



DARK ENERGY
SURVEY



Laboratório Interinstitucional de e-Astronomia

The Dark Energy Survey: an overview and recent results

Rogério Rosenfeld

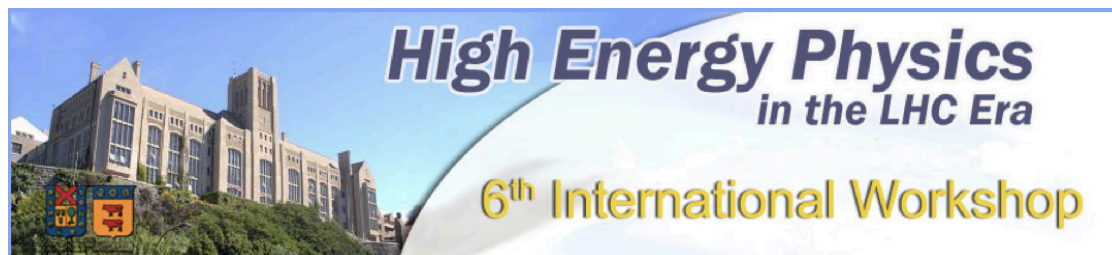
IFT-UNESP 



International Centre for Theoretical Physics
South American Institute for Fundamental Research

LineA

January 12, 2016





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Cosmology has become a data driven science!

Many experiments are taking a huge amount of data that are being analyzed in order to find out which model best describes the universe.



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DES-BRAZIL



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Cosmological probes

- Cosmic Microwave Background (CMB)
- Big bang nucleosynthesis (BBN)
- Supernovae (type Ia)
- Baryon acoustic oscillation (BAO)
- Gravitational lensing
- Number count of clusters of galaxies

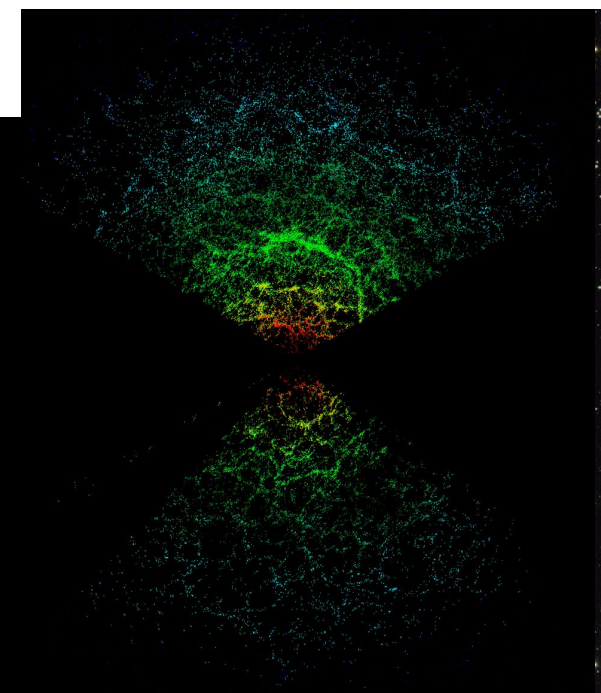
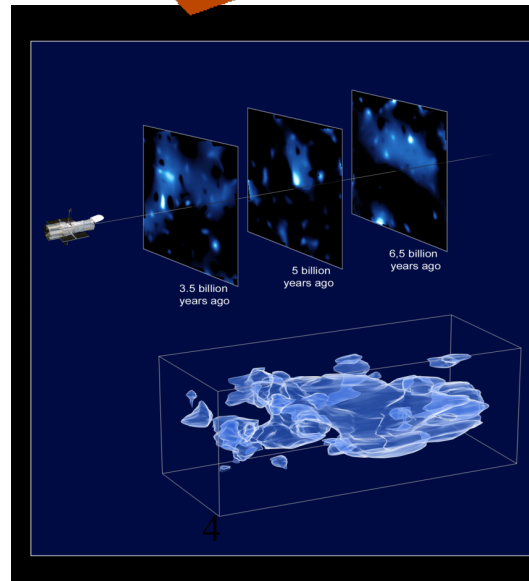
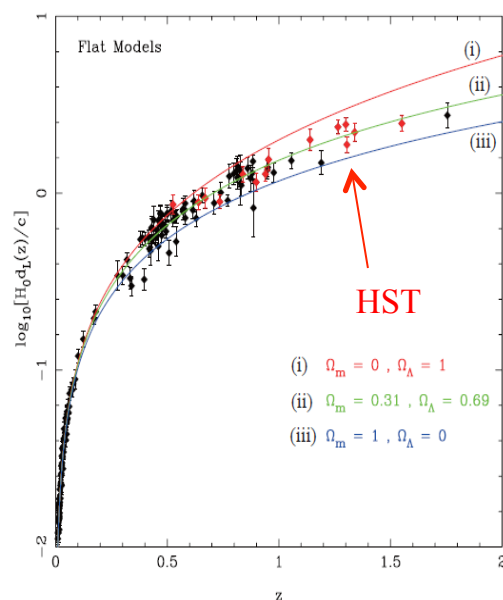
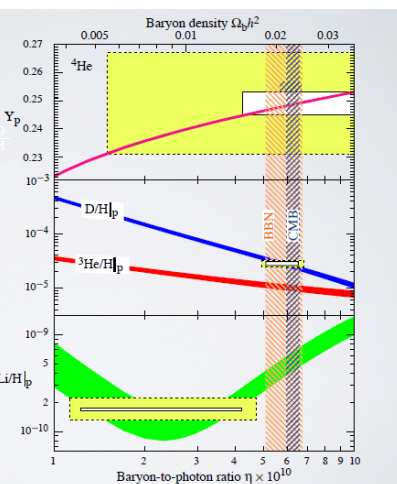
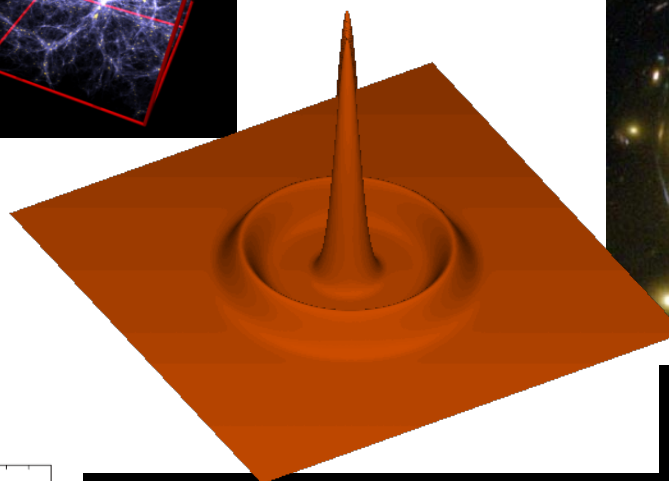
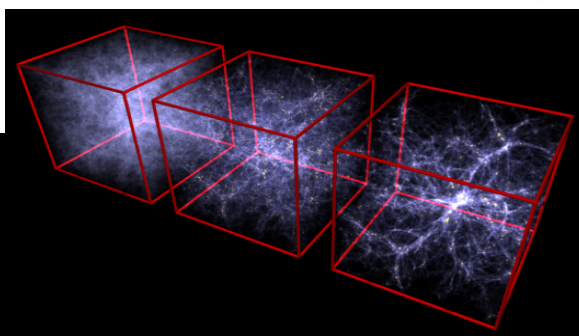
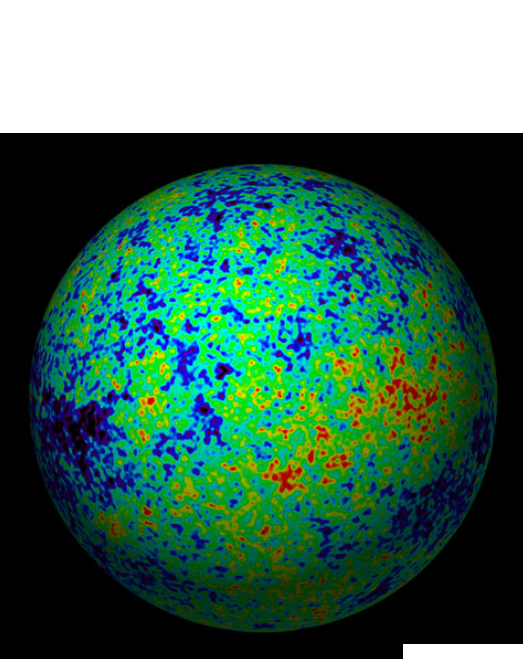


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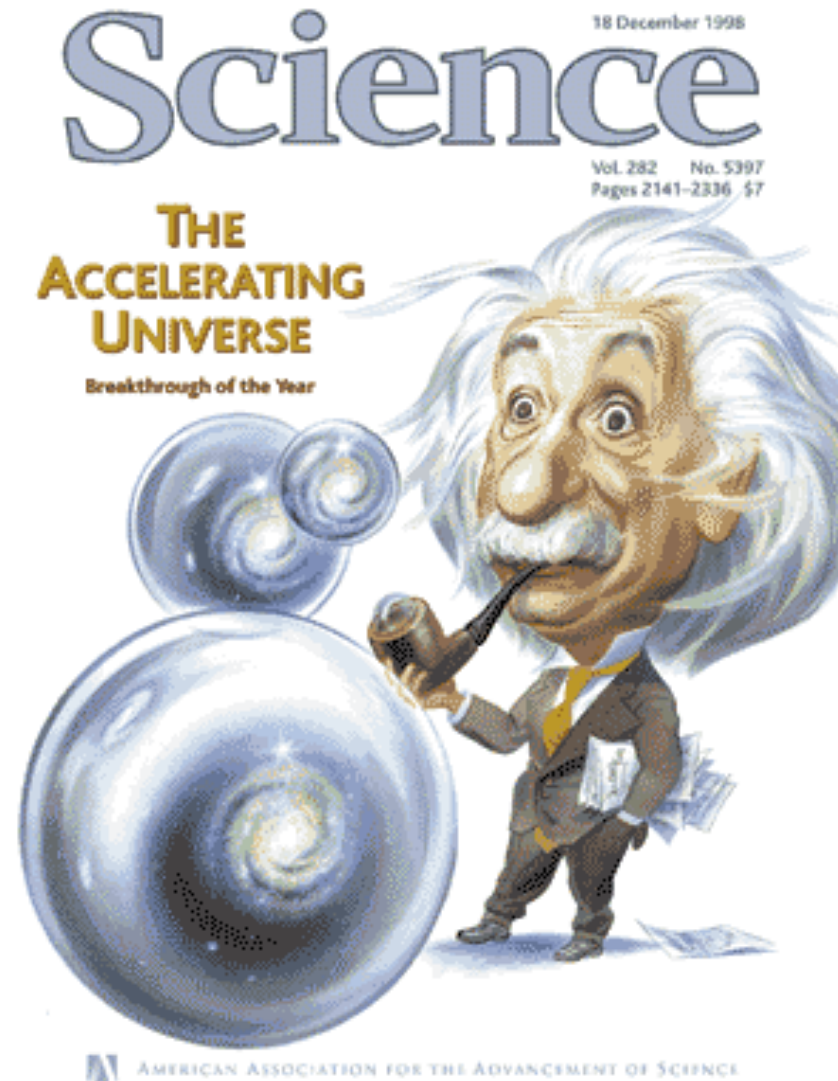
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Cosmological probes



The big surprise in 1998:

The Universe is accelerating!





The Nobel Prize in Physics 2011

Saul Perlmutter, Brian P. Schmidt, Adam G. Riess

Share this:     290 

The Nobel Prize in Physics 2011



Photo: U. Montan

Saul Perlmutter

Prize share: 1/2



Photo: U. Montan

Brian P. Schmidt

Prize share: 1/4



Photo: U. Montan

Adam G. Riess

Prize share: 1/4

The Nobel Prize in Physics 2011 was divided, one half awarded to Saul Perlmutter, the other half jointly to Brian P. Schmidt and Adam G. Riess *"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"*.

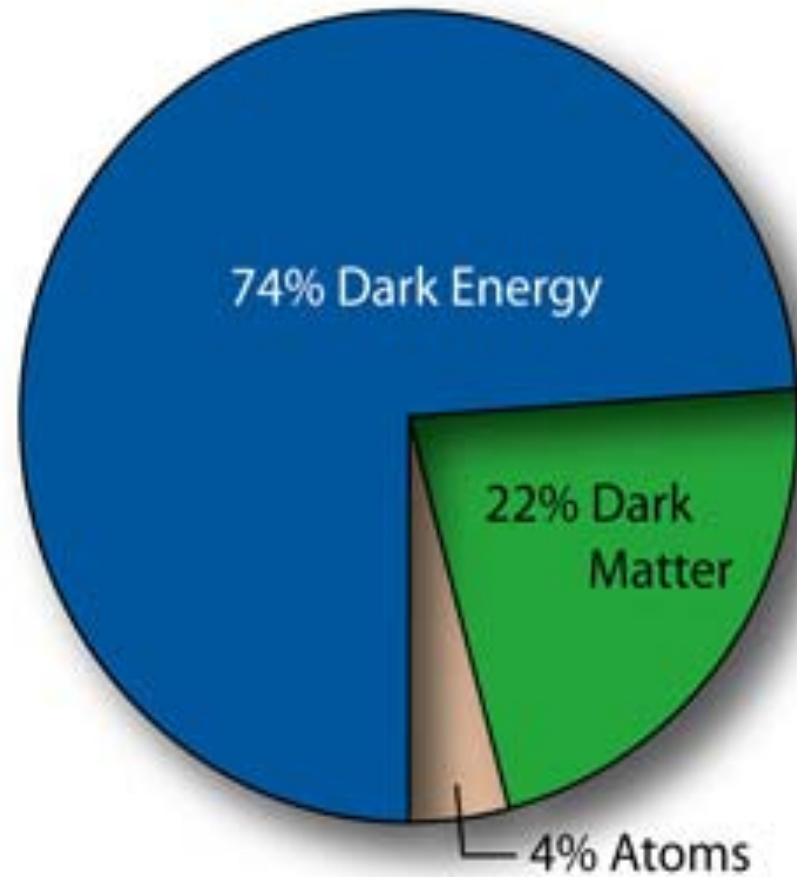


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We know that we don't know what the universe is made of:



Astronomy

LHC

DARK MATTER

DARK ENERGY

INFLATION

CMB

Rests upon three mysterious pillars
All implicate new physics!



DARK ENERGY SURVEY COLLABORATION

Josh Frieman – Project Director
John Peoples was 1st director

~300 scientists

Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of Pennsylvania, Argonne National Lab, Ohio State University, Santa-Cruz/SLAC/Stanford, Texas A&M





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DES-Brazil is a LineA Project

Laboratório Interinstitucional de e-Astronomia (LineA)

<http://www.linea.gov.br>



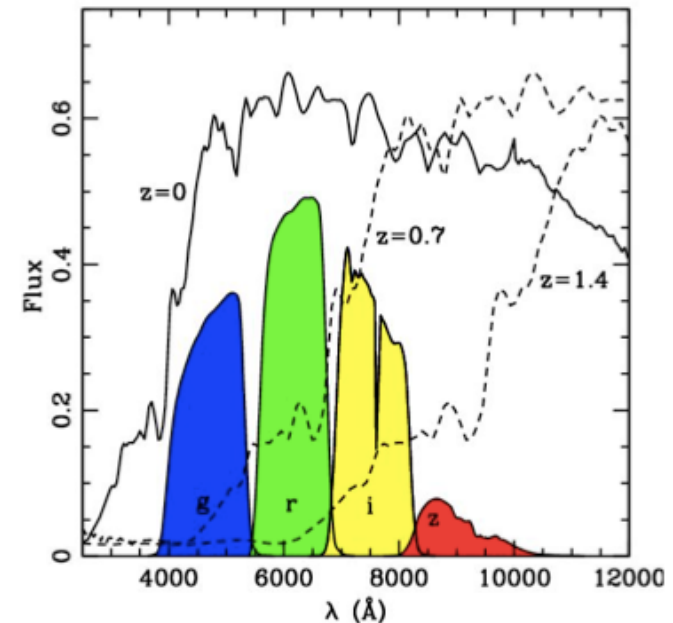
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DES Project

- Survey of 5000 deg² ($\sim 1/8$ of the sky)
- 300 millions of galaxies up to $z \sim 1.4$
(+ 100,000 clusters + 4,000 SN Ia)
- Photometric redshift with 5 filters
- Blanco telescope (4m, CTIO)
- DECam – 62 (+12) CCDs (LBNL) - 570 Megapixels





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Rough LSS-HEP dictionary

Red shift $\leftarrow \rightarrow$ energy

Area of the survey $\leftarrow \rightarrow$ luminosity

Red shift error $\leftarrow \rightarrow$ energy resolution

Structure formation $\leftarrow \rightarrow$ hadronization

Catalogue $\leftarrow \rightarrow$ data

DES Project Timeline

NOAO Blanco Announcement of Opportunity 2003

DECam R&D 2004-8

Camera construction 2008-11

First light DECam on telescope September 2012

Science Verification (SV) run: Sept. 2012 - Feb. 2013

First Season (Year 1): Aug. 31, 2013 - Feb. 9, 2014

Second Season (Year 2): Aug. 2014 - Feb. 2015

Third Season (Year 3): Aug. 2015 - Feb. 2016

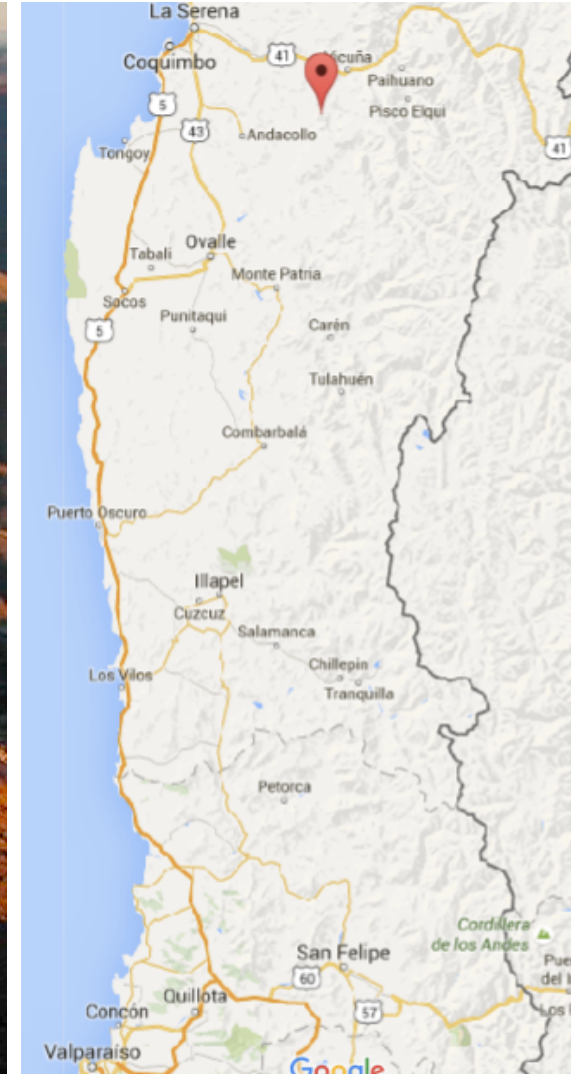
Planning on 5 years of 105-nights each (maybe 6 years)



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DES site: 4m Blanco telescope at the Cerro Tololo Inter-American Observatory (CTIO) in Chile

January 12, 2016

HEP-Chile

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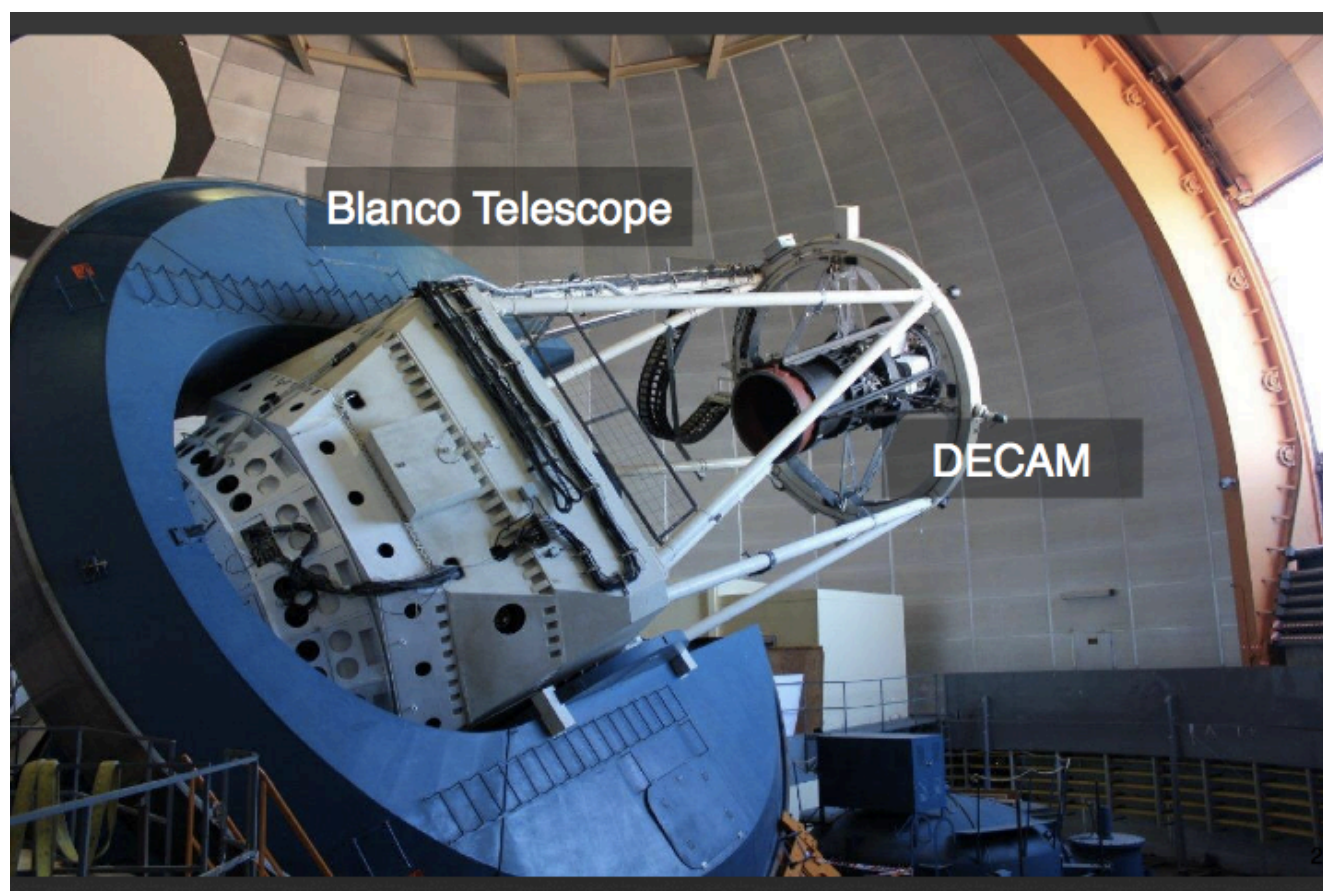
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DECam

Able to see light from more than 100,000 galaxies up to 8 billion light-years away in each snapshot. Weighs ~4 tons!



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HEP-Chile

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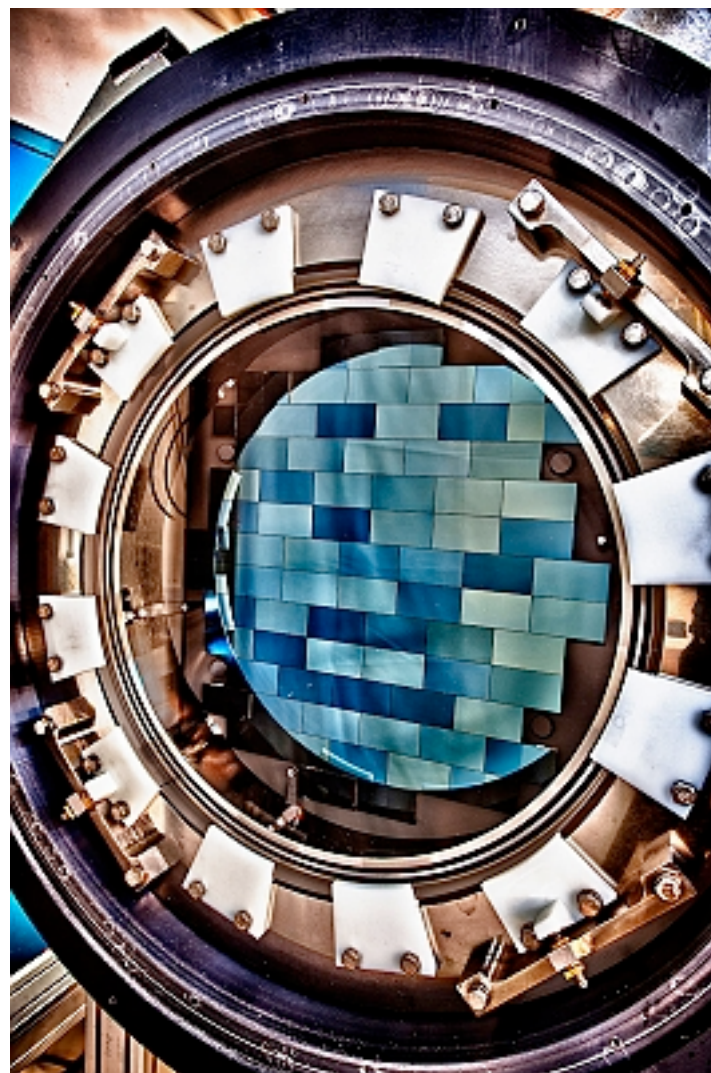
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DECam

[arXiv:1504.02900](https://arxiv.org/abs/1504.02900)



January 12, 2016

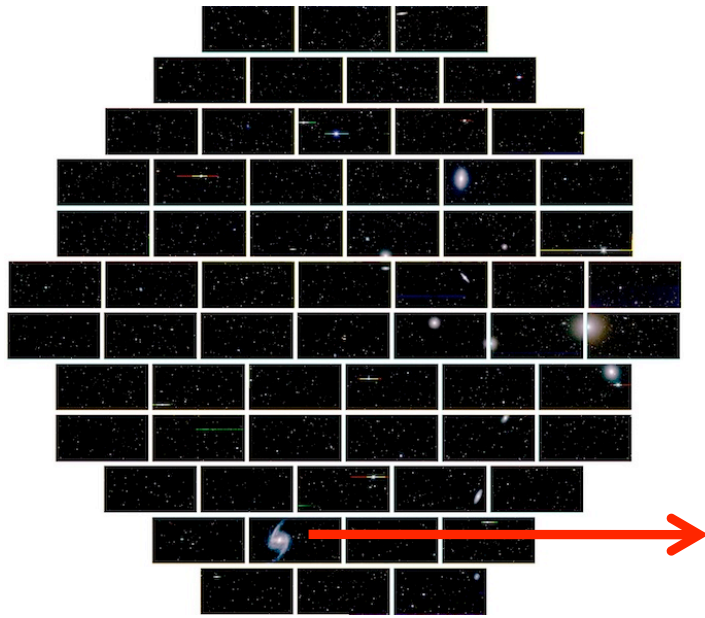
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Fornax cluster of galaxies



Barred spiral galaxy NGC 1365 in the Fornax cluster of galaxies



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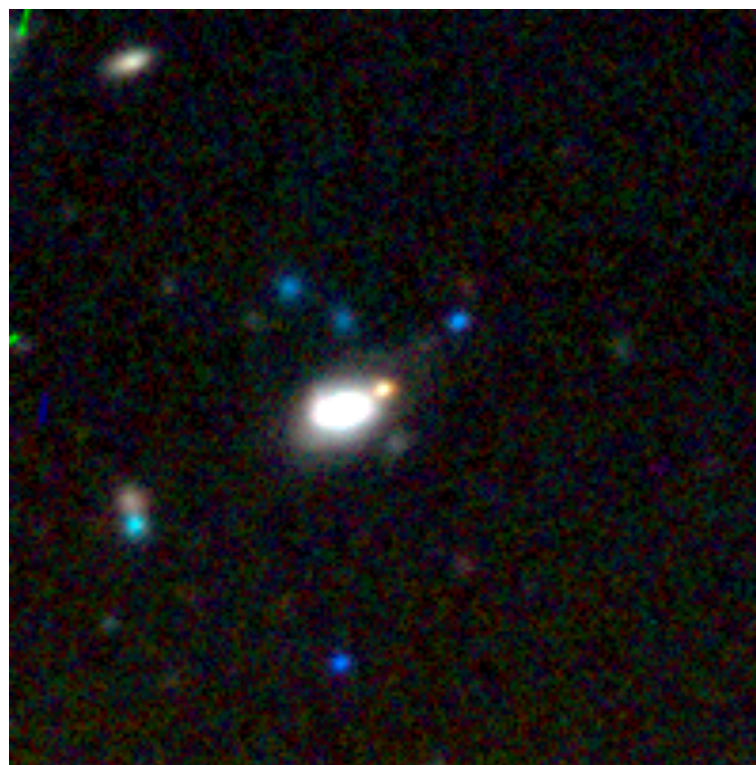
DECam



First supernova found by the Dark Energy Survey



Nov. 7

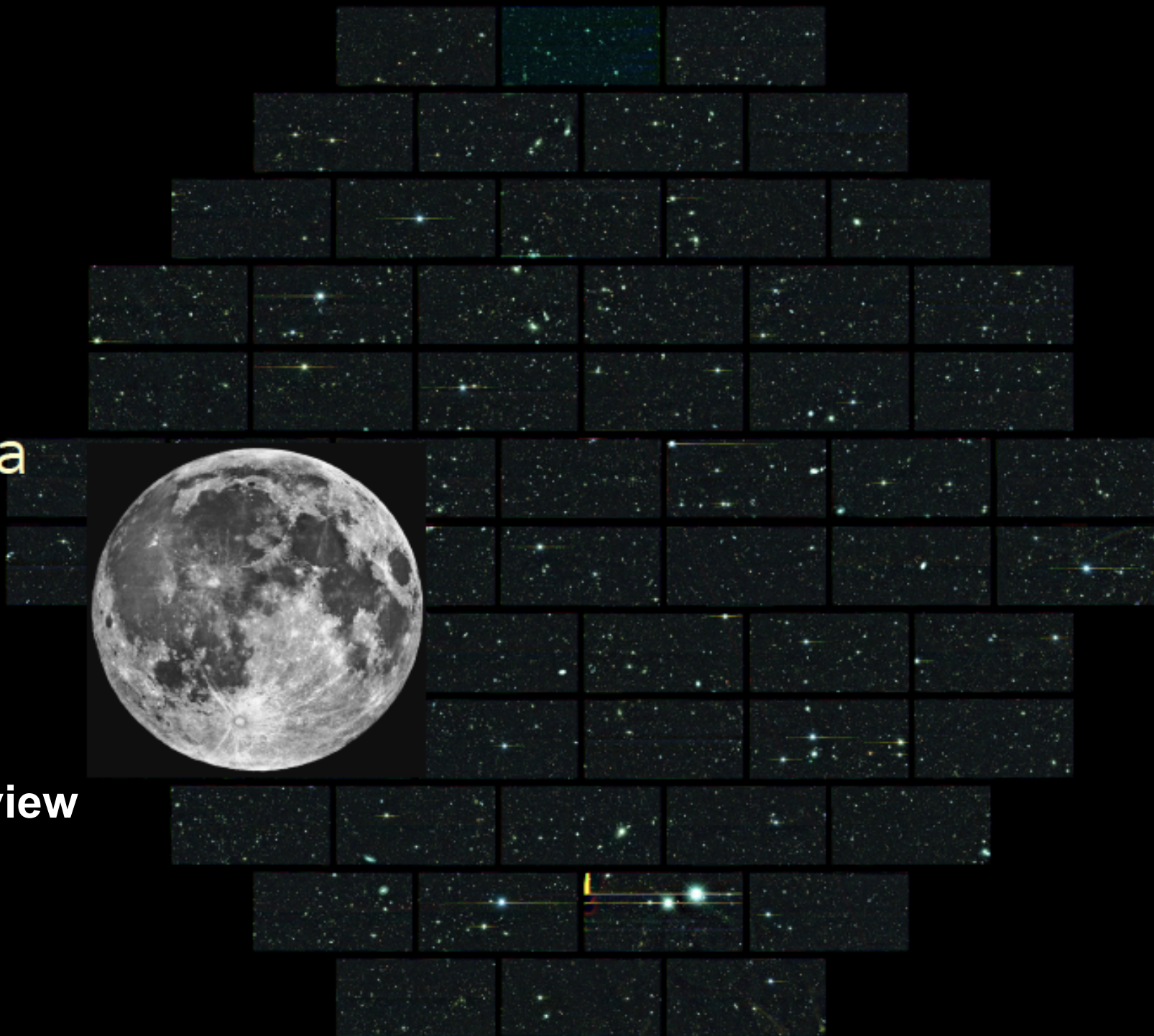


Dec. 15

SN Ia at $z=0.2$ confirmed at AAO



DES SV
image of a
deep SN
field



3 deg² field of view



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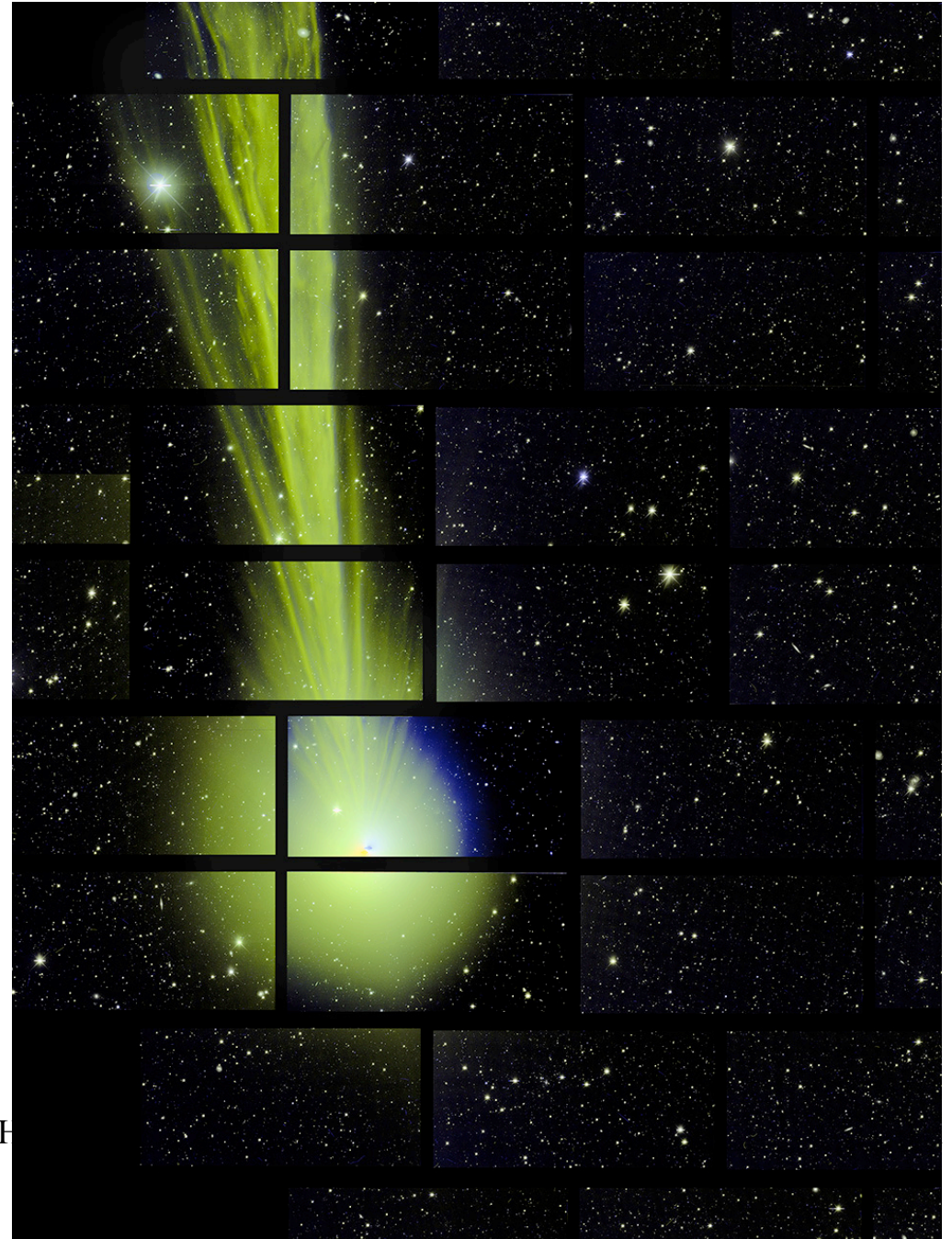
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Dark Energy Camera catches breathtaking glimpse of comet Lovejoy

December 27 2014

82 million km away

January 12, 2016



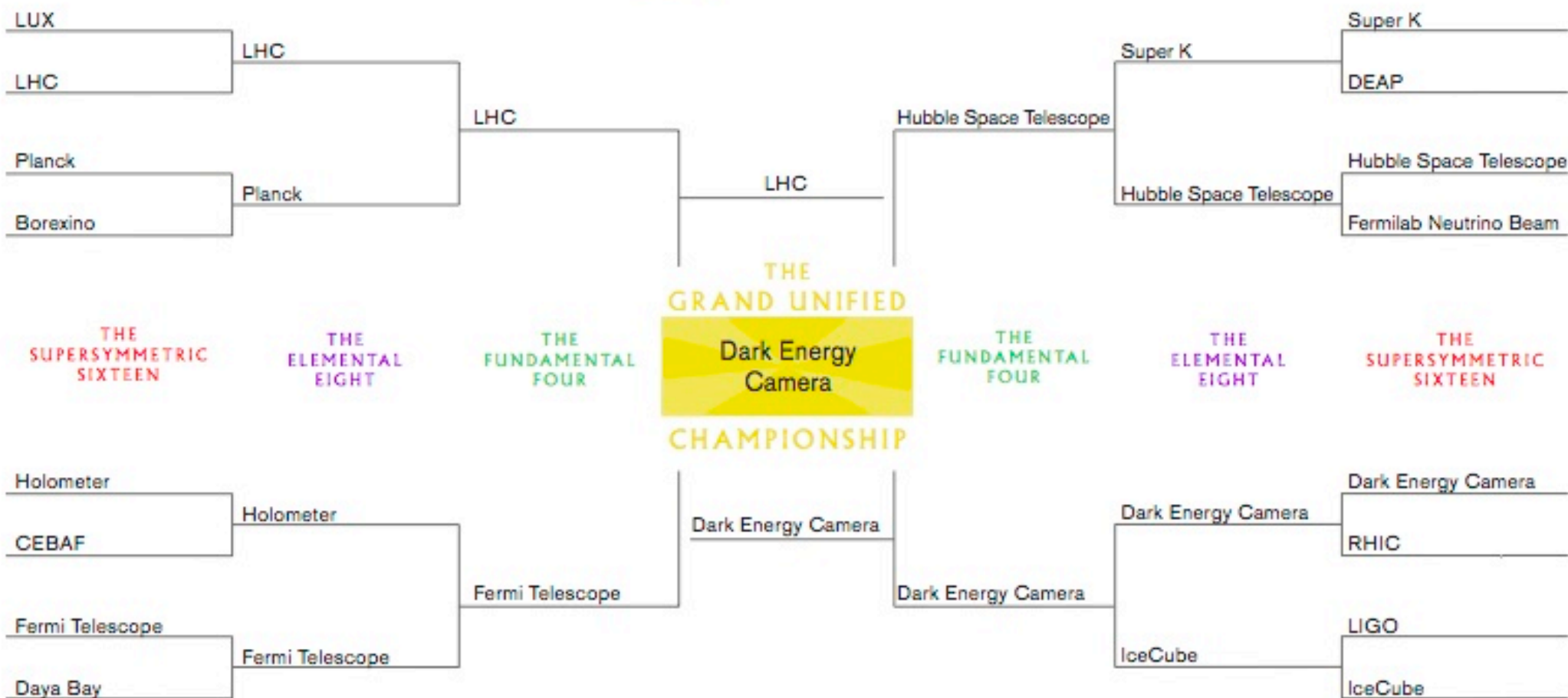
F

contest

April 06, 2015

Physics Madness Grand Champion

And your 2015 winning physics machine is...





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DES Data Management

Each exposure (in a given filter) generates 500Mb

300 exposures/night – 150 Gb/night

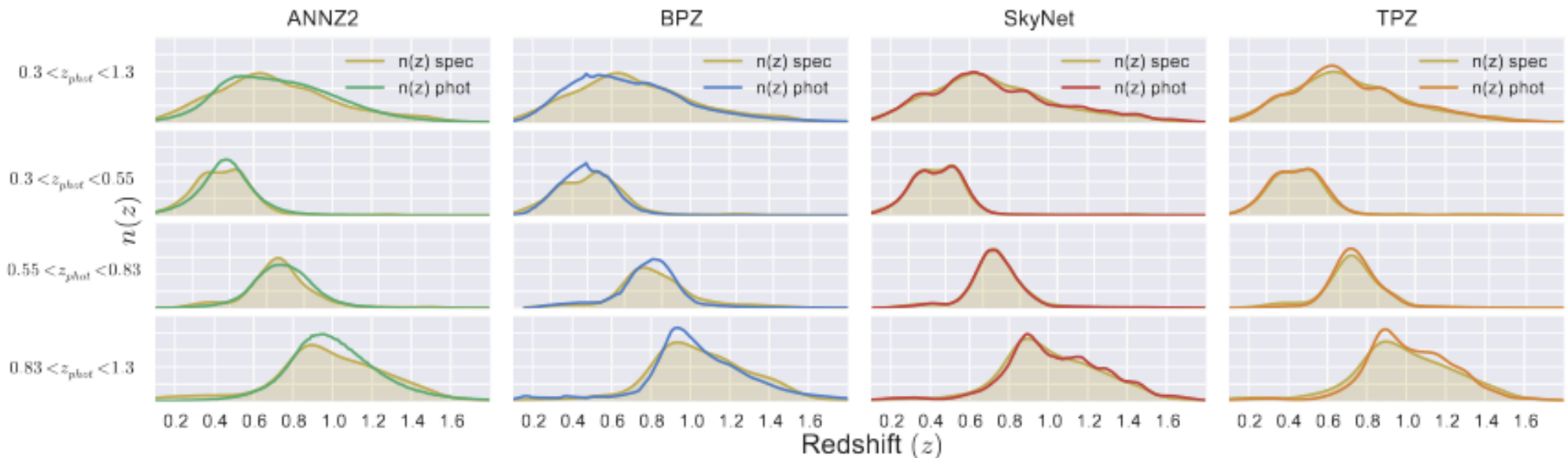
Transferred and processed at NCSA in Urbana



Photometric redshift

Single-epoch images are calibrated, background-subtracted, coadded, and processed in 'tiles' ($0.75 \times 0.75 \text{ deg}^2$) needed to cover the entire DES footprint. A catalogue of objects was extracted from the coadded images using Source Extractor (SExtractor).

Several algorithms to estimate photo-z: machine learning and template based. Must use a probability distribution function to characterize a measurement of the photo-z.





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Brazilian infrastructure contribution

- QuickReduce: software for fast assessment of image quality at CTIO
- The Science Portal: Data Server, Value Added Catalogs and scientific pipelines

Creating a science-ready catalog is the crux:
selection of objects, photo-z, systematic effects, ...



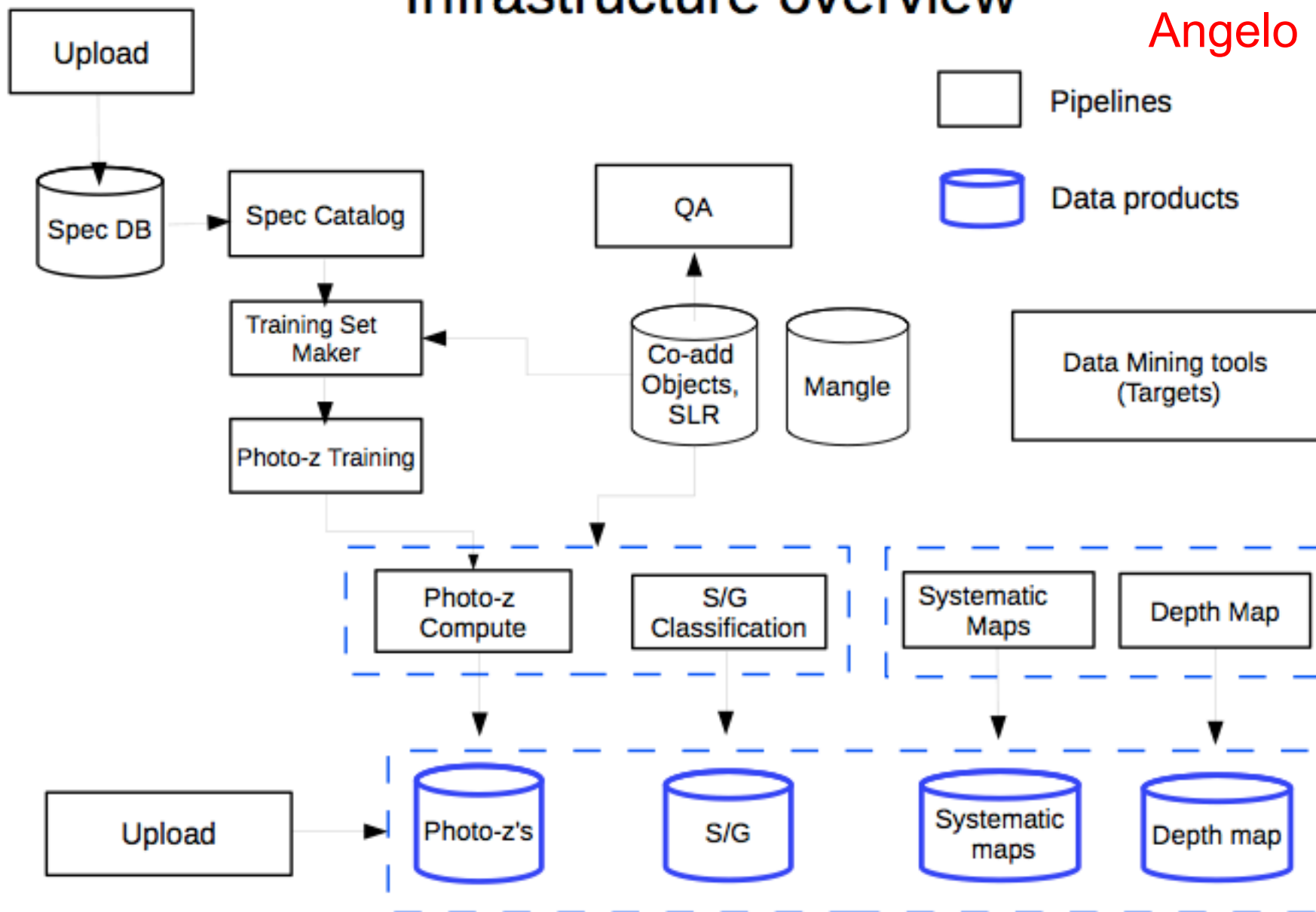
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Infrastructure overview

Angelo Fausti





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<https://des-portal.fnal.gov/>

[Release Notes](#)

DES Science Portal: Data Server

The DES Science Portal hosts tools for Quality Assessment (QA), Value-Added Catalogs (VACs) preparation and Science Analysis.


From the **Data Server** instance @ FNAL you have access to following tools:


- **Observations:** information about DES observations from the Night Summary and Quick Reduce
- **Data Releases:** list of the releases currently installed and associated data
- **Footprint:** spatial coverage and overlapping with external catalogs
- **Tile Viewer:** visual inspection of co-add images and catalogs
- **Catalog Server:** access to VACs produced by the portal, uploaded catalogs, reference catalogs and simulations
- **Science Products:** access to science products produced by the portal or uploaded by other authors


The system is designed to be self-evident, use the help icon "(?)" available on each page.


The Science Portal is a facility developed by [LineA](#). If you have any question please contact us through the helpdesk@linea.gov.br

Tweets Follow

 **DES Science Portal** @des_portal 14 Jul
A new Upload process was published by Elizabeth Buckley-Geer. des-portal.fnal.gov/VP/getViewProc...

 **DES Science Portal** @des_portal 14 Jul
A new Upload process was published by Elizabeth Buckley-Geer. des-portal.fnal.gov/VP/getViewProc...

 **DES Science Portal** @des_portal 14 Jul
The status of 5.0 (IM3Shape) has been updated to "Do not use".

 **DES Science Portal** @des_portal 8 Jul
A new Upload process was published by Helia Gaitan...

Tweet to @des_portal



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Browser address bar: <https://des-portal.fnal.gov/static/tileviewer/index.html>

Search:

Tile Viewer

Release: Field:

QA DaCHS Comment on Release

Footprint Tile Mosaic Tile List Favorites Targets Gallery Tile Detail

Tile DES0002+0001 Overplot Exposures Defects Comments

Selected Tile

g r i z Y RGB Masks Inspected Flag this tile

Selected Object

Object Id

RA (deg)	
Dec (deg)	
l (deg)	
b (deg)	
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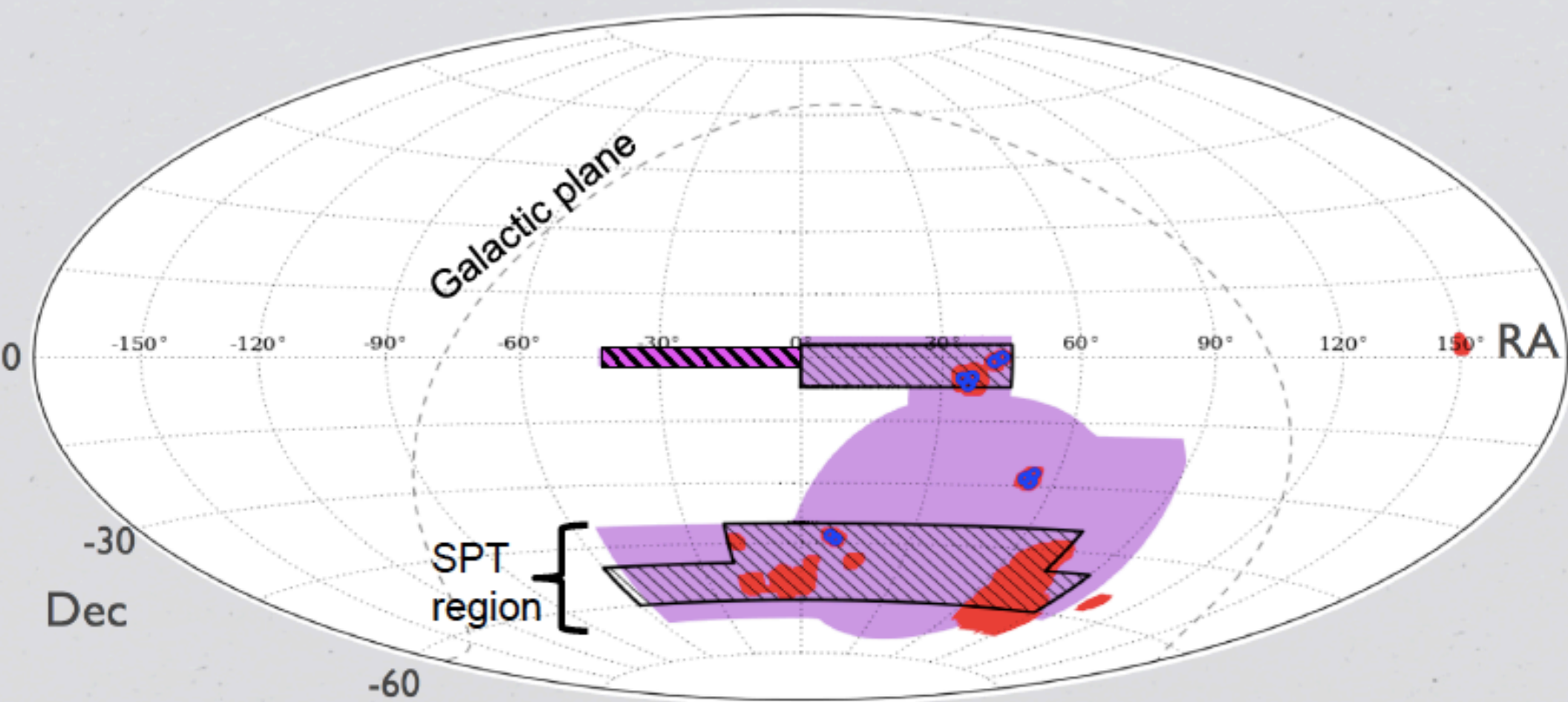
RA (deg): 1.0046 Dec (deg): -0.0353

Tiles: Inspected: Blacklisted:



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DES SURVEY FOOTPRINT



- 5000 sq. deg. 5-yr footprint
- SN fields
- Science Verification
- Year 1

- Science Verification (SV): ~250 sq. deg. to ~full depth; 45 M objects
- Year 1 (Y1): ~2000 sq. deg.; overlap SPT, SDSS: 4/10 tilings; 140 M objects



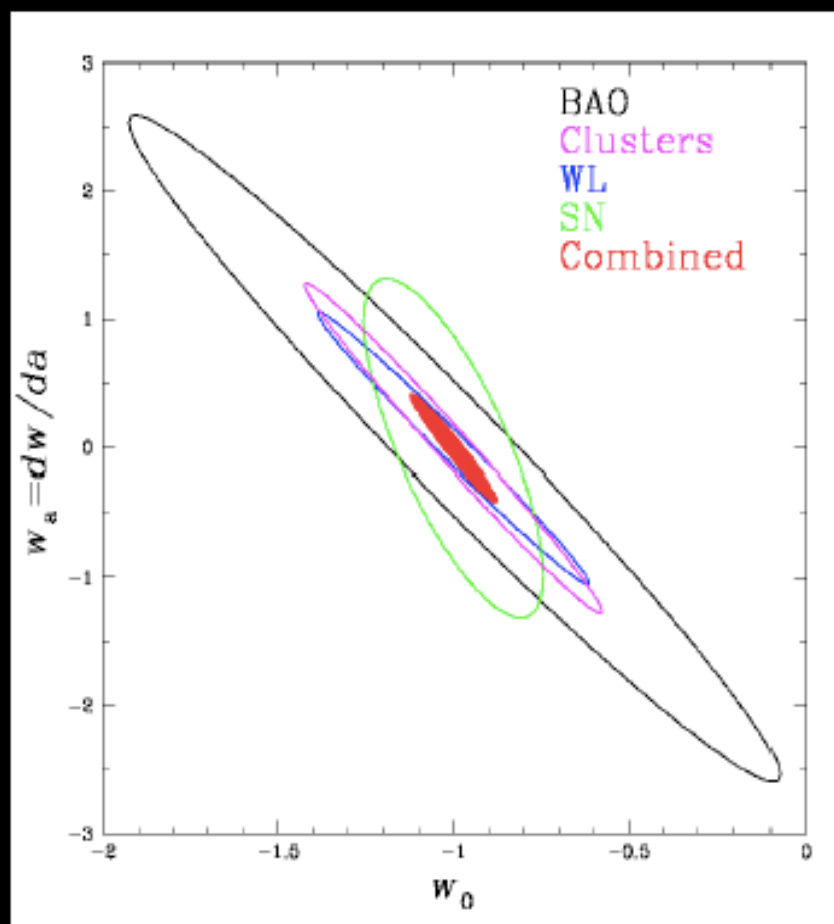
DES Science Summary

Forecast Constraints on DE Equation of State

$$w(a) = w_0 + w_a(1 - a(t)/a_0)$$

Four Probes of Dark Energy

- **Galaxy Clusters**
 - Tens of thousands of clusters to $z \sim 1$
 - Synergy with SPT, VHS
- **Weak Lensing**
 - Shape and magnification measurements of 200 million galaxies
- **Baryon Acoustic Oscillations**
 - 300 million galaxies to $z = 1$ and beyond
- **Supernovae**
 - 30 sq deg time-domain survey
 - 3500 well-sampled SNe Ia to $z \sim 1$



DES forecast



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Some recent results

DES is not only
about Dark Energy!

The Dark Energy Survey: more than dark energy - an overview

1601.00329



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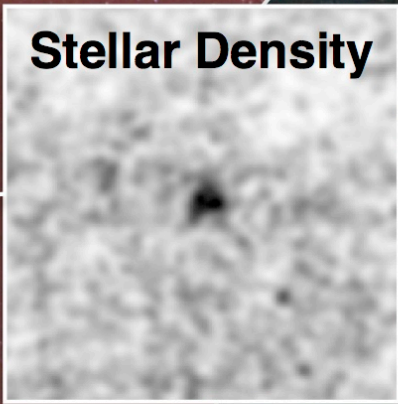
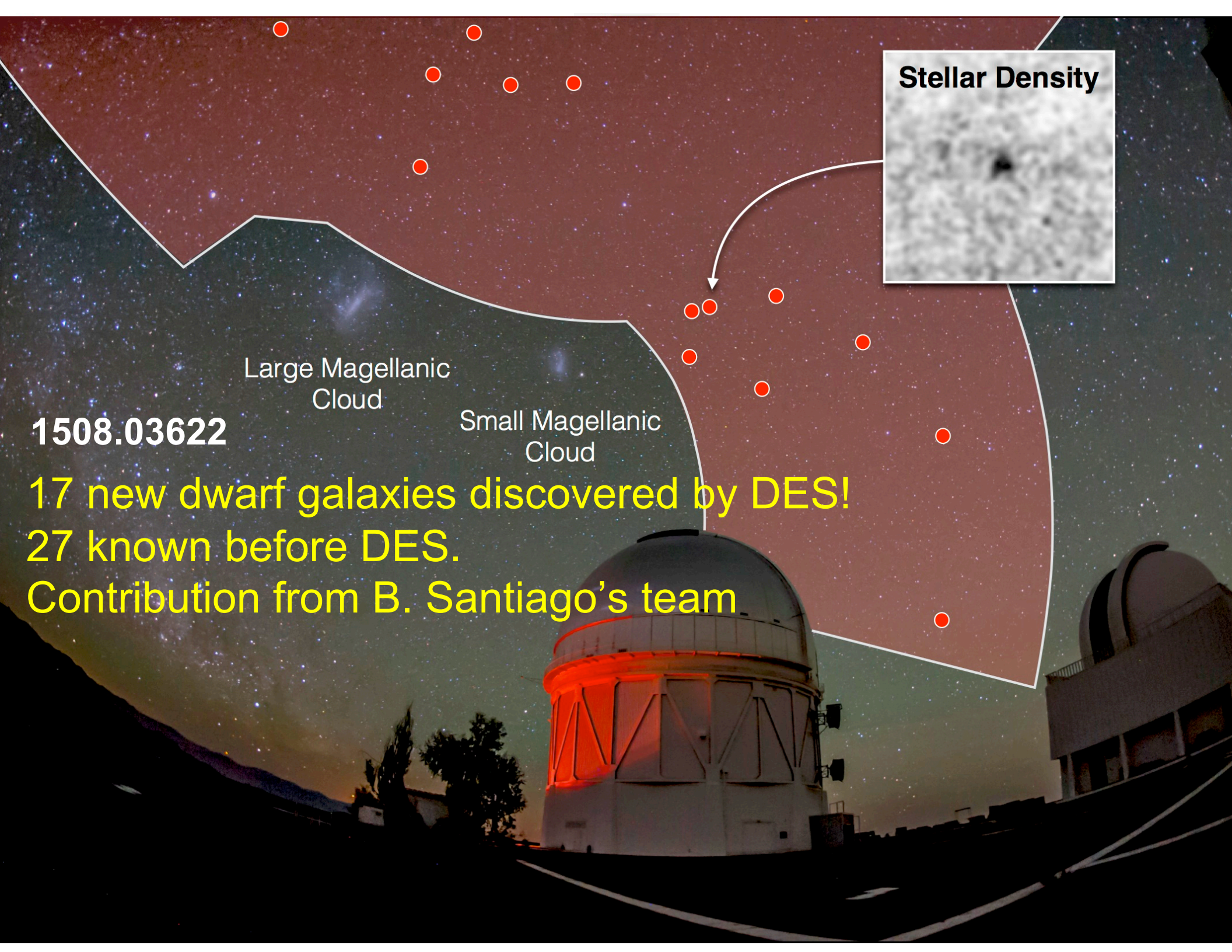
DES-BRAZIL



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50+ papers submitted (mostly from SV data)

- Produced the largest contiguous mass map of the Universe;
- Discovered nearly a score of Milky Way dwarf satellites and other Milky Way structures;
- Measured weak lensing cosmic shear, galaxy clustering, and cross-correlations with CMB lensing and with X-ray and SZ-detected clusters;
- Continued to measure light curves for large numbers of type Ia supernovae and discovered a number of super-luminous supernovae including the highest-redshift SLSN so far;
- Discovered a number of redshift $z > 6$ QSOs;
- Discovered a number of strongly lensed galaxies and QSOs;
- Discovered a number of interesting objects in the outer Solar System.



Large Magellanic
Cloud

Small Magellanic
Cloud

1508.03622

**17 new dwarf galaxies discovered by DES!
27 known before DES.
Contribution from B. Santiago's team**



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**Eight New Milky Way Companions Discovered in First-Year Dark Energy
Survey Data**

1503.02584

Closest and best characterized one is Reticulum II (32 kpc). Mass-to-light ratio is

$$240 \pm 80 M_{\odot} / L_{\odot}$$

Strongly dark matter dominated system!

**Search for Gamma-Ray Emission from DES Dwarf Spheroidal Galaxy Candidates
with Fermi-LAT Data**

1503.02632 (joint DES-Fermi)



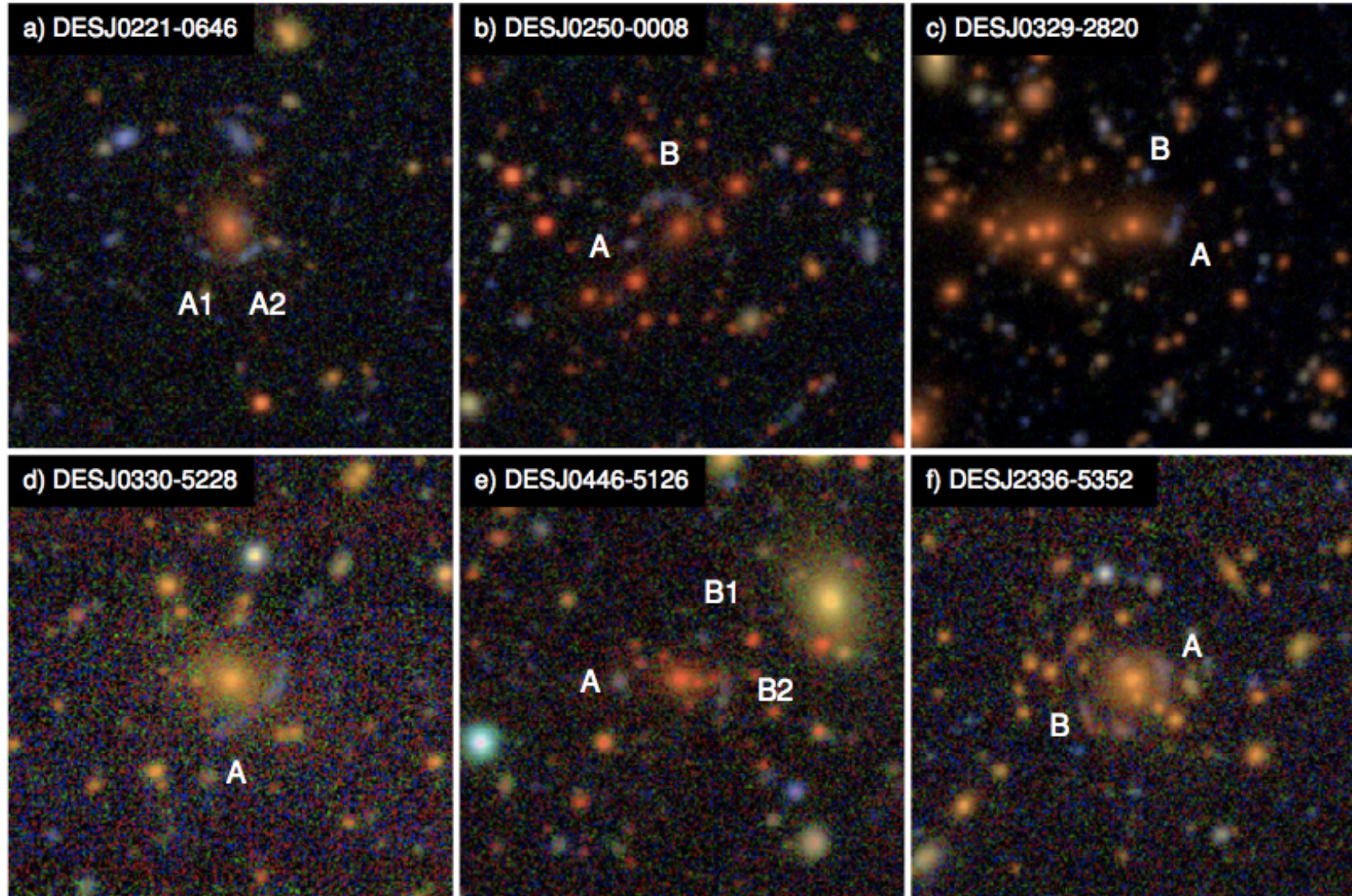
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OBSERVATION AND CONFIRMATION OF SIX STRONG LENSING SYSTEMS IN THE DARK ENERGY SURVEY SCIENCE VERIFICATION DATA

1512.03062



January

35



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NATURE | NEWS



Dark matter mapped at cosmic scale

Survey charts clusters and voids of invisible matter over hundreds of millions of light years.

Davide Castelvecchi

13 April 2015

Wide-Field Lensing Mass Maps from DES Science Verification Data:
Methodology and Detailed Analysis - [arXiv:1504.03002](https://arxiv.org/abs/1504.03002)



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LINRA

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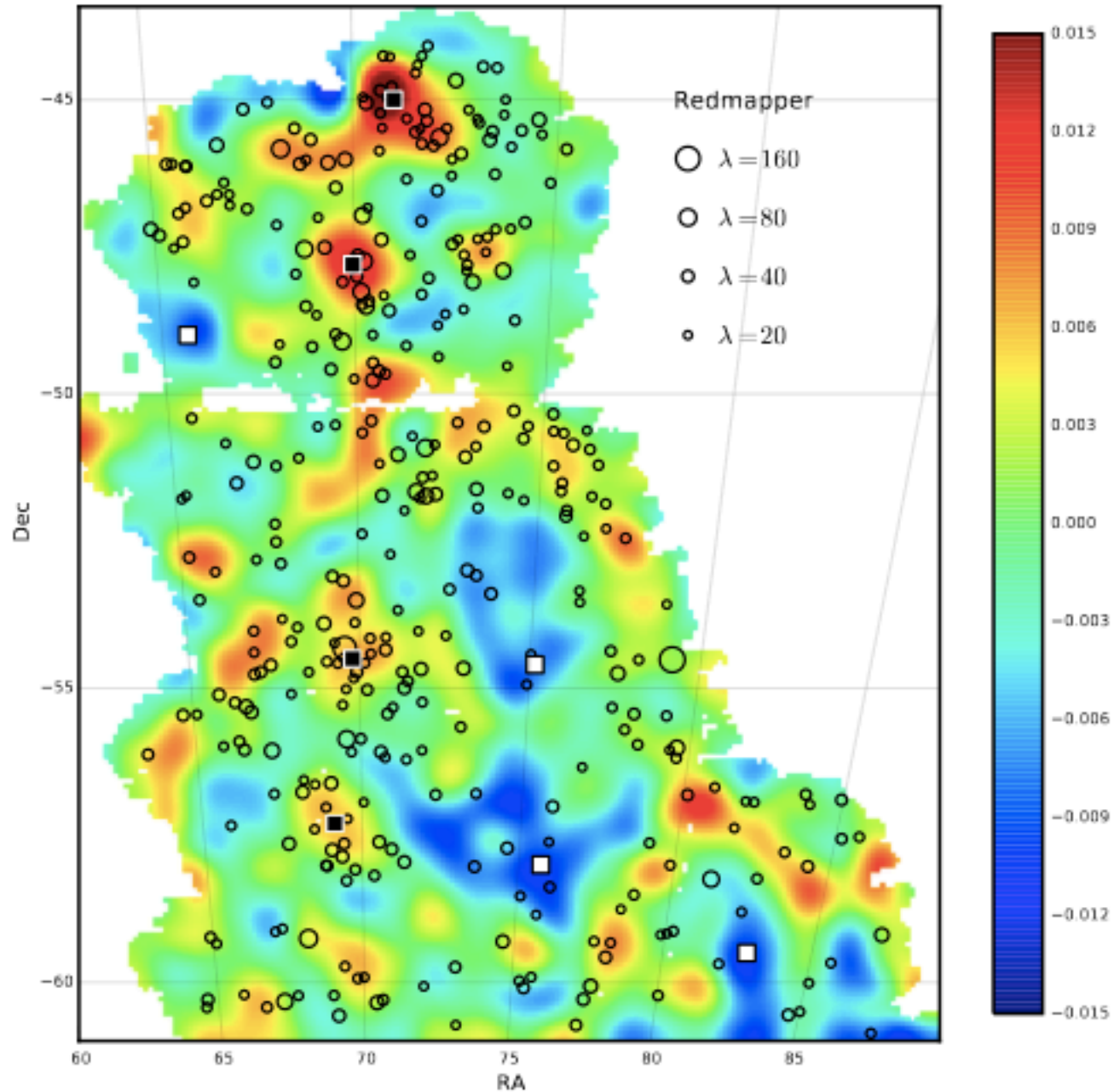


FIG. 4: The DES SV mass map along with foreground galaxy clusters detected using the Redmapper algorithm. The clusters are overlaid as black circles with the size of the circles indicating the richness of the cluster. Only clusters with richness greater than 20 and redshift between 0.1 and 0.5 are shown in the figure. The upper right corner shows the correspondence of the optical richness to the size of the circle in the plot. It can be seen that there is significant correlation between the mass map and the distribution of galaxy clusters. Several superclusters (black squares) and voids (white squares) can be identified in the joint map.

January 12, :

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Some highlights: measuring bias

Baryons are only $\sim 15\%$ of the total matter in the Universe!

Galaxies are a **biased** tracer of the total matter distribution.
DES measures the distribution properties of galaxies.

$$\delta_g(\vec{x}) = b(z)\delta(\vec{x})$$

galaxy overdensity

bias

matter overdensity (cosmological model)

Two-point correlation functions are measured using 2.3×10^6 galaxies over a contiguous 116 deg^2 region in five bins of photometric redshift width $\Delta z = 0.2$ in the range $0.2 < z < 1.2$.

Galaxy clustering, photometric redshifts and diagnosis of systematics in the DES SV data - 1507.05360
MNRAS 455,4301–4324 (2016)

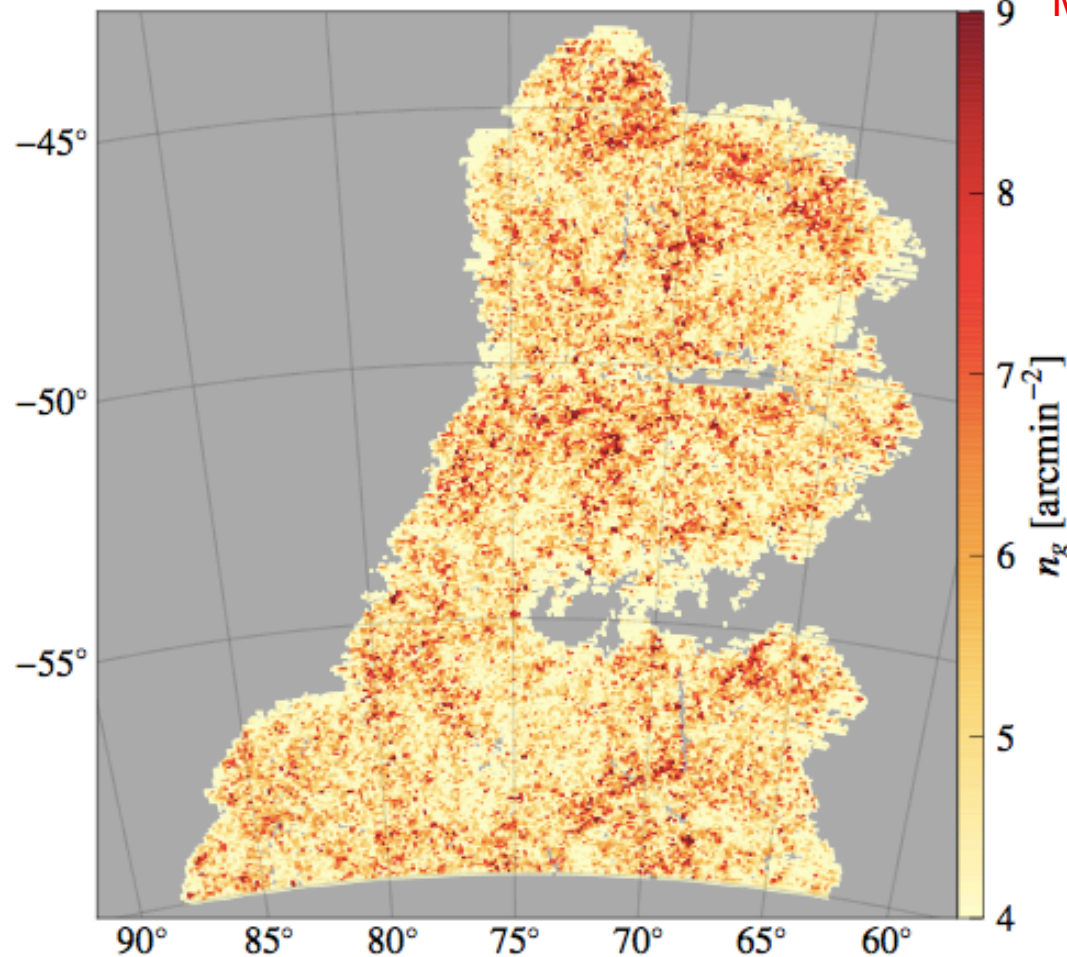


Figure 3. The distribution of LSS bench-mark sample galaxies over the angular footprint defined by regions with survey limiting magnitude in the i -band > 22.5 . The sample is selected to be flux limited to $i < 22.5$ and has a mean density of 5.6 arcmin^{-2} . All the regions considered provide at least $S/N > 10$ measurements.

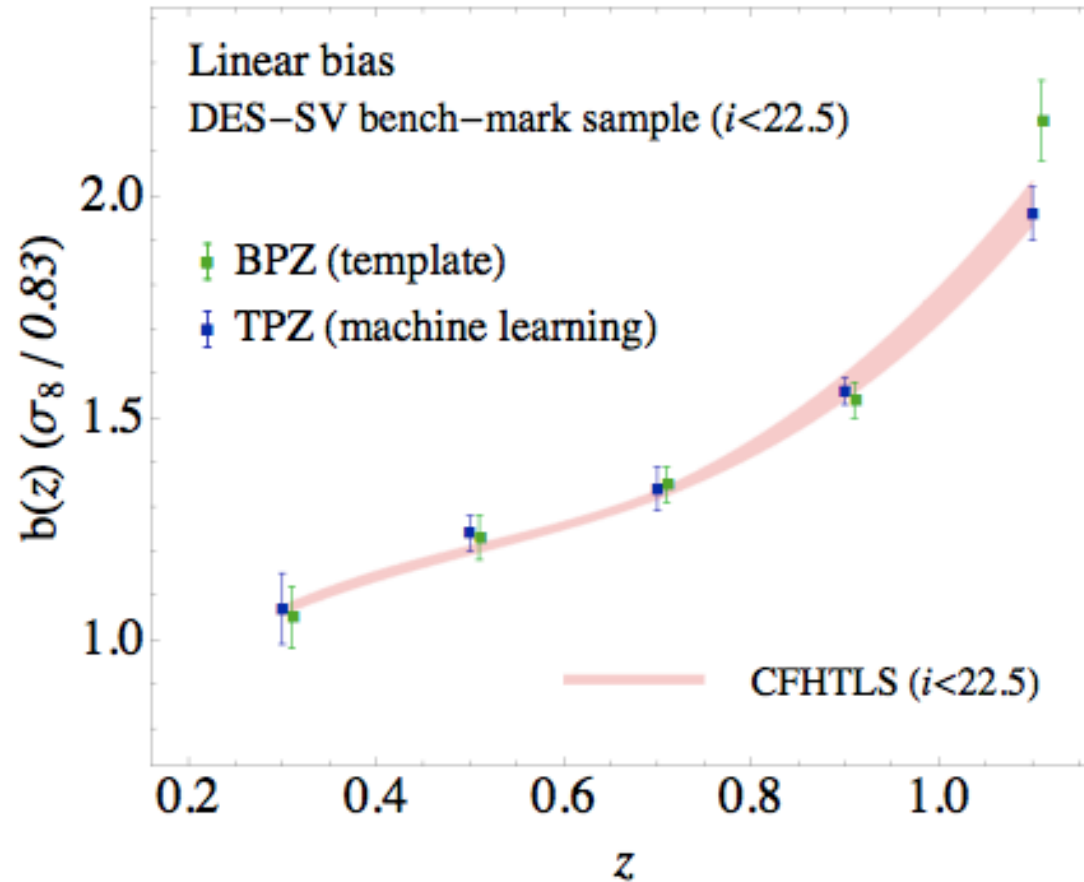
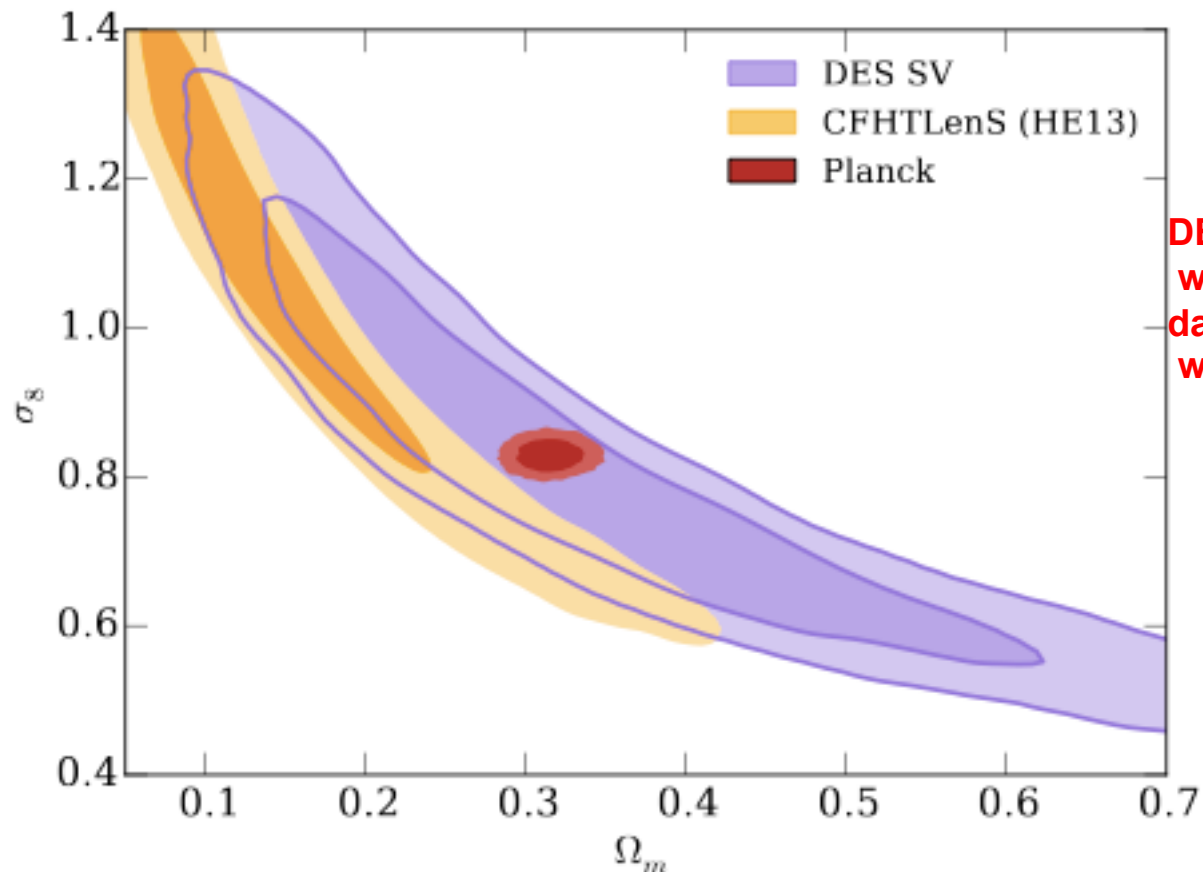


Figure 11. Comparison of the large-scale bias measured in a DES-SV flux limited sample ($i < 22.5$) to equivalent measurements from CFHTLS derived from Coupon et al. (2012). We present DES results for two different photometric redshift catalogs, one obtained using a template method (BPZ), another with a machine learning approach (TPZ). The overall agreement between the two DES samples as a function of redshift is better than 2 per cent for $z < 1$. At $z > 1$ the difference is not statistically significant ($\sim 2\sigma$). This represents a non-trivial test for DES-SV photometric redshift estimation. Our results are also in good agreement with those from CFHTLS, with $\chi^2/d.o.f = 4/5$ for TPZ and $8.7/5$ for BPZ, representing a cross-validation of data quality and sample selection.

Some highlights: first cosmological constraints

Cosmology from Cosmic Shear with DES Science Verification Data - [1507.05552](#)

Uses 139 square degrees of SV data, which is less than 3% of the full DES survey area



DES SV alone places weak constraints on the darkenergy equation of state $w < -0.68$ (95%)

DES SV and CFHTLenS are marginalised over the same astrophysical systematics parameters and DES SV is additionally marginalised over uncertainties in photometric redshifts and shear calibration.



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Conclusions

- Dark Energy Survey third season (Y3) is ongoing
- DECam is working to specification
- Pipelines for data analysis are in place (still work to do)
- Y1 science-ready catalogue finished last December
- Science Verification public data release scheduled for Jan. 15
- Some results from the Science Verification data (less than 5 % of total area already interesting) – catalogues for LSS and shear are fine!
- DES is a precursor to the LSST (8.4 m telescope in Chile – CTIO)