News from The Dark Energy Survey

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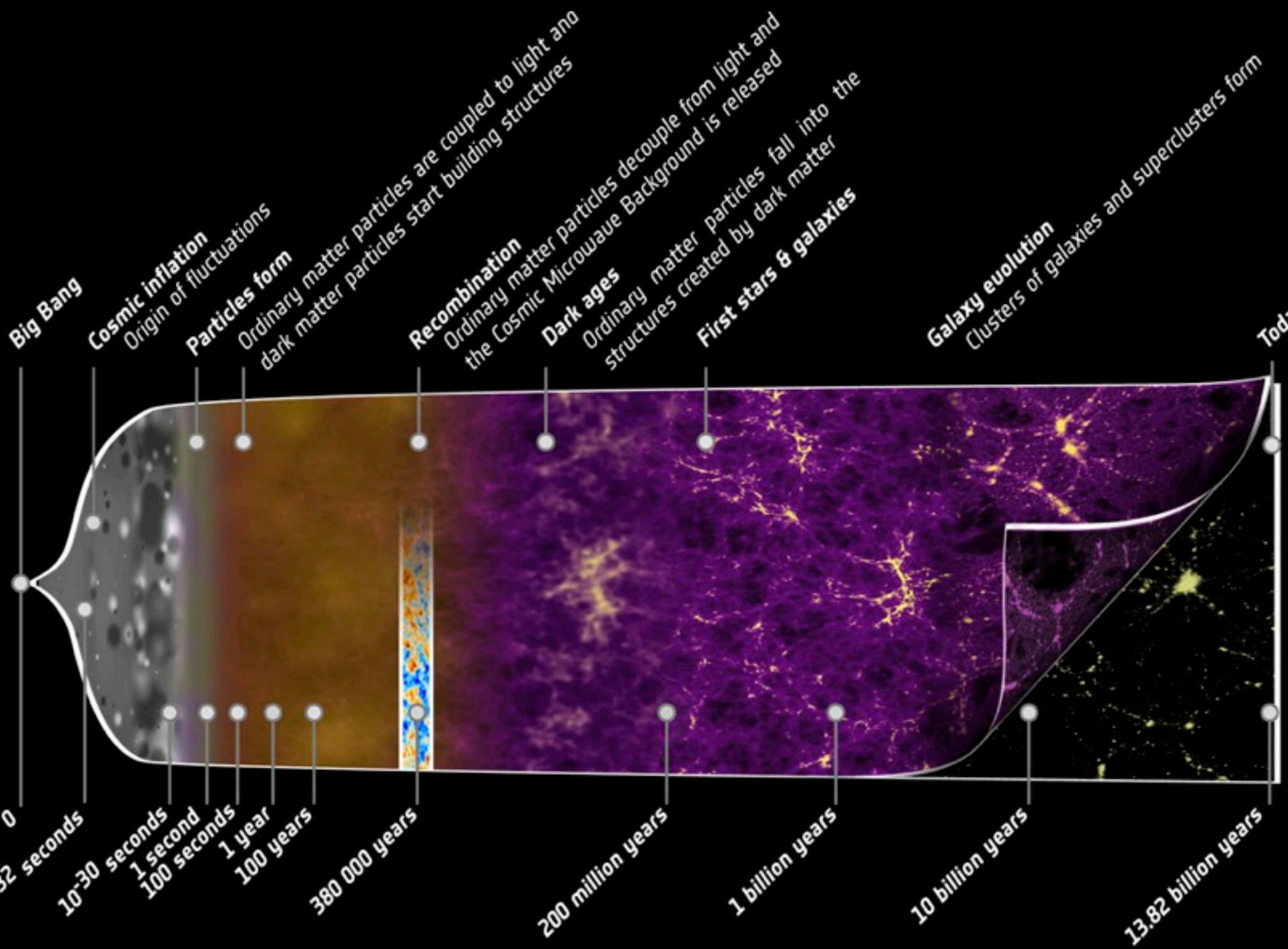
University College London
On behalf of the DES Collaboration

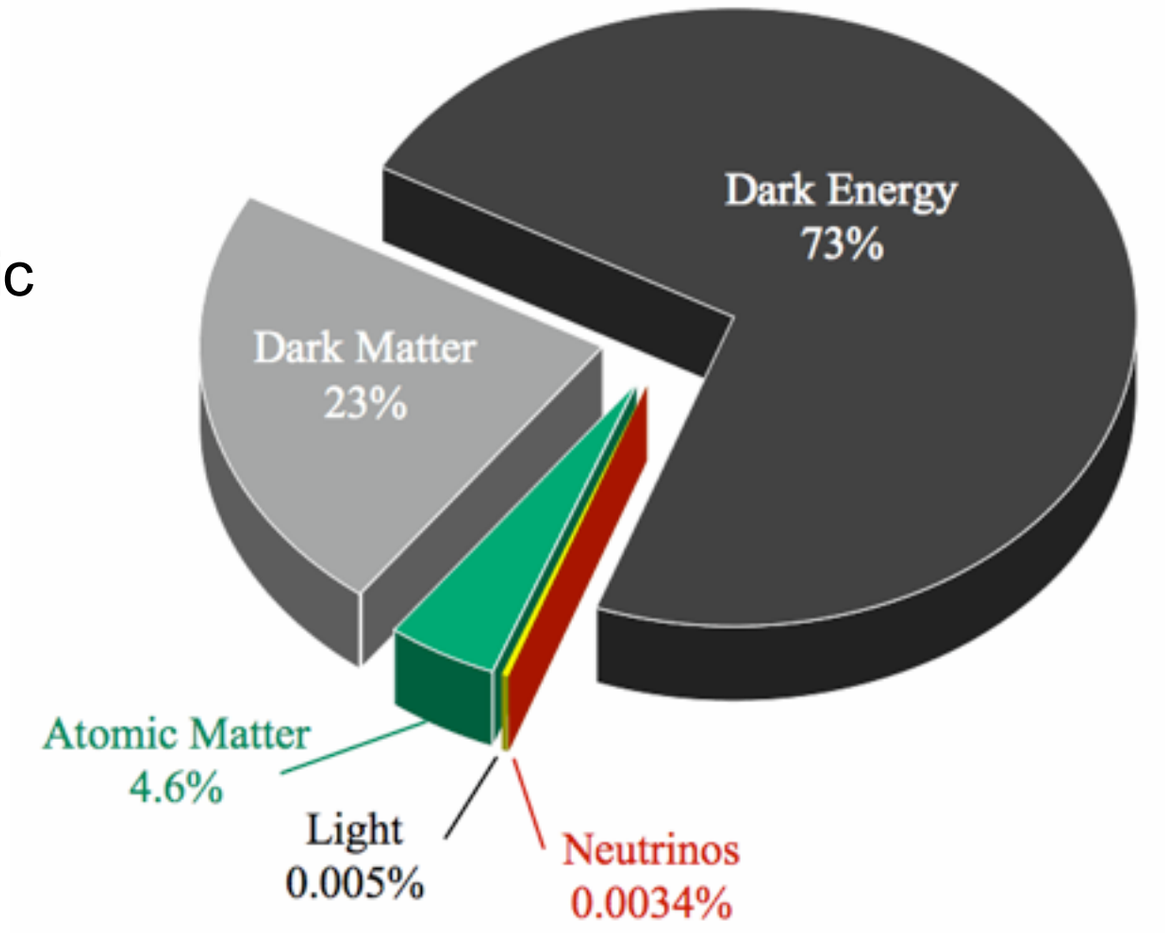
Séminaire du LAL - 27 Janvier 2014

A quick summary of the current status of cosmology



Dark Energy?

Baryonic &
non-baryonic



Source of the acceleration
of the expansion

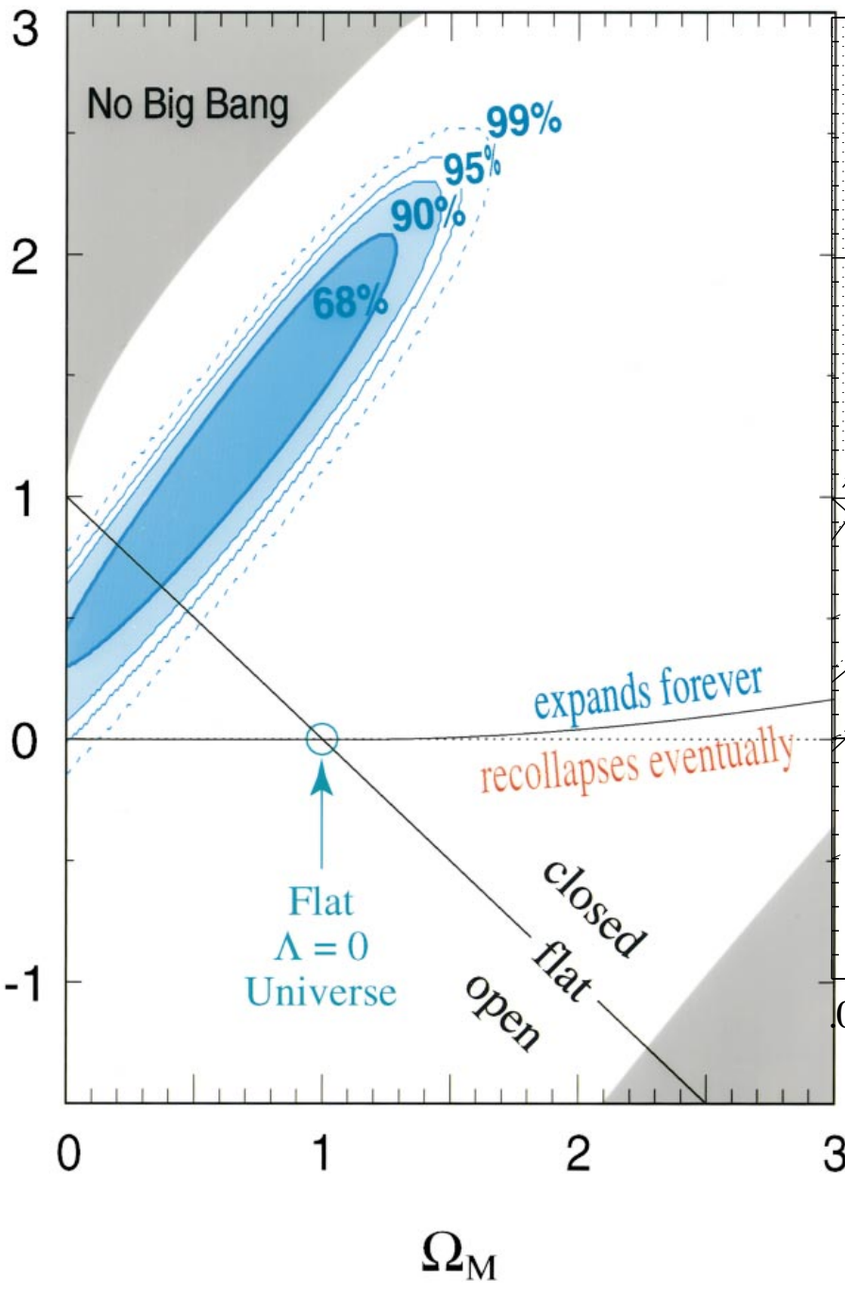
Friedmann equation

$$\left(\frac{\dot{a}}{a}\right)^2 = H_0^2 \left(\Omega_M \hat{a}^{-3} + \Omega_R \hat{a}^{-4} + \Omega_k \hat{a}^{-2} + \Omega_\Lambda\right)$$

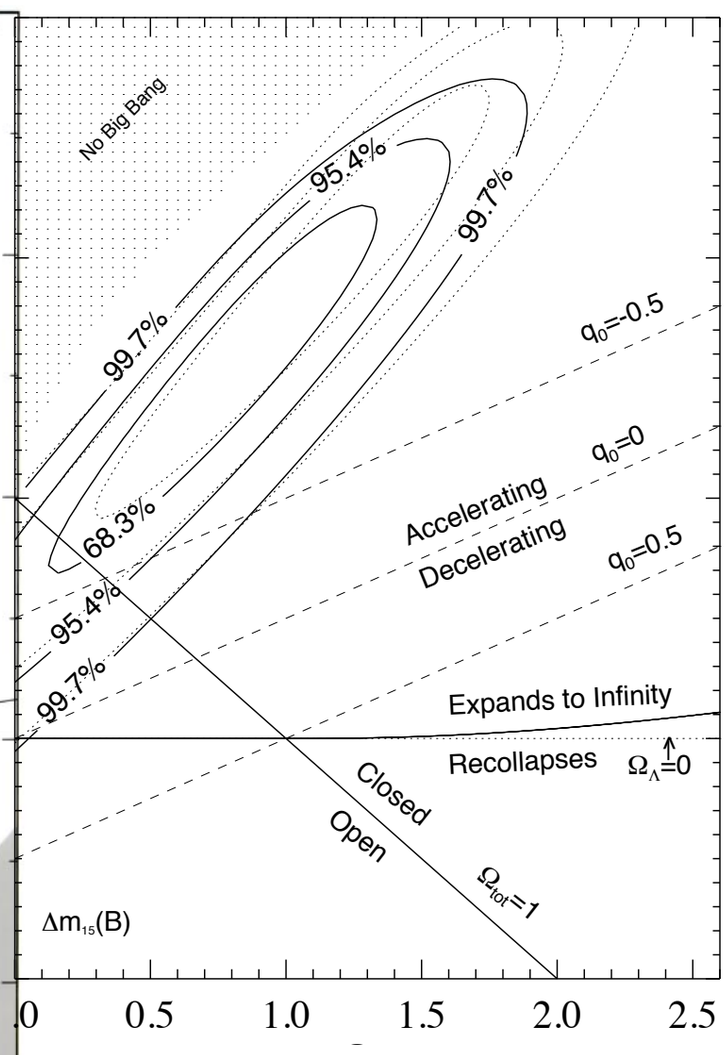
Dark Energy!

Type Ia Supernovae are the main indication for the acceleration of the expansion

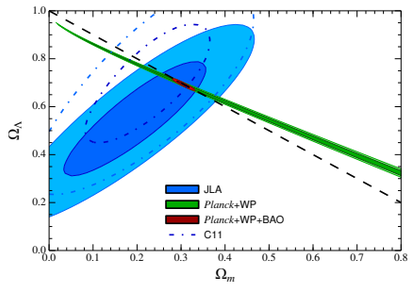
Perlmutter et al, 1999



Riess et al, 1998



Betoule et al, 2014

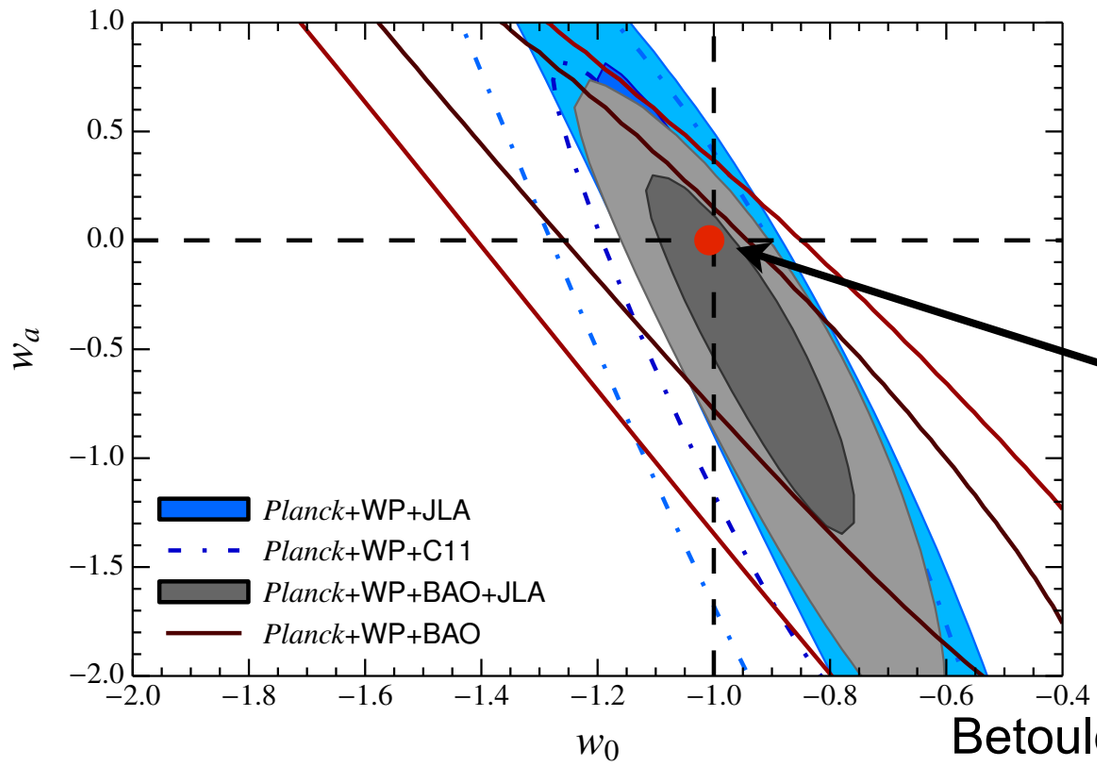


SNLS + SDSS

What could be Dark Energy?

Pure cosmological constant?, vacuum energy?, quintessence?, Modification of gravity?, ...

$$p = w\rho \qquad\qquad w(a) = w_0 + w_a(1-a)$$

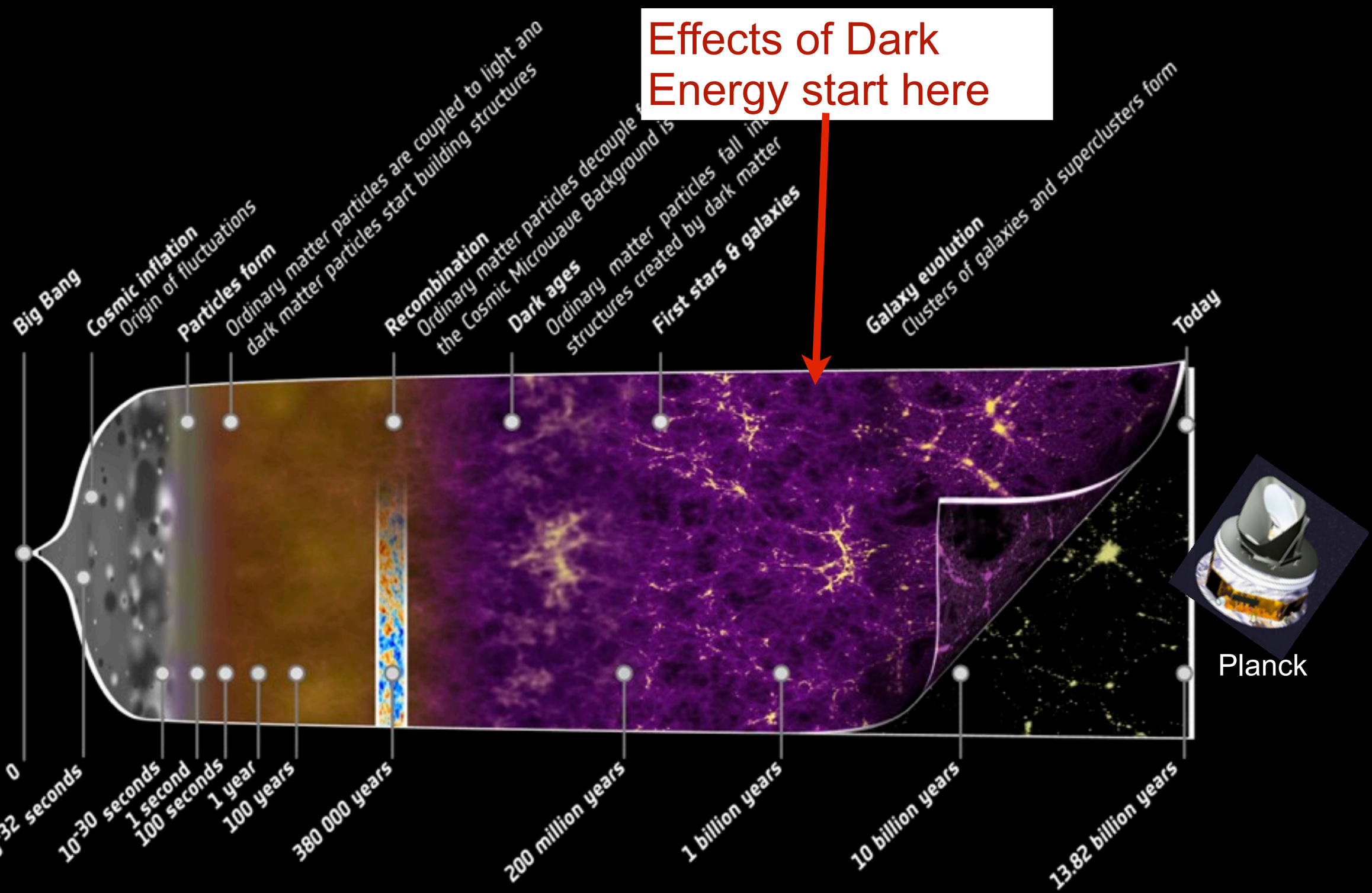


Pure cosmological constant

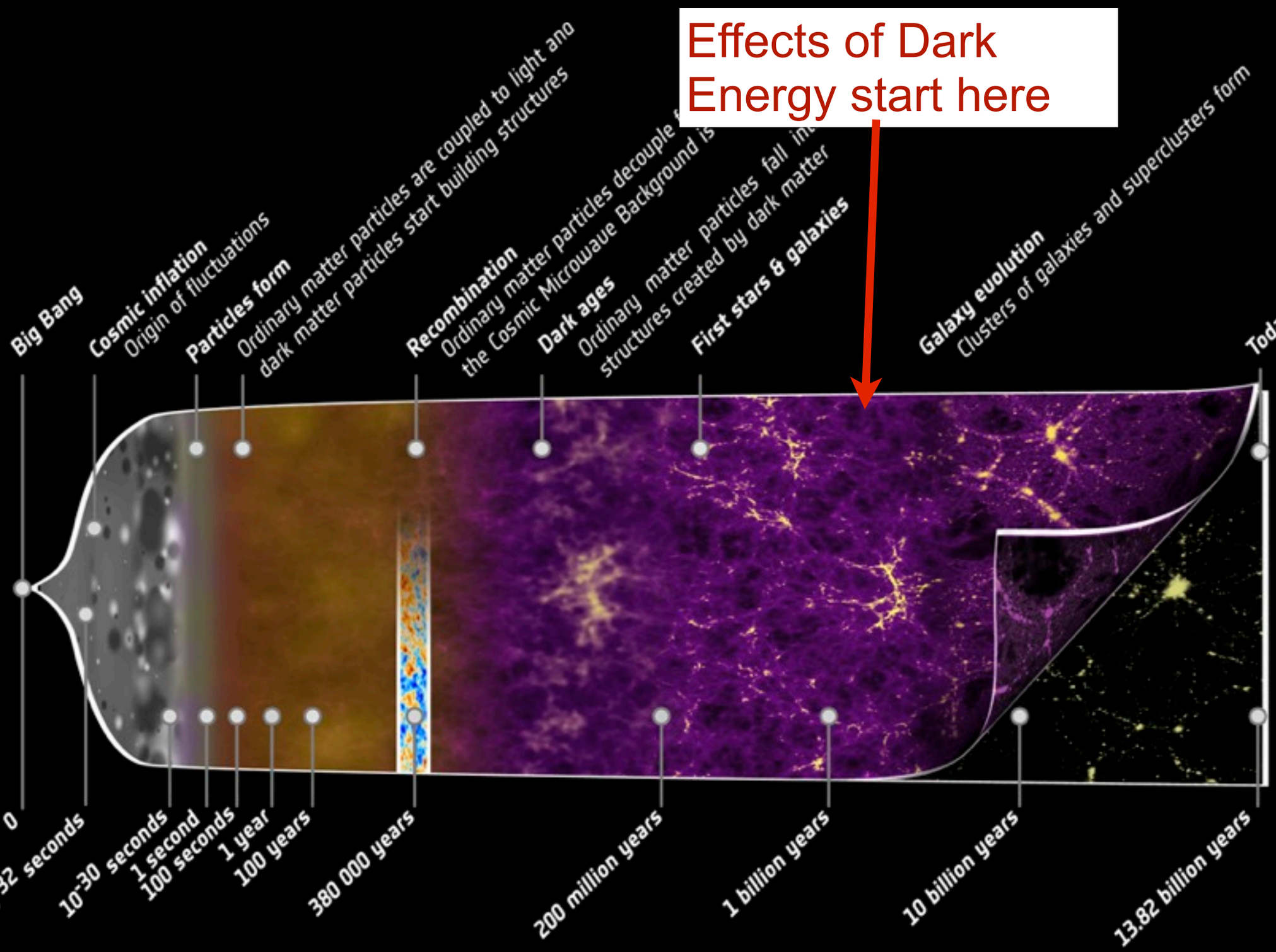
Betoule et al, 2014

Best constraint on DE currently brought by SNIa. That's right, from SNIa, not by CMB!

A quick summary of the current status of cosmology



A quick summary of the current status of cosmology



DES

Parameter degeneracies

Dark Energy has no direct effect on the CMB anisotropies at recombination.
Its effect are mainly geometrical but are degenated with other paramters

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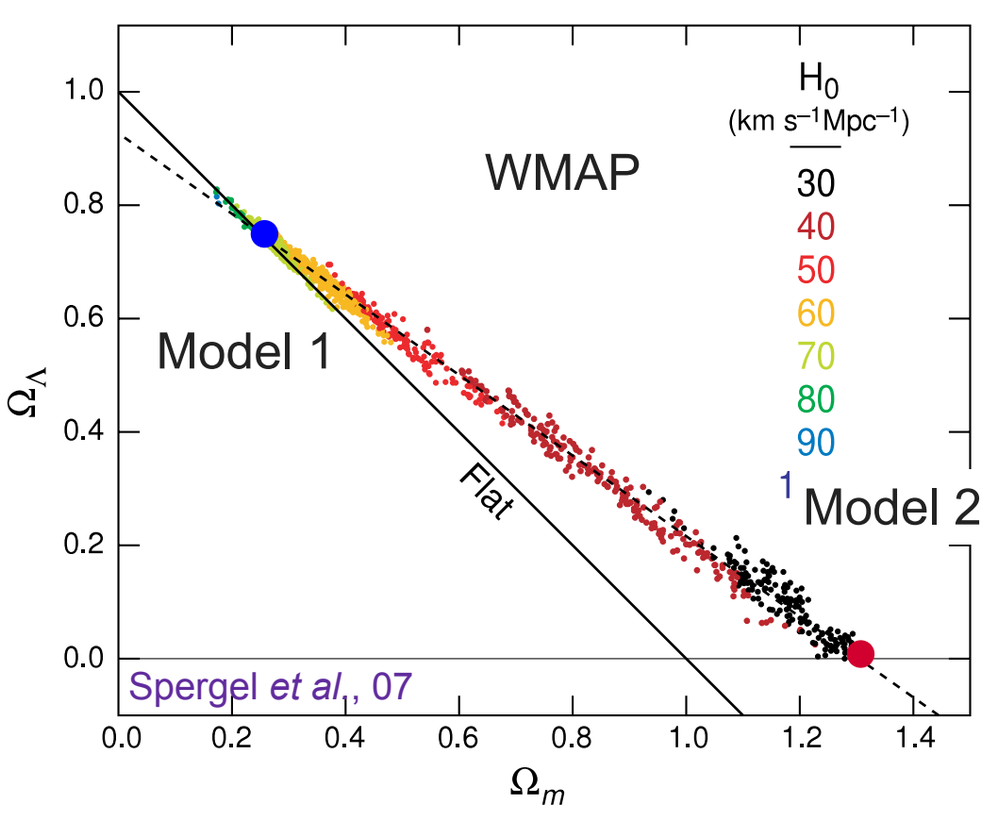

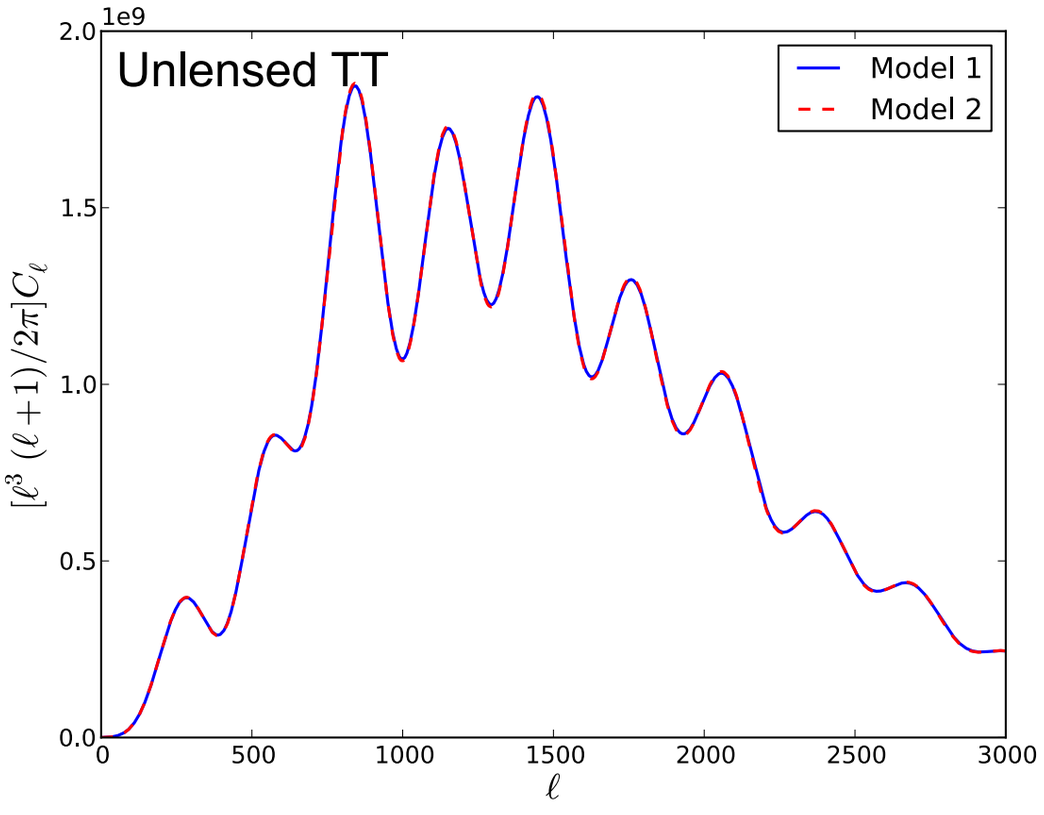

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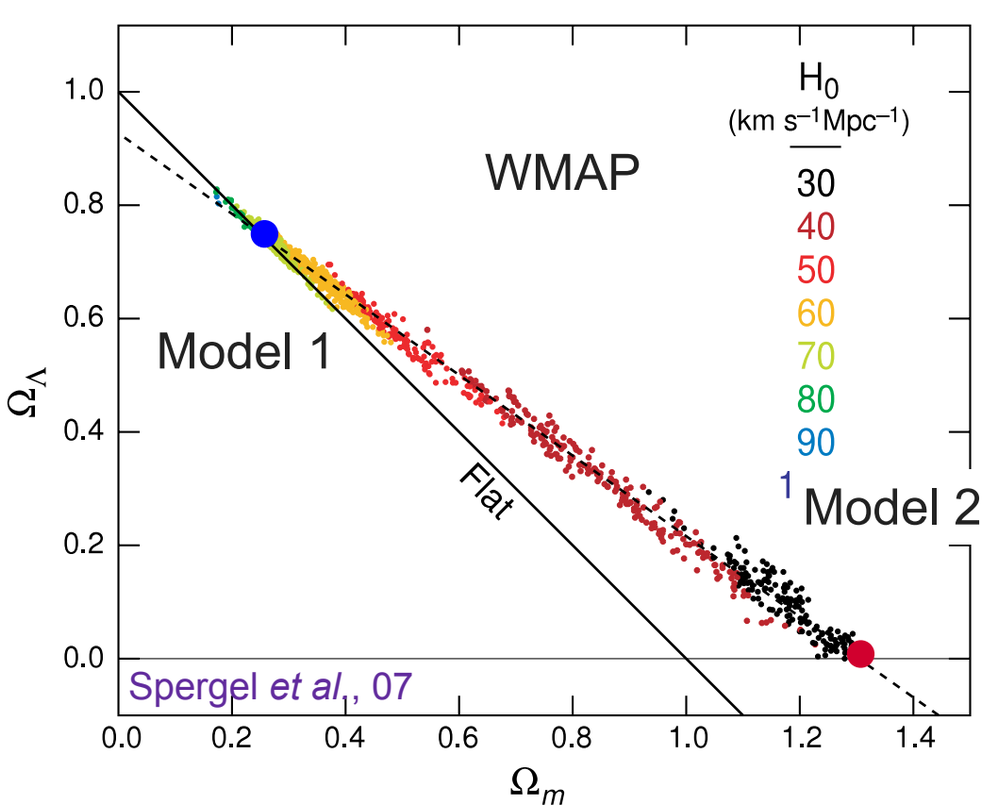
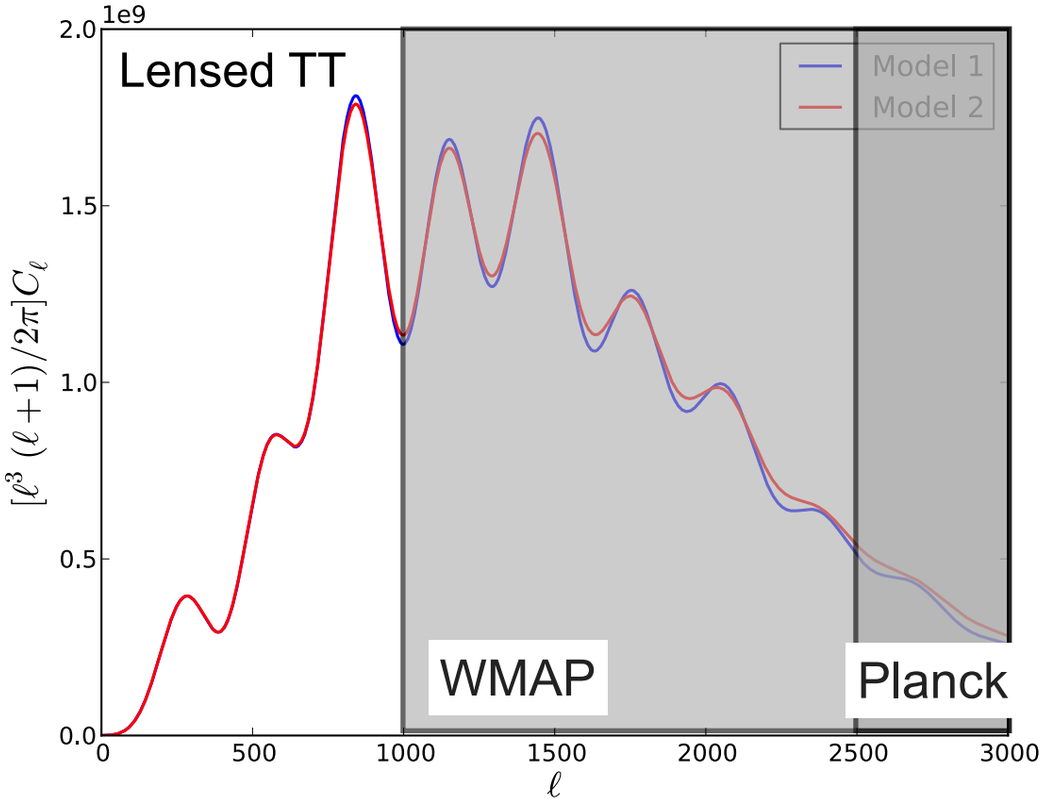
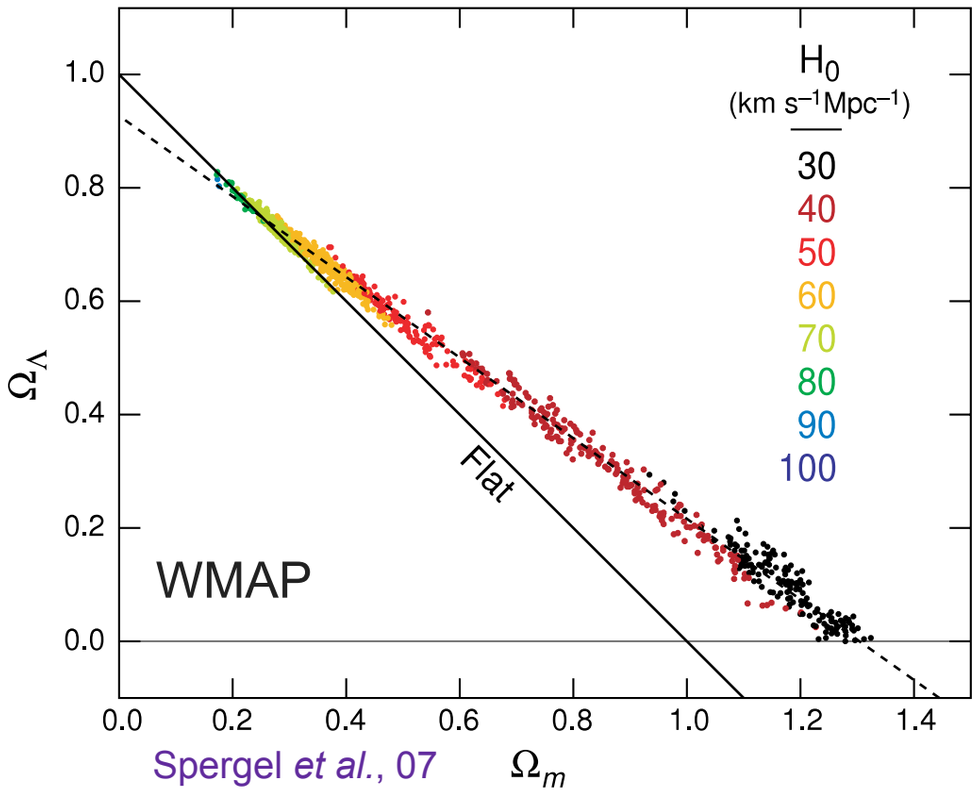


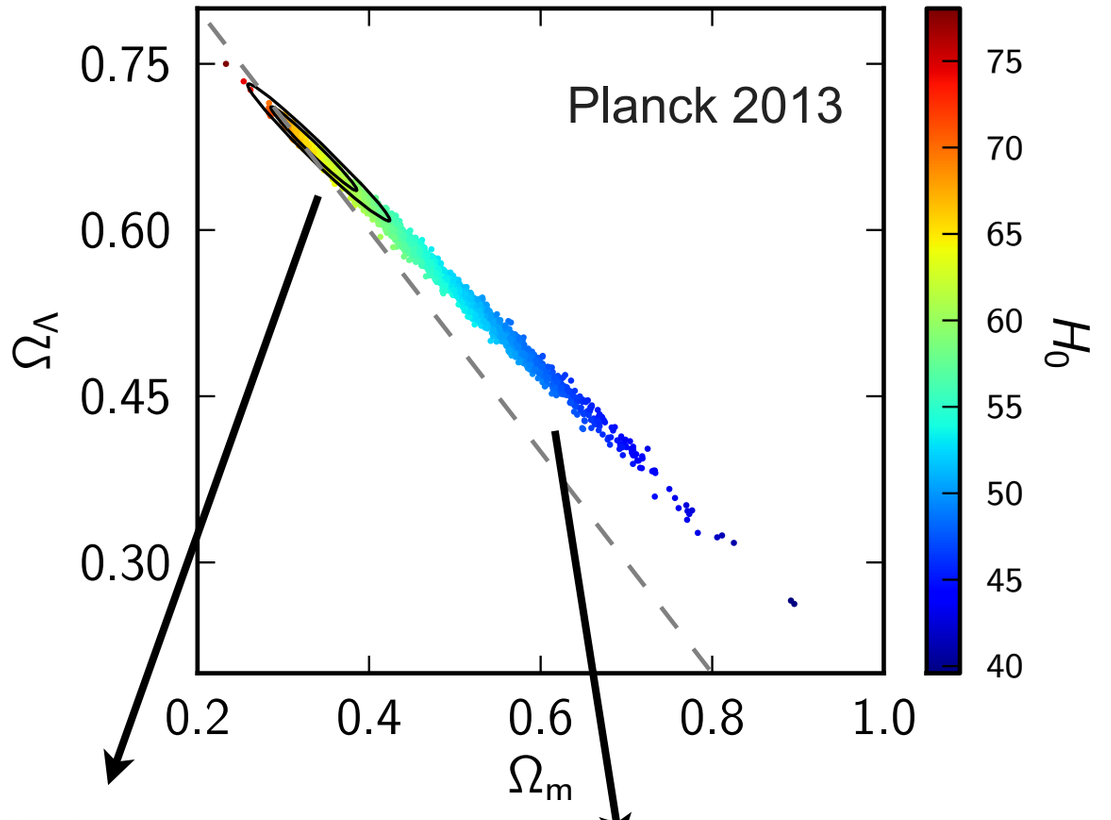


Parameters degeneracies

Information from the large-scale structure can break those degeneracies!



Spergel *et al.*, 07

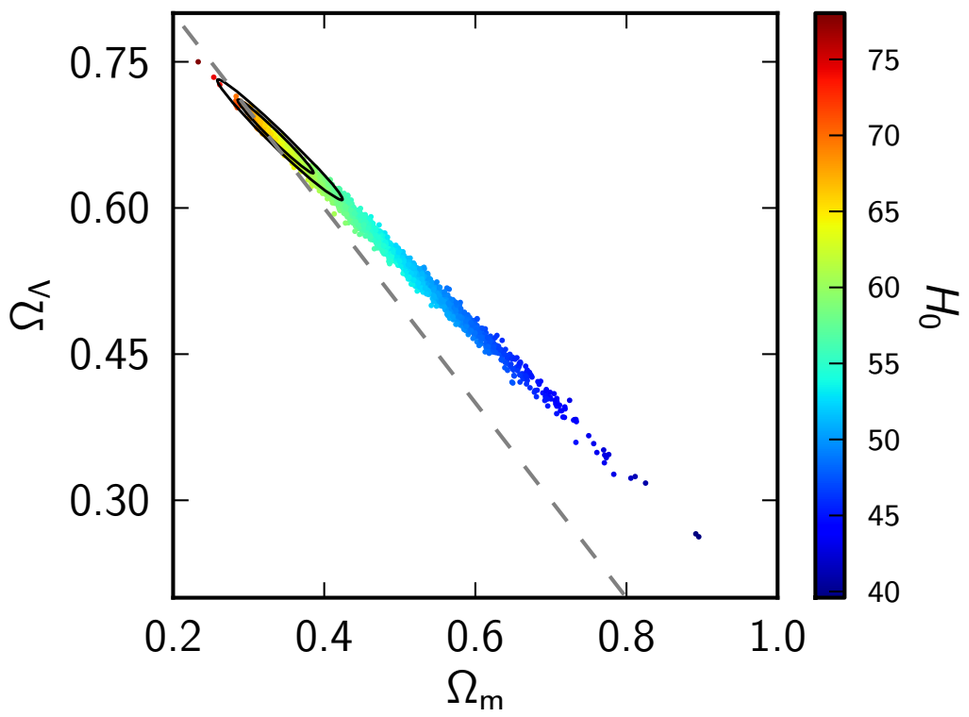


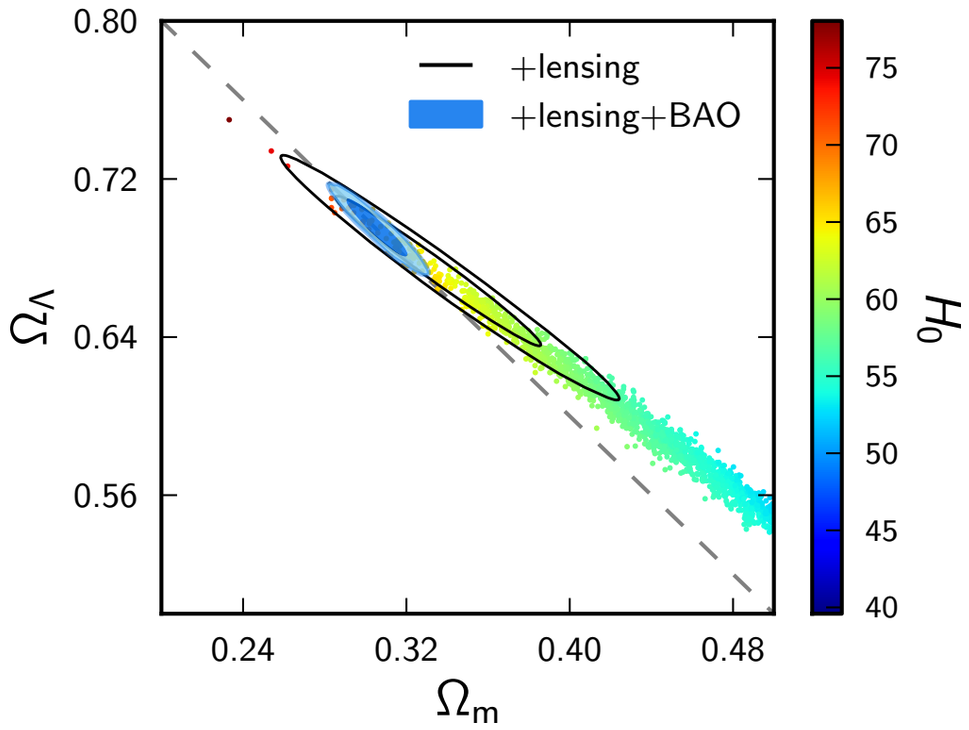
Adding CMB lensing reconstruction

Using only the temperature power spectrum

Parameters degeneracies

Information from the large-scale structure can break those degeneracies!





Parameters degeneracies

Large-scale structure will provide constraints on cosmology from

Geometry

- The scale of the sound horizon at recombination is imprinted in the matter distribution: Baryonic Acoustic Oscillations

- Distances

Structure growth

- Dark Energy, hence acceleration of the expansion will impede structure formation

So... Let’s observe those galaxies!

The Dark Energy Survey

New camera mounted on the 4m Blanco telecope at Cerro-Tololo Inter-American Observatory in Chili

The DES Collaboration

~300 scientists from 28 institutions from around the world

DARK ENERGY SURVEY

facebook.com/darkenergysurvey
http://darkenergysurvey.org

USA: Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of Pennsylvania, Argonne National Laboratory, Ohio State University, Santa Cruz/ SLAC/Stanford Consortium, Texas A&M University, CTIO (in Chile

UK Consortium: UCL, Cambridge, Edinburgh, Portsmouth, Sussex, Nottingham

Participation from a few individuals...

Germany: Munich

Switzerland: ETH Zurich

4m Blanco telescope at CTIO

Brazil Consortium

Spain Consortium: CIEMAT (Madrid), ICE, IFAE (Barcelona)

What is DES ?

DES is:

- 1” resolution picture of the sky (pixel size 0.26”)
- 5000 sq. deg. (1/8th of the sky)
- Five photometric bands (grizY)
- 24th magnitude (galaxies,10σ)

~ 1-2 mag deeper than SDSS
25 larger than CFHTlens

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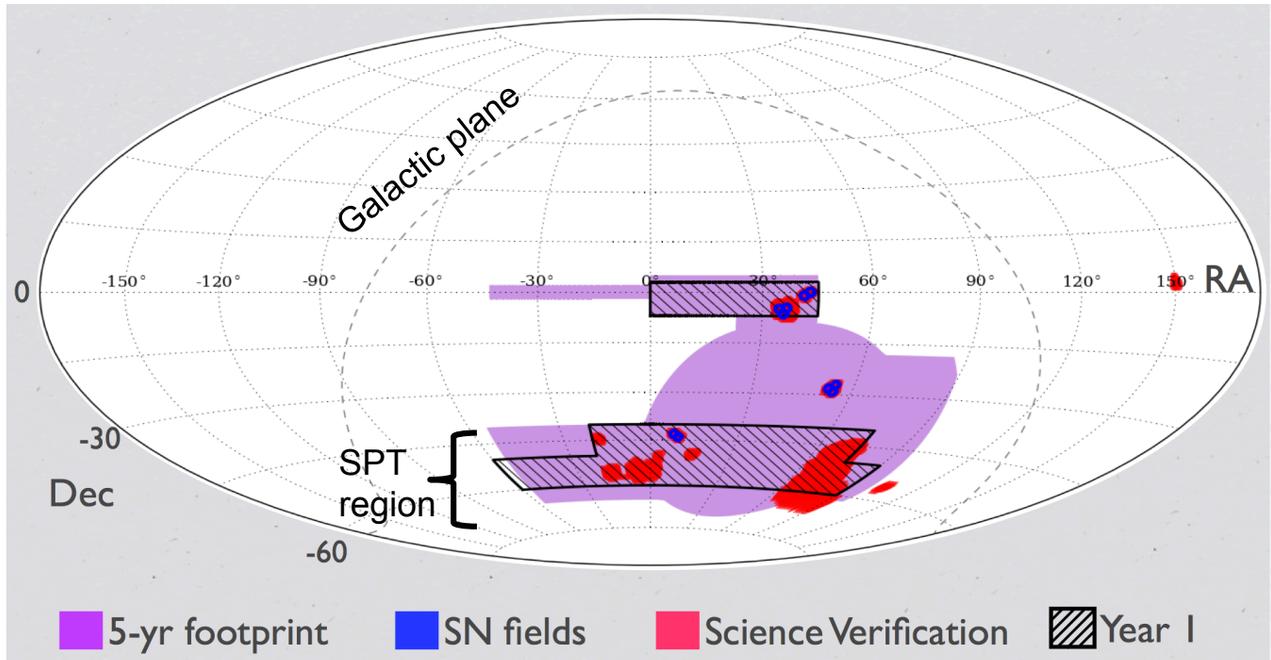
Supplemented by:

- 2500 sq. deg. South Pole Telescope
- Vista Hemisphere Survey (JHK)



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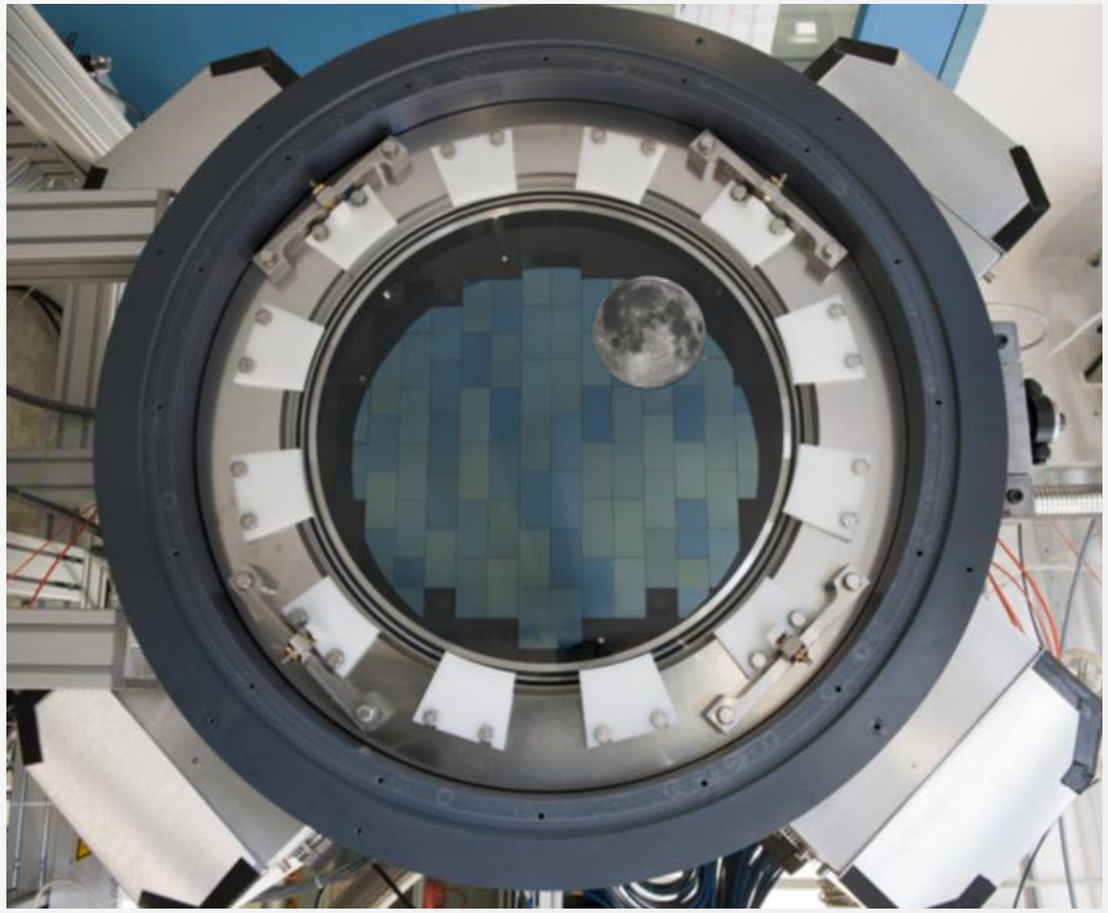

Supplemented by:

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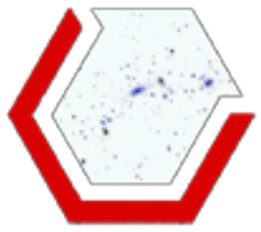
DECam:

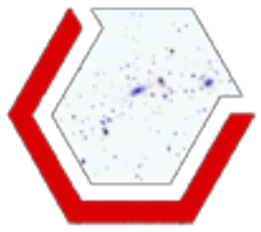
- 570 Mpixels, 62 CCD
- 3 sq. deg. field of view



4 probes of Dark Energy

Galaxy Clusters (distance, structure growth)
ten of thousands of clusters up to z~1
synergies with SPT, VHS

$$\frac{d^2N(z)}{dzd\Omega} = \frac{c}{H(z)} D_A^2 (1+z)^2 \int_0^\infty f(M,z) \frac{dn(z)}{dM} dM \ ,$$



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Weak lensing (distance, structure growth)
shape and measurements of 200
millions galaxies

$$C_l^{x_a x_b} = \int dz \frac{H(z)}{D_A^2} W_a(z) W_b(z) P^{s_a s_b}(k = l/D_A; z) ,$$

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Baryonic acoustic Oscillations (distance)
300 millions galaxies to z=1 and beyond

$$C^i_{\rm gal}(l) = \int_0^\infty k^2 dk \, \frac{2}{\pi} f_i^2(l,k) P_{\rm gal}(k),$$

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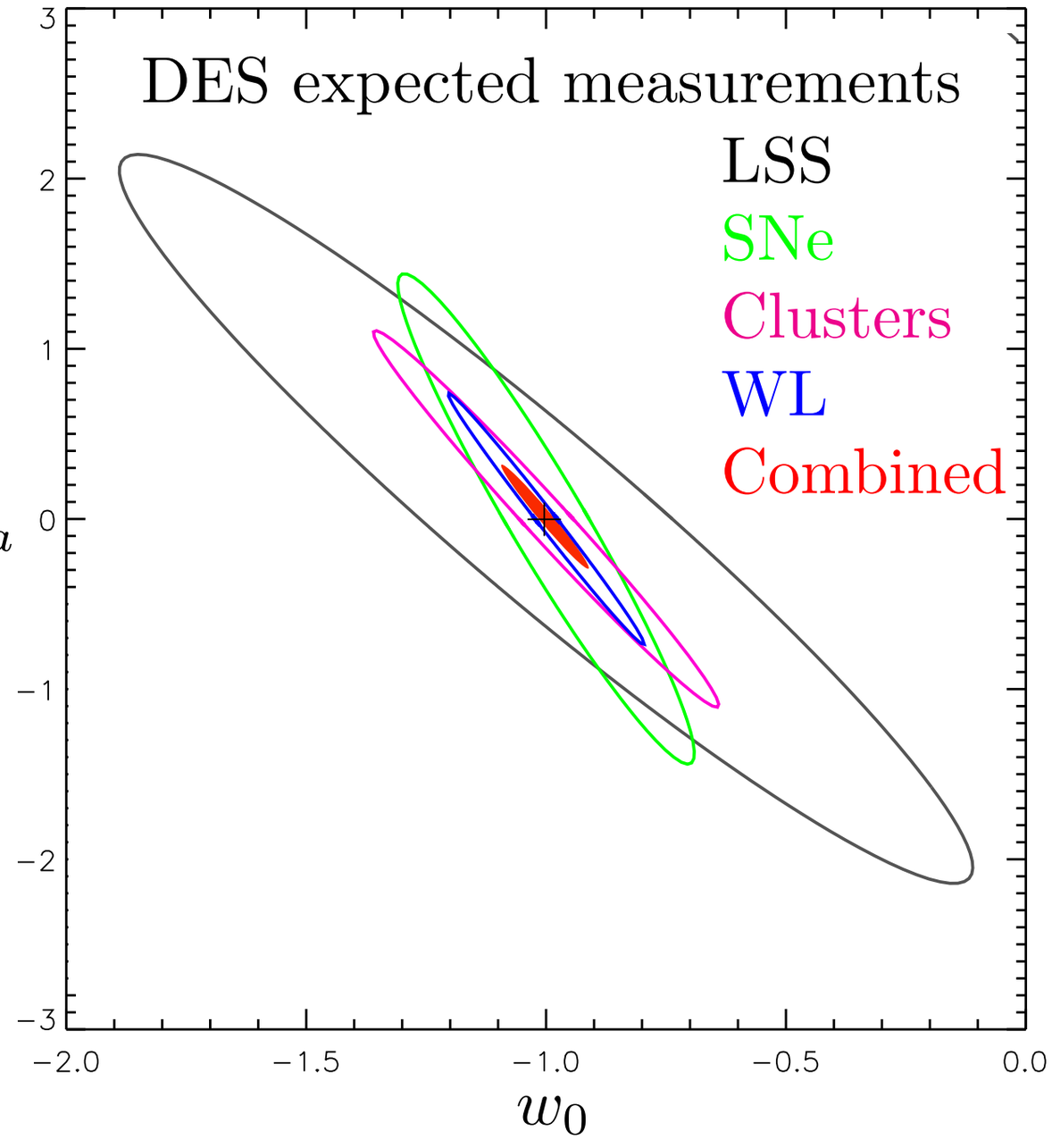
Type Ia supernovae (distance)
30 sq. deg. SN fields
3500 SNIa to z~1



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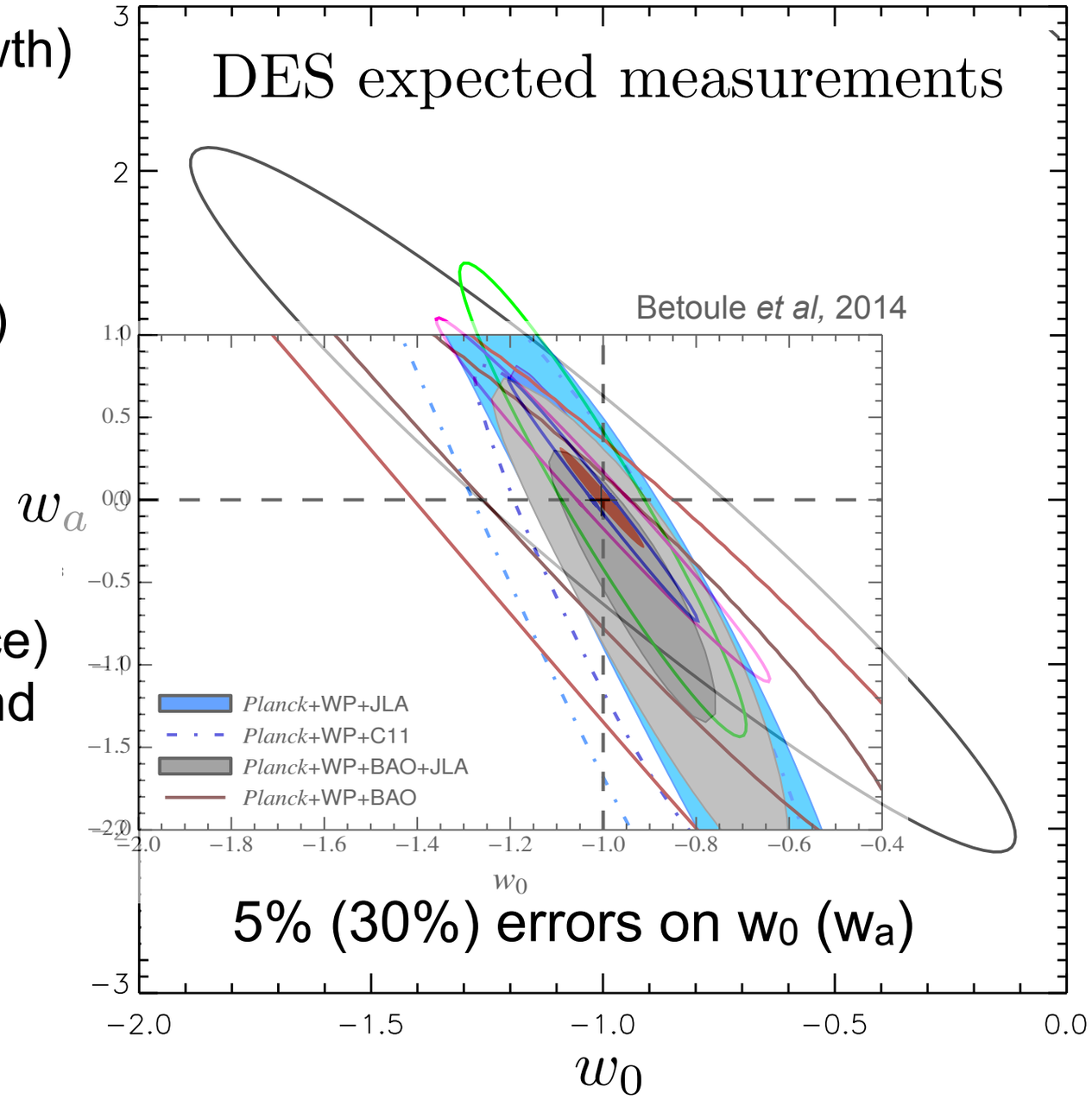
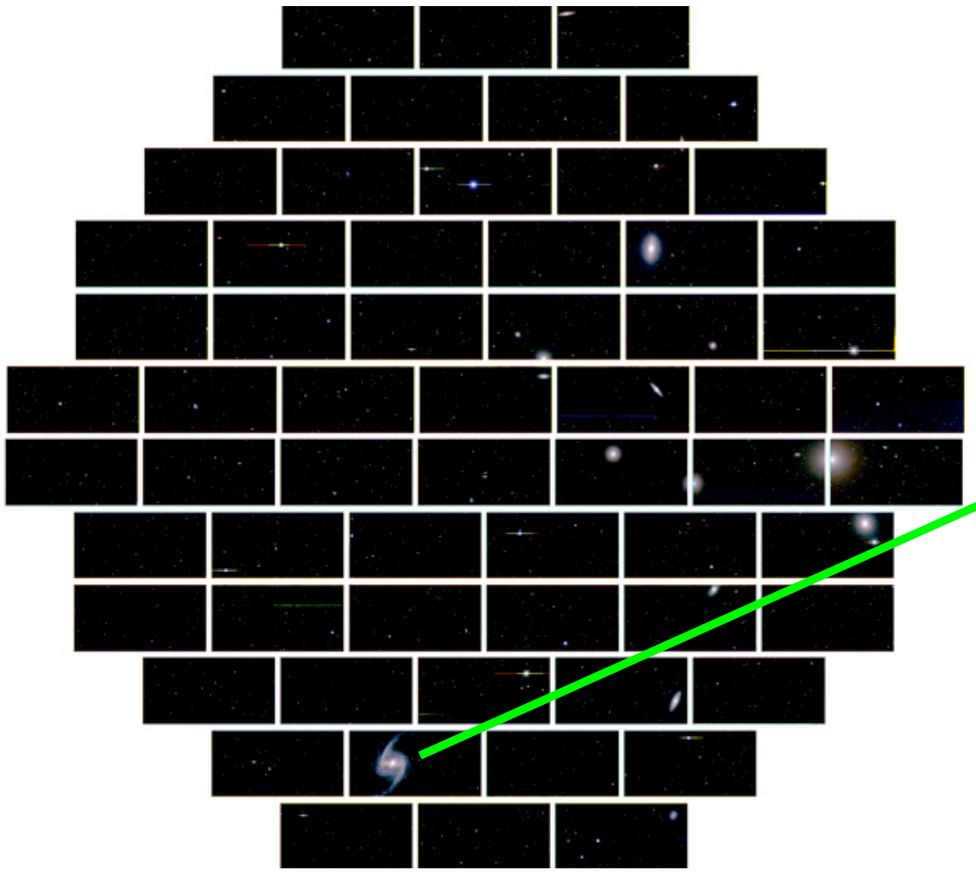


DES Timeline

2003	Project start
2004-8	***R&D***
2008-11	DECam construction
2012 [Sept]	***Installation and first light***

Sept. 2012: First light

Fornax galaxy cluster



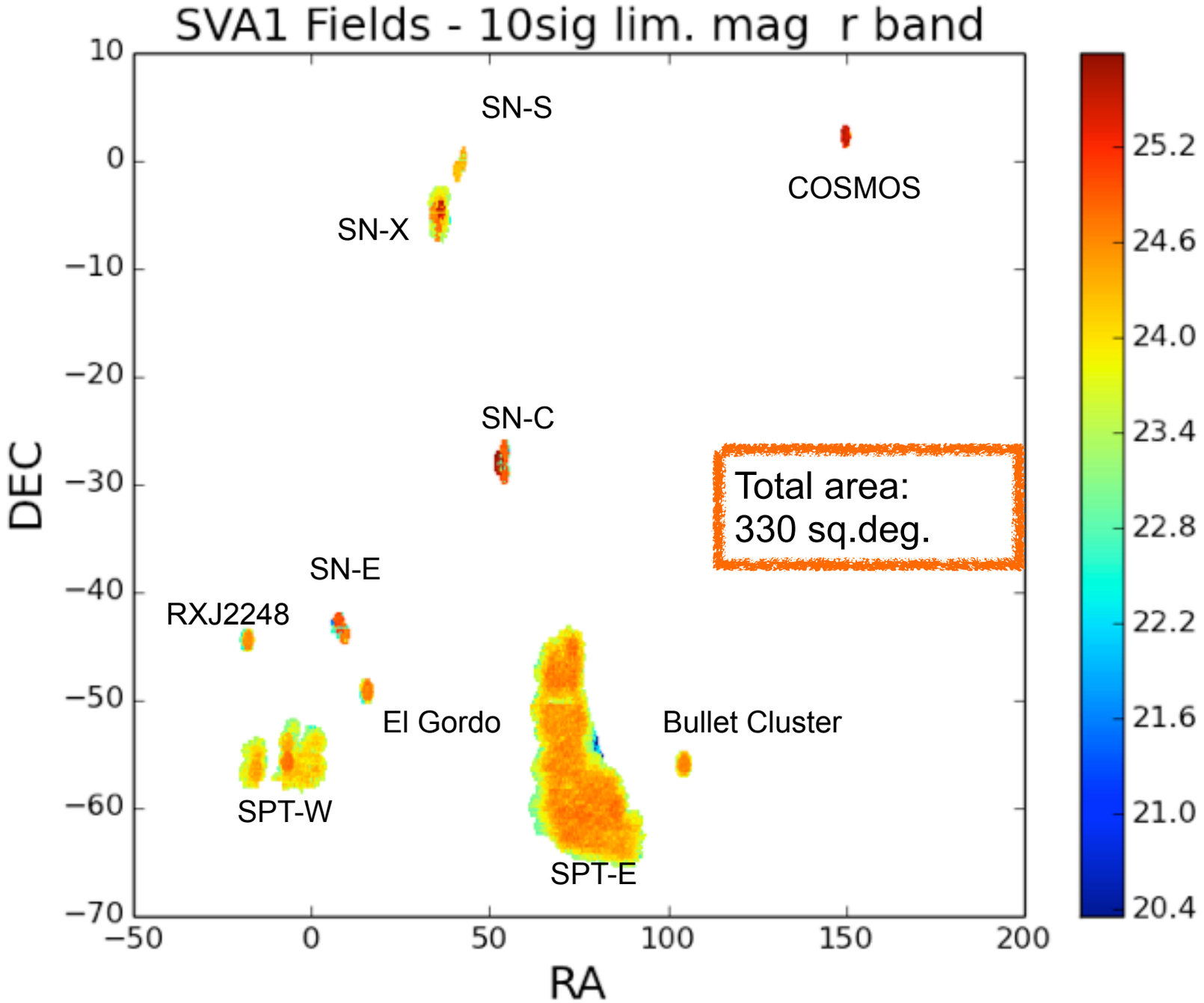
NGC 1365

DARK ENERGY SURVEY

DES Timeline

2003	Project start
2004-8	***R&D***
2008-11	DECam construction
2012 [Sept]	***Installation and first light***
2012 [Sept-Oct]	Commissioning
Nov 2012 - Feb 2013	***Science Verification***
Aug 31 2013 - 9 Feb 2014	**First Season (Y1)**
Aug 15 2014 - Feb 2015	***Second Season (Y2)***
2015-2018	***Third-Fifth Seasons***

Nov. 2012 - Feb. 2013: Science Verification campaign

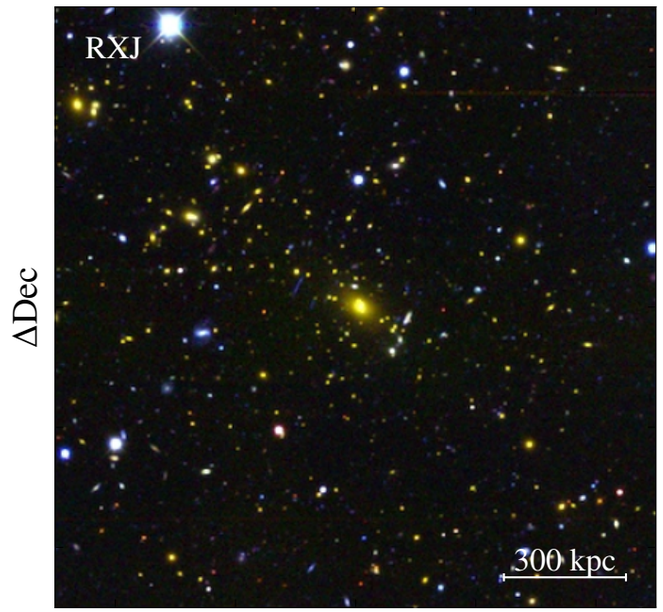


All the results presented in this talk are based on these pre-survey data

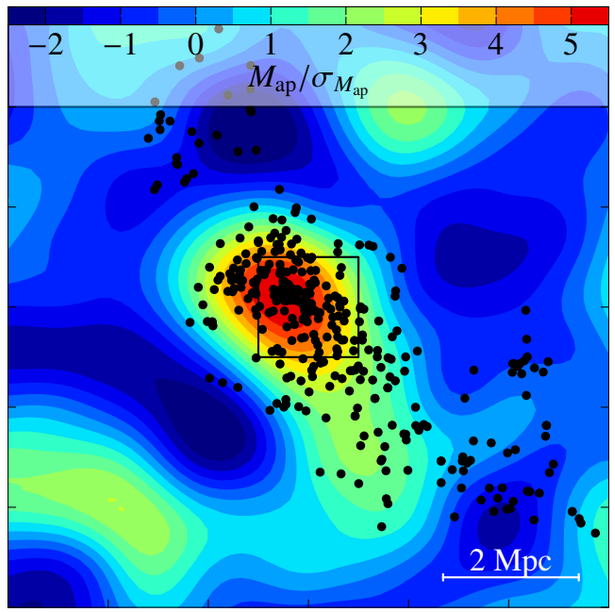
Mass and galaxy distributions of four massive galaxy clusters from Dark Energy Survey Science Verification data

P. Melchior *et al.*, 1405.4285

multi-color image of the inner 5 armin



WL aperture mass significance



Surface density contrast profile

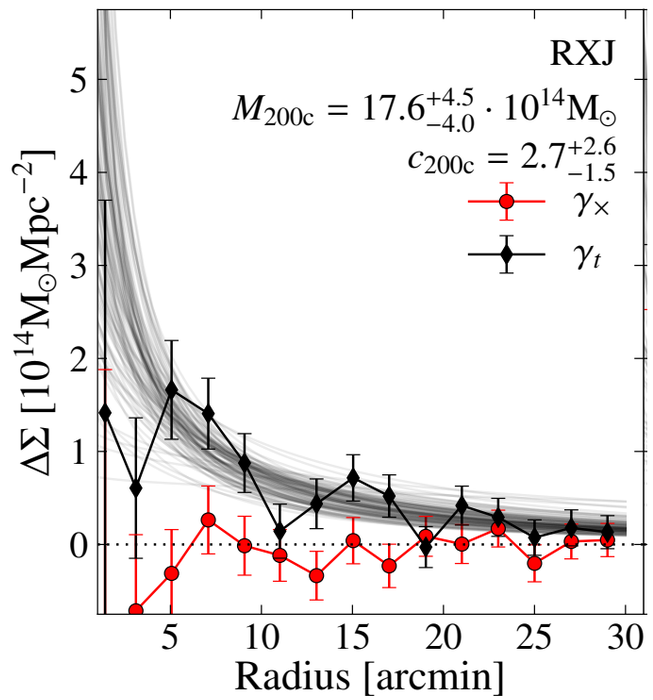
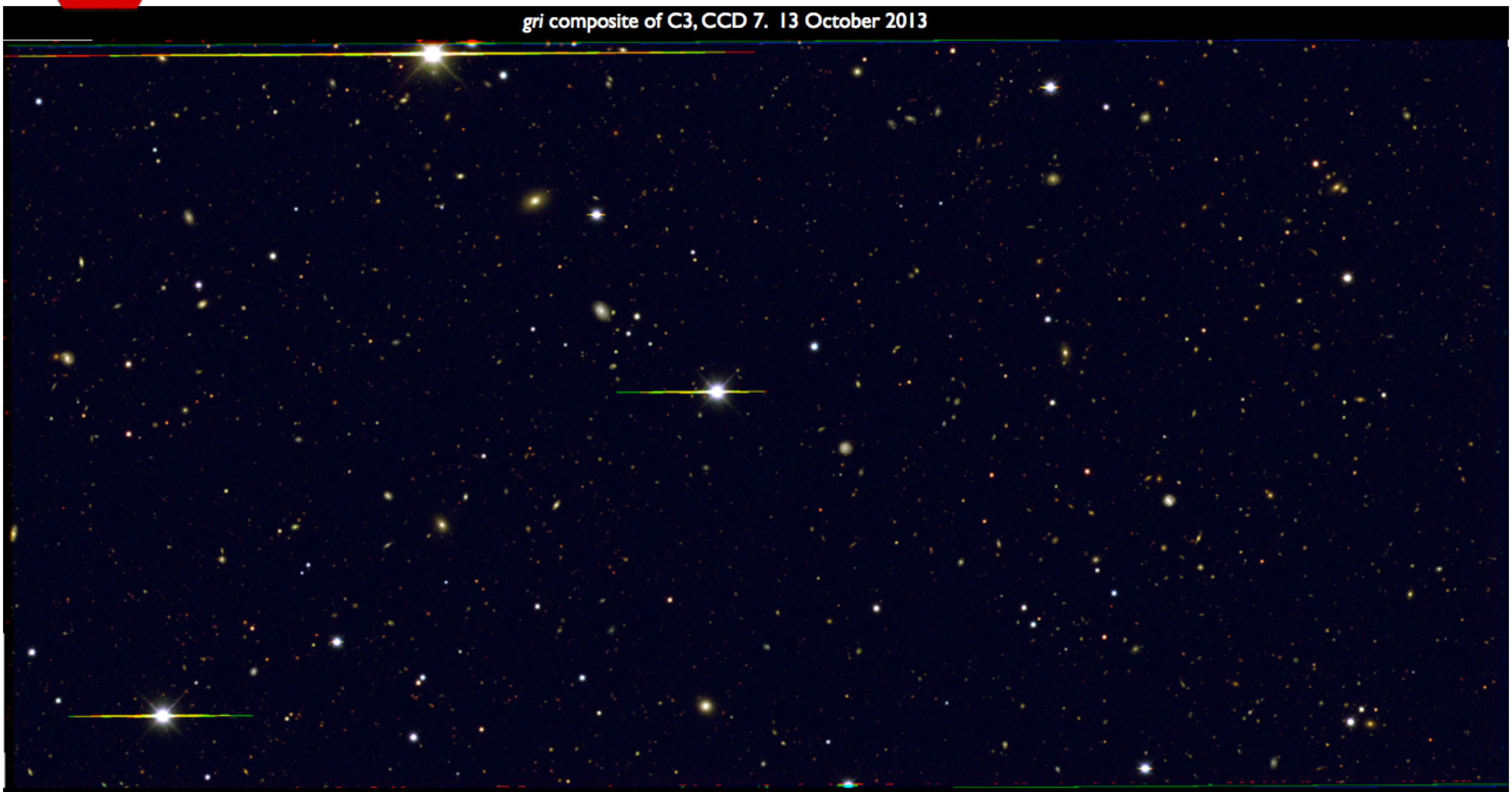


Table 4. Weak lensing masses M_{200c} in units of $10^{14} M_\odot$ (with a flat prior on c_{200c}), redMaPPer richness λ and redshift estimate z_λ, and their statistical errors (see Section 3.2 and Section 5.1 for details). The literature mass estimates are derived from weak lensing, galaxy dynamics (D) or optical richness (R).

Cluster name	M_{200c}	λ	z_λ	Literature value M_{200c}
RXC J2248.7-4431	$17.6^{+4.5}_{-4.0}$	203 ± 5	0.346 ± 0.004	$22.8^{+6.6}_{-4.7}$ (Gruen et al. 2013b), 20.3 ± 6.7 (Umetsu et al. 2014), 16.6 ± 1.7 (Merten et al. 2014)
1E 0657-56	$14.2^{+10.0}_{-6.1}$	277 ± 6	0.304 ± 0.004	17.5 (Clowe et al. 2004)[i], 12.4 (Barrena et al. 2002, D)
SCSO J233227-535827	$10.0^{+3.7}_{-3.4}$	77 ± 4	0.391 ± 0.008	$11.2^{+3.0}_{-2.7}$ (Gruen et al. 2013a), $4.9 \pm 3.3 \pm 1.4$ (High et al. 2010, R)
Abell 3261	$8.6^{+8.6}_{-3.9}$	71 ± 3	0.216 ± 0.003	—

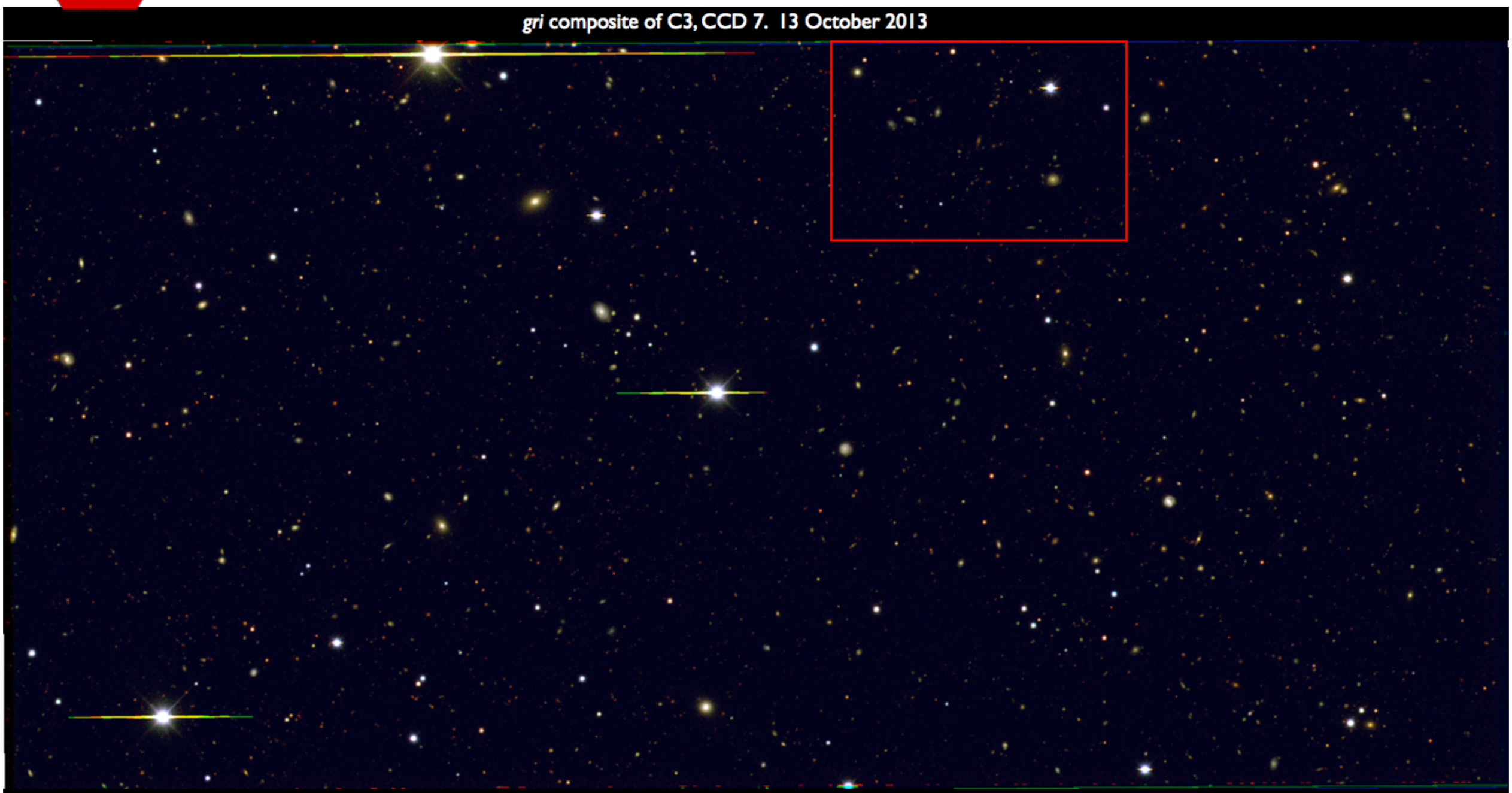
Type Ia SN search



Multi wavelength gri composite of a single CCD chip
Deep field search for SNe Ia

Graphics: C. D'Andrea

Type Ia SN search



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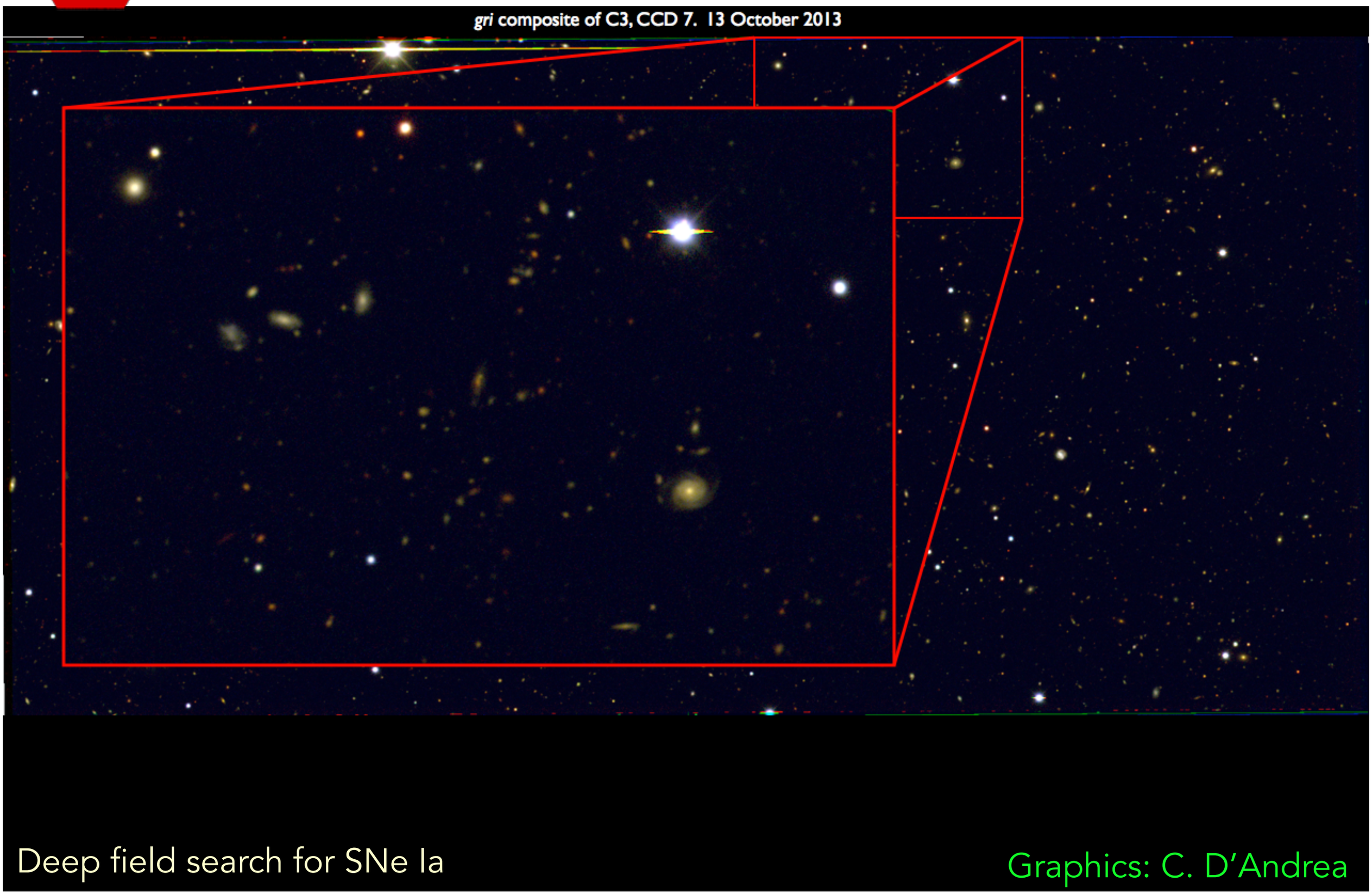

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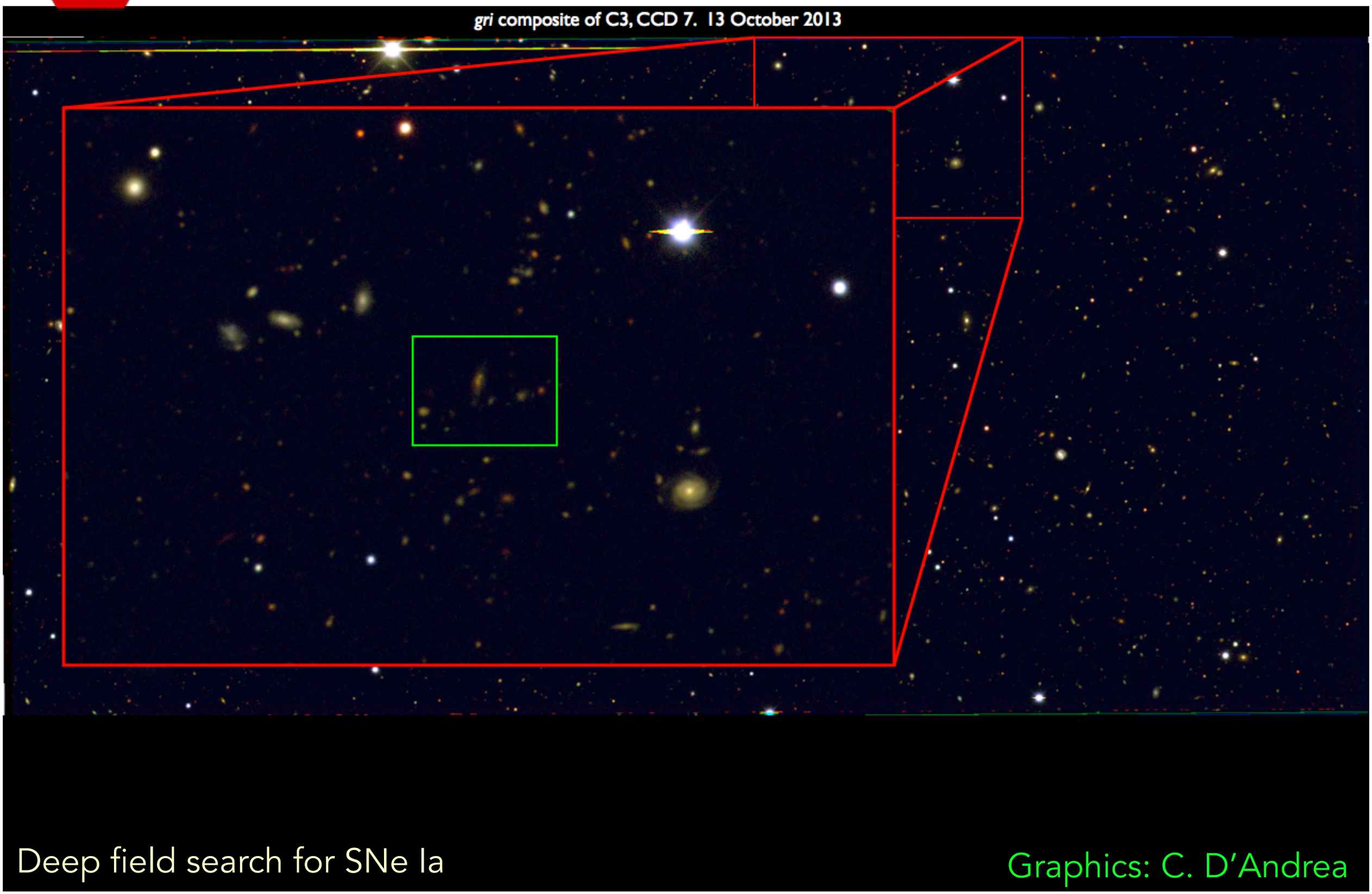

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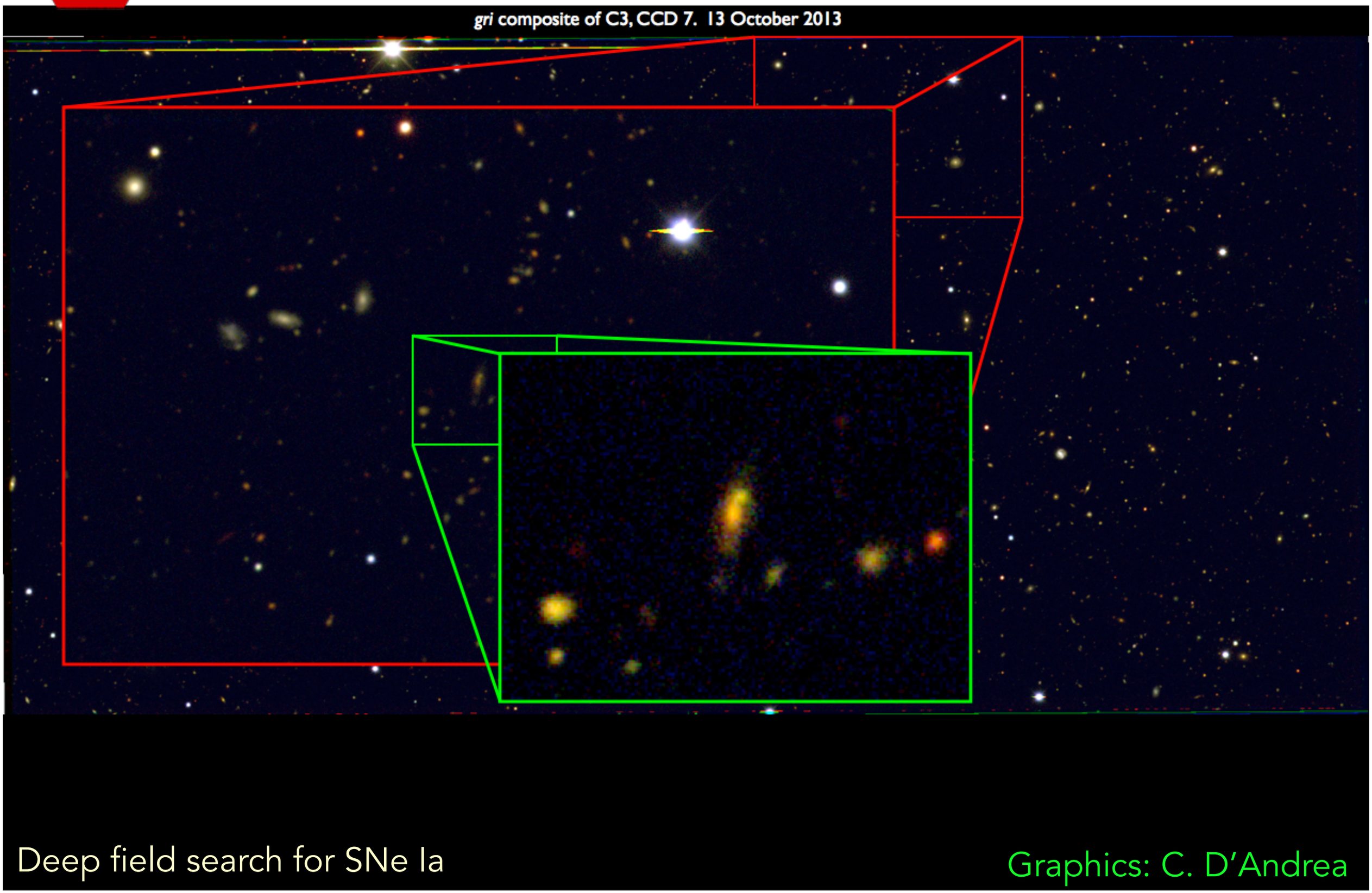

Deep field search for SNe Ia

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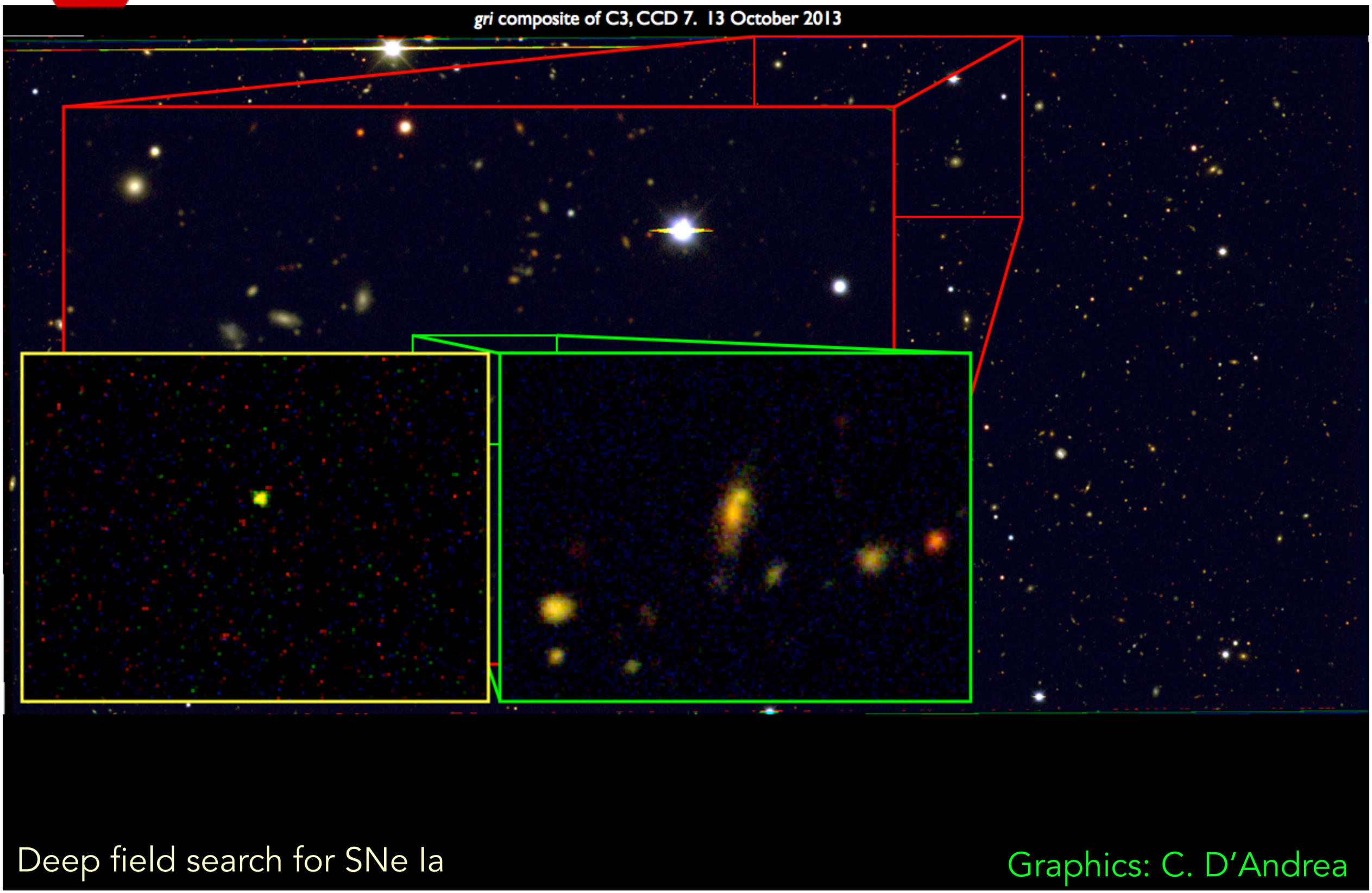
Type Ia SN search



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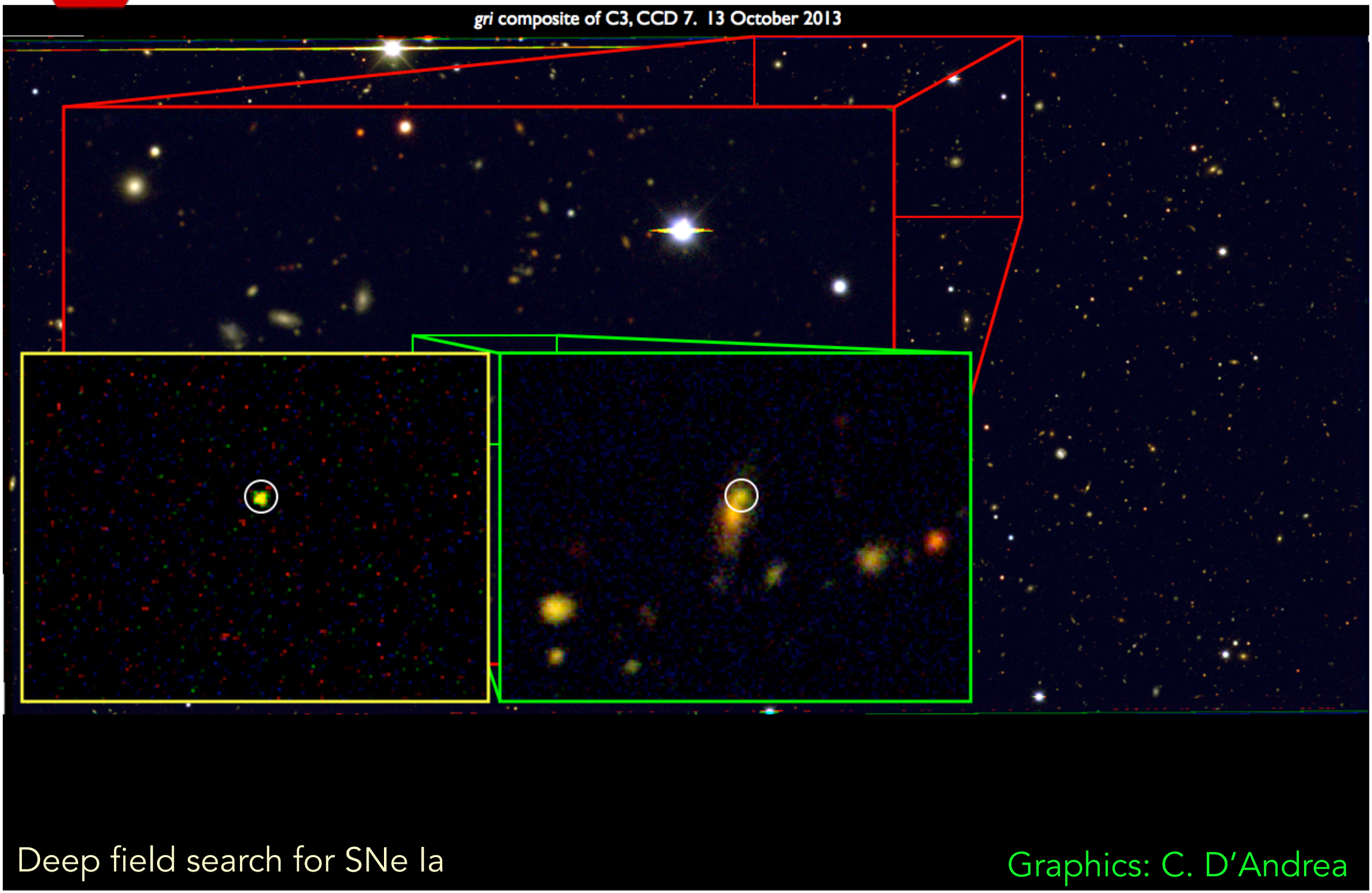
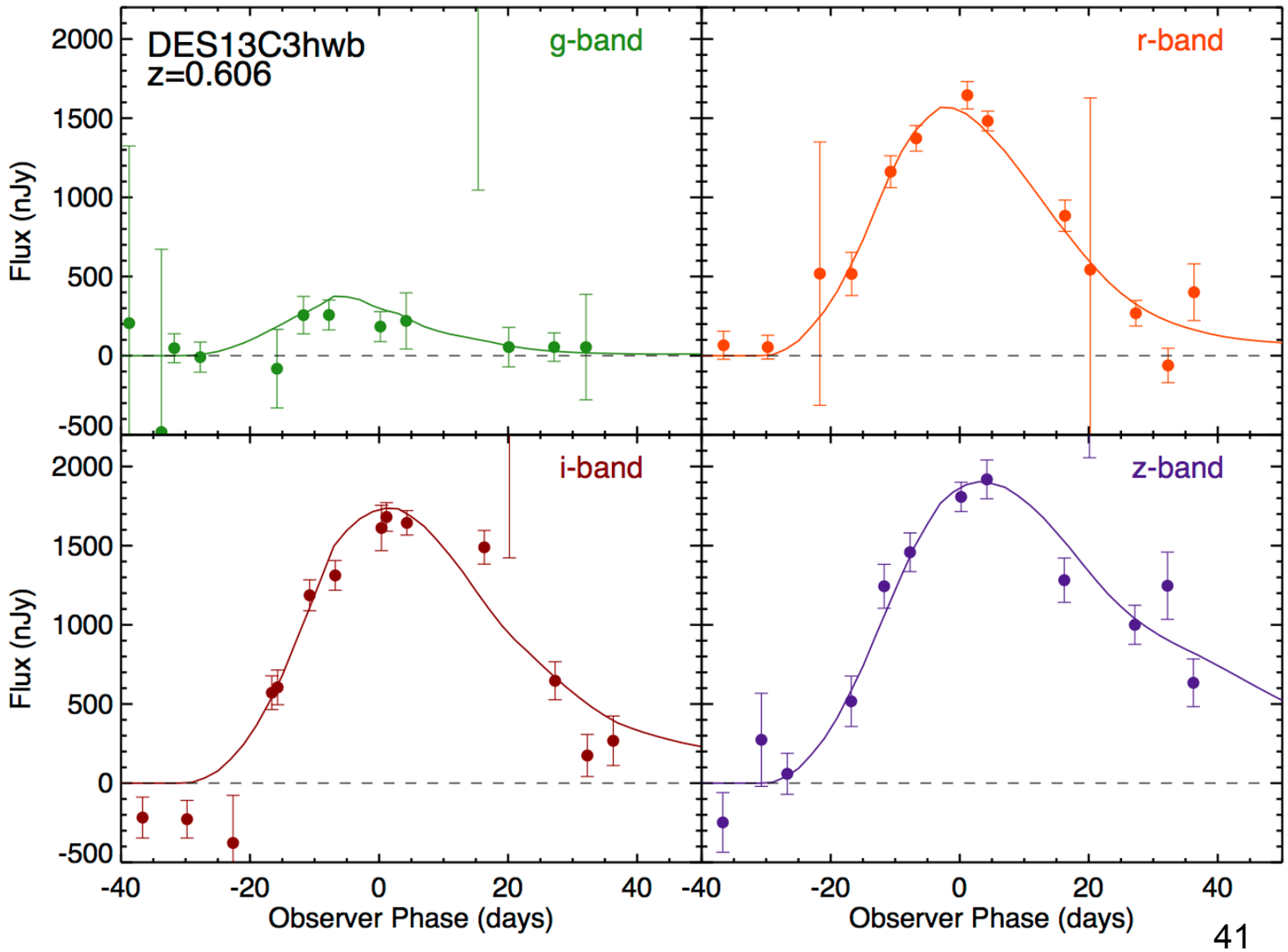


Type Ia SN search

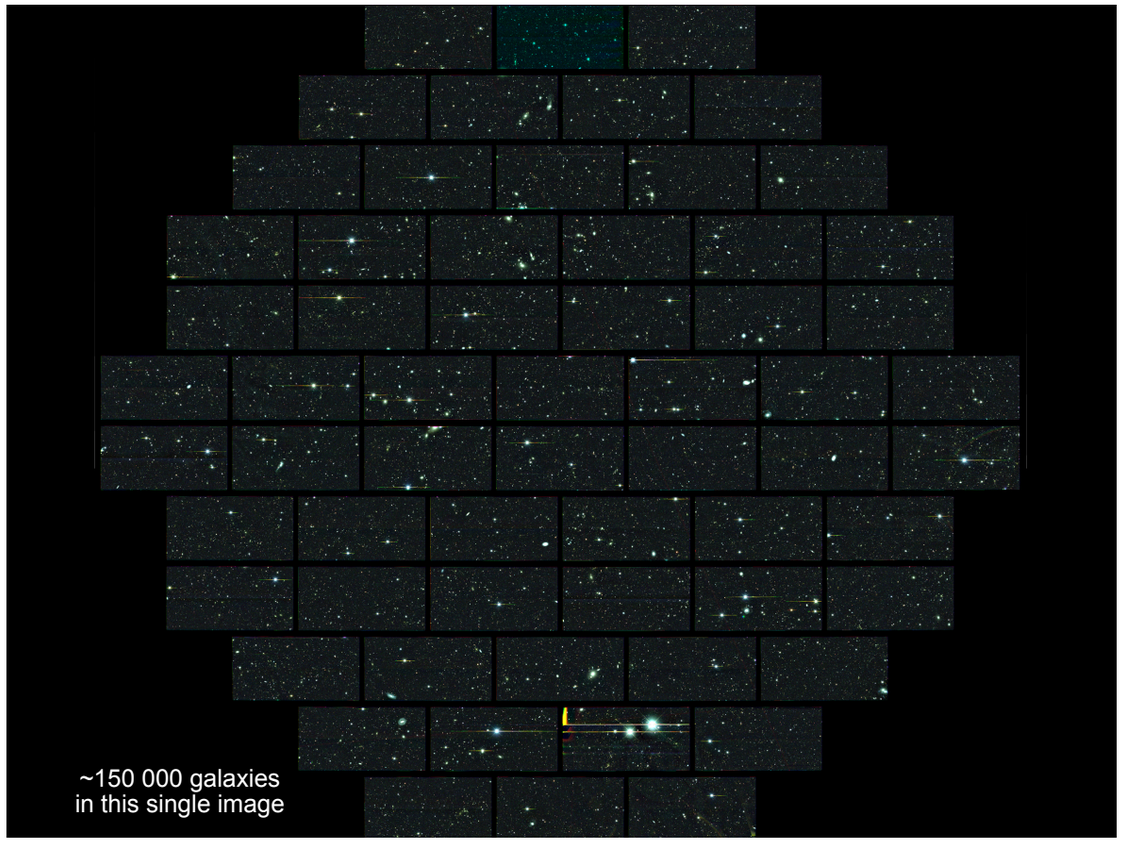
DES13C3hwb, SN-Ia at z=0.606



SN fields are oberved when seeing is bad or if they have not been recently observed.

41

Weak lensing and galaxy clustering



For each galaxy we have:

- Position
- Shape measurement

Angular power spectrum

$$C_\ell^{XY} \sim \int_0^{\chi_*} d\chi \underbrace{w^X(\chi) w^Y}(\chi) P(\ell/\chi, \chi)$$

- source distribution
- galaxy bias
- lensing efficiency, ...

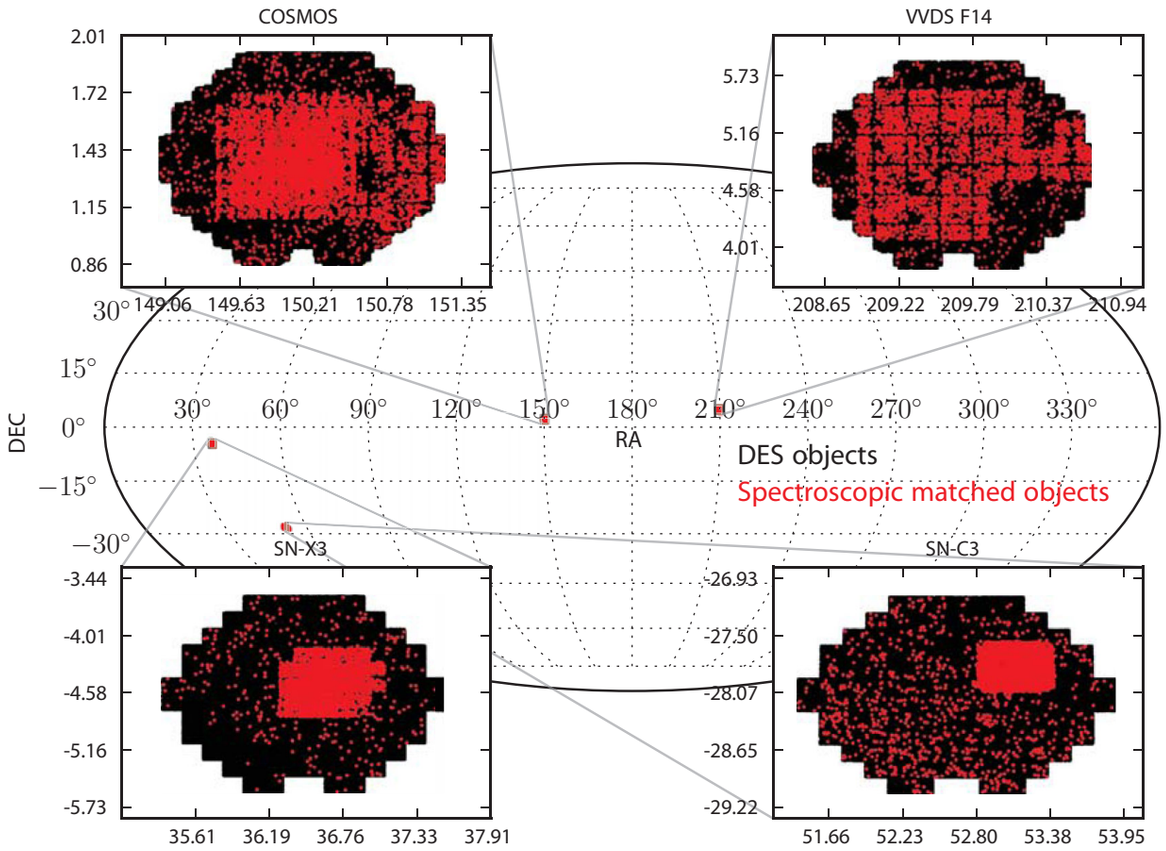
Many ingredients required, including:

- reliable photometric redshifts
- shape measurements for cosmic shear
- good control of systematics

Photometric redshift analysis in the Dark Energy Survey Science Verification data

MNRAS **445,** 1482–1506 (2014)

C. Sánchez *et al.*, 2014



15,000 spectroscopic galaxies used to calibrate/validate photo z's codes

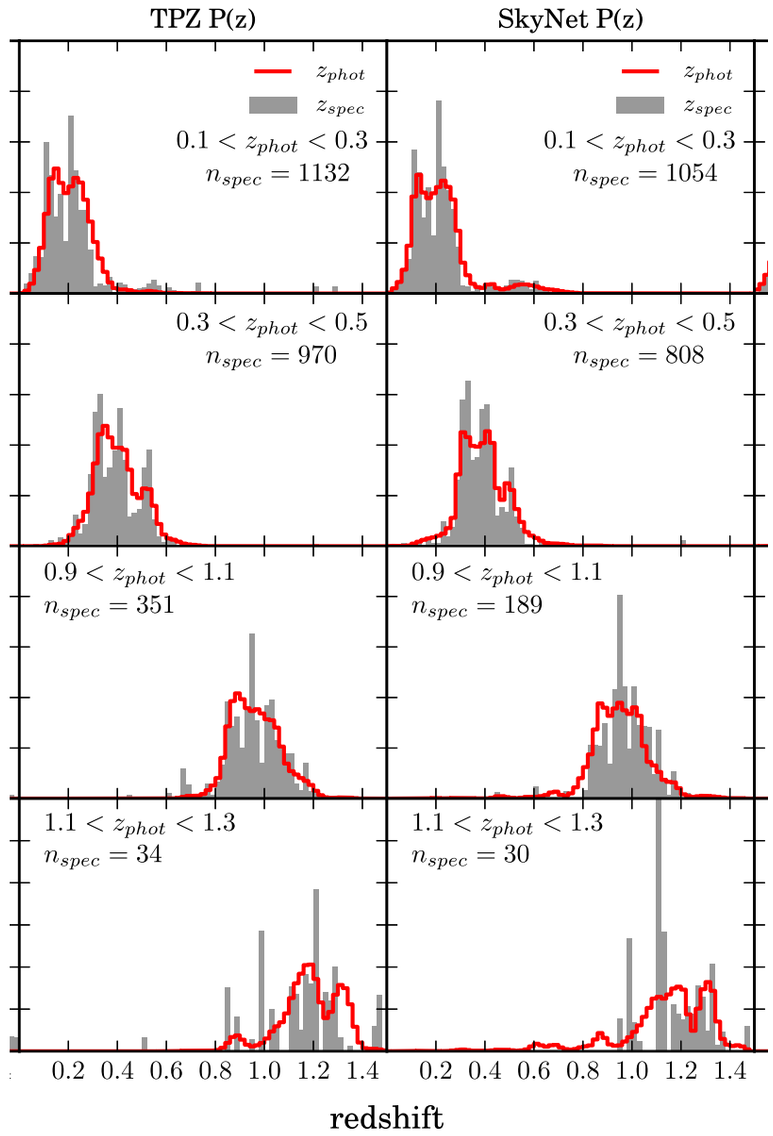
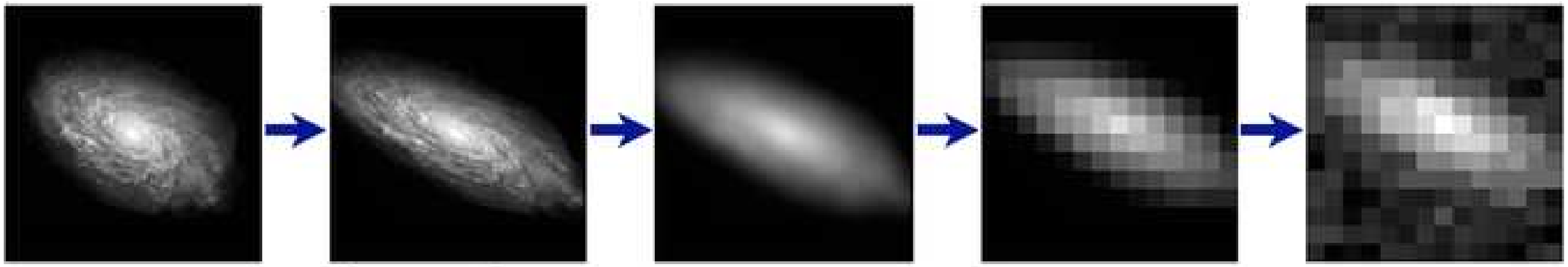


photo-z codes meet DES requirements, even with preliminary data

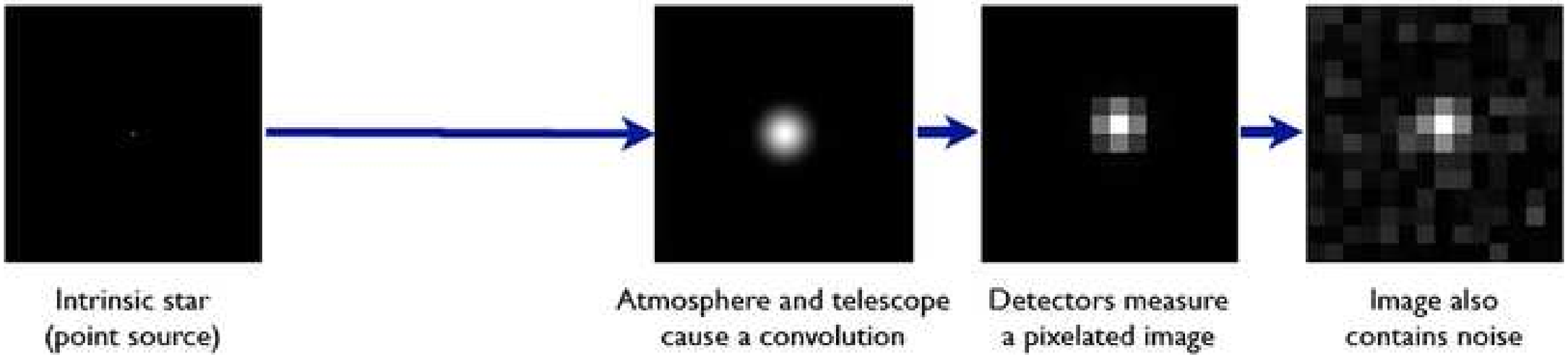
Shape measurements

The Forward Process.

Galaxies: Intrinsic galaxy shapes to measured image:



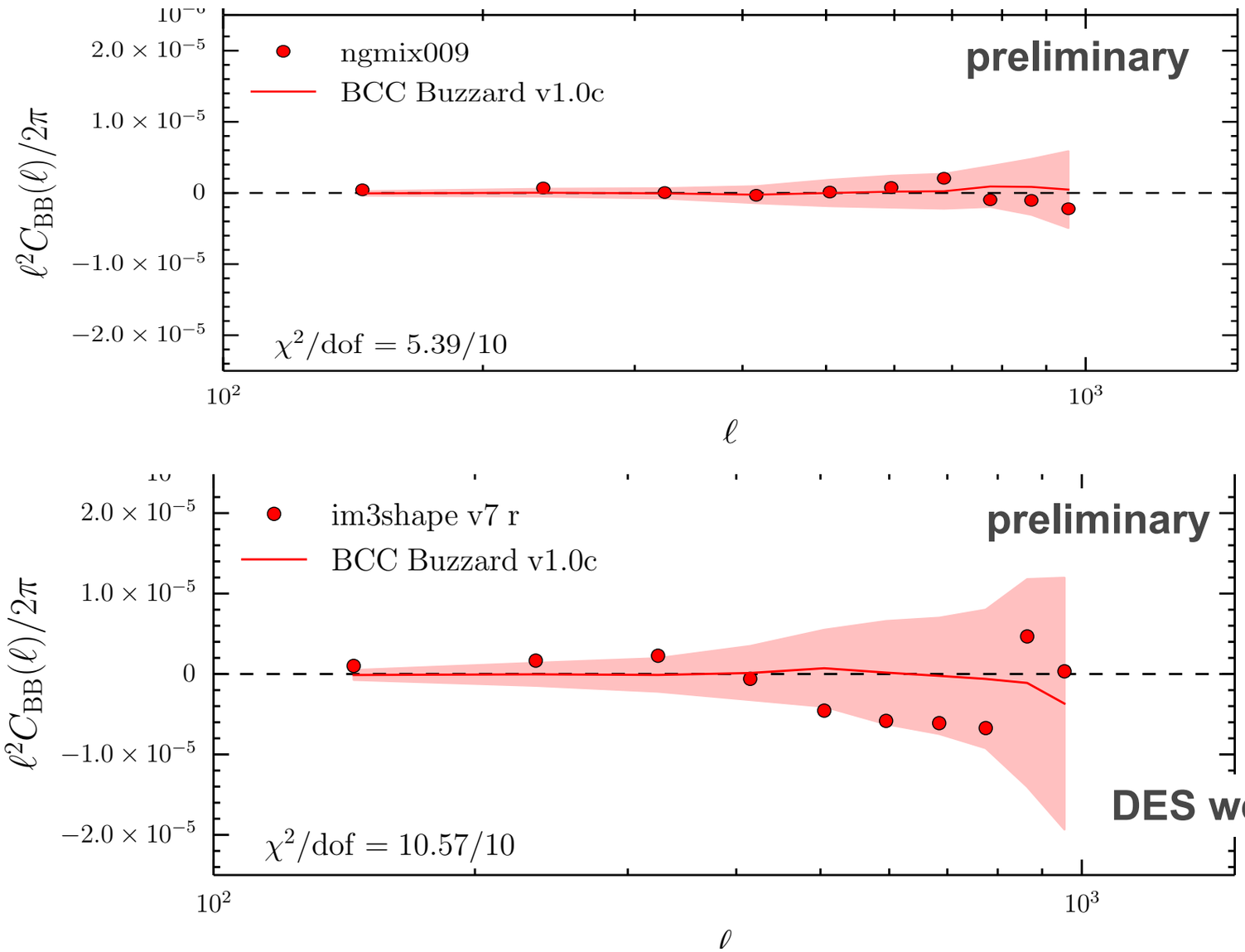
Stars: Point sources to star images:



HANDBOOK FOR THE GREAT08 CHALLENGE: AN IMAGE ANALYSIS COMPETITION FOR COSMOLOGICAL LENSING

Weak lensing

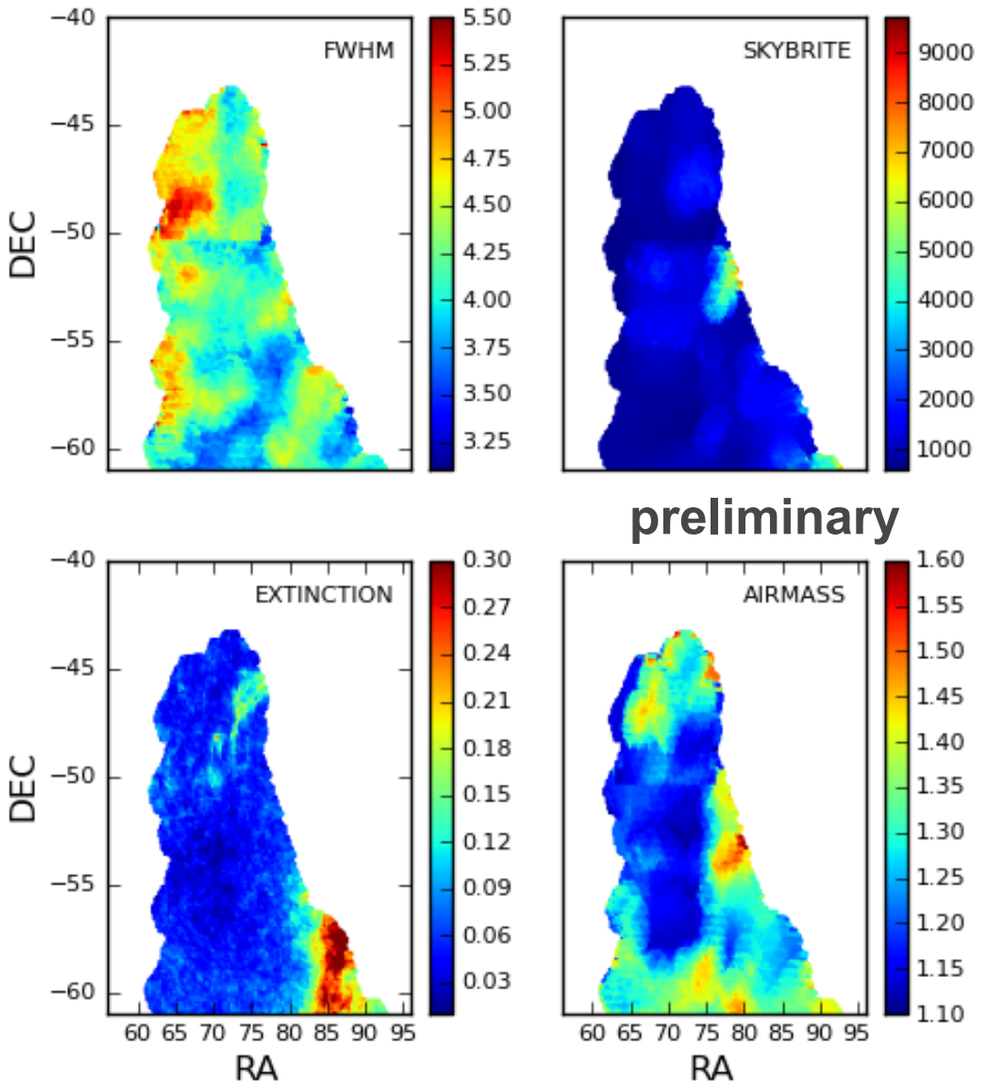
Shape measurements for cosmic shear with DES are good



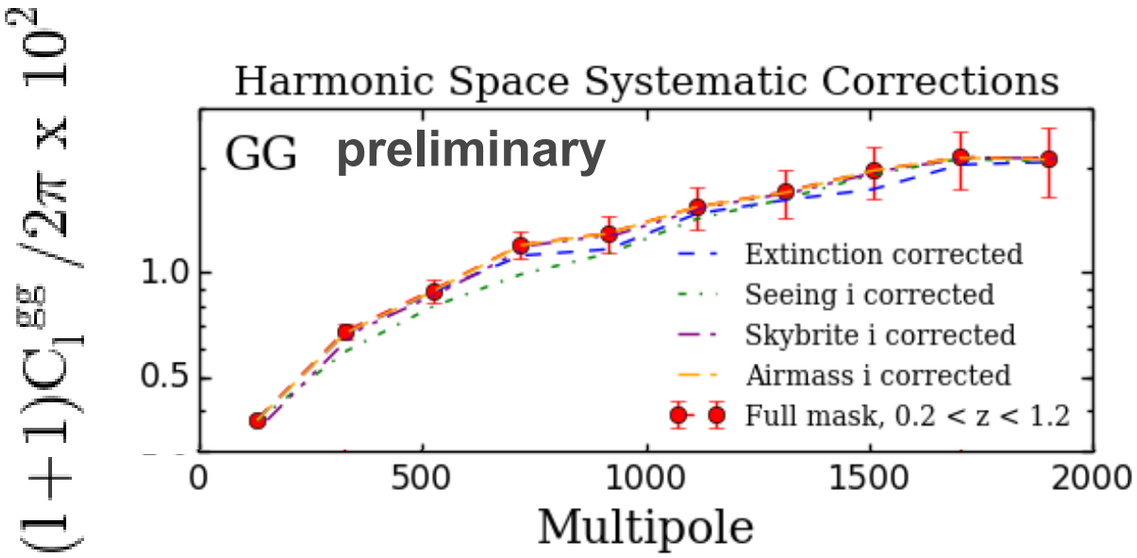
DES weak lensing WG

Shear B-mode are compatible with 0

Systematics maps



Systematic effects (atmosphere, dust) are mapped and projected out in the measurements



DES Large Scale Structure WG

Galaxy clustering

Galaxy selection

18.0 < *i* <22.5

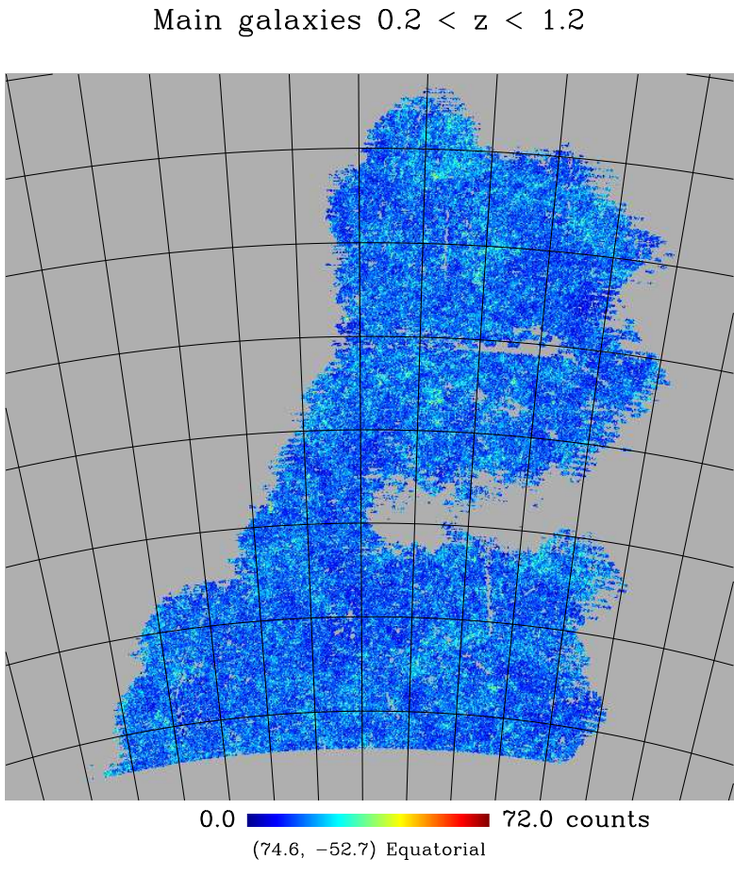
0.2 < photo-z < 1.2

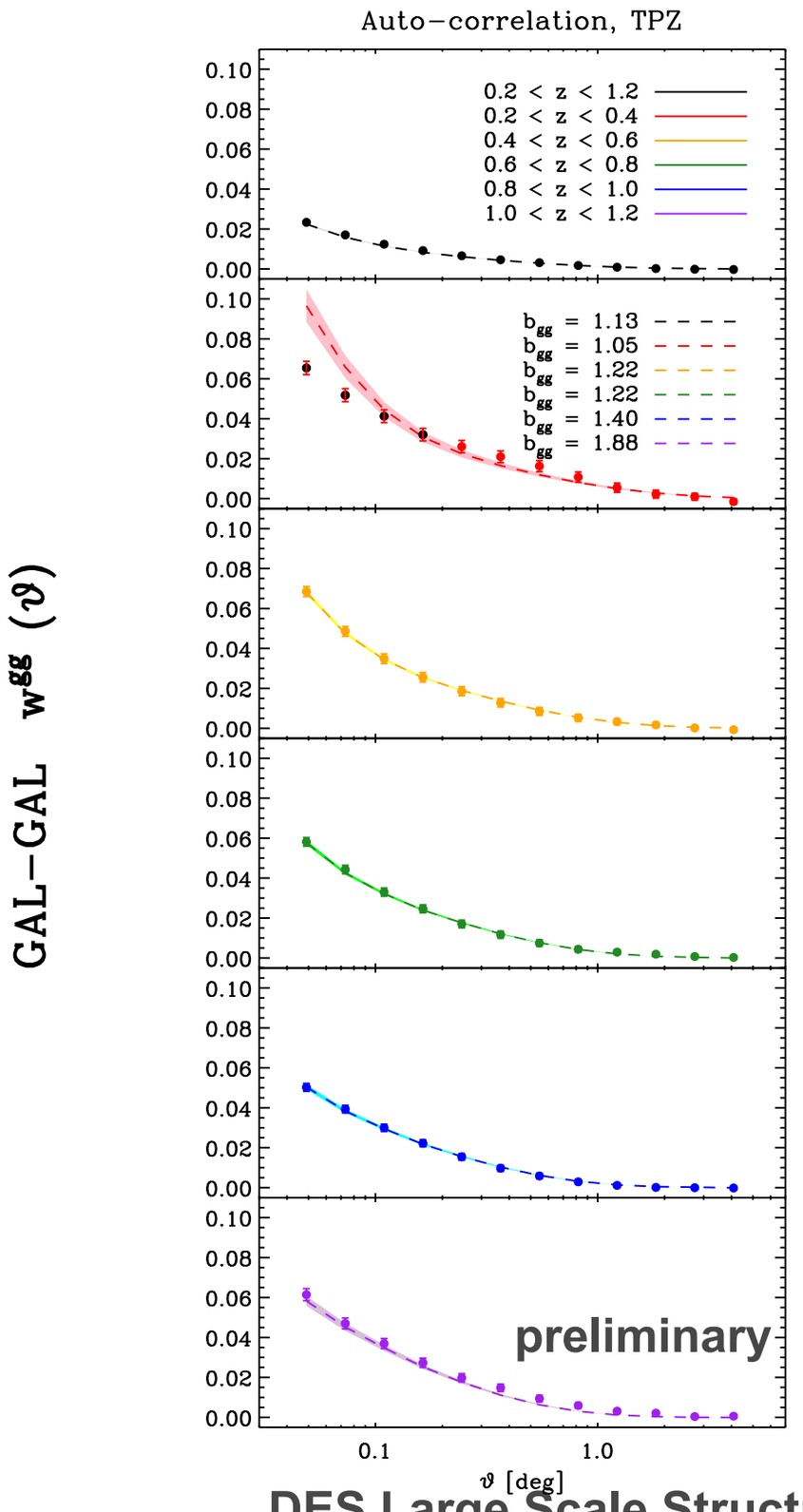
Star-galaxy separation

SPT-E field (130 sq. deg.)

~2.6 million galaxies

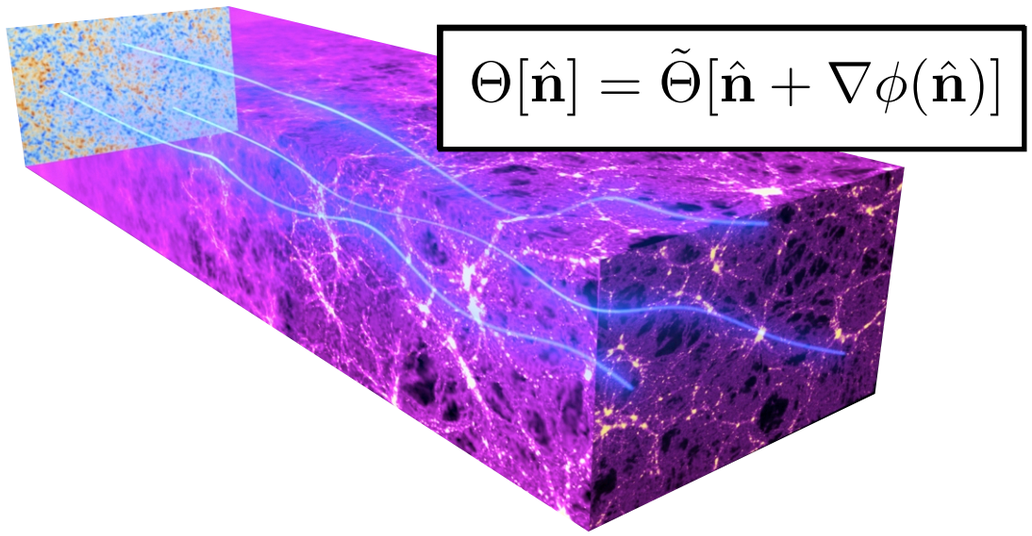
5.6 gal/ sq. arcmin



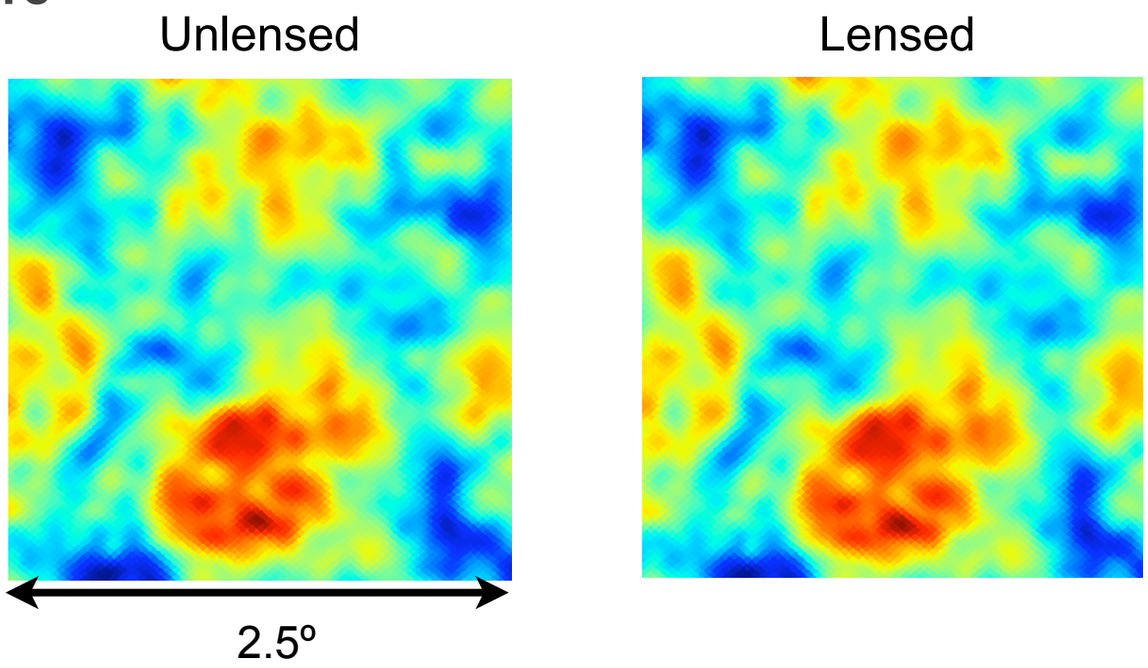


CMB is back: CMB lensing!

- **Photons from last scattering surface deflected by gravitational potential of large-scale structure**



$$\Theta[\hat{\mathbf{n}}] = \tilde{\Theta}[\hat{\mathbf{n}} + \nabla\phi(\hat{\mathbf{n}})]$$



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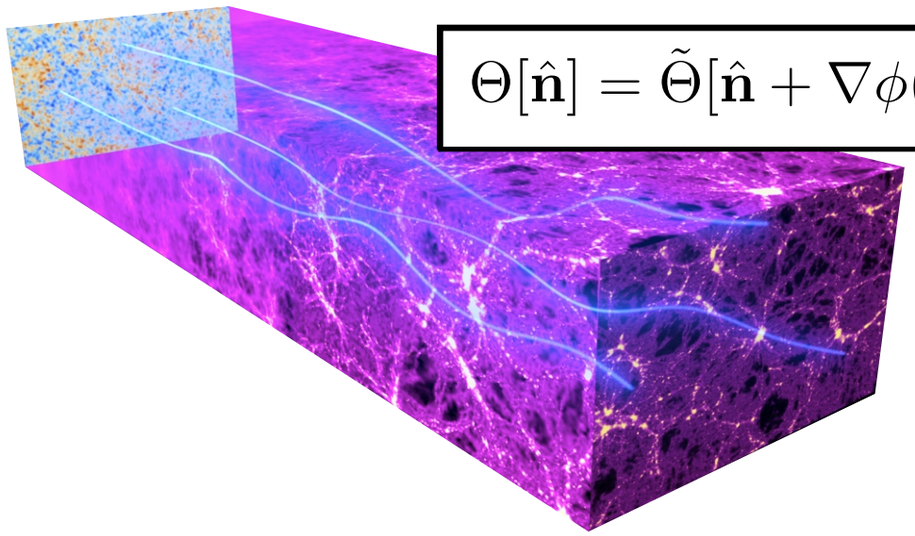

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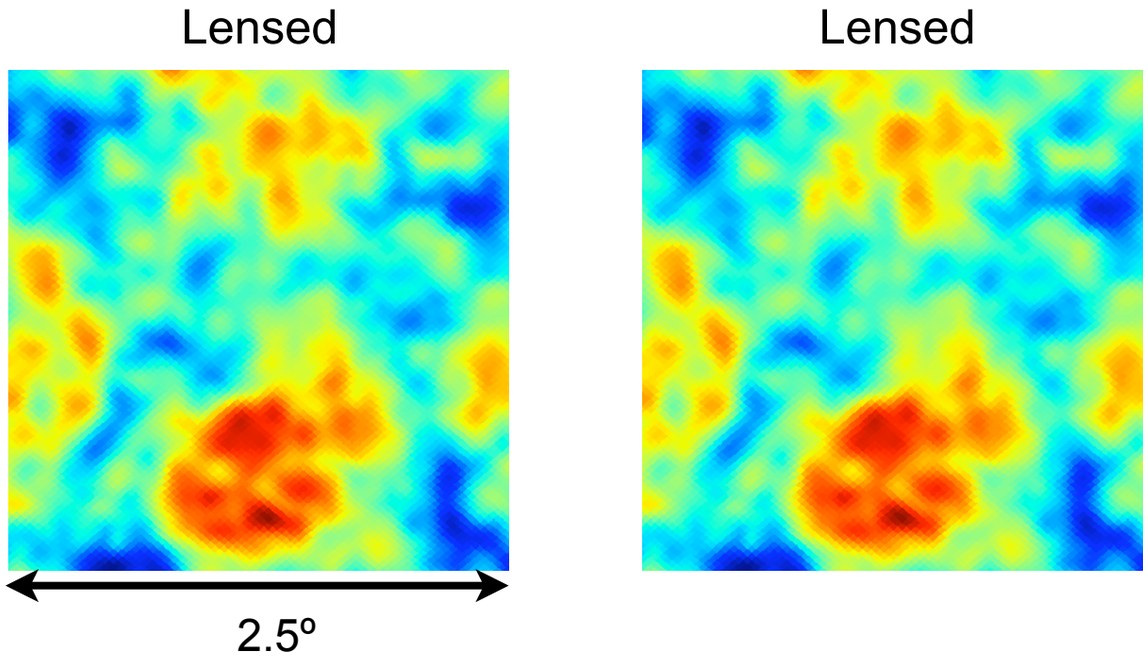

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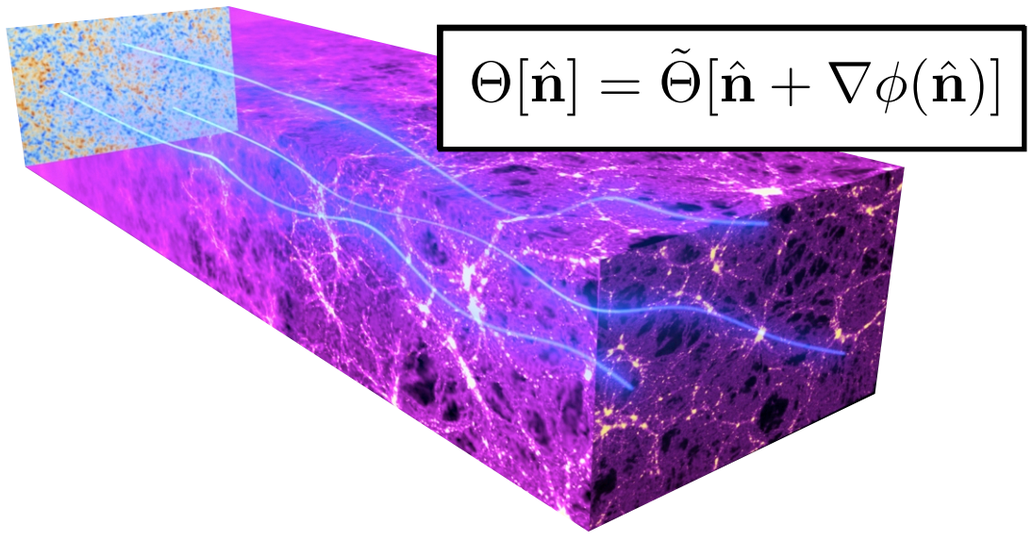

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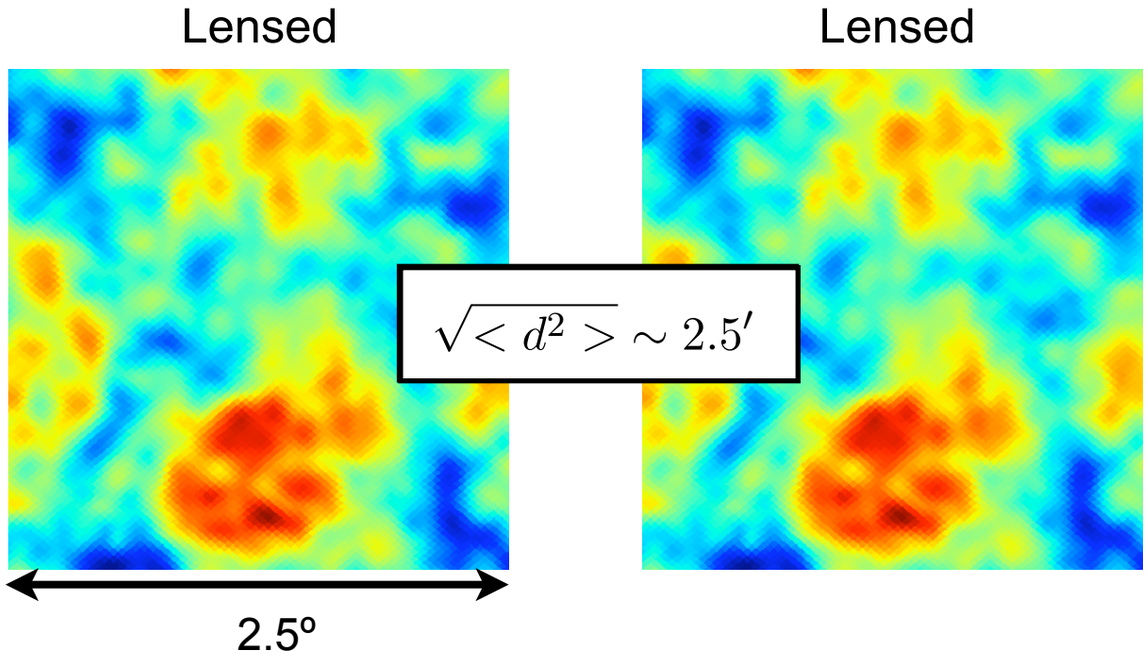


$$\phi(\hat{\mathbf{n}}) = -2 \int d\eta \frac{\chi(\eta - \eta_{\rm rec})}{\chi(\eta_{\rm rec})\chi(\eta)} \Psi(\chi\hat{\mathbf{n}}, \eta)$$

- Typical deflections: ~2.5 arcmin
- Coherent on the degree scale
- CMB lensing induces temperature-gradient correlations

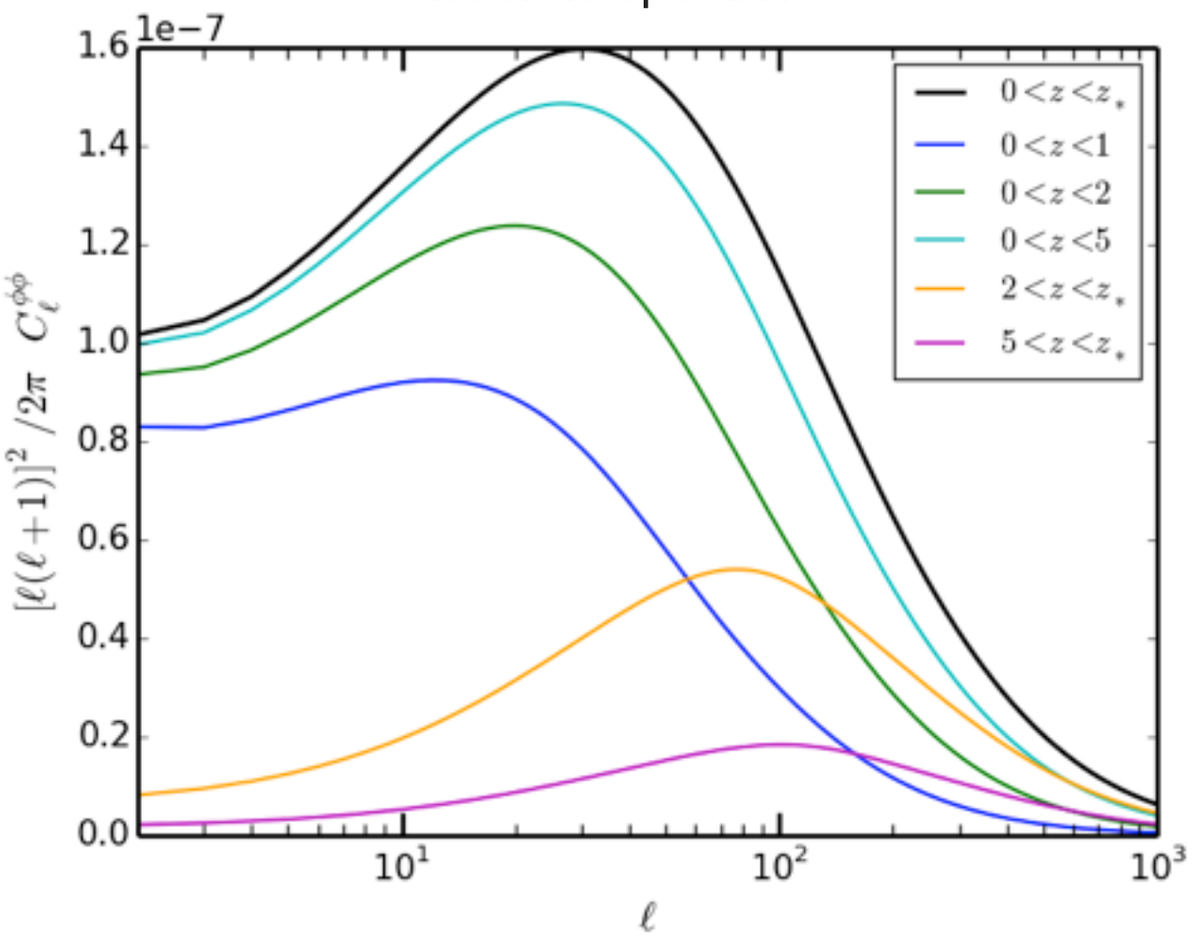
$$\Theta[\hat{\mathbf{n}}] = \tilde{\Theta}[\hat{\mathbf{n}} + \nabla\phi(\hat{\mathbf{n}})] \approx \tilde{\Theta}[\hat{\mathbf{n}}] + \nabla\phi[\hat{\mathbf{n}}]\ \nabla\tilde{\Theta}[\hat{\mathbf{n}}] + \cdots$$

Lensing potential reconstruction

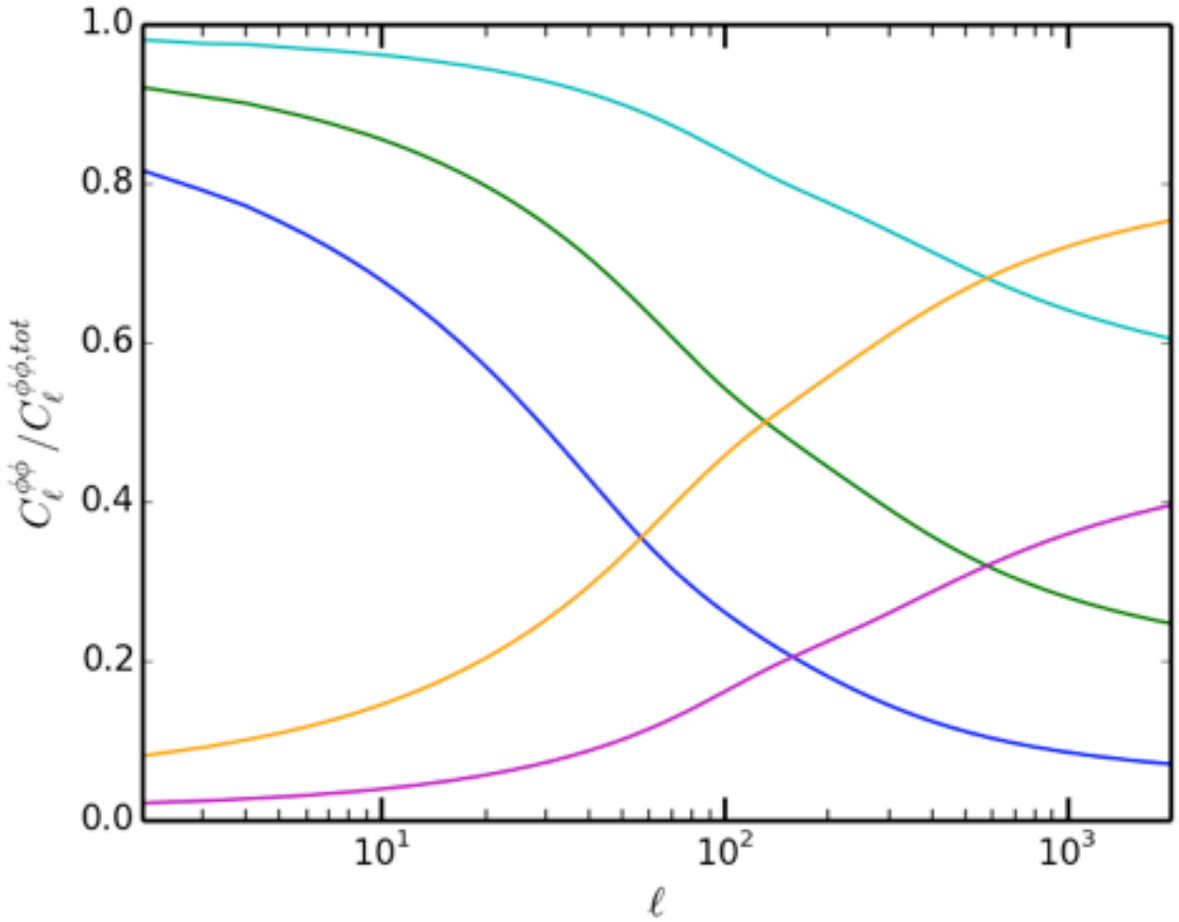
CMB lensing from South Pole Telescope and Planck

CMB lensing potential is an unbiased tracer of all the matter distribution up to z~1100

Absolute spectrum



Ratio

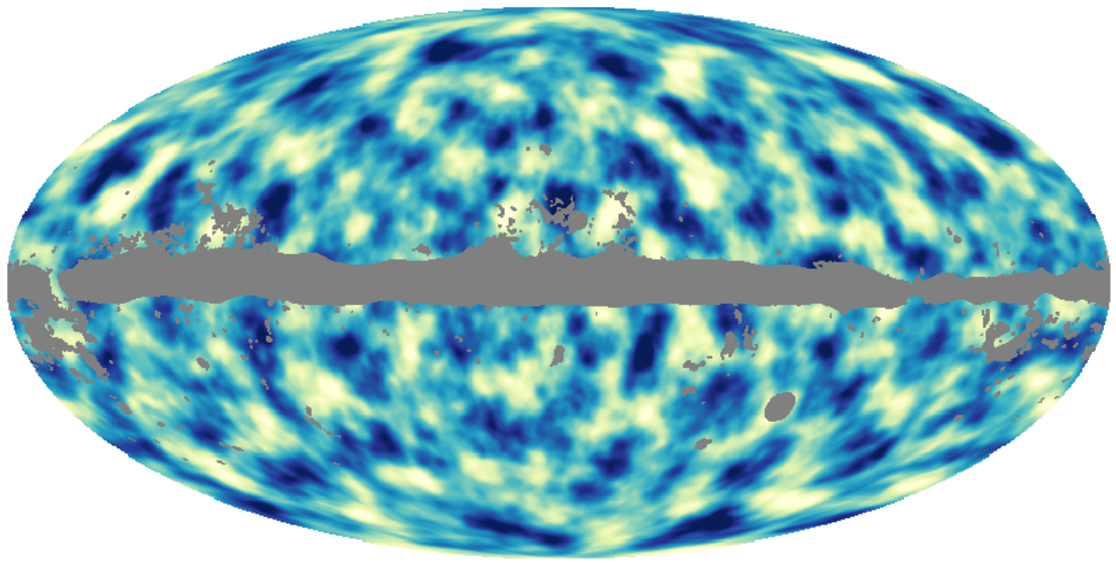


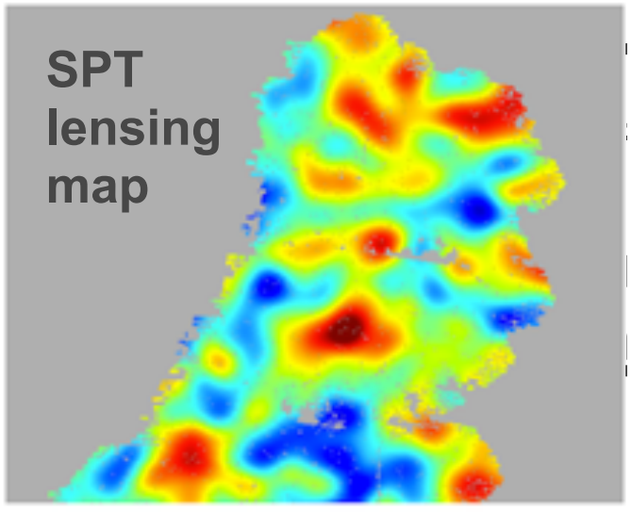
CMB Lensing kernel is wide and peaks at z ~2

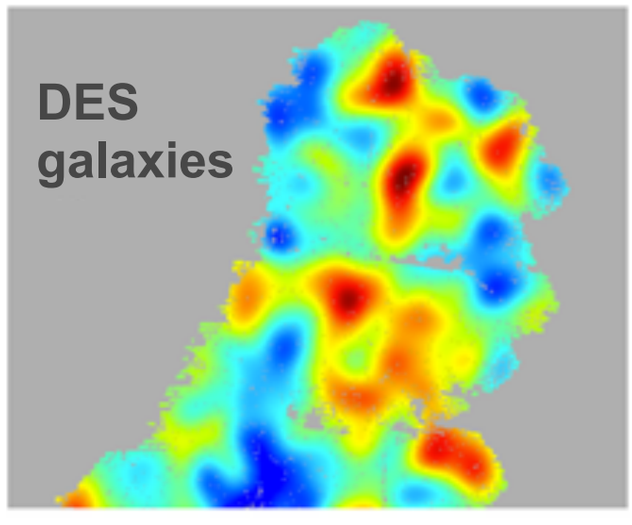
DES will enable CMB lensing tomography

CMB is back: CMB lensing!

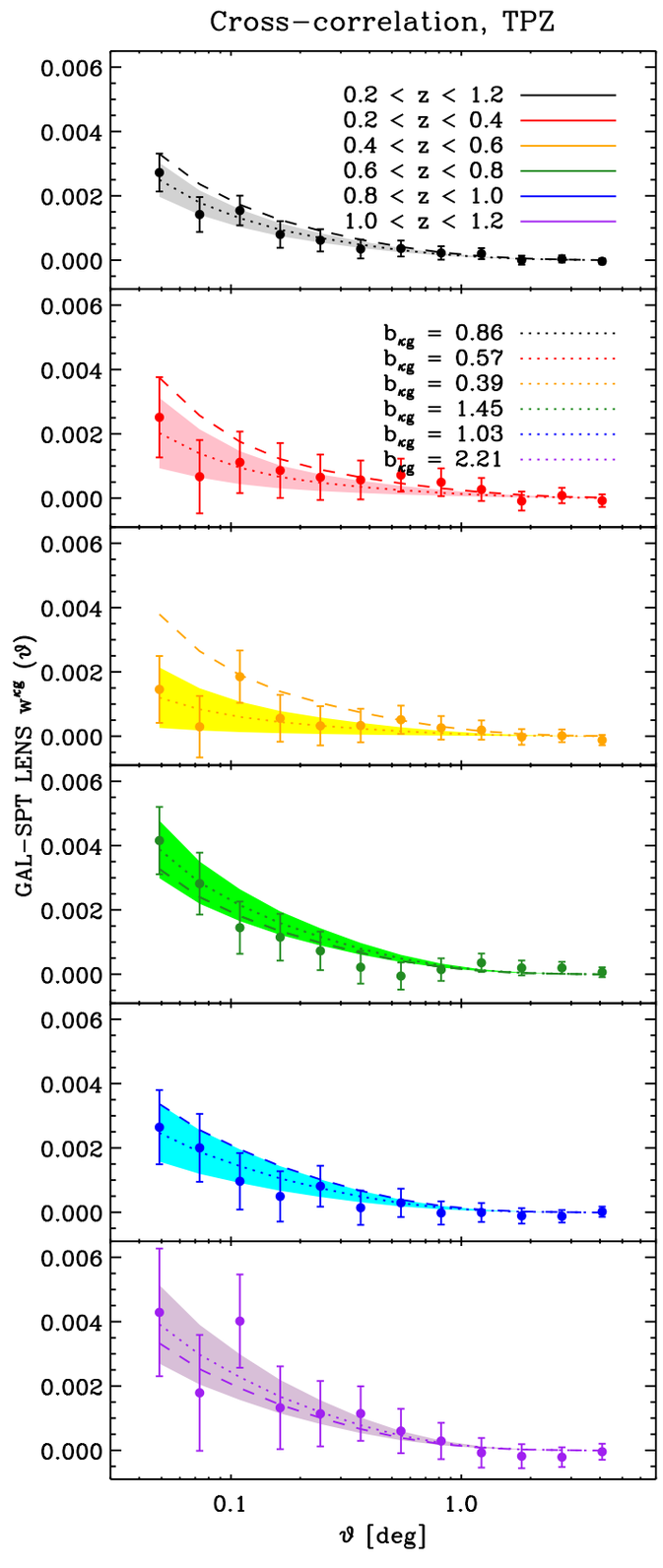
Planck full-sky lensing potential







Thanks to DES depth CMB lensing tomography.
Coming soon!



Science papers in preparation with SV data

Galaxy Clustering and validation against CFHTLS

DES SV Galaxies cross-correlated with CMB lensing

SPT-SZE signature of DES SV RedMaPPer clusters

Galaxy Populations within SPT Selected Clusters

DES/XCS: X-ray properties of galaxy clusters in DES SV

The Dark Energy Survey SV Shear Catalogue: Pipeline and tests

Calibrated Ultra Fast Image Simulations for the Dark Energy Survey

The Dark Energy Survey Supernova Survey: Search Strategy and Algorithm

Wide-Field Mass Mapping with the DES SVA1 data

Galaxy bias from cross-correlation of weak lensing and galaxy maps in DES SVA1 data

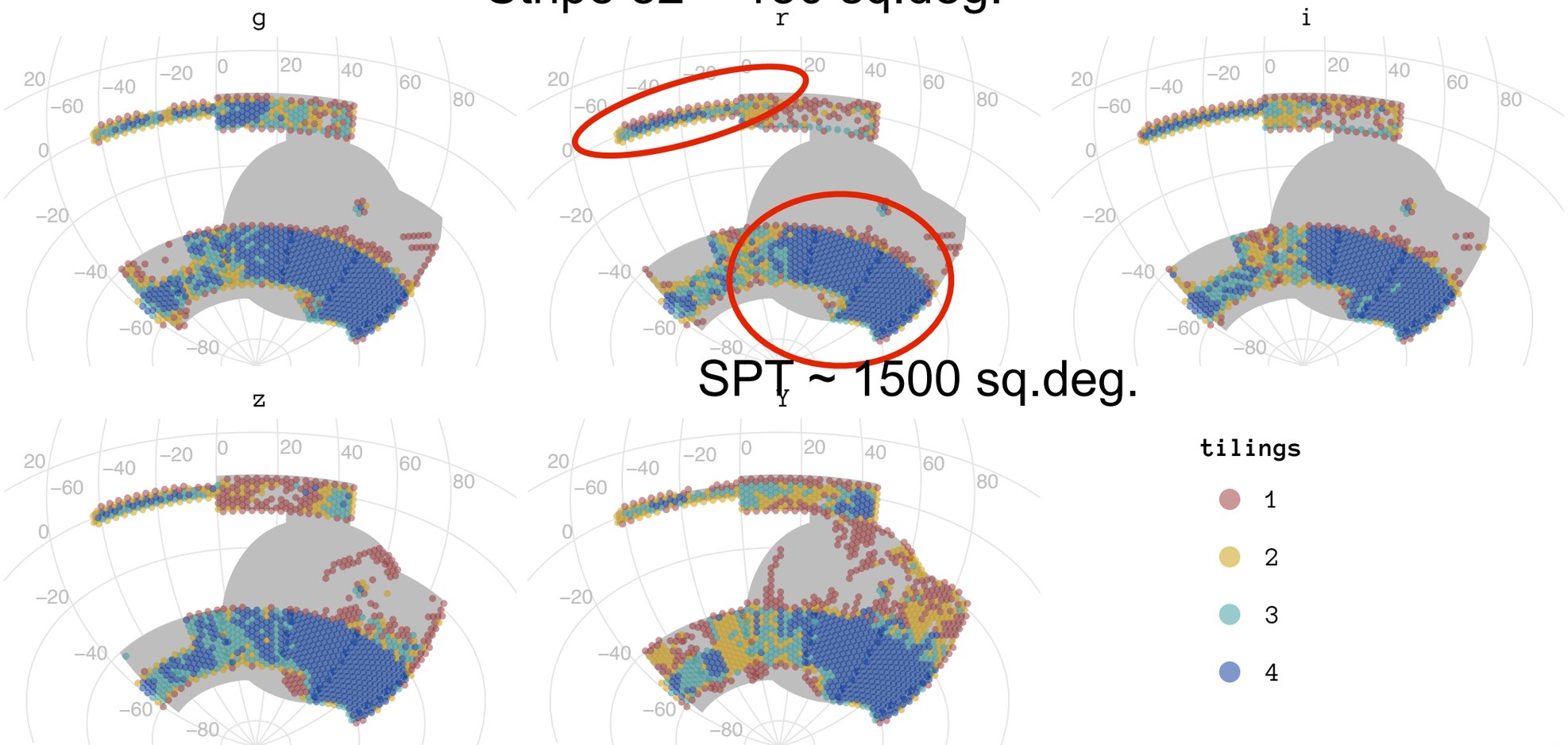
Measurement of galaxy bias and stochasticity in DES SVA1 data

Galaxy-galaxy lensing with the DES SVA1 data.

etc., etc.

Aug. 2013 - Feb. 2014 (105 nights): 1st year campaign

Stripe 82 ~ 150 sq.deg.



SPT ~ 1500 sq.deg.

E. Nielsen

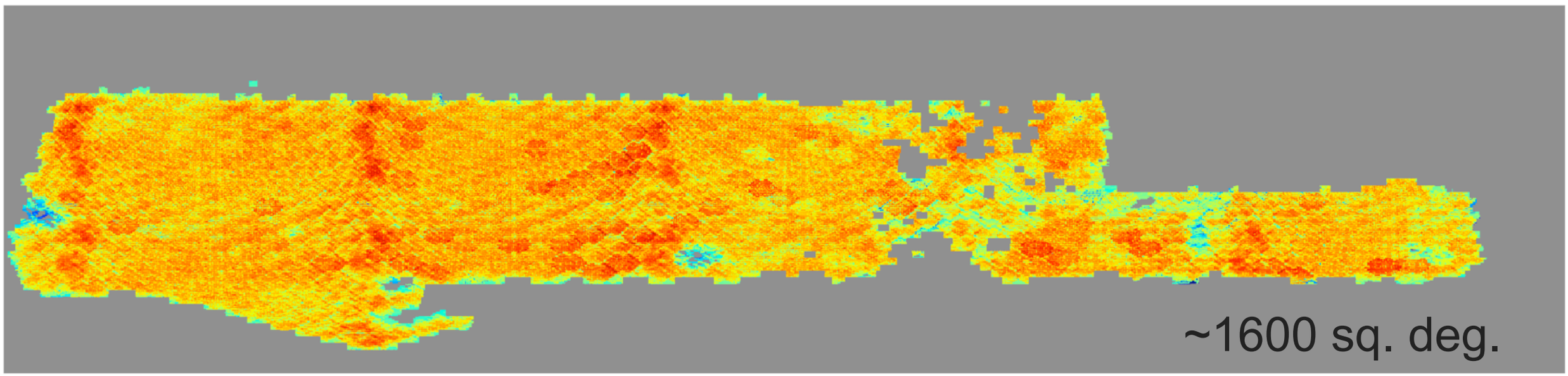
Data is released to the collaboration

2

Aug. 2013 - Feb. 2014 (105 nights): 1st year campaign

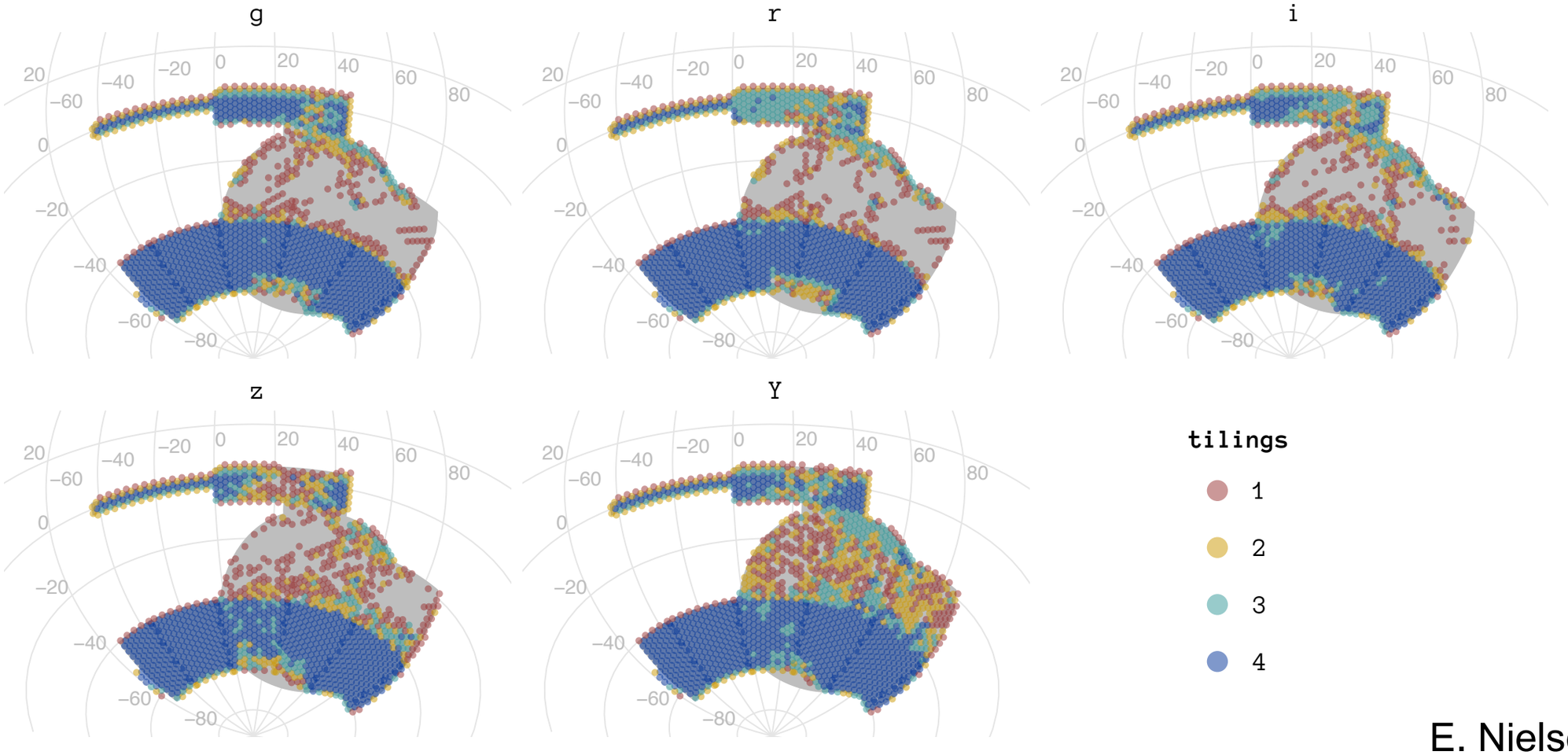
Mangle mask

10sig. limiting magnitude in a 2” diameter aperture



Aug. 2013 - Feb. 2014: 2nd year campaign (on-going)

aim: 5000 sq.deg. at 4 tilings



E. Nielsen

Current wide-survey exposures completed (as of mid Nov 14)

Conclusions (I)

DES started operation in August 2013, end planned in 2018

Preliminary Science Verification data have enough quality to do science:

- Photo-z required precision reached
- Measure galaxy shapes around clusters
- Cosmic shear B-modes consistent with zero
- Clustering measurement in line with previous results

DES papers submitted and published. More to come soon.

Year 1 data is released to the collaboration

First competitive scientific results expected from first 2 seasons of data

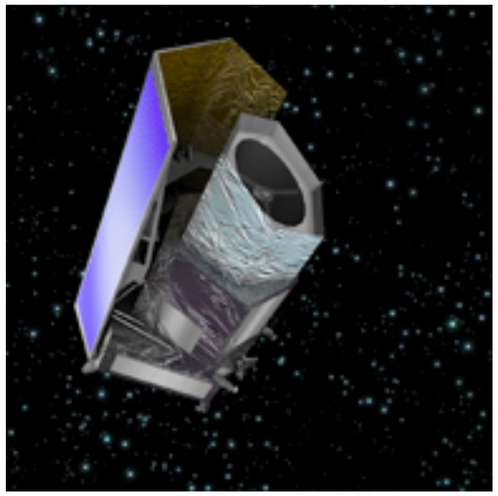
More coming soon!

Conclusions (II)

DES paves the way for larger photometric and spectroscopic surveys

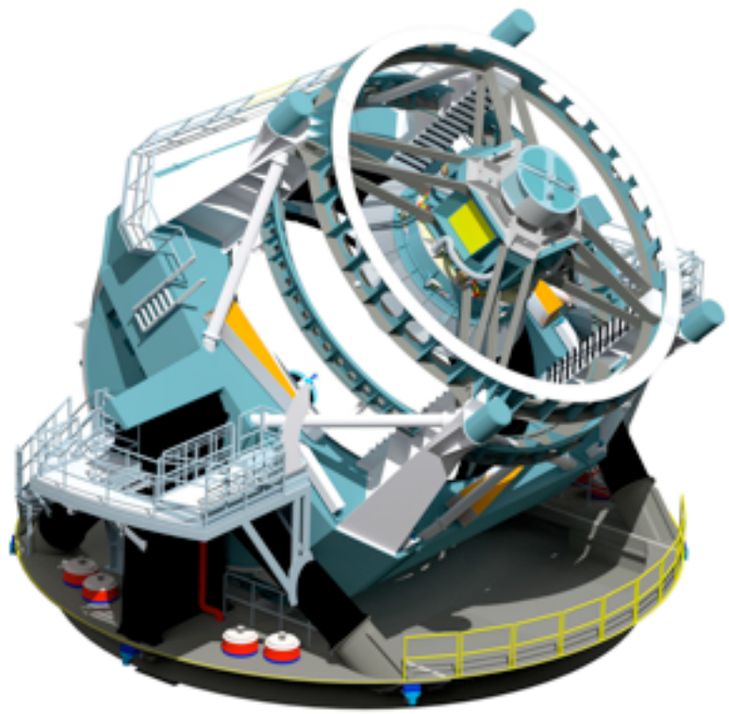
Euclid

- satellite,1.2m mirror, 2 instruments : visible, infrared
- shape measurements for 1 billion de galaxies
- photometric redshift provided by ground observatories DES
- spectroscopic redshift for 50 millions galaxies
- launch ~ 2020



LSST

- 8.4 meter telescope in Chile
- 3200 megapixel camera, 9.6 sq.deg. field-of-view
- 6 photometric bands (ugrizY), deep r~27.5 coadd
- 20,000 sq.deg.
- data taking ~ 2020



Exciting times ahead!

DES 5yr VS Euclid footprint