



DARK ENERGY
SURVEY

Photometric Standards Module

Douglas L. Tucker
Munich Algorithms Meeting
22 April 2010



DARK ENERGY
SURVEY

Nightly Absolute Calibration

Standard Star Observation Strategy:

- Observe 3 standard star fields, each at a different airmass ($X=1-2$), between nautical (12°) and astronomical (18°) twilight (evening and morning).
- Observe up to 3 more standard fields (at various X 's) in the middle of the night
- There will also be serendipitous observations of standard stars from the PreCam Survey throughout the night (might partly obviate need for 1st two points above).
- Also can observe standard star fields when sky is photometric but seeing is too poor for science imaging (seeing > 1.1 arcsec)
- Use fields with multiple standard stars
- Keep an eye on the photometricity monitors

Nightly Absolute Calibration Strategy:

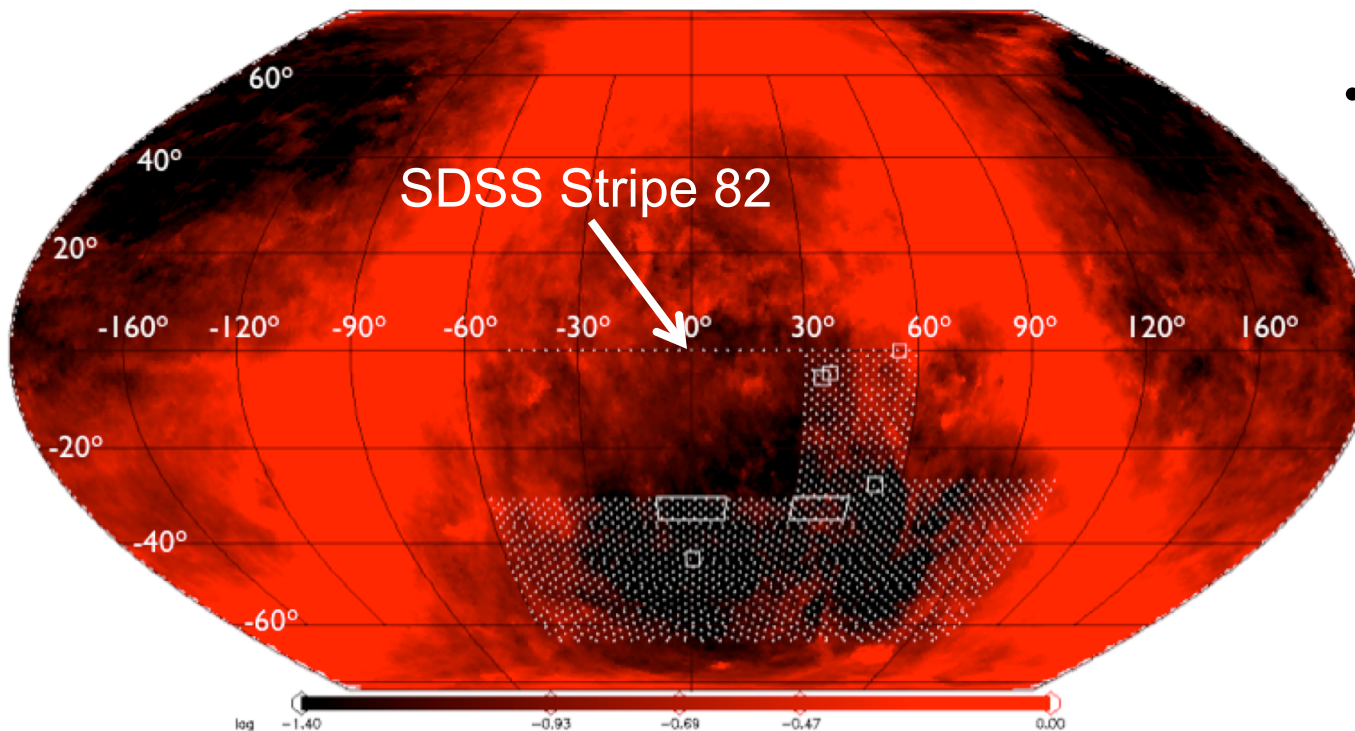
- Calibrate to the DES *grizy* “natural” system
- Use $u'g'r'i'z'$ and *ugriz* standards transformed to the DES *griz* “natural” system
 - SDSS $g'r'i'(z')$ and *gri(z)* are similar to DES *griz*, so transformations should be well behaved
 - July CTIO-1m run (DECam CCD + set of DES *grizy* filters) will be first measure of the transformations
- Create DES *y* band standards
 - July CTIO-1m run (DECam CCD + set of DES *grizy* filters)
 - PreCam Survey (Curtis-Schmidt + 2 DECam CCDs + set of DES *grizy* filters)



3. Nightly/Intermediate Calibrations: Standard Stars

DARK ENERGY
SURVEY

- **SDSS Stripe 82 Standards**
 - $\sim 10^6$ tertiary *ugriz* standards
 - $r = 14.5 - 21$
 - ~ 4000 per sq deg
 - See Ivezić et al. (2007)
- **Southern u'g'r'i'z' Standards**
 - ≈ 15 13.5'x13.5' fields in DES footprint
 - $r = 9 - 18$
 - Typically tens of stds. per field
 - http://www-star.fnal.gov/Southern_ugriz/



- **y-band Standards**
 - Under development
 - UKIDSS observations in Stripe 82
 - CTIO-1m
 - **PreCam observations**



Nightly Absolute Calibration: The Photometric Standards Module (PSM)

DARK ENERGY
SURVEY

- The PSM is basically a big least squares solver, fitting the observed magnitudes of a set of standard stars to their “true” magnitudes via a simple model (photometric equation); e.g.:

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

- m_{inst} is the instrumental magnitude, $m_{inst} = -2.5 \log(\text{counts/sec})$ (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:

$$m_{inst} - m_{std} = a_n + b_n \times (\text{stdColor} - \text{stdColor}_0) + kX \quad (2)$$

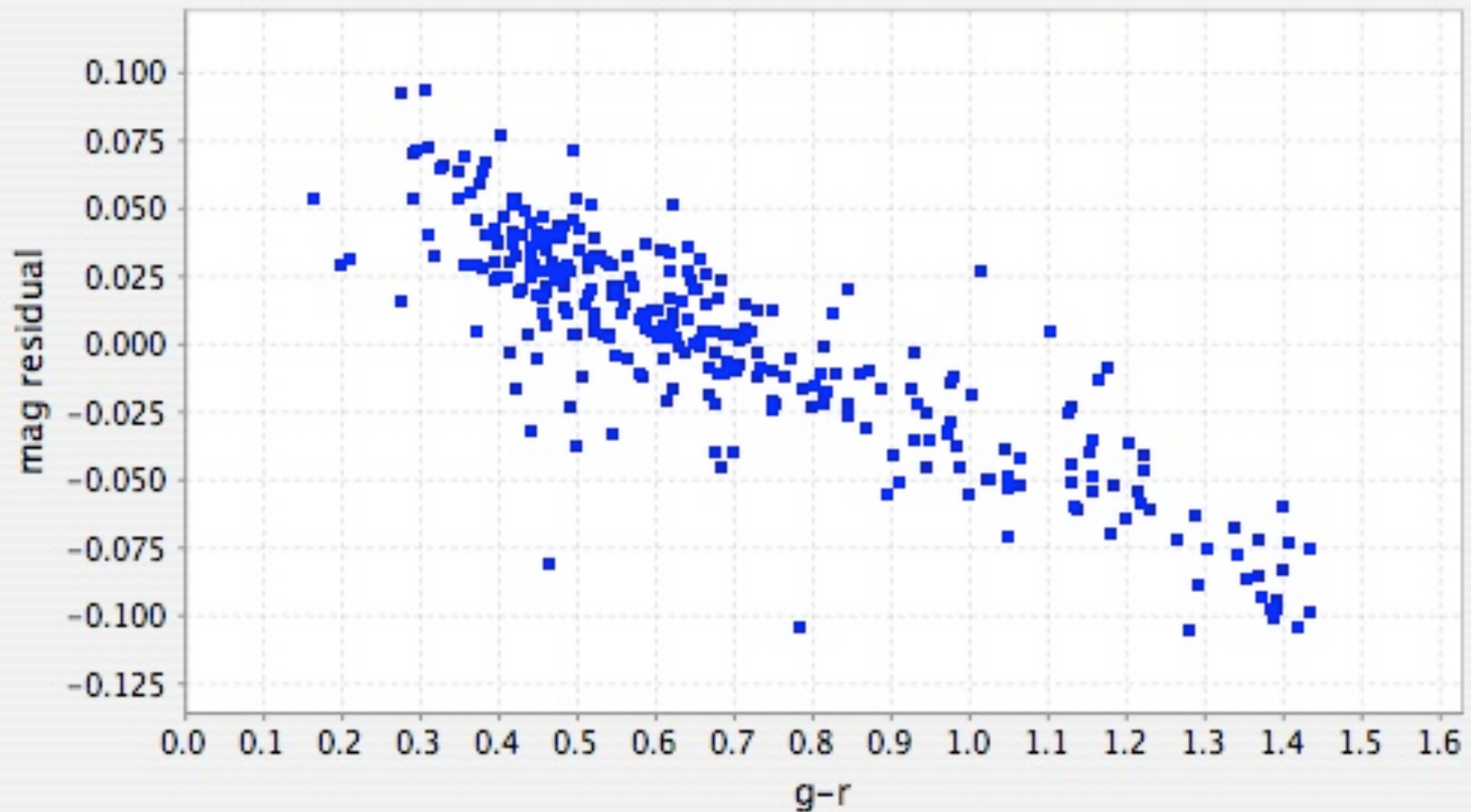
- b_n is the instrumental color term coefficient for CCD n ($n = 1-62$) (input/output)
- stdColor is a color index, e.g., $(g-r)$ (input)
- stdColor_0 is a constant (a fixed reference value for that passband) (input)
- DES calibrations will be in the DECam natural system
 - Even if SDSS Stripe 82 $ugriz$ and Smith et al. Southern $u'g'r'i'z'$ standards are “pre-transformed” to the DES system, eq. 2 is still useful for track changes in DECam instrumental response across the focal plane and over time



DARK ENERGY
SURVEY

Blanco Cosmology Survey, Fixing b 's to 0 (rms=0.041 mag, $\chi^2/\nu=4.24$)

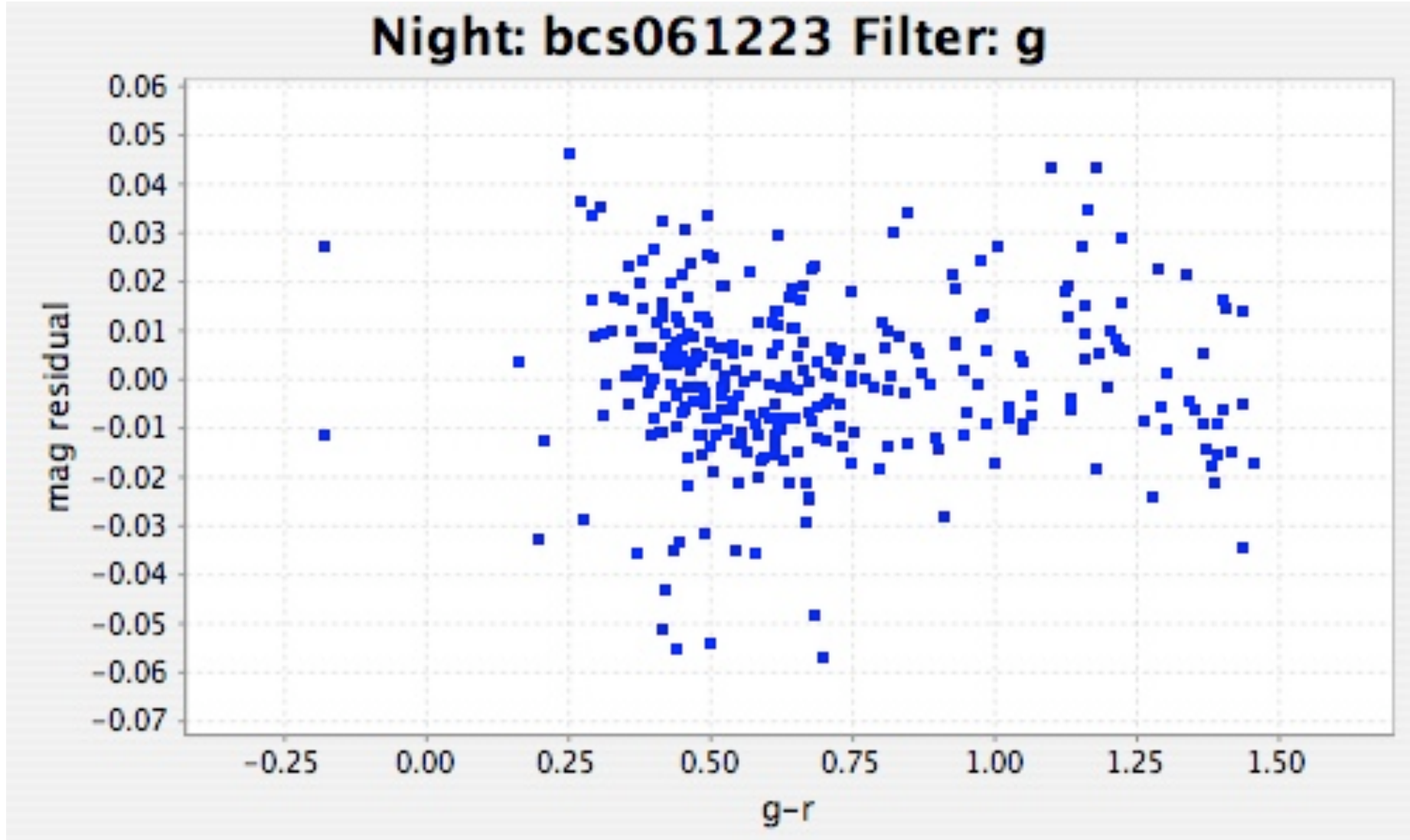
Night: bcs061223 Filter: g





Blanco Cosmology Survey, Solving for b 's (rms=0.017 mag, $\chi^2/\nu=0.74$)

DARK ENERGY
SURVEY





DARK ENERGY
SURVEY

Nightly Absolute Calibration: The Photometric Standards Module (PSM)

- Additional refinements suggested at the April 22 DES Calibrations Review:
 1. Add a quadratic instrumental color term for each CCD (" $b_{n,2}$ "), and
 2. Add a second-order extinction term (or "atmospheric color term") for each CCD (" c_n ")

$$m_{inst} - m_{std} = a_n + b_{n,1} \times (stdColor - stdColor_0) + b_{n,2} \times (stdColor - stdColor_0)^2 \\ + kX + c_n \times (stdColor - stdColor_0) \times X \quad (3)$$

- The quadratic instrumental color term should improve the measurement of the color terms (which need not be strictly linear).
- The second-order extinction will likely be mostly helpful for stars of extreme red or blue colors at high airmass ($X > 2$), and perhaps only in the bluer filter passbands.
- Could set PSM so that the $b_{n,2}$ and c_n coefficients could either be solved for or just fixed to a given value (even zero).

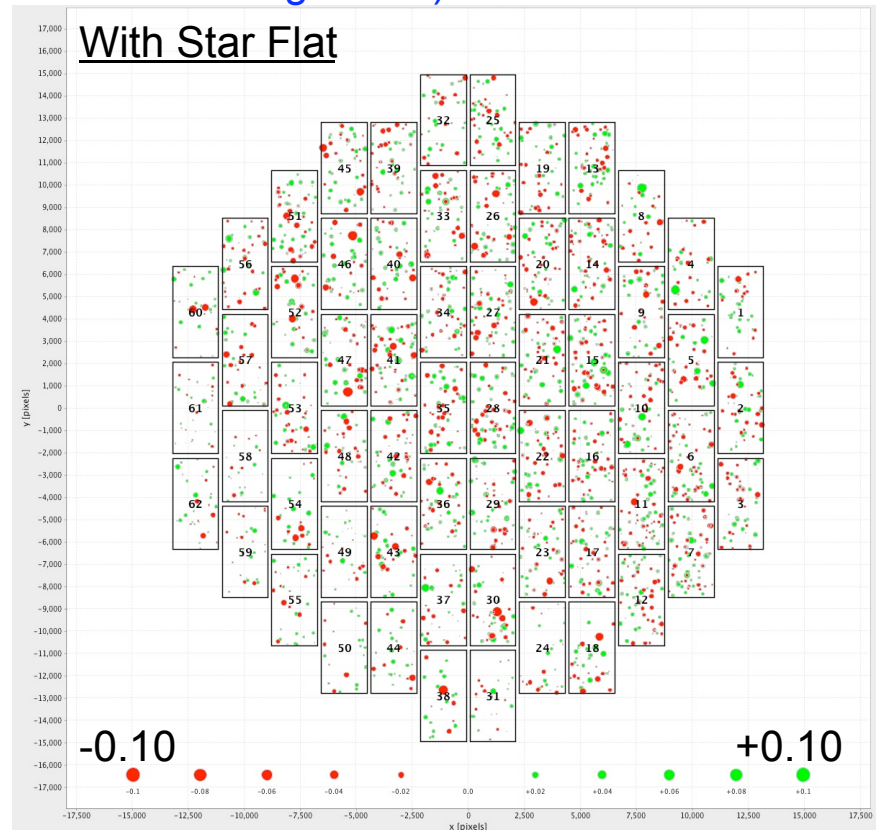
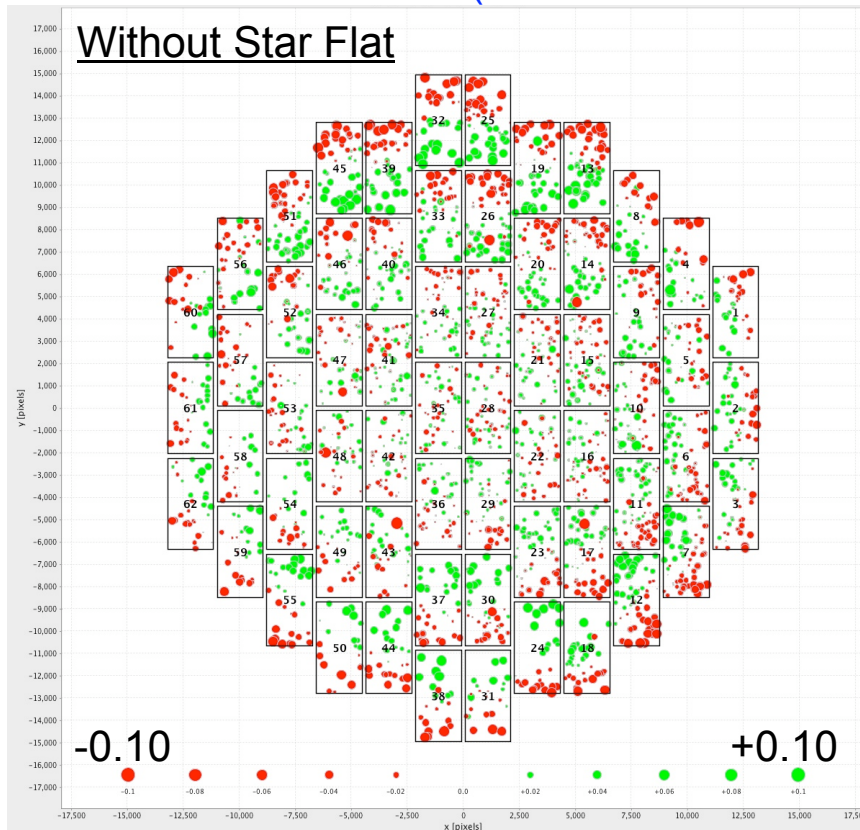


Nightly Absolute Calibration: PSM-StarFlat

DARK ENERGY
SURVEY

- An enhanced version of the PSM (“PSM-StarFlat”) is in development which can calculate radial flat-fielding errors based on nightly SDSS Stripe 82 observations.
- Currently, the radial flat-fielding errors are modeled using a 3rd-order polynomial.

Mag Residuals vs. Position on Focal Plane for Night 20091001, g filter
(with simulated 3rd-order radial flat-fielding errors)





DARK ENERGY
SURVEY

Extra Slides



DARK ENERGY
SURVEY

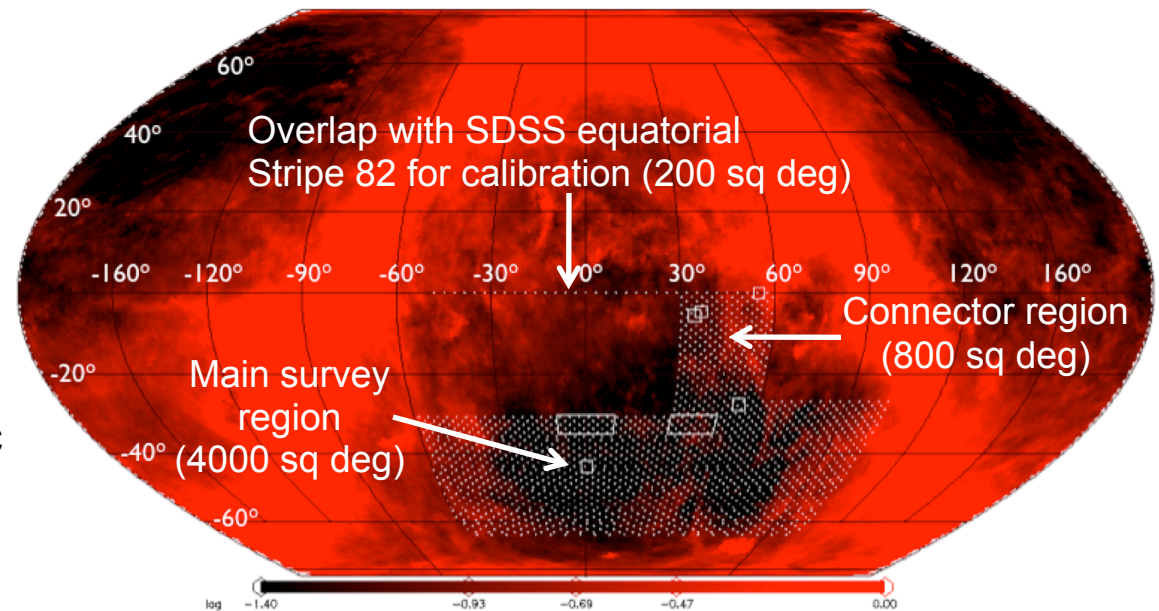
Basic DES Observing Strategy

Observing Strategy

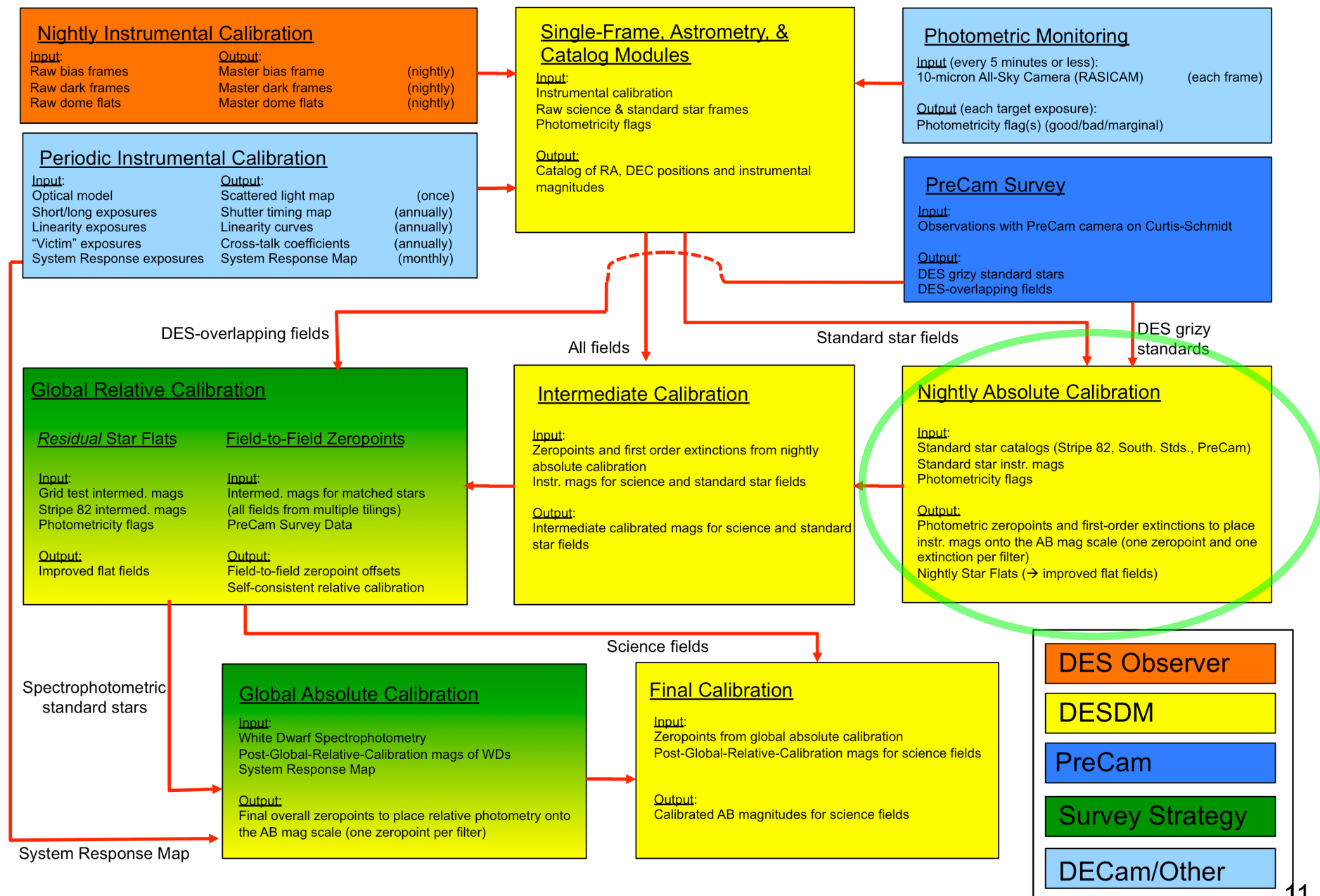
- 100 sec exposures (nominally)
- 2 filters per pointing (typically)
 - *gr* in dark time
 - *izy* in bright time
- Multiple overlapping tilings (layers) to optimize photometric calibrations
- 2 survey tilings/filter/year
- All-sky photometric accuracy
 - Requirement: 2%
 - Goal: 1%

Survey Area

Credit: J. Annis



Total Area: 5000 sq deg



DES Photometric Calibrations Flow Diagram (v4.1)

