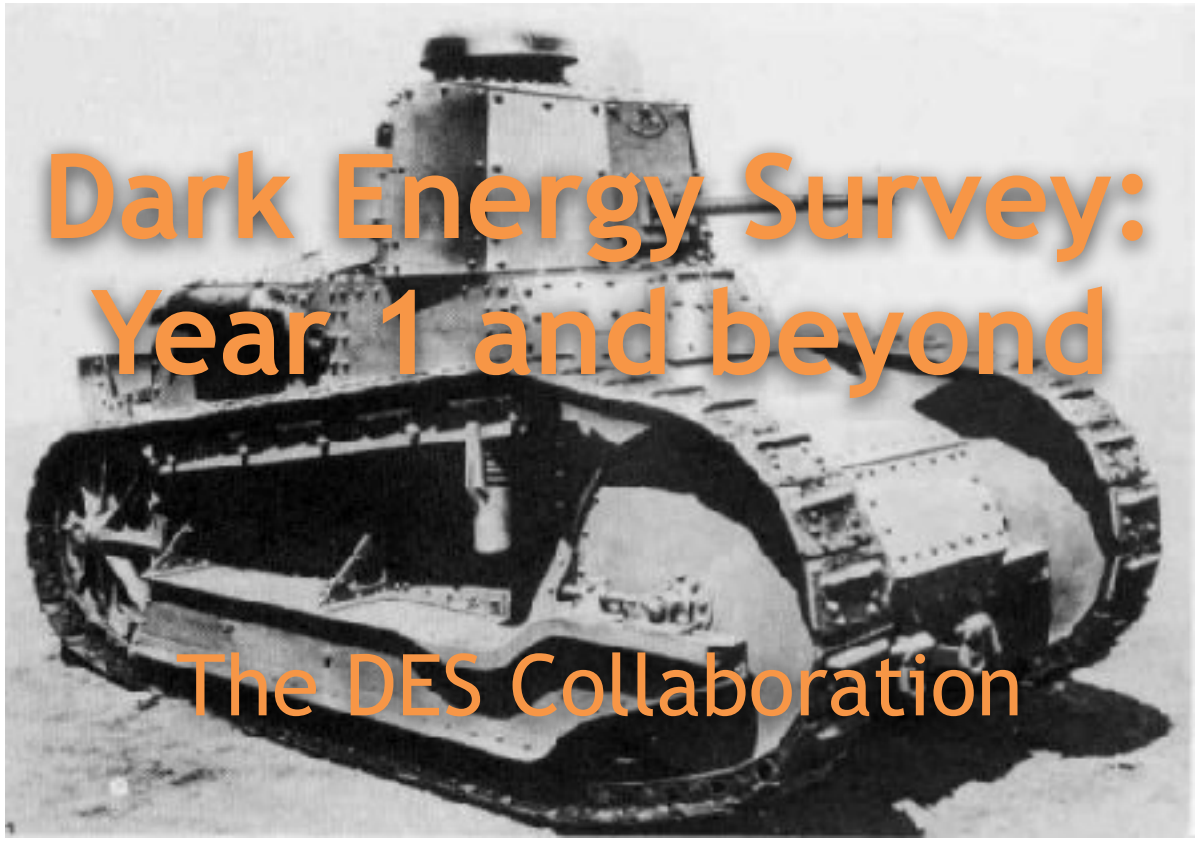
DARK ENERGY SURVEY

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
EXCELENCIA MARÍA DE MAEZTU
CIEMAT física de partículas



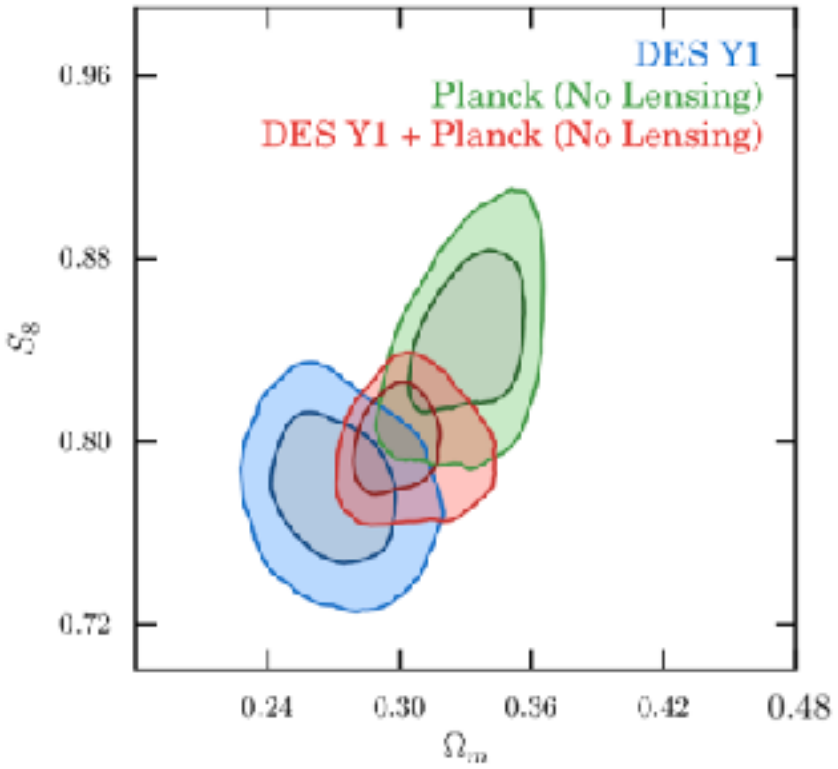
Dark Energy Survey: Year 1 and beyond

The DES Collaboration

Nacho Sevilla-Noarbe (CIEMAT)

XI ESTALLIDOS Workshop 2018

A spoilery teaser slide



Come work with us in the next generation of exciting results!

DES-Y1 on its own is compatible with high-z inferred cosmological parameters

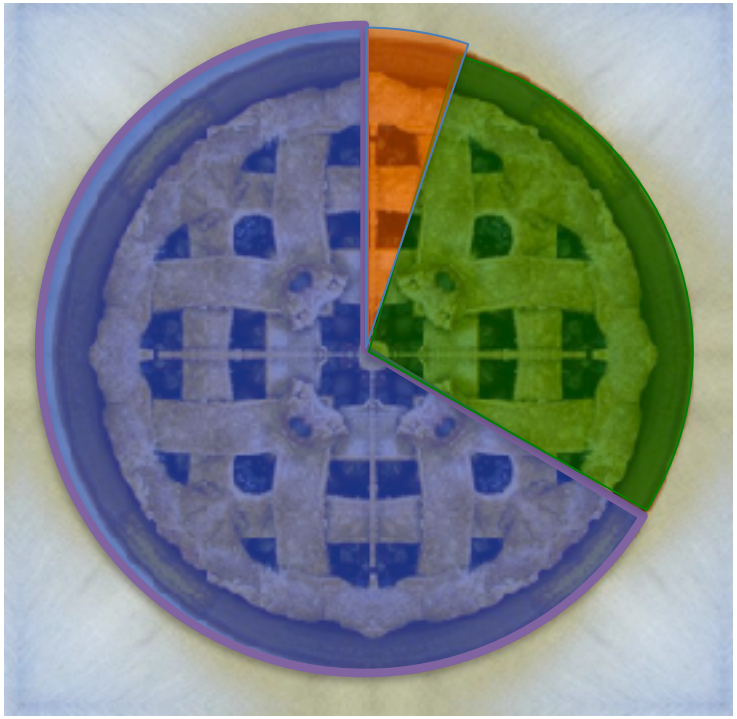
BAO and SNe measurements point to a fascinating w=-1 universe!

Y3 catalogs available **since January** (DR1)

Current cosmological model accounts for all observations

The so-called **ΛCDM model describes** the observed Universe and dynamics at large scales.

Cosmic pie



Atoms 5%
Dark Matter 25%
Dark Energy 70%

Assumptions:
Homogeneity and isotropy

Initial conditions:
Big-Bang origin (+ inflation)

Evolution:
General Relativity

Quantum fluctuations →Large Scale Structure
Cold Dark Matter 'seeds' of structure
Acceleration in recent times (cosmo. constant)

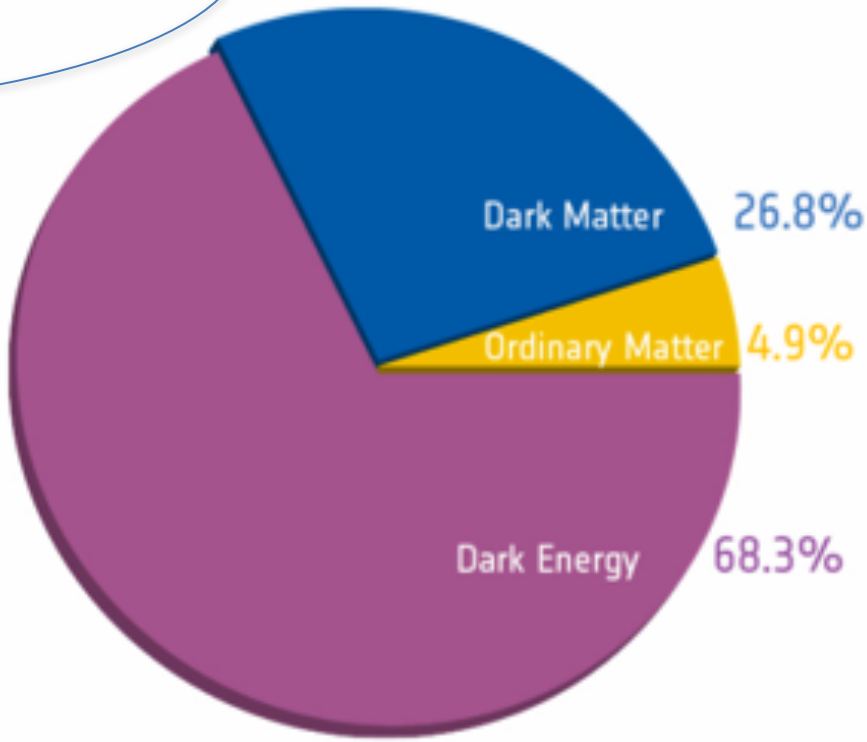
Only six parameters!! (Ω_b,Ω_m,Ω_ν,h,n_S, Δ)

Cosmology provides an astonishing picture of the contents of the Universe

Si hubiera estado presente en la Creación, habría dado algunas indicaciones útiles



Alfonso X el Sabio



A few equations describe the content and evolution of the Universe

$$\frac{H^2}{H_0^2} = \Omega_R a^{-4} + \Omega_M a^{-3} + \Omega_\Lambda$$

Dynamical evolution (Friedmann equation)

$$w = \frac{p}{\rho}$$

Dynamical behavior (equation of state)

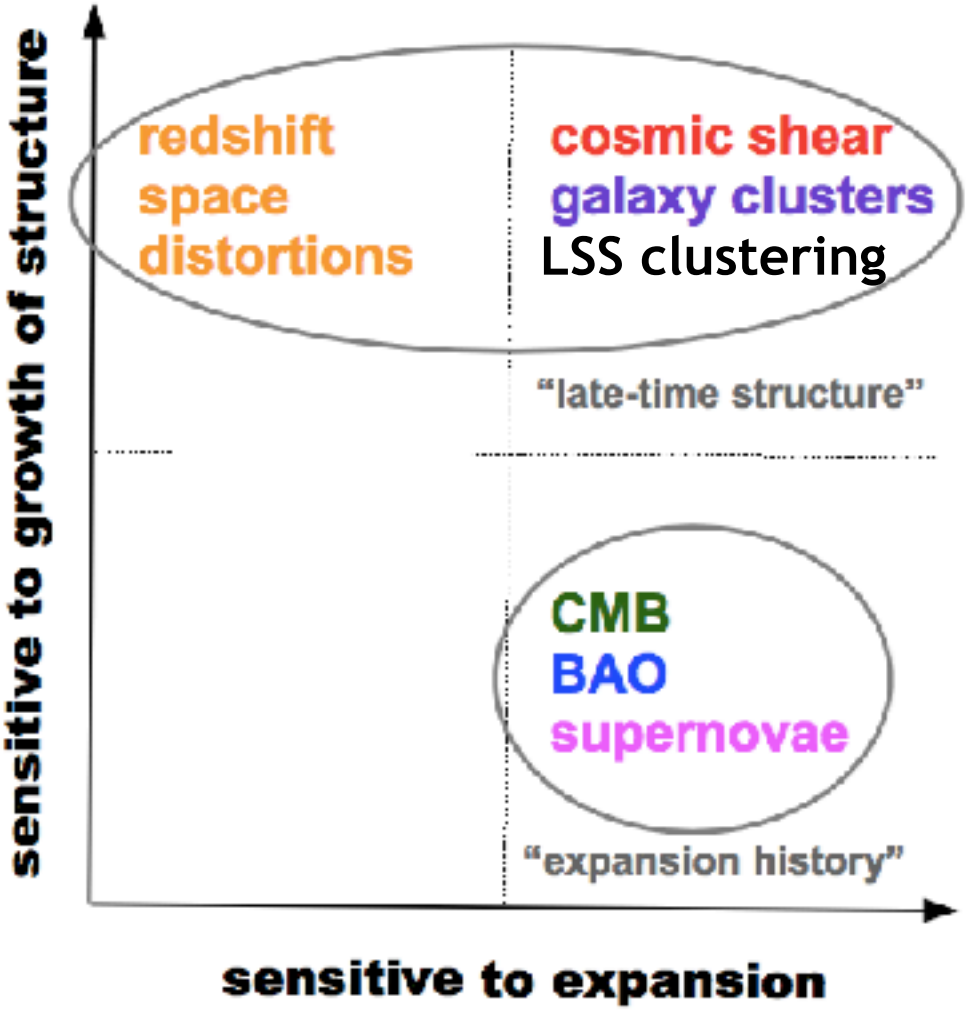
$$\Delta^2_{\mathcal{R}}(k) = \Delta^2_{\mathcal{R}}(k_*) \left[\frac{k}{k_*}\right]^{n_S - 1}$$

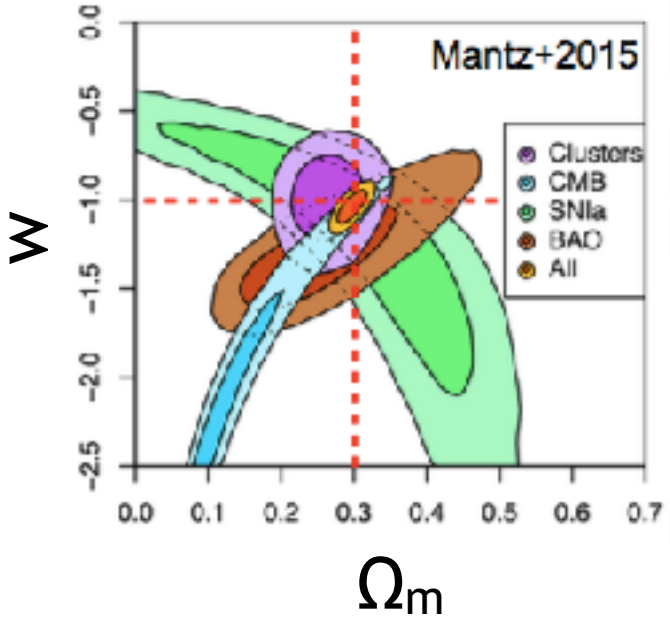
Perturbation description (power spectrum)

$$\sigma^2 = \frac{1}{2\pi^2} \int dk\, k^2 P(k,z) |W(kR)|^2$$

σ_8 ; $S_8 = \sigma_8 \left(\frac{\Omega_m}{0.3}\right)^{0.5}$

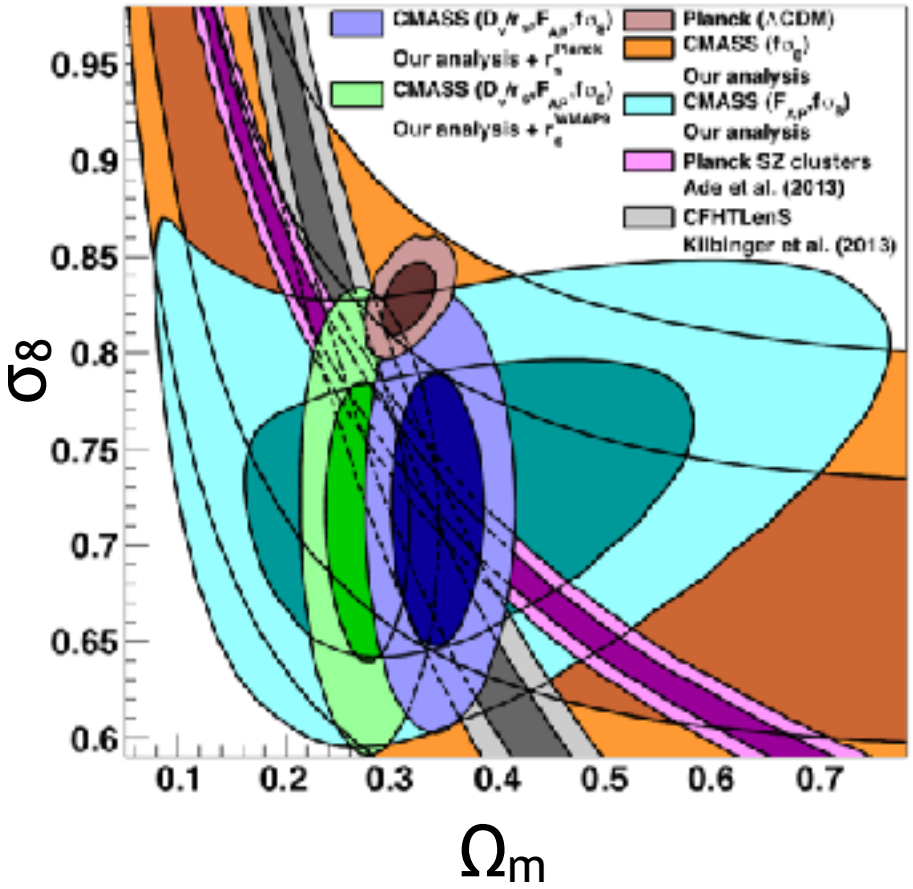
Two ways to survey Dark Energy

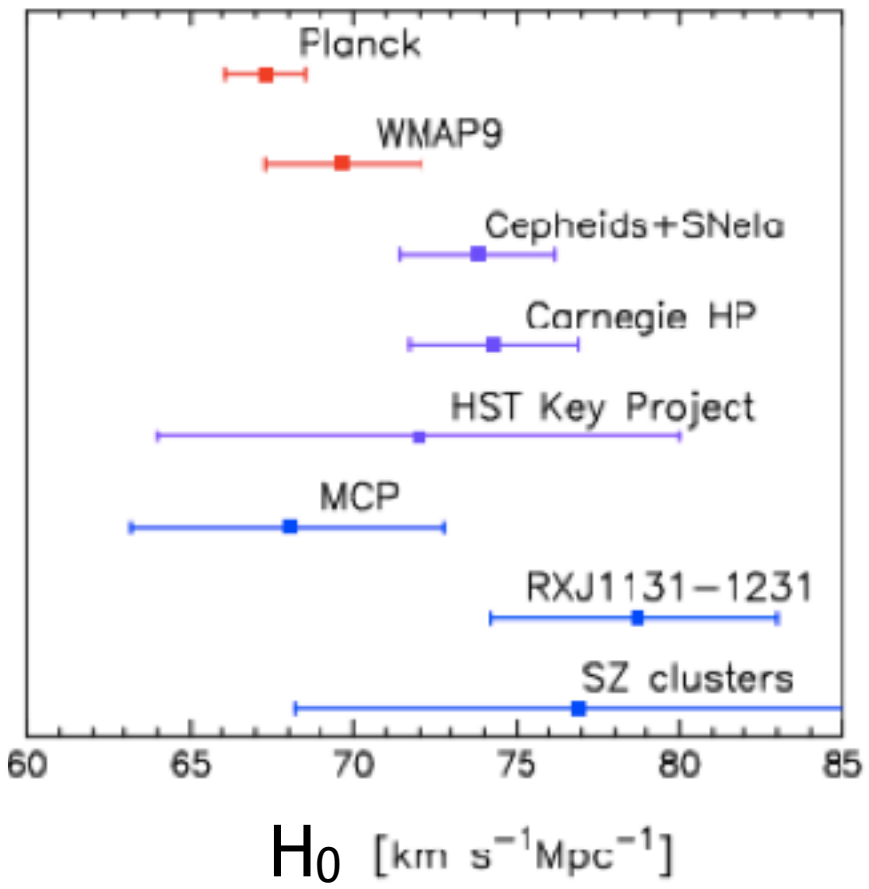




Do all these measurements agree?

Some slight inconsistencies have shown up





Beutler et al. 2014

The Planck Collaboration: Ade et al. 2014

The triple consistency question

- Consistency with ΛCDM.
- Consistency among probes of expansion and growth of structure.
- Consistency between high-z and low-z measurements.

The Dark Energy Survey is …

… a 1” resolution map of 1/8 of the southern sky

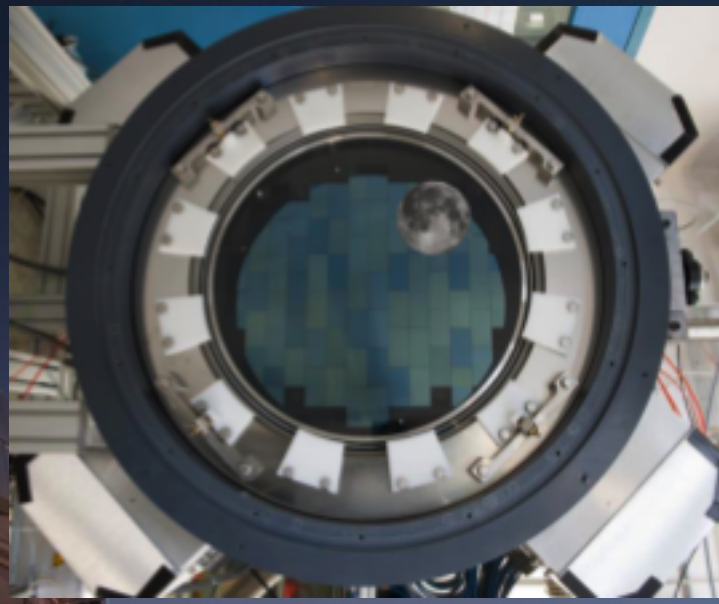
… up to depths of i_AB = 23.7

… in 5 photometric bands (g, r ,i , z , Y)

… to explore dark energy using four probes:

- Cluster counts
- Large Scale Structure (BAOs)
- Supernovae
- Weak Lensing

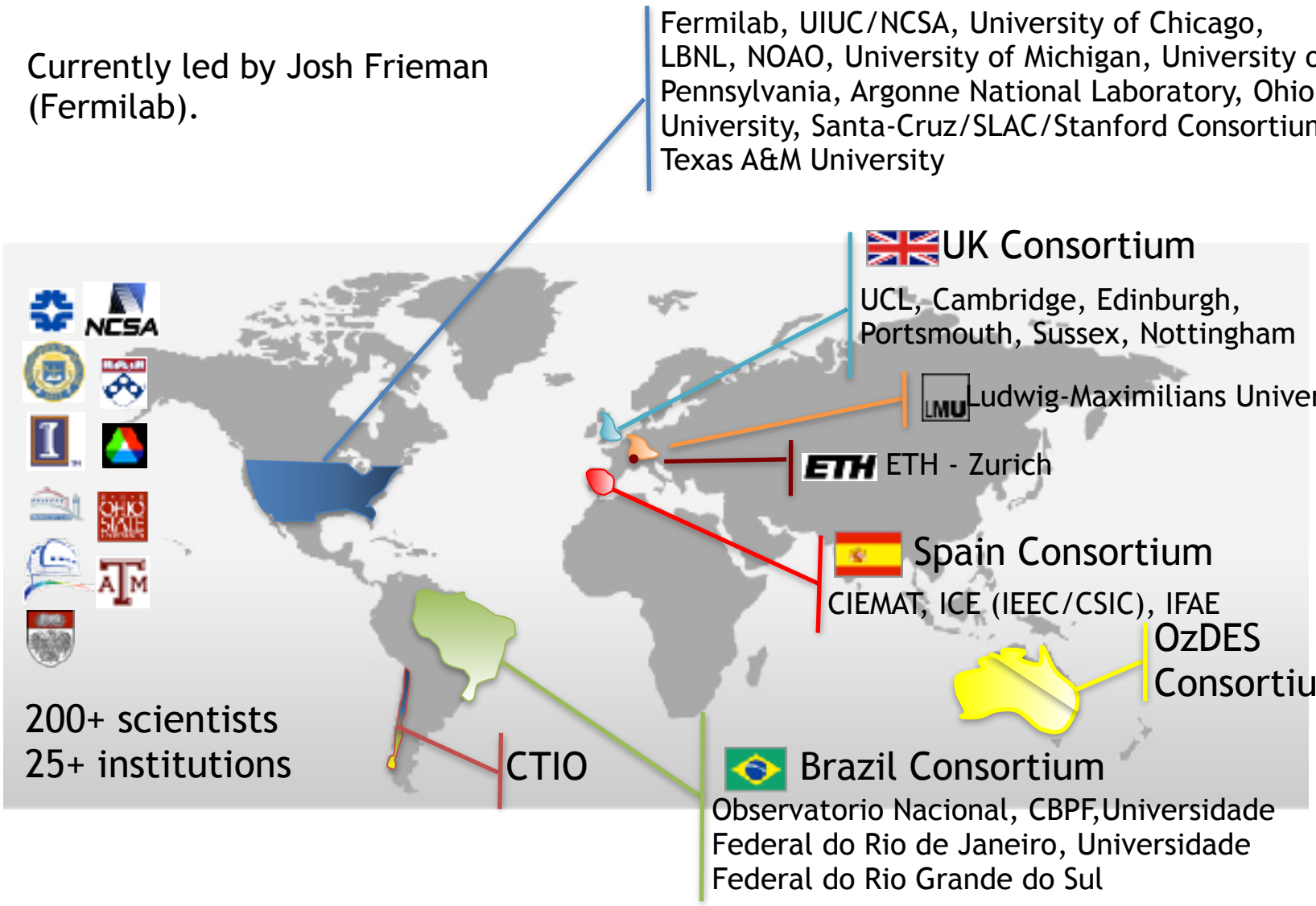
… during 525+(~50) nights in 5 years (2013-2018)



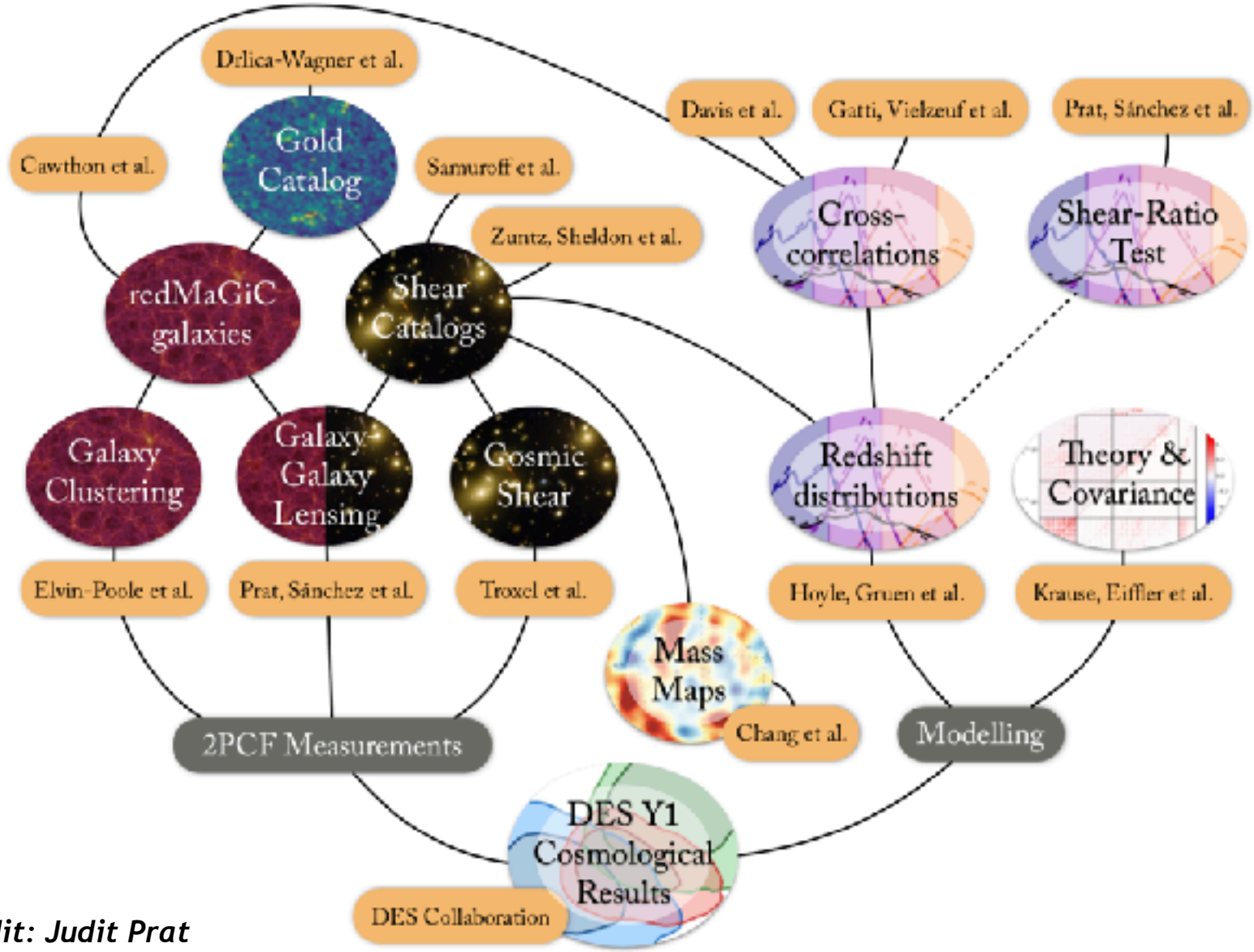
Credit: Tim Abbott

The inevitable collaboration slide

- Currently led by Josh Frieman (Fermilab).

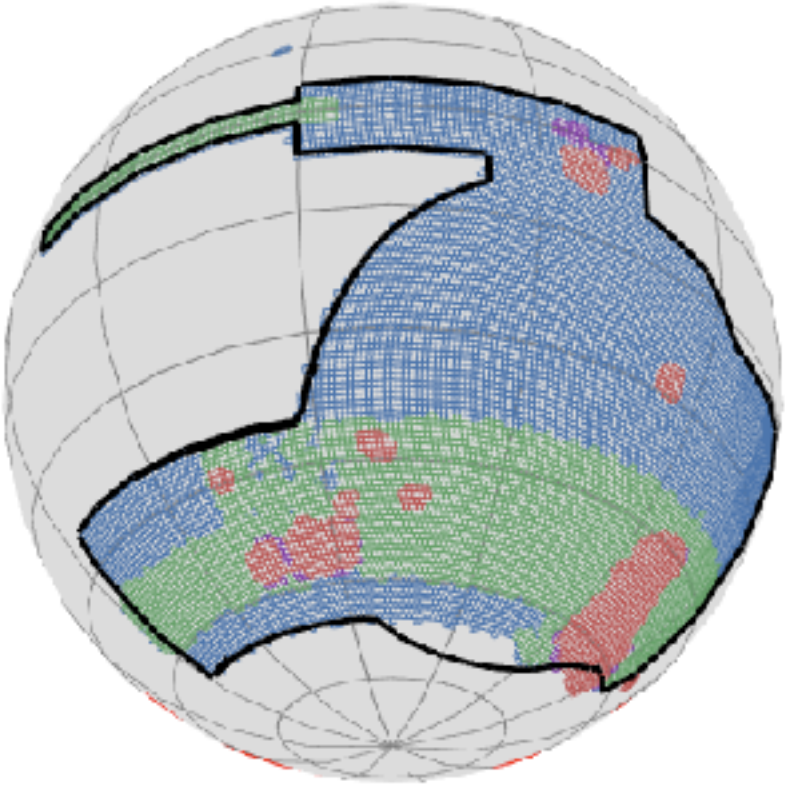


And an alternative to the usual collaboration slide

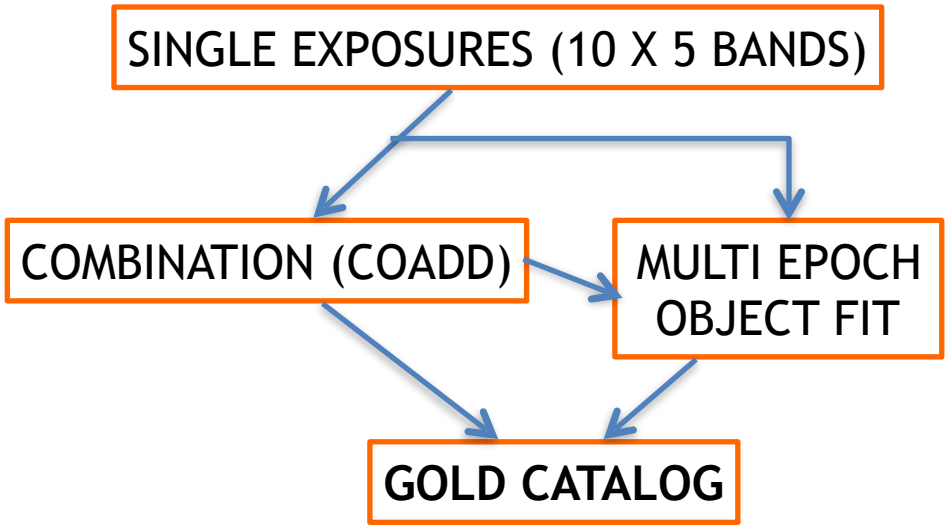


Credit: Judit Prat

DES Data Management converts raw data into galaxy catalogs used for cosmological inference

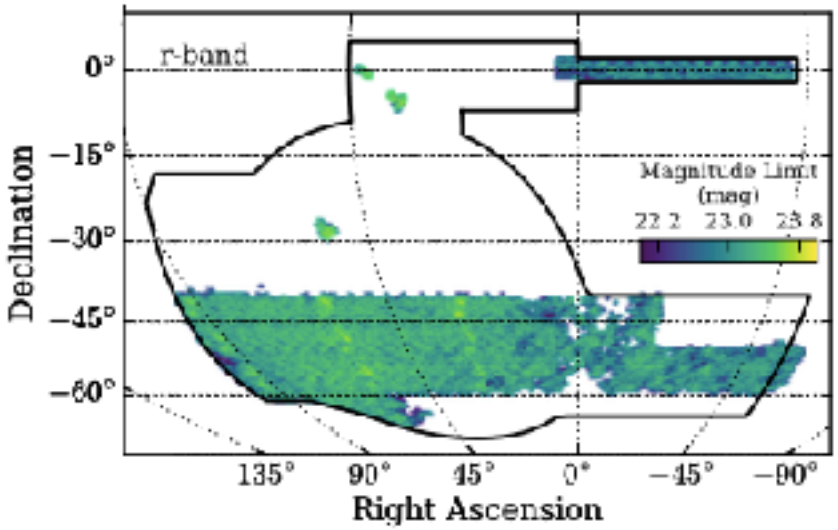


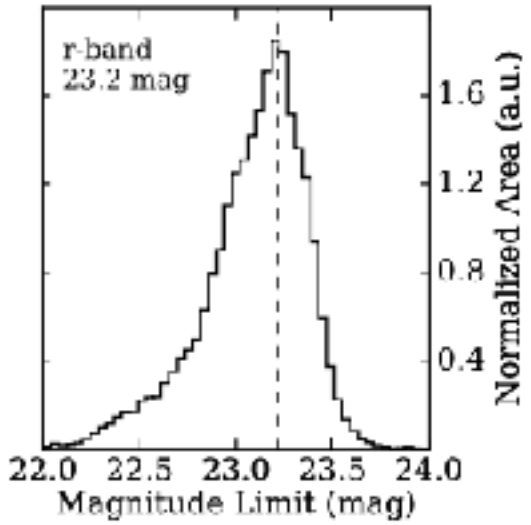
SV ~250 sq.deg.; 10 exposures
Y1 ~1800 sq.deg; 3-4 exposures
Y3, Y5 ~5000 sq.deg; 6, 10 exp.

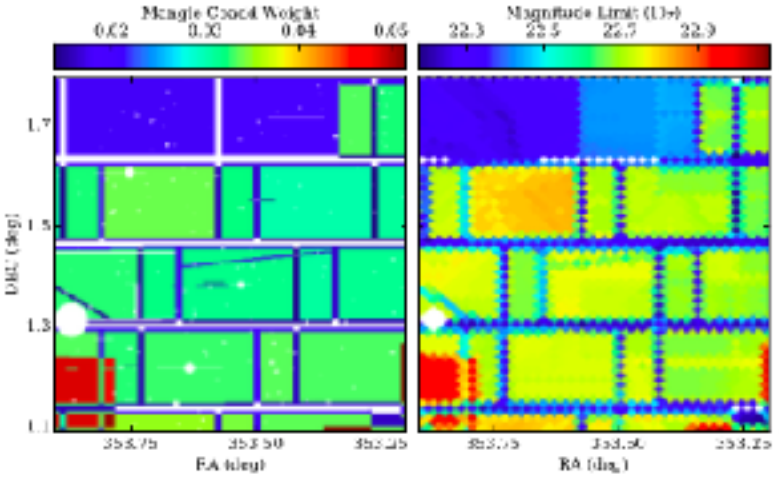


A.Drlica-Wagner, I.S.-N. et al. 2018

Survey properties and depth for each exposure are registered and combined in maps







A.Drlica-Wagner, I.S.-N. et al. 2018

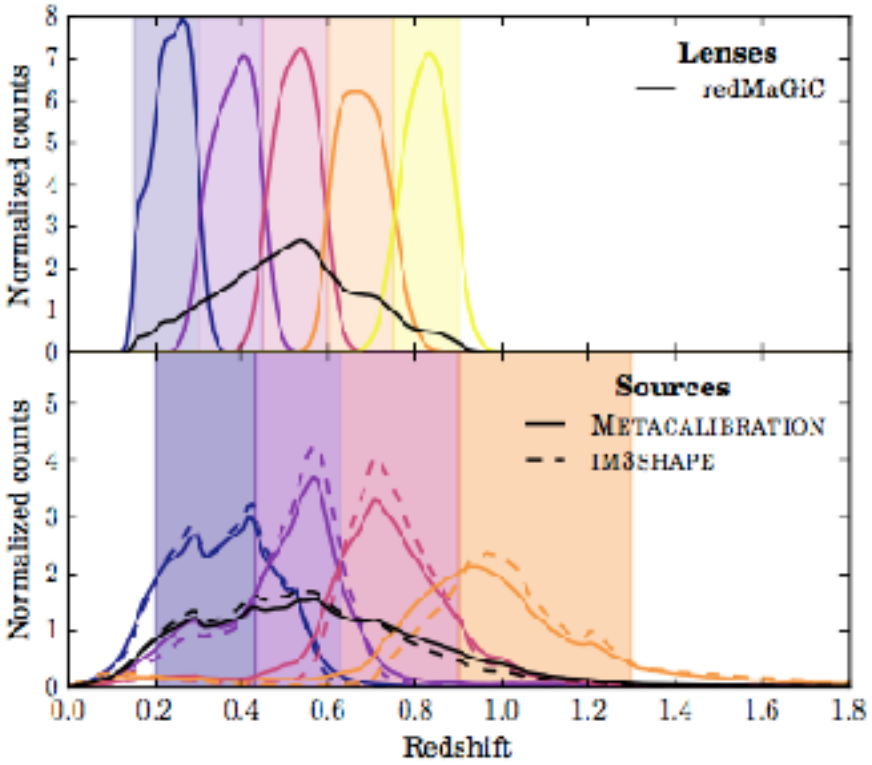
Band	g	r	i	z	Y
Depth (10s) (Sext/MOF)	23.4/ 23.7	23.2/ 23.5	22.5/ 22.9	21.8/ 22.2	20.1
PSF FWHM	1.25”	1.07”	0.97”	0.89”	1.07”

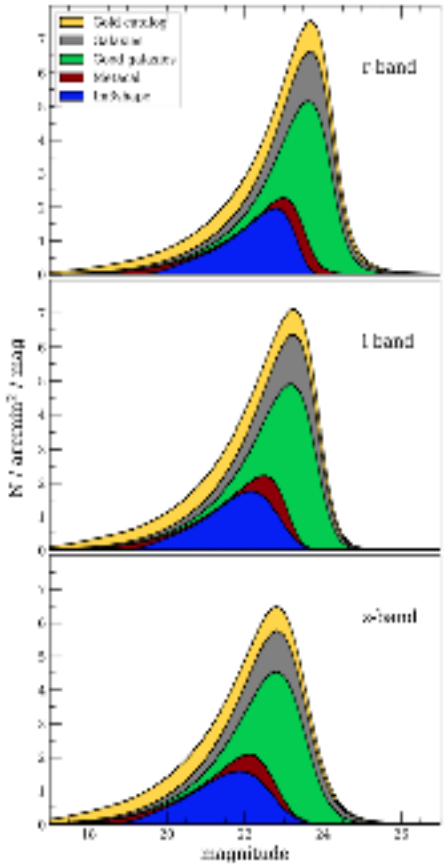
Y1 Astrometric precision: ~0.3 arcsecs
Y1 Photometric precision: 1-2 %

From the Gold catalog, luminous red galaxies are selected as lenses and general extended objects as sources

Five photo-z bins for foreground samples

J.Elvin-Poole, M.Crocce et al. 2017





Four photo-z bins for the background sample

J.Prat, C.Sánchez et al. 2017

Two independent shear catalogs

J.Zuntz, E.Sheldon et al. 2017

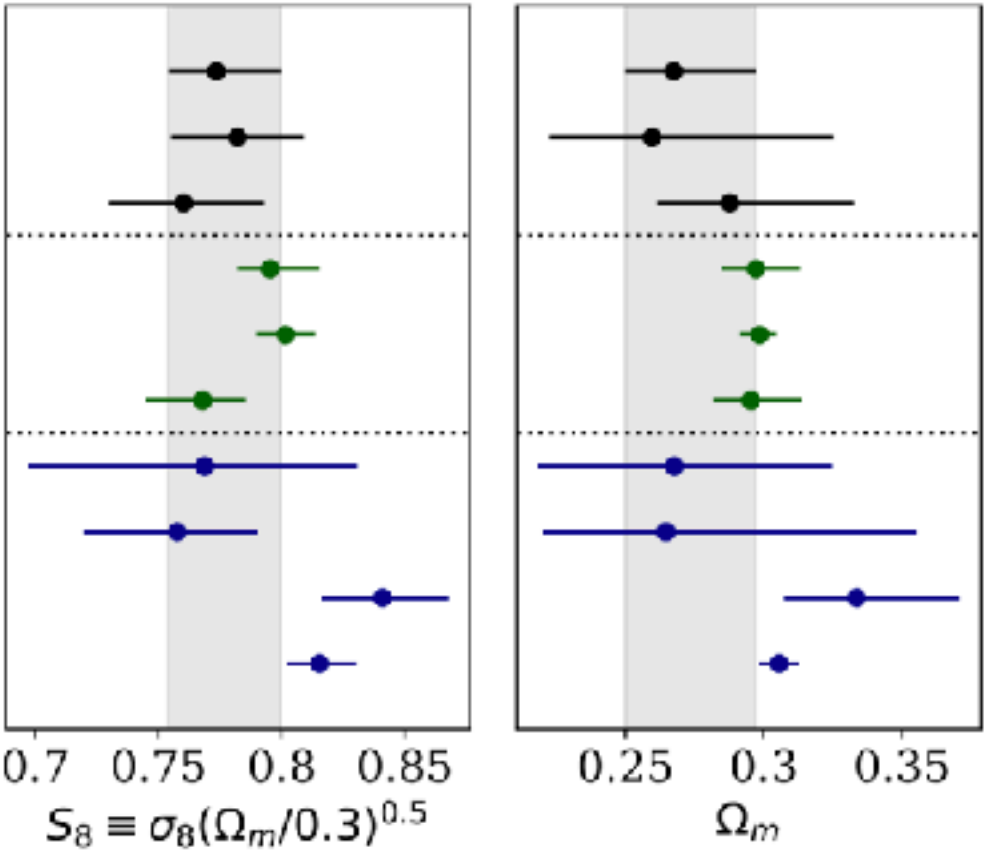
With these ingredients we proceed to infer cosmology for ΛCDM and wCDM

- Data vector (3x2pt stats): $w(\theta)$, $\gamma_t(\theta)$, $\xi_{\pm}(\theta)$ for 4x5 bins
- 20 nuisance parameters (photo-z biases, multiplicative shear biases, lens galaxy bias, IA parameters).
- 6/7 cosmo parameters ($A_S \rightarrow S_8$, n_S, h, Ω_m, Ω_b, Ω_ν, (w))
- Redundancy – rule of twos:
  - 2 shear catalogs
  - 2 photo-z validations
  - 2 cosmological estimator codes
  - 2 levels of blinding
  - 2 years analyzing
- We use evidence ratio to check compatibility

$$R = \frac{P\left(\vec{D}_1, \vec{D}_2 | M\right)}{P\left(\vec{D}_1 | M\right) P\left(\vec{D}_2 | M\right)}$$

- Covariance is computed theoretically, validated with sims. ***E.Krause et al. 2017***

In ΛCDM, we constrain S_8 and Ω_m to a similar level as Planck

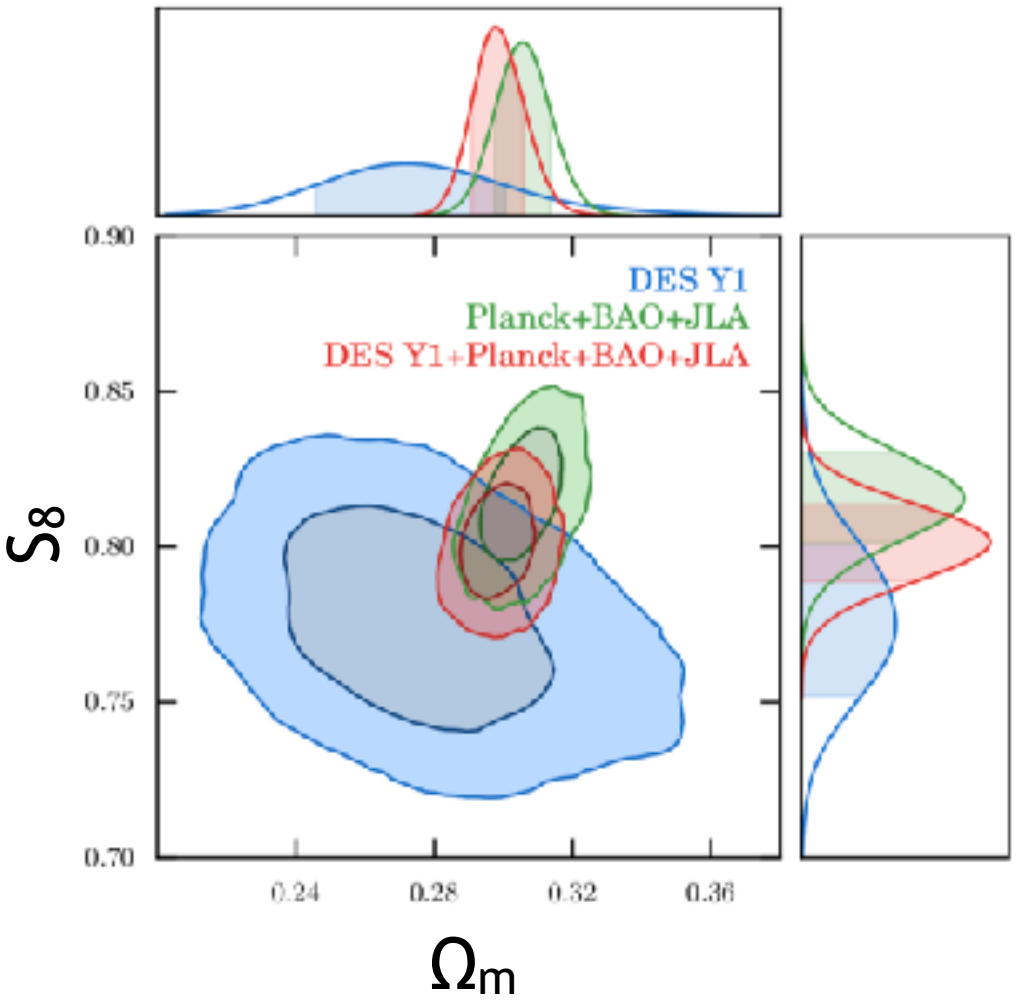


DES Y1 All
DES Y1 Shear
DES Y1 $w + \gamma_t$
DES Y1 All + Planck (No Lensing)
DES Y1 All + Planck + BAO + JLA
DES Y1 All + BAO + JLA
DES SV
KiDS-450
Planck (No Lensing)
Planck + BAO + JLA

$R = 6.6$ DES-Planck compatibility

DES Collaboration 2017

Bayesian evidence ratio points to compatibility with Planck



DES Collaboration 2017

$$\Omega_m = 0.298 \pm 0.007$$

$$\sigma_8 = 0.808^{+0.009}_{-0.017}$$

$$S_8 = 0.802 \pm 0.012$$

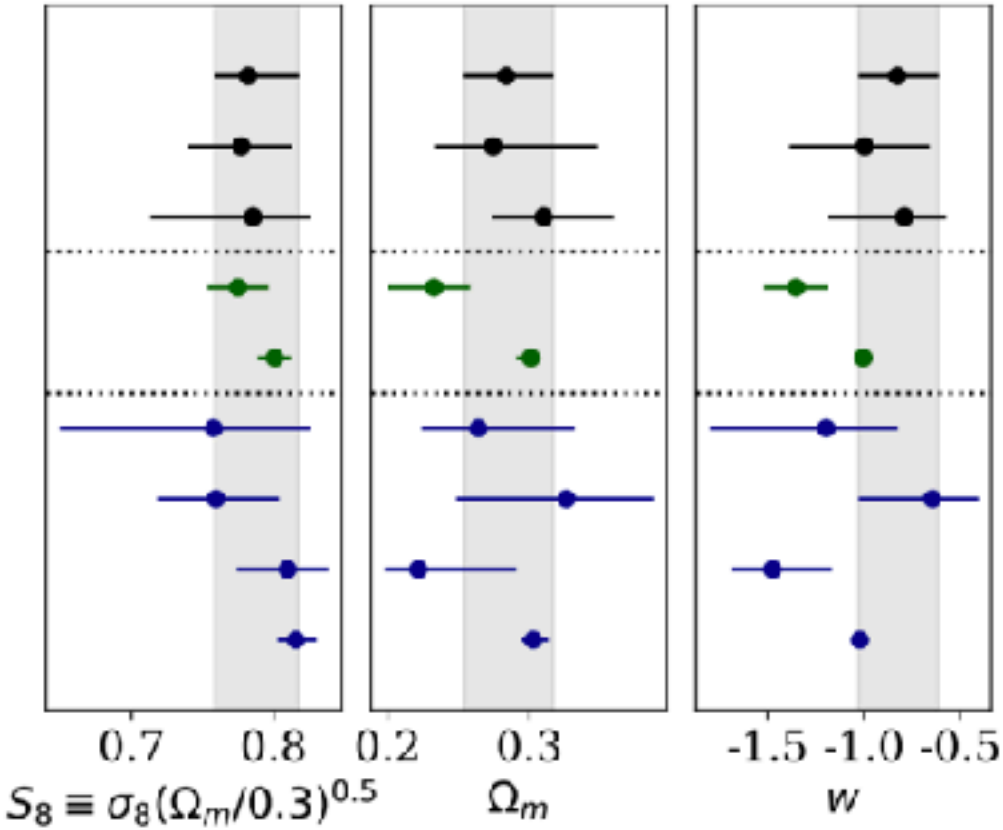
$$h = 0.685^{+0.005}_{-0.007}$$

$$\chi^2/\nu = 1.12$$

Strong evidence for IA with photometric survey.

Lens bias constrained to 10%

wCDM is disfavored, w compatible with -1 :D :(



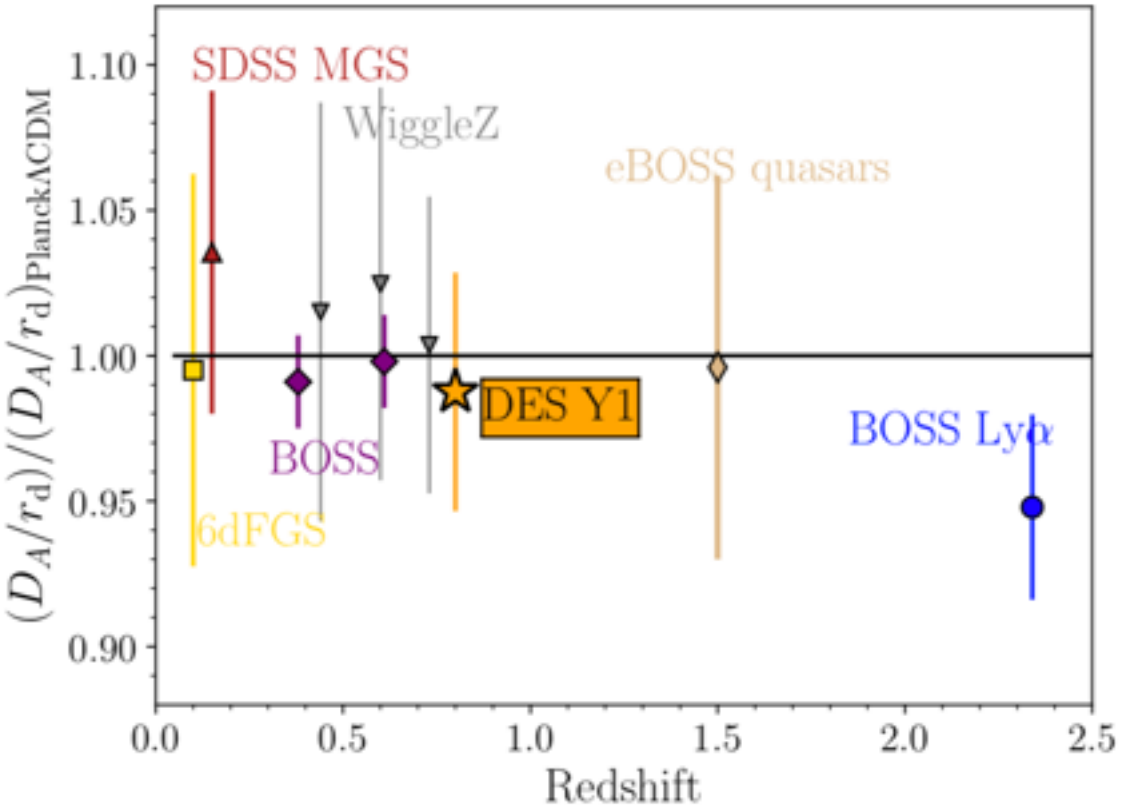
DES Y1 All
DES Y1 Shear
DES Y1 $w + \gamma_t$
DES Y1 All + Planck (No Lensing)
DES Y1 All + Planck + BAO + JLA
DES SV
KiDS-450
Planck (No Lensing)
Planck + BAO + JLA

$$R_w = \frac{P(\vec{D}|w\mathrm{CDM})}{P(\vec{D}|\Lambda\mathrm{CDM})} = 0.1$$

DES Collaboration 2017

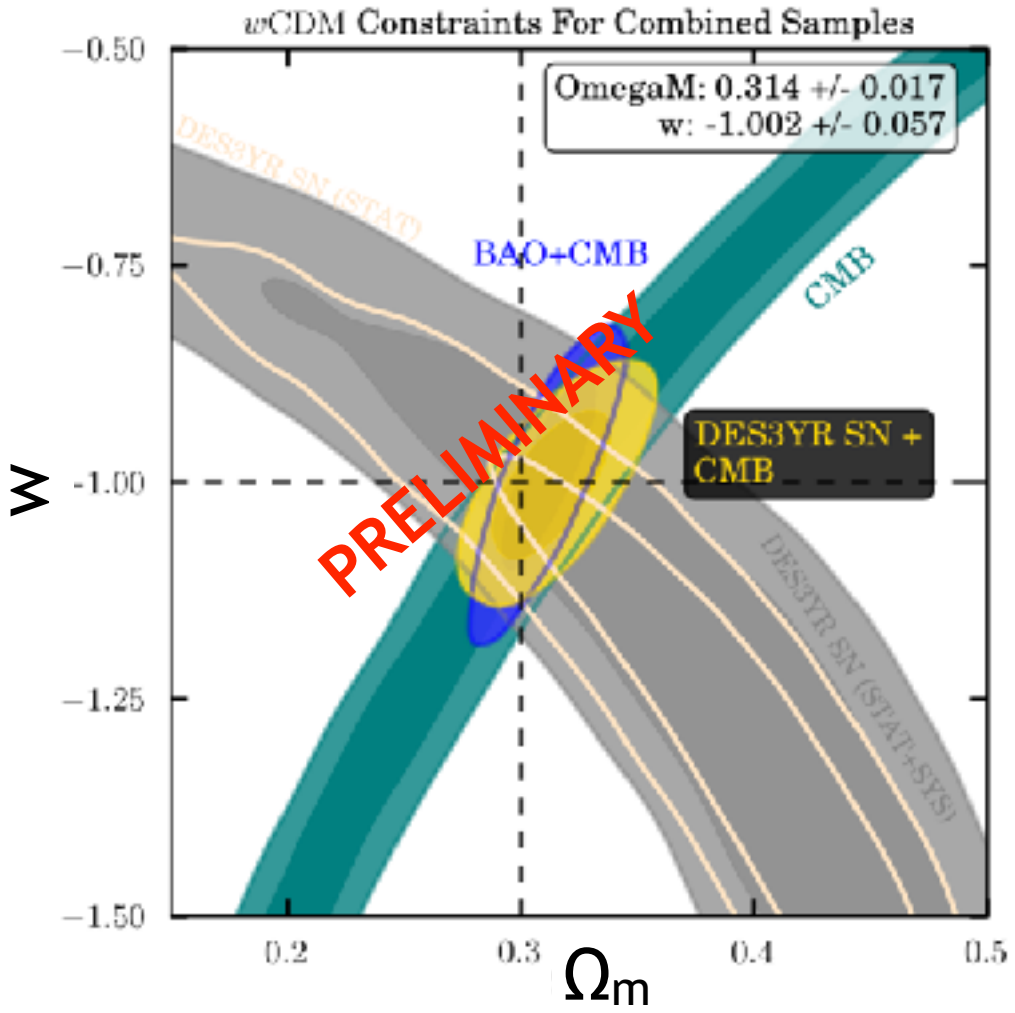
A 4% BAO measurement is obtained fully consistent with ΛCDM :D :(

- Competitive angular distance measurement at high redshift.
- Expect a ~40% improvement for Y3 and put to z~0.9 for Y5.



DES Collaboration 2017

A 6% erro SNe measurement is obtained fully consistent with w=−1 :D :(

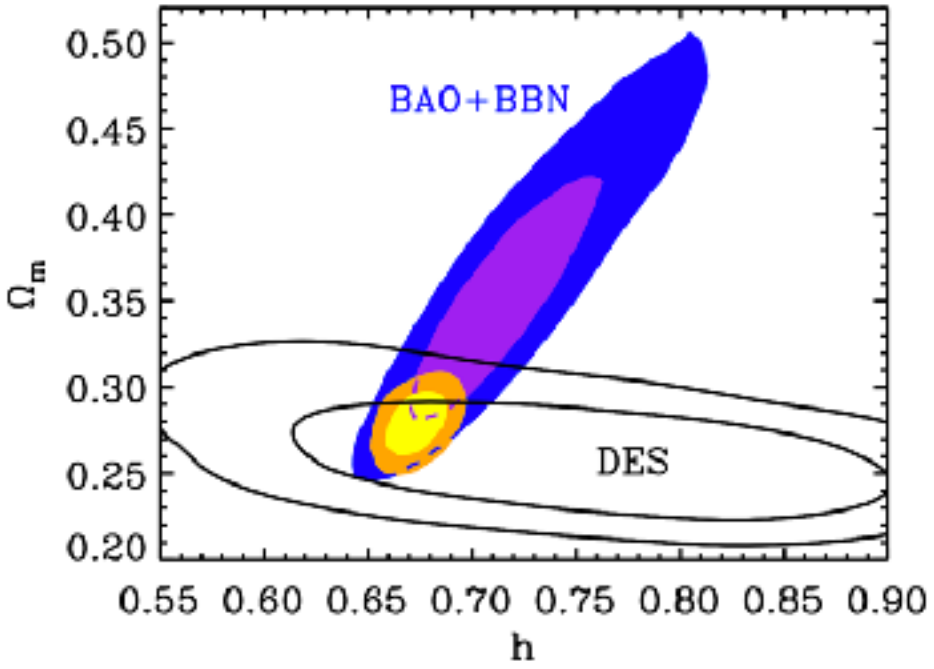


SURVEY	SNe	wErr
JLA (2014)	740	0,054
Pantheon (2018)	1049	0,040
DES 3YR (2018) spec	**334**	**0,057**
DES 5YR spec	~500	?
DES 5YR photo	~2000	?

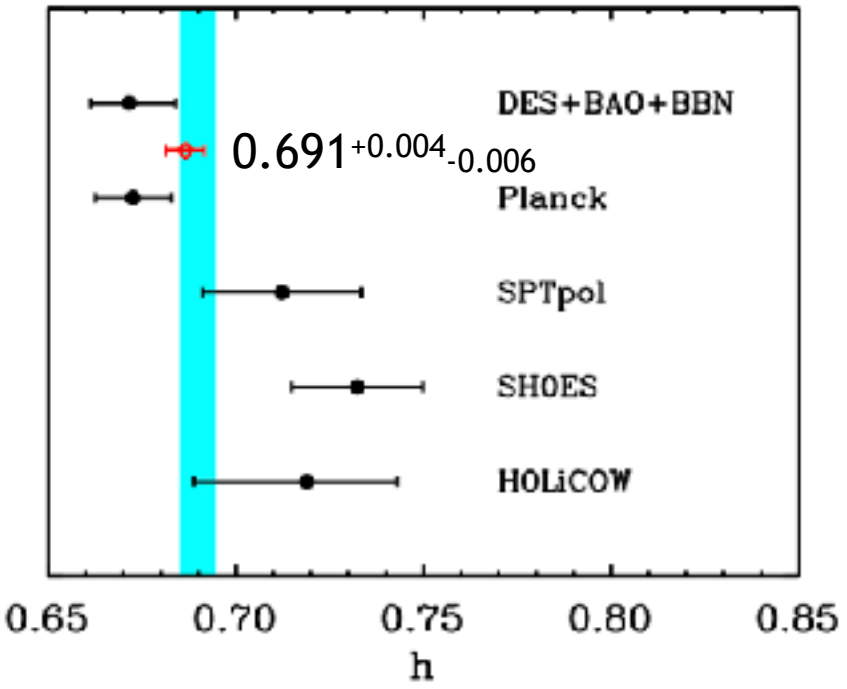
- We are now hitting the systematics wall.
- Several parallel analysis in internal review now slated for summer release.

DES Collaboration in prep., D.Brout in prep., also H0! E.Macaulay et al. in prep.

One can also constrain H0 with just low-z data and no SNe!



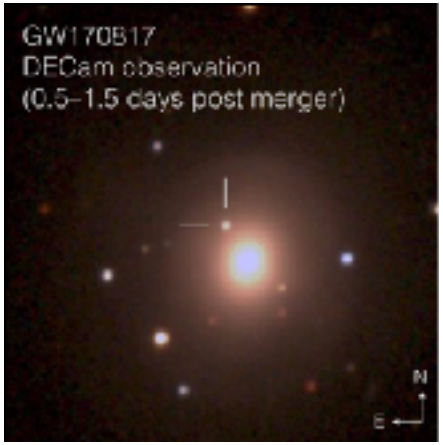
BAO —> $\Omega_b h^2$, Ω_m, h: Use BOSS,6dF++
BBN —> $\Omega_b h^2$: Cooke et al. 2016
Clustering & shear —> Ω_m: Dark Energy Survey 2017 (1)



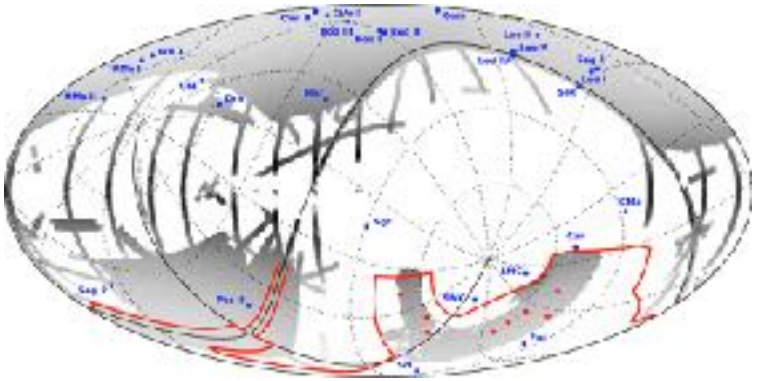
A 2-sigma result measurement compatible with ΛCDM :D :(

DES Collaboration 2017

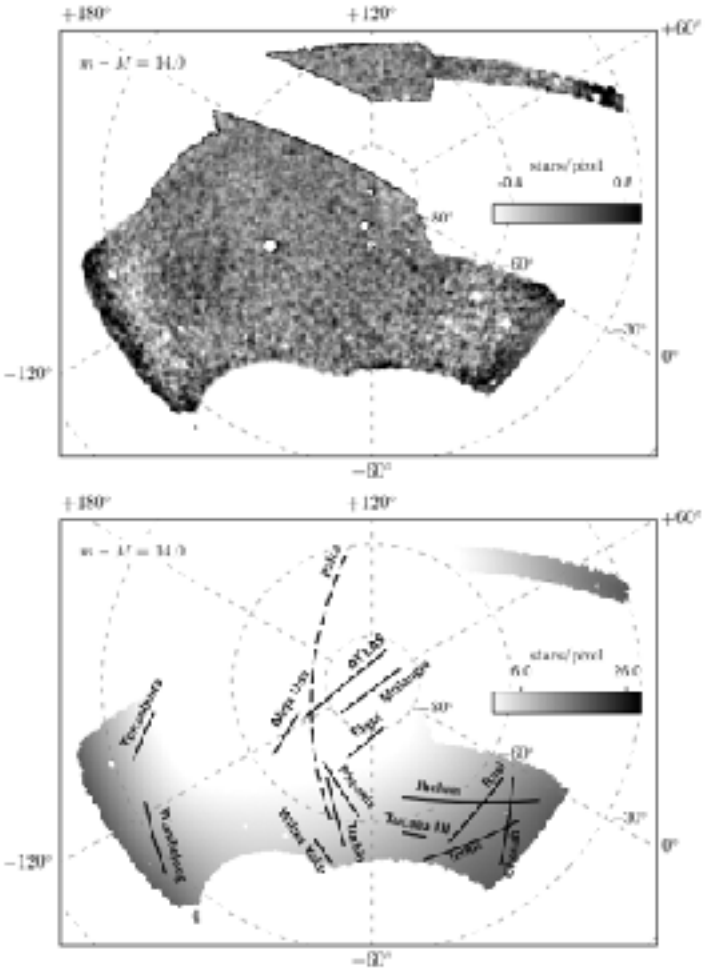
Unchained cosmology!



M. Soares-Santos et al. 2017

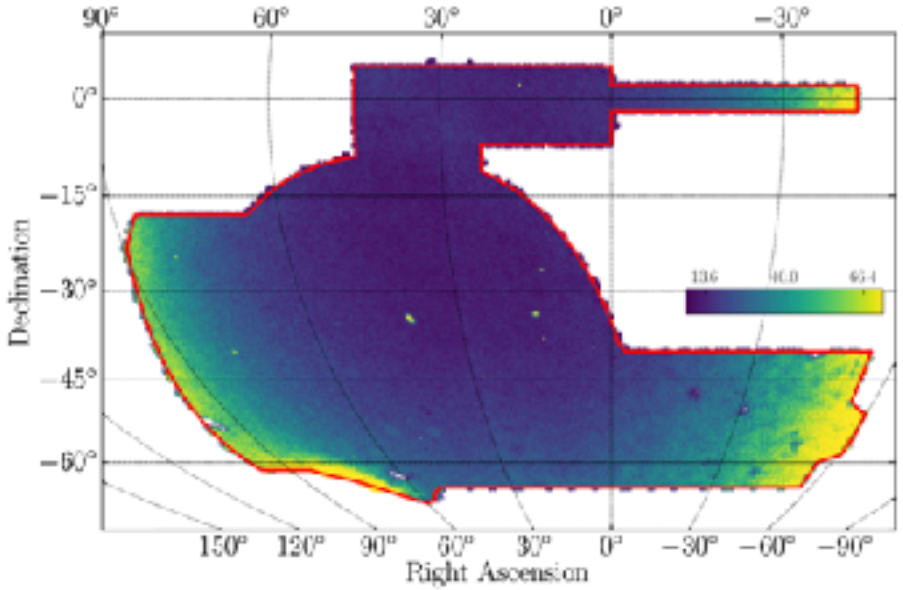


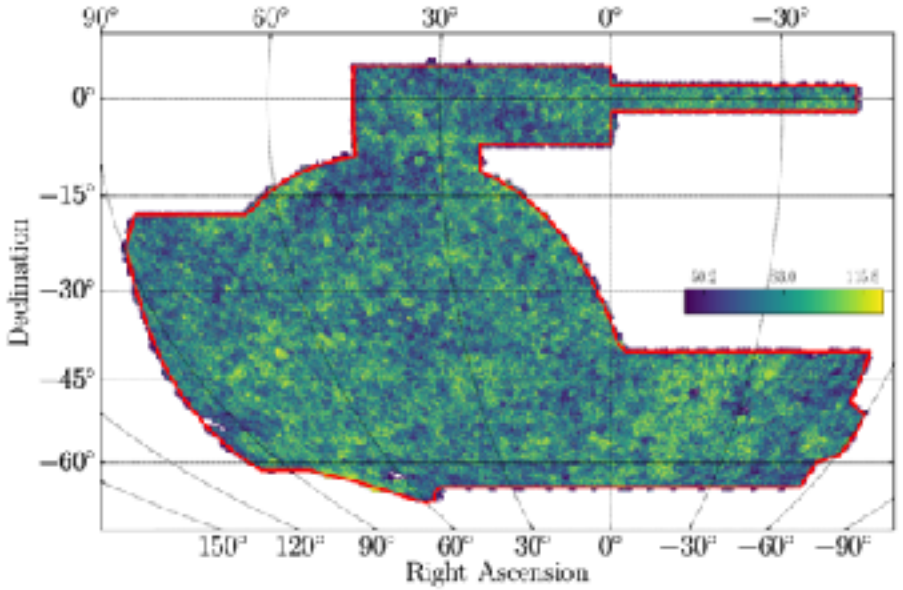
K. Bechtol et al. 2015
A. Drlica-Wagner et al. 2017



N. Shipp et al. 2018

What can you think of? DR1!





https://des.ncsa.illinois.edu/releases/dr1

400 million objects in 4-5 bands, 5000 sq.deg.

DES Collaboration 2018

DES DR1 Summary Statistics

Parameter	Value
Observations (3 years of operations)	345 distinct nights from Aug 2013 to Feb 2016
Number of DECam Exposures	~39,000
Sky Coverage in *grizY*	5186 deg^2
Delivered Seeing (FWHM)	$g = 1.21$, $r = 0.96$, $i = 0.88$, $z = 0.84$, $Y = 0.90$ arcsec
Coadd Astrometric Precision (vs Gaia)	151 mas
Coadd Photometric Precision	< 1 % in *grizY*
Coadd depth (S/N = 10 in 1.95" Aperture)	$g = 24.3$, $r = 24.1$, $i = 23.4$, $z = 22.7$, $Y = 21.4$ mag
Distinct Coadd Objects in 10,338 tiles	~400M: ~310M galaxies and ~80M stars after basic quality cuts ~ 35,000 clusters @ z~1

DES DR1 Products and Services

- Catalogs: Year 3 Catalogs based on SExtractor
- Images: Year 3 Coadd images, Y1-Y2-Y3 Single-epoch calibrated images
- Bulk Data Access: Coadd tile-based image and catalog files
- Interfaces: SQL Web Client, File access, Cutout server, Image exploration, Landing release page, Jupyter Notebooks, Science Portal, NOAO Data Lab
- Documentation: DR1 paper, Web documentation, Table Schemas, Interface and software, DR1 Standard Bandpasses
- Software: Main components of pipeline on Github. Minimal usage information
- Support: Limited collaboration support (similar to SV) and institutional (NCSA, NOAO, LIneA) support for tools