Calibration Plan for Early DES Data

DARK ENERGY SURVEY

Douglas L. Tucker
(FNAL)

DES Director's Council Review
10-11 May 2011

Basic DES Observing Strategy

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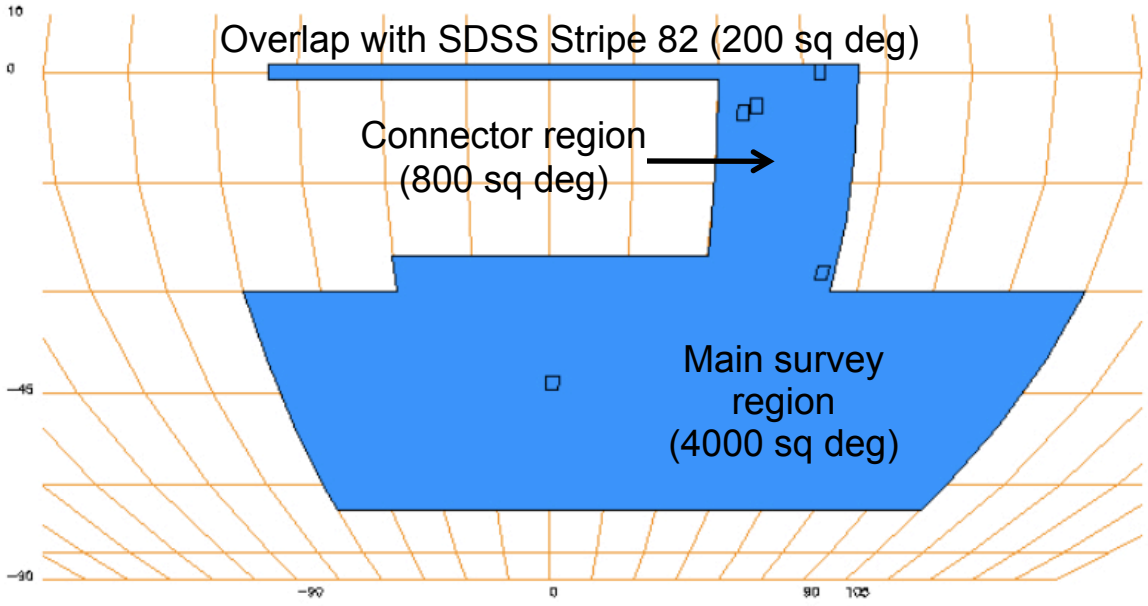
Observing Strategy

- 100 sec exposures (nominally)
- 2 filters per pointing (typically)
  - *gr* in dark time
  - *izy* in bright time
- Multiple overlapping tilings (layers) to optimize photometric calibrations
- 2 survey tilings/filter/year
- 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*)
  - Absolute Flux: 0.5% in *i*-band (relative to BD+17 4708)

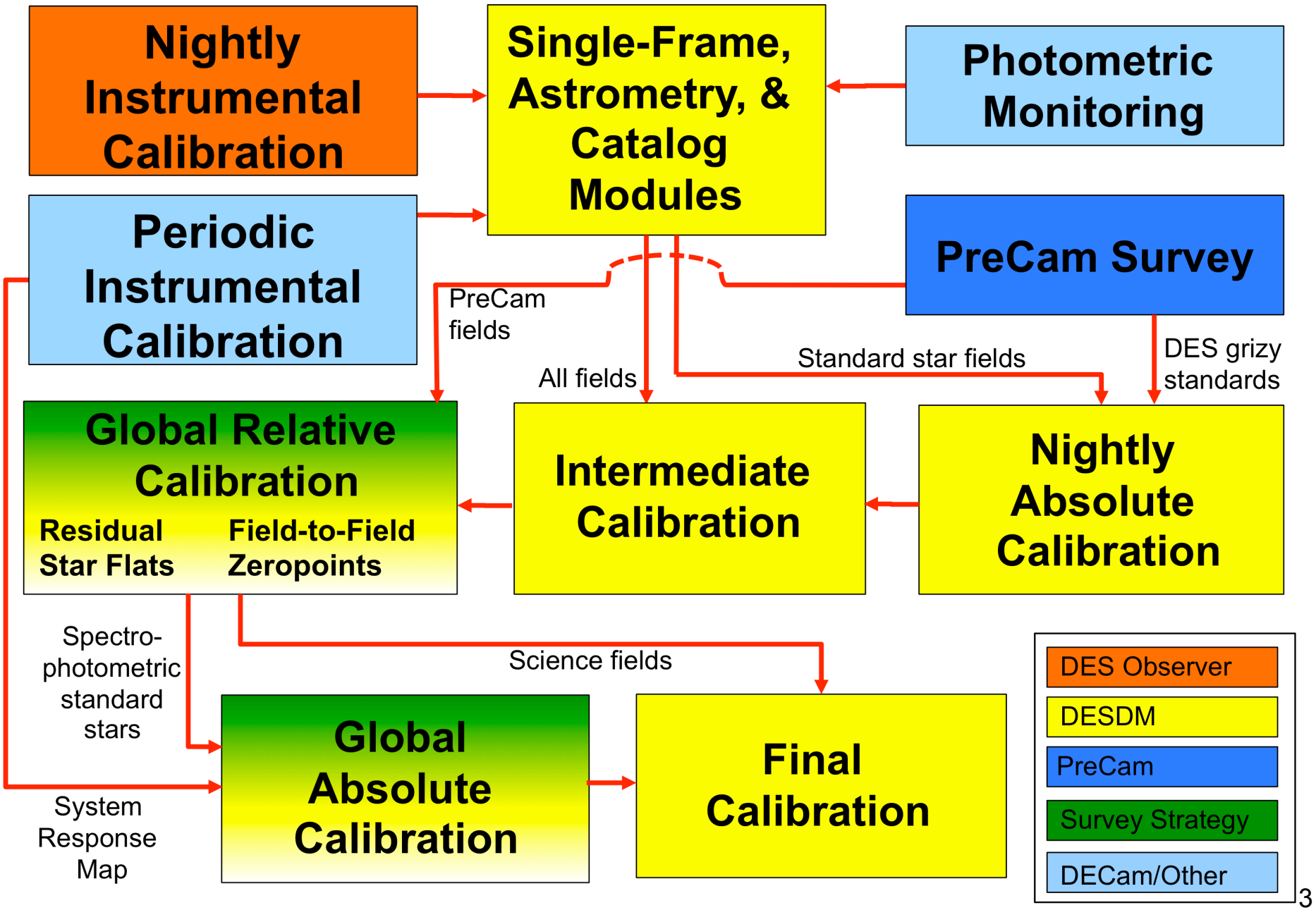
Survey Area

Credit: J. Annis



Total Area: 5000 sq deg

DES Photometric Calibrations Flow Diagram (v4.1)



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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 with 10μm All-Sky Cloud Camera.
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.

1. Instrumental Calibration:
An Example of Periodic Instr. Calibration

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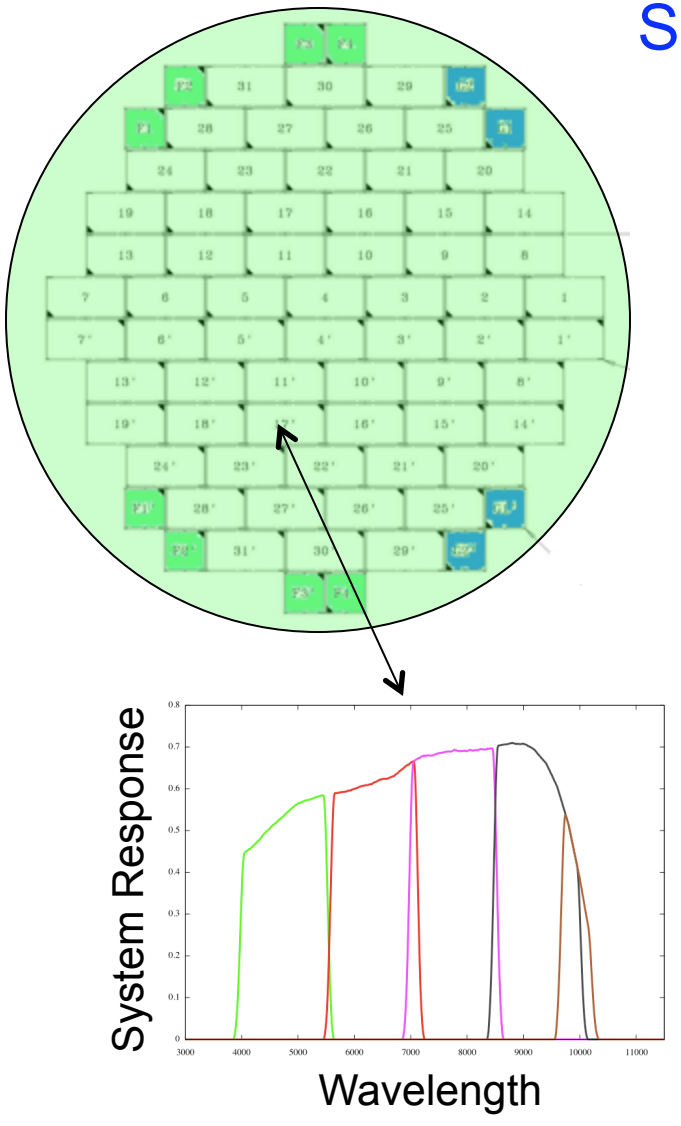

Spectrophotometric System Response Map

(See Jennifer Marshall's talk.)

- It is expected that the shape of the system response will be a function of position on the focal plane.
- Therefore, the system response map from the spectrophotometric calibration system will be important for Global Absolute Calibration, catalog and image co-adds, enhanced calibration of specific classes of astronomical objects, and system performance tracking over time.
- This would typically be a once-a-month calibration, taking several hours to measure all 5 DES filters.

2. Photometric Monitoring: The 10 micron All-Sky Camera

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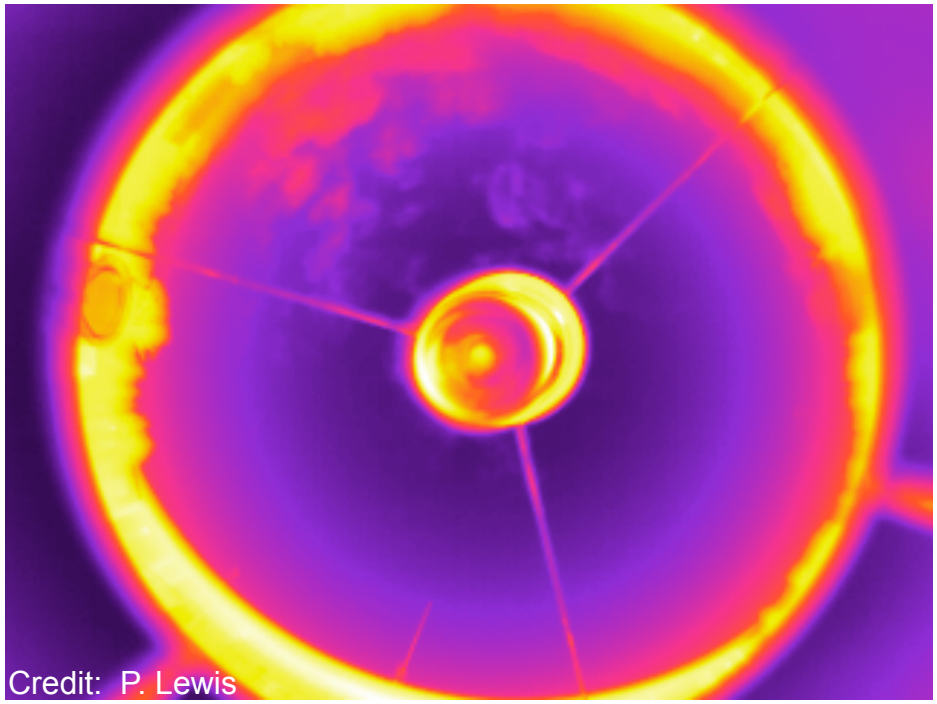
10 micron All-Sky Camera

- Provides real-time estimates of sky conditions for survey strategy
- Provides a measure of the photometric quality of an image for off-line processing
- Detects even light cirrus under a full range of moon phases (no moon to full moon)



RASICAM image: light cirrus

The DES Camera: "RASICAM"

- "Radiometric All-Sky Infrared CAMera"
- Web interface for observers
- Photometricity flags passed to each exposures FITS header via SISPI for use by DESDM
  - Nightly calibrations
  - Global relative calibrations

3. The PreCam Survey:
What is it?

PreCam Survey: a quick, bright *grizy* survey in the DES footprint using a 4kx4k camera composed of DECam CCDs – the "PreCam" – mounted on the University of Michigan Dept. of Astronomy's Curtis-Schmidt Telescope at CTIO.

Observations took place in Aug/Sep 2010 and Nov 2010 - Jan 2011.

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3. The PreCam Survey: Characteristics

- 2 DECam 2k x 4k CCDs
  - FOV of 1.6º x 1.6º (2.56 sq deg) at a pixel scale of 1.4 arcsec/pixel
- 112 scheduled nights (which includes includes installation & commissioning)
- Goals: to act as a test-stand of DECam h/w and s/w and to obtain a sparse-but-rigid gridwork of stars in DES *grizy* photometrically calibrated to better than ~1%

Baseline PreCam Survey Point-Source Magnitude Limits (optimized to achieve S/N=50 at DES saturation + 1.5mag)

Band	Exposure time [seconds]	PreCam saturation limit	PreCam mag limit S/N=50	Number of usable stars per sq deg (SGP)
g	36	12.8	17.8	186
r	51	13.2	17.8	265
i	65	13.4	17.7	344
z	162	14.1	17.5	317
y	73	11.6	14.3	150

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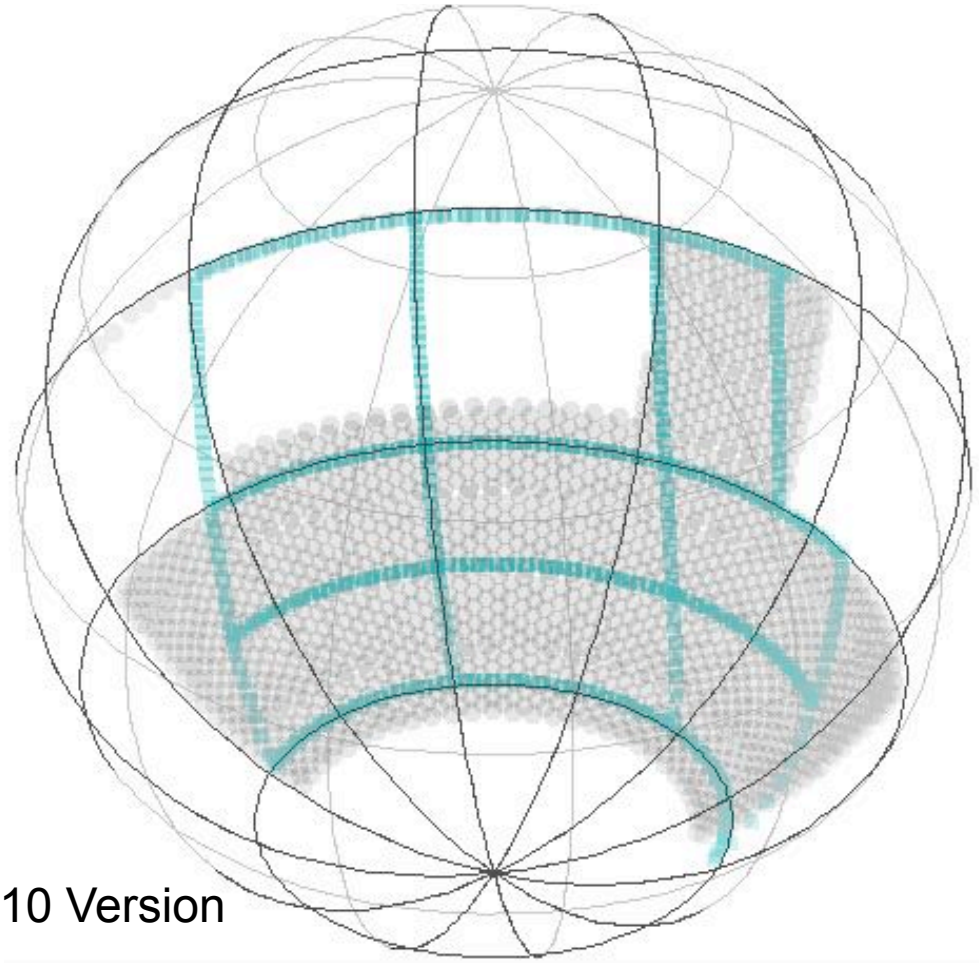
3. The PreCam Survey:
The Survey Strategy as Planned

- ≈500 sq deg (10% DES area)
- ≈30° grid pattern
- Cover grid 10x in each filter (*g*, *r*, *i*, *z*, *y*)



Aug 2010 Version

3. The PreCam Survey:
Some Results on SDSS-DES Color Terms

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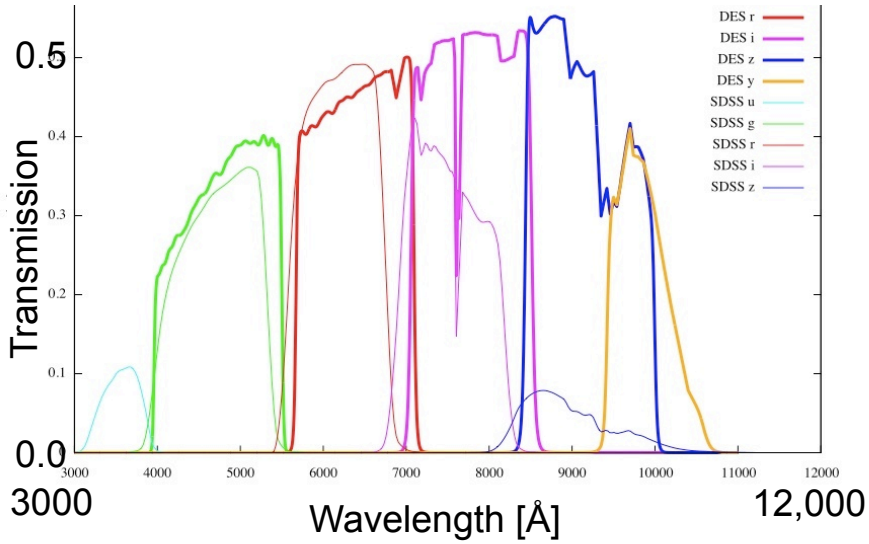
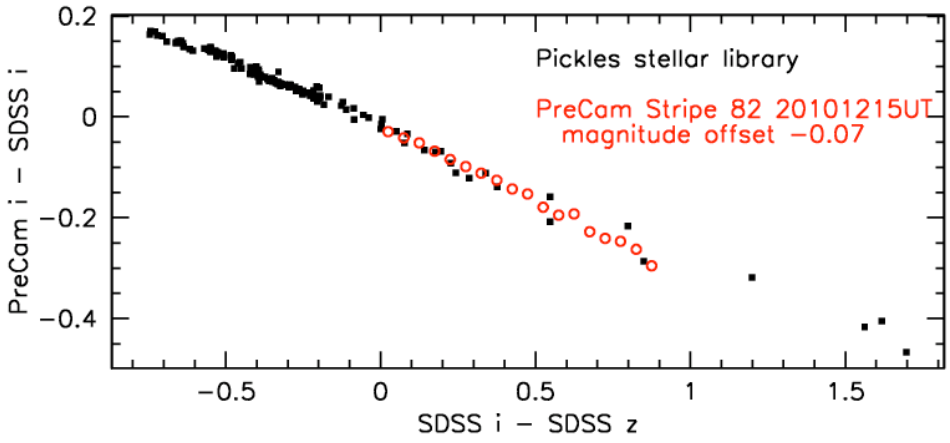
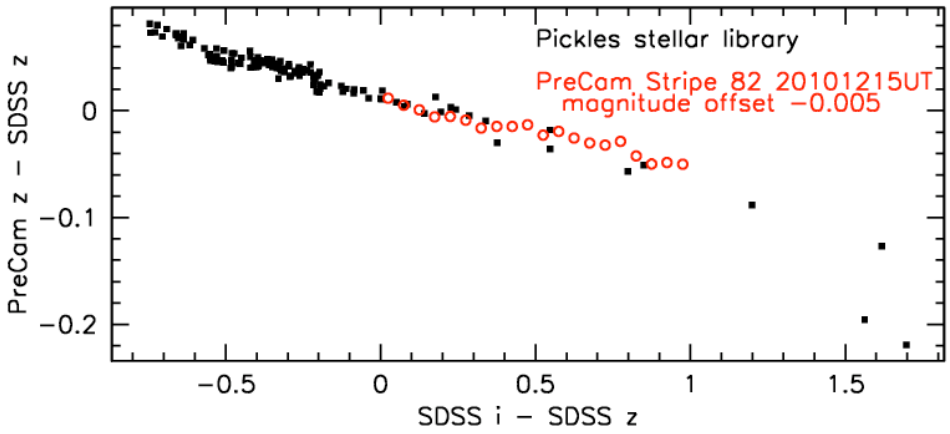
SDSS & DES Response Curves



Synthetic & Observed PreCam Color Terms





Credit: Huan Lin

4. Nightly/Intermediate Calibrations: Standard Stars for DES

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Photometric Equation: $m_{inst} - m_{std} = a_n + b_n \times (stdColor - stdColor_0) + kX$

SDSS Stripe 82

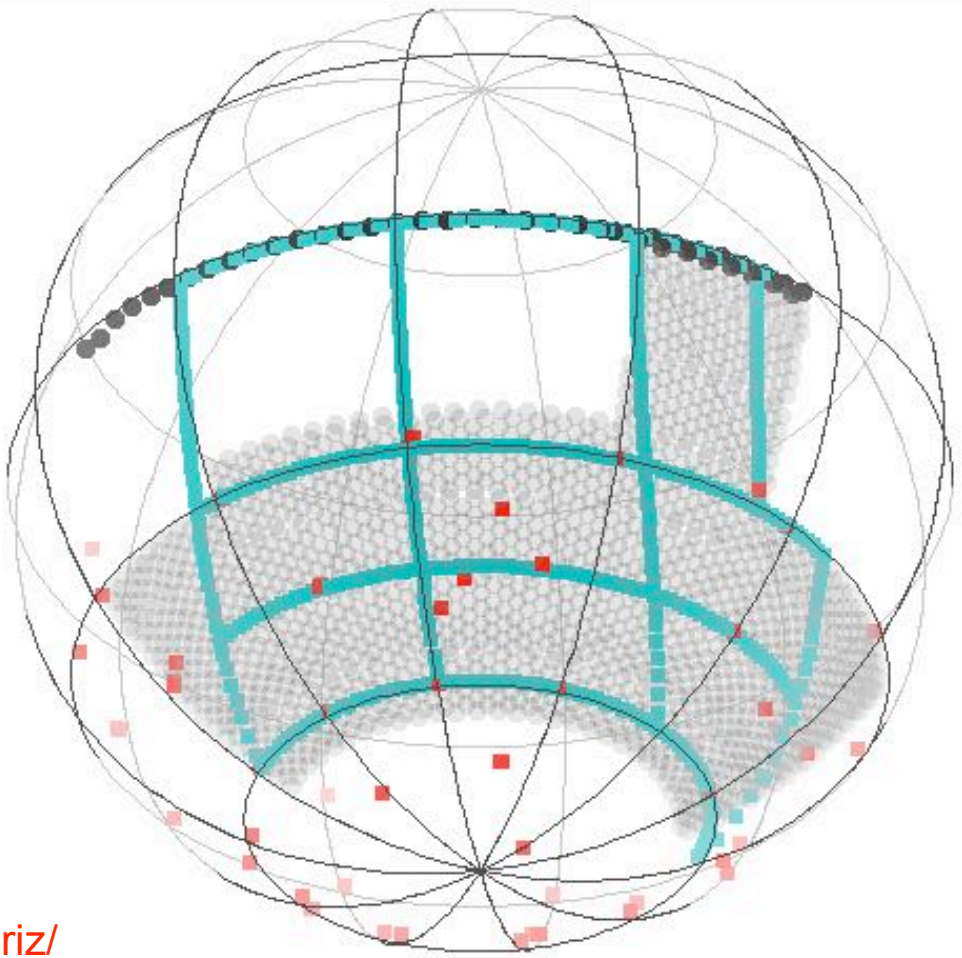
- ~10^6 tertiary *ugriz* standards
- *r* = 14.5-21
- ~4000 per sq deg
- 2.5° x 100° area
- See Ivezic et al. (2007)

PreCam

- DES *grizy*
- 500 sq deg
- ≈200 per sq deg

Southern u'g'r'i'z' Standards

- Sixty 13.5'x13.5' fields
- *r* = 9-18
- Typically tens per field
- See http://www-star.fnal.gov/Southern_ugriz/



4. Global Relative Calibrations: The Need and The Strategy

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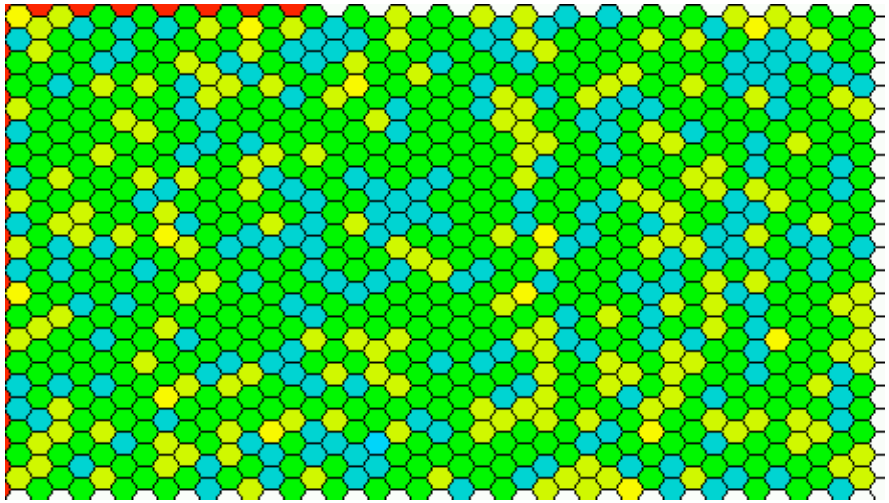
We want to remove field-to-field zeropoint offsets to achieve a uniformly "flat" all-sky relative calibration of the full DES survey, but…

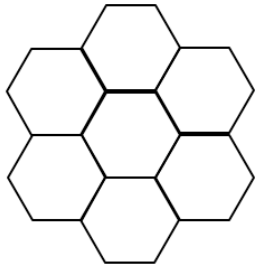
DES will not always observe under truly photometric conditions…

…and, even under photometric conditions, zeropoints can vary by 1-2% rms field-to-field.

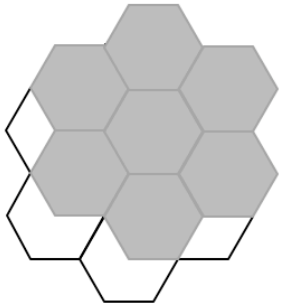


scaling bar is –0.20 mags to +0.20 mags

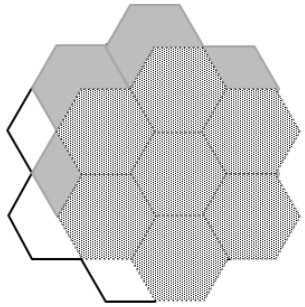
1 tiling



2 tilings



3 tilings



The solution: multiple tilings of the survey area, with large offsets between tilings.

We cover the sky twice per year per filter. It takes ~ 1700 hexes to tile the whole survey area.

5. Global Relative Calibrations: The Role of PreCam Data

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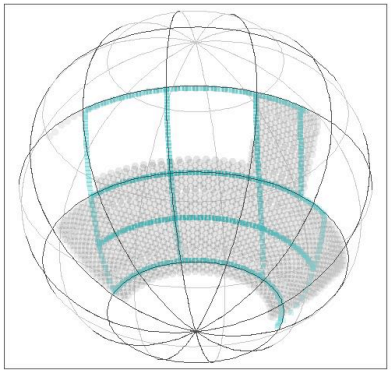
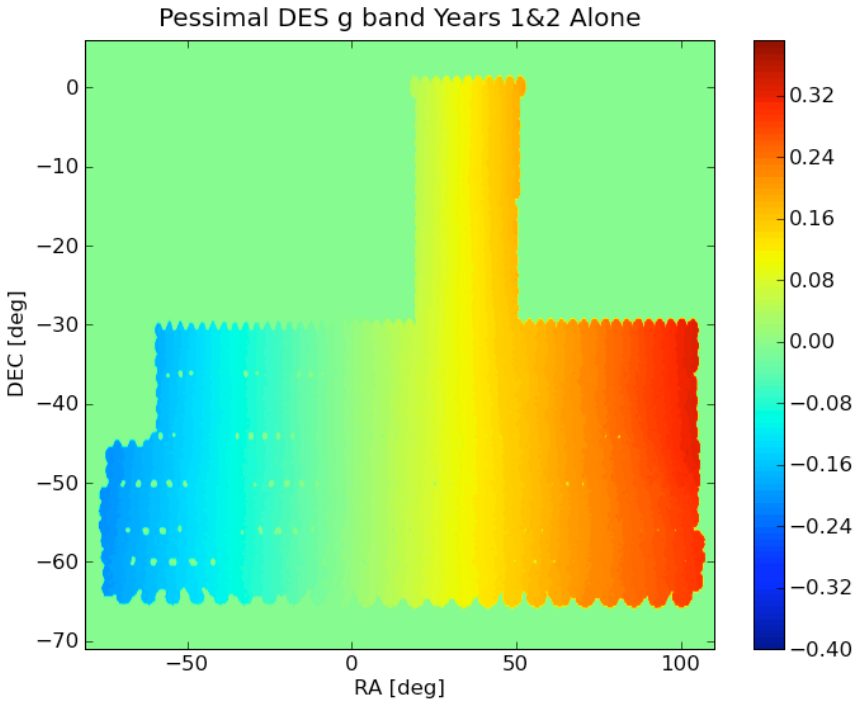
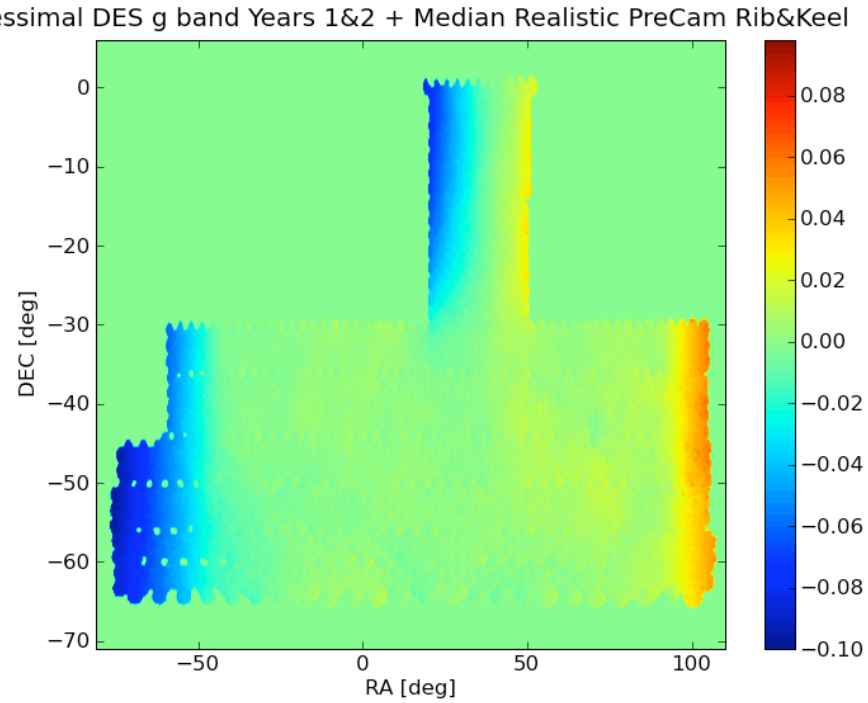
- A rigid framework onto which to tie the DES photometry
- PreCam helps DES achieve its global relative calibrations requirements sooner (and also helps protect against certain pathological calibration failures).







6. Global Absolute Calibrations: Basic Method

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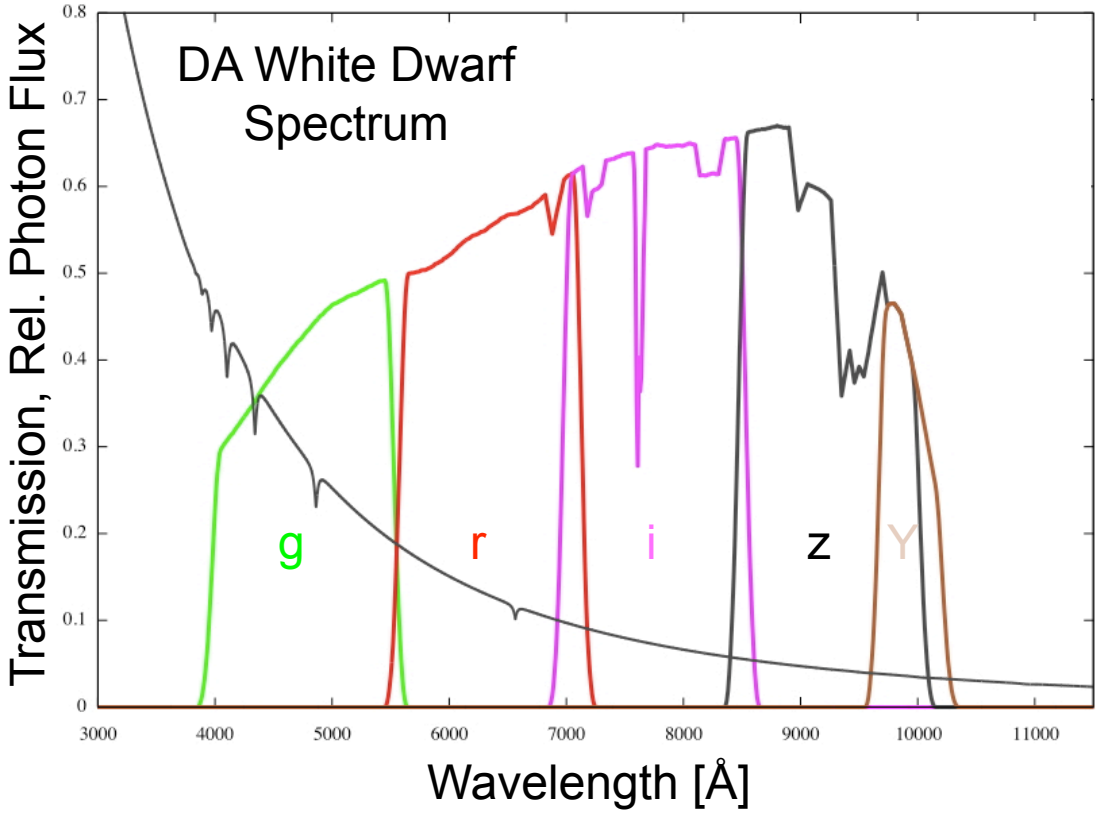
- Compare the synthetic magnitudes to the measured magnitudes of one or more spectrophotometric standard stars observed by the DECam.
- The differences are the zeropoint offsets needed to tie the DES mags to an absolute flux in physical units (e.g., ergs s^{-1} cm^{-2} $Å^{-1}$).
- Absolute calibration requires accurately measured total system response for each filter passband as well as one or more well calibrated spectrophotometric standard stars.



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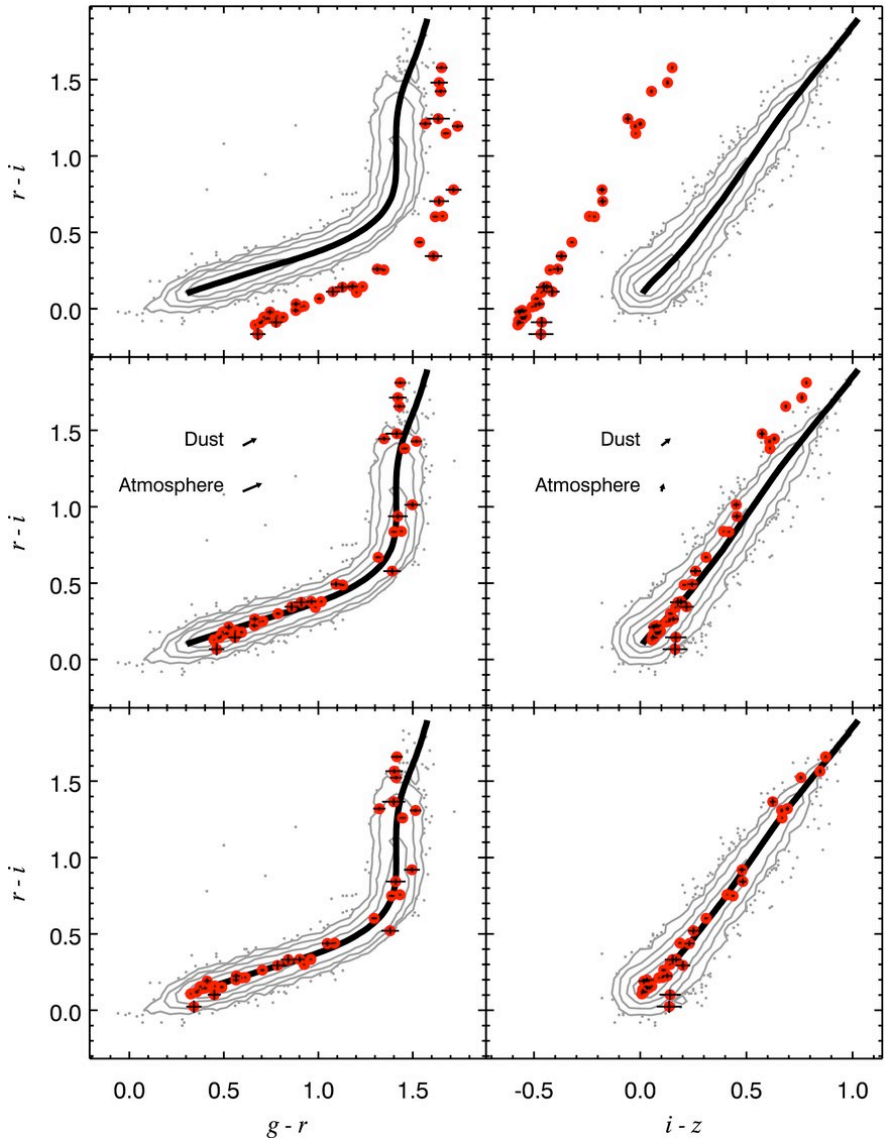
Additional:
For Rapid Calibration…

- The global relative and absolute calibrations will be performed seasonally (annually).

- For rapid calibrations between the seasonal running of the global calibration modules, one can make use of the stellar locus regression method of High et al. (2009), as implemented by Bob Armstrong of the DESDM team.



High et al. (2009)

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Summary

- There is a plan in place for the calibration of the early DES data. The plan consists of components for:
  1. Nightly & Periodic Instrumental
  2. Photometric Monitoring
  3. The PreCam Survey
  4. Nightly and Intermediate Calibrations
  5. Global Relative Calibrations
  6. Global Absolute Calibrations

- The Stellar Locus Regression method of High et al. (2009) is an alternate method for global calibrations that can be used for rapid turn-around between processing seasons.

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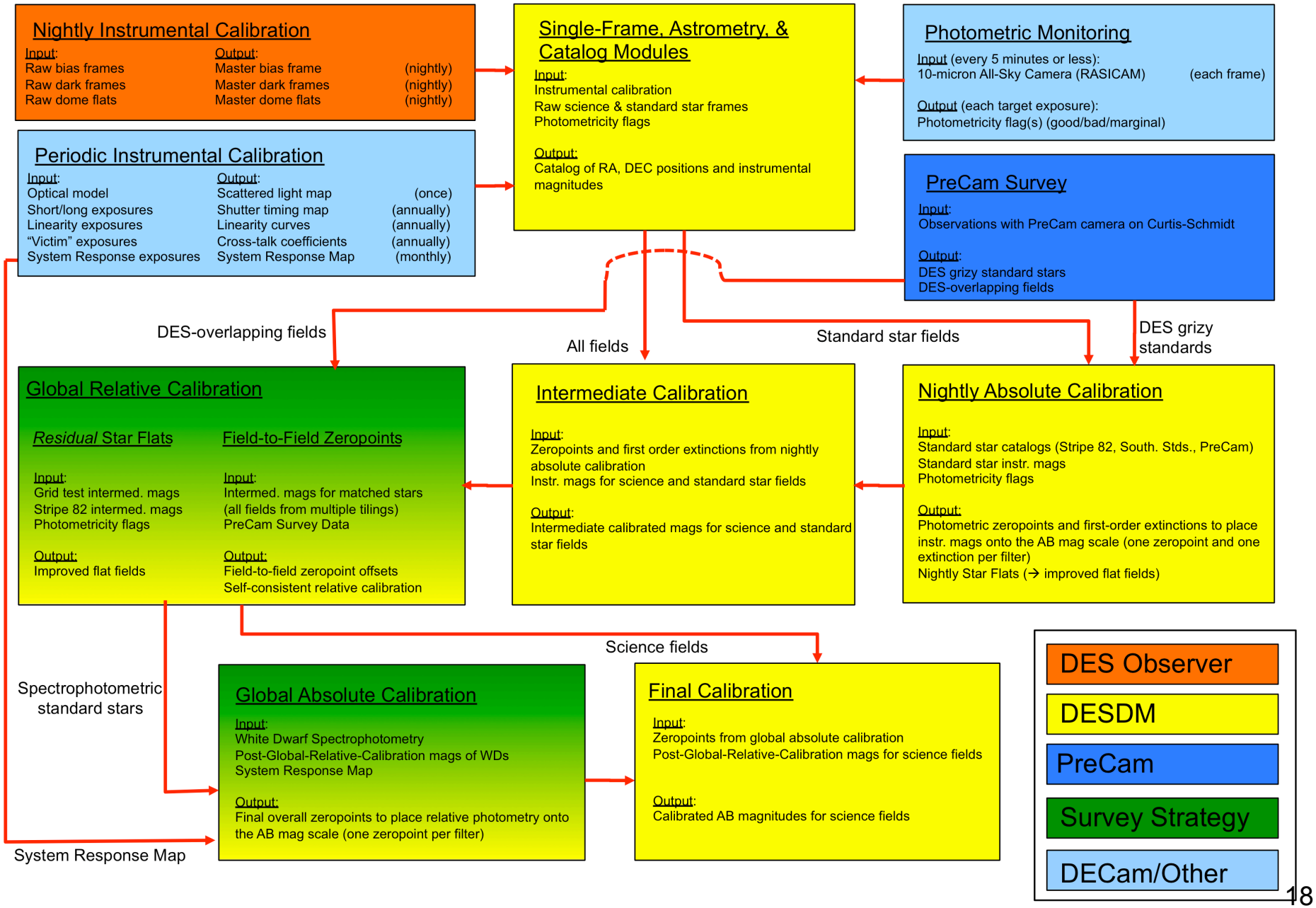
Extra Slides

DES Photometric Calibrations Flow Diagram (v4.1)



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3. The PreCam Survey: Benefits to DES

1. Early on-sky tests with a "1/32nd scale" DECam.

2. DES *grizy* standard stars (*y*-band in particular), supplementing the Stripe 82 standards and Smith et al. Southern *u'g'r'i'z* standards and permitting a much finer time-resolution of extinction measurements during DES operations
   a) DES survey strategy simulations indicate that DES nightly observations will cross a PreCam field about once an hour on average.
   b) These DES observations of PreCam fields reduces the need for additional dedicated standard star observations during the night by the Blanco – ***this can increase DES observing efficiency by up to 10%***, or, in monetary terms, a savings of 10% x $10,000/night x 525 nights = $525,000.
   c) The PreCam sparse grid also provides improved spatial coverage of calibration fields throughout the DES footprint – any part of the DES footprint is that much closer to a calibration field.

3. Determinations of the transformations between SDSS *griz* and DES *griz* (via observations in SDSS Stripe 82).

4. Identification of candidate DA white dwarfs (in conjunction with SkyMapper *u*), useful for DES absolute calibrations.

5. Stars that can be used for "quick look" diagnostics of the DES data in during DES operations.

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4. Nightly/Intermediate Calibrations: The Photometric Equation

- The Photometric Equation is a simple model that fits the observed magnitudes of a set of standard stars to their "true" magnitudes via a simple model; e.g.:

$$m_{inst} - m_{std} = a_n + kX \qquad (1)$$

  - m_{inst} is the instrumental magnitude, $m_{inst} = -2.5log(counts/sec)$ (input)
  - m_{std} is the standard ("true") magnitude of the standard star (input)
  - a_n is the photometric zeropoint for CCD n (n = 1-62) (output)
  - k is the first-order extinction (input/output)
  - X is the airmass (input)

- A refinement: add an instrumental color term for each CCD to account for small differences between the standard star system and the natural system of that CCD:

$$m_{inst} - m_{std} = a_n + b_n \times (stdColor - stdColor_0) + kX \qquad (2)$$

  - b_n is the instrumental color term coefficient for CCD n (n = 1-62) (input/output)
  - $stdColor$ is a color index, e.g., $(g-r)$ (input)
  - $stdColor_0$ is a constant (a fixed reference value for that passband) (input)
  - DES calibrations will be in the DECam natural system, but there may be variations from CCD to CCD within the DECam focal plane or over time.

6. Global Absolute Calibrations:
Search for DA White Dwarfs in DES Area

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Resubmission of 10B-0469

NOAO Observing Proposal *Standard proposal* **Panel:** *For office use.*
Date: March 31, 2011 **Category:** Stellar Pops (GAL)

Targeted Samples of the Hot Stellar Content in the Blanco Cosmology Survey

PI: J. Allyn Smith **Status:** P **Affil.:** Austin Peay State University
Physics and Astronomy, 601 College St.; P.O. Box 4608, Clarksville, TN 37044 USA
Email: smithj@apsu.edu Phone: 931-221-6104 FAX: 931-221-6129

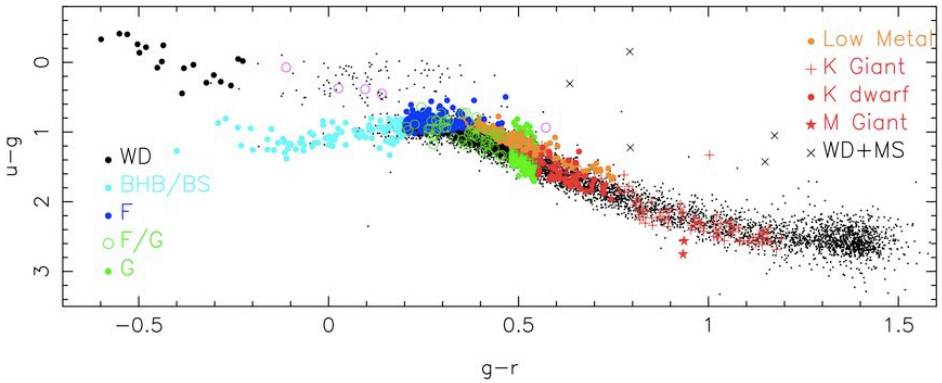
CoI: Douglas L. Tucker **Status:** P **Affil.:** Fermilab
CoI: Chow Choong Ngeow **Status:** P **Affil.:** National Central University
CoI: Melissa Butner **Status:** U **Affil.:** Austin Peay State University
CoI: Joe Mohr **Status:** P **Affil.:** Universitaets-Sternwarte Muenchen
CoI: Sahar S. Allam **Status:** P **Affil.:** Fermilab
CoI: Susana E. Deustua **Status:** P **Affil.:** STScI

Abstract of Scientific Justification *(will be made publicly available for accepted proposals)*:
We request observing time on the Blanco + MOSAIC II (plus ancillary calibration time on the CTIO-1m) to obtain *u*-band imaging data for targeted regions within the footprint of the Blanco Cosmology Survey (BCS). These data will supplement the existing BCS *griz* data to enhance stellar content studies. The *u*-band data are critical in separating F-type turn-off stars, BHB stars, and moderate redshift QSOs, and in distinguishing the various A-type stars (hot white dwarfs, RR Lyr, sdA). These data will also aid in identification of hot white dwarfs which will be used as calibration objects for later surveys which include the BCS area (specifically the DES, which begins in October 2011, and LSST). Part of this effort will be an extensive calibration program to completely tie the *u*-band data to the existing *griz* data collected for BCS during the NOAO Surveys Program (Joe Mohr, PI). We note that, with the imminent retirement of the Mosaic II image, such studies will soon be impossible from the Blanco for the foreseeable future, since a *u*-band will not be part of the initial complement of filters available for use with the Dark Energy Camera (DECam). Due to the substantial expected cost of such a DECam *u*-band filter, it may be some time before the ability to perform *u*-band studies will return to the Blanco.

Summary of observing runs requested for this project

Run	Telescope	Instrument	No. Nights	Moon	Optimal months	Accept. months
1	CT-4m	MOSAIC	5	dark	Oct - Oct	Aug - Oct
2	CT-1.0m	CFIM + 4K	7	dark	Oct - Oct	Aug - Oct
3	CT-1.0m	CFIM + 4K	7	dark	Dec - Jan	Dec - Jan
4						
5						
6						

Yanny et al. 2009



From the Scientific Requirements Document

(sciReq-9.86, 10 June 2010)

(Update of a slide from Jim Annis)

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R-10 For each of the *grizY* bandpasses of the wide-area survey, the fluctuations in the spatially varying systematic component of the magnitude error in the final co-added catalog must be smaller than 2% rms over scales from 0.05 to 4 degrees.

Internal (Relative) Calibration

$m_i = -2.5\log(f_{i1}/f_{i2}) + C$

R-11 The color zeropoints between the survey fiducial bandpasses (*g-r, r-i, i-z*) must be known to 0.5% rms. The *z-Y* color zeropoint shall be known to 1% rms.

Absolute Color Calibration

$m_i - m_z = -2.5\log(f_i/f_z) + zp_{iz}$

R-12 The i-band magnitude zeropoint relative to BD+17, and therefore the AB system, must be known to 0.5% rms.

Absolute Flux Calibration

$m_i = -2.5\log(f_i) + zp_i$

R-13 The system response curves (CCD + filter + lenses + mirror + atmosphere at 1.2 airmasses) must be known with sufficient precision that the synthesized *grizY* magnitudes of any astronomical object with a calibrated spectrum agree with the measured magnitudes to within 2%. When averaged over 100 calibrating objects randomly distributed over the focal plane, the residuals in magnitudes due to uncertain system response curves should be < 0.5% rms.

System Response

G-4 A goal of the survey is to achieve **R-10** at the enhanced level of 1% for the final co-added catalog.

G-5 A goal of the survey is to achieve **R-10** over 160 degrees of Right Ascension and 30 degrees of Declination.