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The Dark Energy Survey: status and DES-Spain contributions

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Abstract

The goal of the Dark Energy Survey (DES) is to measure the dark energy equation of state parameter with four complementary techniques. DES will survey 5000 square degrees using a new multi-CCD mosaic camera with 62 science detectors, which will be installed at the Cerro Tololo Inter-American Observatory, in Chile. In this contributed paper, we overview the goals and status of the project, as well as the specific contributions of the DES-Spain Consortium which are mainly the design, development and construction of most of the electronic boards for the CCDs, large-scale structure simulations and associated science.

1 Introduction

The Dark Energy Survey (DES) is a project designed to perform a deep optical-near infrared survey of 5000 square degrees of the South Galactic Cap to $\sim$ 24th magnitude using the *grizY* filters (up to $\sim$ 22 in Y). The goal is to measure the properties of dark energy through the determination of its equation of state parameter w using four independent methods: galaxy clusters, weak gravitational lensing tomography, galaxy angular clustering and type Ia supernova distances (see the Report of the Dark Energy Task Force by [2] and the DES White Paper by [1]). The obvious advantage of this approach is to have the same instrument making the four measurements, providing important information on the instrumental systematic errors. The multi-channel approach also allows us to set a more robust constraint on theories which modify General Relativity in order to explain the observed acceleration (see, for example, [10]).

DES arose from an announcement of opportunity issued by the United States National Optical Astronomy Observatory in 2003 to build a new instrument for the Blanco Telescope in exchange of 30% of the observation time during a 5 year period. The project includes the building of the camera, a data management system and improvements at the telescope site.

The Dark Energy Survey Camera (DECam) is the instrument currently being built

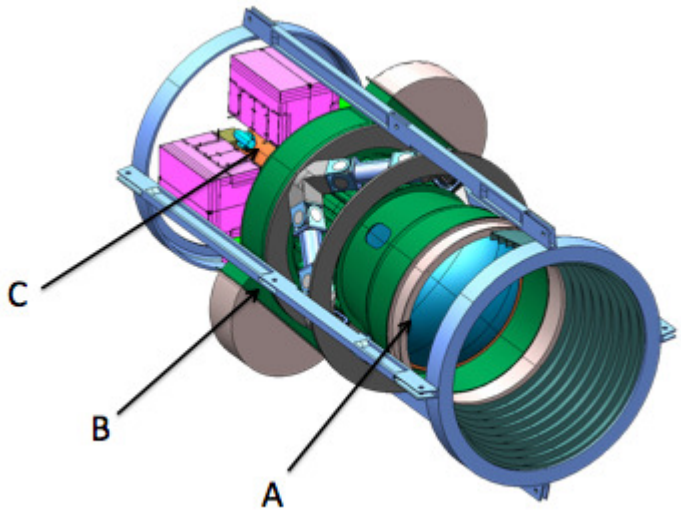

Figure 1: Diagram of DECam, showing the positions of the optical corrector (A), shutter and filter system (B) and camera vessel (C).

to carry out the project (Fig. 1) The detector consists of a wide field imaging mosaic of 62 Charged-Coupled Devices (CCD), mounted with the associated electronics in a cryostat at the primary focus of the Blanco 4 meter telescope at the Cerro Tololo Inter-American Observatory in Chile. The corrector lenses, filters, filter wheel, shutter and hexapod adjustor are being built for this specific project as well. The Dark Energy Survey Data Management system (DESDM) is being set up to specifically address the high volume of data that will be produced (O(300 GB) per night).

2 Expected performance

Figure 2 shows a plot of the expected constraints at the 68% confidence level, in the parameters w_a and w_0, considering the Linder parametrization [8] and assuming ΛCDM (priors coming from 5 year WMAP CMB measurements). Constraints for each individual probe and from all of them combined are shown. For this plot, only statistical and photometric redshift errors are being considered.

3 Contributions by DES-Spain

The DES-Spain Consortium is composed of the *Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas* (CIEMAT), *the Institut de Ciències de l'Espai* (ICE-IEEC(CSIC)) and the *Institut de Física d'Altes Energies* (IFAE) as well as the *Universidad Autónoma de*

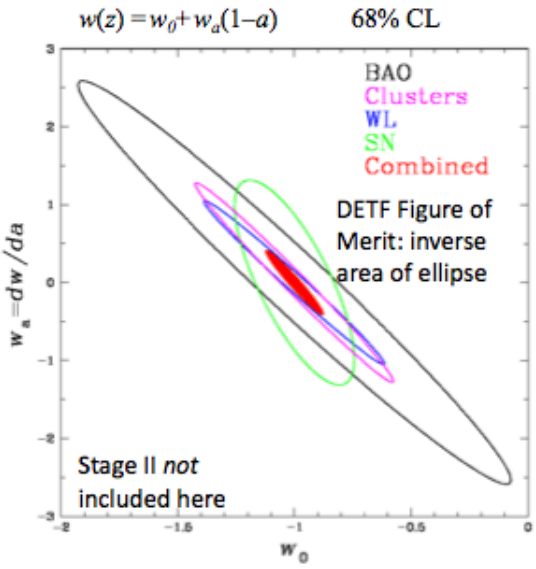

Figure 2: Expected performances on the equation of state parameters w_a and w_0 for DES. See the Dark Energy Survey proposal.

Madrid as an associated partner. This Consortium has been part of DES almost since its inception and it is the first international partner, jointly with the UK Consortium. The main responsabilities of this group are described in the following sections.

3.1 CCD electronics

DECam consists of 62 science CCDs, 4 guide CCDs and 8 alignment CCDs. The survey requirements impose a < 10 e^- rms noise limit and a maximum readout time of 17 s. Additionally, there are tight space constraints given that 1110 clock signals and 518 bias voltages have to be supplied to the CCDs packed in the focal plane, while at the same time extracting 148 video signals.

The main effort of the DES-Spain Consortium (CIEMAT, IFAE) in this area was the redesign of the Monsoon system (see the Monsoon webpage for more information) to comply with these requirements (see [5]), in particular the Master Control Board (controlling clocks and readout and communicating with higher-level control) and the Clock and Bias Board. Additionally, all boards, including the Acquisition board, were produced and financed by DES-Spain. In total, more than 80 boards were designed (except Acquisition), produced, tested and shipped to Fermilab, for integration during 2010.

3.2 Large scale structure simulations

In order to test the DESDM, the complete sequence from simulated data to images to final catalogs has to be executed beforehand in a series of "Data Challenges". The goal is to check the functionality of the system with such a large quantity of data and, most importantly, to verify the scientific reach of the project in each of its four probes, by considering as many systematic effects as possible. This will allow a more complete understanding of the complex nature of the raw data produced during real observations, when images start flowing in.

One of the responsabilities of the ICE team was to generate huge simulated mock catalogs of "dark matter halos" containing the cosmological information that is used as input for this process. This effort is incorporated as part of the MICE project whose goal is to run these simulations in the range of 10^9–10^{11} particles in Gpc-scale volumes for use in several cosmology projects, using the Marenostrum supercomputer at the Barcelona Supercomputing Center. In particular, for DES, lightcones were built from these N-body simulations up to the DES depth, using a "shell" discretization that matched the expected photometric redshift error, producing a much more manageable version of the simulations [7].

3.3 Science

Many DES-Spain members (CIEMAT, ICE, UAM) develop their scientific work in the area of Large Scale Structure. E. Gaztañaga is one of the coordinators of this group. Their involvement is mainly in the study of the statistical distribution of certain types of galaxies, whether it is to measure the dark energy equation of state via the acoustic peak of the Baryonic Acoustic Oscillations [9, 4] or the extraction of cosmological parameters via the precise modellization of the two-point correlation function [6].

IFAE members currently also take part in the Supernova Working Group and were involved initially in the determination of the figure of merit for the dark energy equation of state on this front. Photometric redshift determinations (coordinated by F. J. Castander) has also an active participation by DES-Spain members. There is also a work in progress to define the equation of state parameter with the cluster correlation function and cluster richness-mass relationship [3].

3.4 Other contributions

There are several other fields in which DES-Spain members have or have had an important involvement:

- *Star-guider software*: this algorithm processes the images from the guide CCDs to correct errors in the telescope motion in order to stabilize the image. Tests of this code have already been performed successfully on-site.

- *Quality assessment of DESDM products*: development and execution of plan to validate the catalogs produced by the Data Management.

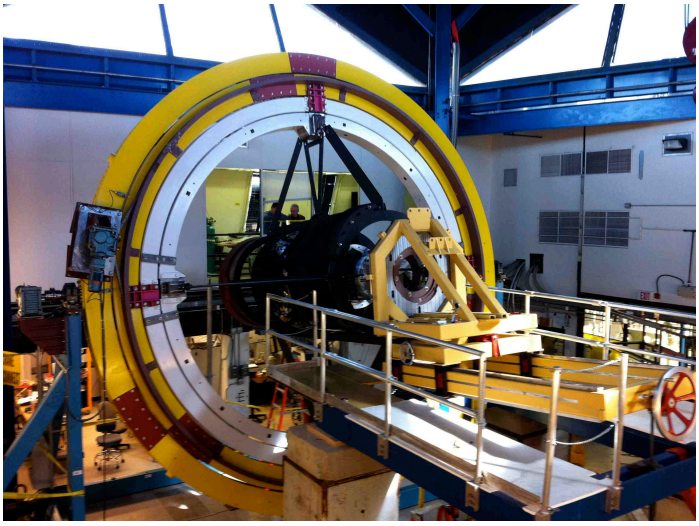

Figure 3: Telescope simulator at Fermilab. The purpose of this setup is to mechanically test the fully integrated camera, fiter and shutter jukebox and hexapod adjustors. Lenses are directly shipped to the telescope, so mock weights are used instead. Also the cryogenic system and the detector grounding are tested with this fixture.

- *CCD characterization*: development of CCD testing algorithms in the lab (linearity and charge transfer efficiency).

- *Data reduction modules*: development of modules for cosmic-ray and satellite track removal.

In addition to all of this, DES-Spain members chair or have members in all of the project's committees (Management, Publication, Science, etc.).

4 Current status of DES

Currently (November 2010) all camera components except for the corrector lenses are at Fermilab for final mechanical integration and testing at a specifically built telescope simulator (Fig. 3). Science-grade CCDs have been characterized and selected at Fermilab as well and are ready for integration.

Shipping of the first handling equipment and fixtures has already begun. The first elements of the camera will be shipped during the first half of 2011, and the imager will finally arrive during July of the same year. DES is foreseen to have its first light in October 2011.

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