# The Dark Energy Survey: Some Lessons learned

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Data Release Scientist, DES

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# The Dark Energy Survey

- 4 meters telescope, 520 Mpx camera
- 5 year survey, ⅛ of the sky, Telescope in Chile, data @ NCSA, about to start 6th season
- Main Goal: To constrain the models of the Universe regarding Dark Energy and Dark Matter.
- Many other Science Cases! (New dwarf planet, New galaxy satellites, Supernovae, etc)
- 1 - 3 TB of data per night, 1 PB of data
- Processing done at FermiGrid, Campus Cluster and Blue Waters
- Thousands of images and billions of rows, ~500 millions objects
- 1st Public Data Release in January 2018
- NCSA provide means to access and interact with data → Containers

# The DES Data Access

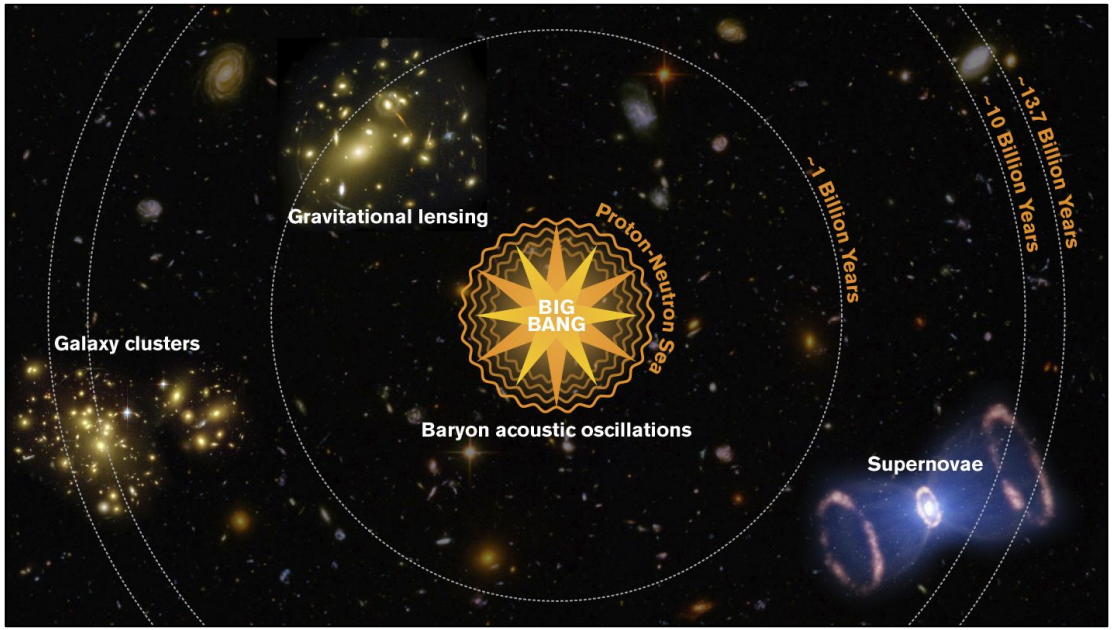
Challenges:

- Data access wasn't very clear in original proposal
- People
- Time
- Collaborations Needs
- All the rest of technical challenges

- DES Survey: Gold (Data) Mine
- DESDM: Excellent job at mining the data
- Consumers outside the mine
- Need to bring/expose gold (data) outside
- Tools and interfaces
- DES DR1 is out!

# The DES Science

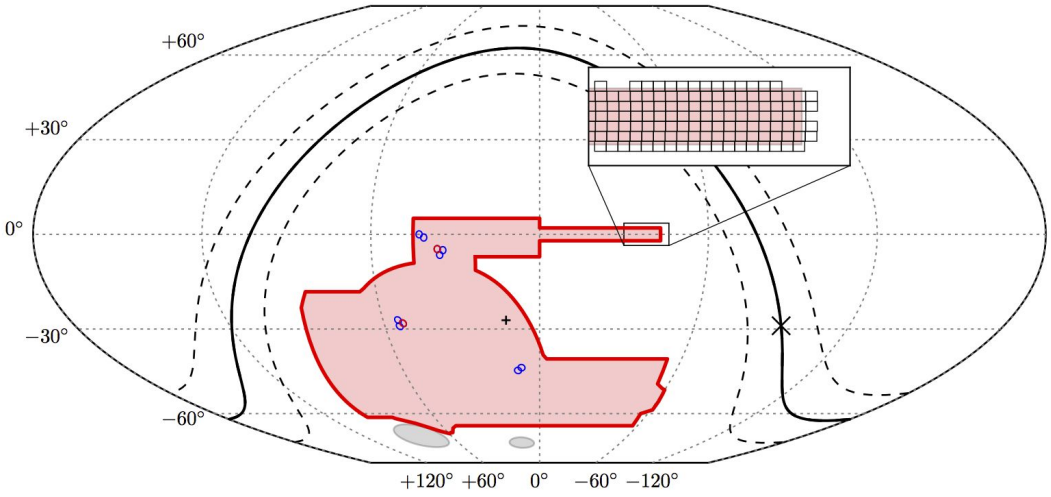
DES is designed to improve our understanding of **cosmic acceleration** and the **nature of dark energy** using four complementary probes of the expansion history and growth of cosmic structure




... and like other cosmic surveys, the DES data enable a wide range of additional science ranging from the Solar System to the high-redshift Universe

See also *The Dark Energy Survey: more than dark energy - an overview*
DES Collaboration, arXiv:1601.00329

# The DES Survey




**Dark Energy Survey (DES)**

Wide-field Survey: 5000 deg$^2$, 10 visits in each of *grizY*

Target S/N = 10 coadd depth ~24 mag

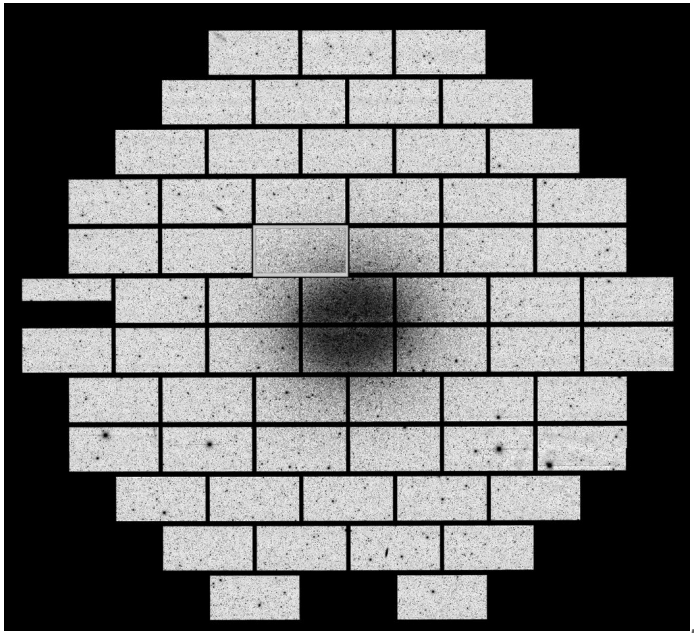
Supernova Survey: 27 deg$^2$, observed at weekly cadence

**Dark Energy Camera (DECam)**
**(Flaugher, B. et al. 2015)**

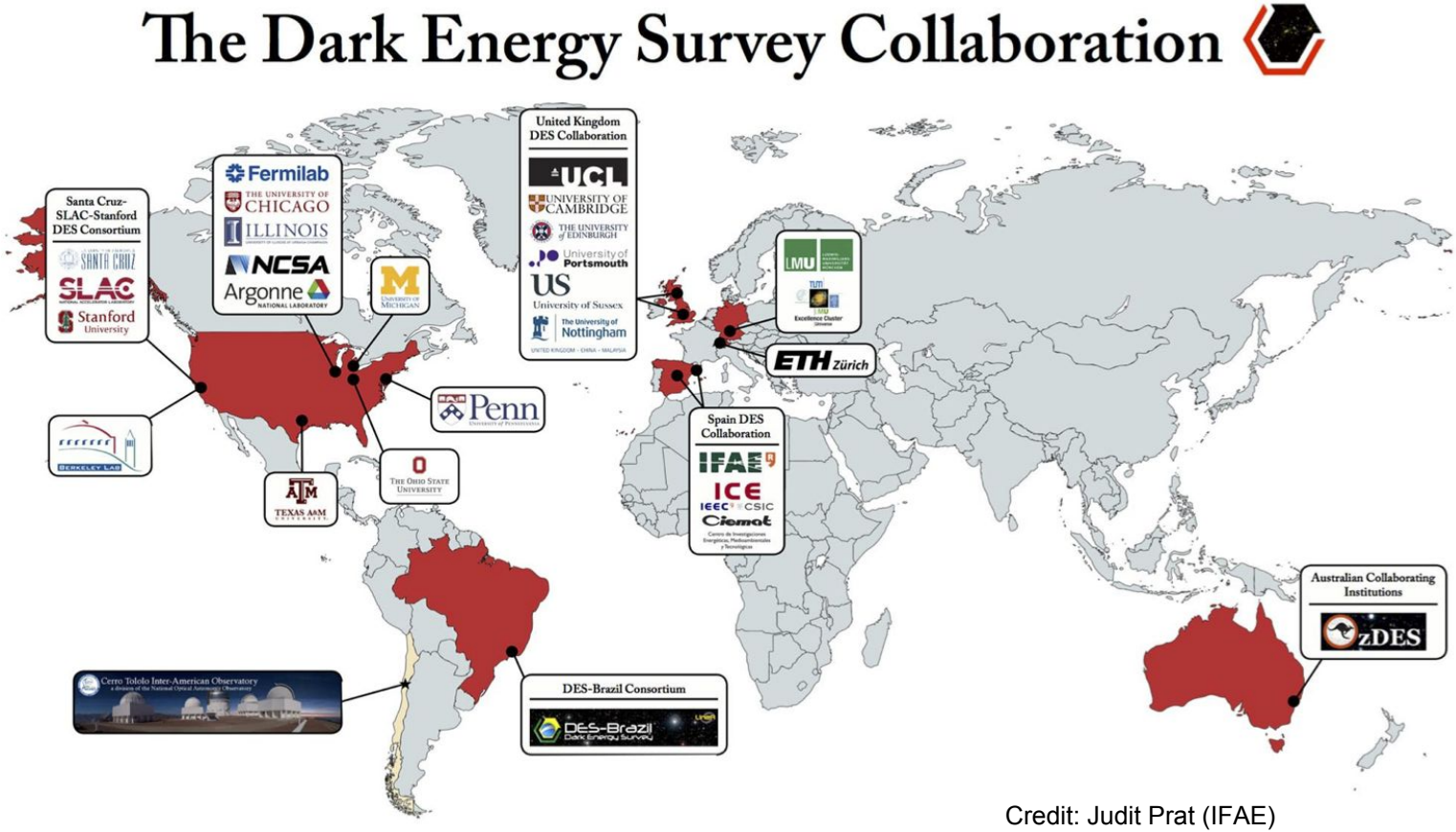
570 Mpix camera on

**Blanco 4-m telescope at CTIO**

3 deg$^2$ field of view, 62 science CCDs



# The DES Collaboration




Credit: Judit Prat (IFAE)

# DES in the last decade

DES vision circa 2005

## The Dark Energy Survey

arXiv:astro-ph/0510346

Brenna Flaugher
for the Dark Energy Survey Collaboration*

*Fermilab*
*M.S. 310, Box 500*
*Batavia, IL 60510, USA*

Dark Energy is the dominant constituent of the universe and we have little understanding of it. We describe a new project aimed at measuring the dark energy equation of state parameter, $w$, to a statistical precision of $\sim$5%, with four separate techniques. The survey will image 5000 deg$^2$ in the southern sky and collect 300 million galaxies, 30,000 galaxy clusters, and 2000 Type Ia supernovae. The survey will be carried out using a new 3 deg$^2$ mosaic camera mounted at the prime focus of the 4m Blanco telescope at CTIO.

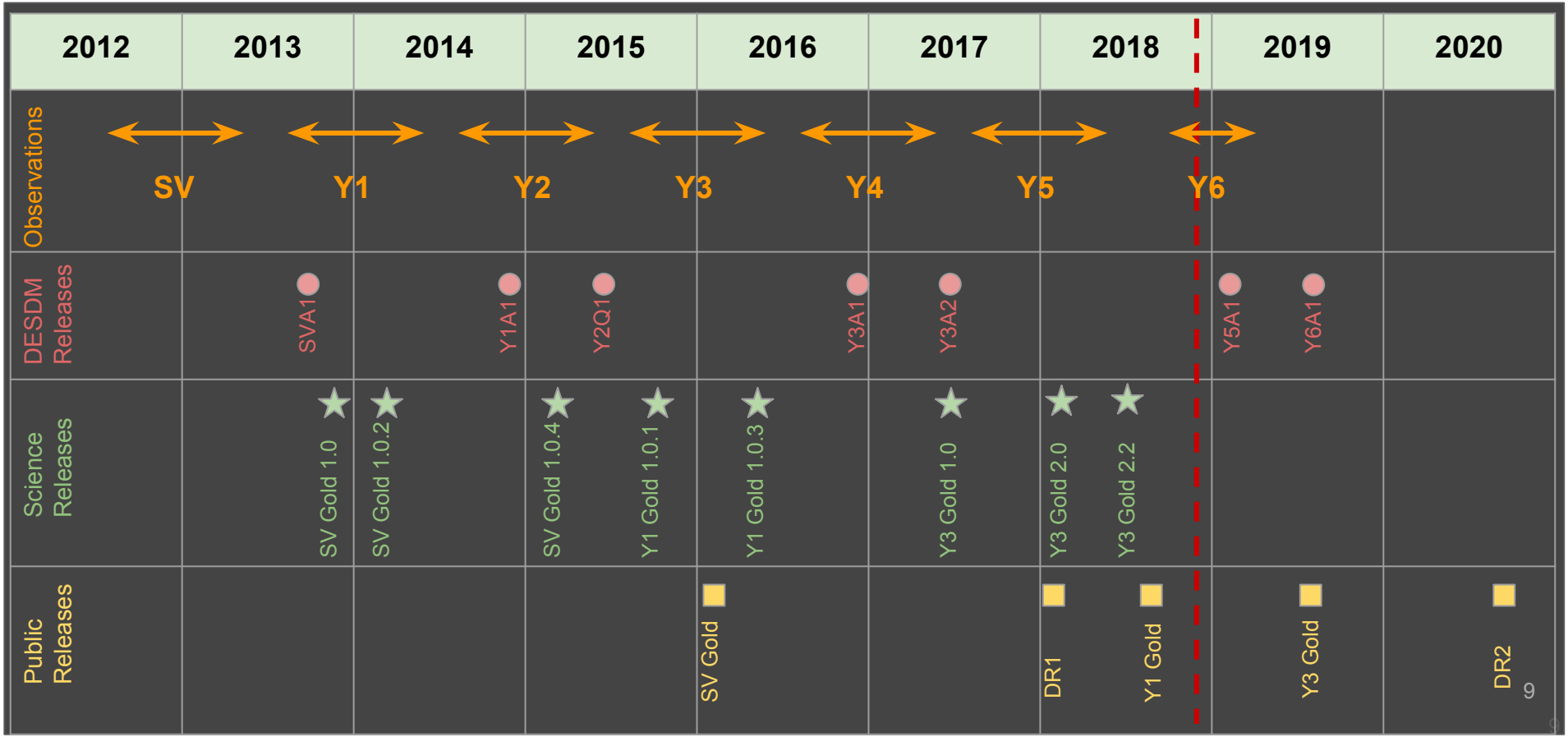
*Keywords*: Dark energy ; galaxies; supernovae.

# 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<br>~ 35,000 clusters @ z~1 |

**Largest photometric dataset to date at the achieved depth and photometric precision**

# DES Data Releases



# The DES Science

## DES Data Management

- Home
- Releases
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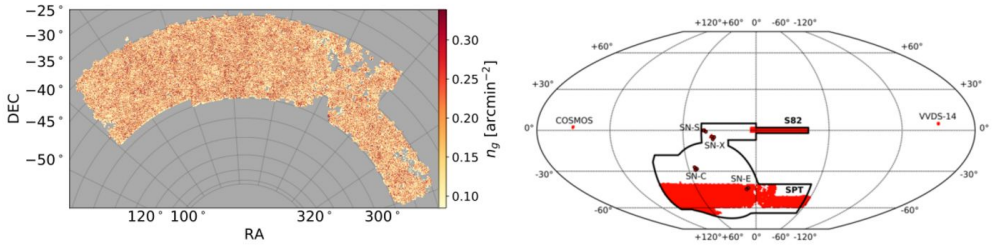
### DES Y1 RELEASE




This page presents the release of the DES Year 1 (Y1) data products. For a detailed description and list of available files of this release please see the links below. Users may also consider using the DES DR1 based on three years of survey operations for improved astrometric accuracy and precision.

Files | Data Summary | Help

# The DES Science

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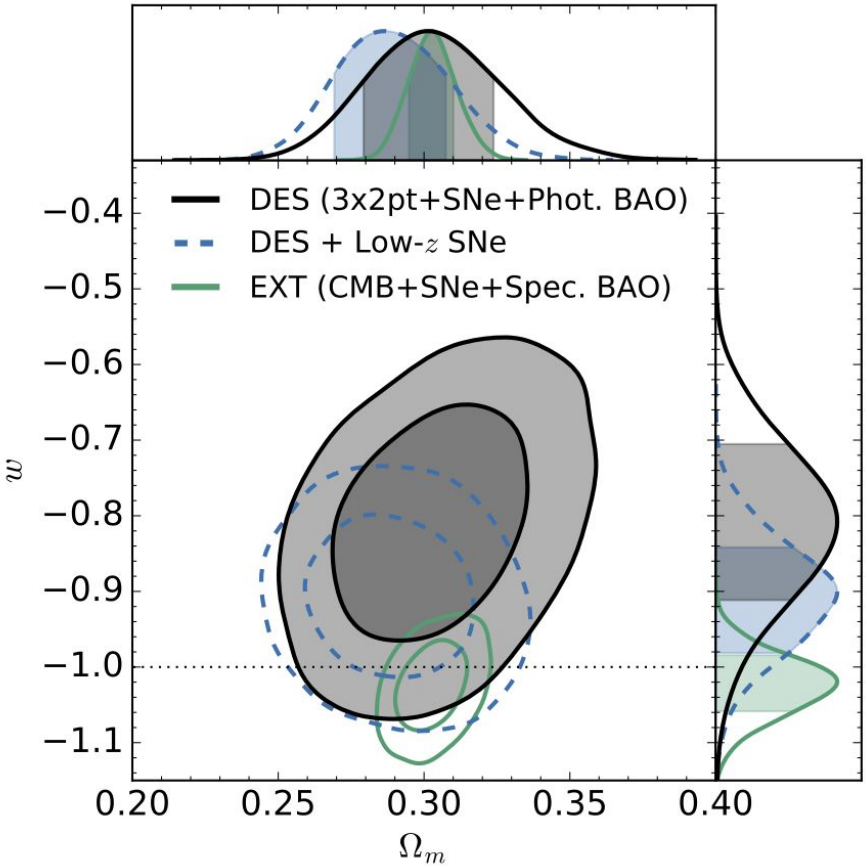
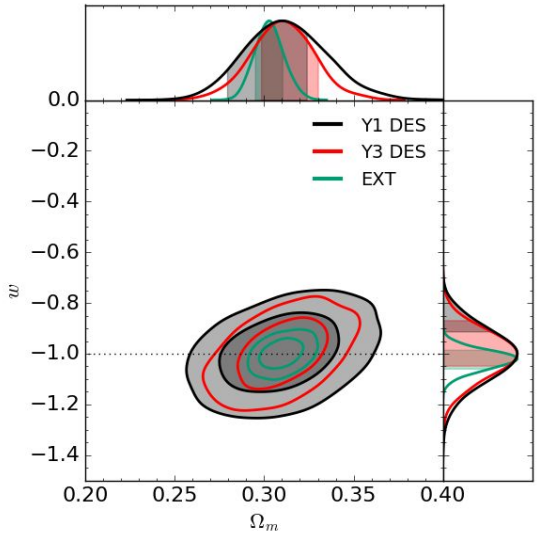
| Main Category | Product | Documentation | Filename(s) | Reference |
|---|---|---|---|---|
| Y1A1 Gold | Gold Catalog | Y1A1 Gold Data | Link | Drlica-Wagner et al. (2018) |
| Y1A1 Gold | Morphological Catalog | Morphological Catalogs | Link | Tarsitano et al. (2018) |
| Y1A1 Gold | Star/Galaxy Separation | Star-Galaxy Separation | Link | Sevilla-Noarbe et al. (2018) |
| Y1A1 Gold | Footprint/Mask | Footprint/Depth | Link | Drlica-Wagner et al. (2018) |
| Y1A1 Gold | Observing Conditions | Observing Conditions | Link | Drlica-Wagner et al. (2018) |
| | | | | |
| Y1KP catalogs | Multi-Object-Fitting Photometry | Link | Link | Drlica-Wagner et al. (2018) |
| Y1KP catalogs | Shape Catalogs | Link | Link | Zuntz & Sheldon et al. (2018) |
| Y1KP catalogs | PSF Catalog | Link | Link | Zuntz & Sheldon et al. (2018) |
| Y1KP catalogs | redMaPPer Catalogs | To be released | To be released | McClintock & Varga et al. (2018) |
| Y1KP catalogs | redMaGiC Catalogs | Link | Link | Elvin-Poole et al. (2018) |
| Y1KP catalogs | Photometric Redshift Catalog | Link | Link | Hoyle & Gruen et al. (2018) |
| | | | | |
| Y1A1 Key Project | Data Vectors | Link | Link | DES Collaboration (2018) |
| Y1A1 Key Project | Redshift Distributions in Tomographic Bins | Link | Link | DES Collaboration (2018) |
| Y1A1 Key Project | Likelihoods/Chains | Link | Link | DES Collaboration (2018) |
| Y1A1 Key Project | Mass Maps | Link | Link | Chang et al. (2018) |
| | | | | |
| Y1A1 BAO | Catalogs, Footprint, and Redshift Distributions | Link | Link | Crocce et al. (2018) |
| Y1A1 BAO | Consensus Likelihood from BAO measurement | Link | Link | DES Collaboration (2017) |
| Y1A1 BAO | Angular Correlation Function | Link | Link | DES Collaboration (2017) |
| Y1A1 BAO | Angular Power Spectrum | To be released | To be released | Camacho et al. (2018) |
| Y1A1 BAO | 3D Clustering | Link | Link | DES Collaboration (2017) |
| Y1A1 BAO | Mock Catalogs | Link | Link | Avila et al. (2018) |
| | | | | |
| Y1 Density Split Stats | Data Vectors | Link | Link | Gruen et al. (2018) |
| Y1 Density Split Stats | Covariance | Link | Link | Gruen et al. (2018) |
| Y1 Density Split Stats | Redshift Distributions | Link | Link | Hoyle & Gruen et al. (2018) |

# The DES Science: Y1 Results

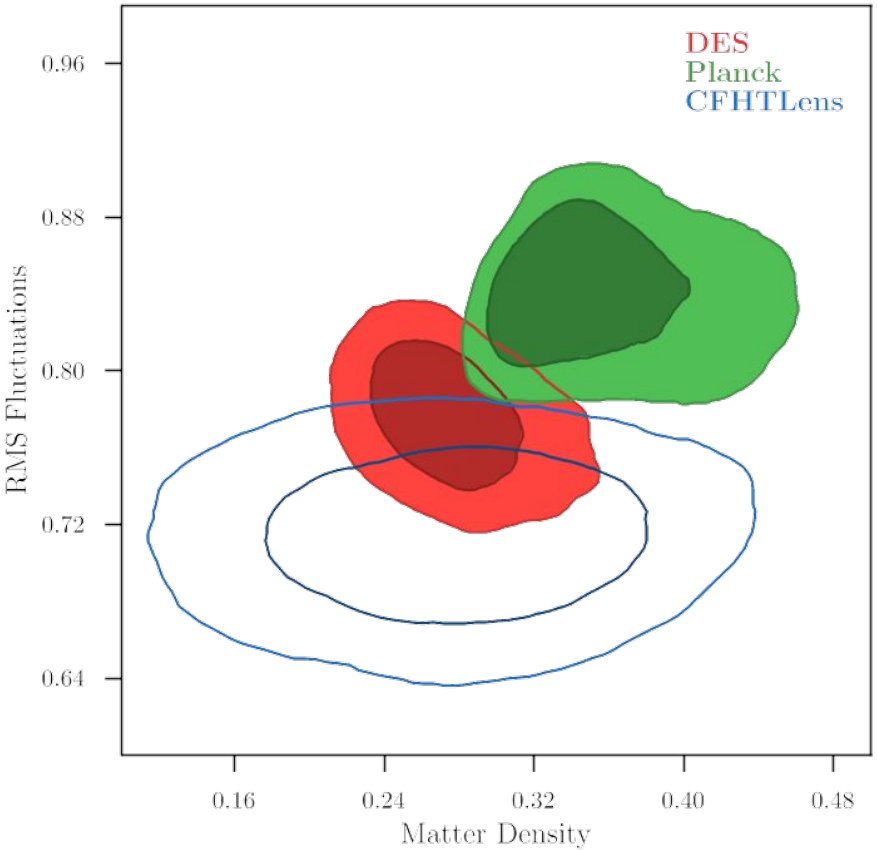



This is where we are with Y1* and no clusters.

We are already a factor of three better than the next best experiment (Planck) at constraining w.



# The DES Science: The DES Science: Y1 Results



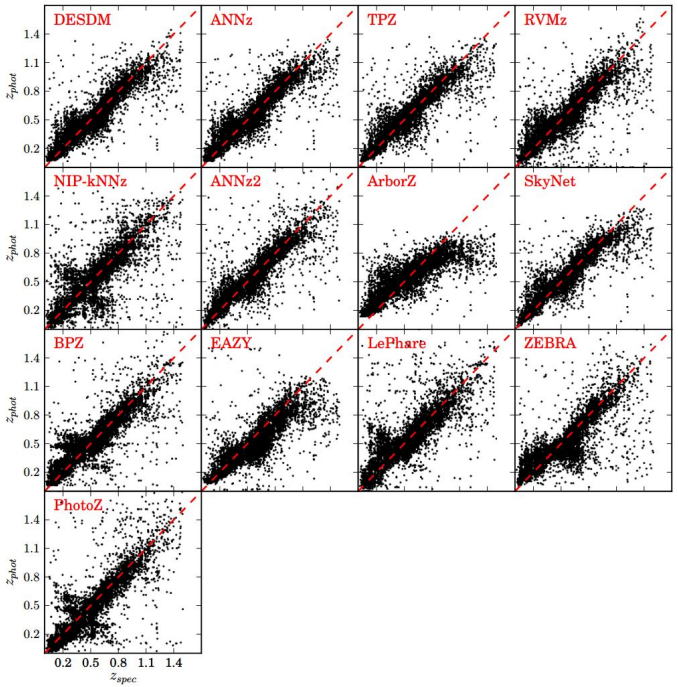

This is the time we can really achieve precision cosmology, maybe even break LCDM

# Study case

# The photo-z paradigm: SV

**Photometric redshift analysis in the Dark Energy Survey Science Verification data**

C. Sánchez[1⋆], M. Carrasco Kind[2], H. Lin[3], R. Miquel[1,4], F. B. Abdalla[5], A. Amara[6], M. Banerji[5], C. Bonnett[1], R. Brunner[2], D. Capozzi[7], A. Carnero[8,9], F. J. Castander[10], L. A. N. da Costa[8,9], C. Cunha[11], A. Fausti[9], D. Gerdes[12], N. Greisel[13,14], J. Gschwend[8,9], W. Hartley[6,15], S. Jouvel[5], O. Lahav[5], M. Lima[16,9], M. A. G. Maia[8,9], P. Martí[1], R. L. C. Ogando[8,9], F. Ostrovski[8,9], P. Pellegrini[8], M. M. Rau[13,14], I. Sadeh[5], S. Seitz[13,14], I. Sevilla-Noarbe[17], A. Sypniewski[12], J. de Vicente[17], T. Abbot[18], S. S. Allam[19,3], D. Atlee[20], G. Bernstein[21], J. P. Bernstein[22], E. Buckley-Geer[3], D. Burke[23,11], M. J. Childress[24,25], T. Davis[26,25], D. L. DePoy[27], A. Dey[20,28], S. Desai[29,30], H. T. Diehl[3], P. Doel[5], J. Estrada[3], A. Evrard[12,31,32], E. Fernández[1], D. Finley[3], B. Flaugher[3], J. Frieman[3], E. Gaztanaga[10], K. Glazebrook[33], K. Honscheid[34], A. Kim[35], K. Kuehn[36], N. Kuropatkin[3], C. Lidman[36], M. Makler[37], J. L. Marshall[27], R. C. Nichol[7], A. Roodman[23,11], E. Sánchez[17], B. X. Santiago[38,9], M. Sako[21], R. Scalzo[24], R. C. Smith[18], M. E. C. Swanson[39], G. Tarle[12], D. Thomas[7,40], D. L. Tucker[3], S. A. Uddin[33,25], F. Valdés[20], A. Walker[18], F. Yuan[24,25], J. Zuntz[41]



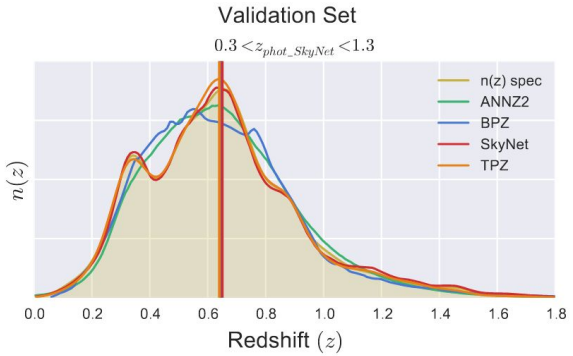
# The photo-z paradigm: SV

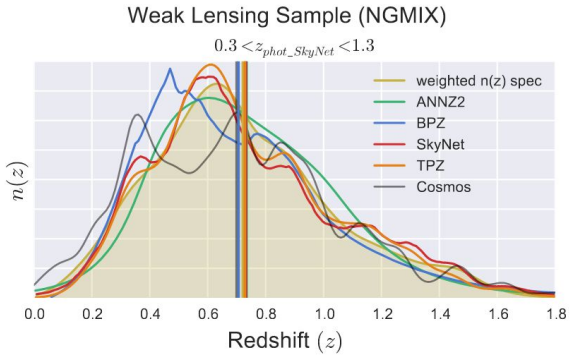
**Redshift distributions of galaxies in the DES Science Verification shear catalogue and implications for weak lensing**

C. Bonnett[1], M. A. Troxel[2], W. Hartley[3], A. Amara[3], B. Leistedt[4], M. R. Becker[5,6], G. M. Bernstein[7], S. L. Bridle[2], C. Bruderer[3], M. T. Busha[5], M. Carrasco Kind[9,10], M. J. Childress[48], F. J. Castander[11], C. Chang[3], M. Crocce[11], T. M. Davis[47], T. F. Eifler[7,12], J. Frieman[13,14], C. Gangkofner[51,52], E. Gaztanaga[11], K. Glazebrook[49], D. Gruen[33,35], T. Kacprzak[3], A. King[8], J. Kwan[15], O. Lahav[4], G. Lewis[46], C. Lidman[16], H. Lin[13], N. MacCrann[2], R. Miquel[1,17], C. R. O'Neill[47], A. Palmese[4], H.V. Peiris[4], A. Refregier[3], E. Rozo[18], E. S. Rykoff[6,19], I. Sadeh[4], C. Sánchez[1], E. Sheldon[51], S. Uddin[20], R. H. Wechsler[5,6,19], J. Zuntz[2], T. Abbott[21], F. B. Abdalla[4], S. Allam[13], R. Armstrong[22], M. Banerji[23,24], A. H. Bauer[11], A. Benoit-Lévy[4], E. Bertin[25,26], D. Brooks[4], E. Buckley-Geer[13], D. L. Burke[6,19], D. Capozzi[27], A. Carnero Rosell[28,29], J. Carretero[1,11], C. E. Cunha[6], C. B. D'Andrea[27], L. N. da Costa[28,29], D. L. DePoy[30], S. Desai[31,32], H. T. Diehl[13], J. P. Dietrich[32,33], P. Doel[4], A. Fausti Neto[28], E. Fernandez[1], B. Flaugher[13], P. Fosalba[11], D. W. Gerdes[34], R. A. Gruendl[9,10], K. Honscheid[36,37], B. Jain[7], D. J. James[21], M. Jarvis[7], A. G. Kim[38], K. Kuehn[16], N. Kuropatkin[13], T. S. Li[30], M. Lima[45,28], M. A. G. Maia[28,29], M. March[7], J. L. Marshall[30], P. Martini[36,39], P. Melchior[36,37], C. J. Miller[34,40], E. Neilsen[13], R. C. Nichol[27], B. Nord[13], R. Ogando[28,29], A. A. Plazas[12], K. Reil[19], A. K. Romer[41], A. Roodman[6,19], M. Sako[7], E. Sanchez[42], B. Santiago[28,43], R. C. Smith[21], M. Soares-Santos[13], F. Sobreira[13,28], E. Suchyta[36,37], M. E. C. Swanson[10], G. Tarle[34], J. Thaler[44], D. Thomas[27], V. Vikram[15], A. R. Walker[21]

(The DES Collaboration)





# The photo-z paradigm: Y1

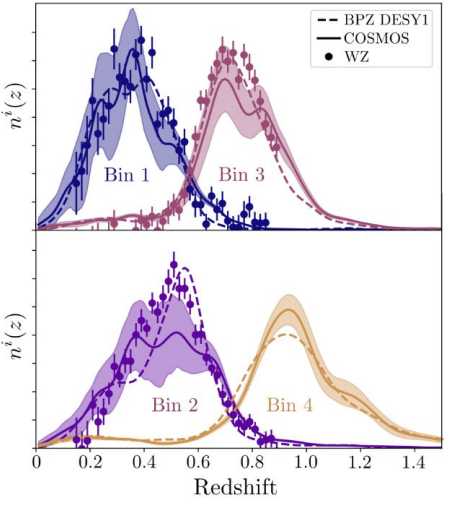
**Dark Energy Survey Year 1 Results:**
**Redshift distributions of the weak lensing source galaxies**

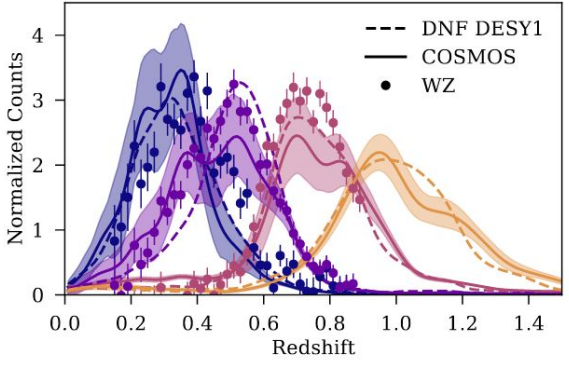
B. Hoyle[1,2⋆], D. Gruen[3,4†], G. M. Bernstein[5], M. M. Rau[1], J. De Vicente[6], W. G. Hartley[7,8], E. Gaztanaga[9], J. DeRose[10,3], M. A. Troxel[11,12], C. Davis[3], A. Alarcon[9], N. MacCrann[11,12], J. Prat[13], C. Sánchez[13], E. Sheldon[14], R. H. Wechsler[10,3,4], J. Asorey[15,16], M. R. Becker[10,3], C. Bonnett[13], A. Carnero Rosell[17,18], D. Carollo[15,19], M. Carrasco Kind[20,21], F. J. Castander[9], R. Cawthon[22], C. Chang[22], M. Childress[23], T. M. Davis[15,16], A. Drlica-Wagner[24], M. Gatti[13], K. Glazebrook[25], J. Gschwend[17,18], S. R. Hinton[16], J. K. Hoormann[16], A. G. Kim[26], A. King[16], K. Kuehn[27], G. Lewis[15,28], C. Lidman[15,27], H. Lin[24], E. Macaulay[16], M. A. G. Maia[17,18], P. Martini[11,29], D. Mudd[29], A. M¨oller[15,30], R. C. Nichol[31], R. L. C. Ogando[17,18], R. P. Rollins[32], A. Roodman[3,4], A. J. Ross[11], E. Rozo[33], E. S. Rykoff[3,4], S. Samuroff[32], I. Sevilla-Noarbe[6], R. Sharp[30], N. E. Sommer[15,30], B. E. Tucker[15,30], S. A. Uddin[15,34], T. N. Varga[2,1], P. Vielzeuf[13], F. Yuan[15,30], B. Zhang[15,30], T. M. C. Abbott[35], F. B. Abdalla[7,36], S. Allam[24], J. Annis[24], K. Bechtol[37], A. Benoit-Lévy[38,7,39], E. Bertin[38,39], D. Brooks[7], E. Buckley-Geer[24], D. L. Burke[3,4], M. T. Busha[3], D. Capozzi[31], J. Carretero[13], M. Crocce[9], C. B. D'Andrea[5], L. N. da Costa[17,18], D. L. DePoy[40], S. Desai[41], H. T. Diehl[24], P. Doel[7], T. F. Eifler[42,43], J. Estrada[24], A. E. Evrard[44,45], E. Fernandez[13], B. Flaugher[24], P. Fosalba[9], J. Frieman[24,22], J. García-Bellido[46], D. W. Gerdes[44,45], T. Giannantonio[47,48,1], D. A. Goldstein[49,26], R. A. Gruendl[20,21], G. Gutierrez[24], K. Honscheid[11,12], D. J. James[50], M. Jarvis[5], T. Jeltema[51], M. W. G. Johnson[21], M. D. Johnson[21], D. Kirk[7], E. Krause[3], S. Kuhlmann[52], N. Kuropatkin[24], O. Lahav[7], T. S. Li[24], M. Lima[53,17], M. March[5], J. L. Marshall[40], P. Melchior[54], F. Menanteau[20,21], R. Miquel[55,13], B. Nord[24], C. R. O'Neill[15,16], A. A. Plazas[43], A. K. Romer[56], M. Sako[5], E. Sanchez[6], B. Santiago[57,17], V. Scarpine[24], R. Schindler[4], M. Schubnell[45], M. Smith[23], R. C. Smith[35], M. Soares-Santos[24], F. Sobreira[58,17], E. Suchyta[59], M. E. C. Swanson[21], G. Tarle[45], D. Thomas[31], D. L. Tucker[24], V. Vikram[52], A. R. Walker[35], J. Weller[60,2,1], W. Wester[24], R. C. Wolf[5], B. Yanny[24], J. Zuntz[61]

15 May 2018

(DES Collaboration)

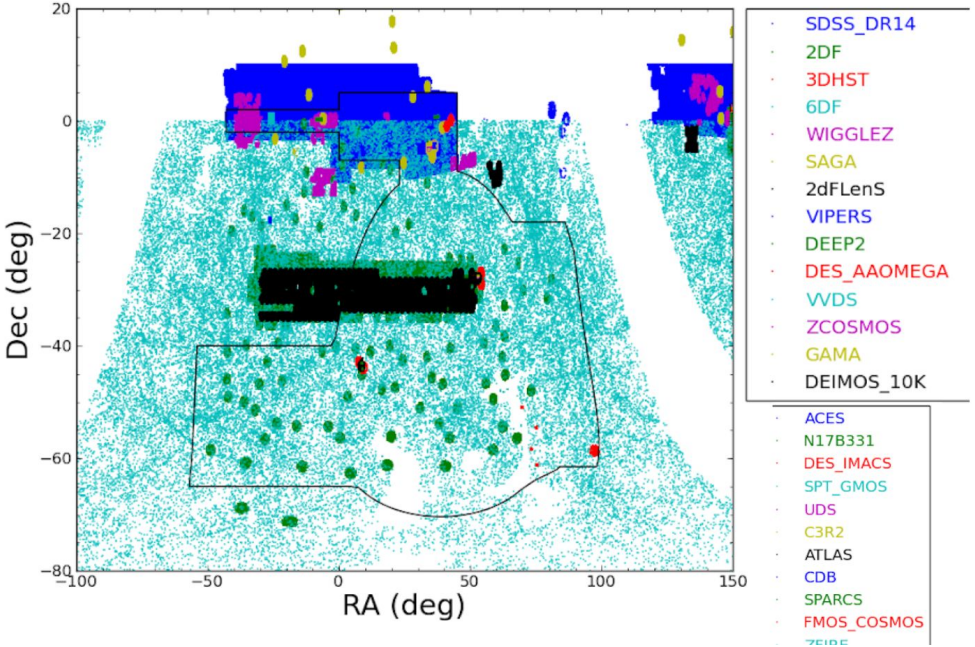




# The photo-z paradigm: Y3

- Photo-z is complex
- Heterogeneous sample of spec-z ar terrible for ML methods
- Emission lines are terrible for template methods
- New techniques being developed
- Hybrid methods



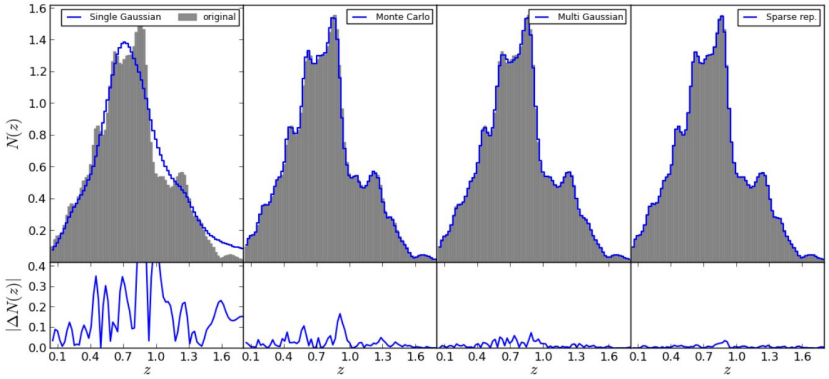
# Compression: Photo-z PDF

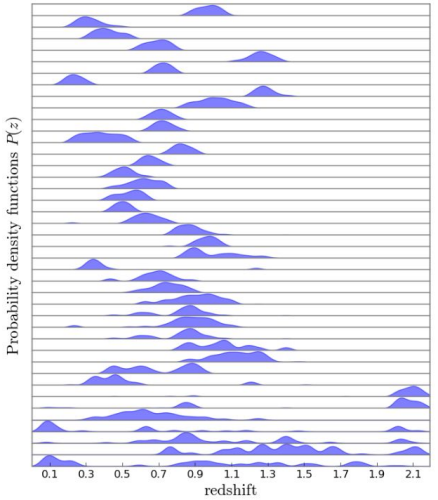
**Sparse Representation of Photometric Redshift PDFs: Preparing for Petascale Astronomy**

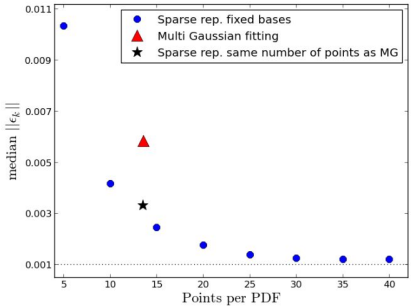
Matias Carrasco Kind* and Robert J. Brunner
*Department of Astronomy, University of Illinois, Urbana, IL 61820 USA*

11 June 2018

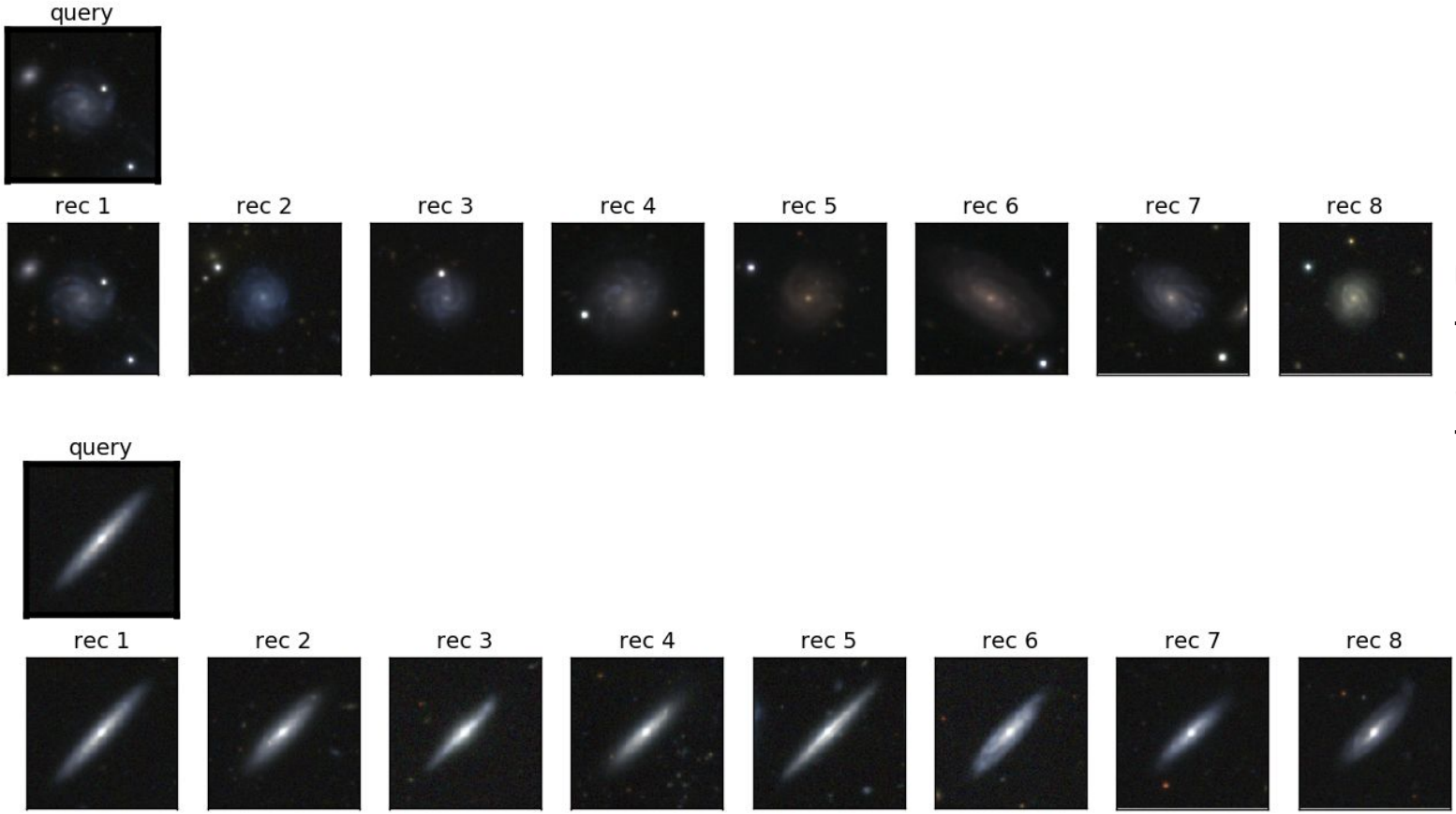
*Sparse representation of photo-z PDFs* 9



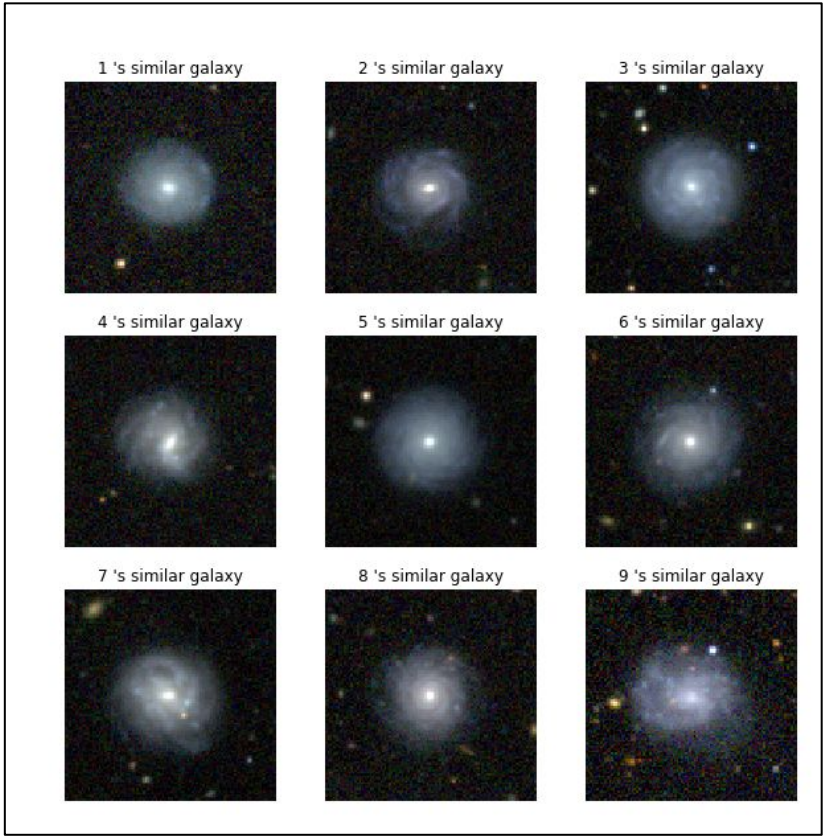
# Compression: Galaxy selection and similarity search

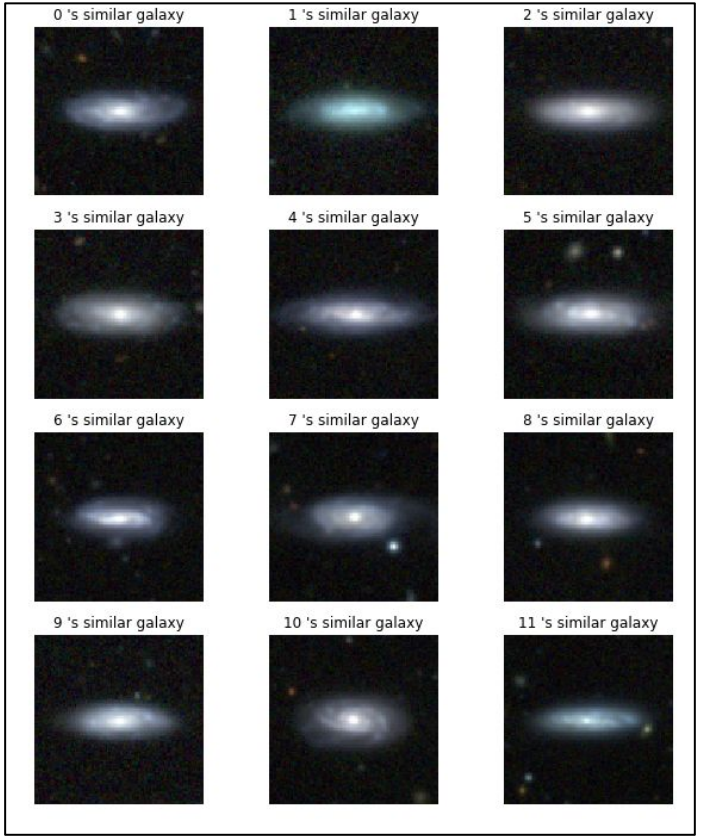



Compress images from 200x200 to 50 or less, for fast search

Bowen, Carrasco-Kind, et al. in prep.

# Galaxy selection and similarity search




Bowen, Carrasco-Kind, et al. in prep.

# Learn from one survey to another

**Knowledge transfer of Deep Learning for galaxy morphology from one survey to another**

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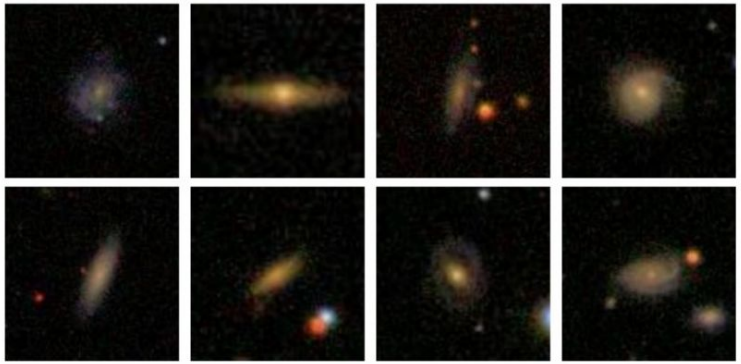
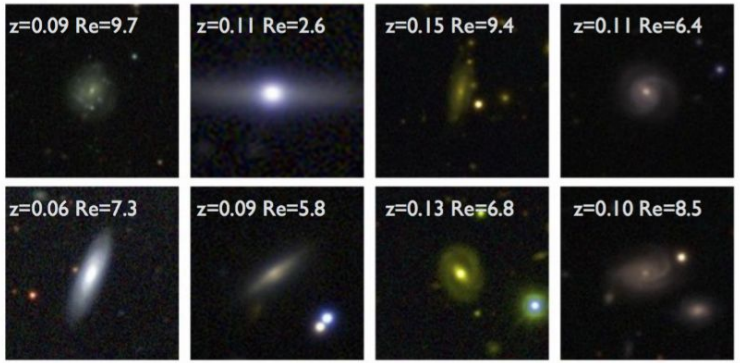
## SDSS (GalaxyZoo) transfer learning to DES images for morphological classification



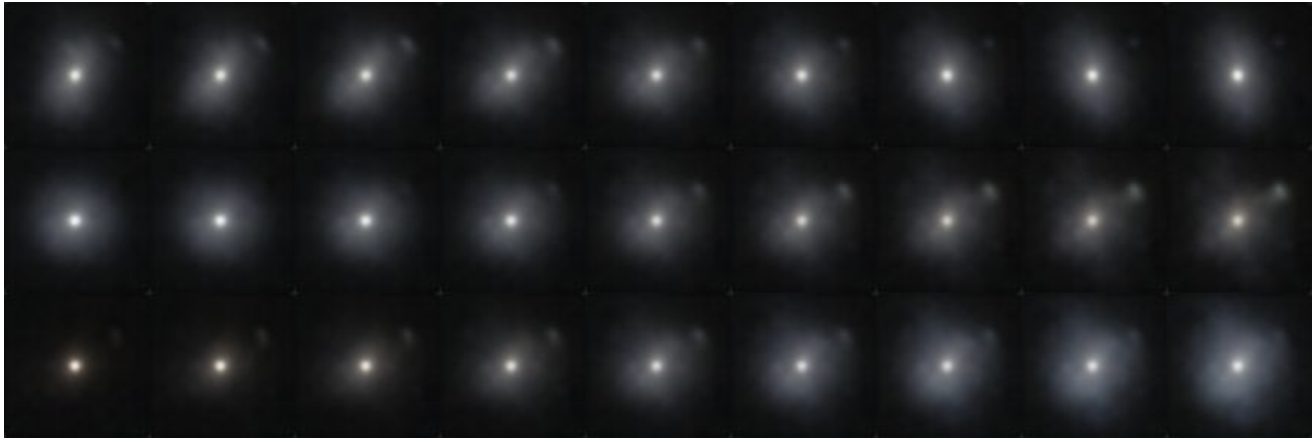


# Create realistic samplings of galaxy images with prior (DES)

angle

eccentricity

brightness



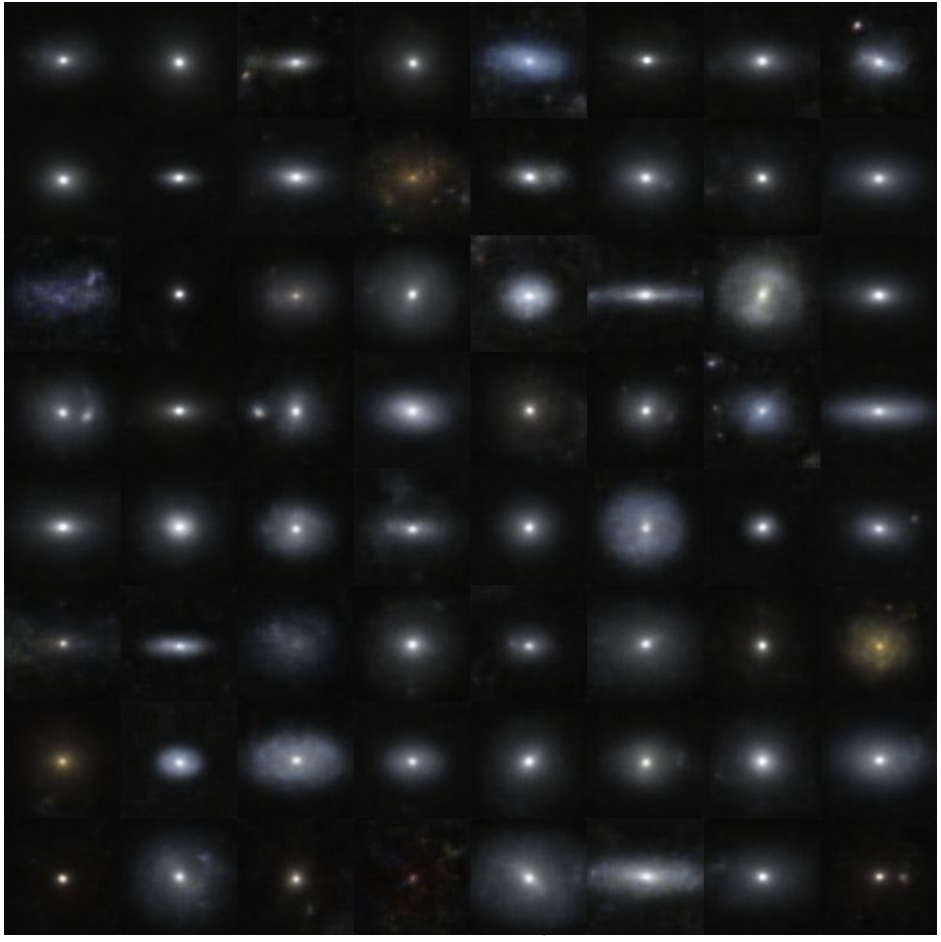
angle

eccentricity

brightness

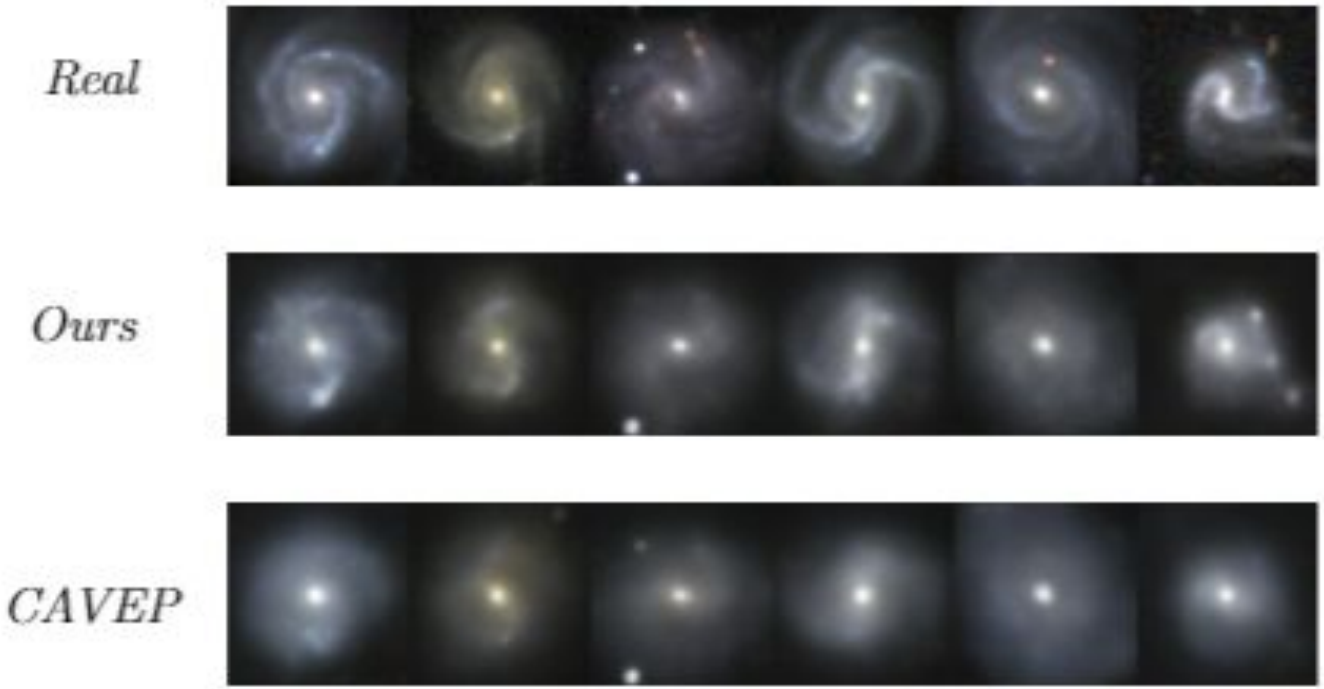
Bowen, Carrasco-Kind, et al. in prep.

# Create realistic samplings of galaxy images with no prior (DES)



Bowen, Carrasco-Kind, et al. in prep.

# Create realistic samplings of galaxy images with no prior




Bowen, Carrasco-Kind, et al. in prep.

# If I were to write a WP today

- Make our big data problem bigger
  - Unified all galaxy photometry/spectroscopy, this time for real in centralized place.
  - Leverage Big Data solutions to analyze the huge amount of data and exhaust all possible information. → ML and SED consumers
  - And yes, dont forget  images as well !
  - Photo-z, LSS, Clusters, Galaxy formation and evolution.
  - Peter's 'Standard Model'  for galaxies

# Thank you!

## Questions?

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