2015.00740±14

**Dark matter halo properties of GAMA galaxy groups from 100 square degrees of KiDS weak lensing data**

M. Viola[1⋆], M. Cacciato[1], M. Brouwer[1], K. Kuijken[1], H. Hoekstra[1], P. Norberg[2],
...itert[4,5], M. Alpaslan[12], I.K. Baldry[6], A. Choi[7],

## Gravitational Lensing Analysis of the Kilo Degree Survey

Konrad Kuijken[1⋆], Catherine Heymans[2], Hendrik Hildebrandt[3], Reiko Nakajima[3],
Thomas Erben[3], Jelte T.A. de Jong[1], Massimo Viola[1], Ami Choi[2], Henk Hoekstra[1],
Lance Miller[4], Edo van Uitert[3,5], Alexandra Amon[2], Chris B...
Axel Buddendiek[3], Ian Fenech Conti[7,8], Martin Eriksen[1], An...

## Towards a census of super-compact massive galaxies in the Kilo Degree Survey

C. Tortora[1⋆], F. La Barbera[1], N.R. Napolitano[1], N. Roy[1,2], M. Radovich[3],
...go[2], E. Getman[1], M. Capaccioli[2], L. Grado[1]

## First discoveries of $z \sim 6$ quasars with the Kilo Degree Survey and VISTA Kilo-Degree Infrared Galaxy survey⋆

B. P. Venemans,[1]† G. A. Verdoes Kleijn,[2] J. Mwebaze,[2] E. A. Va...
E. Bañados[1] R. Decarli[1] J. T. A. de Jong[3] J. R. Findlay[4] K. H...

## Structure and substructure in the stellar halo of the Milky Way

Proefschrift

## Machine Learning based photometric redshifts for the KiDS ESO DR2 galaxies

S. Cavuoti[1⋆], M. Brescia[1], C. Tortora[1], G. Longo[2], N. R. Napolitano[1], M. Radovich[3],
F. La Barbera[1], M. Capaccioli[4], J. de Jong[5], E. Getman[1], A. Grado[1], M. Paolillo[2]

**The masses of satellites in GAMA galaxy groups from 100 square degrees of KiDS weak lensing data**

Cristóbal Sifón[1⋆], Marcello Cacciato[1], Henk...
Edo van Uitert[2,3], Massimo Viola[1], Ivan Bald...
Ami Choi[7], Simon P. Driver[8,9], Thomas Erber...

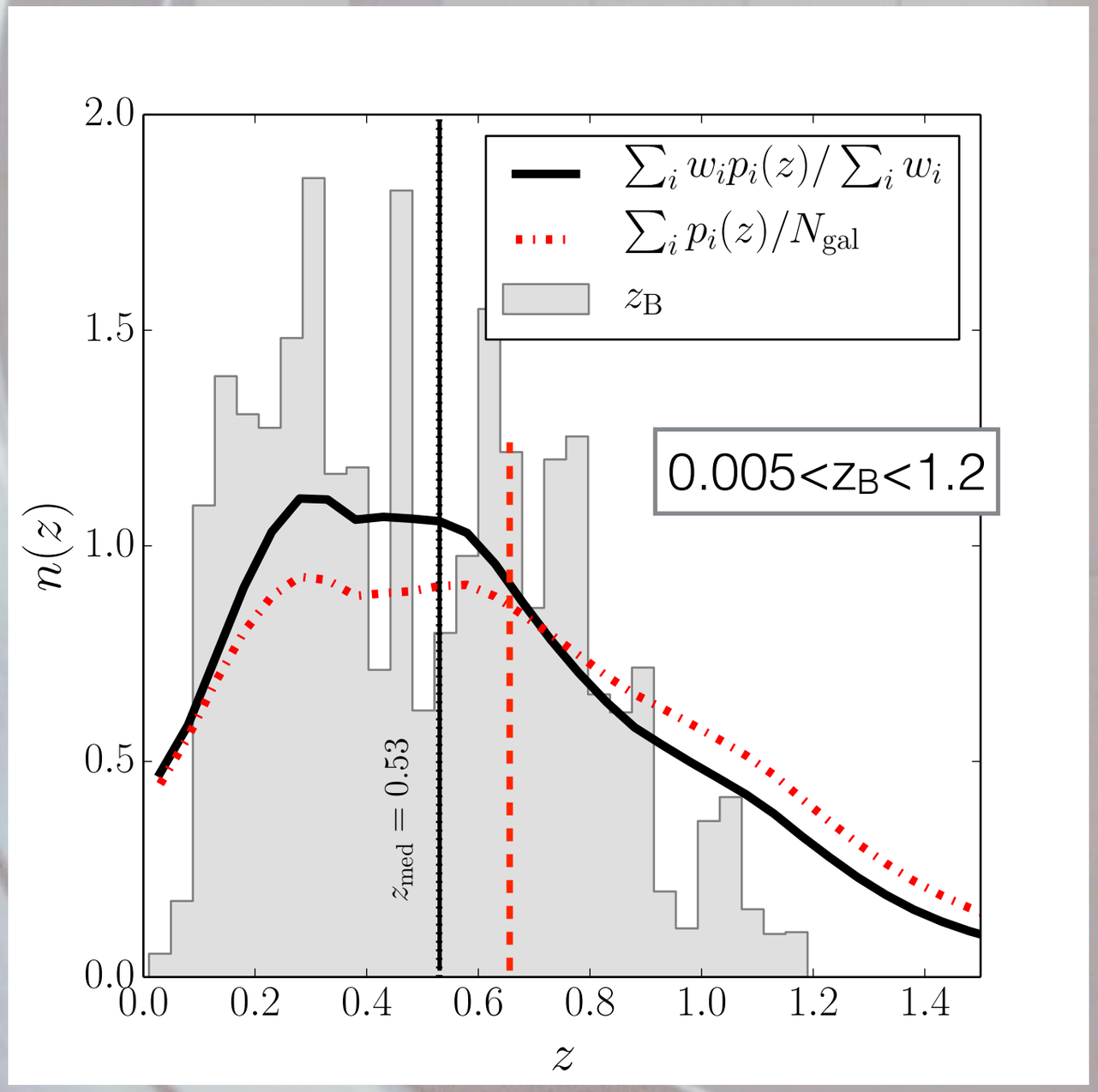
**The first and second data releases of the Kilo-Degree Survey**

Jelte T. A. de Jong[1], Gijs A. Verdoes Kleijn[2], Danny R. Boxhoorn[2], Hugo Buddelmeijer[2], Massimo Capaccioli[3], Fedor Getman[3], Aniello Grado[3], Ewout Helmich[1], Zhuoyi Huang[3], Nancy Irisarri[1], Konrad Kuijken[1], Francesco LaBarbera[3], John P. McFarland[2], Nicola R. Napolitano[3], Mario Radovich[4], Gert Sikkema[2], Edwin A. Valentijn[2], Kor G. Begeman[2], Massimo Brescia[3], Stefano Cavuoti[3], Ami Choi[5], Oliver-Mark Cordes[6], Giovanni Covone[7], Massimo Dall'Ora[3],

# Summary of first-lensing data

- 109 square degrees of lensing + photo-z data
  - data observed before Oct 2013 that overlap with GAMA
- 75 sq.deg. after conservative masking

Reiko Nakajima




8.9 galaxies arcmin$^{-2}$ with shape measurement

—> $n_{\rm eff}$=4.5 arcmin$^{-2}$

—> shear inverse variance density = 69 arcmin$^{-2}$.

median redshift 0.63, —> 0.53 with lens weight.

# Lensing data quality

- Good seeing helps ***precision***
  - $\sigma(e) \sim [1+(r_{PSF}^2/r_{gal}^2)]^{1/2}$ at given flux, background
  - so does a benign PSF pattern
- Various systematic tests for ***accuracy***:
  - print-through of PSF ellipticity pattern
  - scaling of galaxy lensing with redshift
  - dependence of lensing signal on signal-to-noise ratio
  - clustering of photo-z bins
  - 2-pt correlation function B-modes

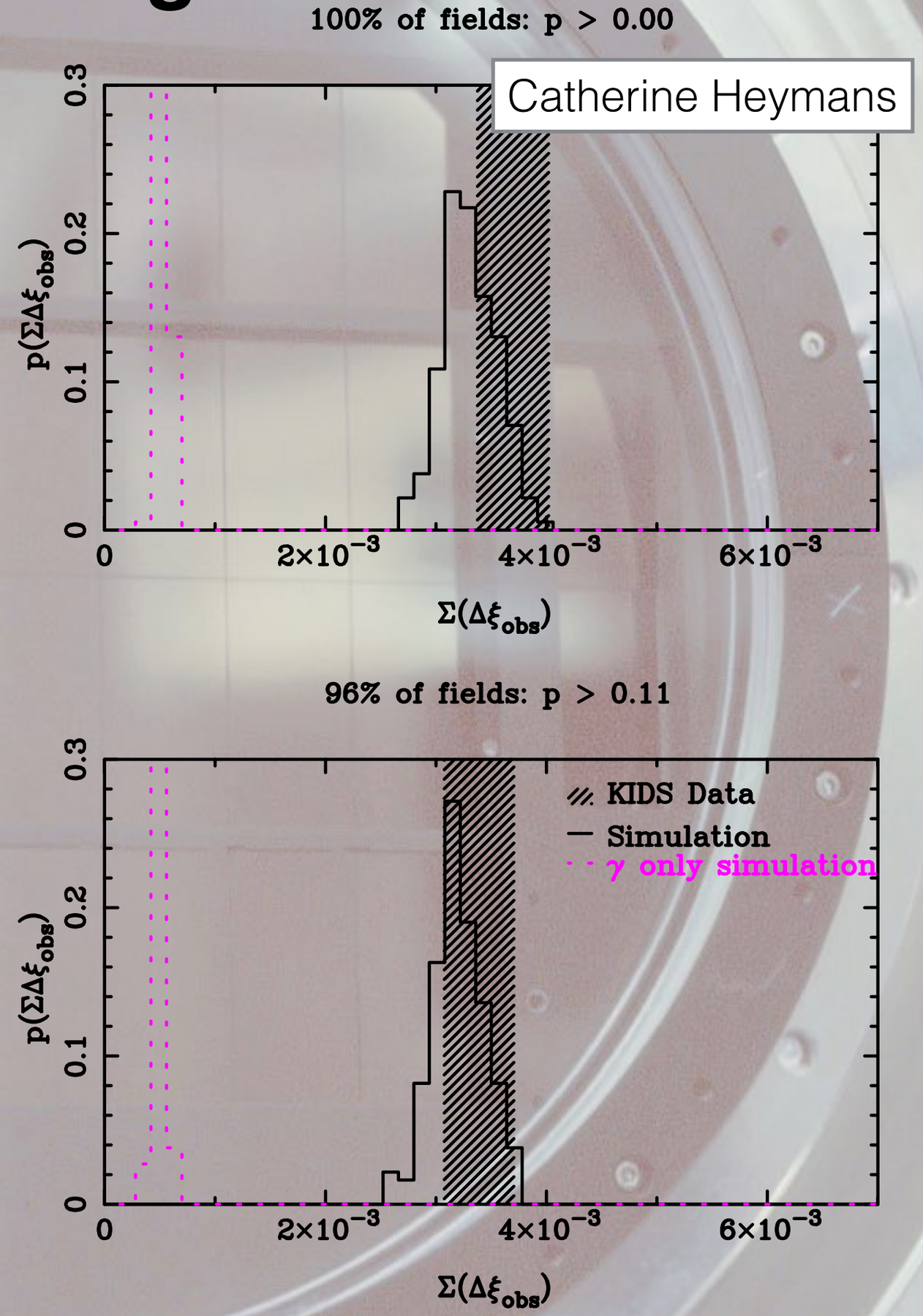
# Test PSF print-through in shears

- Use sub-exposures for each field to disentangle PSF and galaxy contributions to fitted ellipticities (cf CFHTLenS: Heymans et al 2012).

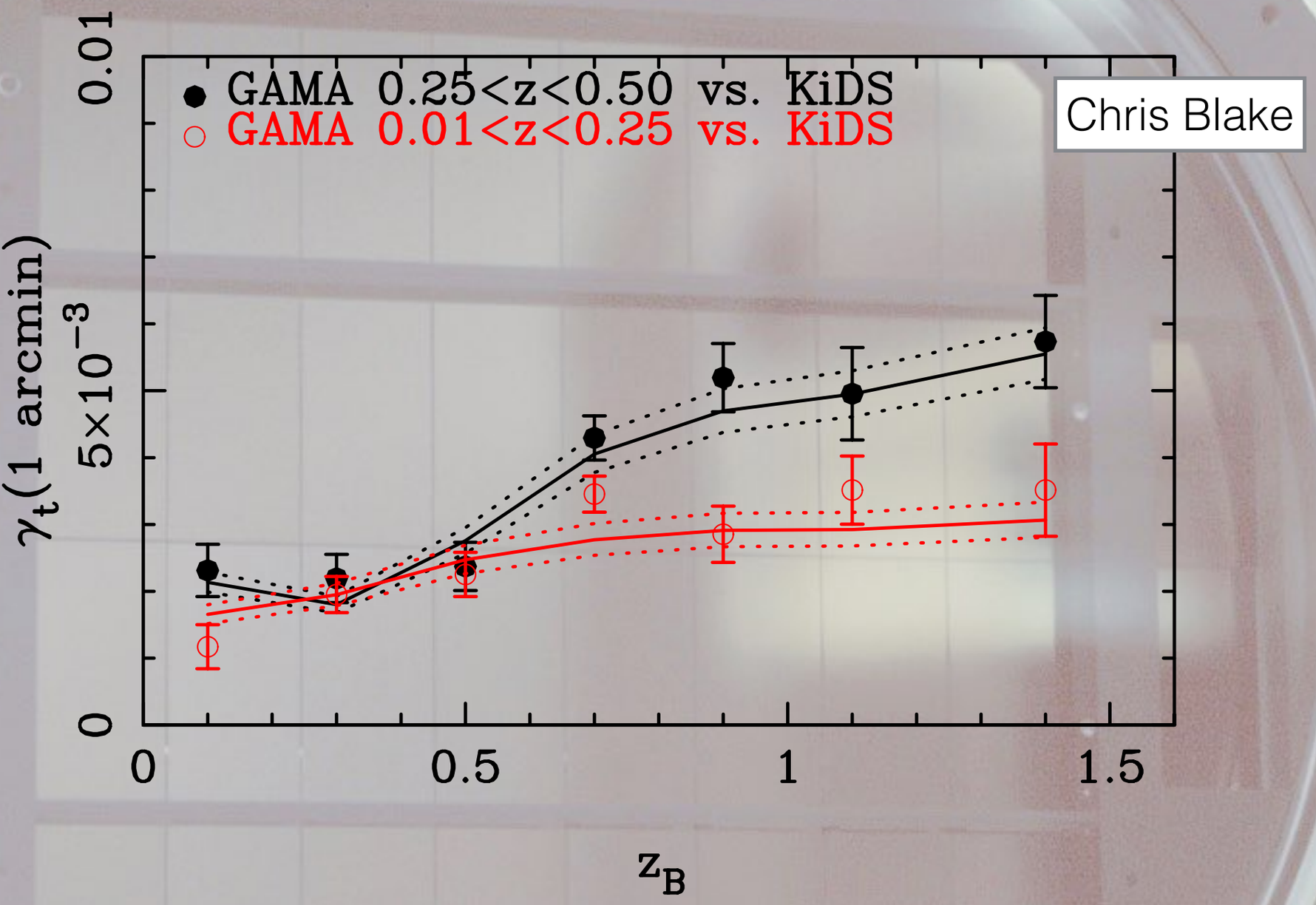
- Some chance alignment expected - check with mocks

- Consistent!

- (CFHTLenS had to reject 25% of fields)

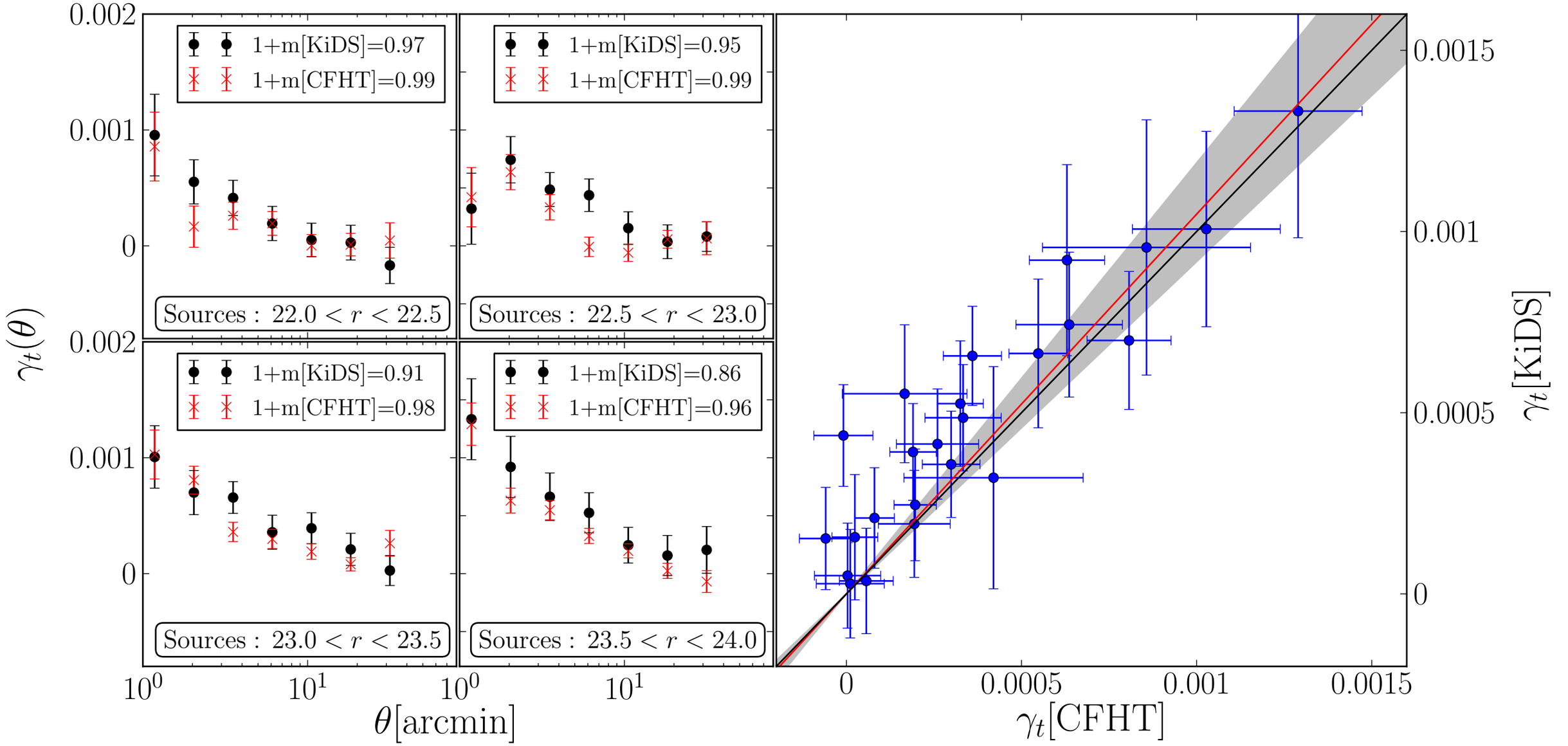


# Galaxy lensing source redshift scaling




- Spectroscopic lens samples from GAMA
- Photo-z sources in bins of best-fit photo-z
- Use full p(z) posteriors to predict signal in each bin

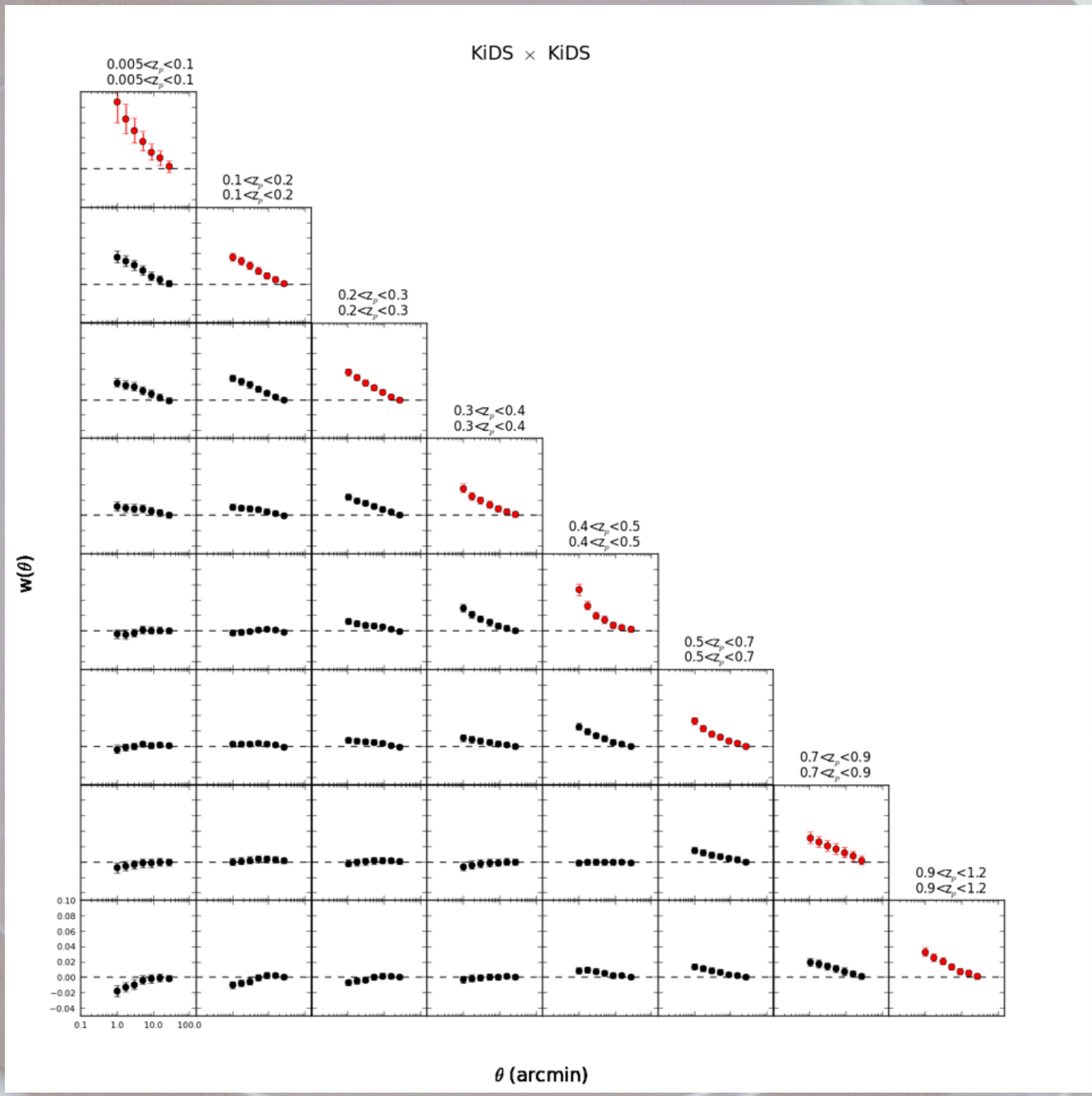
# Galaxy lensing at different SNR




- galaxy-galaxy lensing by lenses with 20<*r*<21
- compare CFHTLenS vs KiDS, each corrected for own noise bias

# Clustering of photo-z bins

Ami Choi



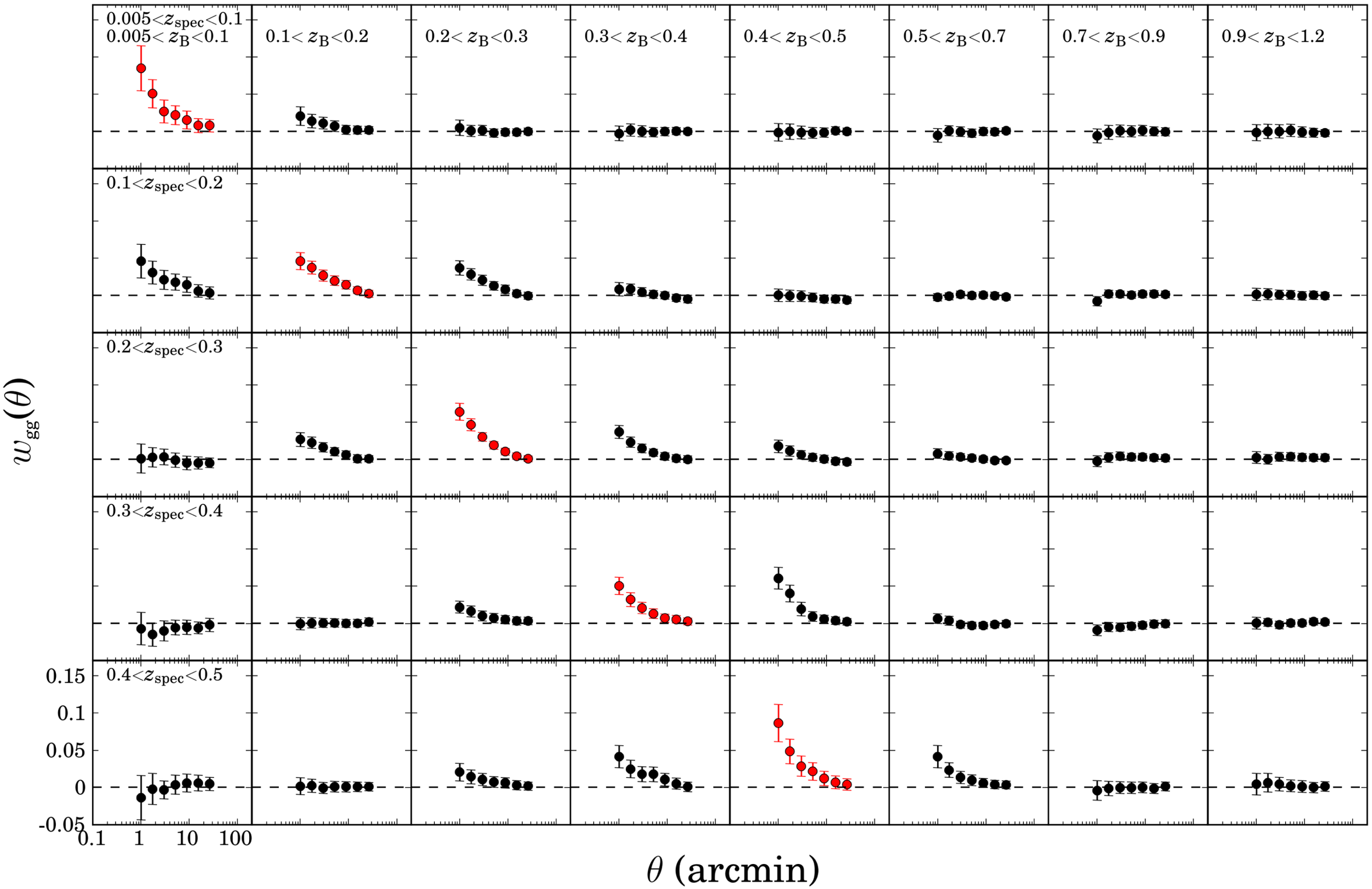
# Clustering of photo-z bins

Ami Choi

KiDS × KiDS

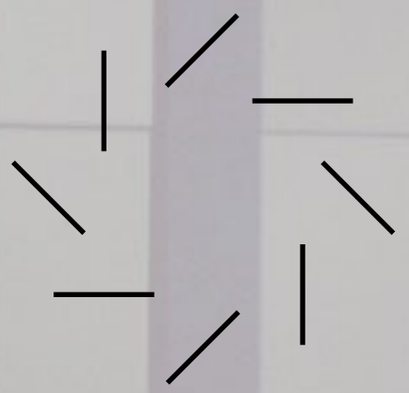
$0.005<z_p<0.1$

GAMA × KiDS



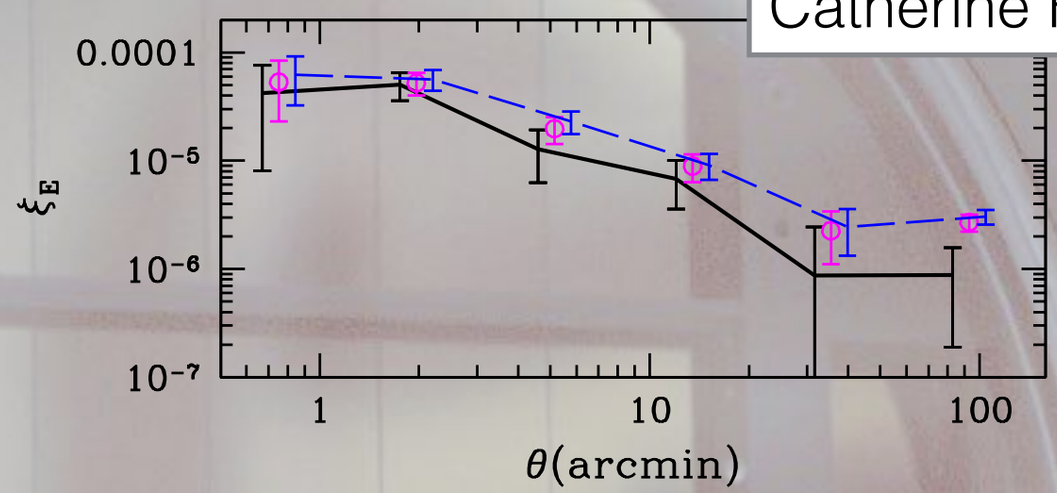
# E-B mode in 2-pt shear correlation

E mode

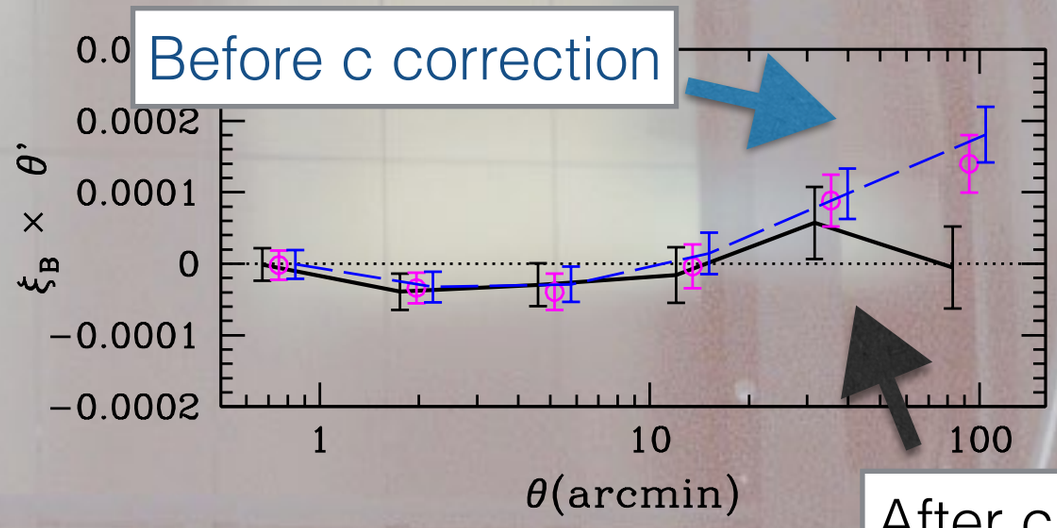


B mode

Catherine Heymans




Before c correction



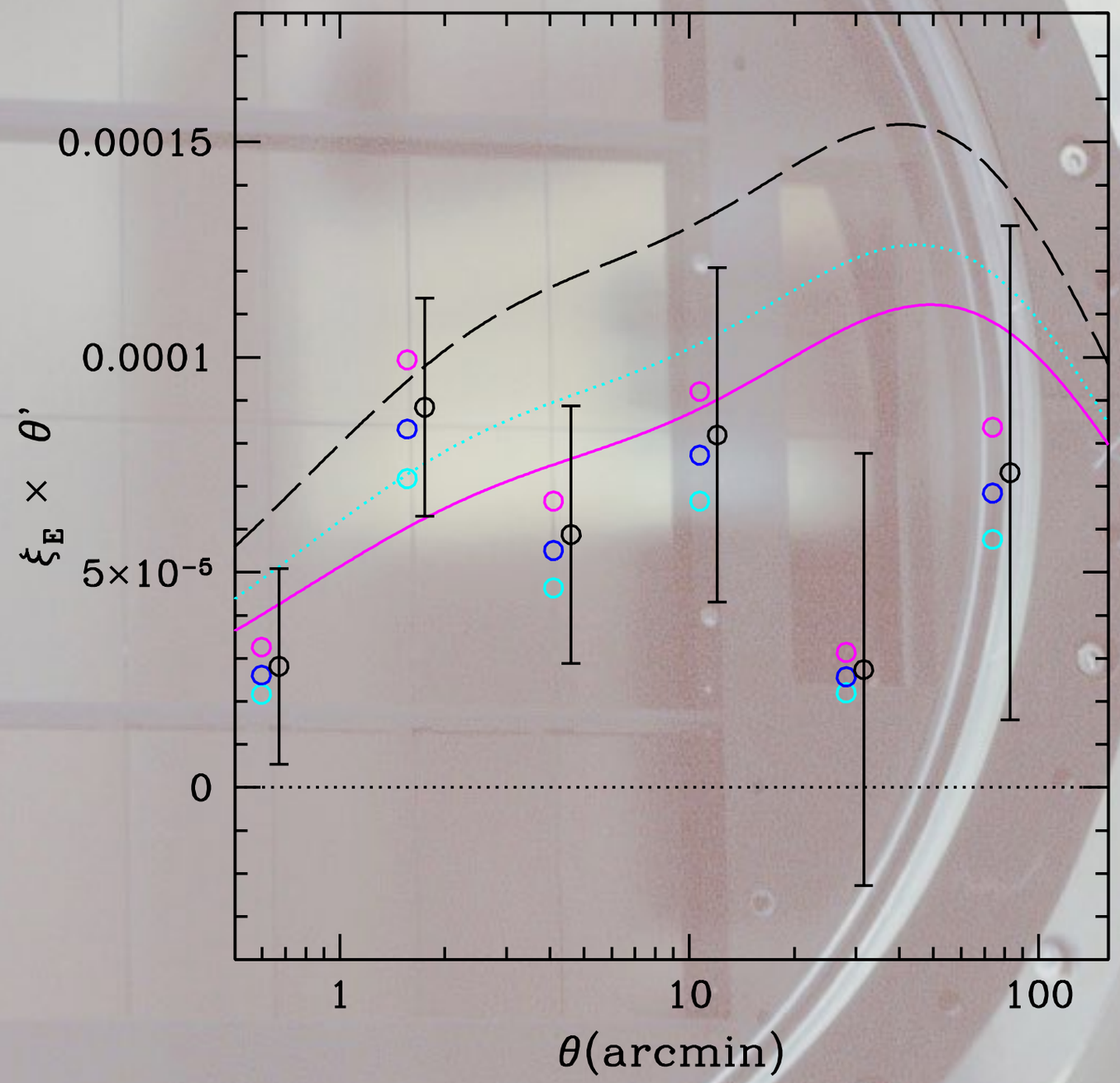

After c correction

- No sign of B mode, as expected when no systematic residuals remain

# Yes! We have no bananas

- E-mode 2pt correlation function, compared to Planck-EE, Planck-TT, CFHTLenS

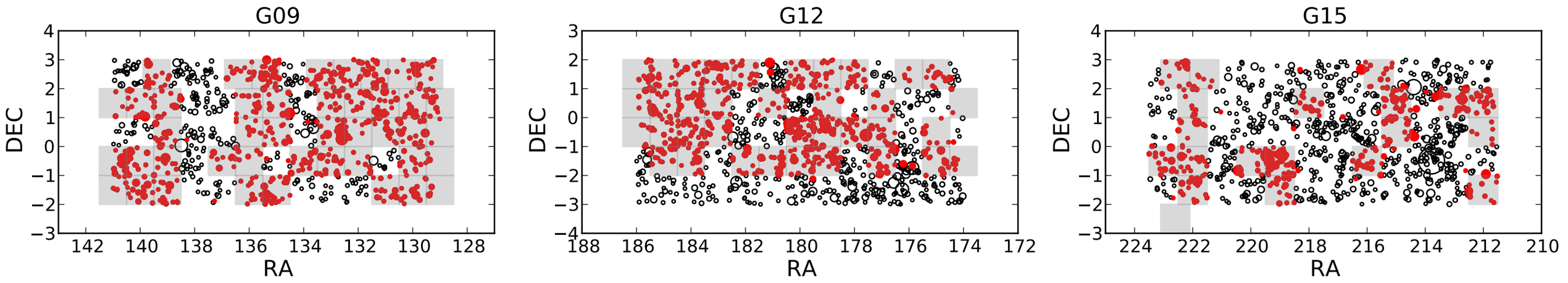
- Four different blindings shown (black o = data)

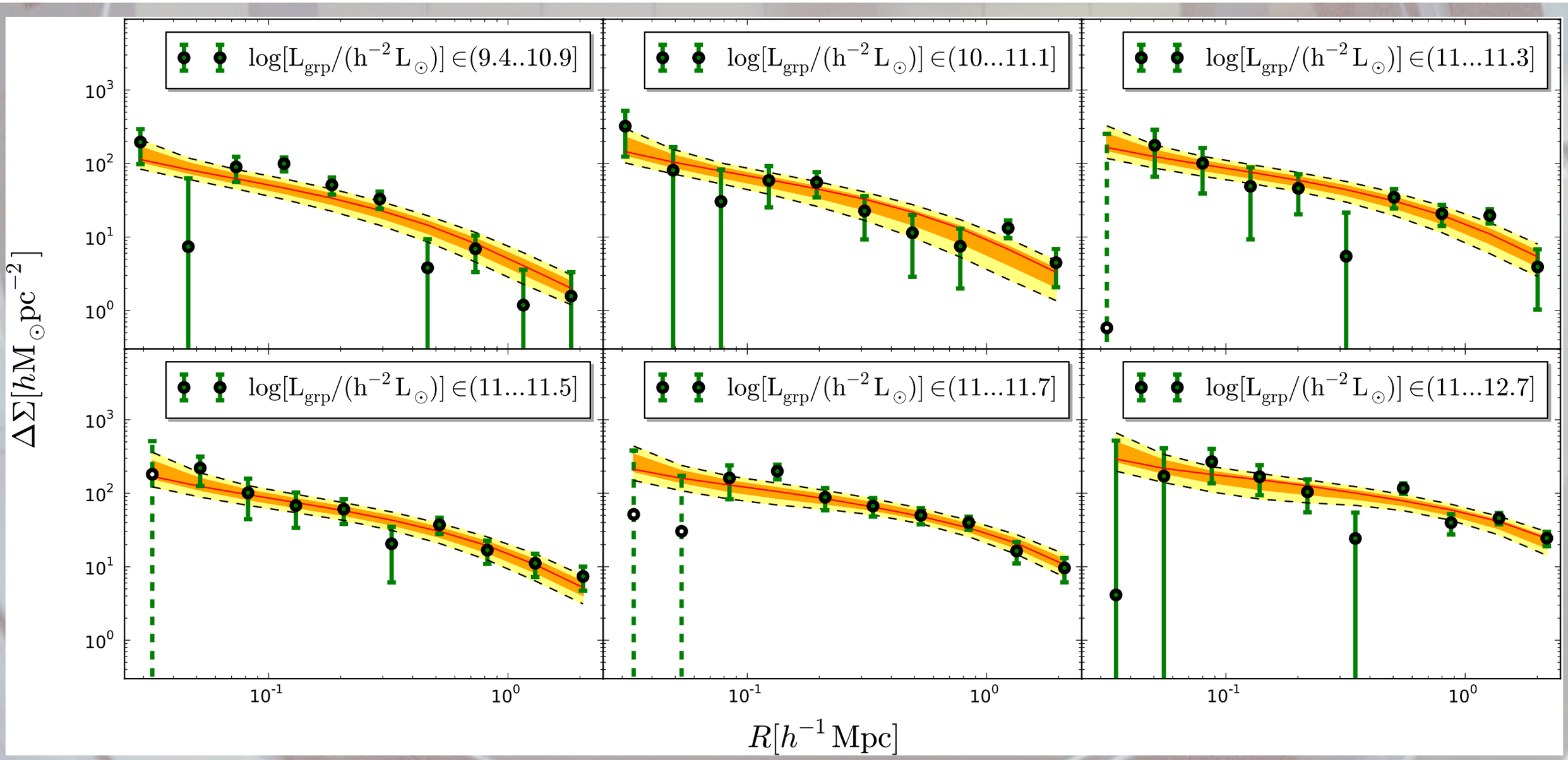


# First science!

- Focussed on synergy with GAMA survey
  - 4 patches of 60 sq.deg., >95% complete redshifts to r=19.8
- Group catalogue (Robotham et al 2011), $z_m$~0.2
- Weigh groups and galaxies with lensing

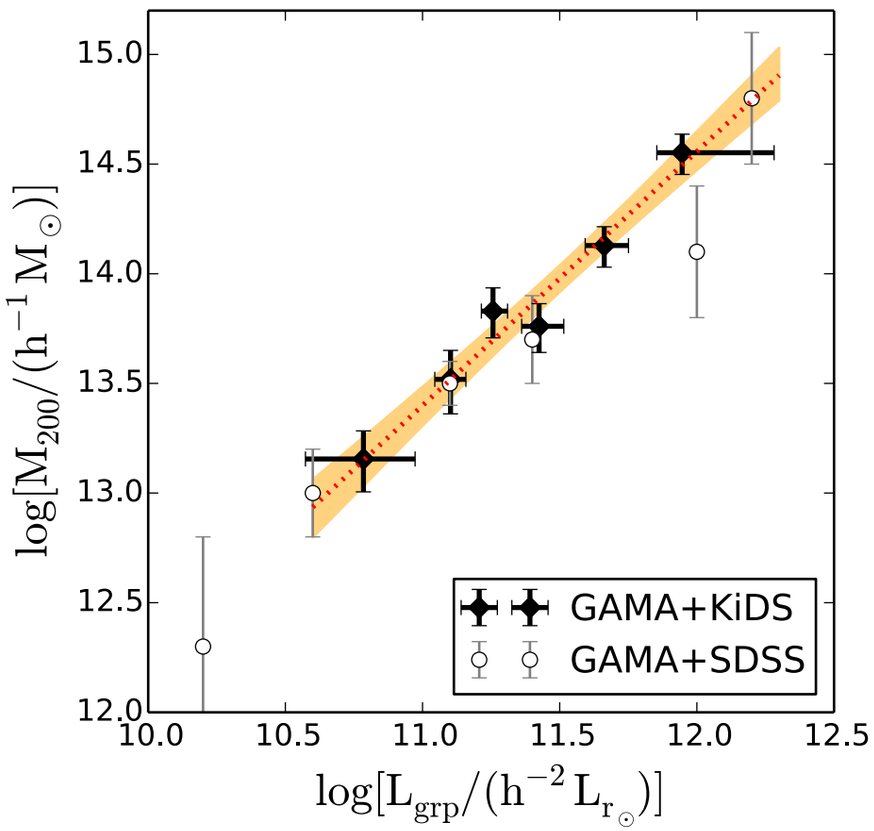
# GAMA groups (Viola, Cacciato, Brouwer, KK et al 2015)

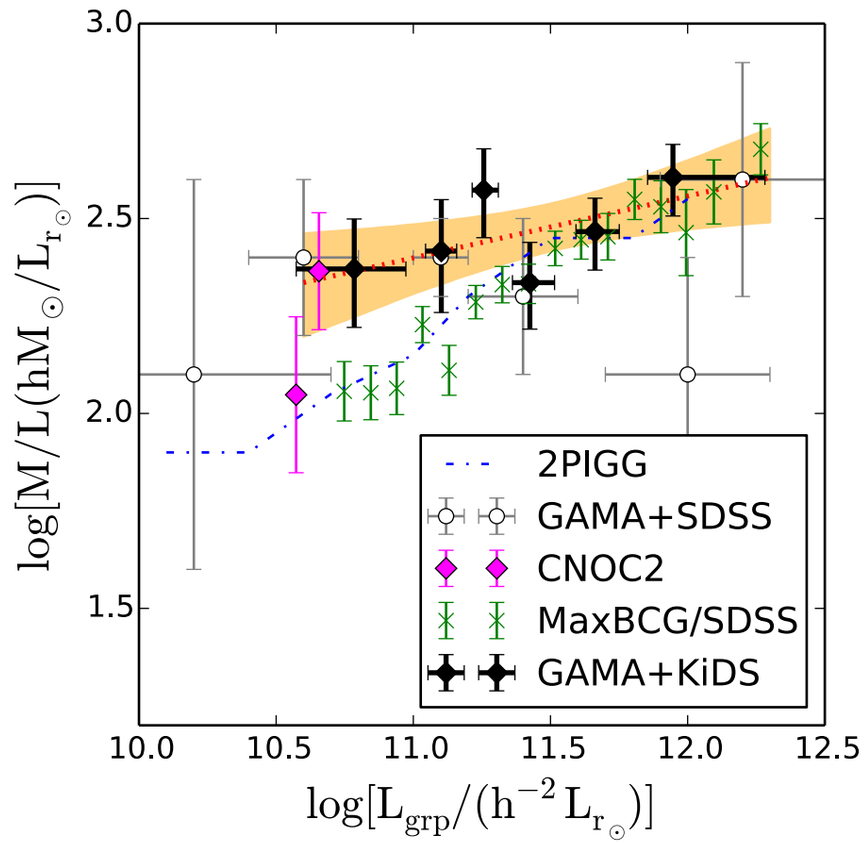


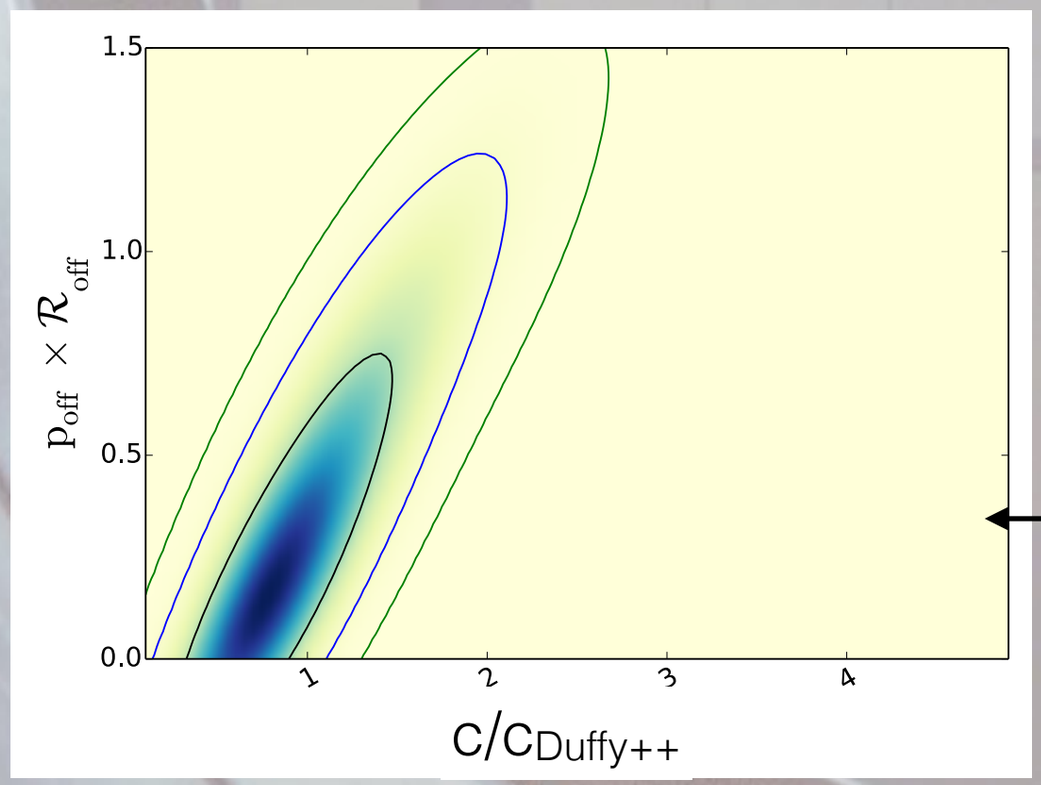
# GAMA groups (Viola, Cacciato, Brouwer, KK et al 2015)

Mass-Luminosity



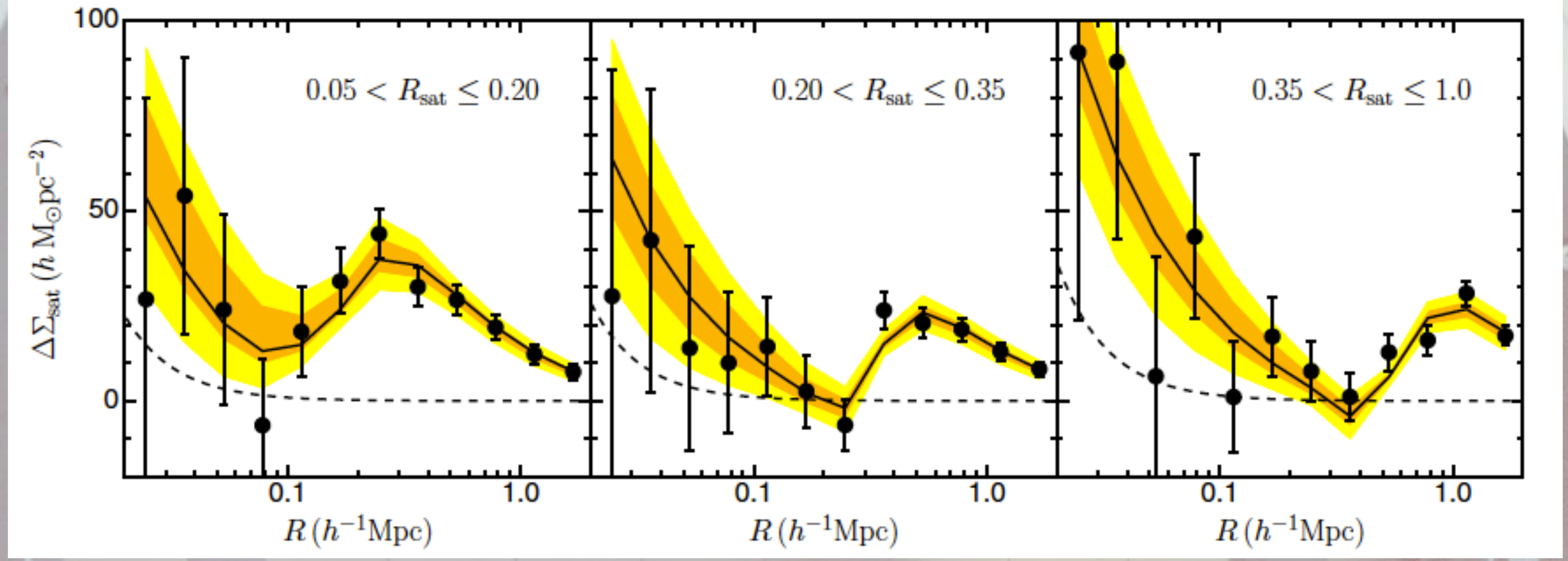

11-parameter halo model fit
$M_{1\text{-}6}$, σ(L|M), halo conc, $A_{star}$,
Prob(offset), σ(offset)
Track Poisson covariance



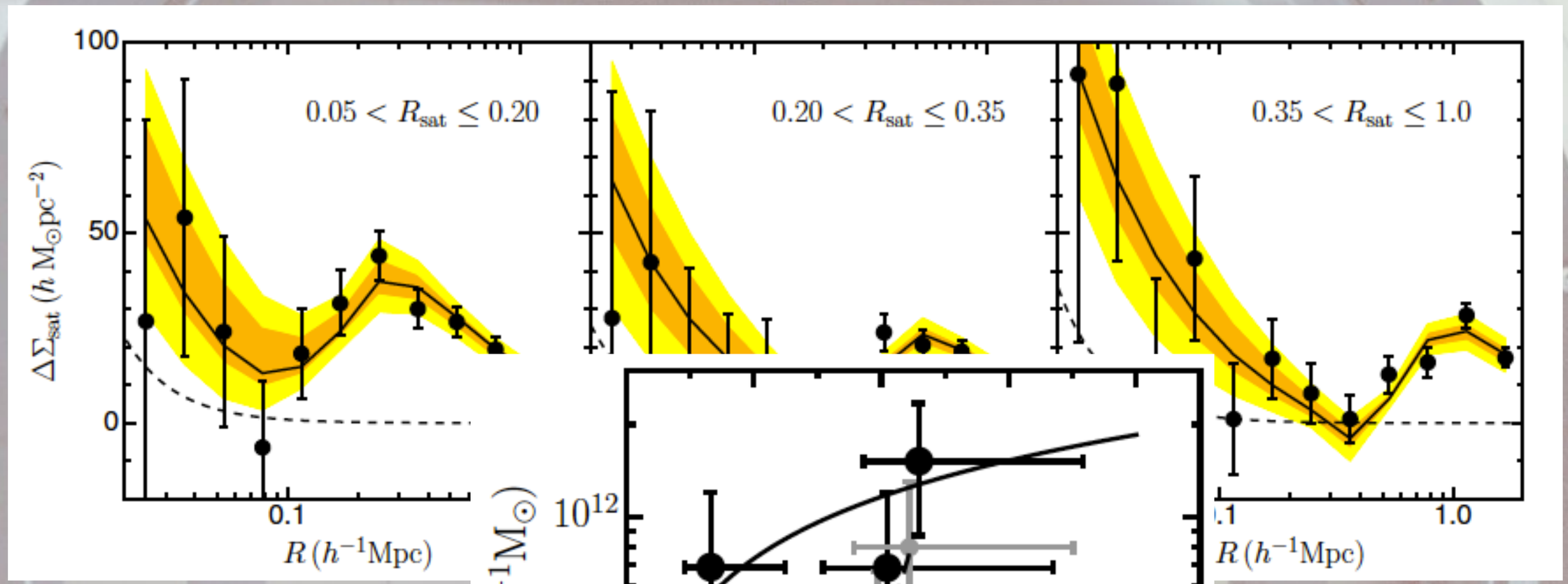

Large SNR improvement over SDSS (Han++14), despite 60% of area, more complex model

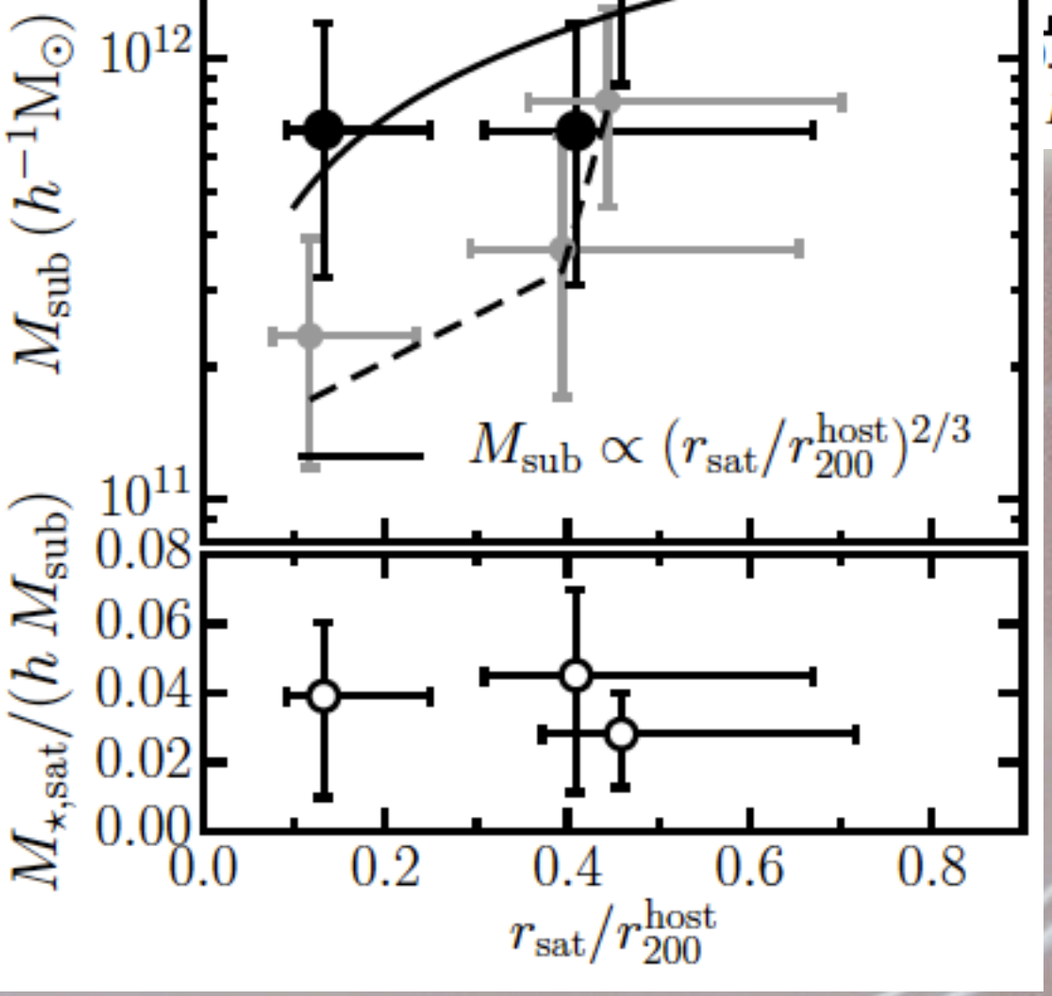
Miscentering-concentration

# Satellites in groups (Sifón, Cacciato, Hoekstra, et al 2015)




# Satellites in groups (Sifón, Cacciato, Hoekstra, et al 2015)




# Other science

- Galaxy morphology studies (2m deeper than SDSS)
- Milky Way halo (star /gal separation to faint levels)
- Cluster searches
- z~6 QSO search (with VIKING)
- Asteroids (dithered observations)
- …

# Follow-up / external data sets

- **GAMA** fantastic resource

Edo van Uitert

- **2dfLenS** @ AAT - 100k redshifts in KiDS - BOSS footprint

Chris Blake

  - (ATLAS photometry for target selection)

Dominik Klaes

- **WAVES** @ 4MOST

  - (GAMA-like survey over KiDS-S footprint)

Simon Driver, Joe Liske

- **ACTpol** overlap with KiDS-N

# Summary

- KiDS delivering lensing science (1507.00735, 37, 38, 42)
  - lensing/photo-z catalogues available kids.strw.leidenuniv.nl
- depth ~ DES; seeing 0.7”; PSF benign; *ugri* (+ ZYJHK)
- systematic/null tests check out
- *lens*fit/THELI shapes,  BPZ/GAaP photometric redshifts
- 500 sq.deg. observed; 1500 target
- First results `weighing’ GAMA structures
- Ready for cosmology!

KiDS

ESO

# Thanks.