Description of the Dark Energy Survey for Astronomers

May 1, 2012

Abstract

The Dark Energy Survey (DES) will use 525 nights on the CTIO Blanco 4-meter telescope with the new Dark Energy Camera built by the DES collaboration to carry out two interleaved surveys: a wide-area survey covering 5000 square degrees and a smaller-area, time-domain survey optimized for supernova cosmology. This document describes the DES footprint on the sky, limiting magnitudes, and other basic survey design parameters.

1 Introduction

The DES comprises two multi-band imaging surveys, a wide-area survey and a narrow time-domain survey for supernovae. The wide-area survey covers 5000 deg^2 in the south Galactic cap. The design of the Dark Energy Camera and the depth ($\sim 24^{th}$ magnitude) and filter coverage ($grizY$) of the wide-area survey were chosen primarily to achieve accurate galaxy photo-z (color) and shape measurements to redshifts $z \sim 1.3$. The wide-area survey will detect over 100,000 galaxy clusters and will measure shapes, photo-z's, and positions for $\sim$ 200 million galaxies. The DES Supernova (SN) Survey (Bernstein et al 2011) comprises *griz* imaging of 10 DECam fields (2 deep, 8 shallow, of 3 sq. deg. each) with a cadence of $\sim$ 5 visits per lunation and will discover and measure good-quality light curves for $\sim$ 4000 type Ia supernovae to redshift $z \sim 1$. DES will collaborate with the ESO Vista Hemisphere Survey, which will provide deep JHK imaging over the same wide sky area, improving photo-z precision at redshifts $z = 1 - 2$, and with the ESO VIDEO Survey, which is expected to provide coincident NIR measurements for a subsample of DES supernovae.

2 The Wide-Area Survey

As of this writing (May 1, 2012), the DES footprint is under final review by the collaboration, but we expect to adopt the footprint shown in Figure 1, with bounding coordinates given in Table 1.

Table 1: Wide-Area Survey Boundaries

	RA			Dec		
SPT	-60	$\leq \alpha \leq$	105	-65	$\leq \delta \leq$	-40
Viking	-30	$\leq \alpha \leq$	60	-40	$\leq \delta \leq$	-25
Round 82	-3	$\leq \alpha \leq$	45	-25	$\leq \delta \leq$	3
Stripe 82	-43	$\leq \alpha \leq$	-3	-1	$\leq \delta \leq$	1

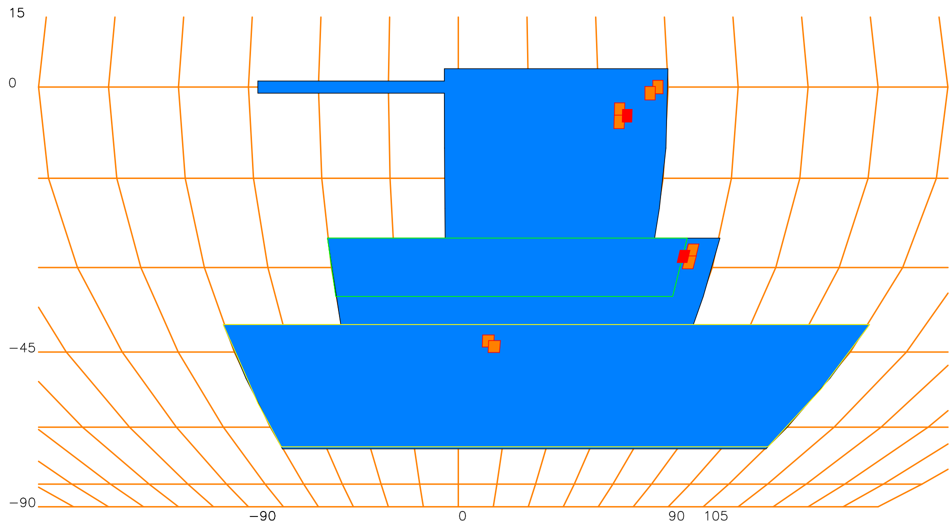

Figure 1: The expected DES footprint is shown in blue. The shallow supernova fields are shown in orange and the deep supernova fields in red. Two companion surveys that guide the thinking about the DES footprint are the South Pole Telescope Sunyaev-Zel'dovich survey, outlined in yellow, and the VISTA Viking NIR survey, outlined in green. In the diagram, N is up and E is to the right; time and RA increase to the right.

The footprint is defined by the set of DECam pointings ("hexes") that cover the total area. The DES footprint is currently defined as a set of 1673 ra,dec pairs. The hex centers define a single tiling. A tiling is one complete visit to the entire survey area in one filter. The DES survey strategy is to observe 2 tilings/season/bandpass, i.e., to cover the entire survey area in each filter twice each season, where a season comprises 105 nights in the Sept-Feb timeframe. With succeeding seasons, the depth and photometric calibration precision of the survey will improve. Each tiling (for this purpose, imagine counting tilings in each bandpass individually so that there are slots for 1-10 in each filter) uses the hex centers of the map but applies a unique set of offsets, shown in table 2. These offsets are a large fraction of the camera field of view and are chosen to maximize

Table 2: Tiling Offsets

Tile #	Δ RA (degrees)	Δ Dec (degrees)
1	0.000	0.000
2	0.000	0.900
3	0.521	-0.465
4	-0.538	-0.061
5	0.243	0.343
6	0.073	-0.318
7	-0.222	0.122
8	0.185	0.065
9	-0.058	-0.141
10	-0.051	0.106

the performance of ubercal photometric calibration techniques to both link CCDs together in astrometry and photometry and to extract photometry correction maps via instrumental and atmospheric models.

The resulting survey parameters are shown in Table 3. The values are for a simulated survey using median weather conditions; they are more stable and trustworthy over five years than for 1 year. The upper portion of the table shows cumulative exposure times and limiting mags for one full season; the lower portion corresponds to the completed 525-night survey. The limiting 5σ PSF[1] magnitudes are $\sim 26^{th}$. The median delivered PSF is based on site seeing statistics and design parameters of DECam, assuming negligible dome seeing and telescope jitter.

Table 3: Expected Cumulative Wide-Area Survey Depths and Median Delivered PSF

tilings	filter	total exp (sec)	mean PSF 5σ m_{lim}	mean galaxy 10σ m_{lim}	median PSF (arcsec)
1-2					
	g	160		24.1 ± 0.3	0.89 ± 0.13
	r	160		23.7 ± 0.2	0.85 ± 0.12
	i	200		23.1 ± 0.2	0.81 ± 0.11
	z	200		22.5 ± 0.2	0.79 ± 0.10
	y	100		20.3 ± 2.6	0.78 ± 0.10
1-10					
	g	800	26.5	25.2 ± 0.1	0.83 ± 0.05
	r	800	26.0	24.8 ± 0.1	0.79 ± 0.05
	i	1000	25.3	24.0 ± 0.1	0.79 ± 0.05
	z	1000	24.7	23.4 ± 0.1	0.78 ± 0.04
	y	500	23.0	21.7 ± 0.1	0.77 ± 0.04

psf mag $\equiv$ 1.0*FWHM aperture mag; galaxy mag $\equiv$ 1.6*FWHM aperture mag
5^{th} & 6^{th}column errors denote variations across the survey area

3 Supernova Survey

The supernova survey adopts a strategy using two deep fields and 8 shallow fields, where the exposure times of all 8 shallow fields sum to a single deep field. The list of fields and their exposure times per visit is given in table 4.

Our baseline plan is to switch from the wide-area survey to the supernova survey when the delivered PSF $\geq 1.1''$. However, if the time since the last observation of any given SN field-filter pair has been longer than 7 days, the wide-area survey is interrupted to obtain the SN data.

The resulting mean SN Survey cadence is ~ 5 days, and the fraction of > 7-day interruptions is $\leq 20\%$.

The cumulative depths for the SN fields will be substantially greater due to the large number of revisits: for the 2 deep (8 shallow) SN fields, the 5σ point-source limiting magnitudes are estimated to be $g, r, i, z = 27.9(27.6), 28.1(26.4), 27.8(26.7), 27.6(26.5)$ (Bernstein et al 2011).

[1]LSST has adopted a PSF magnitude using an aperture of 1.42*FWHM. Adopting this, the stellar (PSF) limiting magnitudes in column 3 of Table 2 would be brighter by ~ 0.4 magnitudes.

Table 4: DES Supernova Fields

Name	DES Name	α (degrees)	δ (degrees)	filters	exposure (sec)
Elias S1	E1 shallow	7.8356	-42.9860	griz	(80,25,100,100) x (2,2,2,5)
	E2 shallow	9.5000	-43.9980	griz	(80,25,100,100) x (2,2,2,5)
XMM-LSS	X1 shallow	34.6356	-3.6880	griz	(80,25,100,100) x (2,2,2,5)
	X2 shallow	34.6356	-5.7120	griz	(80,25,100,100) x (2,2,2,5)
	X3 deep	36.3000	-4.7000	griz	(100,300,300,300) x (3,4,6,13)
Stripe 82	S1 shallow	49.1000	0.0000	griz	(80,25,100,100) x (2,2,2,5)
	S2 shallow	47.4356	-1.0120	griz	(80,25,100,100) x (2,2,2,5)
CDFS	C1 shallow	54.2644	-27.0000	griz	(80,25,100,100) x (2,2,2,5)
	C2 shallow	54.2644	-29.1120	griz	(80,25,100,100) x (2,2,2,5)
	C3 deep	52.6000	-28.1000	griz	(100,300,300,300) x (3,4,6,13)

4 DES Year 1: 2012B Semester

The plan for the first DES season differs from the program outlined above. In order to test the new instrument and our ability to extract dark energy science in the presence of systematic errors, we aim to carry out a smaller-area survey to the full, five-year depth of the wide-area survey given in the lower portion of Table 3. To realize this, we have defined three fields of $\sim 100 - 250$ sq. deg. each ; depending on when DECam commissioning finishes, we will observe 1, 2, or all 3 fields. The field parameters are given in table 5. If there is sufficient available time, we will also pursue a normal two-tiling strategy on a larger area covering the SPT, up to ~ 1350 sq. deg. In addition, we will carry out the SN survey using the usual DES protocols outlined above.

Table 5: DES First Season Survey

	α (degrees)	δ (degrees)	filters	exposure (sec)	area (deg^2)
West SPT deep	$-17 \leq \alpha \leq 2$	$-58 \leq \delta \leq -49$	grizY	(80,80,100,100,50) x10	100
Spectroscopic training	$14 \leq \alpha \leq 40$	$-7 \leq \delta \leq +3$	grizY	(80,80,100,100,50) x10	258
Maximum visibility	$65 \leq \alpha \leq 90$	$-58 \leq \delta \leq -48$	grizY	(80,80,100,100,50) x10	149
SPT main survey	$20 \leq \alpha \leq 105$	$-65 \leq \delta \leq -40$	grizY	(80,80,100,100,50) x2	1344

These fields are shown on our footprint in Figure 2. The fields are staggered so that if the commissioning schedule slips we give up a deep field each month of slippage. These fields are lost in order of west to east.

During the DECam System Science Verification phase, we aim to cover ~ 100 sq deg to full survey depth in one of these deep fields (depending on commissioning schedule) as well as to obtain SN survey observations. The science verification and first-year plans combine seemlessly. At the end of the five years of DES, the plan is to have a homogeneous survey in which the identity of the 3 first-year deep fields has been lost. This is done by pursuing the 10 tilings in the first year on the same hex centers and tiling offsets as the rest of the five-year survey.

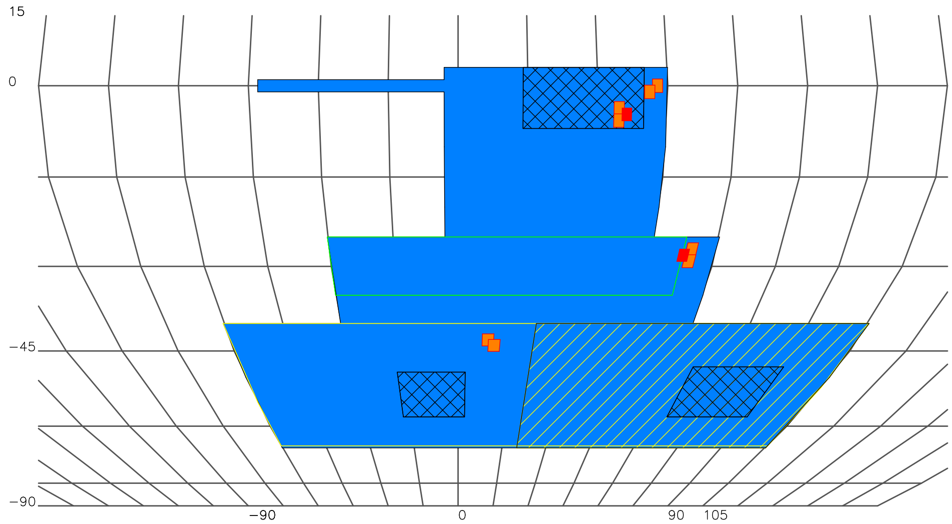

Figure 2: The DES footprint with SN fields, with first-year fields shown. The black cross hatched regions are the full-depth, 10 tiling, year-1 fields, and the yellow single-hatched region is the year-1 two-tiling area. In the diagram, N is up and E is to the right; time and RA increase to the right.