PROCEEDINGS OF SCIENCE

# The Dark Energy Survey

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The Dark Energy Survey will employ a powerful instrument, the Dark Energy Camera, and a state-of-the-art data management system on the improved Blanco 4-meter telescope at CTIO to probe the nature of dark energy and the cause of cosmic acceleration. The instrument includes a 520-Megapixel optical imager with red-sensitive CCDs covering a 3 square degree field of view and an active alignment system. Starting in 2012, using 525 nights over 5 years, the survey will image 300 million galaxies over 5000 square degrees to 24th magnitude and several thousand supernovae over a smaller area, using the grizY passbands. The 120-member international collaboration will use these data to probe dark energy using the galaxy cluster abundance, weak gravitational lensing, baryon acoustic oscillations, and supernovae and carry out studies of strong lensing, galaxy evolution, the structure of the Milky Way, and QSOs, among other topics. We will discuss the status of the project, the survey strategy and prospects for cosmological tests.

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## 1. Introduction

The causes for the acceleration of the Universe are the main drivers of the Dark Energy Survey (DES) project. Its goal is to measure the properties of dark energy through the determination of its equation of state using four independent methods: galaxy clusters, weak gravitational lensing tomography, galaxy angular clustering and type Ia supernova distances [1][2]. Using this approach a careful control of systematics can be made and possible inconsistencies between the results obtained through different channels can lead to a deeper understanding of the nature of cosmic acceleration.

## 2. The Dark Energy Camera and Survey Strategy

DES will perform a 5-filter photometric survey of the southern sky in two modes: the main survey covering 5000 square degrees and a time-domain survey for supernovae (which will take 10% of the time). The survey will be carried out during 5 years using 30% of the observation time available at the Blanco Telescope. The instrument used to perform these observations is DECam [3], and it has been built as a joint effort of several of the collaborating institutions, led by Fermilab. It consists of a focal plane with 74 red-sensitive CCDs; a camera vessel which serves as an enclosure to achieve the required vacuum and cryogenic temperatures and supporting the CCD electronics; a filter and shutter system; an optical corrector and the hexapod adjustor, which will fit the system into the existing cage at the Blanco Telescope. In Figure 1 the fully-assembled imager at the Fermilab clean room is shown as well as one of the filters to be employed as it was being produced at Asahi's premises.

**Figure 1:** (left) Fully assembled CCD imager for DECam; (right) One of the filters for DECam.

## 3. The Data Management System

The DES Data Management system [4] constitutes a project in itself and deals with the transfer, processing and distribution the data generated by DECam. It is a combined effort of individual scientists and computing specialists from several DES institutions, and is led by the National Center of Supercomputing Applications (NCSA). Data is transferred in the form of raw images, calibration images and metadata off the mountain and processed daily to obtain reduced single-epoch images. At the end of the season, these are combined into deeper, coadded images, necessary to reach the magnitude limit requirements of DES, and final catalogs are produced from them. Currently, the system is being developed and tested through very detailed Data Challenges. In these runs galaxies and stars are simulated precisely together with camera and atmospheric effects. The resulting images are processed through the whole reduction pipeline.

## 4. Science with DES

Two of the probes mentioned above specifically target the geometrical evolution of the Universe. Supernovae Ia measurements will allow using these 'standard candles' as beacons of known luminosity at different redshifts so distance and redshift can be related and connected to different cosmological models. Baryonic acoustic oscillations can be observed in the large scale distribution of galaxies and clusters and provide a 'standard ruler' of known size that also allows to build a relationship between redshift and distance, converting this scale to an angular size depending on the cosmology. On the other hand, the other types of observations also incorporate the effect of gravity and clustering therefore providing a handle to distinguish a purely geometrically based acceleration from one based on modifications on general relativity. The weak lensing probe is based on the statistical measurement of distortions of background galaxies by intervening matter. Cluster number counts will measure how these structures have been building up at different eras in the evolution of the Universe.

One way to evaluate the scientific reach of a dark energy project is to build a figure of merit based on the reciprocal area of the confidence level region in a relevant parameter space. A widely used set of parameters are $w_p$ and $w_a$, based on the dark energy equation of state parametrization $w(a) = w_0 + w_a(1-a)$ where $a$ is the cosmic scale factor (set to be equal to one at our current time). $w_p$ would be the equation of state value for a pivot value of $a$ in which the uncertainty would be minimized. In Table 1 the most recent Fisher matrix estimations for the 68% CL for DES are provided, to be compared with the combined results of all previous projects (so-called stage II).

| Method | $\sigma(\Omega_{DE})$ | $\sigma(w_0)$ | $\sigma(w_a)$ | $\sigma(w_p)$ | $[\sigma(w_a)\sigma(w_p)]^{-1}$ |
|---|---|---|---|---|---|
| All DES probes combined | 0.004 | 0.061 | 0.217 | 0.018 | 263.7 |
| All Stage II projects combined | 0.012 | 0.112 | 0.498 | 0.035 | 57.9 |

**Table 1:** Forecast for DES and combined stage II projects in terms of 68% CL marginalized errors

Although with the assumption of constant $w$ the dark energy equation of state currently seems compatible with a cosmological constant within 5% [5], there is a large (O(60%)) indetermination in $\sigma(w_a)$ if we allow the equation of state to vary over time, thus allowing for alternative explanations (such as modifications to GR) to be also well within the confidence level regions. There other important fundamental physics studies that can be carried out with large scale structure analyses such as setting new constraints in the sum of the neutrino masses [6]. These forecasts will be checked in the near term with the study of multiple sets of cosmological simulations produced by the Stanford team, including realistic systematic effects observed during the Data Management data



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challenges described above. The science working groups will test their analysis pipelines trying to recover the input cosmological parameters.

## 5. Status of the project

As of October 2011, DECam is being deployed at the Blanco telescope. The imager and the corrector will be shipped from Fermilab and UK respectively in early November. After some basic preparatory tests, the current imager at the telescope will be removed and DECam will be placed in its stead during the first months of 2012 and the telescope will be recommissioned. First light is expected around June 2012 with a commissioning period of two months for the camera. Scientific operations will start in September 2012. With respect to the Data Management System, the full suite of acceptance tests to check its compliance against the scientific requirements will be done using a detailed 200 square-degree simulation during the first months of 2012.

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