DARK ENERGY
SURVEY

Y1A1 Calibrations

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DES Chicagoland Meeting
23 February 2015

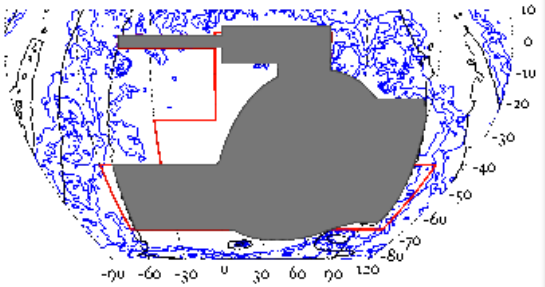
DES Photometric Calibration Requirements (5-year, coadded)

DARK ENERGY SURVEY

1. **Relative:** 2% rms on scales of 0.05° - 4°.

   Goals: 1% rms and/or over 160° in RA, 30° in DEC.

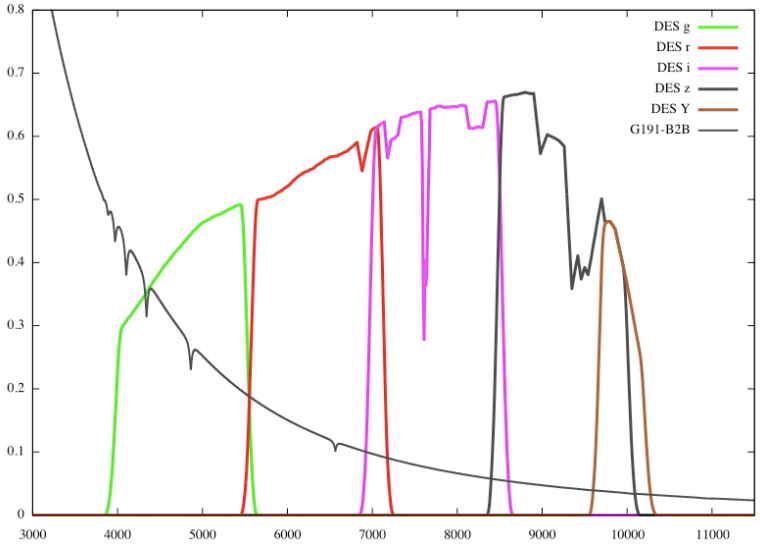
   (We will focus mostly on this req. in this talk.)



2. **Absolute Color:** 0.5% (*g-r, r-i, i-z*); 1% (*z-Y*).

   Averaged over 100 objects scattered over the focal plane.

   "Between-filters" calibration.



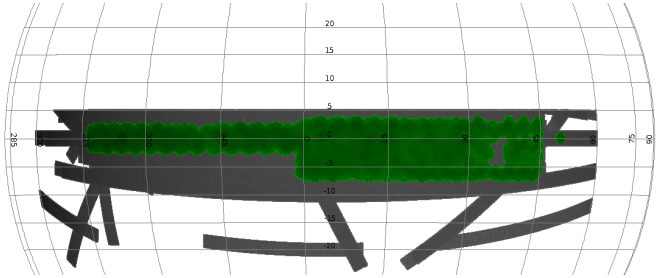
3. **Absolute Flux:** 0.5% in *i*-band.

   Relative to standard star BD+17 4708.

   Zeropointing the overall filter system.

DARK ENERGY SURVEY

Stripe 82 Equatorial Area for Y1A1

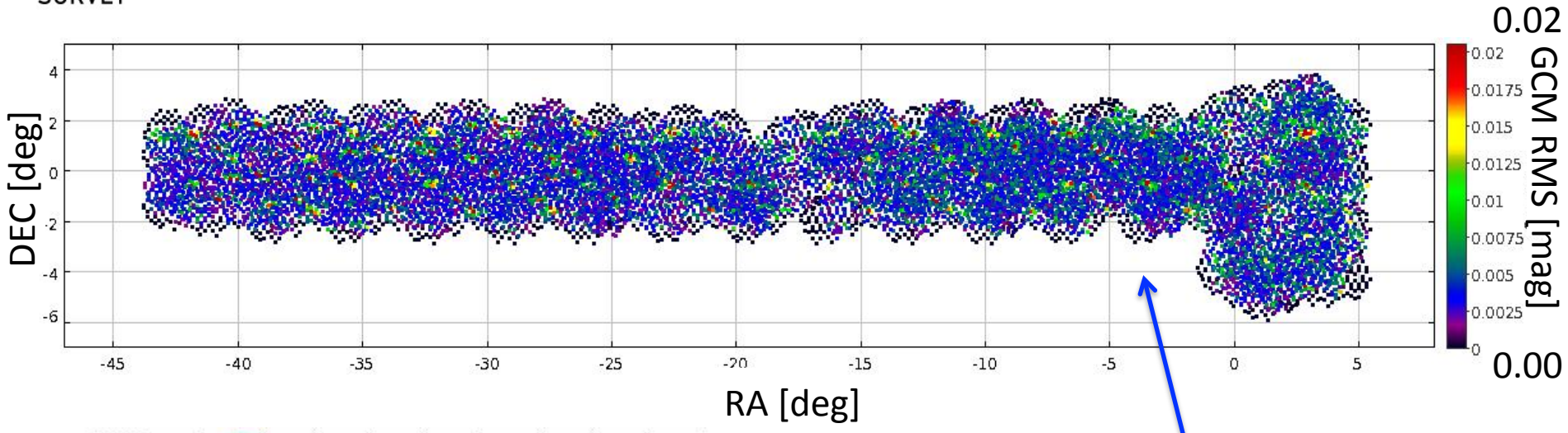


- ***Essentially complete overlap with SDSS DR10.***
- → "Punted" and just used SDSS DR10 (transformed into the DES AB mag system) as local tertiary standards.
- Performed a single-pass Global Calibration Module (GCM)* solution, solving for photometric zeropoints on a CCD image by CCD image basis.

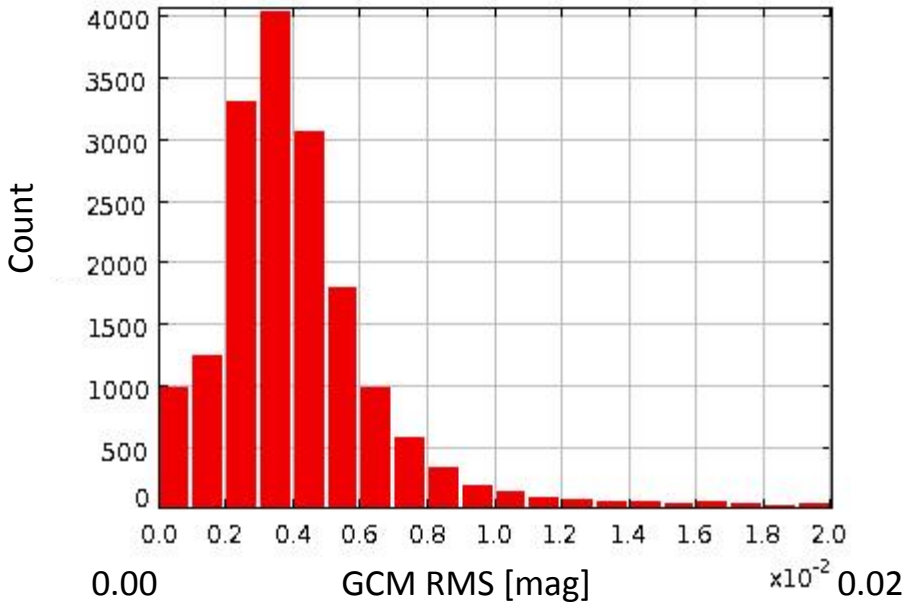
*GCM, as with most current global calibration methods, uses the overlaps between images to estimate the photometric zeropoints for individual images.

Y1A1 Equatorial Area: g-band GCM RMS's (internal errors)

DARK ENERGY SURVEY



Each "point" is an Individual CCD image



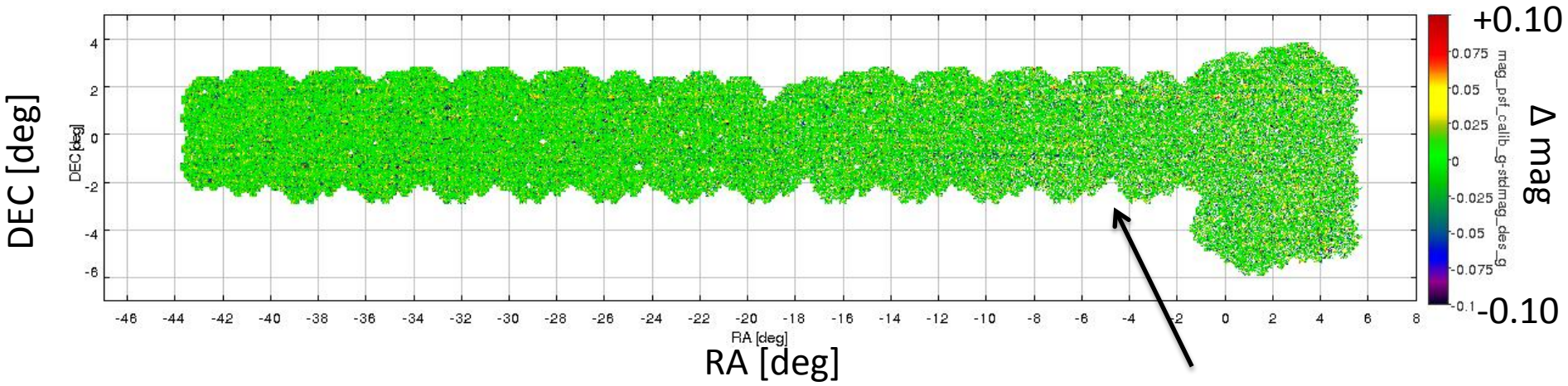
RMS of overall solution: 0.0055 mag (0.55%)

← (Note that the x-axis is in units of 0.01 mag)

Y1A1 Equatorial Area: Cross-Check for Systematic Errors

DARK ENERGY SURVEY

GCM-calibrated mag_psf minus stdmag* vs. (RA,DEC):
g-band



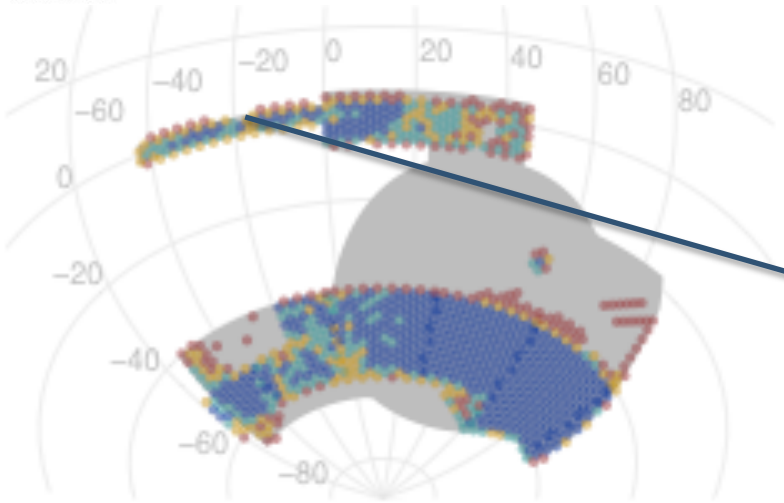
Each point is an individual star

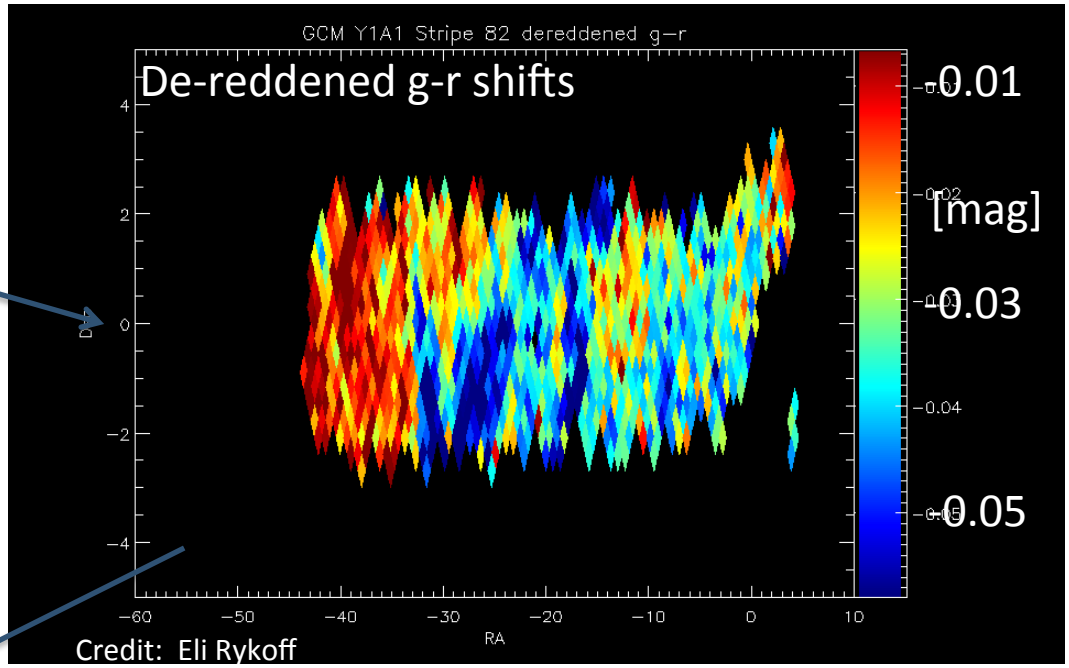
RMS of Δmag: <0.02mag (<2%)

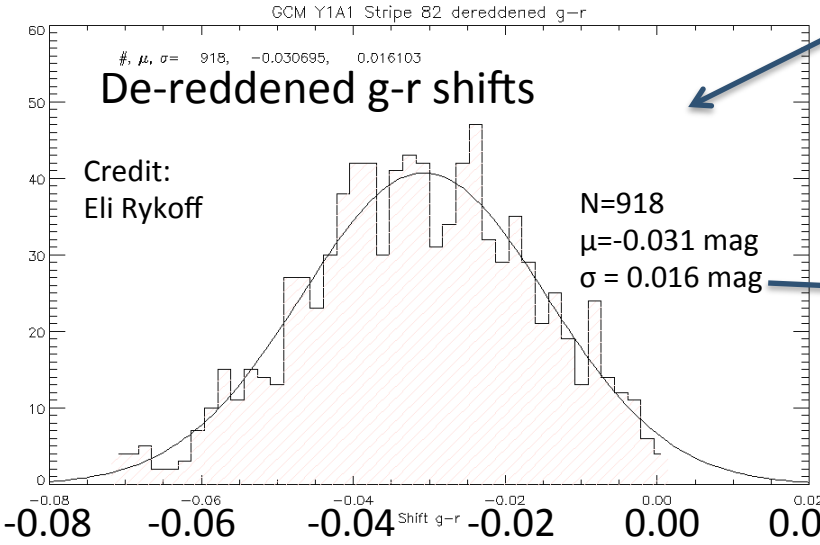
*stdmag = SDSS DR10 mag transformed to DES AB mag

Eli Rykoff's SLR Results for GCM: Stripe 82

DARK ENERGY SURVEY







Year 1 Relative Calibrations

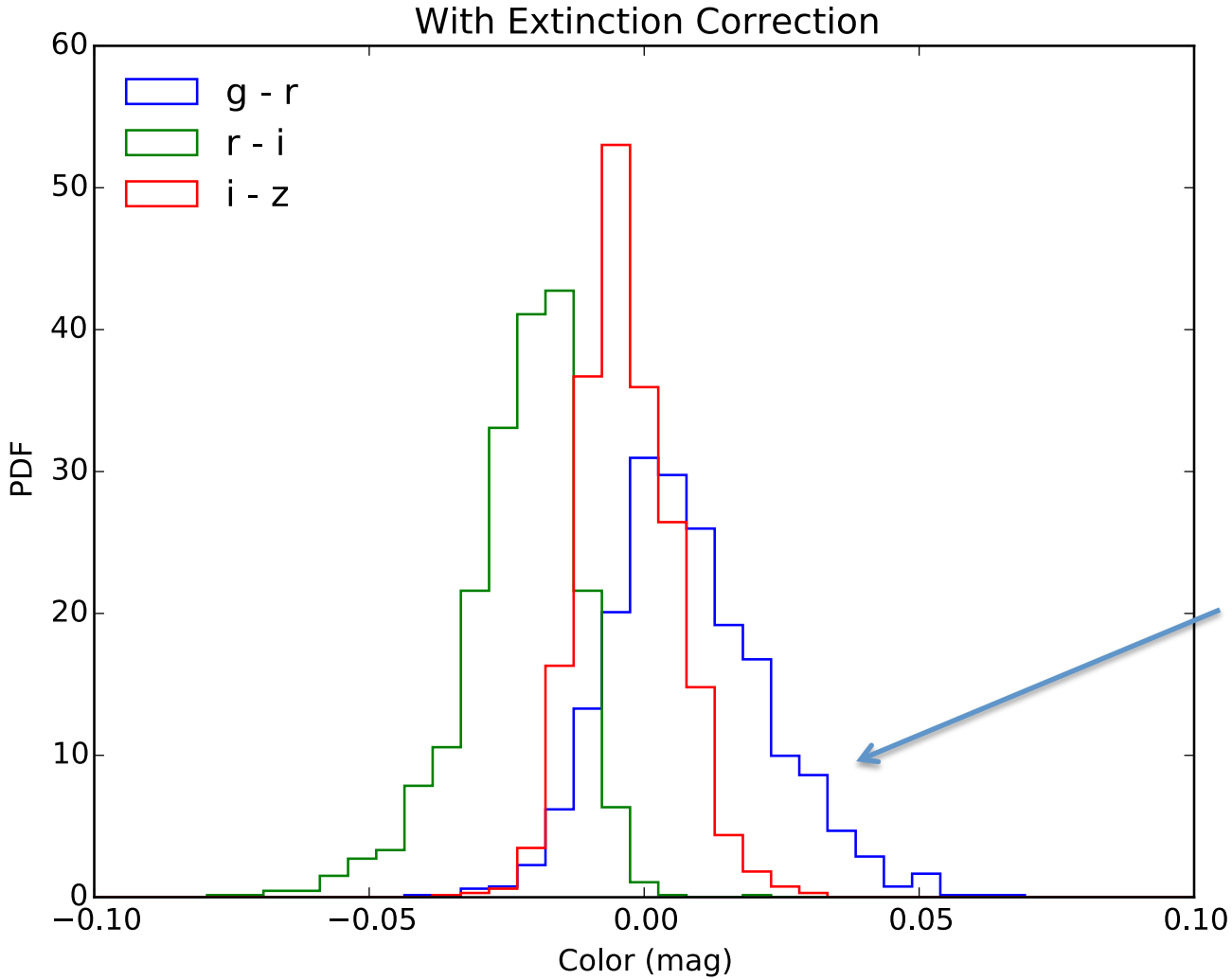
- g-r: 0.016 mag rms
- r-i: 0.010 mag rms
- i-z: 0.007 mag rms

(DES Sussex 2014 Meeting)

Keith Becthol's SLR Results for GCM: Stripe 82

(From Antarctica!)

DARK ENERGY SURVEY



Stars were binned in a NSIDE = 128 HEALPix grid, which is equivalent to a bin size of

- an area of ~ 0.21 sq deg
- a box ~ 27.5 arcmin on a side.

Offsets from Color=0.00 indicative of our current understanding of:

- the DES stellar locus
- Milky Way dust
- DES absolute calibrations

SPT Area for Y1A1

- Not much overlap with previously calibrated grizY standards stars
- Needed to create local tertiary standards* from PSM solutions or from other sources.
- Calibrated SPTE in two steps:

1. Calibrated photometric exposures on an exposure-by-exposure basis, tossing out dome occluded/non-photometric exposures iteratively, and tying to the local tertiary standards, creating a set of “quaternary standards” spanning nearly the full SPT footprint in RA,DEC.
2. Calibrated all SPT data (non-photometric/dome-occluded exposures as well as photometric exposures) on a CCD image by CCD image basis by tying to quaternary standards from Step 1.

(*Thanks to Sam Wyatt for creating these tertiaries!)

Y1A1 SPT Area:
Tertiary Standards (Main & Supplementary)

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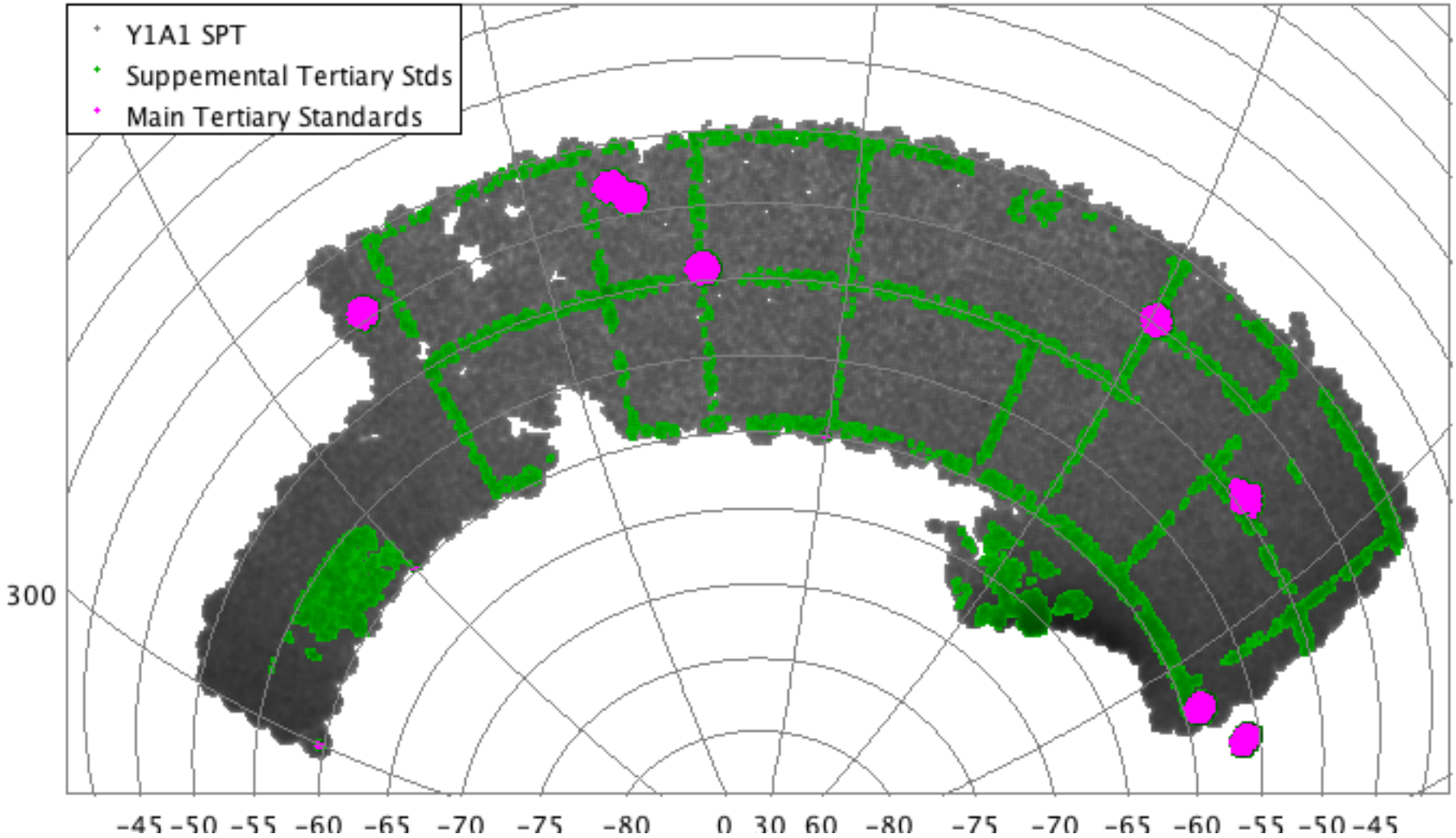
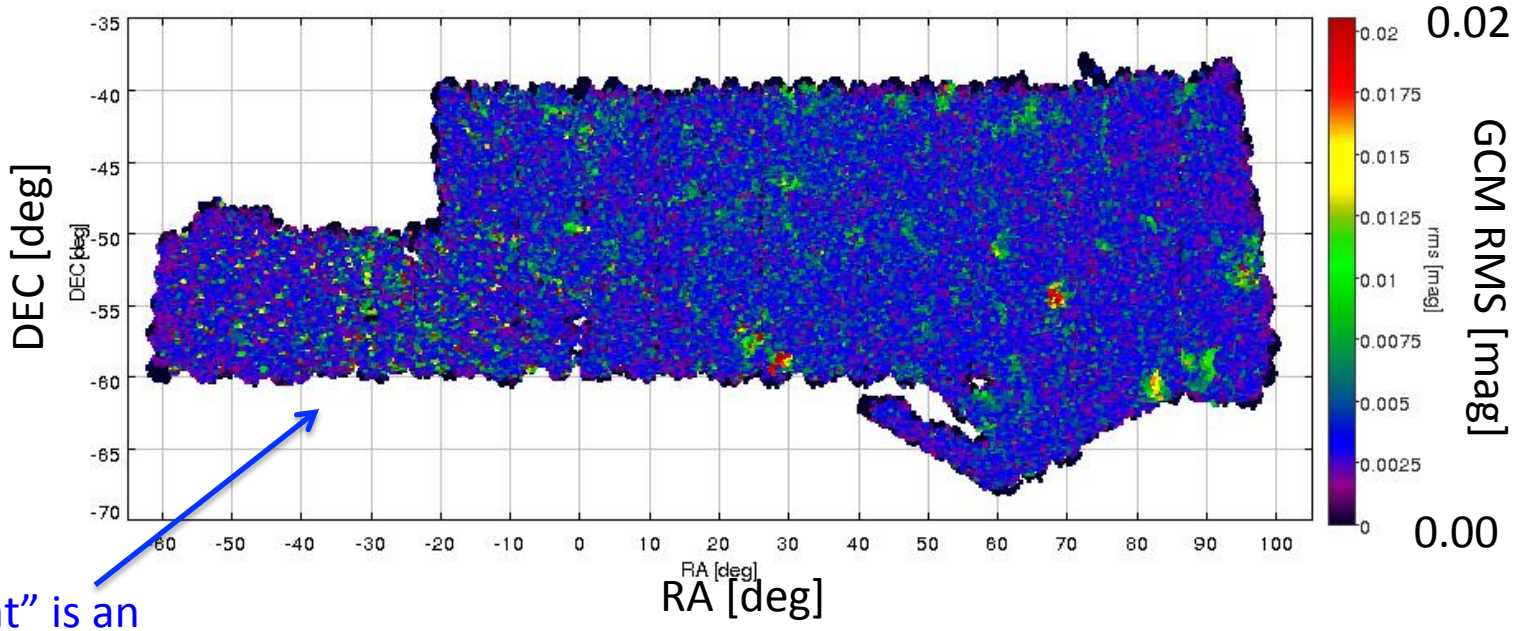
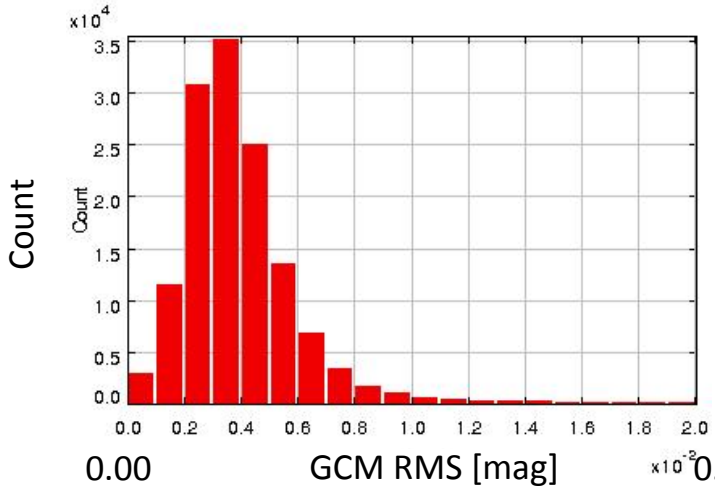


Y1A1 SPT Area: g-band GCM RMS's (internal errors)

DARK ENERGY SURVEY



Each "point" is an individual CCD image

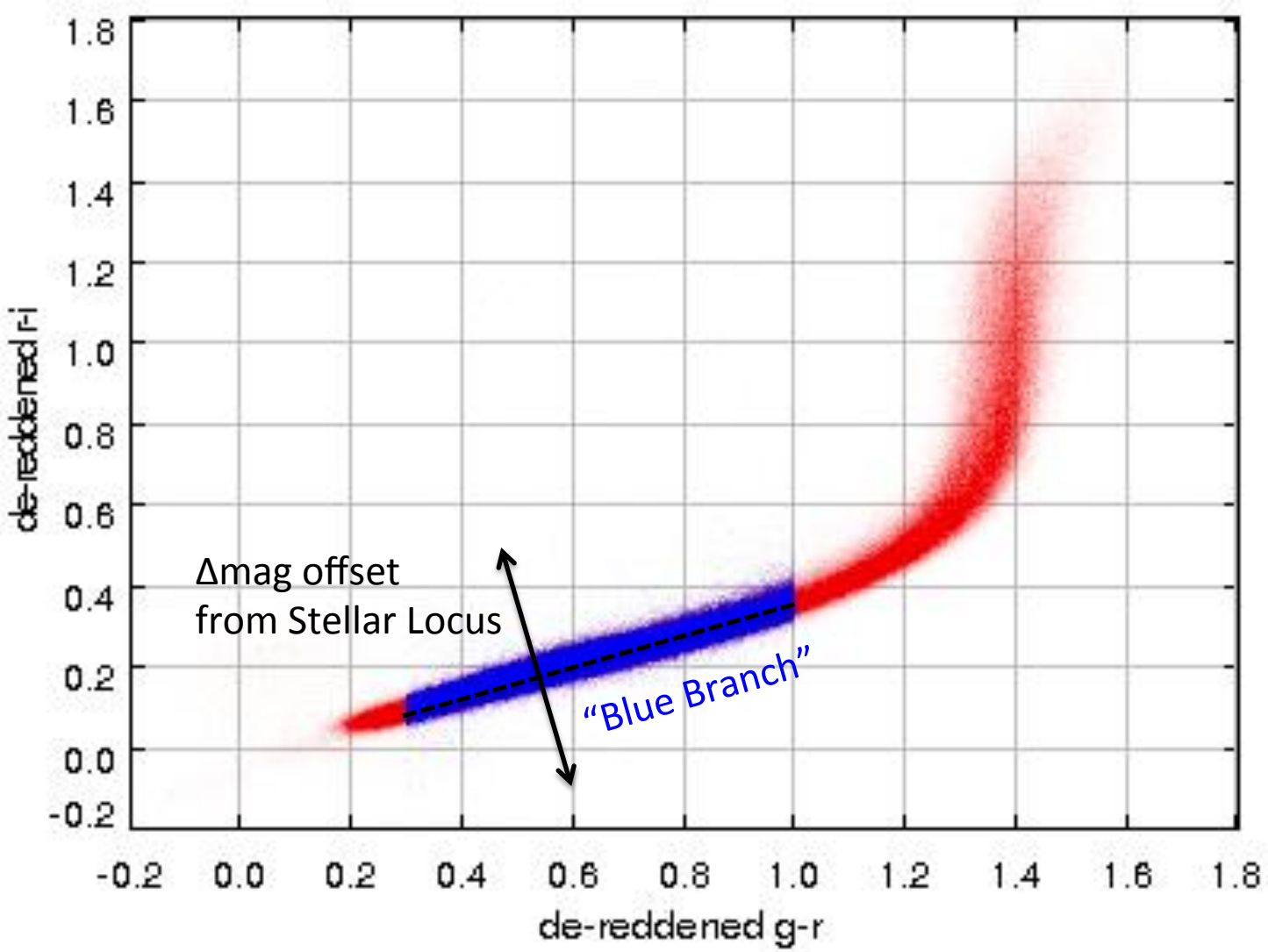


RMS of overall solution: c. 0.005 mag (0.5%)

(Note that the x-axis is in units of 0.01 mag)

Y1A1 SPT Area: External Check using a "Poor Man's SLR"

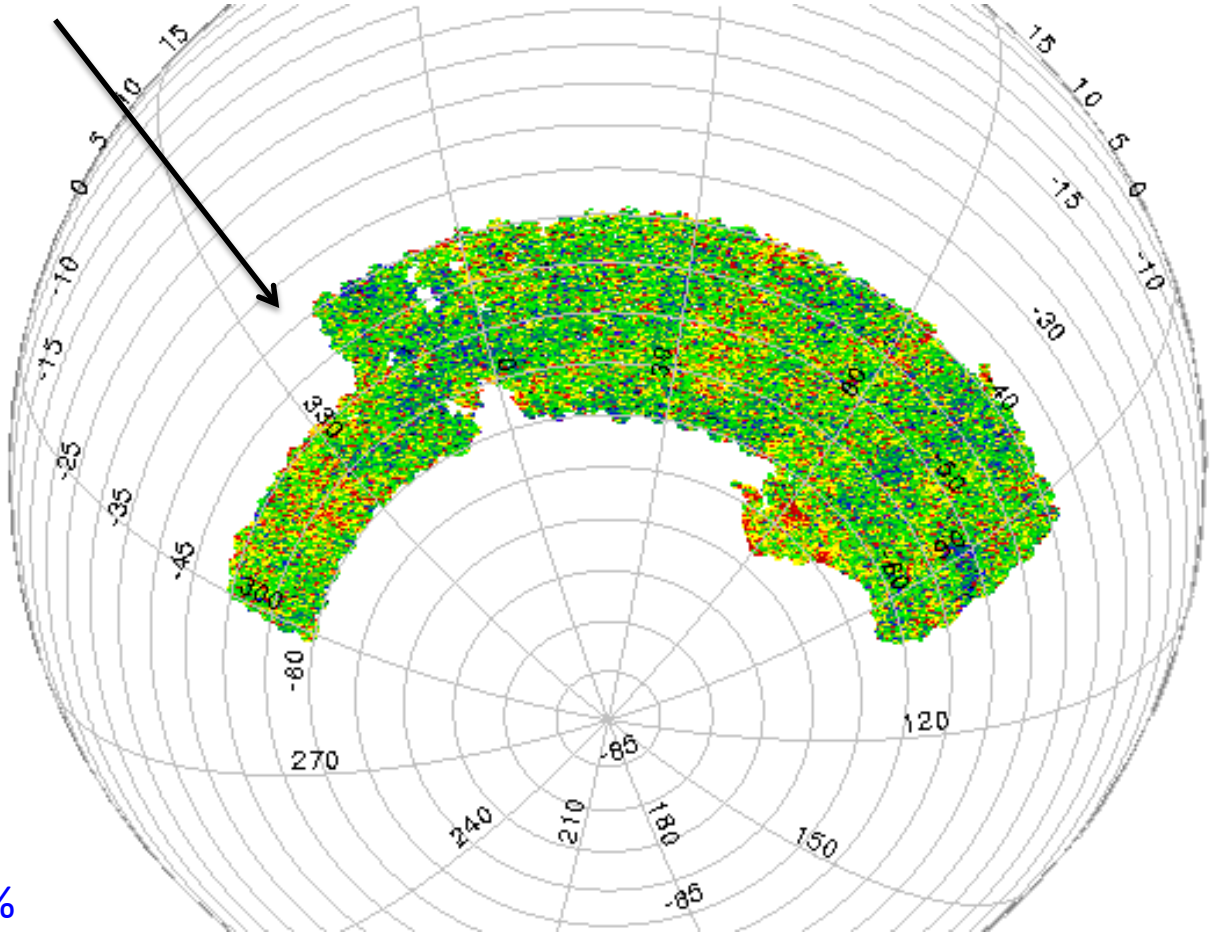
DARK ENERGY SURVEY

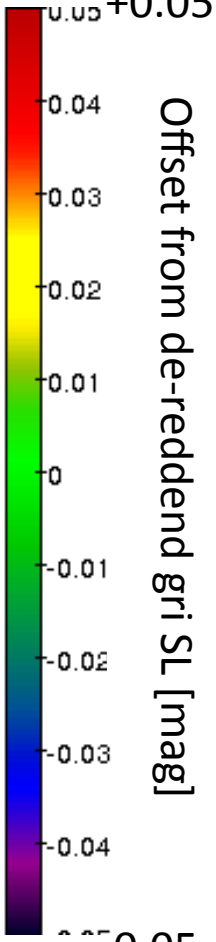


Y1A1 SPT Area: External Check using a "Poor Man's SLR"

DARK ENERGY SURVEY

Each point is an individual star





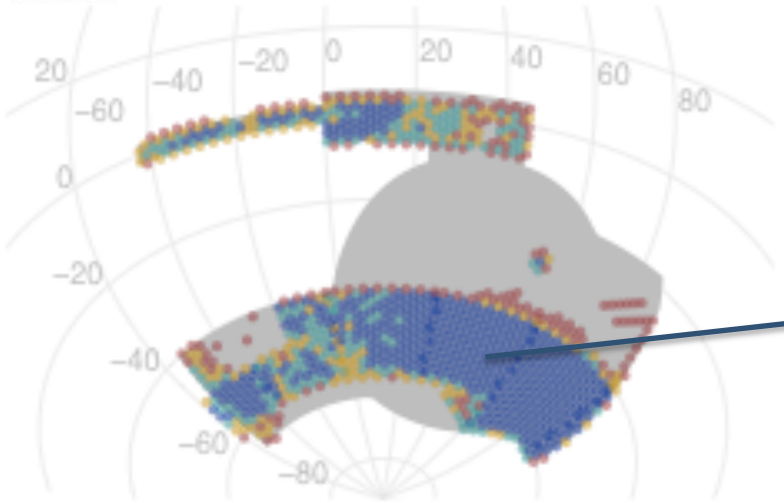
1σ RMS:

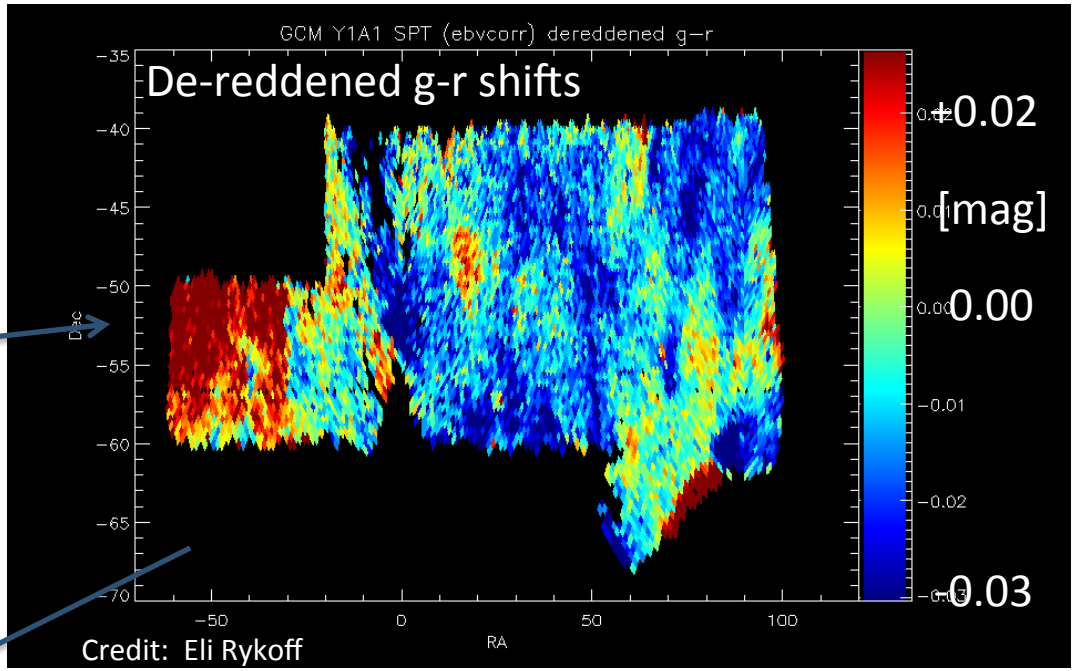
- gri: 1.9%
- riz: 2.8%
- izY: 2.6%

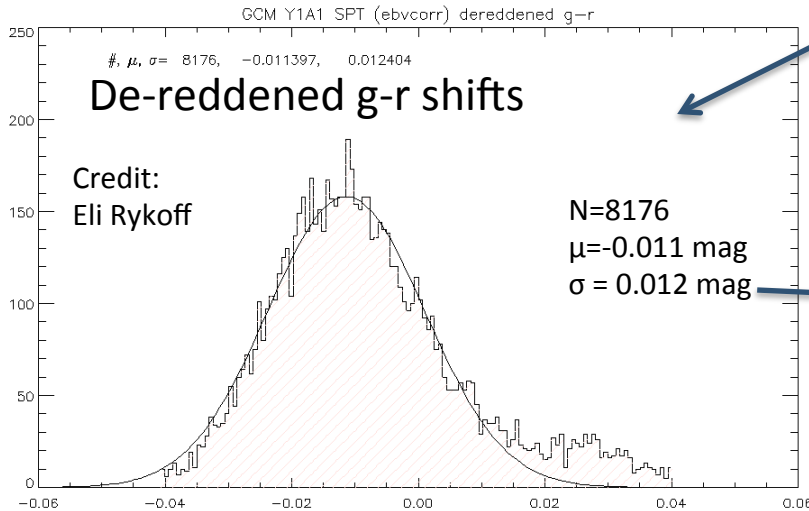
(Thanks, Brian Yanny!)

Eli Rykoff's SLR Results for GCM: SPT

DARK ENERGY SURVEY







-0.06 -0.04 -0.02 0.00 0.02 0.04 0.06 [mag]

Year 1 Relative Calibrations

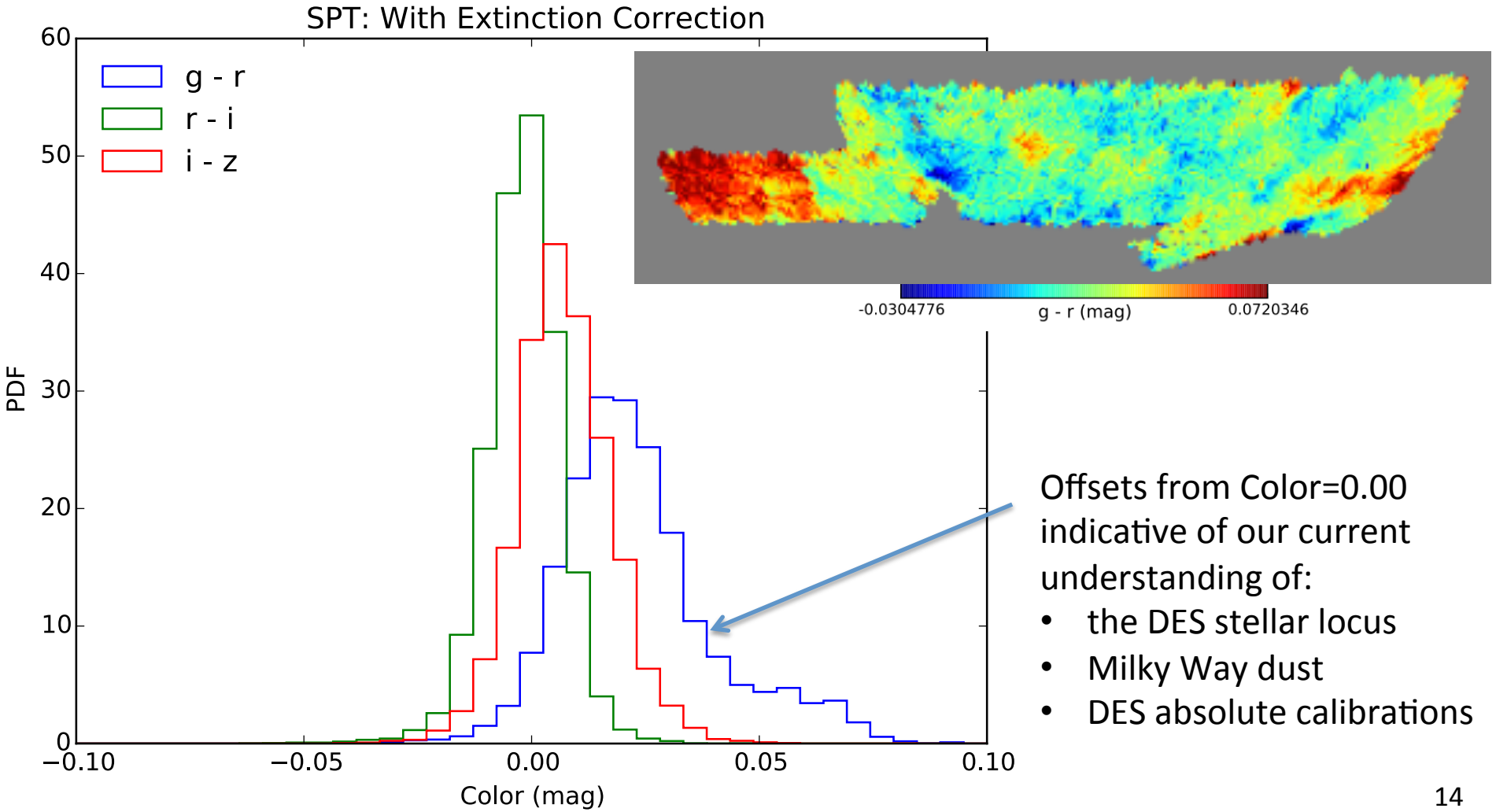
- g-r: 0.012 mag rms
- r-i: 0.008 mag rms
- i-z: 0.009 mag rms

(DES Sussex 2014 Meeting)

Keith Becthol's SLR Results for GCM: SPT

(From Antarctica!)

DARK ENERGY SURVEY



Offsets from Color=0.00 indicative of our current understanding of:

- the DES stellar locus
- Milky Way dust
- DES absolute calibrations

SN Areas for Y1A1

- Lots of overlap with previously calibrated DES grizY tertiary standards.
- Update previously calibrated DES grizY tertiary standards* using new data from Year 1.
- Perform a single-pass GCM solution, solving for photometric zeropoints on a CCD image by CCD image basis.
- Split into two data sets:
  - **SNplus:** exposures that passed the Wide-Field Survey "firstcut_eval" test
  - **SNplus_extra:** those that didn't but were still in the Y1A1_FINALCUT data set

(*Thanks to Sam Wyatt for creating these tertiaries!)

SNplus Exposures: g-band GCM RMS's (internal errors)

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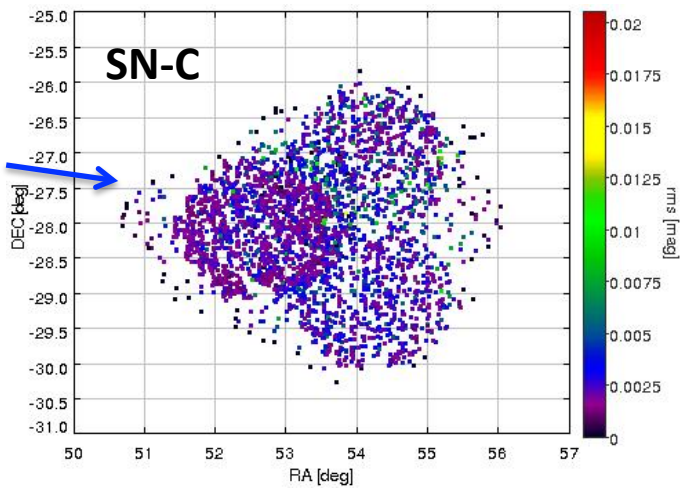
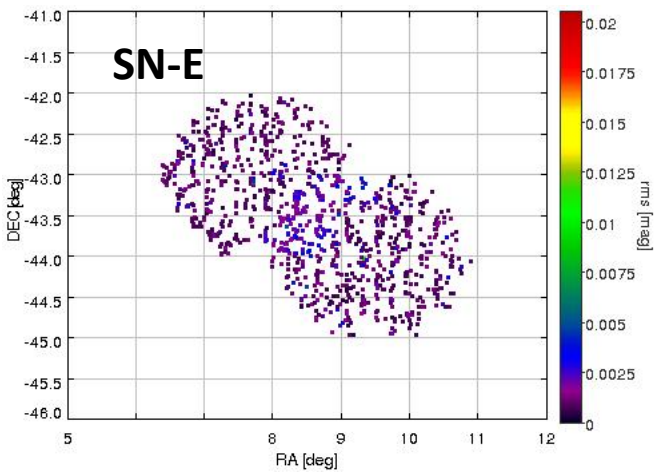
Each "point" is an Individual CCD image

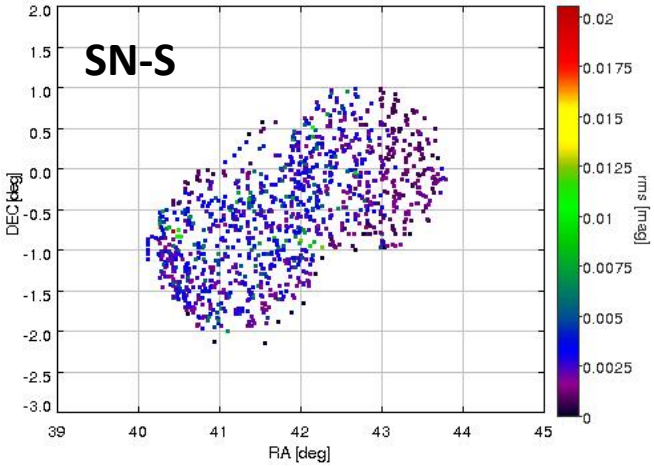


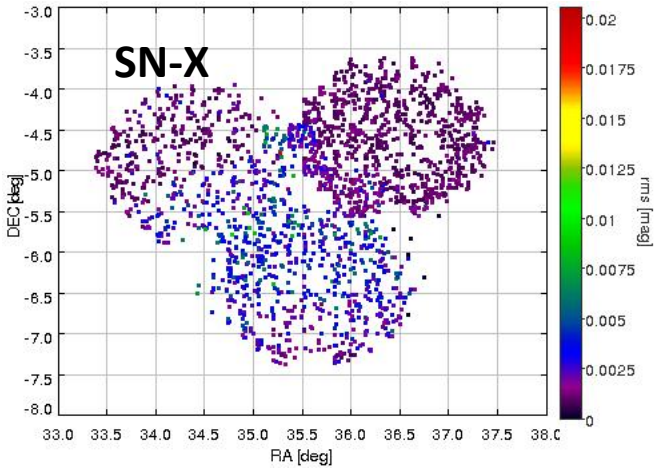


0.02 GCM RMS [mag] 0.00

RMS of overall solution:

- **SN-C: 0.29%**
- **SN-E: 0.19%**
- **SN-S: 0.38%**
- **SN-X: 0.19%**





0.02 GCM RMS [mag] 0.00

Y1A1 SNplus Exposures: Cross-Check for Systematic Errors

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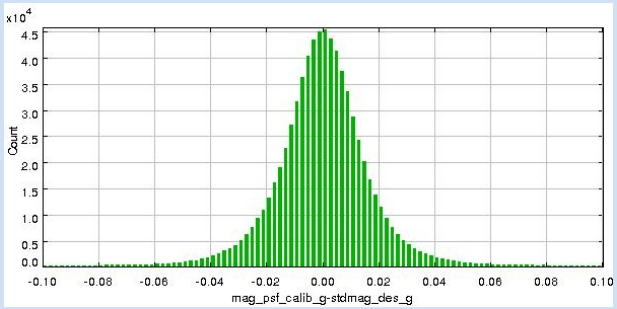
GCM-calibrated mag_psf minus stdmag vs. (RA,DEC): **g-band**



RMS of Δmag: ~0.013mag (~1.3%)

Each point is an individual star

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Y1A1 Calibrations Caveats

- These are single-epoch calibrations.
  - The coadd process *could* in principle imprint additional errors.
  - One reason to tie the Y1A1_STRIPE82 directly to SDSS Stripe 82 (transformed to DES) is to try to isolate any problems in the calibrations in the single-epoch data from those in the coadds.

- GCM calibrations – like SDSS calibrations – do ***not*** include interstellar reddening.
  - This is true even when we are not tying calibrations directory to SDSS as with the Y1A1_STRIPE82 data set.
  - So don't forget to apply interstellar reddening corrections to the data if they are important to your science!
  - SLR calibrations *do* include interstellar reddening, so be careful when comparing between the two types of calibration!

- For Y1A1_COADD_OBJECTS, we are quoting the following level of calibration:
  - about 2% rms in g,r,i 3% rms in z and ~3-5% in Y (**relative and absolute**) with few excursions or outliers beyond these limits.

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Extra Slides

Yearly Science Goals: Photom. Calibrations

(DESDM talk at May 2014 Collaboration Meeting: DES-docdb#7832)

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- Year 1 (Y1A1): <4% relative photometry
- Year 2 (Y2A1): <3% photometry
- Year 3 (Y3A1): 2% photometry
- Year 4 (Y4A1): <2% photometry across large areas
- Year 5 (Y5A1): attempt 1% (stretch goal) photometry

From the Scientific Requirements Document
(DES-doc#20-v32: sciReq-9.86, 10 June 2010)

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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.

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.

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

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.

For 5-year Survey

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.

Enhanced goals

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Global Calibration Module (GCM): Field-to-Field Zeropoints

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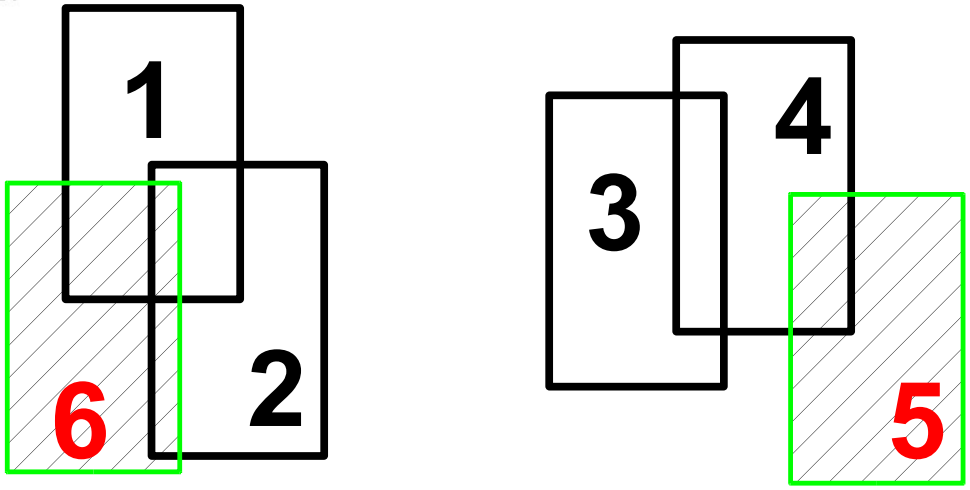

A Generic Example:
Frames 5 & 6 are calibrated.
The others are uncalibrated.

- 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 $S = \Sigma\Sigma\ \theta_{ij} (\Delta_{ij} + ZP_i - ZP_j)^2$

Global Relative Calibration Steps for Y1A1

(using the Global Calibrations Module, or GCM)

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1. **Pre-Calibrate:** create a set of local DES tertiary standards in each isolated area (Stripe 82 equatorial area, SPT areas, SN areas) to tie the zeropoints to the DES AB system as well as to anchor the relative calibrations against gradients.

2. **StarMatch:** find all unique matches for star detections in the image-to-image overlaps and between star detections and the local tertiary standards.

3. **GCM-zeropoint:** solve for the photometric zeropoints for all the images observed in a given isolated Y1P1 area.

4. **NCSA Handoff:** hand off list of ccd image zeropoints to NCSA for uploading into database.

Statistical vs. Systematic Errors

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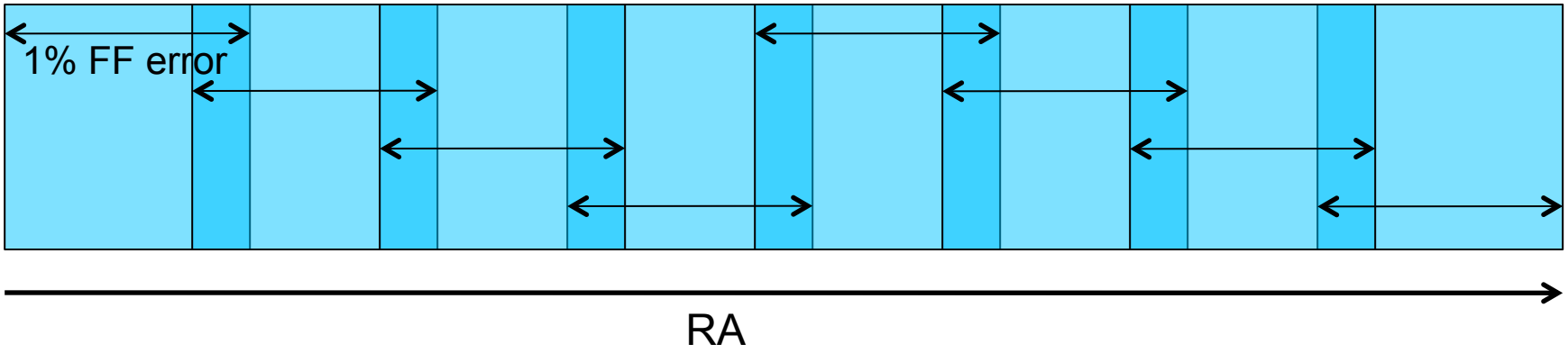
- It is possible to get a statistically good solution from a relative calibrations solver (like GCM) but still have large systematic errors.

- Consider the a long, thin strip in RA, with a 1% flat fielding error (edge-to-edge) from West to East:



- One could still get a statistically tight offset between fields from the overlaps, but still end up with large systematic errors.

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Global Calibrations Challenge

- **Purpose:** To test out new and improved global calibration codes for use in the Year 2 processing campaigns and beyond.
- **Wiki:** https://cdcvs.fnal.gov/redmine/projects/descalibration/wiki/Global_Calibrations_Challenge

Codes taking part in the current Challenge:

- Jim Annis's **YaCal** (DES-doc#7690)
- Anne Bauer's **Ubercal/Nebencal** (DES-doc#7687)
- Dave Burke's **Forward Calibration** (DES-doc#7688)
- [Current **GCM** (for comparison)]

All did very well and there was no clear single "winner".

Next few months will be spent refining the techniques and performing "cross-pollination" of the different methods.

External Check: Eli Rykoff's full SLR technique

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Global Calibrations Challenge

Data sets to cover (still under some discussion):

- **Y1A1 Equatorial ("Stripe82") Area** as defined by Robert Gruendl's Y1A1_STRIPE82/ Y1A1_STRIPE_NOCAL exposure tags. (SDSS provides a measure of "truth".)
- **Either the Y1A1 SPTE or the Y1A1 SPTW Area**, to be defined by Robert Gruendl's exposure tags for these areas. (No "truth", but larger area.)
- If time, Y1A1 SN data, including **SN exposures that do not meet the coadd image quality cuts** but are still needed by the SN group for differential photometry, etc.
- If time, **SV-A1 SPTE**. (Goes to full 5-year DES depth, but data have more problems compared with later data)

Priority of filter bands to test (still under some discussion):

- For the Y1A1 Equatorial Area: griz (Y if time)
- For the Y1A1 SPT Area: r, z (others if time)
- For the SN fields: TBD, but probably griz
- For the SV-A1 SPTE Area: TBD

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Global Calibrations Challenge: Metrics

- Repeatability (single-image rms errors)
- Systematics (comparison against "truth", for some value of "truth" -- e.g., against SDSS, which is "truth" to about 1-2%, and/or against SLR)
  - plots of systematics vs. position on the sky
- Completeness
  - number of filters with solved-for calibrations by the October Y2P1 decision deadline
  - fraction of ccd images from Y1A1 exposure tags defining the data sets for which the code can supply zeropoints (perhaps also sky plot indicating location of those ccd images without zeropoints)
- Others?

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Global Calibrations Challenge: Future

- Any of the codes under the current review should in the end be able to achieve the survey requirements.
- In the end, we may wish to merge 2 or more methods for the best results.
- Further, we will likely be refining the global calibrations algorithms up through the end of the survey.
- We may wish to consider having a series of Global Calibration Challenges, on a cadences of about one per year.
- For Year 2, if we do not have a “clear winner” (and even if we do), we may wish to run all the current codes (or their Feb 2015 versions) for the Year 2 processing, upload all their results to the DESDM zeropoints table (but tagged by the name of their source), and choose then which to use for the Year 2 coadds.

Addendum: Calibrating Early Data with the Stellar Locus Regression (SLR) Method

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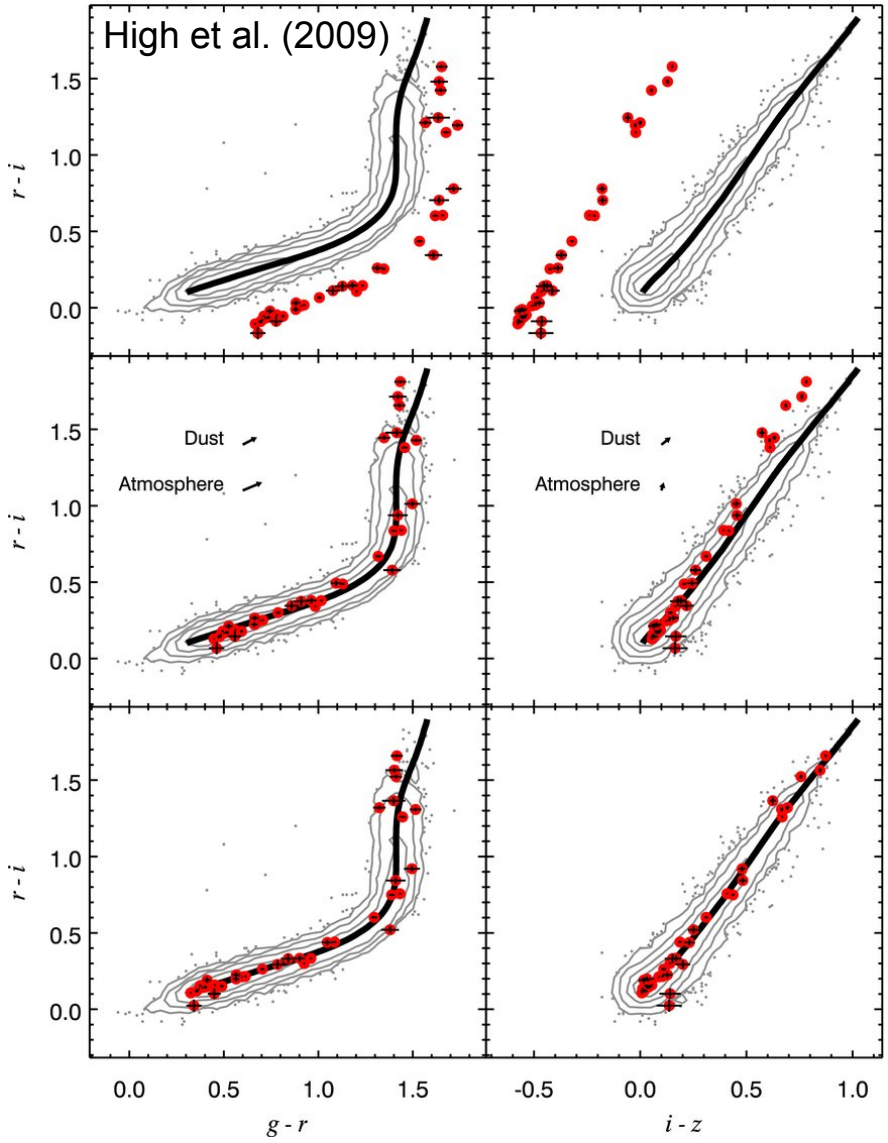
- In the DES, there is a strong philosophical legacy from SDSS to use the stellar locus primarily as a quality assurance check on the photometry (e.g., Ivezic et al. 2004).

- That said, especially in the first year or two, it will be hard to obtain good calibrations for DES.

- Therefore, we are looking into using the SLR method of High et al. (2009), as implemented by Bob Armstrong of the DESDM team, to help with calibrations in the early years. Some of the SWGs have already used SLR on SV data.



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Why the Difference between "Poor Man's" SLR and Full SLR Results?

- Not quite sure…
- Poor Man's SLR is a star-by-star measure.
- The current full SLR analysis bins stars over 0.21 sq deg HEALPIXels (c. 4.5 DECam CCDs' worth of area).
- Different interstellar extinction coefficients used.
- ???

- ***Caveat: the SLR technique depends on the quality of our understanding of the properties and distribution of the dust between us and the stars we are observing…***