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The Dark Energy Survey: Status and First results

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Abstract

The observational results of the latest 15 to 20 years have stablished a standard model for the cosmology which has some amazing consequences. A mysterious entity, the dark energy, has been confirmed as the dominant component of the Universe, and is also responsible for its accelerated expansion. However, its physical nature remains unknown. Unveiling the nature of the dark energy is one of the main problems of cosmology. A powerful way of studying this problem is the measurement of different and complementary probes of the dark energy in very large galaxy surveys. The Dark Energy Survey (DES) is an optical and near infrared survey that is imaging 5000 deg^2 of the southern celestial hemisphere in five broad bandpass filters, to study the properties of this mysterious dark energy. In order to perform such a survey, a new CCD camera of 3 deg^2 field of view has been mounted on the Blanco 4m telescope at Cerro Tololo (Chile). The survey observations started in 2012, with the science verification run. DES will study the dark energy properties using four independent methods: galaxy clusters counts and distributions, weak gravitational lensing tomography, baryon acoustic oscillations and supernovae Ia distances. Obtaining the four measurements from the same data set will allow a strict control of the systematic uncertainties to obtain a robust and precise determination of the cosmological parameters. Here, the first scientific results of the project, based on science verification data and related to photometric redshifts and galaxy shape measurements, are presented.

Keywords: cosmology, dark energy, weak gravitational lensing, galaxy clusters, supernovae, baryon acoustic oscillations

1. Introduction

The current set of cosmological observations solidly establishes an amazing result. Only a small fraction (around 5%) of the content of our Universe is ordinary matter. The other 95% is composed of strange entities called dark matter and dark energy, whose physical nature is unknown. Moreover, the expansion of the Universe is accelerating, as a consequence of the existence of the dark energy. At cosmological distances, the receding velocities of galaxies are increasing. This observed fact has important implications. Either General Relativity is not a complete theory, and fails to describe gravity at cosmological scales, or some mysterious fluid with negative pressure, the dark energy, fills the whole Universe. There are even more exotic possibilities as the dark energy arising from the density inhomogeneities backreaction, but, in any case, new physics is needed. Therefore, the cosmic acceleration puzzle motivates an important component of current research which will grow in the near future.

The current standard model of cosmology, ΛCDM, describes the cosmic acceleration using a non-zero cosmological constant. This model fits all the present cosmological observations [1], some of them to a high degree of precision. Moreover, the progress over the last 15 years on the measurement of the properties of the dark energy has been huge. However, there is still a large room for improvement in the observations and it is generally expected that these developments will produce the next advance in the knowledge about dark energy. Therefore, a rich program of different cosmolog-

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ical surveys has already started and is planned for the future. One of the most important projects, which has very recently started its activity is the Dark Energy Survey (DES) [2], [3].

2. The Dark Energy Survey

DES[1] is a project aimed to unveil the nature of the dark energy. It comprises two interleaved surveys. First, an optical to near-infrared survey that is imaging 5000 square degrees of the southern celestial hemisphere (Figure 1) using five wide bandpass filters, *grizY*, up to magnitude $i_{AB} < 24$, or redshift $z \sim 1.5$. Second, a time domain griz survey over 30 square degrees to discover and measure supernovae Ia light curves. The project is being carried out over 525 nights in the course of five years using the 520-Megapixel imager DECam [4], [5], mounted at the prime focus of the Blanco 4m telescope at NOAO's Cerro Tololo Inter-American Observatory (Figure 2). The collaboration consists of approximately 300 scientists from USA, UK, Spain, Brazil, Switzerland and Germany.

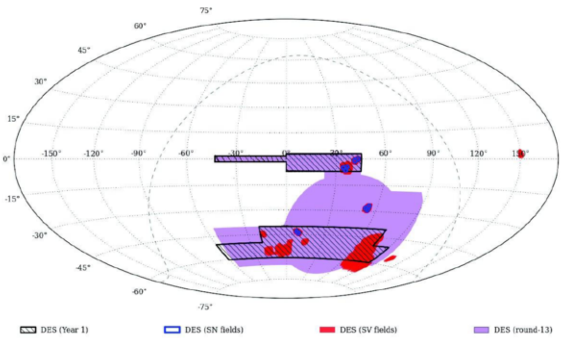

Figure 1: Footprint of the DES survey. Final (violet), Science Verification data (red), supernovae fields (blue), Year 1 (black).

The major components of DECam are a 520 Megapixel optical CCD focal plane, which is housed in a dewar that provides vacuum and cryogenics, a low noise CCD readout electronic system placed in crates around the main dewar that are actively cooled, a shutter, a filter system to house and exchange the DES filters, and a wide-field optical corrector (which gives a field of view of 2.2 degrees of diameter). The CCD vessel and corrector are supported by a hexapod that provides adjustability in all degrees of freedom. DECam mounted on the prime focus of the Blanco telescope is shown in Figure 2.

[1] http://www.darkenergysurvey.org

Figure 2: View of the Cerro Tololo observatory (top). The Blanco 4m telescope (bottom) is located inside the largest building. DECam is installed at the prime focus, and some components are visible in the image.

To have a good detection efficiency for high redshift objects, CCDs that are extremely sensitive at the red part of the spectrum are used. They are fully depleted, 250 μm thick, and have been developed at the Lawrence Berkeley National Laboratory to be used in DES. The quantum efficiency of these devices in the z band is larger than 50%, almost an order of magnitude higher than traditional thinned devices. The DECam focal plane containins 62 CCDs of 2048x4096 pixels for scientific imaging, and 12 CCDs of 2048x2048 pixels for guiding, alignment and focus.

DECam was commissioned in September and October of 2012, followed by an extended testing and survey commissioning period known as DES Science Verification (SV) from November 2012 to February 2013 [6]. With this new instrument, DES will go beyond the reach