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The Dark Energy Survey and Data Release 1.

I. Sevilla-Noarbe[1] on behalf of the DES Collaboration

[1] Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Av. Complutense 40, 28040, Madrid, Spain

Abstract

The Dark Energy Survey is a major international effort to pin down the nature of dark energy by performing a photometric survey of the southern sky, covering 5000 square degrees up to magnitude i = 23.7 and doing a repeat, deep scan of 27 square degrees to identify and accumulate type Ia supernovae. In this contribution, we summarize the most relevant cosmological results to date from this project. The first data release of the project DR1, encompassing the first three years of the project, is also presented for the community to explore and exploit.

1 The Dark Energy Survey project

The Dark Energy Survey (DES, [5]) is a photometric survey using the $grizY$ filters of the DECam camera ([11]). Its main goal is to create a deep and wide map of galaxies to probe the nature of cosmic acceleration, using the observational channels proposed by the Dark Energy Task Force ([4]) within a single project and using the same instrument. It has been operating since 2013 and is scheduled to finish operations in early 2019. By the end of it, the camera will have surveyed approximately 5000 square degrees, reaching depths in flux of $i = 23.7$ and redshifts of $z \sim 1.2$.

In addition to providing tight constraints to cosmological parameters, including those related to the dark energy equation of state, the richness of this dataset allows for a very varied array of research lines both for astrophysics and fundamental cosmology, including the measurement of the optical counterparts of gravitational wave events ([17]), the discovery of new Milky Way companions ([1]), accurate measurements of tidal streams around our own Galaxy ([16]), or the discovery of new Solar System objects ([2]).

In this contribution, we briefly summarize the main cosmological results obtained from the detailed analysis of the first year dataset and present the first Data Release, which includes three years of observations and is available publicly.

2 Year 1 cosmology results

2.1 Constraints from galaxy clustering and weak lensing

One of the most constraining sources of information from this type of dataset comes from the information provided by the statistical correlations of shapes and positions of galaxies at different redshifts, specially for the Ω_m, S_8 parameters. With DES data, we obtained a constraining power comparable to Cosmic Microwave Background experiments, and jointly with them, it is possible to obtain the most precise ones to date (Figure 1) in the context of the ΛCDM model [7]: $S_8 = 0.802 \pm 0.012$ and $\Omega_m = 0.298 \pm 0.007$.

The galaxy samples used are of two types: the lens sample, which is characterized by Luminous Red Galaxies defined with a uniform comoving space density (`redMaGiC`,[15]); and the source sample, on which we will infer the weak lensing shears produced by foreground matter density. The correlation function of the positions of galaxies in the former category is estimated within a redshift bin and between bins (five redshift bins in total, spanning the range $z = 0.15 - 0.9$, [10]) whereas the correlation of shapes with respect to positions in the sky using the source samples is measured in four redshift bins as well (in the range $z = 0.2 - 1.3$), that is, the shear-shear correlation function ([18]). The combination of both types of measurements is also included (galaxy-galaxy lensing) ([14]).

Each of them provides a data vector which is combined in a Markov Chain MonteCarlo estimation of the most probable contours for the cosmological parameters, using as nuisance parameters different astrophysical and methodological biases. Besides the precise constraints on the current cosmological standard model, galaxy biases have been determined with a precision of 10% and intrinsic alignments have been determined as a necessary feature to include in any current or future modeling of shear measurements.

The data and MCMC chains are available at http://des.ncsa.illinois.edu/y1a1 for fellow scientists to use and check our results as well as to combine with different datasets.

2.2 Constraints from supernovae

Using the spectroscopically confirmed supernovae from the first three years of the project, plus a collection of supernovae from low redshift surveys (totalling 329 type Ia supernovae), we are able to provide constraints on the equation of state value for dark energy under the wCDM model, which is compatible with -1 as predicted by the cosmological constant hypothesis, when combining with CMB information, reaching a 6% error. See Figure 2. These results are summarized in [8].

In addition, using a distance calibration method based on the baryon acoustic oscillation (BAO) scale from the BOSS 'consensus' measurement from DR12 instead of the commonly used direct approach building up from Cepheid variables, it was possible to measure the Hubble constant as 67.77 ± 1.30 km s^{-1} Mpc^{-1} therefore providing additional insight into the current discrepancies for measuring this parameter using different methodologies ([12]).

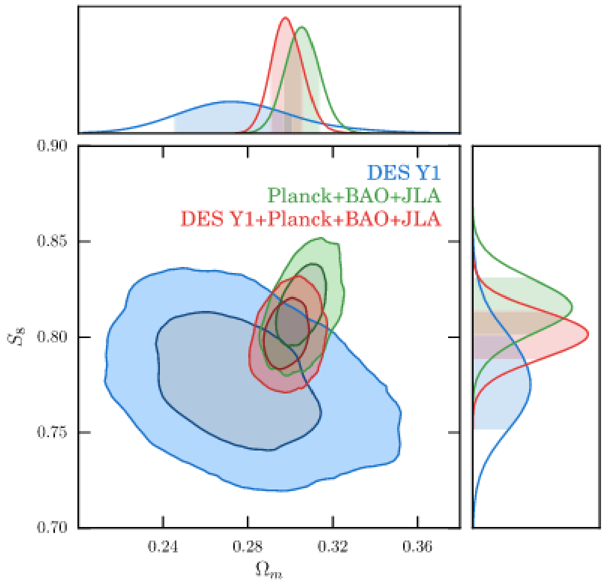

Figure 1: DES clustering constraints combined with external datasets (from [7]).

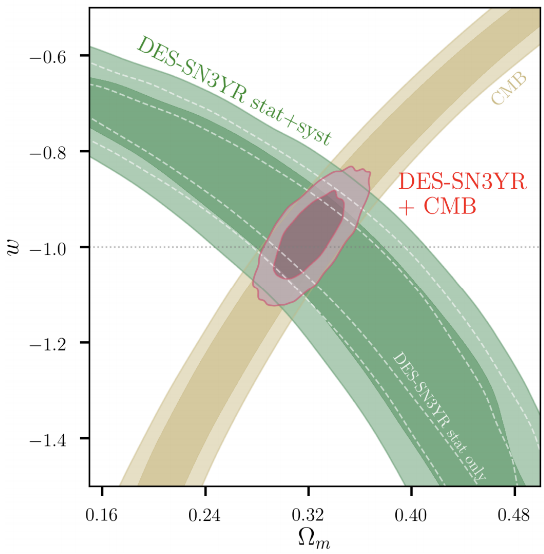

Figure 2: DES SN constraints on $\Omega_m - w$ for a flat wCDM model (from [8]).

2.3 Combined constraints from several probes

Finally for the first time we are able to make multiple probe constraints combining clustering, weak lensing shear, baryon acoustic oscillation scale and the Hubble-Lemaître diagram from type Ia supernova using DES data exclusively ([9]). These measurements rule out a Universe with no dark energy with 4σ significance, without requiring a flat Universe in our model. It also provides, with a probe independent of the CMB, a constraint on Ω_b being different than Ω_m at a very high significance. See Figure 3.

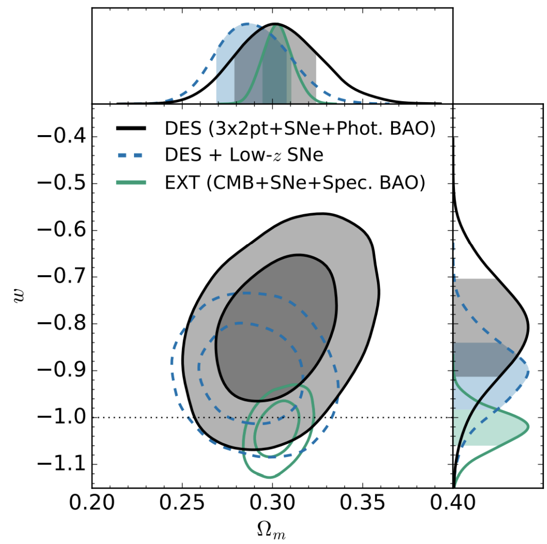

Figure 3: Multiple probe constraints on the equation of state for dark energy w and the density of matter parameter using DES data only, compared to the constraints of the combination from Planck's CMB measurements, BOSS BAO and the Pantheon supernova compilation (from [9]).

3 Data Release 1

The DES Data Release 1 (DR1, [6]) includes nearly 400 million objects detected over the complete DES footprint, using coadd detections from combinations of $\sim 39,000$ distinct single-epoch exposures. These have been collected over 345 nights of observations corresponding to DES operations from August 2013 to February 2016. See Figure 4 for a diagram of the footprint in celestial coordinates. Some of the characteristics of this dataset are listed below:

- The median PSF Full-Width-Half-Maximum is below 1 arcsecond in most bands except for g.
- The depth for signal-to-noise 10 objects is 24.33, 24.08, 23.44, 22.69, 21.44 for $grizY$.

- The astrometric precision is ∼ 150 milliarcseconds vs Gaia's DR1 measurements.
- The photometric precision is ∼ 0.5% (the statistical precision of the zero points).

The release itself is available at http://des.ncsa.illinois.edu/dr1 and is composed of both calibrated single-epoch images and coadd images, and a coadd catalog including morphological and photometric information obtained from the DESDM ([13]) pipelines based on SExtractor ([3]). The data can be accessed through different toolsets provided by NOAO, LineA and NCSA, including an SQL web client, cutout servers, sky/image viewers, Python and command-line query clients, and a Jupyter notebook server.

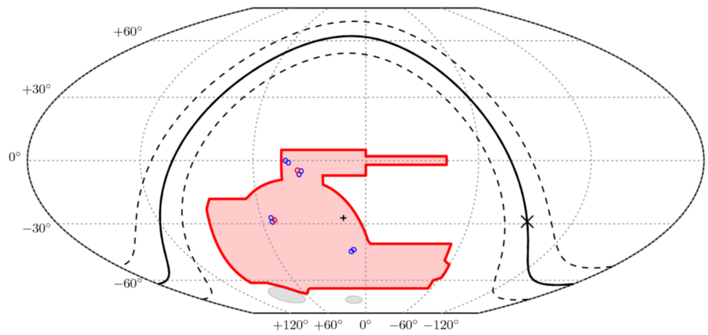

Figure 4: The DES survey area in celestial coordinates. The 5000 square degree DR1 footprint is shown in red. The 8 shallow supernova fields are shown as blue circles, and the 2 deep supernova fields are shown as red circles. The Milky Way plane is shown as a solid line, with dashed lines in a band 20 degrees wide in galactic latitude. The Galactic center ('x') and south Galactic Pole ('+') are also marked. The Large and Small Magellanic Clouds are indicated in gray (from [6]).

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