Global Photometric Calibrations for SV-A1

DARK ENERGY SURVEY

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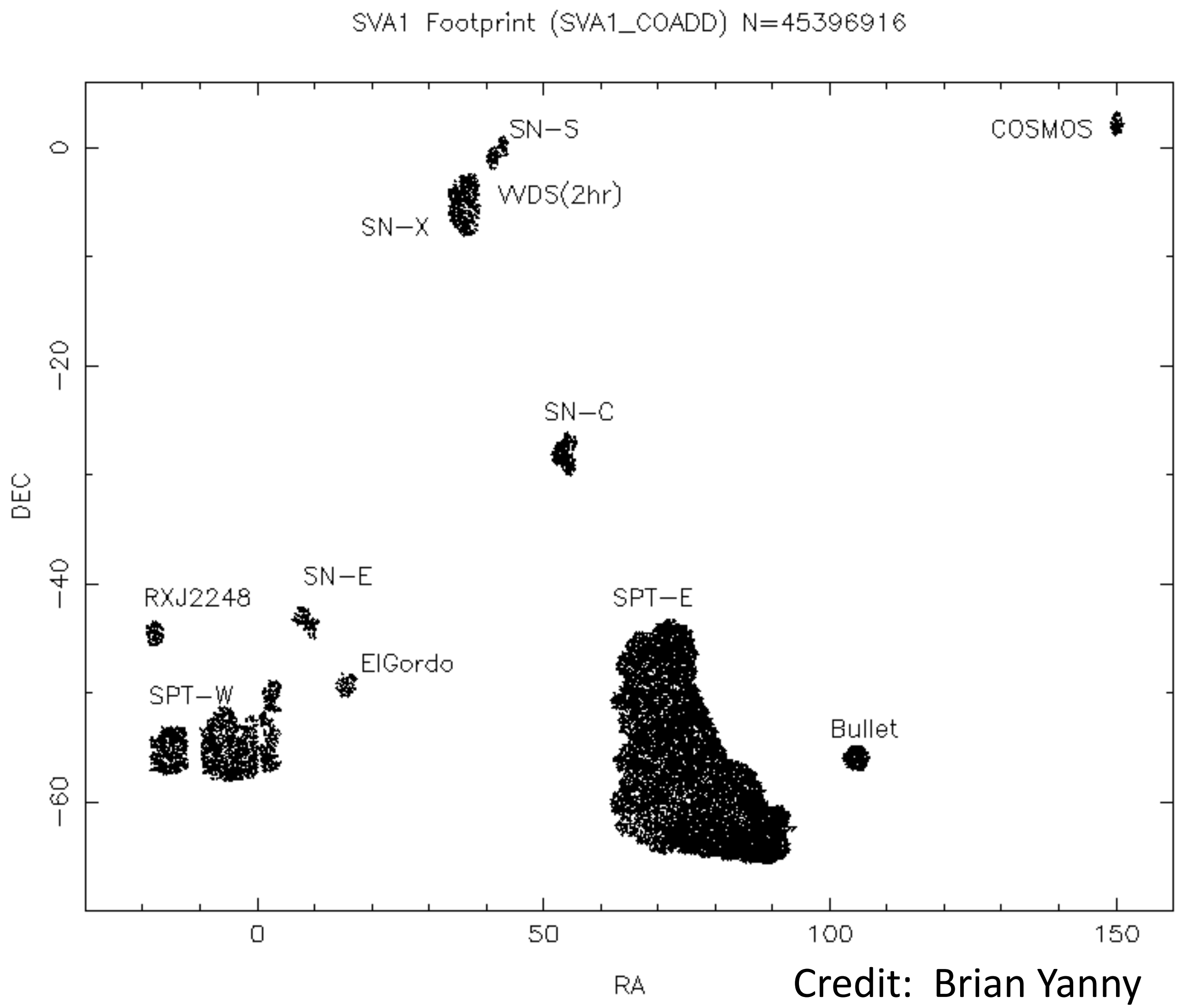
DES Calibrations Meeting
13 September 2013

Science Verification (SV) Coverage



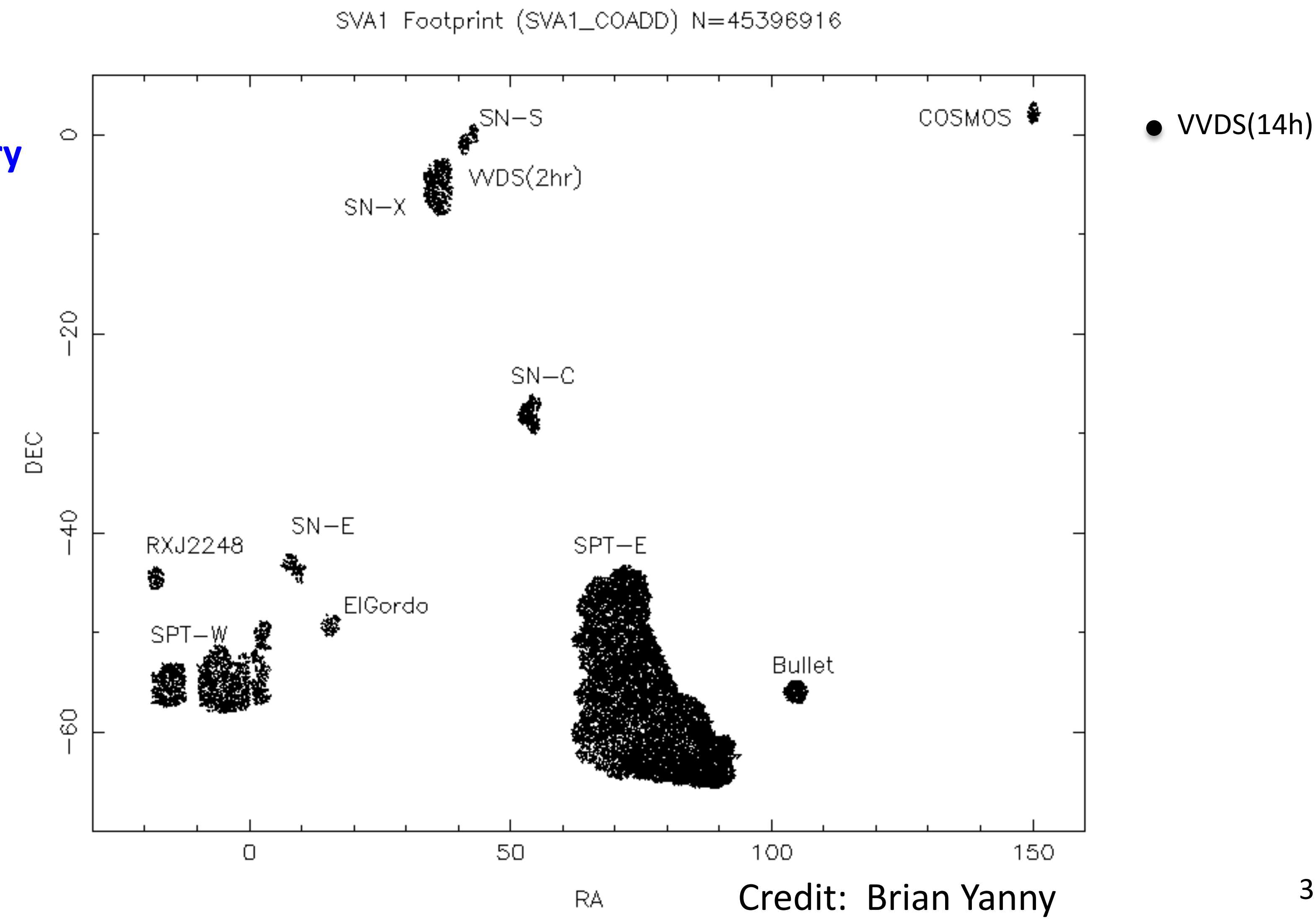
- VVDS(14h)

Credit: Brian Yanny

Science Verification (SV) Coverage

To be done (Supplementary Release):

1. Y-band for SN-C, SN-E, SN-X
2. RXJJ2248 (Aug 15)
3. Std Star Fields



Credit: Brian Yanny

From the Scientific Requirements Document

(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.

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.

For 5-year Survey

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Photometric Calibration Goals for SV

- All-sky internal: 3% rms
- Absolute Color: 3% (*g-r*, *r-i*, *i-z*); 4% (*z-Y*)
- Absolute Flux: 3% in *i*-band (relative to BD+17 4708)

Photometric Requirements (5-year)

- Internal: 2% rms on scales of 0.05°-4° (Goals: 1% rms and/or over 160° in RA, 30° in DEC)
- Absolute Color: 0.5% (*g-r*, *r-i*, *i-z*); 1% (*z-Y*) [averaged over 100 objects scattered over FP]
- Absolute Flux: 0.5% in *i*-band (relative to BD+17 4708)

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

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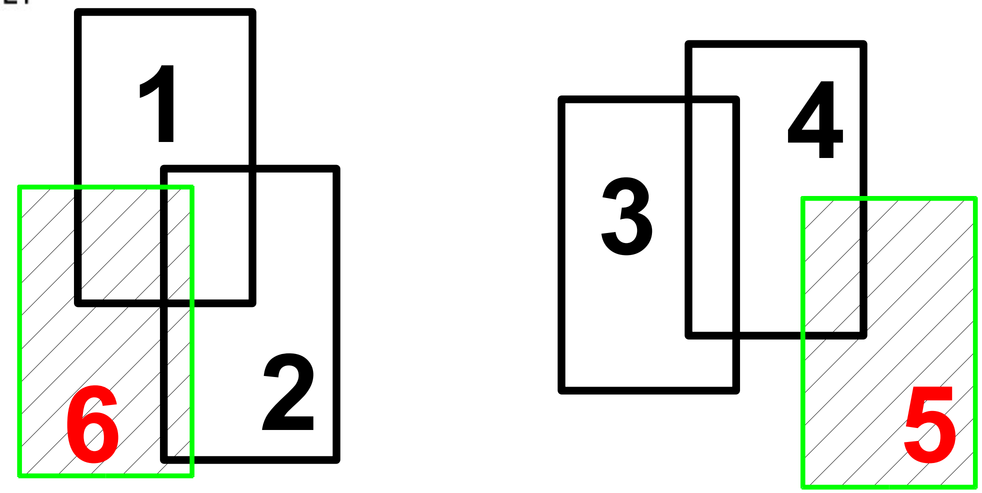

A Generic Example:
Frames 5 & 6 are calibrated.
The others are uncalibrated.

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

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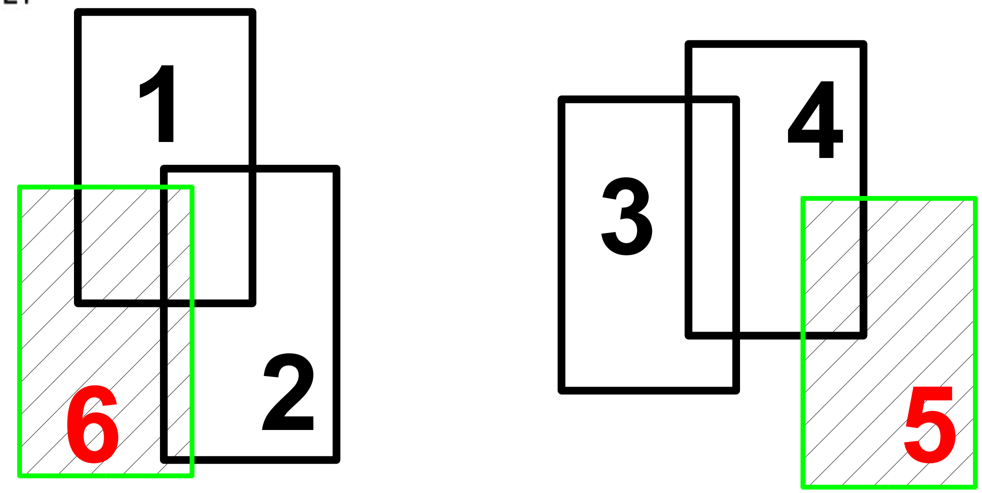
Global Calibration Module (GCM): Field-to-Field Zeropoints (II)



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

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

Steps in the Global Photometric Calibration for SV-A1 (using GCM)

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1. **Pre-Calibrate:** using nights with good PSM (nightly std star) solutions, create a set of local DES tertiary standards in each isolated SV area (Bullet Cluster, El Gordo, SPTE, SPTW, SN-S, SN-E, …) to tie the zeropoints to the DES AB system as well as to anchor the relative calibrations against gradients. (Sam Wyatt's code, plus tweaks, mostly for SN fields and SPTE.)
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 ccd images observed in a given isolated SV area.
4. **NCSA Handoff:** hand off list of ccd image zeropoints to NCSA for uploading into database.

DES Local Tertiary Standards

(Sam Wyatt)

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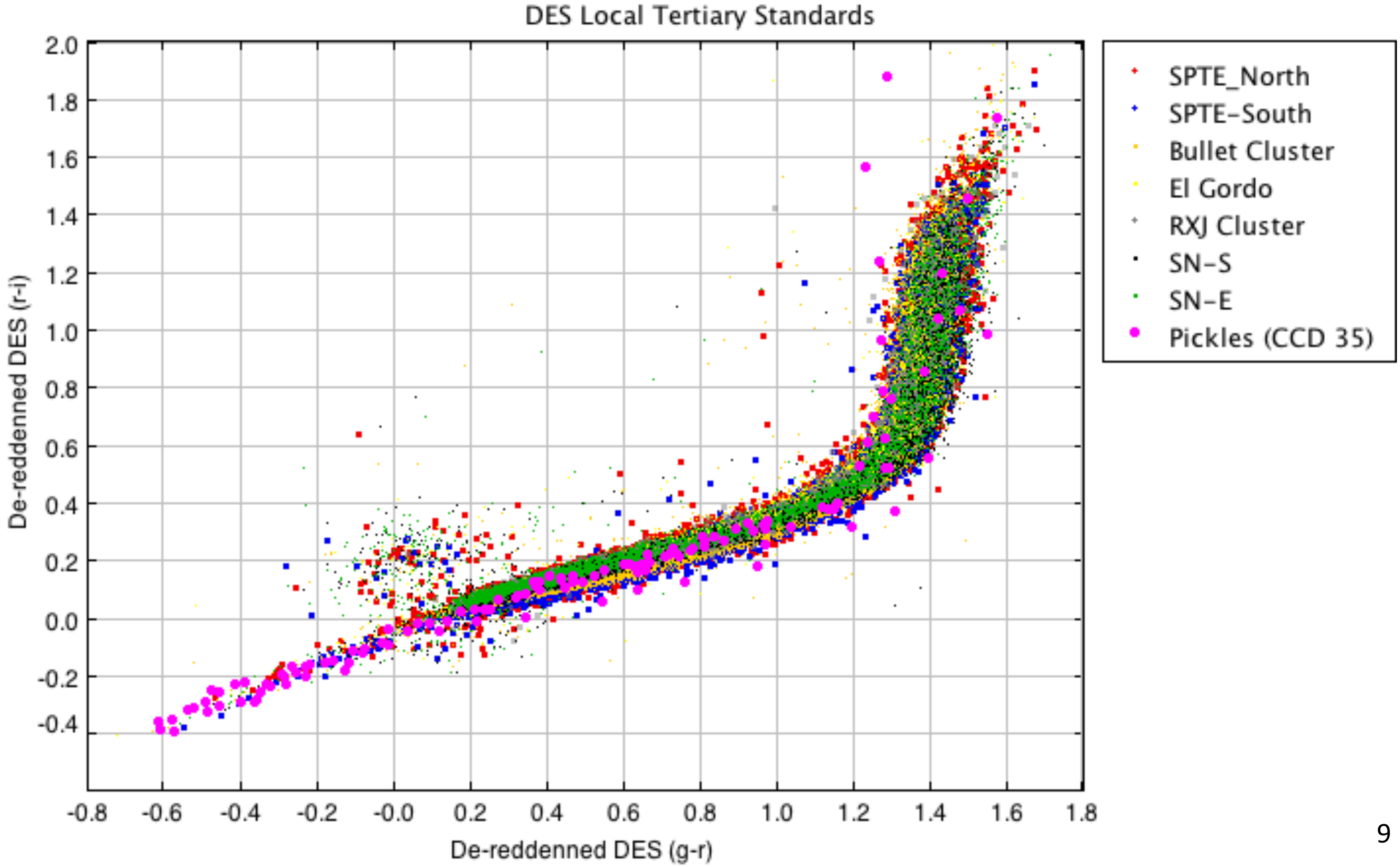
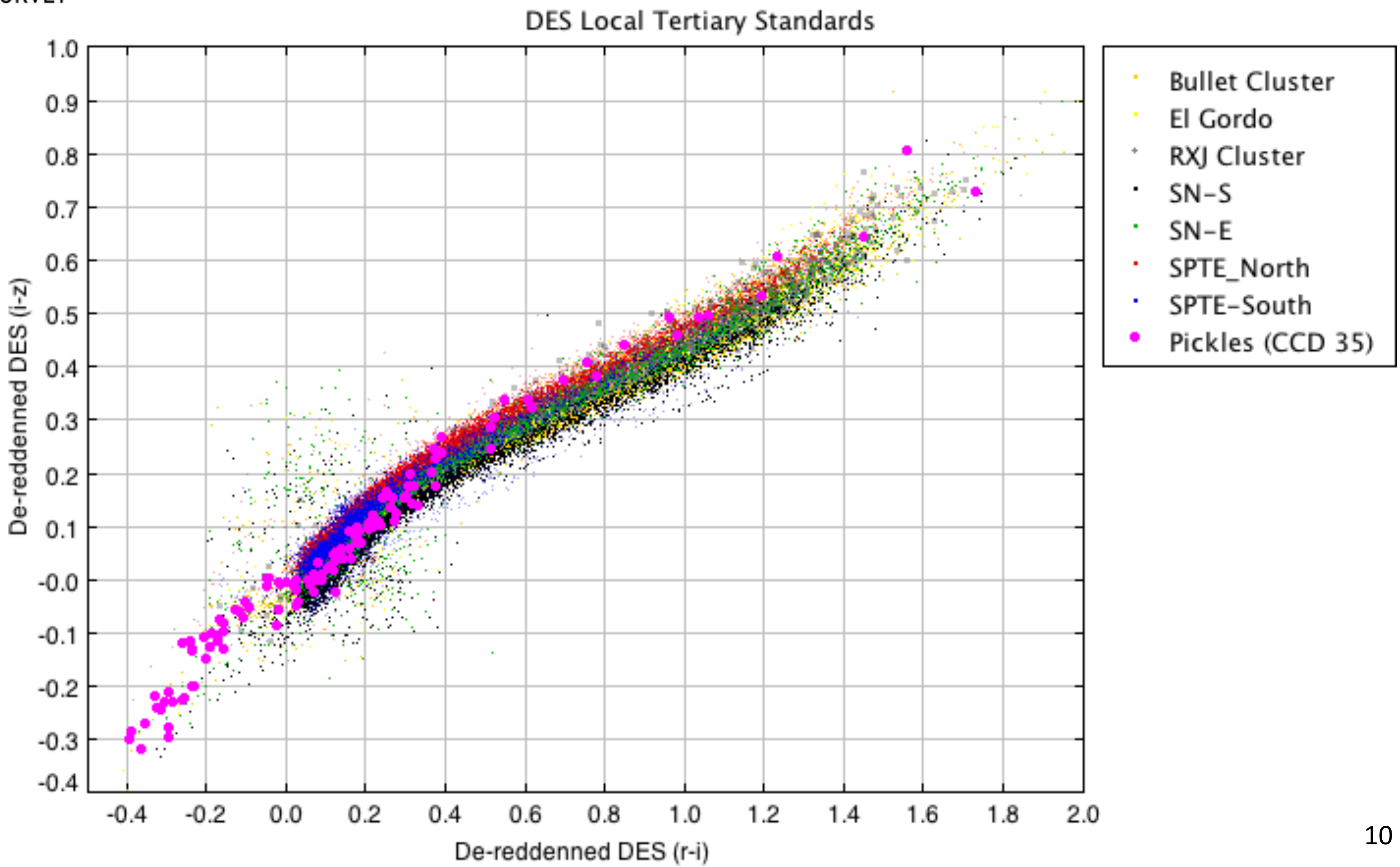


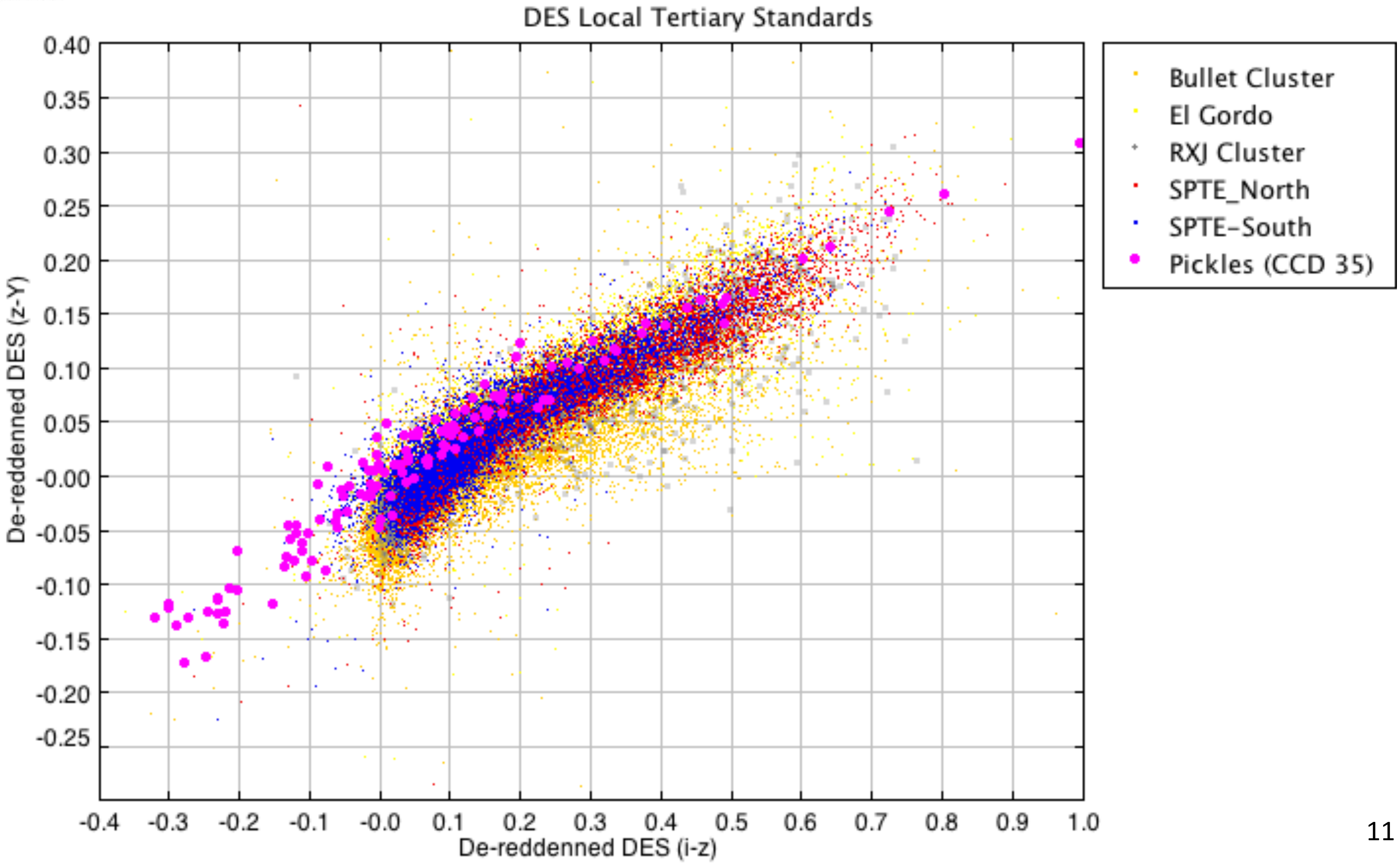
DES Local Tertiary Standards
(Sam Wyatt)

DARK ENERGY SURVEY



DES Local Tertiary Standards
(Sam Wyatt)

DARK ENERGY SURVEY



SN-E: Local Tertiary Standards

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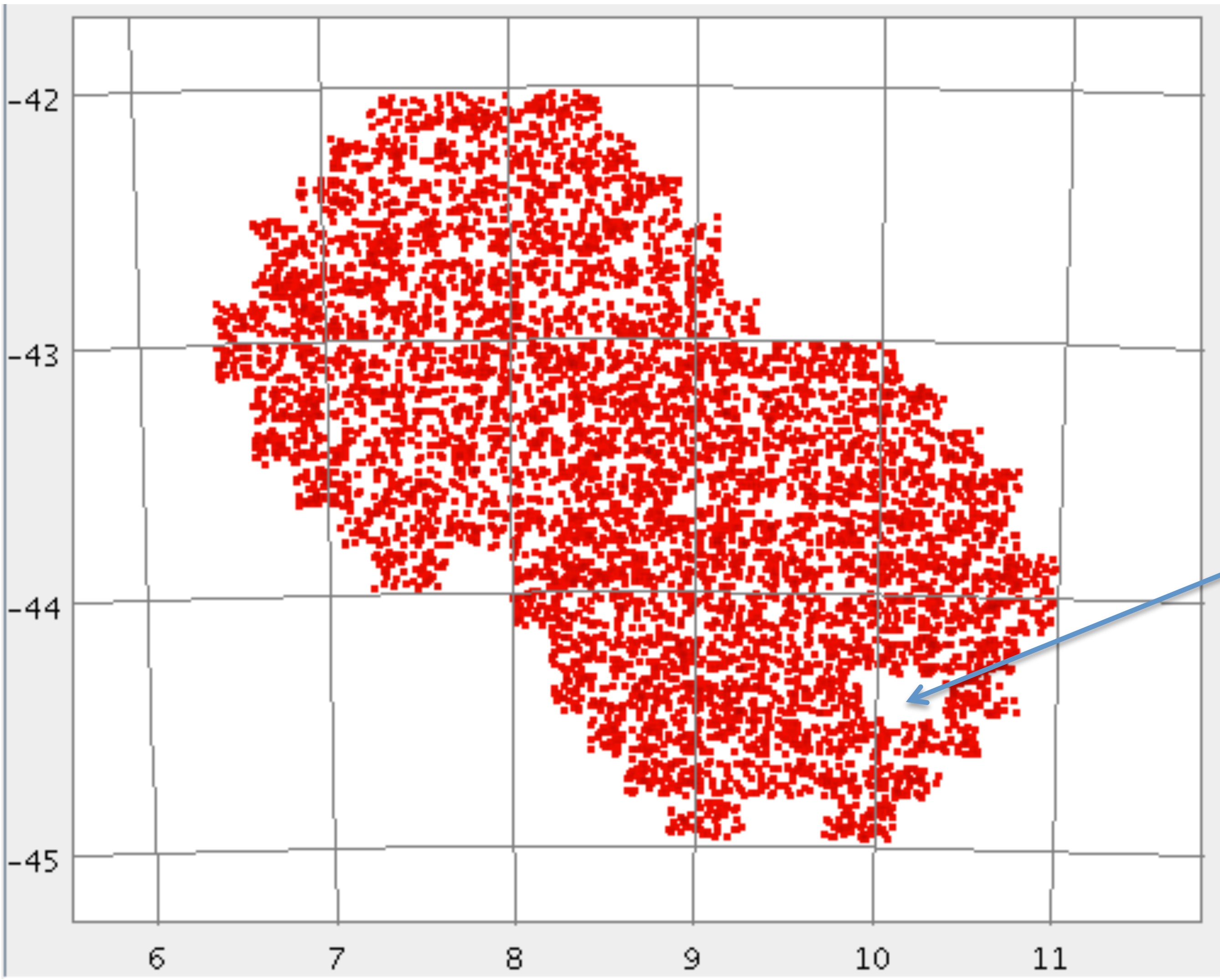
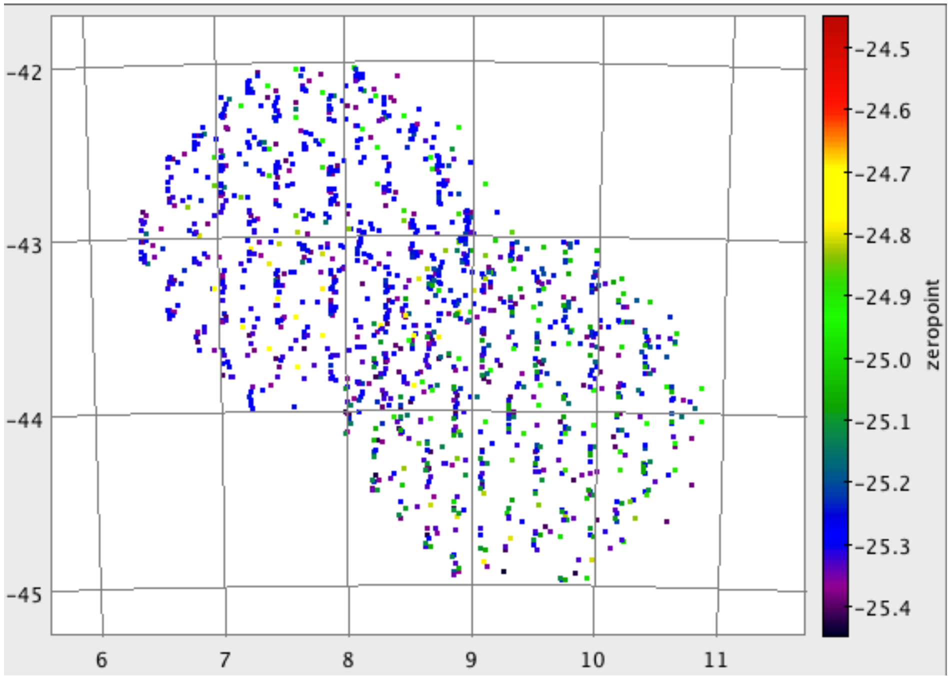


Persistent and annoying gap in coverage for this field

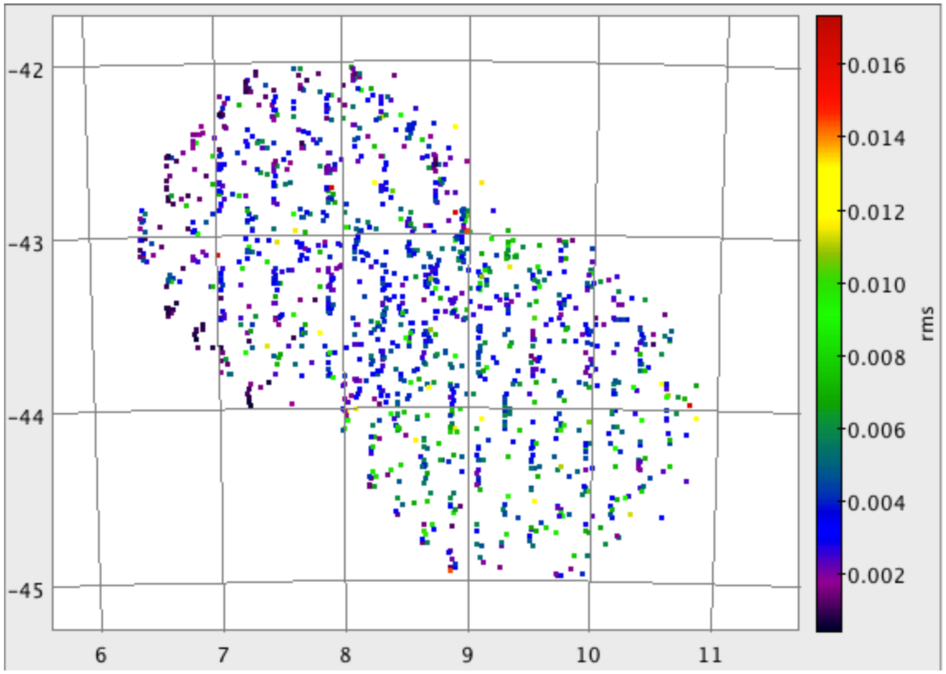
SN-E:
GCM Solution

i-band

zeropoints [mag]



rms [mag]



SPTW: GCM Solution

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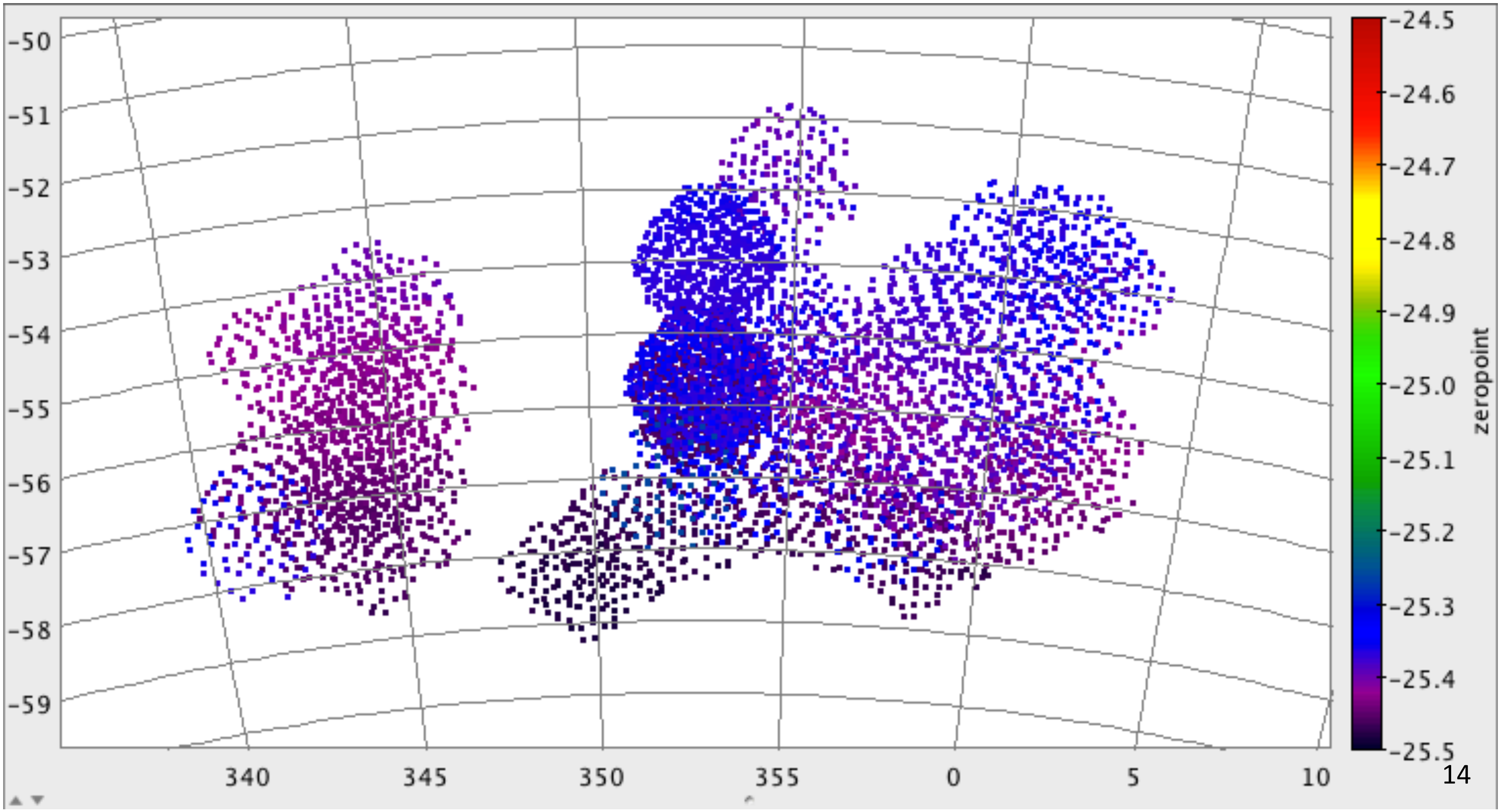
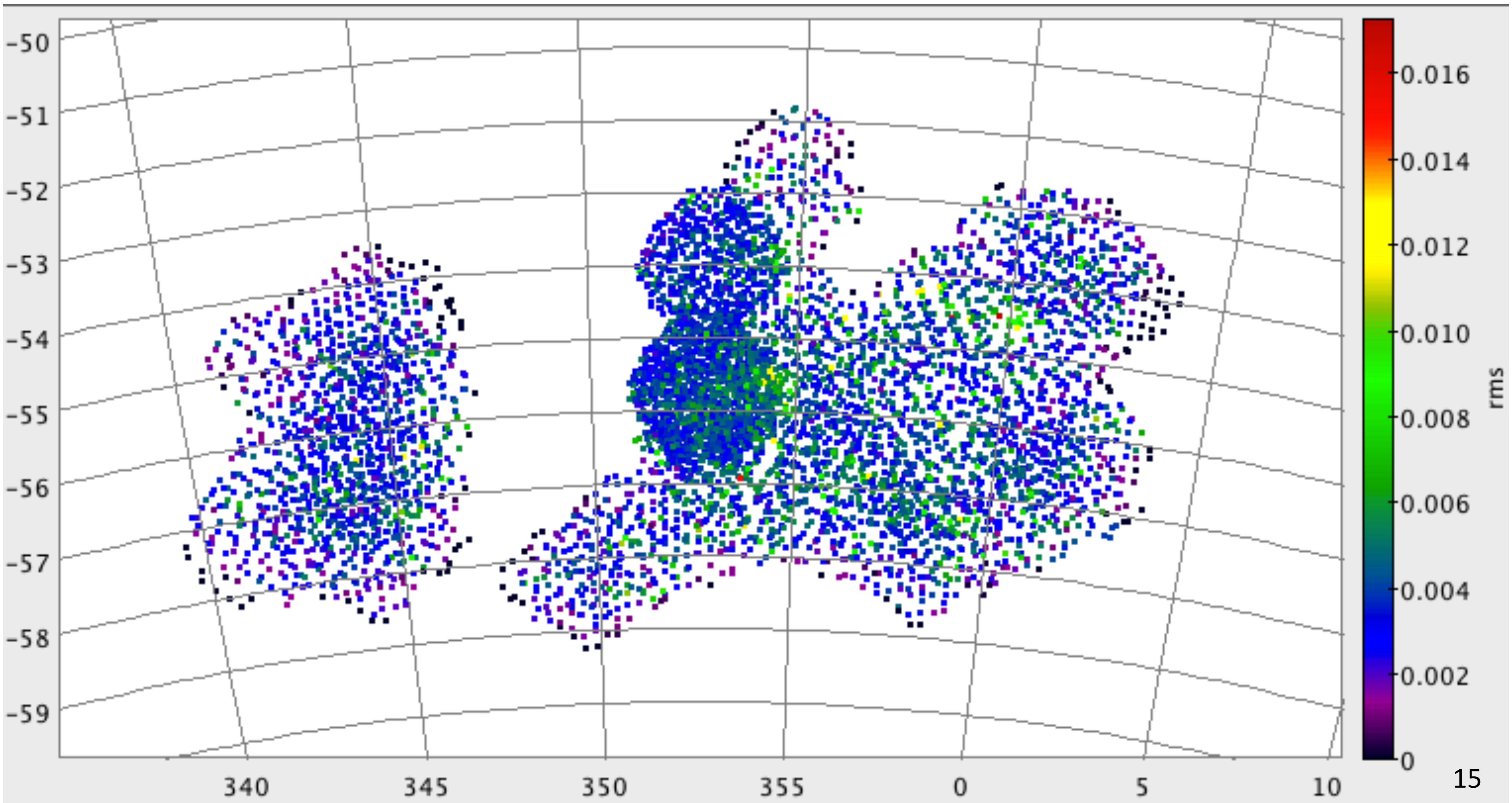
r-band: zeropoints [mag]



SPTW: GCM Solution

DARK ENERGY SURVEY

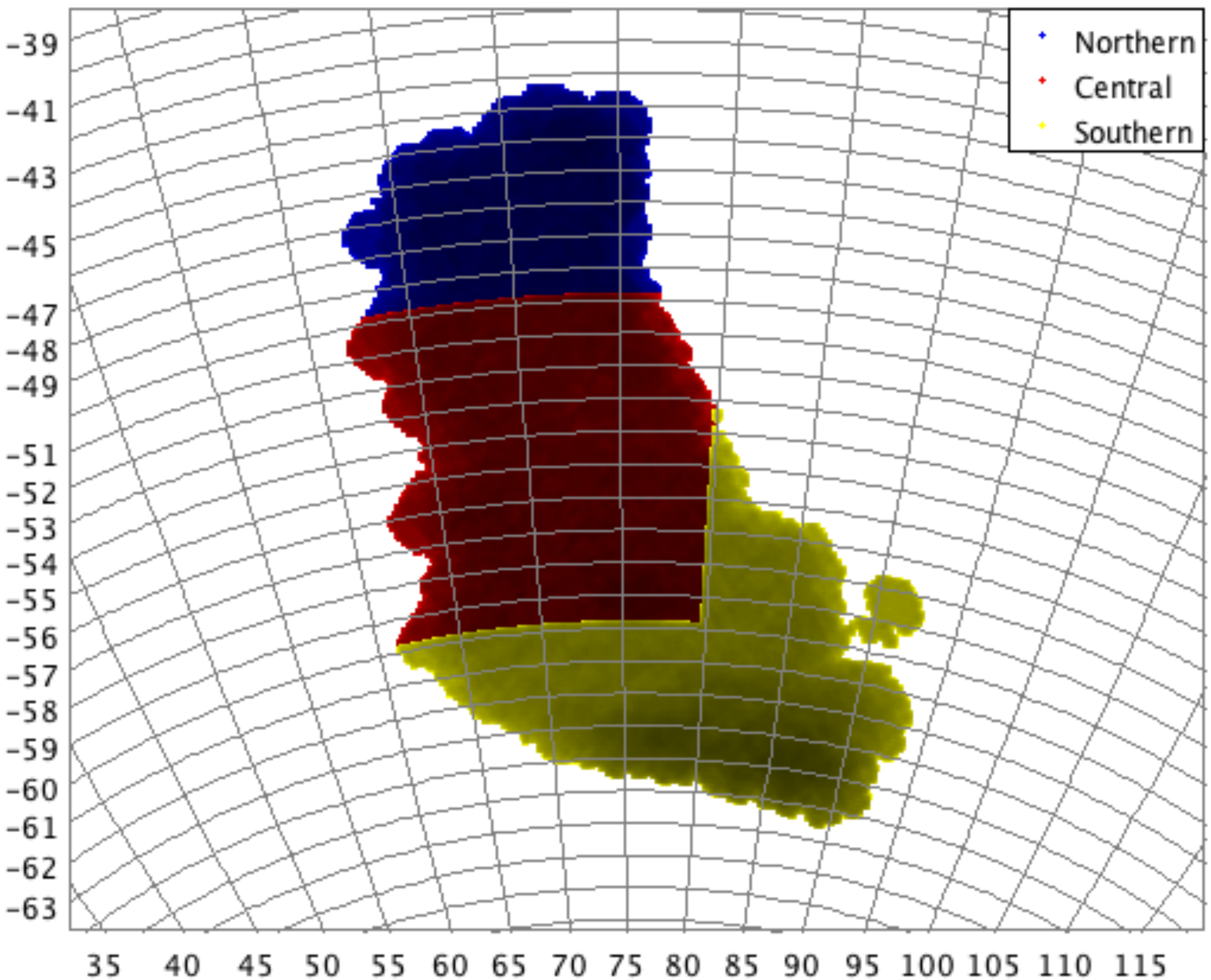
r-band: rms [mag]



SPTE:

"Omnia Gallia in tres partes divisa est."

DARK ENERGY SURVEY



SPTE:

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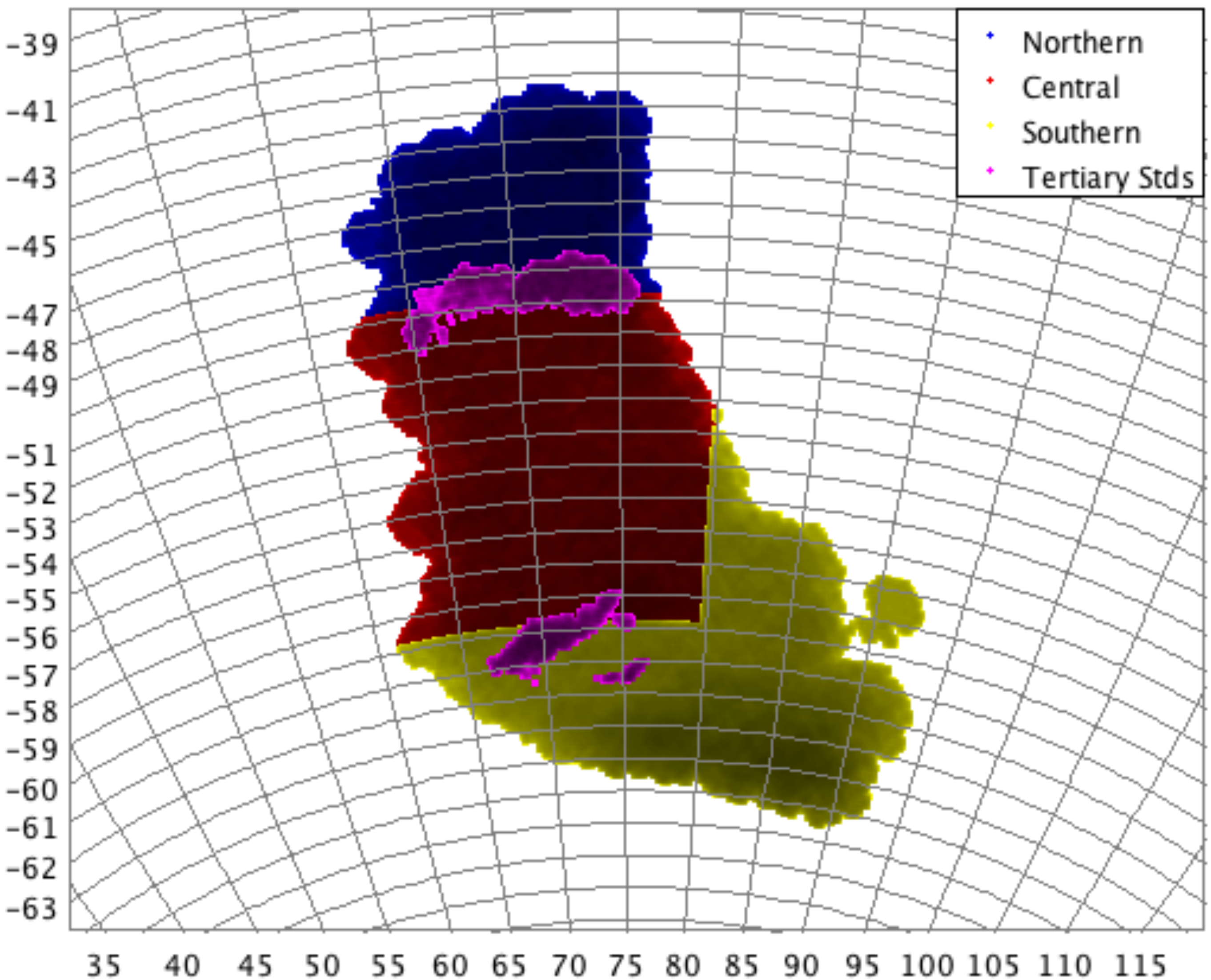
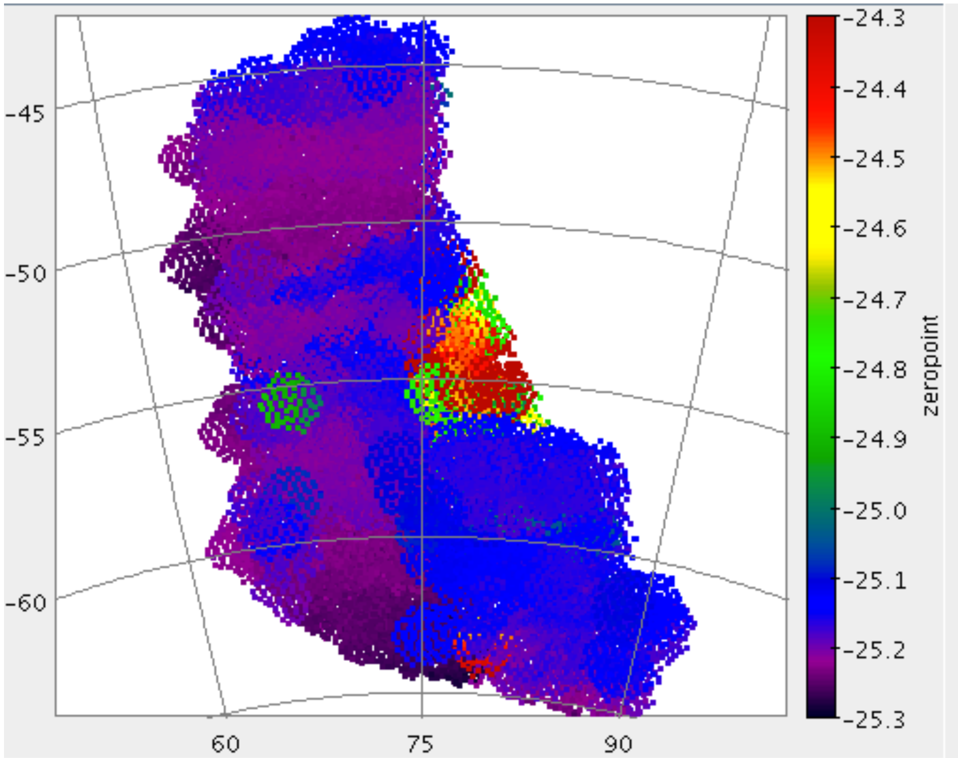


SPTE:
GCM Solution

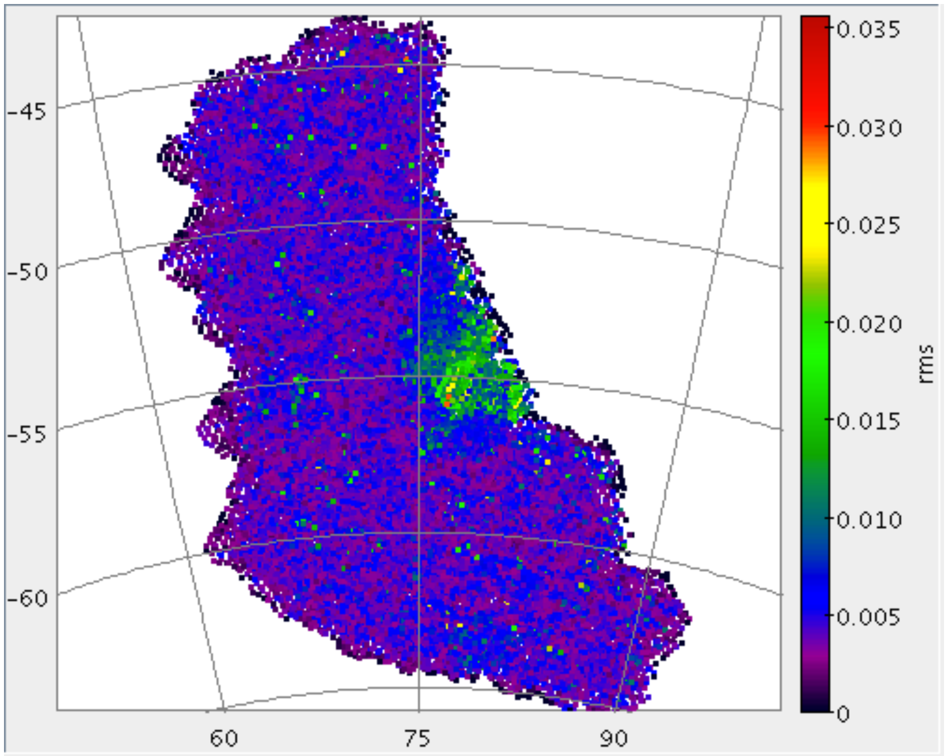
DARK ENERGY SURVEY

g-band

zeropoints [mag]



rms [mag]

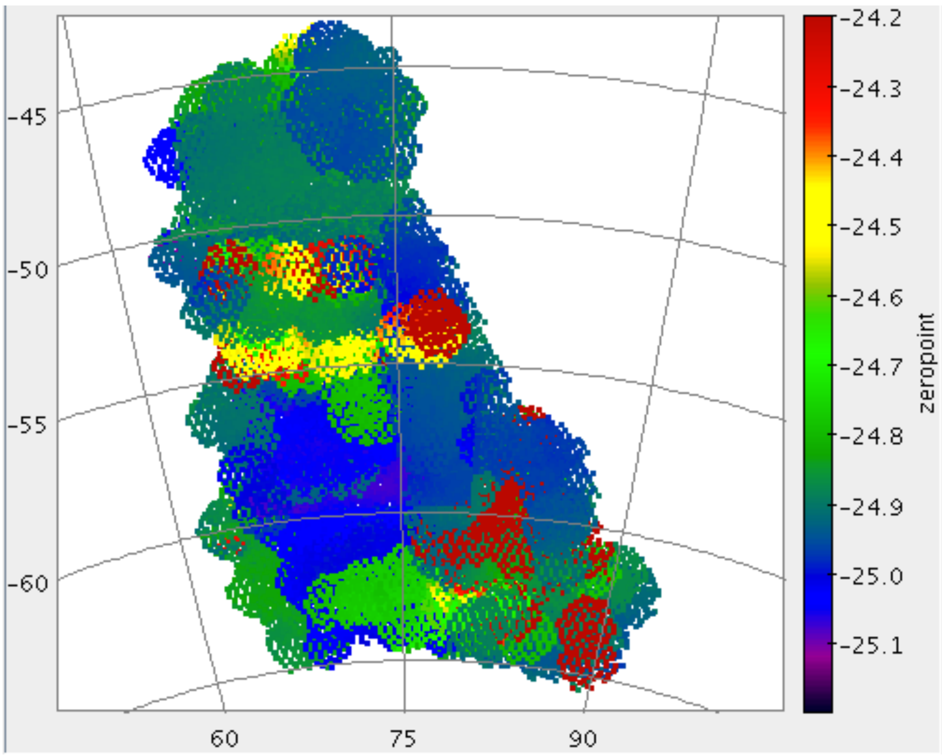


SPTE:
GCM Solution

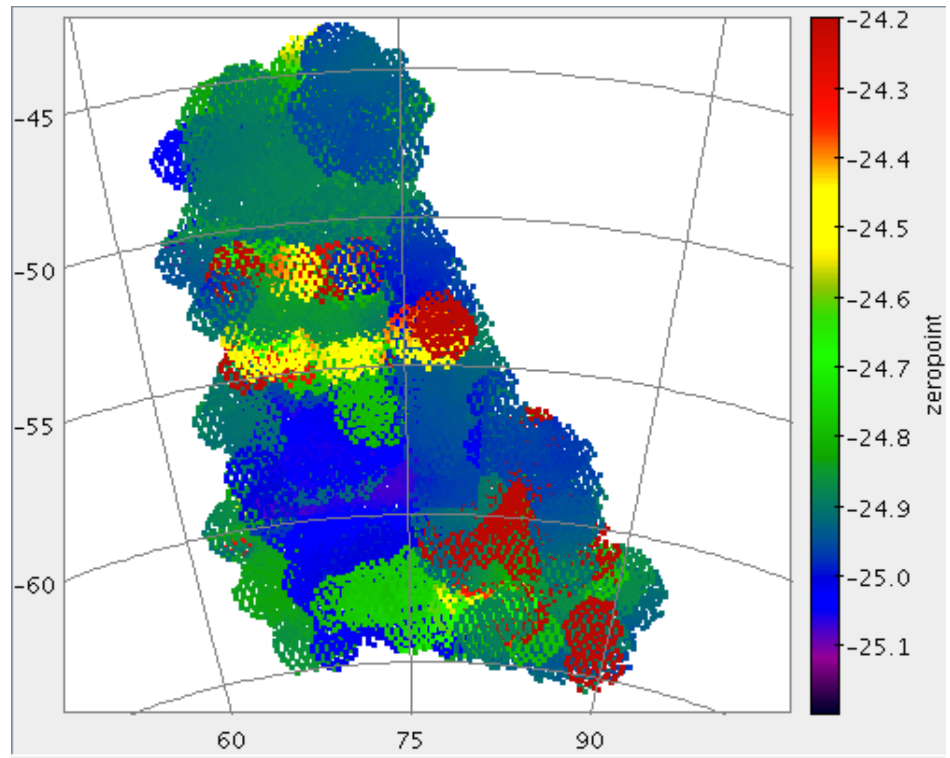
DARK ENERGY SURVEY

z-band

zeropoints [mag]



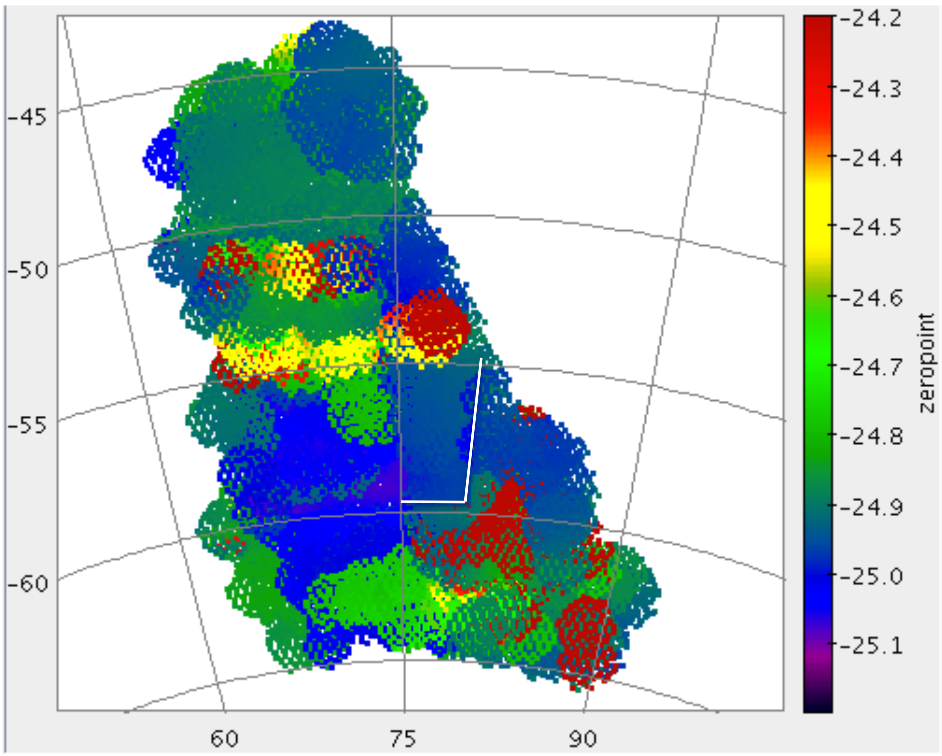
rms [mag]



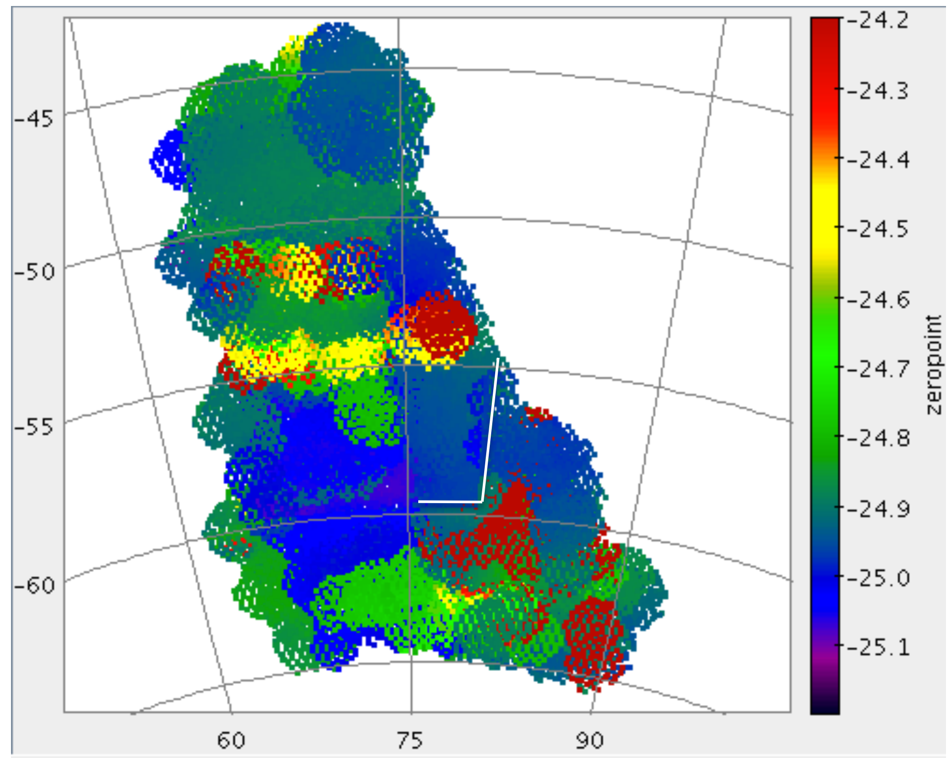
SPTE: GCM Solution

z-band

zeropoints [mag]



rms [mag]



5-10% offset between SPTE (Central) and SPTE (Southern).
(Calibration of SPTE (Southern) was a bit of a rush job…)

External Test of SPTE Photometry: Stellar Locus Regression (R. Armstrong)

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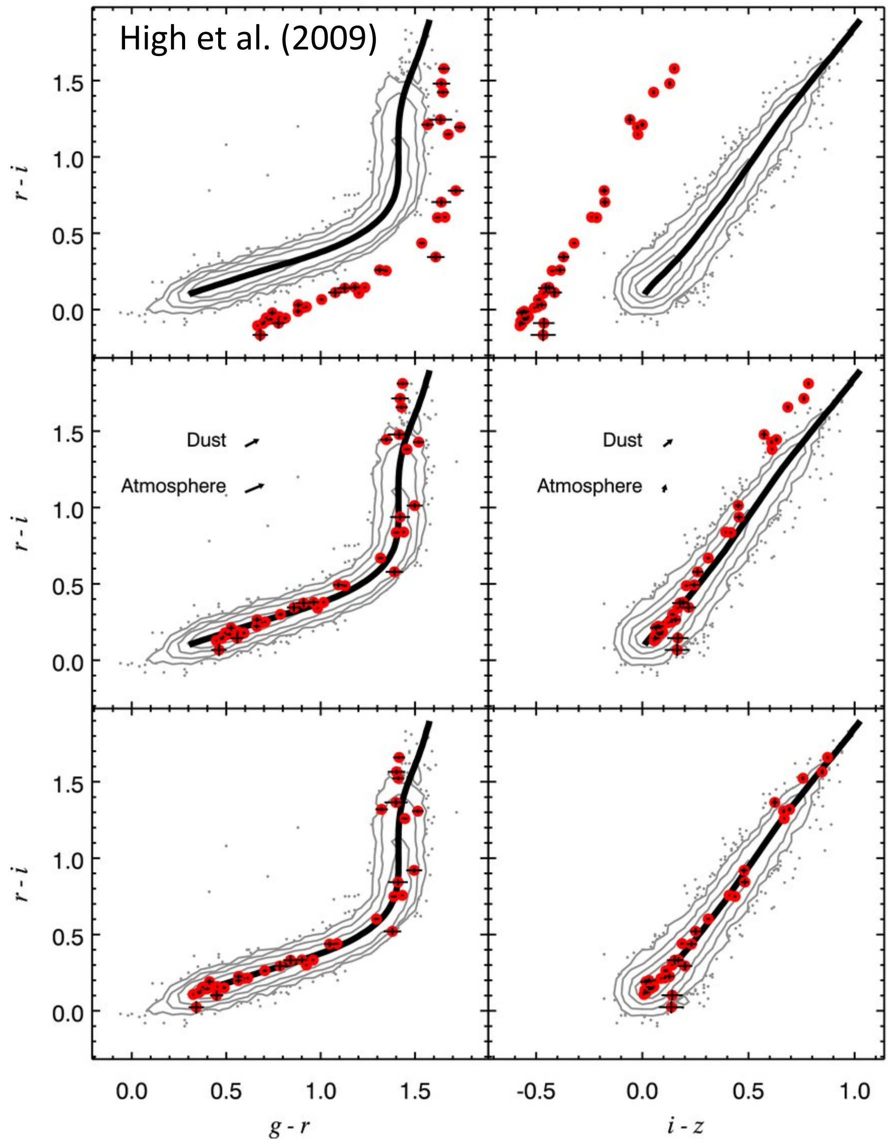
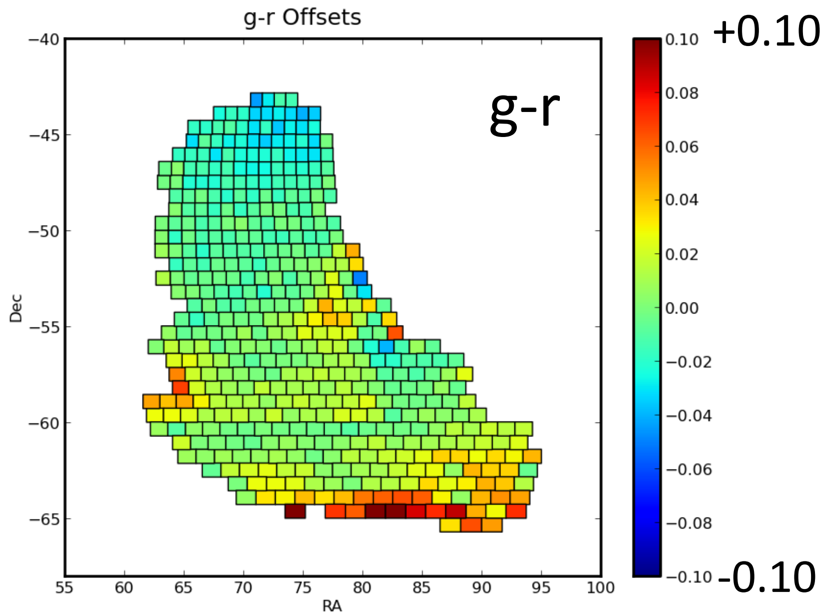
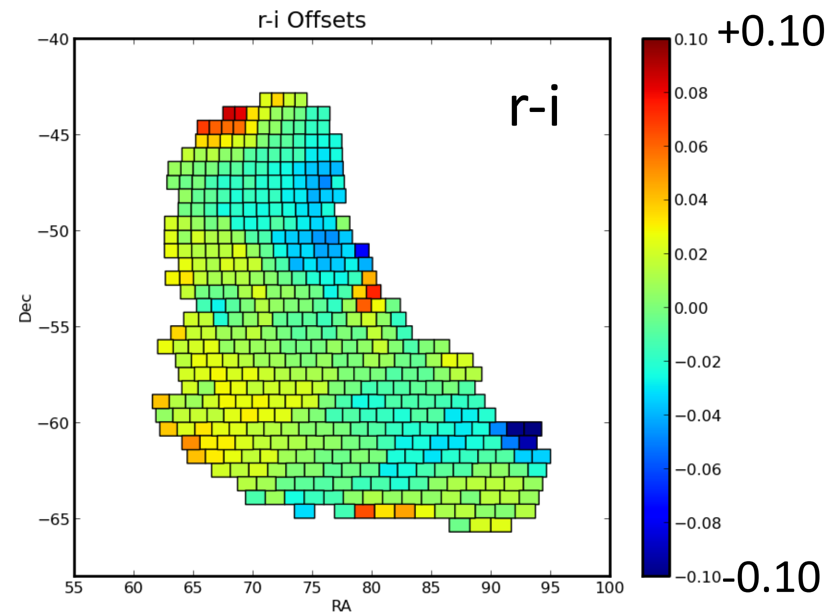
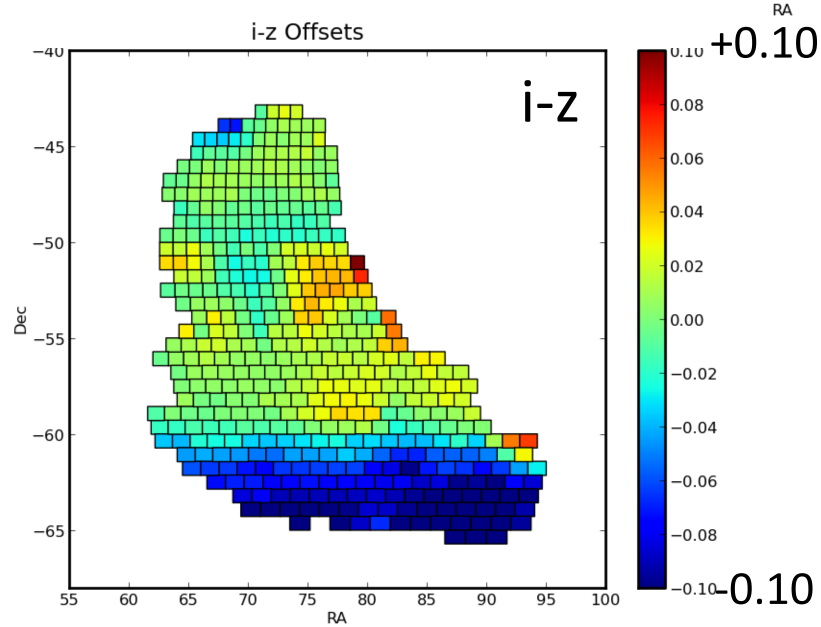


External Test of SPTE Photometry: Stellar Locus Regression (R. Armstrong)







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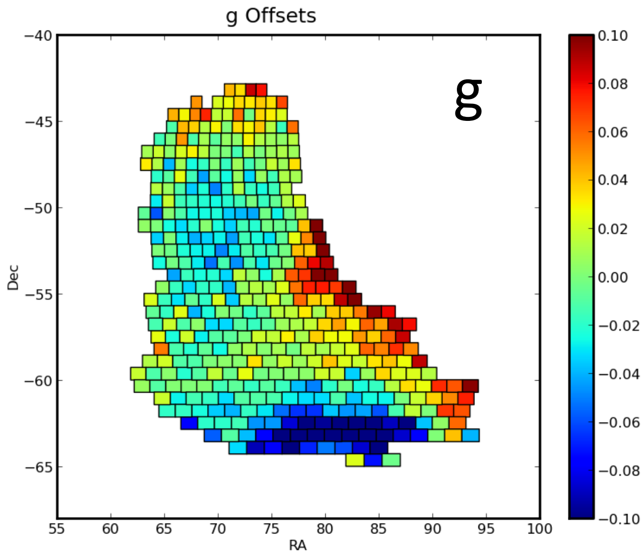

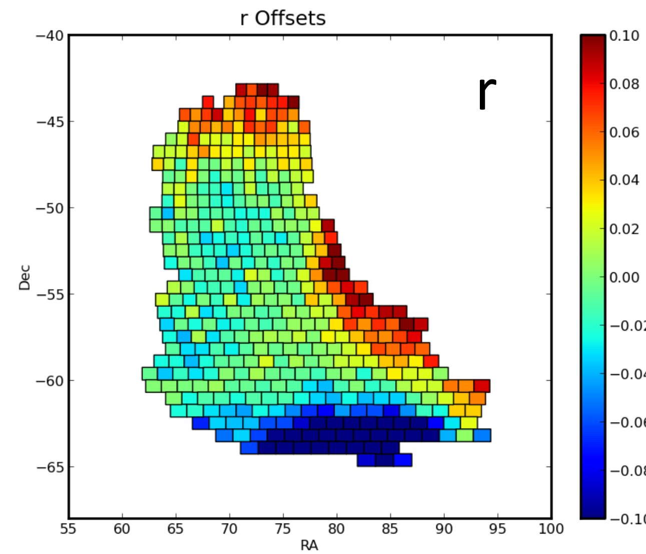

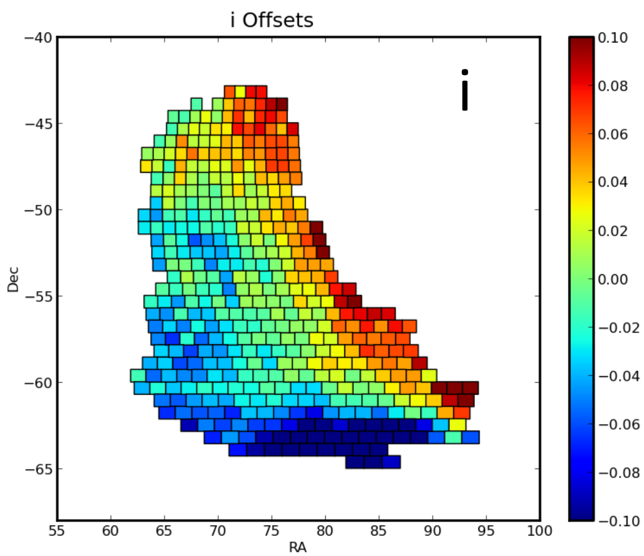

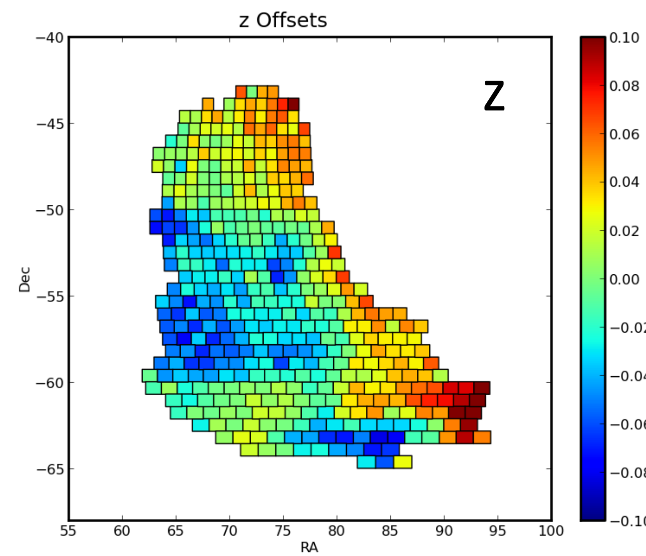

Next Steps

- Compare against UPenn Ueber-cal results for SPTE (and other SV areas)
- Compare against YaCal results for SPTE (and other SV areas)
- Compare against other optical catalogs that pass through SPTE
  - PreCam i-band
  - APASS

Recommendations and Conclusions

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- May actually be approaching 5-year requirements on internal photometry (2% rms over scales between 0.05° and 4° -- i.e., over 5.33 coadd tiles) over much of the SPTE.

- When working with SPTE, avoid extreme edges and near LMC (south of -60°).

- Gradients are the bane of relative calibrations!

- See also: https://desweb.cosmology.illinois.edu/confluence/display/Operations/SV-A1+Global+Calibration+Module

Extra Slides

Lessons Learned/Action Items: Pre-Calibrate Step (Tertiary Standards)

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1. Need RASICAM quantitative measures to identify and exclude exposures taken under non-photometric conditions (**big time sink to do by hand!**).
2. Occasionally, the local tertiary standards for an SV area (particularly for the SN fields) have a gap in coverage for one or more CCDs. This needs to be tracked down.
3. A lot more nights are failing to achieve a good PSM solution than should be the case (> half?). Could the nightly standard star high-airmass fields be suffering more than usual from the "dome occlusion" problem?
4. Although it could not be done for SV-A1 – due to big changes in the calibration after Y1C2 – for next year, it would make sense to create tertiary standards as soon as FirstCut is done.

Lessons Learned/Action Items: Overall

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1. Convert from prototype "bash" scripts to Python.
2. Lots of SN field exposures have poor image quality – include them in the GCM solution?
3. Be aware of inconsistent naming conventions for some fields (should not be a problem for DES Operations, now that all science fields are run through ObsTac).
4. Need to farm out more of the work to other GCM experts once the process is more settled.

Lessons Learned/Action Items: StarMatch Step

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1. Use faster matching algorithms (relatively minor point).

Lessons Learned/Action Items: GCM-Zeropoint Step

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1. Quality of local tertiary standards important, especially for large areas like SPT-E where tertiary standard coverage will be spotty. Iterating the loop PreCalibrate-StarMatch-GCMzp-PreCalibrate-… when things go wrong is time-consuming.
2. For DES Operations Year 1, probably need a hex-worth of tertiary standards for about every 100-225 sq deg (about every 10°x10° to 15°x15°) – or about 10-25 calibrated hexes over the DES Operations Year 1 Footprint.
3. For the current GCM algorithm, which appears to be an N^3 process (where N=# of unique and independent ccd images), soluntions for N>15,000 per filter band become prohibitively long to complete (>1 day). Need to break up DES area into manageable "chunks."

Lessons Learned/Action Items: Handoff to NCSA Step

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1. Current process seems to work OK as a temporary solution.
2. Need to plan what to do for next year.
   a. Plan should be general enough to handle future incarnations of Uebercal-like calibrations (YaCal, PennCal, …)

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Conclusions

1. The SV-A1 calibrations should be much better than either those for Y1C1 or Y1C2.
2. The current process for global photometric calibrations is evolving, and the lessons learned in SV-A1 will be helpful for the future.

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

- 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.