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The Dark Energy Survey

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Abstract.
The Dark Energy Survey (DES) is a proposed 5-year, 5000 deg^2 optical imaging survey, to 24th magnitude in the SDSS *griz* bands, that will use a new wide-field 3 deg^2 mosaic CCD camera on the Blanco 4m telescope at the Cerror Tololo Inter-American Observatory (CTIO). The primary scientific goal of the DES is to probe the nature of dark energy using four complementary methods: galaxy clusters, weak gravitational lensing, galaxy angular correlations, and Type Ia supernovae. For each of these methods, the DES should determine the dark energy equation of state parameter w with a statistical precision of about 5-15%, assuming constant w but without strong priors on other cosmological parameters. By deriving dark energy constraints using four complementary sets of measurements made from the same data set and within a common analysis framework, we will obtain important crosschecks of our systematic errors and thereby make a substantial and robust advance in the precision of dark energy measurements.

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INTRODUCTION

In response to the National Optical Astronomy Observatory (NOAO) Announcement of Opportunity for Blanco Instrumentation Partnership, we have proposed building a new wide-field corrector and 3 deg^2, 62-CCD mosaic camera for the CTIO Blanco 4m telescope. We plan to use this Dark Energy Camera (DECam) to carry out the Dark Energy Survey (DES), a 4-band *griz* imaging survey of 5000 deg^2 in the South Galactic Cap. The primary scientific goal of the DES is to study dark energy using four independent and complementary techniques, from each of which we expect to measure the dark energy equation of state parameter, w, to a statistical precision of about 5-15%. NOAO has accepted the DES proposal for partnership, and if we are funded for this project, we will be awarded 30% of the observing time at CTIO over a five year period from 2009-2013 to conduct the survey.

DARK ENERGY SURVEY SCIENCE

Dark energy has been labeled as one of the most important areas of scientific study for the next decade. Evidence for dark energy came from the surprising observation that the expansion of the universe is accelerating, a conclusion drawn from the measurements

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of distant Type Ia supernovae [6, 7]. Other indirect evidence for dark energy has also come from the CMB temperature anisotropy — which points to a spatially flat universe — and from large-scale structure and galaxy clusters, which constrain the density of matter (mostly dark) to about 30% that of a flat universe. These studies indicate that the remaining 70% of the energy density of the universe is comprised of dark energy, with equation of state parameter $w < -0.75$. While evidence mounts for a picture of the universe that is now dominated by dark energy, more precise measurements of w are needed to help pin down the nature of dark energy and to constrain theoretical models.

The extensive 5000 deg^2 of DES imaging data will be used to constrain dark energy through four different techniques: (1) galaxy clusters; (2) weak lensing; (3) galaxy angular power spectrum; and (4) Type 1a supernovae. The DES will collect 30,000 galaxy clusters out to redshifts $z = 1$ and above. In particular, the DES area is chosen specifically to overlap the planned 4000 deg^2 Sunyaev-Zel'dovich effect (SZE) cluster survey to be carried out by the South Pole Telescope [3], and the DES will provide accurate photometric redshifts for the bulk of the SPT clusters. Independent optical and SZE cluster identification and mass determination from the DES and SPT, respectively, will provide a means to understand systematic uncertainties. The other three measurement techniques will also yield dark energy constraints comparable to that from the cluster survey. The weak lensing study will measure both cosmic shear and galaxy-shear correlations, for an effective surface density of about 10 galaxies/arcmin^2 over the 5000 deg^2 DES area. The angluar power spectrum measurements will probe galaxy clustering for some 300 million galaxies, binned in photometric-redshift shells out to $z \sim 1$. Finally, a time-domain survey of a 40 deg^2 area within the DES will obtain a sample of ~ 2000 Type Ia supernovae, at redshifts $z \sim 0.3 - 0.8$, which should provide the largest such sample for study by the time the DES is completed. We expect that by combining all four measurement techniques, and including the ability to correlate with the SZE cluster data from the SPT, the DES will provide powerful new constraints on the nature of dark energy. The DES will be an important scientific and technical precursor to ambitious future dark energy experiments like LSST and JDEM. Please see the DES white papers for a detailed discussion of the DES dark energy experimental methods, cosmological parameter constraints, and theoretical challenges: [4, 1].

DARK ENERGY SURVEY INSTRUMENT

As described in more detail in [4], the DES instrument (DECam) includes a large mosaic camera, a wide-field optical corrector, four filters, and the associated infrastructure for operation at the 4m Blanco telescope. The camera and corrector will be assembled into a barrel-shaped cage that attaches to the telescope at the prime focus through supporting struts. Our reference design optical corrector consists of five elements - fused silica lenses - which produce an unvignetted 2.2° diameter focal plane, and which also contribute < 0.4" FWHM to the point spread function. We are now actively engaged in further optimizing and finalizing our optics design.

The DECam focal plane consists of 62 2K x 4K CCD modules (0.27"/pixel) arranged in a hexagon inscribed within the 2.2° diameter field of view. The area of the hexagon relevant for tiling the sky is 3 deg^2. Additional focus and guide CCDs will be located

at the edge of the focal plane. A requirement for the CCD devices is that they have high quantum efficiency (QE): >50% for wavelengths 400-1000 nm. This QE has been achieved through 250 μm thick fully depeleted CCDs, built on high resistivity silicon, developed at the Lawrence Berkeley National Laboratory (LBNL) [5]. In particular, the high QE in the red is important for efficiently obtaining the z-band images needed to get complete galaxy samples and accurate photometric redshifts at $z \sim 1$. A packaging factory is being established at Fermilab to produce four-side buttable modules for the LBNL devices, as well as to test and grade the CCDs.

DARK ENERGY SURVEY STRATEGY AND DATA

The Dark Energy Survey strategy is designed to obtain precise photometric calibrations and photometric redshift determinations. The 5000 deg^2 survey area will be covered by overlapping and offset tiles, or pointings, in each of the four filters. Such a multiple-tiling survey strategy allows for ample photometry crosschecks, and we will aim for a 1% photometry calibration goal for the survey. The nominal DES sky tiling rate is 2 survey tilings per filter per year, and at the end of 5 years, the DES 10σ galaxy magnitude limits will be $griz = 24.6, 24.1, 24.3, 23.9$. To accurately calibrate photometric redshifts down to these DES photometric depths, we will use the $\sim 250,000$ galaxy redshifts available from a number of large completed or ongoing spectroscopic redshift surveys which overlap the DES area. Our simulations indicate that our photometric redshift accuracy will be sufficient to meet our scientific goals [4].

The data volume for the survey is expected to be ~ 1 Petabyte and will consist of raw and processed images, databases, and catalogs generated through data reduction and science analysis pipelines. We are engaged in a series of yearly data reduction and analysis challenges, using mock catalog- and image-level simulations, in order to help us develop and test our data processing and analysis framework. See also [2] for a discussion of the challenges involved here for computational cosmology. The DES imaging data, coadded images and catalogs will be made publicly available through periodic data releases, and will serve as a valuable legacy data set for the scientific community, not only for cosmology and dark energy studies, but also for a broad spectrum of other astronomy and astrophysics investigations.

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