DARK ENERGY SURVEY

PreCam Simulations

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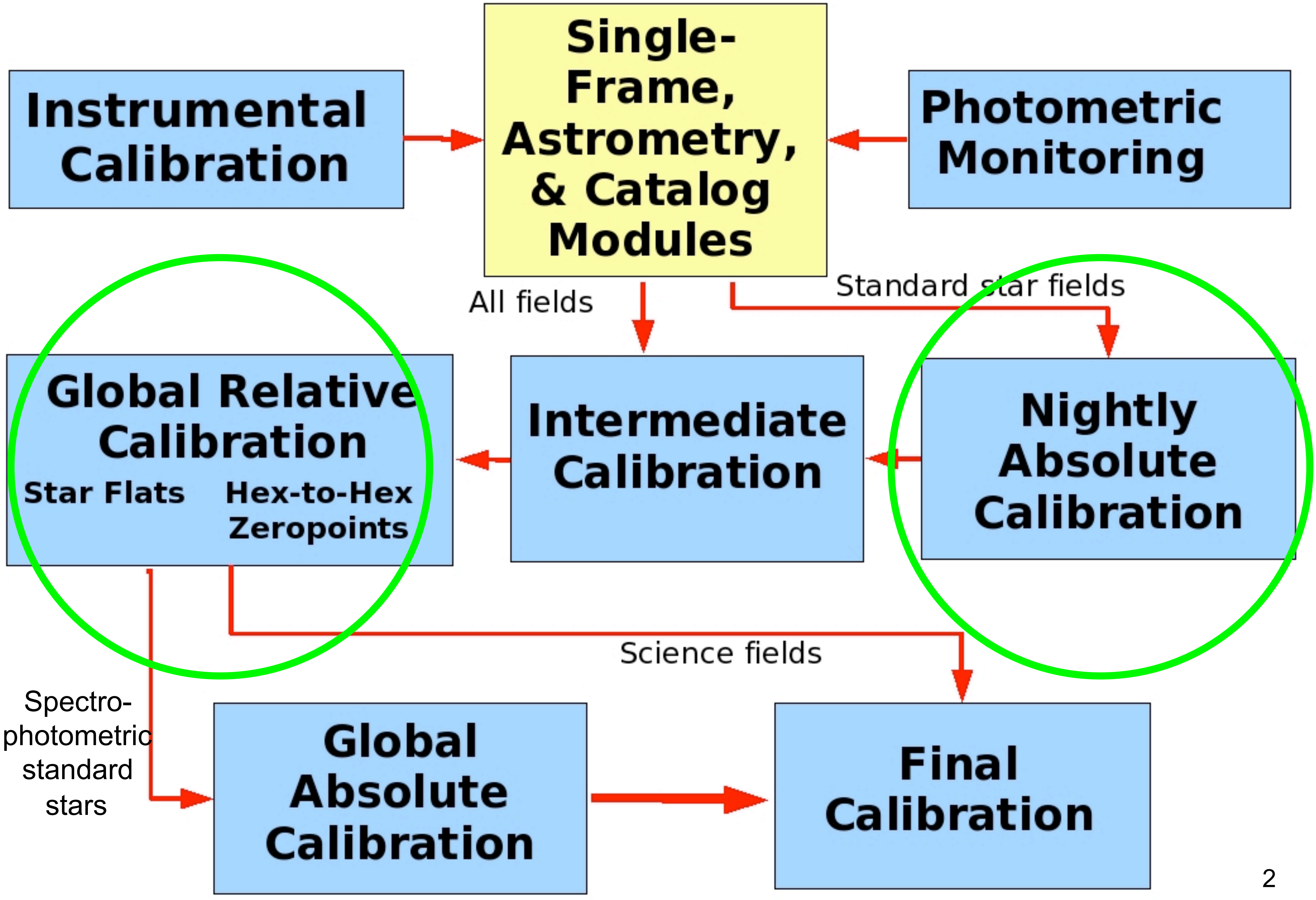
PreCam Workshop
17 September 2009

Outline:

1. PreCam and DES Calibrations
    a. Nightly Calibrations
    b. Global Relative Calibrations
2. PreCam Observing Strategy

DES Calibrations Flow Diagram (v2)



Ia. PreCam Benefits to DES Nightly Calibrations

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The baseline PreCam Survey -- a single-pass survey of the full DES footprint in all 5 DES filters down to $i \approx 18$ -- would yield a catalog of ~ 1 million bright stars calibrated in the DES *grizY* photometric system (typically hundreds per DECam exposure).

If the baseline PreCam Survey (Full Footprint Strategy) can achieve 2% global relative calibrations (do-able), the PreCam star catalog could:

1. Be used as extinction standards, supplementing the SDSS Stripe 82 standards and the Smith et al. Southern *u'g'r'i'z'* standards (could reduce the amount of time needed for observing standard stars during twilight and/or during middle of night)
2. Be used for a robust determination of the transformation relations between the SDSS and DES photometric systems
3. Be used as initial *Y*-band standards (see 1a)

If the baseline PreCam Survey (Full Footprint Strategy) can achieve 1% global relative calibrations (challenging), the PreCam star catalog could also could be used as local standards over the entire DES footprint.

A Test of Nightly Calibrations using the DES Survey Strategy Simulations

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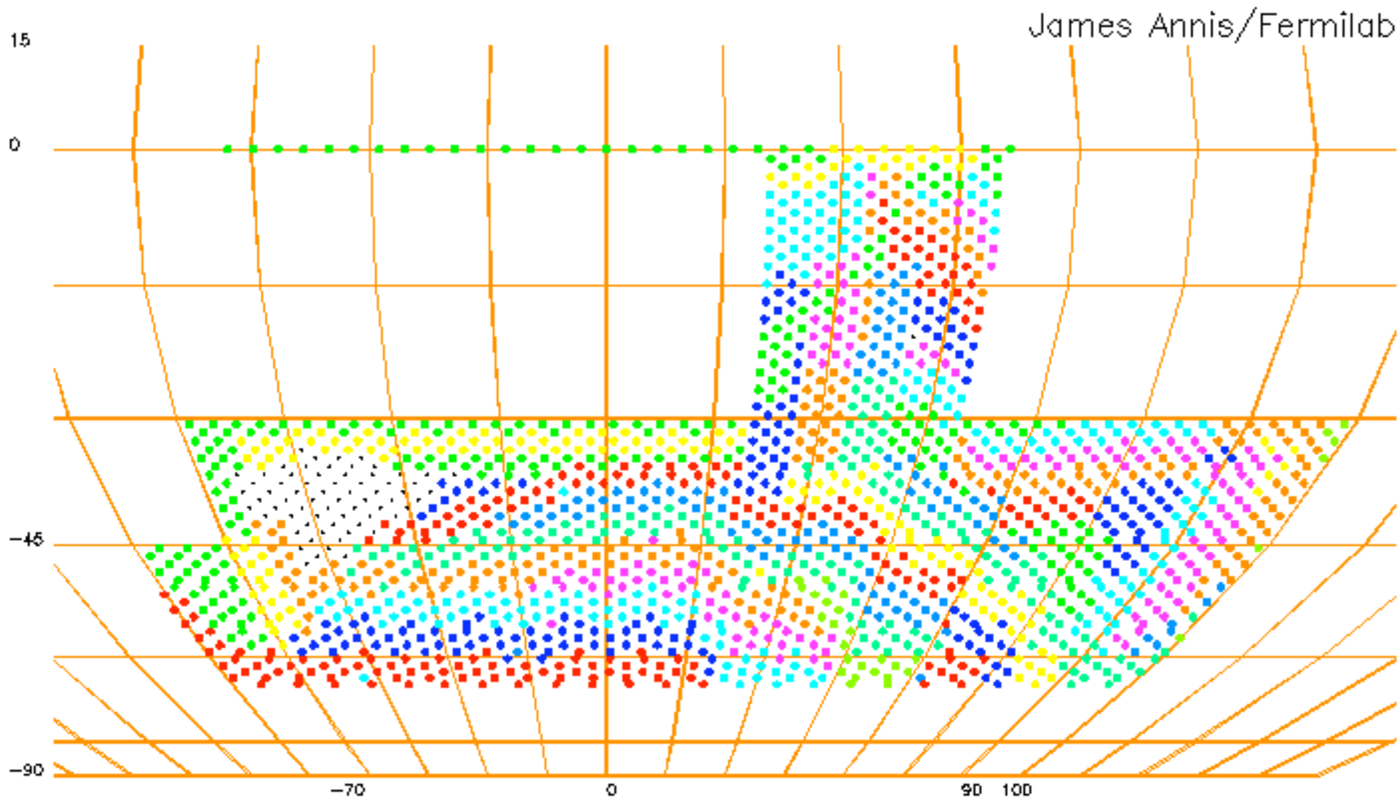
DES Simulation T1/A: tileMap-2012.gif



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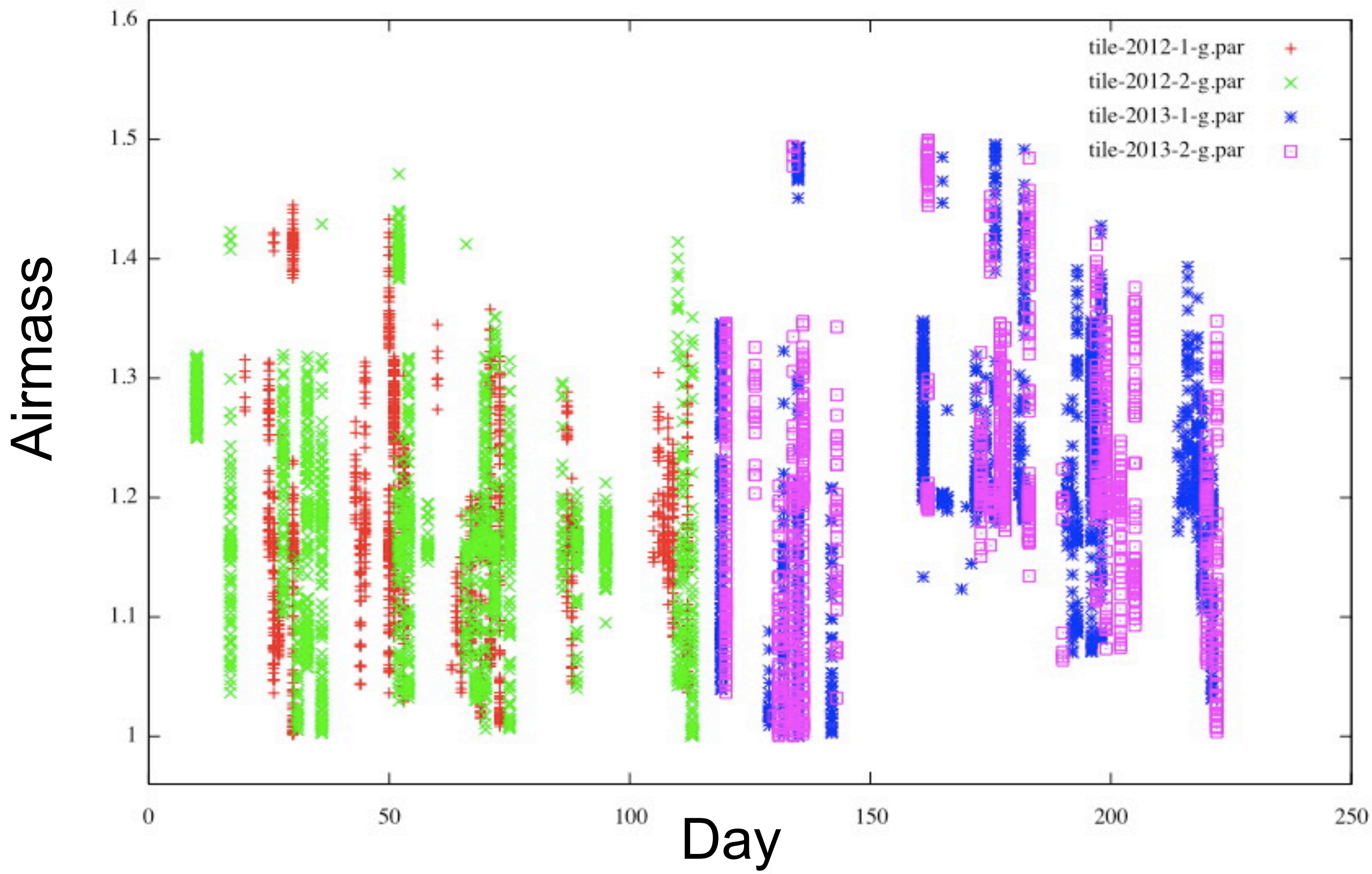
A Test of Nightly Calibrations using the DES Survey Strategy Simulations

Simulation T1/A (tileMap-2012): g-band



PreCam Extinction Study Simulations: Toy Model

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- Assume each PreCam field has a systematic calibration error
  - The accepted magnitudes of all stars in a given PreCam field are all offset by some amount
  - Assume that this calibration error is random and Gaussian, with σ=0.02mag

- Use the PreCam fields to fit a photometric equation of the form:

$$m_{inst} - m_{accepted} = a + k*X$$

where a = photometric zerpoint, k=first order extinction, X=airmass

- Fit the above photometric equation during a DES night using all airmasses *X* from for DES science exposures for that night as tabulated in Jim's simulations.

- Calculate and plot residuals

PreCam Extinction Study Simulations: Default (Stripe 82 alone, No PreCam)

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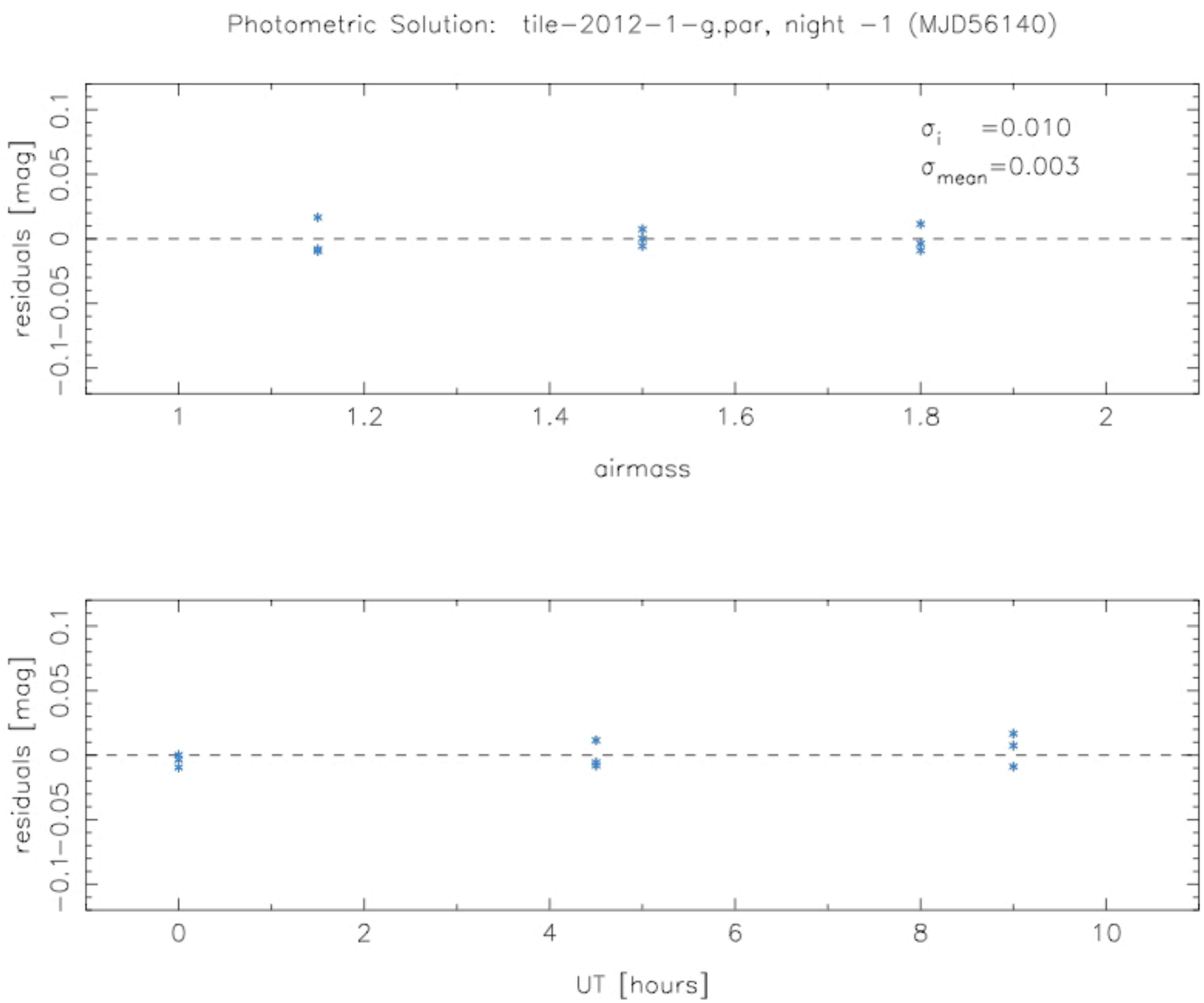
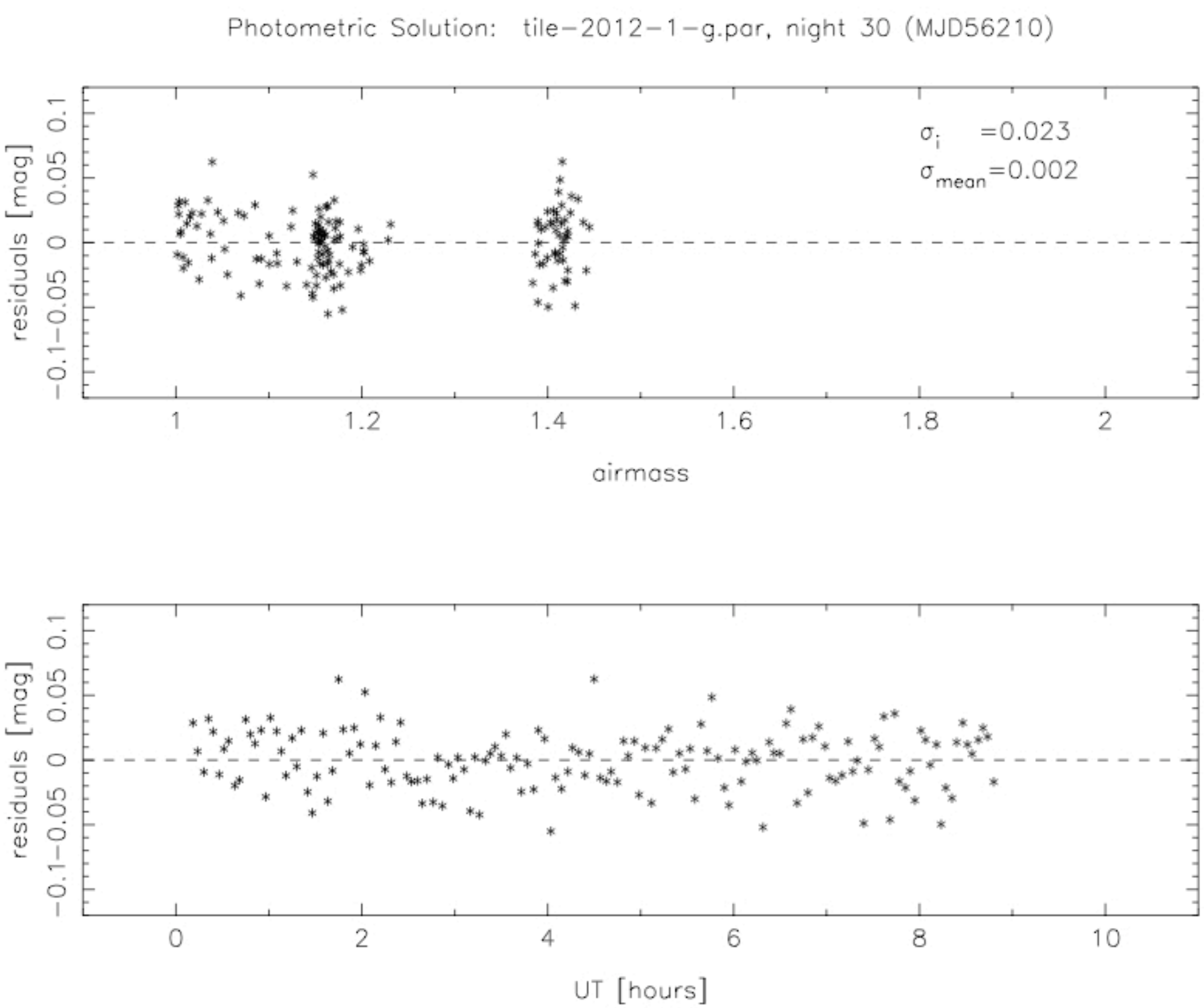
(Stripe 82 field-to-field errors ~ 0.01mag)



Observe Stripe 82 fields at 3 different airmasses at evening and morning twilight and once in the middle of the night

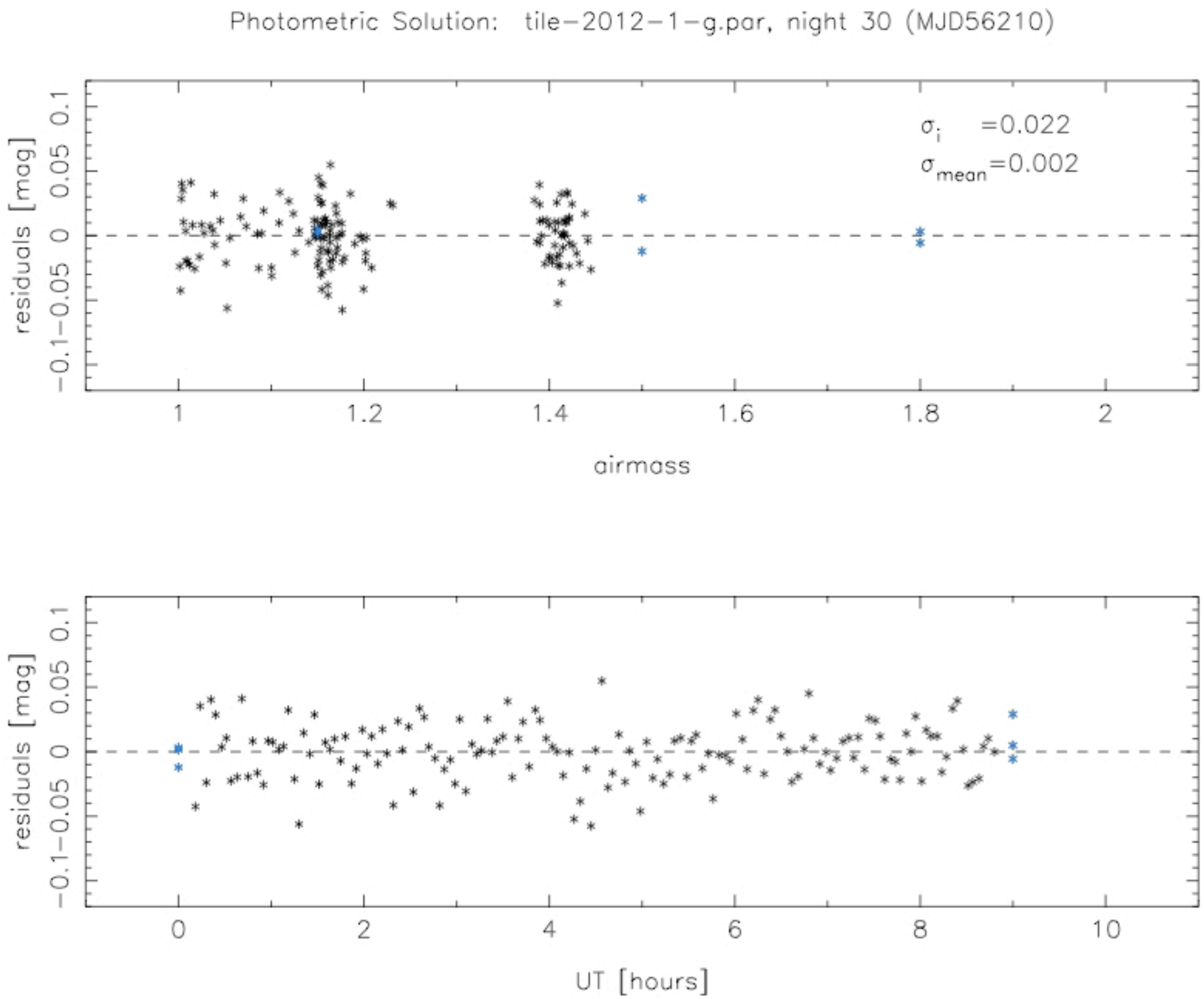
PreCam Extinction Study Simulations: PreCam (0.02mag Errors)



σ_{mean} gets better

Trends at 0.02 mag level become noticeable

PreCam Extinction Study Simulations: PreCam (0.02mag Errors) + Stripe 82



σ_{mean} gets even better

1b. PreCam Benefits to DES Global Relative Calibrations

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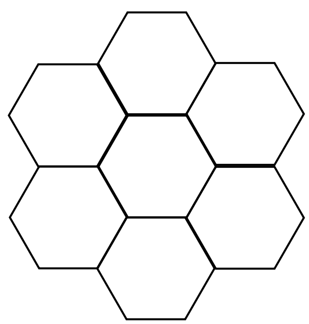
- Both the PreCam Full Footprint Strategy and the PreCam Rib & Keel Strategy can be used in Global Relative Calibrations. They provide additional information that could be especially useful after the first year of DES operations (when DES has only done 2 tilings of the survey area in each filter).

- The PreCam Full Footprint Strategy effectively provides another tiling useful for calibration.

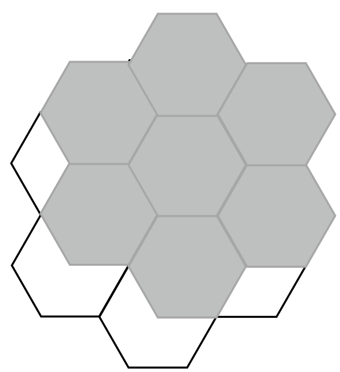
- The PreCam Rib & Keel Strategy provides a rigid framework upon which to tie the calibrations of the DES.

Example of PreCam Full Footprint Strategy + First Year of DES

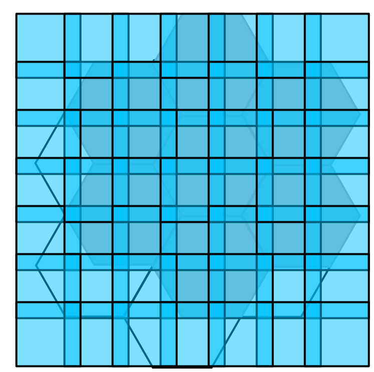
1 tiling



2 tilings



2 tilings + PreCam



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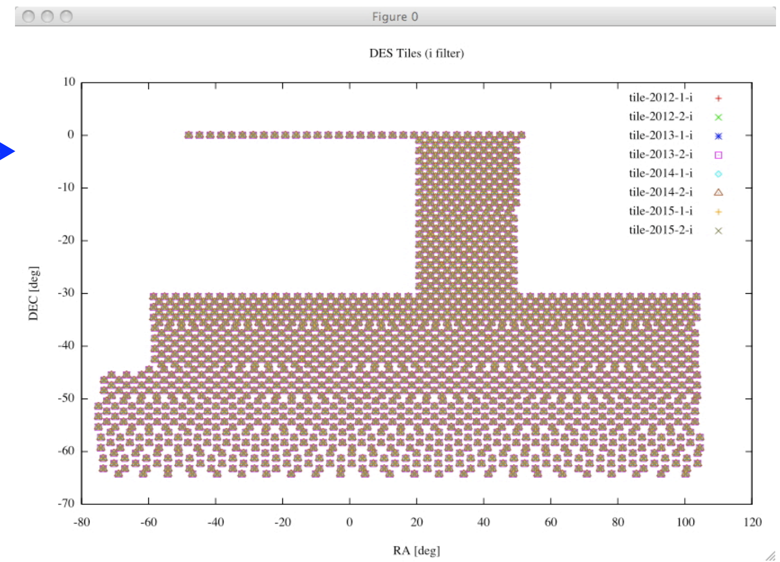
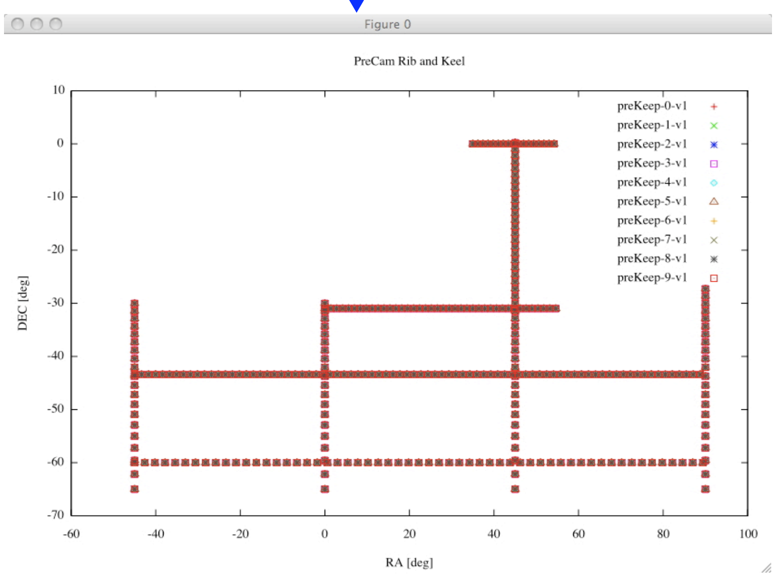
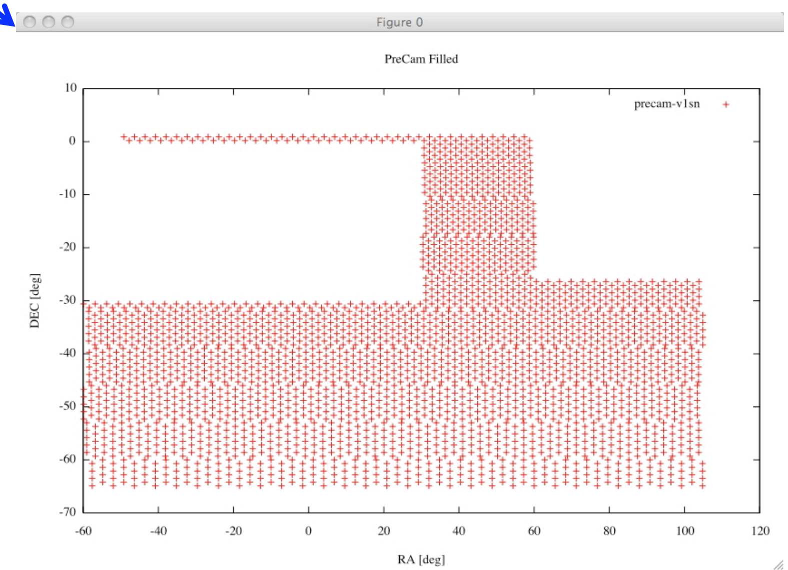
Global Calibrations Test Case

Jim Annis has simulated:

- a realization of the DES
- a realization of the PreCam Full Footprint
- a realization of the PreCam Rib & Keel







Global Calibrations Toy Model

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- Assume 75% of nights are photometric and 25% are non-photometric.
- For photometric nights, randomly assign a PreCam pointing/DECam hex a photometric zeropoint such that <ZP> = 0.00mag with σ = 0.02mag
- For non-photometric nights, randomly assign a PreCam pointing/DECam hex a photometric zeropoint such that <ZP> = +0.25mag with σ = 0.10mag
- Apply an irreducible-but-random center-to-edge flat-fielding error of
  - 1% rms for PreCam pointings
  - 0.6% rms for DES hexes
- Throw the PreCam + DES 1st Year data into the DESDM Global Calibrations Zeropoint Solver to find the optimal zeropoint offsets to apply to both the PreCam pointings and the DES 1st year hexes.
  - Do this for PreCam Full Footprint + DES 1st Year data
  - Do this for PreCam Rib & Keel + DES 1st Year data
  - See which strategy does better.

Global Calibrations Toy Model Results

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- Just ran tests on Tuesday.
- Not quite ready to believe results.
- *Appears* that both PreCam strategies yield similar results, with the resulting DES hexes calibrated to ~1% rms.
- Need to make the simulations more realistic.
  - Currently just make do with pointings/hexes
  - Should simulate at the star catalog level.

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Extra Slides

PreCam Extinction Study Simulations: Toy Model

- $m_{inst} - m_{true} = a + k*X$
- Assume fixed values for a, k, and m_{true}
- Assume the values for m_{true} have Gaussian errors (due to PreCam field-to-field systematics) of
  - 0.05 mag (easy)
  - 0.02 mag (do-able)
  - 0.01 mag (challenging)
- Calculate m_{inst}, assuming zero measurement errors (due to beating down the statistical errors due to the 100's of stars per DECam chip)
- Do above for all airmasses X from a night as tabulated in Jim's simulations.
- Fit for a and k
- Calculate residuals

Global Calibration Module: Two Main Functions

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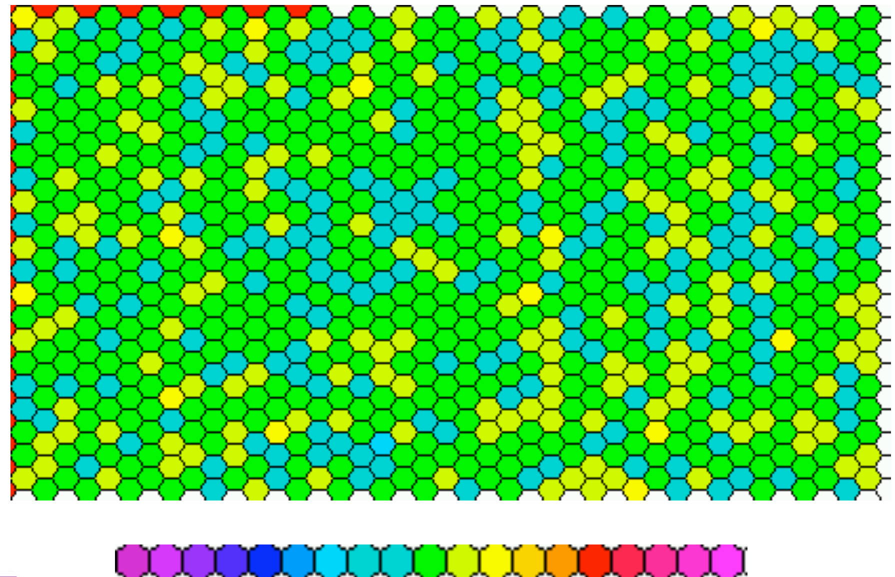
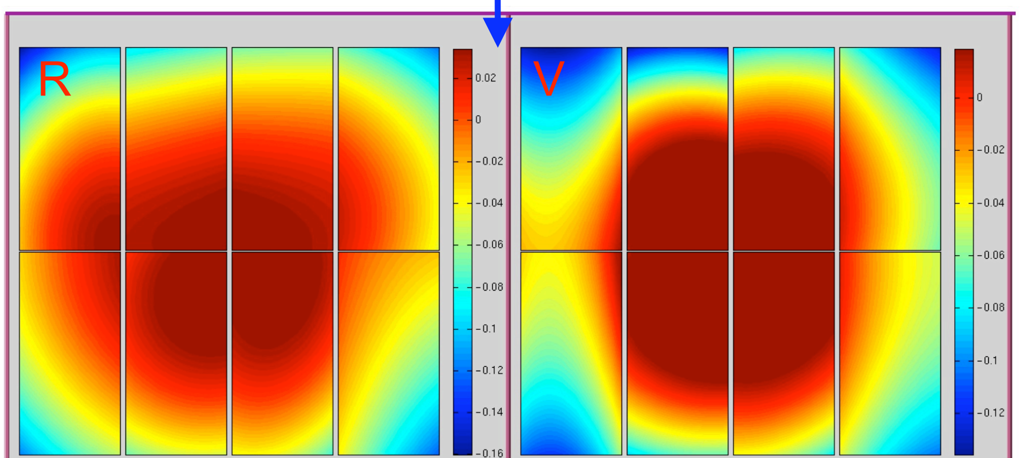
The GCM has two main functions:

1. Remove field-to-field zeropoint offsets to achieve a uniformly “flat” all-sky relative calibration of the full DES survey.

2. Calculate “star flats” to remove any lingering effects of vignetting and stray light in the object photometry.



scaling bar is –0.20 mags to +0.20 mags



Koch et al. 2004, ESO WFI star flats based on SDSS Stripe 82

Currently, these two functions are split into two separate sub-modules, although they could be combined in the future.

The zeropoint solver has been built and is being tested. The star flat solver is under development.

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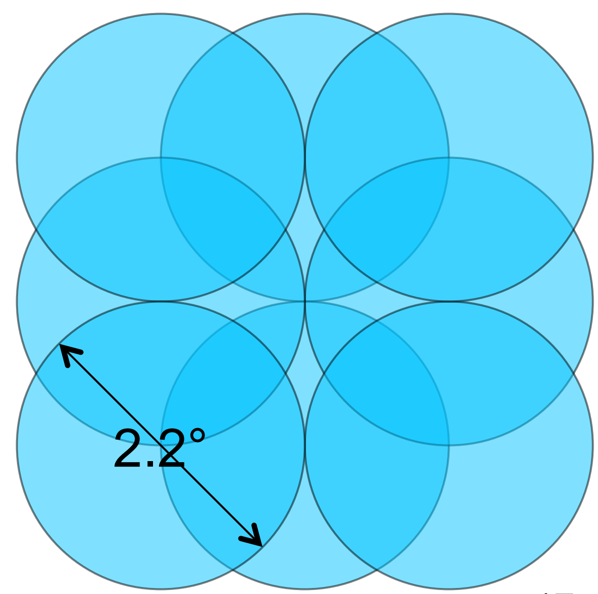
3. Global Relative Calibrations: The Code + A Simple Test Case

Global Calibrations Module Zeropoint Solver Code

- One of the DESDM Astronomy Modules, written in Java, uses cern.colt.matrix
- **Input:** An ASCII table of all unique star matches in the overlap regions
- **Output:** The ZP offsets to be applied to each field and the rms of the solution

Simple Test Case

- 38,000 stars randomly spread over 3800 sq deg
- 4500 overlapping 2.2°-diameter circular fields in 5 tilings
  - 70% photometric (ZP = 0.00 +/- 0.02 mag (rms))
  - 30% non-photometric (ZP = 0.25 +/- 0.50 mag (rms))
- **Tie relative calibrations to a single reference field:**
  - **Run time on 2.8 GHz MacBook Pro: 728 sec (685 sec for the 4500x4500 matrix inversion)**
  - **RMS of solution: 0.008 mag (0.8%)**



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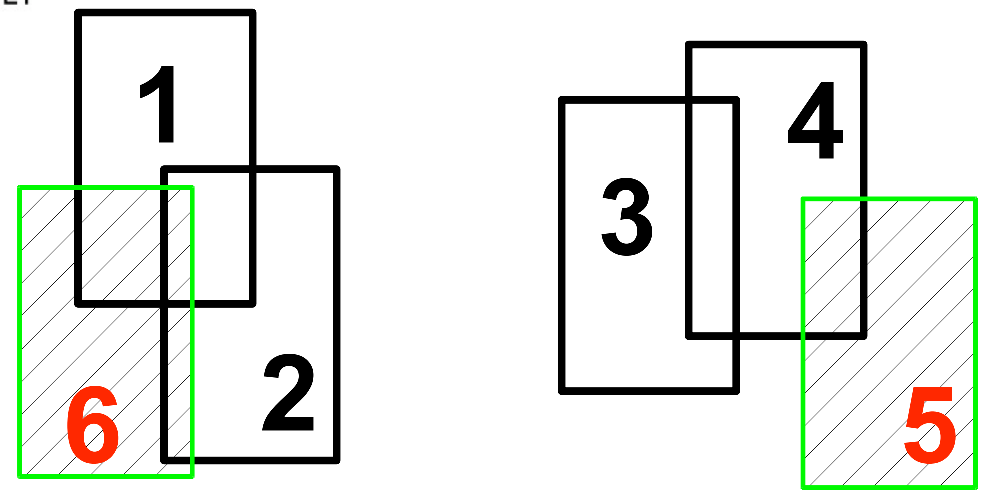
Field-to-Field Zeropoints
The Algorithm (I)



A Generic Example:
Frames 5 & 6 are calibrated.
The others are uncalibrated.

- Method used by Oxford-Dartmouth Thirty Degree Survey (MacDonald et al. 2004)
- Developed by Glazebrook et al. (1994) for an imaging K-band survey

- Consider n frames, of which (1, …, m) are calibrated and (m+1,…,n) are uncalibrated.
- Let $\Delta_{ij} = \langle mag_i - mag_j \rangle_{pairs}$ (note $\Delta_{ij} = -\Delta_{ji}$).
- Let ZP_i be the floating zero-point of frame i, but fixing $ZP_i = 0$ if $i > m$.
- Let $\theta_{ij} = 1$ if frames i and j overlap or if $i = j$; otherwise let $\theta_{ij} = 0$.
- Minimize $S = \Sigma\Sigma\, \theta_{ij} (\Delta_{ij} + ZP_i - ZP_j)^2$

Field-to-Field Zeropoints: The Algorithm (II)

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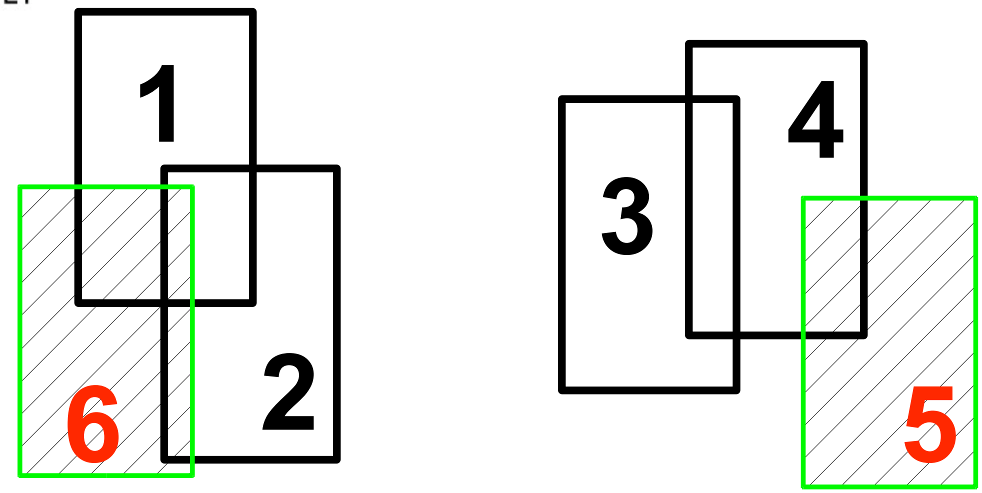

Example:
Frames 5 & 6 are calibrated.
The others are uncalibrated.
(From Glazebrook et al. 1994)

$$\begin{vmatrix} -2 & 1 & 0 & 0 & 0 & 1 \\ 1 & -2 & 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & 1 & -2 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{vmatrix} \times \begin{vmatrix} ZP1 \\ ZP2 \\ ZP3 \\ ZP4 \\ ZP5 \\ ZP6 \end{vmatrix} = \begin{vmatrix} \Delta_{12} + \Delta_{16} \\ \Delta_{21} + \Delta_{26} \\ \Delta_{34} \\ \Delta_{43} + \Delta_{45} \\ 0 \\ 0 \end{vmatrix}$$

Figure 0

GCM and the DC4 Coadd (of 18 Dec 2008)