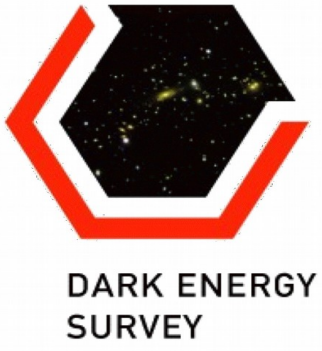


The Dark Energy Survey: Status and new lensing results

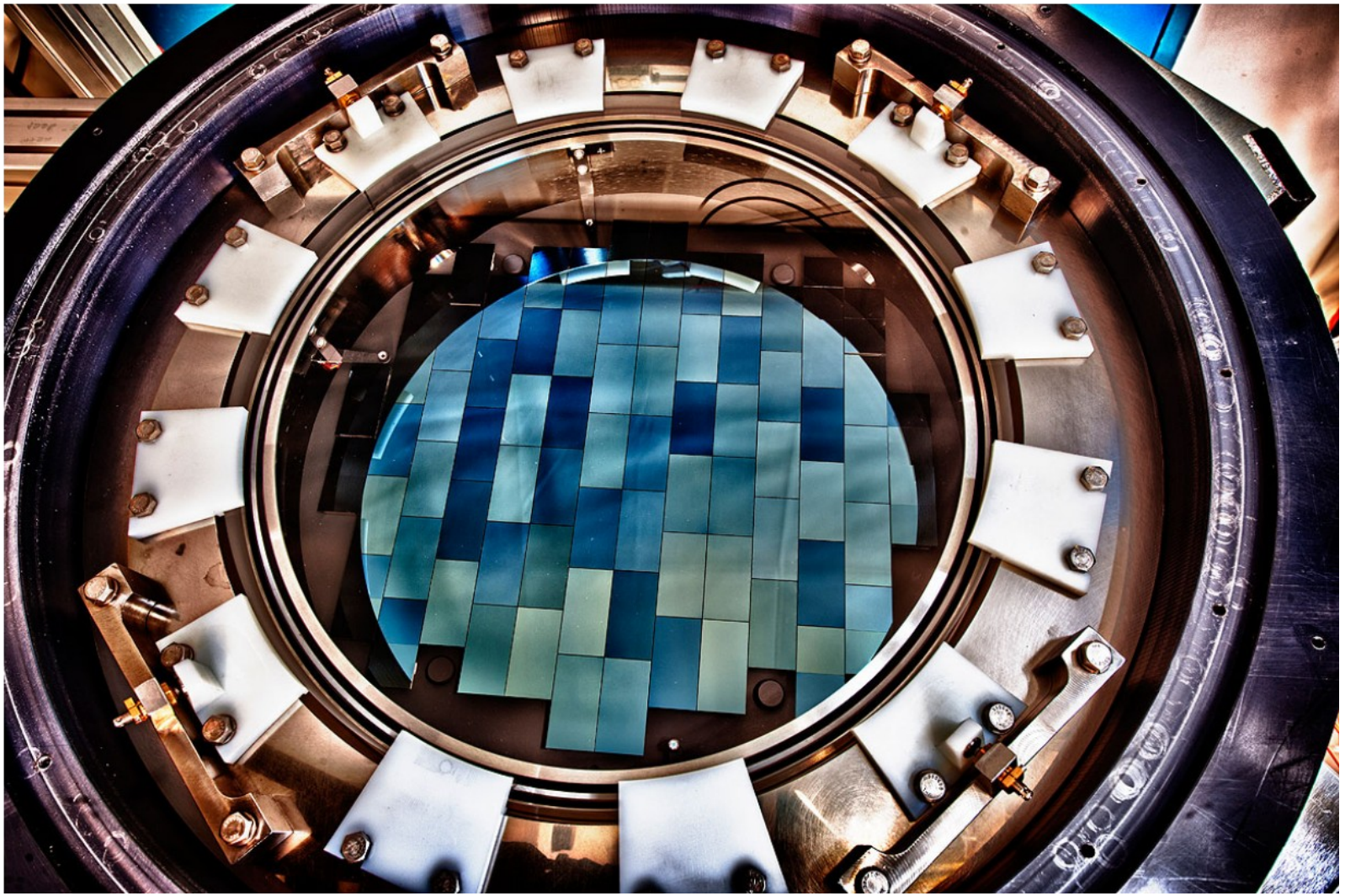
Daniel Gruen, USM/MPE

with the DES weak lensing working group

Contents

- **Introduction**
  - DES
  - Weak Lensing
- **DES results**
  - Overview of 0th year results
  - Lensing results
  - **Lensing by galaxy troughs**
- **Summary and Outlook**

The Dark Energy Camera



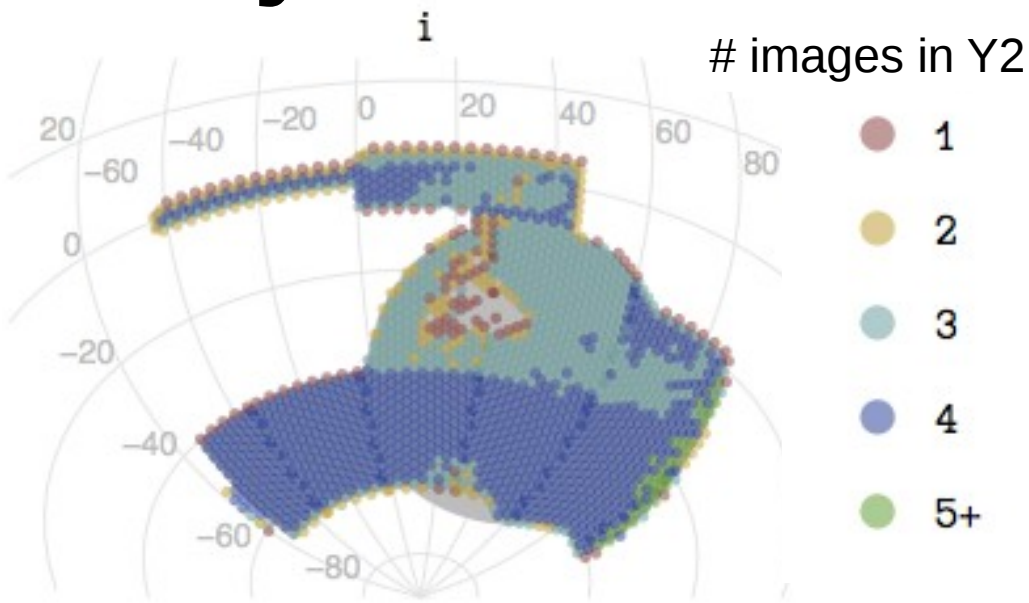
62 science CCDs, 3 sq. deg FOV,
prime focus of Blanco 4m telescope

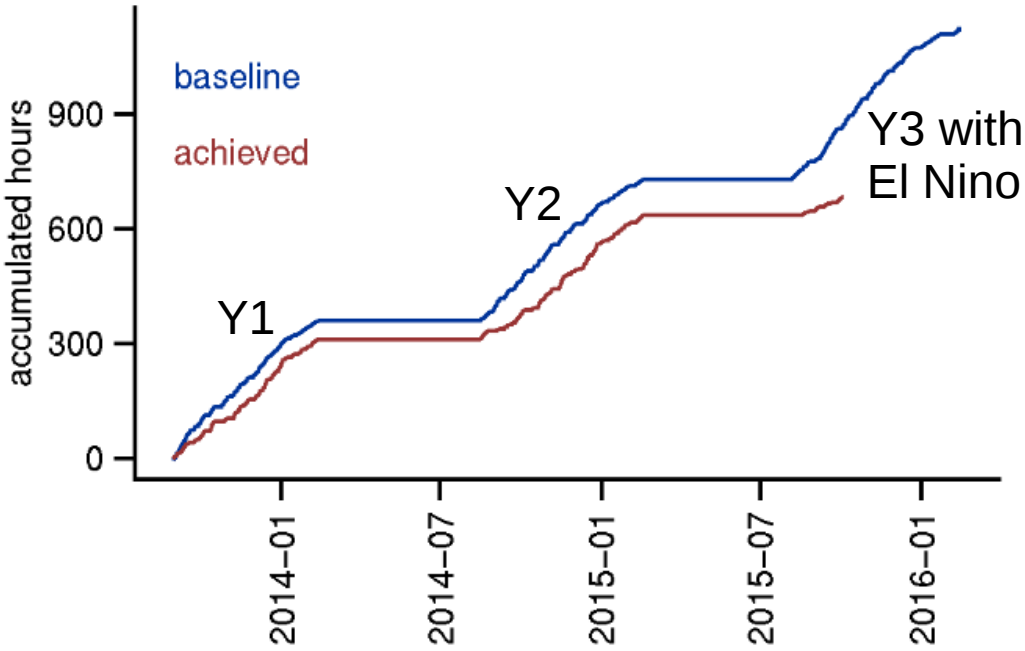
Source: darkenergysurvey.org

The Dark Energy Survey

- 5000 sq. deg. survey in grizY, 10 exposures, 5 years, ~300 scientists, 28 institutions
- Primary goal:

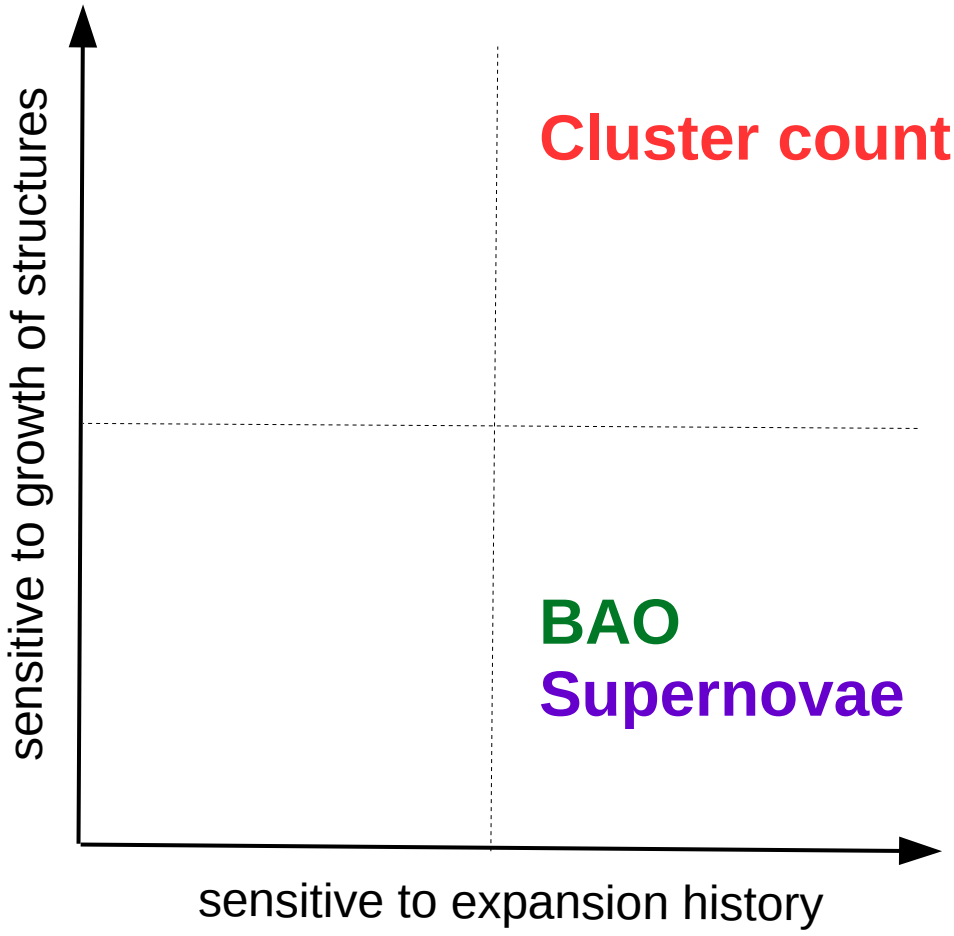
  dark energy equation of state
- Status:
  - SV (150 sq. deg, full depth): data understood, most science done
  - Y1 (2000 sq. deg, 40% depth): data processed, science starting
  - Y2 (5000 sq. deg, 30% depth): data taken, being processed
  - Y3 (5000 sq. deg, goal 60% depth): observations running



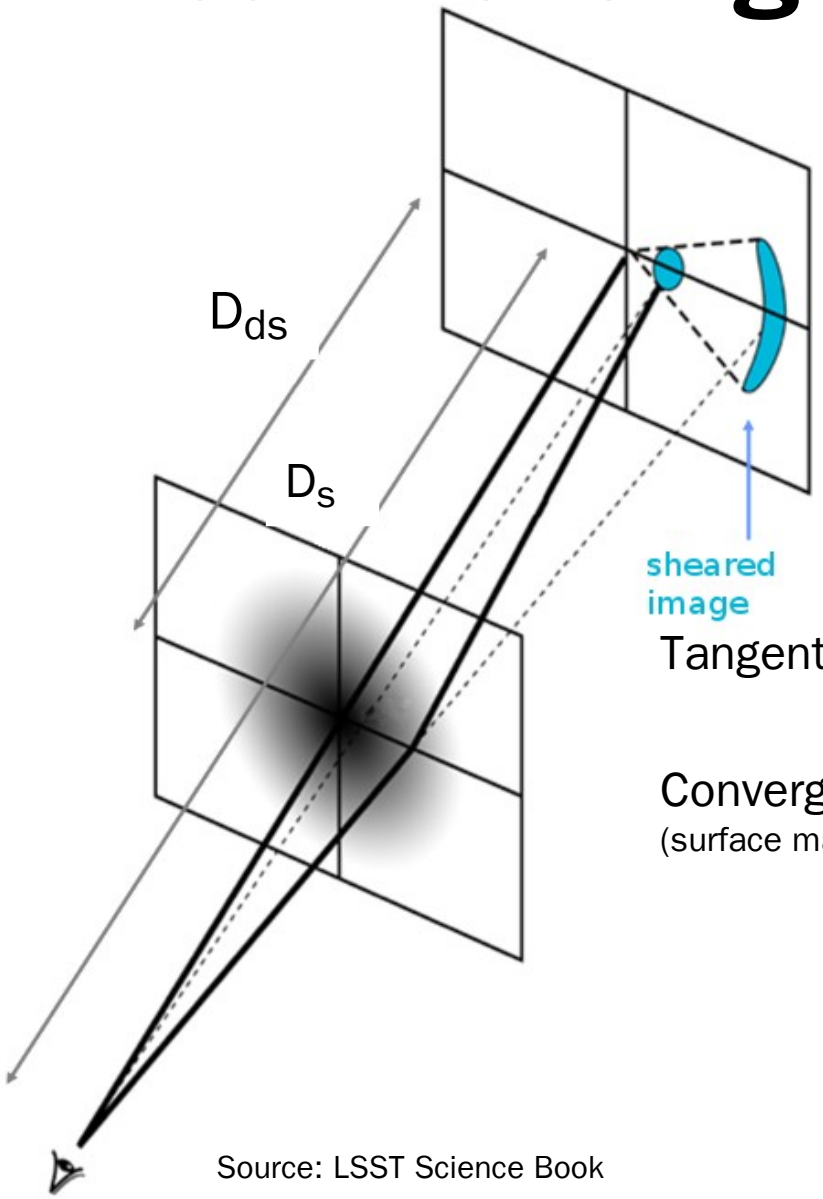


How to learn about Dark Energy by taking pictures of the sky

- Dark energy influences
  - expansion and
  - growth of structures
- DES primary probes:
  - Count of clusters of galaxies
  - Galaxy autocorrelation
  - Supernovae
  - Weak lensing



Weak Lensing



Source: LSST Science Book

- Matter (also dark) bends space-time (and therefore light rays)
- Weak effect: % distortion
- Tangential distortion ~ overdensity

Tangential shear $\gamma_t(\theta) = \langle\kappa(\theta')\rangle_{\theta'<\theta} - \kappa(\theta)$

Convergence (surface mass density) $\kappa = \Sigma / \left[\frac{c^2}{4\pi G}\frac{D_s}{D_d D_{ds}}\right]$

- Measure mass and growth of structure w/o 'dirty' astrophysics!

How to learn about Dark Energy by taking pictures of the sky

- Dark energy influences
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  - growth of structures
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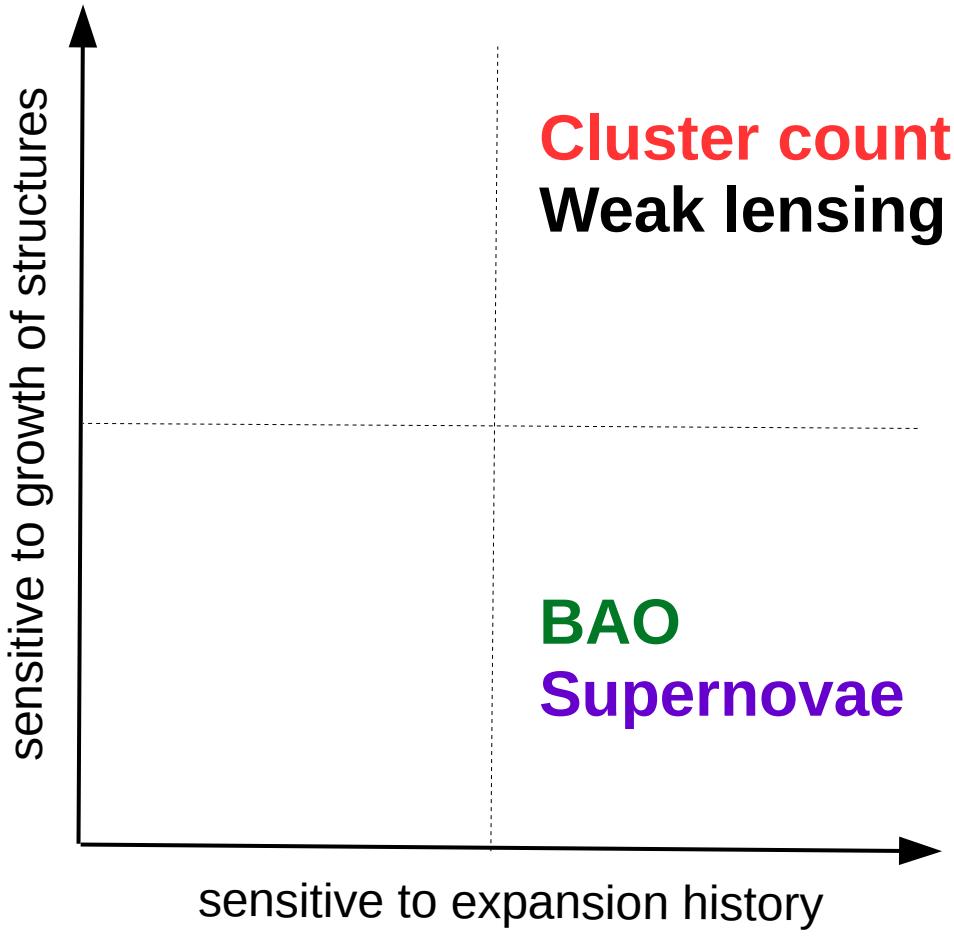
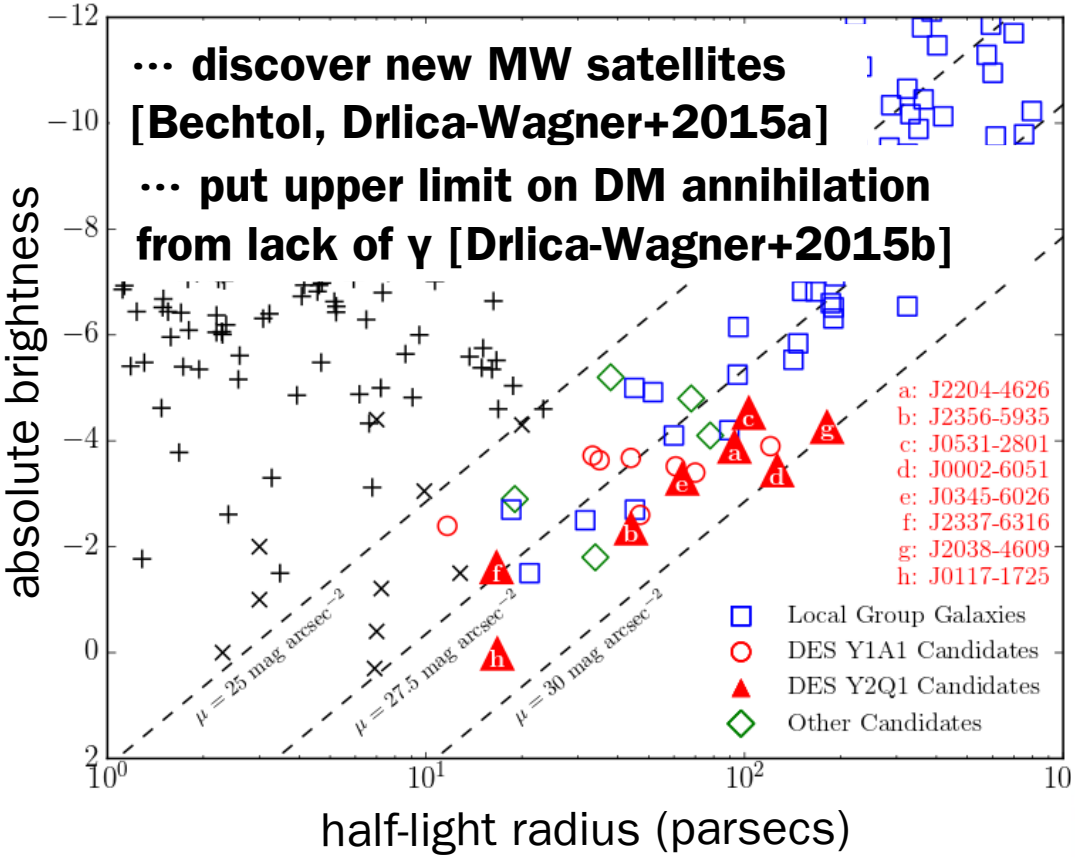
  - Galaxy autocorrelation
  - Supernovae
  - Weak lensing



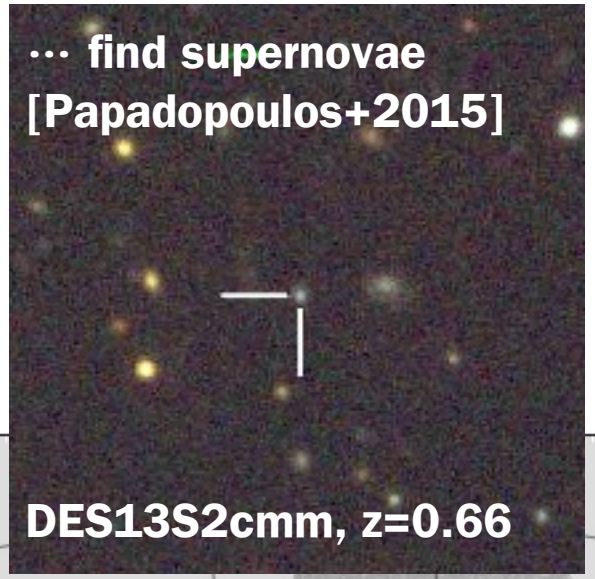
DES early science can...

(a selection apart from lensing...)

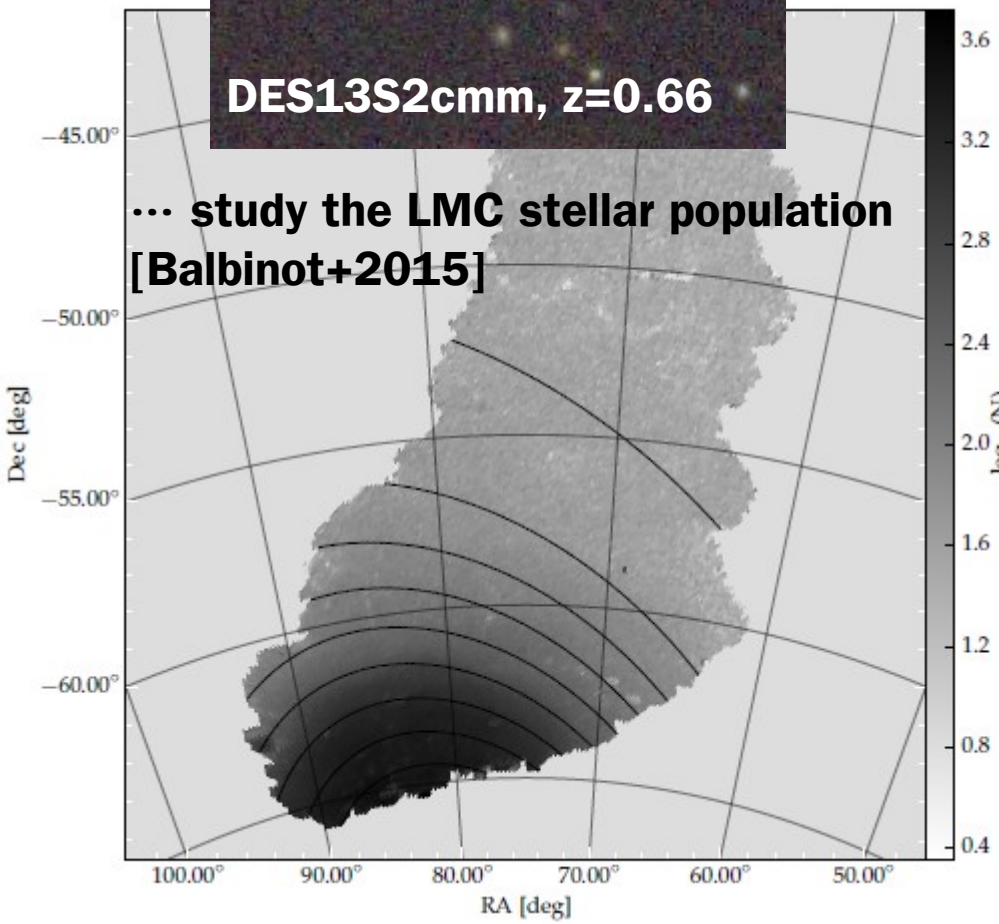


··· discover new MW satellites [Bechtol, Drlica-Wagner+2015a]

··· put upper limit on DM annihilation from lack of γ [Drlica-Wagner+2015b]



··· find supernovae [Papadopoulos+2015]



··· study the LMC stellar population [Balbinot+2015]

··· discover quasars at high redshift (z>6) [Reed+2015]

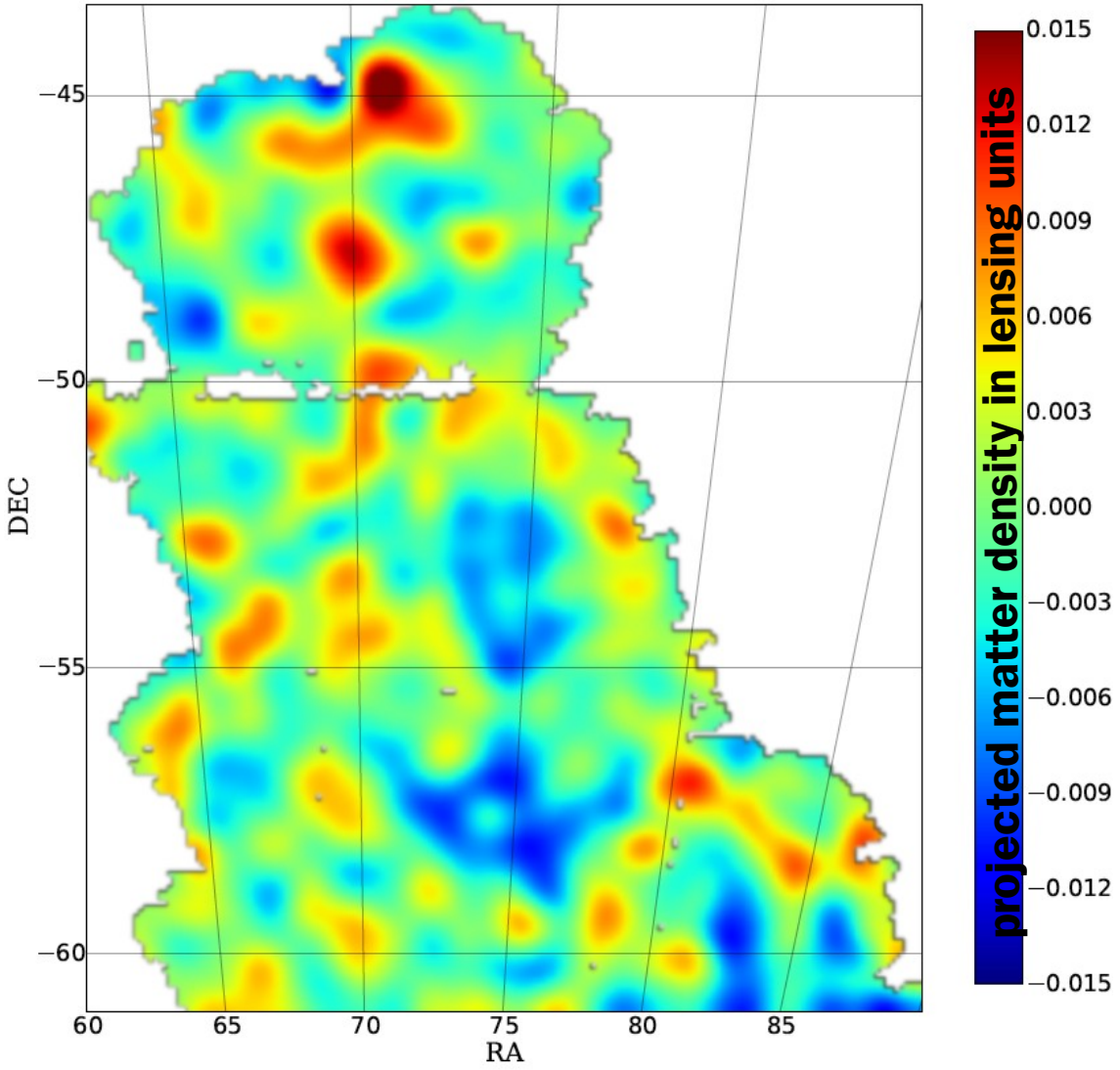
··· find clusters of galaxies out to z>1 [Rozo, Rykoff+ in prep.]

··· cross-calibrate cluster masses [Saro+2015]

··· study large-scale distribution of galaxies [Crocce+2015]

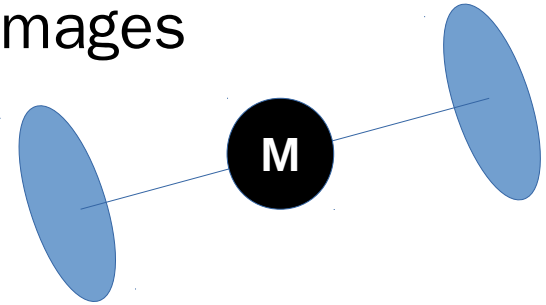
DES early lensing results: mass mapping

- From the measured shear of background galaxies, a (projected) map of foreground matter (incl. Dark) can be made
- DES SV has made the largest such map to date covering 139 sq. deg (Vikram+2015, Chang+2015)



DES early lensing results: cosmic shear

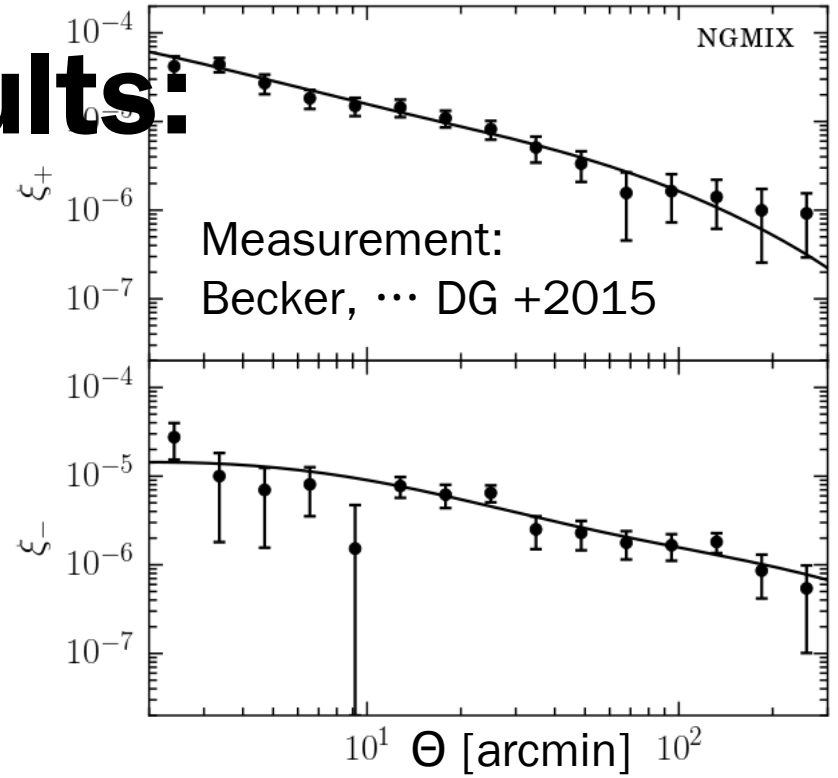
- Structures along line of sight coherently align background galaxy images

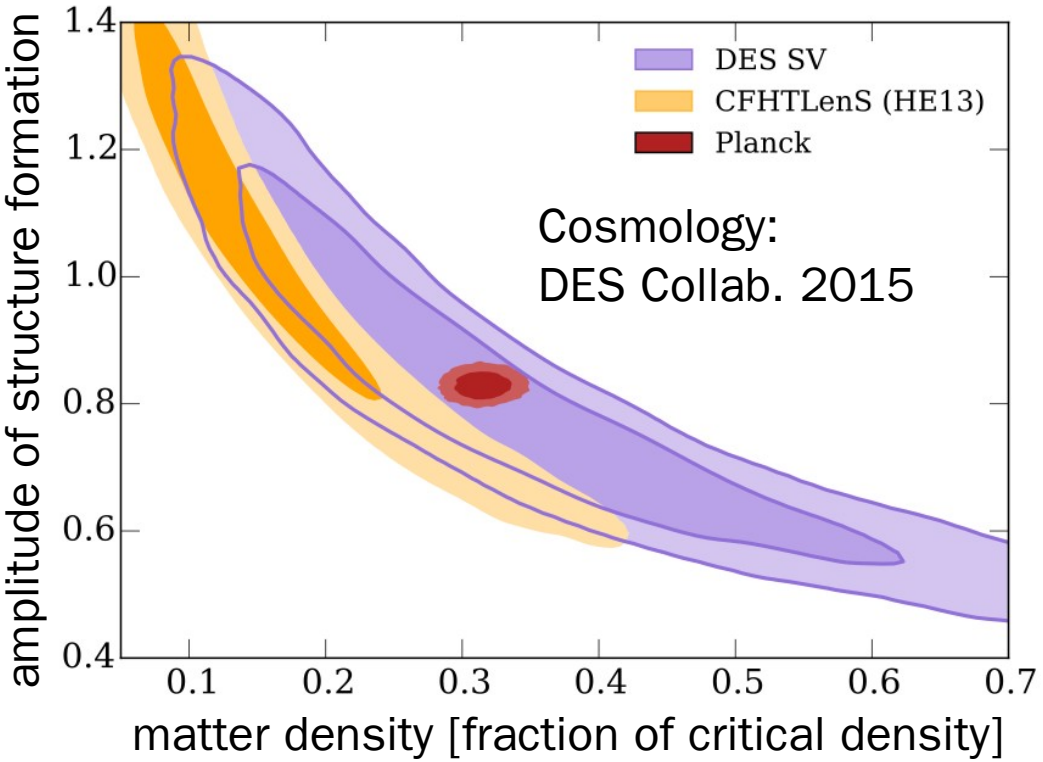


- Shear two-point correlation

$$\xi_{\pm}(\theta) = \langle \gamma_{\rm t}\gamma_{\rm t} \rangle (\theta) \pm \langle \gamma_{\times}\gamma_{\times} \rangle (\theta)$$

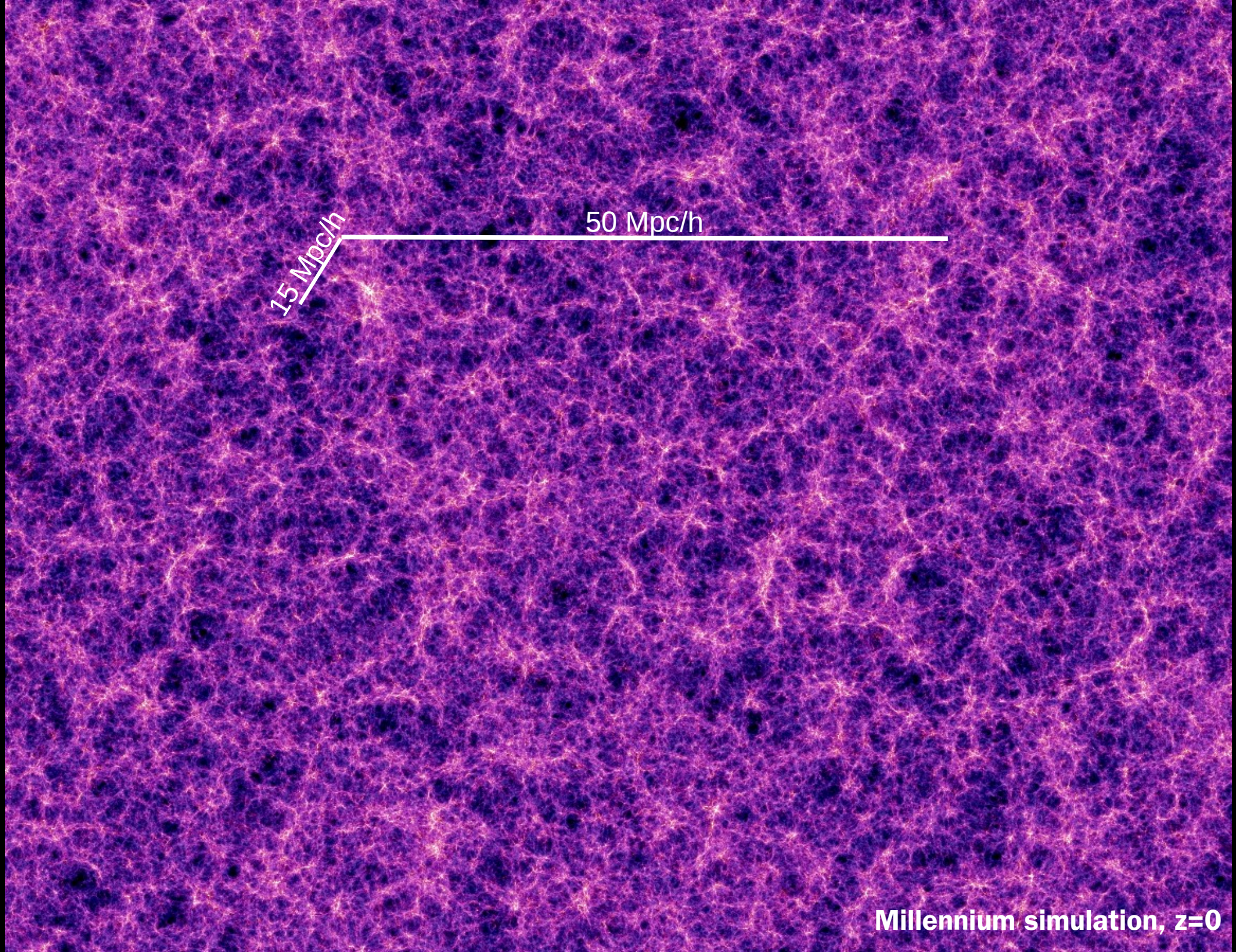
- Cosmology dependence: growth of structure and geometry



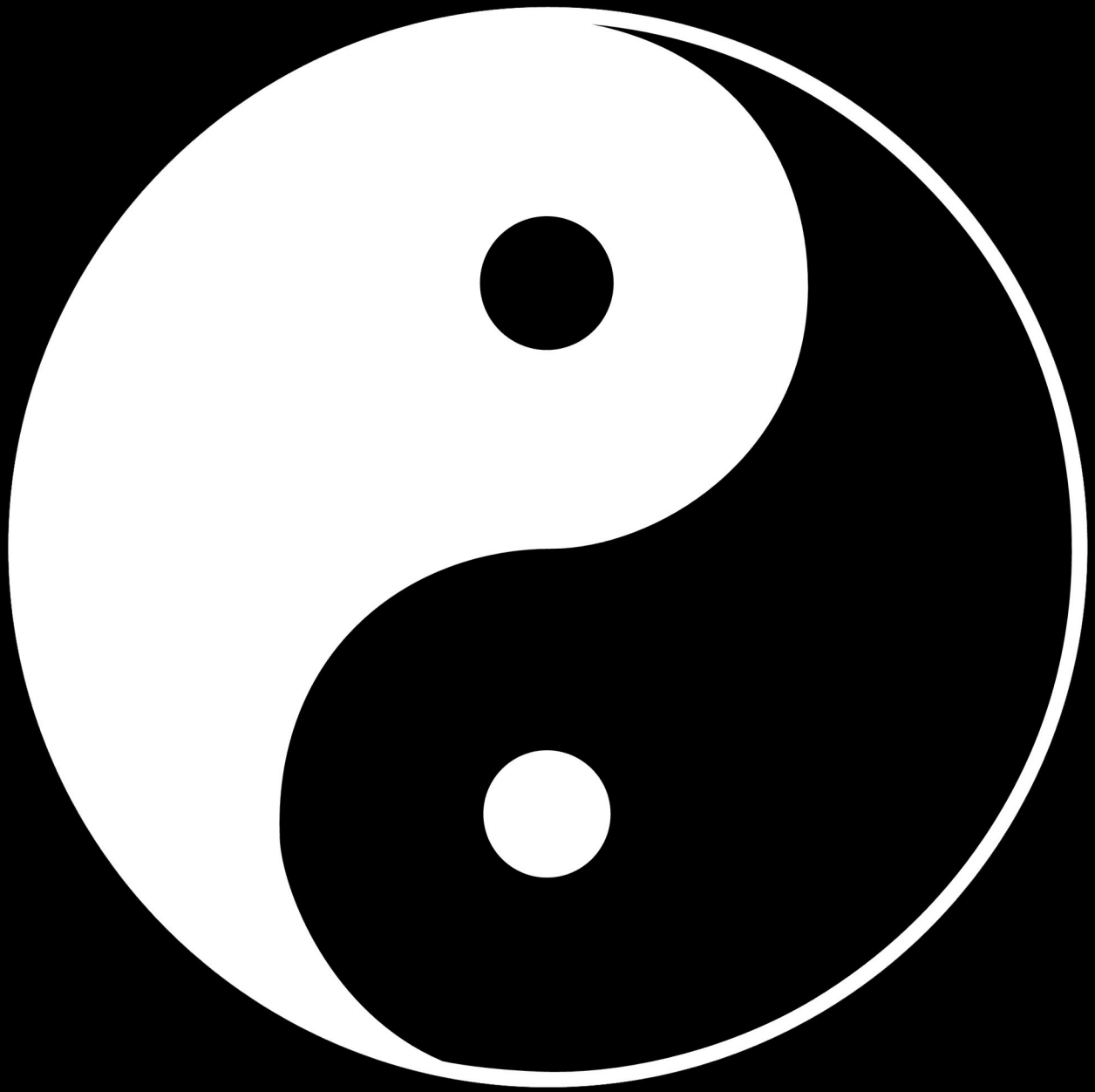


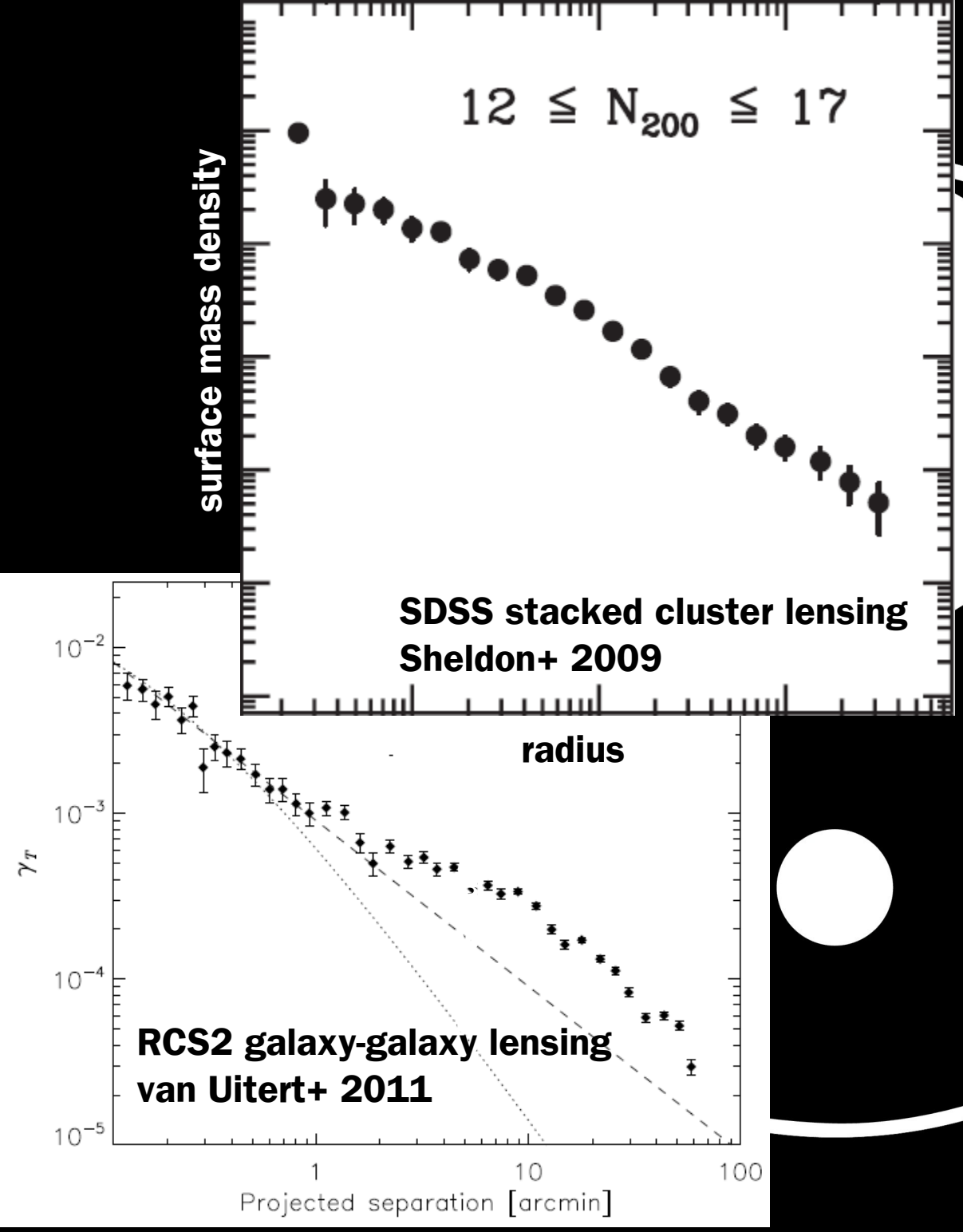
DES early lensing results: Weak lensing by galaxy troughs

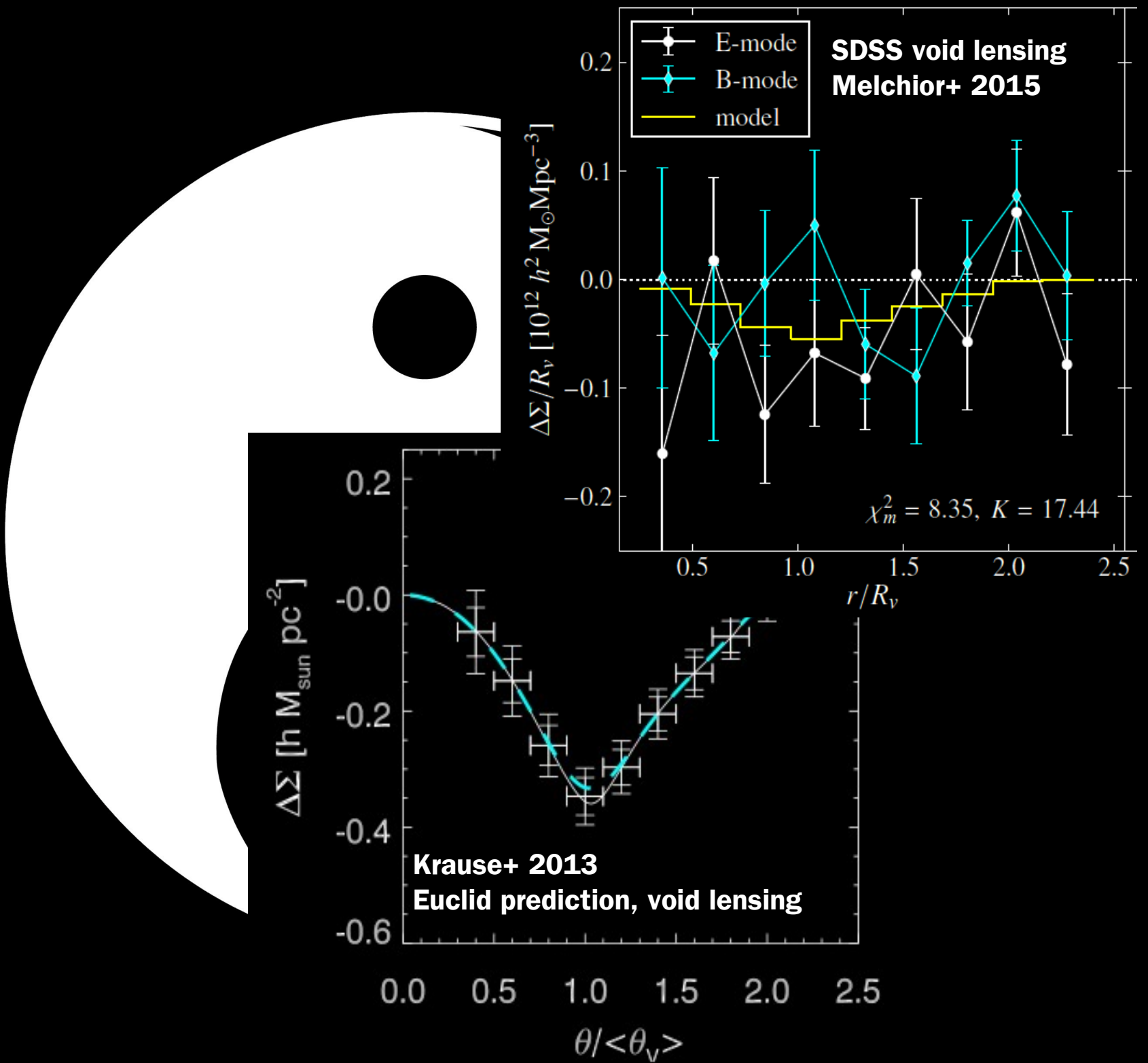
DG, Oliver Friedrich, Bhuvnesh Jain, Annalisa Mana, Eduardo Rozo,
Eli Rykoff, Stella Seitz, Vinu Vikram++, arXiv:1507.05090

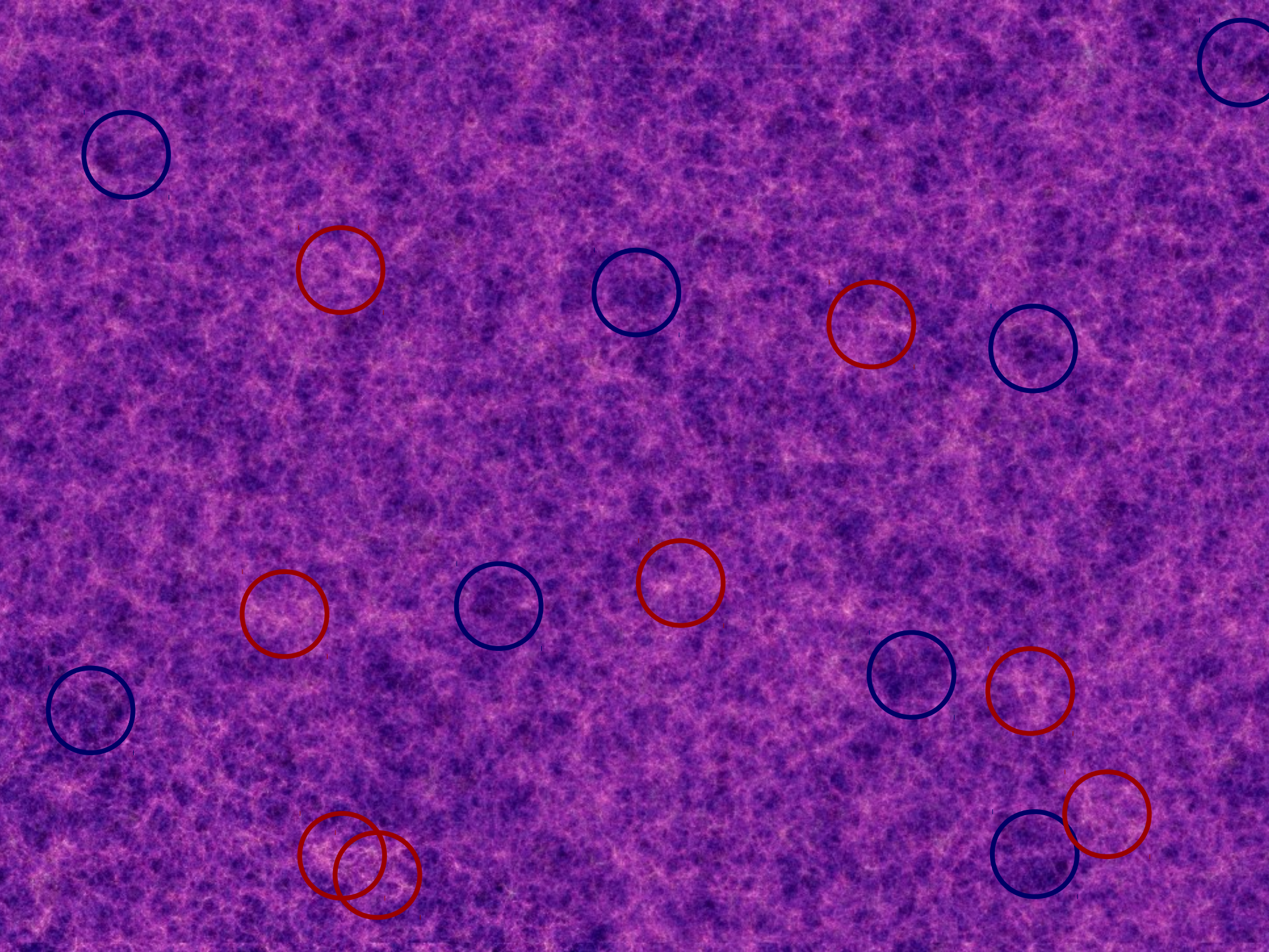

50 Mpc/h
15 Mpc/h
Millennium simulation, z=0


Millennium simulation, z=0, thick slice




$12 \leqq N_{200} \leqq 17$
surface mass density
SDSS stacked cluster lensing
Sheldon+ 2009
radius
10^{-2}
10^{-3}
10^{-4}
10^{-5}
γ_T
RCS2 galaxy-galaxy lensing
van Uitert+ 2011
1
10
100
Projected separation [arcmin]


E-mode
B-mode
model
SDSS void lensing
Melchior+ 2015
$\Delta\Sigma/R_v$ [10^{12} h^2 $M_\odot$Mpc^{-3}]
$\chi^2_m = 8.35,\ K = 17.44$
r/R_v
$\Delta\Sigma$ [h M_{sun} pc^{-2}]
Krause+ 2013
Euclid prediction, void lensing
$\theta/<\theta_v>$



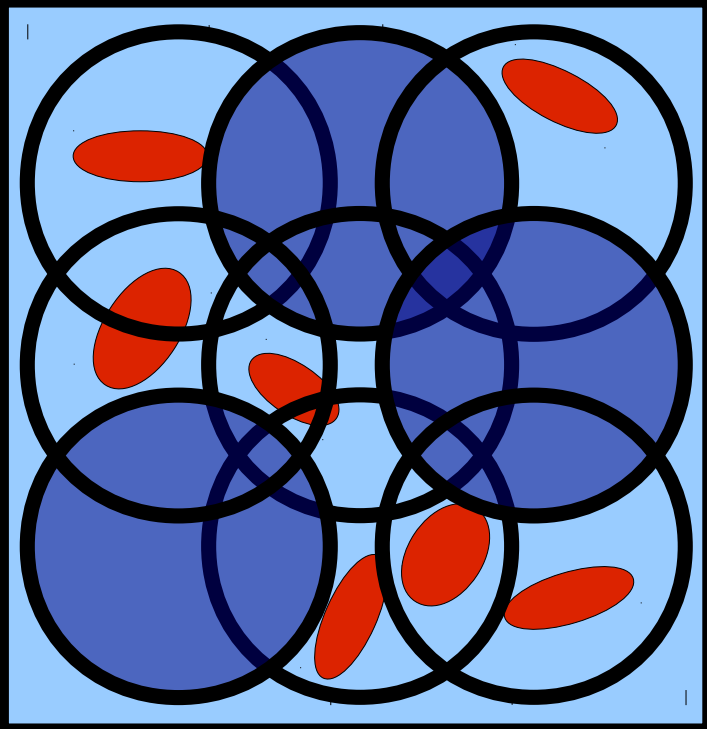
Galaxy troughs

- Trough: (long) cylinder* with galaxy count below some threshold
- Goals: statistics of matter field around underdense lines of sight

\+ easy to find even with poor z coordinate, high S/N of lensing due to suppression of random structures

\+ new way of probing structure and gravity

– not actual individual physical entities

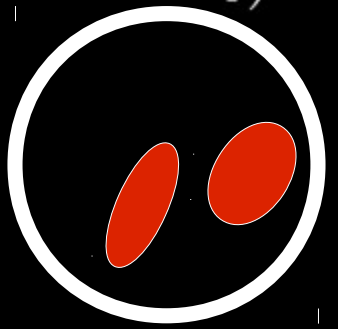


Theory: galaxy count to lensing κ

Galaxy count N in trough

$$p(N|\delta_T) = \frac{1}{N!}\left(\bar{N}\left[1+b\delta_T\right]\right)^N \exp\left(-\bar{N}\left[1+b\delta_T\right]\right)$$

$$\langle\delta_T|N\rangle = \int_{-1}^{\infty} \mathrm{d}\delta_T \; \delta_T \; \frac{p(N|\delta_T)\, p(\delta_T)}{P(N)}$$



Matter contrast δ_T in trough

$$C_{\kappa,\Sigma}(\ell) = \int_0^{\infty} \mathrm{d}w \; \frac{q_1(w)\, q_2(w)}{w^2} \; P_\delta\left(\frac{\ell}{w}, w\right)$$

Convergence κ / shear g_t around trough

Oliver Friedrich

Theory: prediction

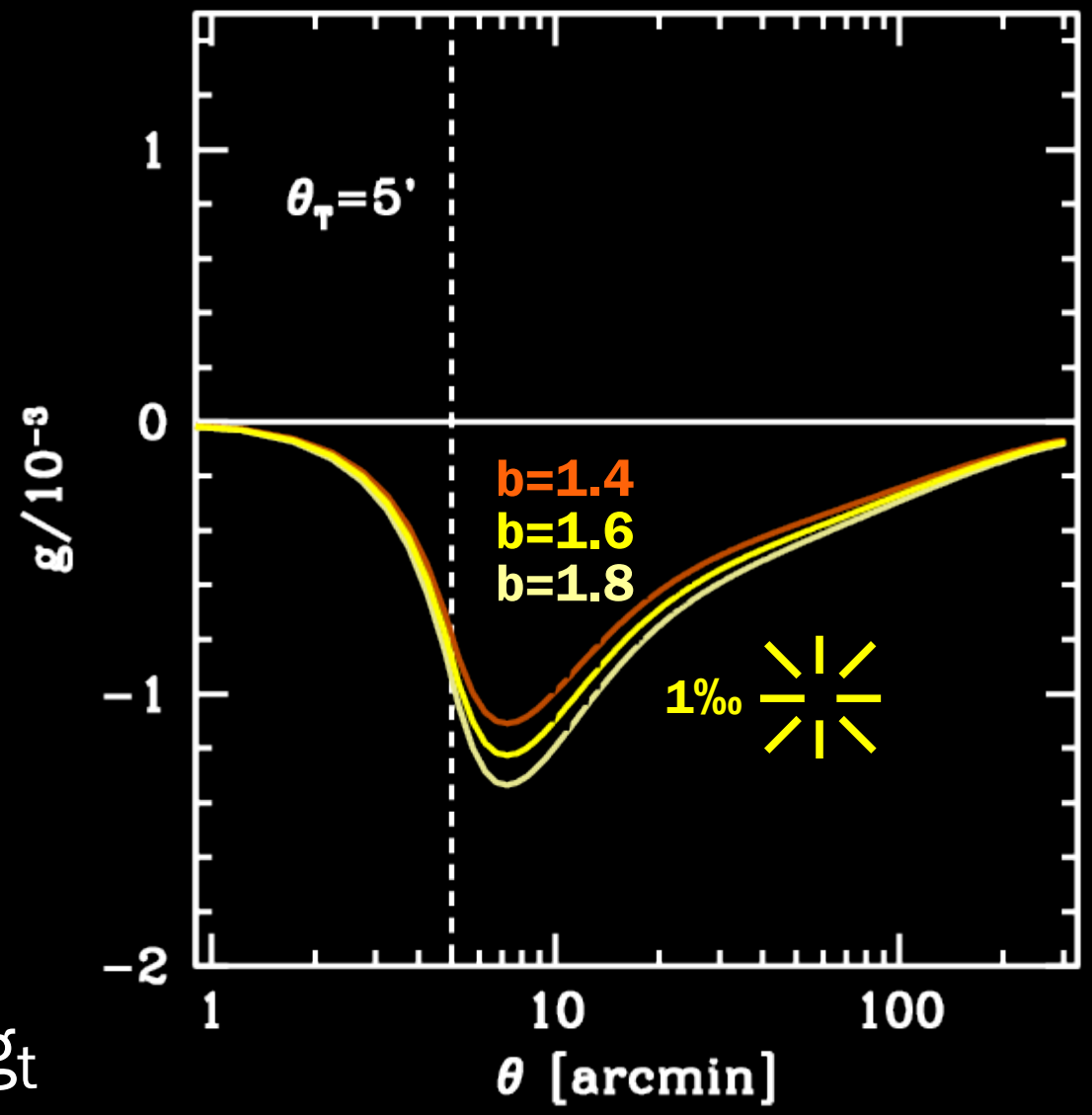
Galaxy count N

↓

Matter contrast δ_T

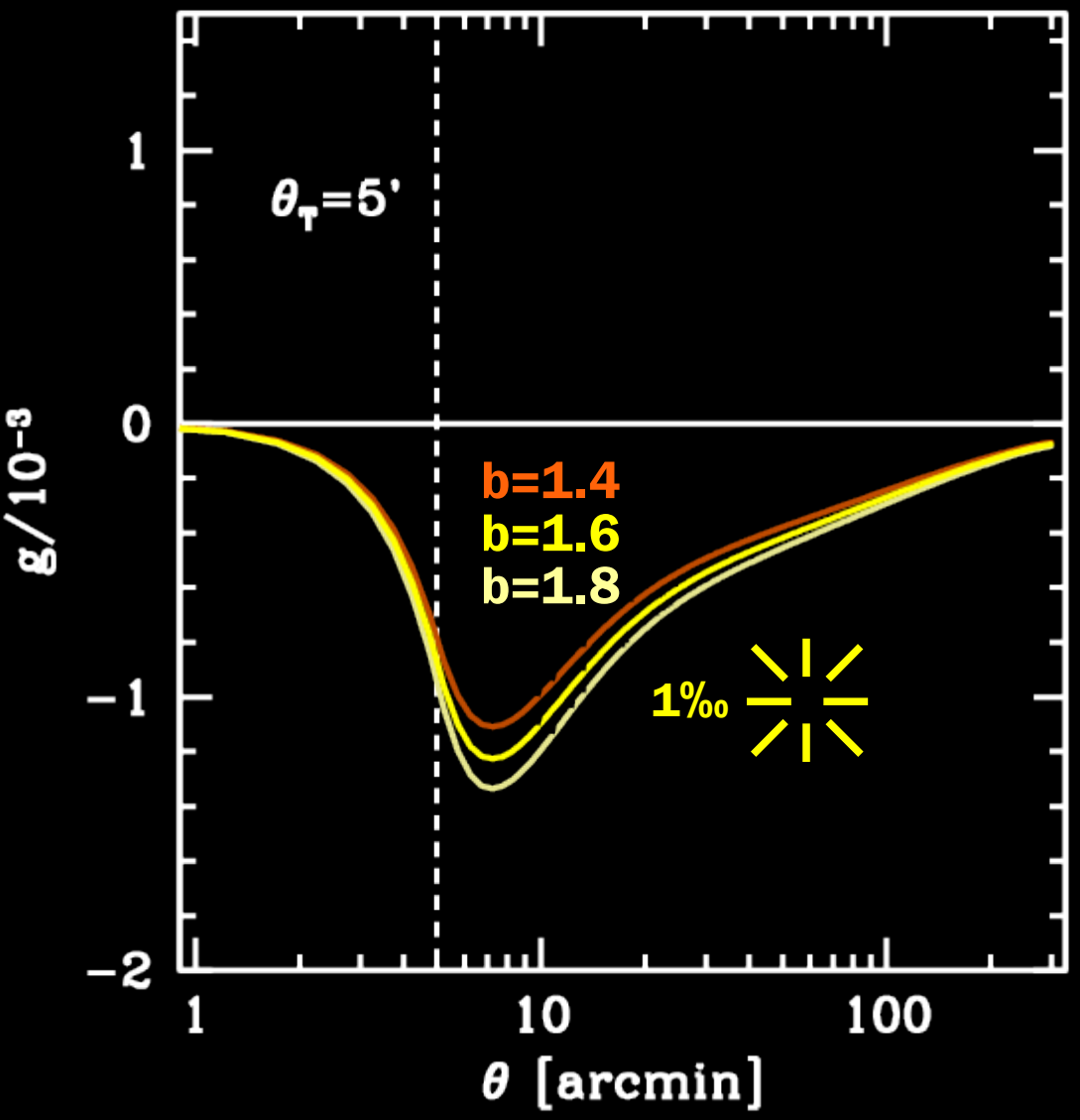
↓

Convergence κ / shear g_t



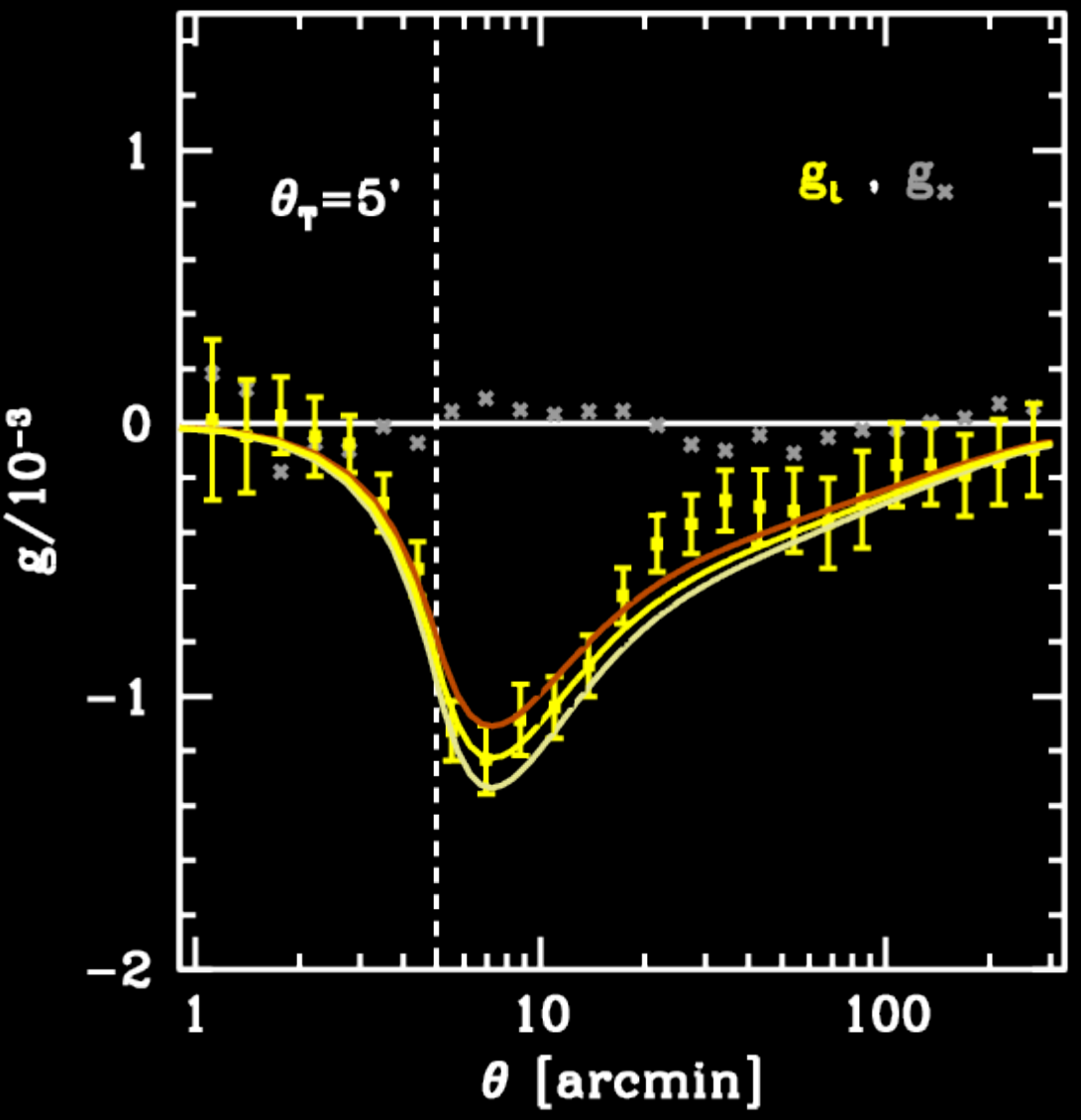
Measurement

- DES Science Verification: 139 sq. deg, grizY, full DES depth
- tracers: Rykoff/Rozo redMaGiC galaxies, 0.2<z<0.5, L>0.5L*, 1/[1000 Mpc^3]
- troughs = lower 20th percentile in galaxy count
- sources:~2x10^6 at z>0.6

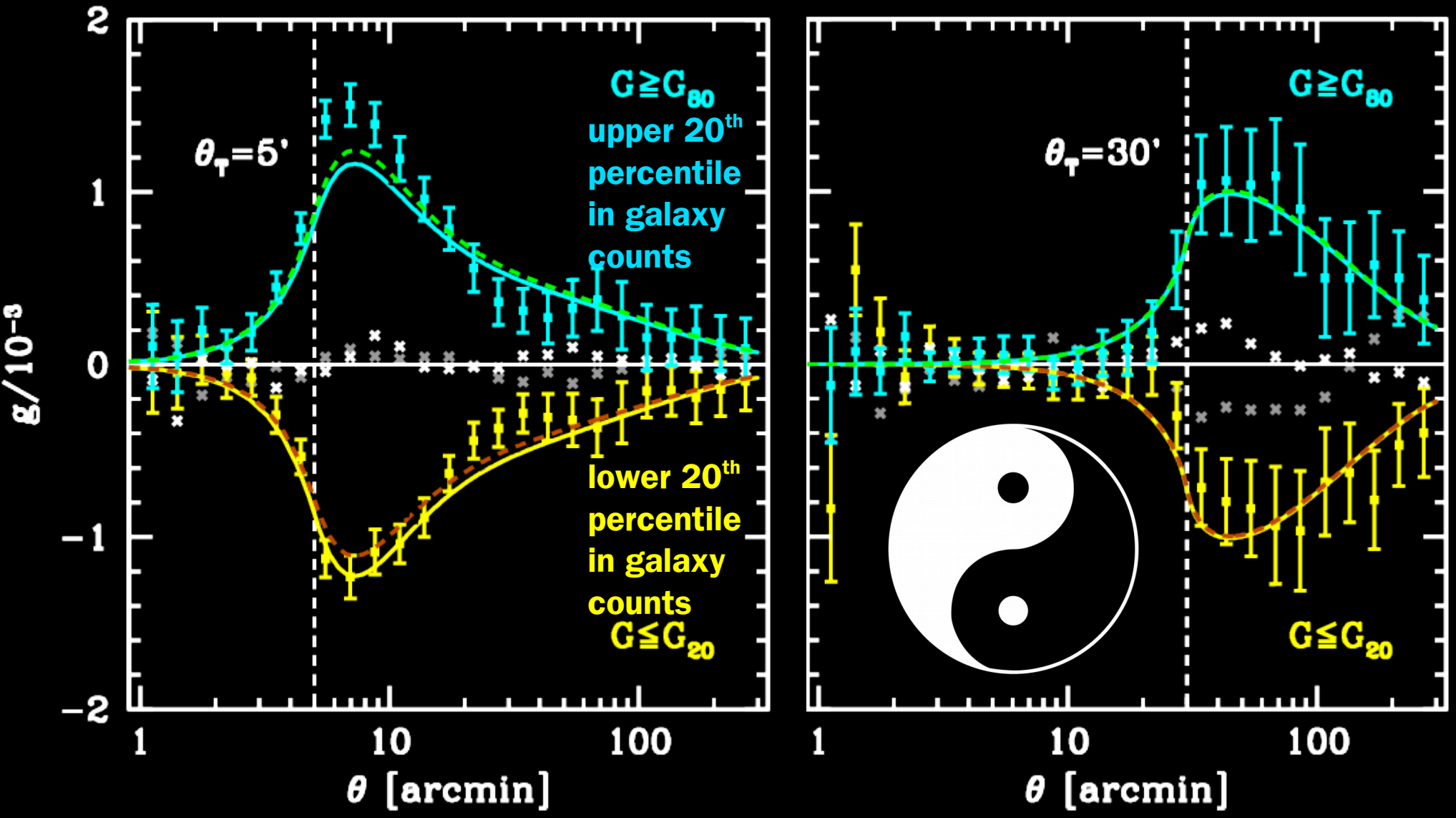


Measurement

- DES Science Verification: ~150 sq. deg, grizY, full DES depth
- tracers: Rykoff/Rozo redMaGiC galaxies, 0.2<z<0.5, L>0.5L*, 1/[1000 Mpc^3]
- troughs = lower 20^{th} percentile in galaxy count
- sources:~$2x10^6$ at z>0.6
- S/N ~ 15!



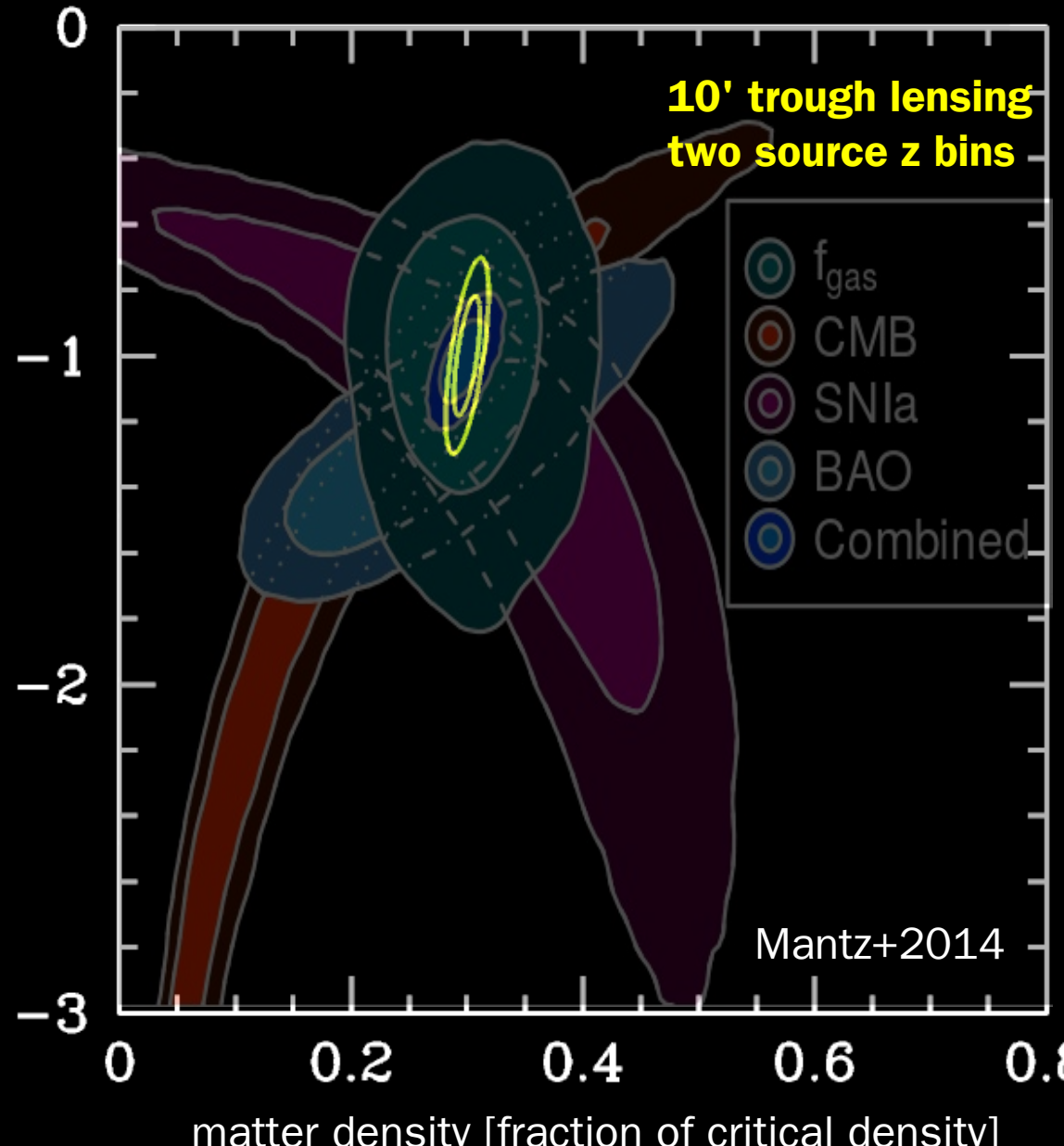
Measurement: under/overdensity



Outlook: Trough lensing for cosmology

Friedrich+ in prep.

- Fisher prediction for DES final Y5 data
- Constraints on Dark energy w
  - Non-marginalized
-



Summary

- DES is on track with a variety of science applications
- Several DES weak lensing projects finished, with new and relevant results
- More to come soon:
  this was 150/5000 sq. deg.