



DARK ENERGY SURVEY

# SDSS Stripe 82 and the Photometric Calibration of the Dark Energy Survey (DES)

Douglas L. Tucker (FNAL), for the Dark Energy Survey Collaboration

## Purpose of the DES

Perform a **5000 sq deg *grizY*** imaging survey of the Southern Galactic Cap down to ***i*-24th mag** (10 $\sigma$ , galaxies) in order to probe the nature of the Dark Energy by constraining its equation of state parameter *w* and its energy density.

## New Camera

Replaced the Prime Focus cage on the CTIO Blanco 4m telescope with a new 3 sq deg optical CCD camera (The Dark Energy Camera, or "DECam").

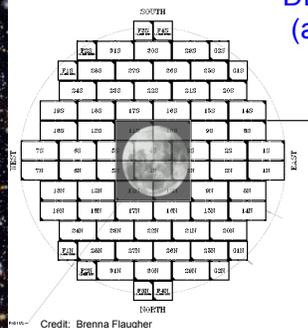


Credit: CTIO

## Survey Period

30% of the telescope time (**525 nights**) from 2013-2018 (September - February)

## DECAM Focal Plane (a.k.a., "The Hex")

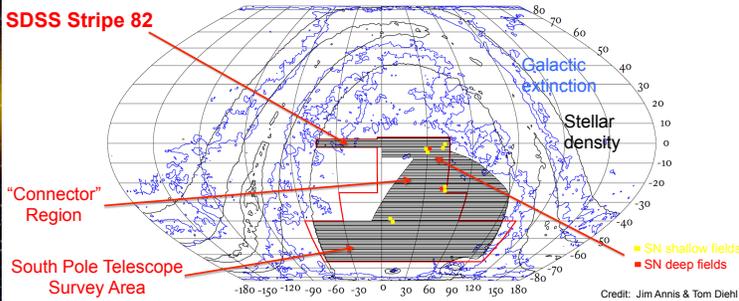


Credit: Brenna Flaugher

- 62 2kx4k Science CCDs (520 Megapixels)
- 8 2kx2k Focus/Alignment CCDs
- 4 2kx2k Guide CCDs
- FOV: 2.2° in diameter (**3 sq deg** in area)
- 0.26 arcsec/pixel
- Red-sensitive (QE > 50% at 1 micron)

## DES Footprint

current (red), proposed (gray)



Credit: Jim Annis & Tom Diehl

## DES Observing Strategy

### Wide-field Survey (*grizY*)

- 90 sec (*griz*); 45 sec (*Y*)
- Multiple overlapping tilings (layers) with large overlaps to optimize photometric calibrations (typically 2 tilings/filter/year).

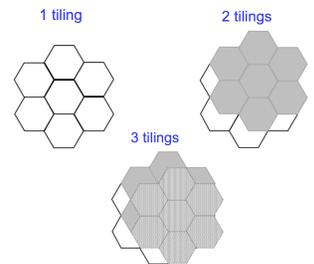
### Supernova Survey (*griz*)

- Ten 3-sq-deg fields
- 150-200 sec (shallow); 200-400 sec (deep)
- Observe under poor seeing conditions or if a SN field has not been observed in 7 nights

### Photometric Requirements (5-year)

- All-sky internal: 2% rms (Goal: 1% rms)
- Absolute Color: 0.5% (*g-r*, *r-i*, *i-z*); 1% (*z-Y*) [averaged over 100 objects scattered over Focal Plane]
- Absolute Flux: 0.5% in *i*-band (rel. to BD+17 4708)

### Zooming in on part of the survey area...



## DES Calibrations Plan in 6 Points

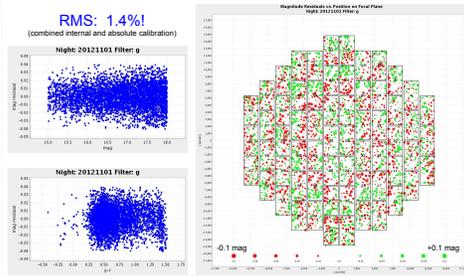
1. **Instrumental Calibration (Nightly & Periodic):** Create biases, dome flats, linearity curves, cross-talk coefficients, system response maps.
2. **Photometric Monitoring:** Monitor sky conditions with 10 $\mu$ m All-Sky Cloud Camera and the GPS and atmCam atmospheric transmission monitors.
3. **PreCam Survey:** Create a network of calibrated DES *grizY* standard stars for use in nightly calibrations and in DES Global Relative Calibrations.
4. **Nightly and Intermediate Calibrations:** Observe standard star fields with DECAM during evening and morning twilight and at least once in the middle of the night; fit photometric equation; apply the results to the data.
5. **Global Relative Calibrations:** Use the extensive overlaps between exposures over multiple tilings to tie together the DES photometry onto an internally consistent system across the entire DES footprint.
6. **Global Absolute Calibrations:** Use DECAM observations of spectro-photometric standards in combination with measurements of the full DECAM system response map to tie the DES photometry onto an AB magnitude system.

## Importance of SDSS Stripe 82 to DES

1. **Nightly Standards:** SDSS Stripe 82 is 2.5 deg thick in declination. Thus, a single pointing within Stripe 82 accommodates full coverage of all 62 CCDs in the 2.2-deg-diameter DECAM focal plane. A set of 6 Stripe 82 fields spaced at roughly 20-deg intervals in RA forms the main set of standard star fields for DES nightly calibrations.
2. **Global Relative Calibrations:** Unless a survey "circumnavigates" a full (hemi-)sphere – where, say, calibrations from east and west can connect up – relative calibration methods can be prone to systematic gradients (due to, e.g., small residual flat fielding errors). For surveys (like DES) that cover smaller regions of the sky, standard stars can be used to "anchor" the global relative calibrations against large-scale gradients. Stars from Stripe 82 are one of the sources of "anchor" stars for DES.
3. **Global Absolute Calibrations:** Stripe 82 not only provides an indirect tie to BD+17 4708, it also provides a set of spectroscopically confirmed DA White Dwarfs and F stars that can be used for absolute color calibration.
4. **Test area:** Stripe 82 is one of the best calibrated areas of the sky in a DES-like filter system. It is therefore an excellent data set for comparing different calibration algorithms for DES.
5. **Photo-z's:** Although not strictly *photometric* calibration, Stripe 82 provides an important training set for photo-z calibration.

## Early DES Photometric Results from Science Verification

(Residuals of Nightly Standard Star Solution in *g*-band for the night of 13 November 2012)



SDSS stars were used as standard stars in the nightly standard star solution. These early QA plots showed:

1. that sub-2% photometry across the DES focal plane was easily obtainable, and
2. that a small-but-noticeable radial pattern in the residuals across the focal plane indicated that we could do better in pupil ghost removal and star flat correction.

In subsequent processing, new pupil ghosts and star flats have essentially removed this radial pattern.

## Caveats

- Comparisons among the multiple versions of Stripe 82 star catalogs (e.g., Ivezić et al. 2007, Aihara et al. 2011 (DR8), Betoule et al. 2013, etc.), between SDSS data and data from other surveys covering the Stripe 82 area (e.g., PanSTARRS), and between SDSS data and Stellar Locus Regression (SLR) results indicate that there may be spatially systematic inconsistencies at the 1-2% level.
- See, e.g., the comparison between the SDSS DR10 and the Betoule et al. (2013) calibrations of SDSS Stripe 82 for *z*-band plotted here.

