DARK ENERGY
SURVEY

Discussions on Variations in Color Corrections while Building Coadds

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Munich Algorithms Meeting

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Color Terms and Global Relative Calibrations (Catalog-level Coadd)

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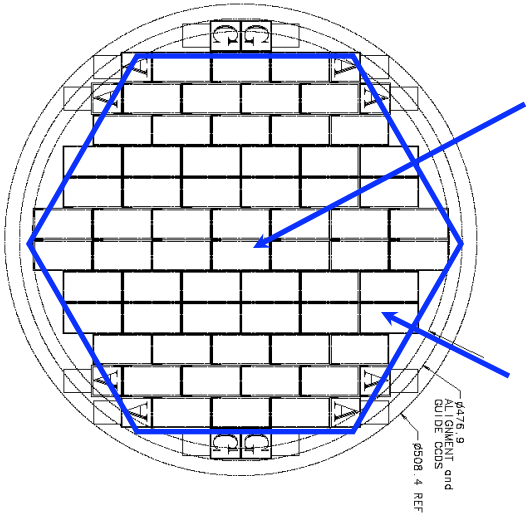
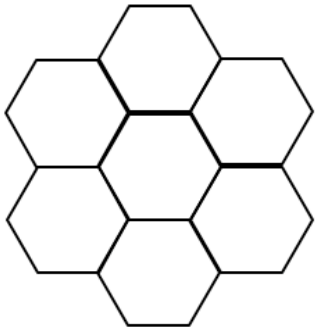
What if there are non-negligible differences in the shape of the response curves for different parts of the focal plane?

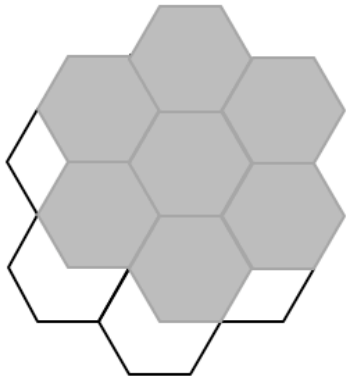


E.g., what if the system response varies from the center to the edge of the filters?

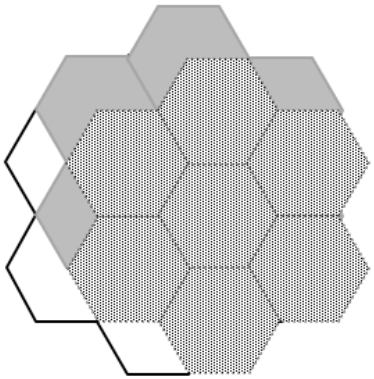
1 tiling



2 tilings



3 tilings



The current Global Relative Calibrations scheme assumes no color terms.

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Color Terms and Global Relative Calibrations (Catalog-level Coadd)

- Variations of the system response will hopefully be quite small (1-2%) across the focal plane (and over time)
- Fit for color terms during nightly calibration and track b_n:

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

e.g., "g-r" — e.g., "$(g-r)_0$"

- Steps:
  1. Initially do not apply the color terms to fields (set $b_n=0$)
  2. Measure and apply field-to-field zeropoint offsets (calczp/GCM)
  3. Apply color terms to fields
  4. Re-do step 2 (e.g., in case there is a cluster of red stars in an overlap region)
  5. Further iteration? (Beware book-keeping!)

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Color Terms and Global Relative Calibrations (Catalog-level Coadd)

Another Method:

- Fit for color terms during nightly calibration:

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

- Apply the color terms to a field as soon as you have:
  - A good measure of b_n for a given CCD (b_n should not change much on daily/weekly/monthly/seasonal timescales)
  - A photometric/calibrated determination of *stdColor* for the objects in that field (this might still require an iteration)
- Let the Global Relative Calibration step only worry about zeropoint offsets and not color terms.
- Caveat: before calczp/GCM step, you could have a mixture of photometric fields with color terms applied and non-photometric fields without color terms applied… could be messy book-keeping…

Color Terms and Global Relative Calibrations (Catalog-level Coadd)

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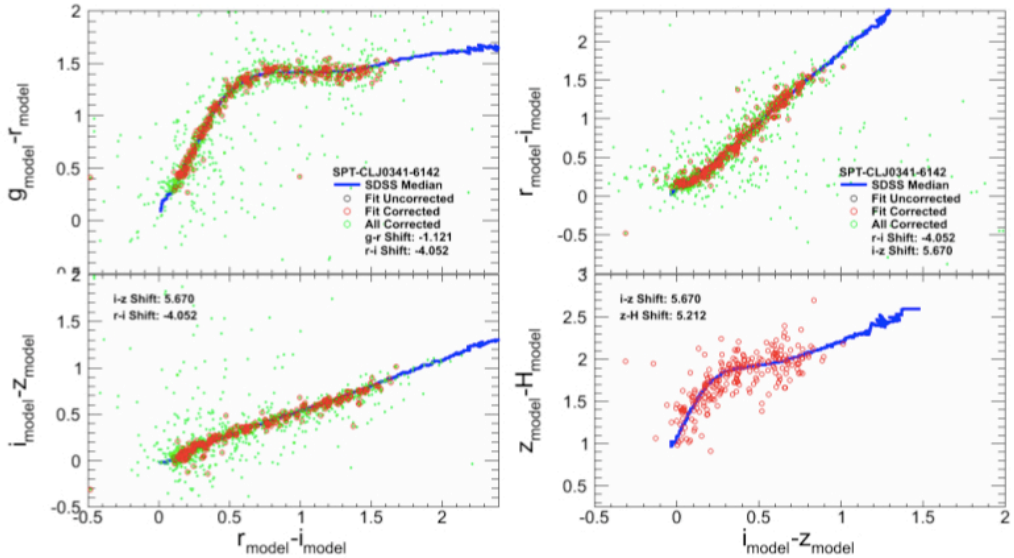
A Third Method:

- Fit data from each CCD image to a synthetic stellar locus based on the response function of the defined DES natural system
  - Fit needs to account for “rotation”/“deformation” of observed stellar locus on CCD relative to the DES natural system due to color terms.
- Need:
  - Stellar spectrophotometric library (e.g., Pickles library, Gunn-Stryker library)
  - The total system response (filter+CCD+optics+atm.) for whatever we define as the DES natural system.
  - More research…



Credit: Bob Armstrong

Spatial System Response Inhomogeneities and the Image-level Co-add

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How to coadd images when there are non-negligible variations in the system response across the focal plane?

- *"In traditional coadds, one averages first and asks questions later. That is, one does the coadd and then attempts a color term correction at the catalog level. It is unclear whether we can get away with this."*
  -- Jim Annis
- If one ignores the spatial variation in the system response function across the focal plane, the photometry in the resulting coadd suffers.
  - Use image coadds for object detection, and (averaged?) single-epoch catalog data for the photometry?
  - Use (x,y) maps of the system response somehow in the image coadds? How?

Spatial System Response Inhomogeneities and the Image-level Co-add

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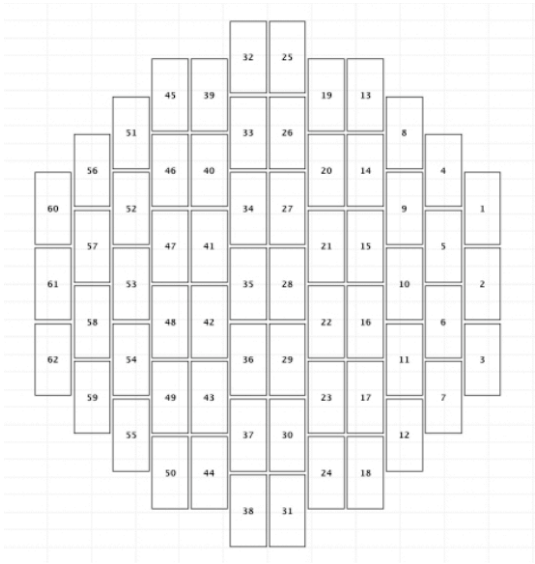
A DECam Science Exposure



Spatial System Response Inhomogeneities and the Image-level Co-add

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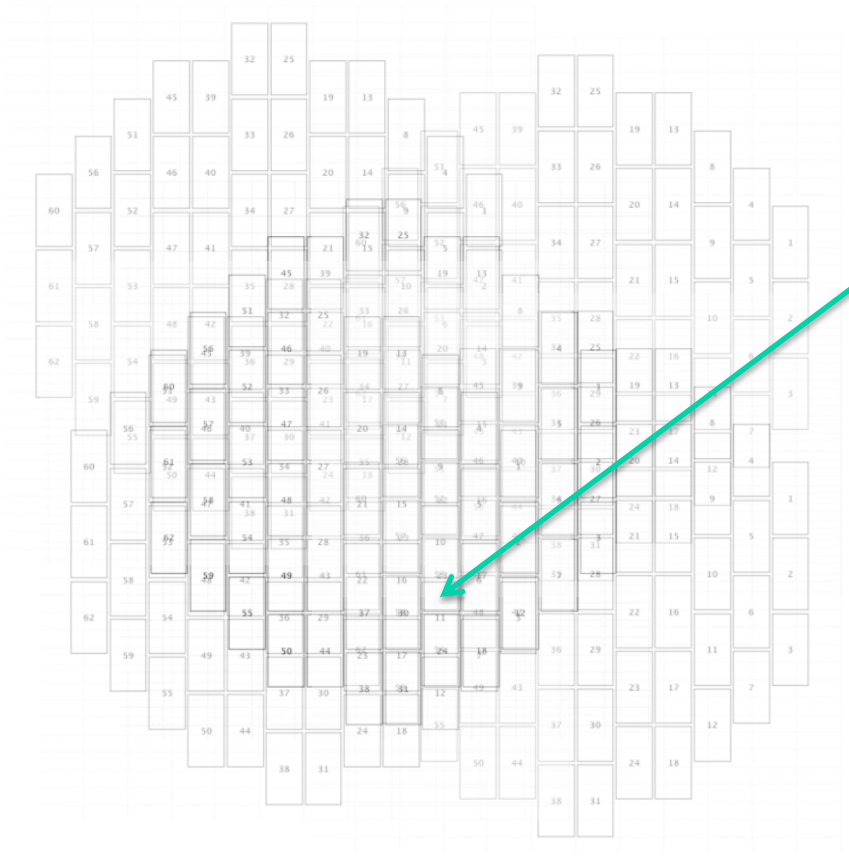
After several overlapping exposures…



Effective color ("b") term for co-add at this point is an average of the single -epoch color terms from all the overlapping CCD images at this point.

Use values of "b" terms from DESDM Photometric Standards Module and/or use synthetic "b" terms calculated from the System Response Map.

(Can we use Mangle to determine which CCDs contribute to a given point, in order to know what values for "b" to average together?)

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Spatial System Response Inhomogeneities and the Image-level Co-add

How to get single-epoch b's?

1. Use the values from the DESDM Photometric Standards Module
   a. These are calculated on a CCD-by-CCD basis using standard stars.
   b. Good first iteration, but, strictly speaking, they are only valid for stars (may need to "tweak" for galaxies, QSOs, and SNe)
   c. Should meet DES photometric requirements even without tweaking (Huan Lin's DES Calibrations Review talk).

2. Calculate synthetic b-terms using total system response (filter+CCD+optics+atm.) and library of spectral energy distributions (SEDs) of the objects to be calibrated.
   a. Filter+CCD+optics response over full DECam focal plane comes from Darren DePoy's system response measuring engine (similar to Chris Stubbs' tunable laser system, but using a bright white light + monochromator instead of a tunable laser as the illumination source.)
   b. Can in principle create a pixel-by-pixel map of b-terms for a given object type (stars, galaxies, QSOs, SNe, sky background). (Could perhaps also do this on a coarser level with the PSMFIT b terms.)
   c. Complicated book-keeping.

Global Absolute Calibration: System Response

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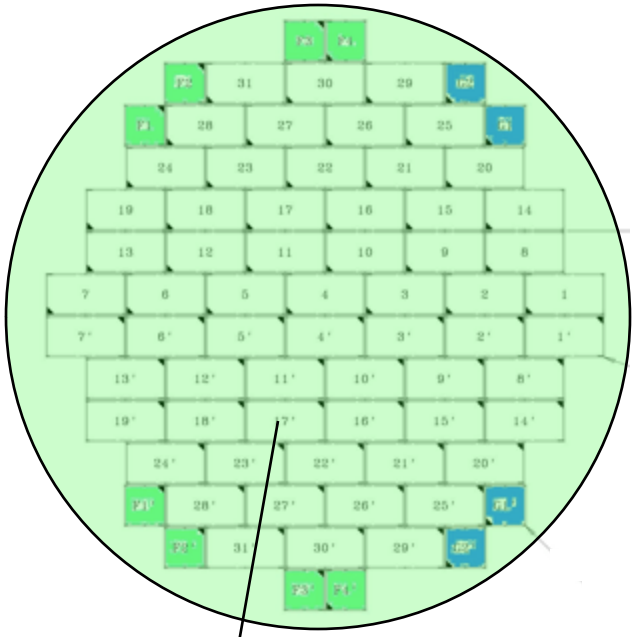
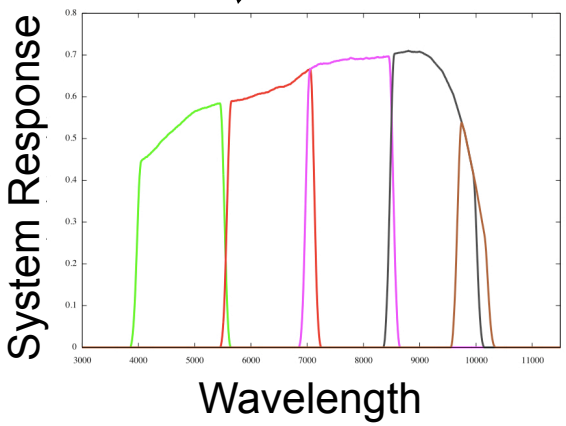


- For the Total System Response, we will combine:
  - the System Response Map of the CCDs +filters+optics nearest in time to the spectrophotometric standard star observations (uses Darren's spectrophotometric calibration reverse monochromator system)
  - a mean seasonal atmospheric transmission curve



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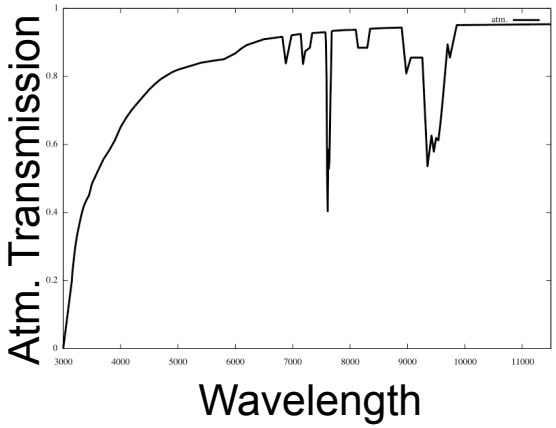

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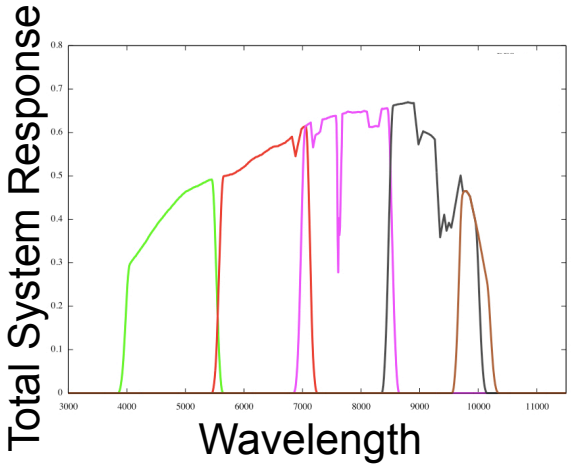

Spatial System Response Inhomogeneities and the Image-level Co-add

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- Still needs thought…

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Extra Slides

Basic DES Observing Strategy

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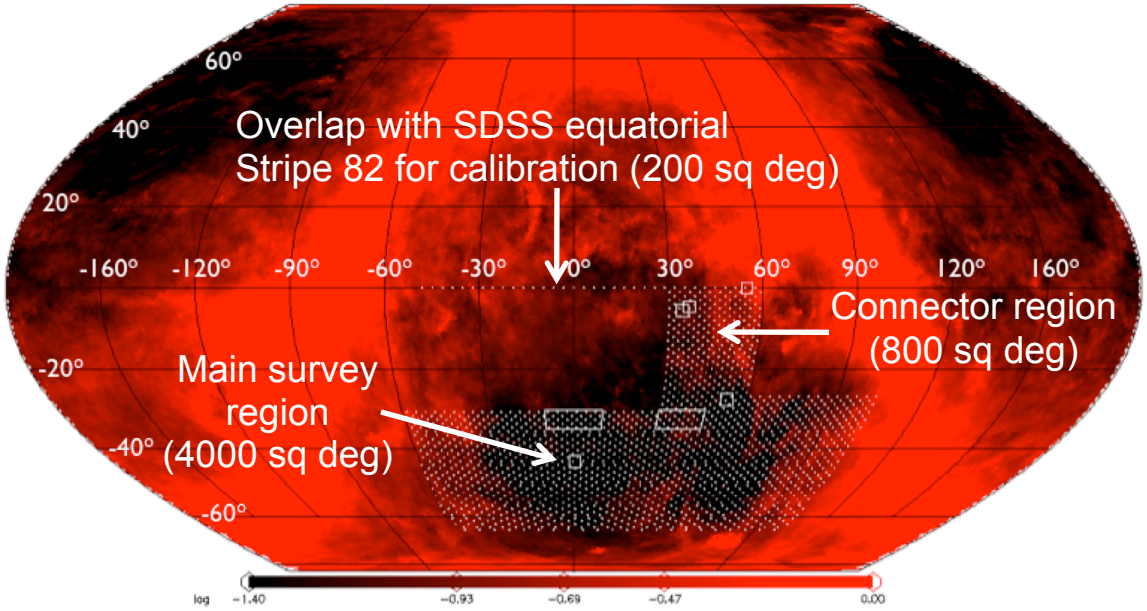
Observing Strategy

- 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
- All-sky photometric accuracy
  - Requirement: 2%
  - Goal: 1%

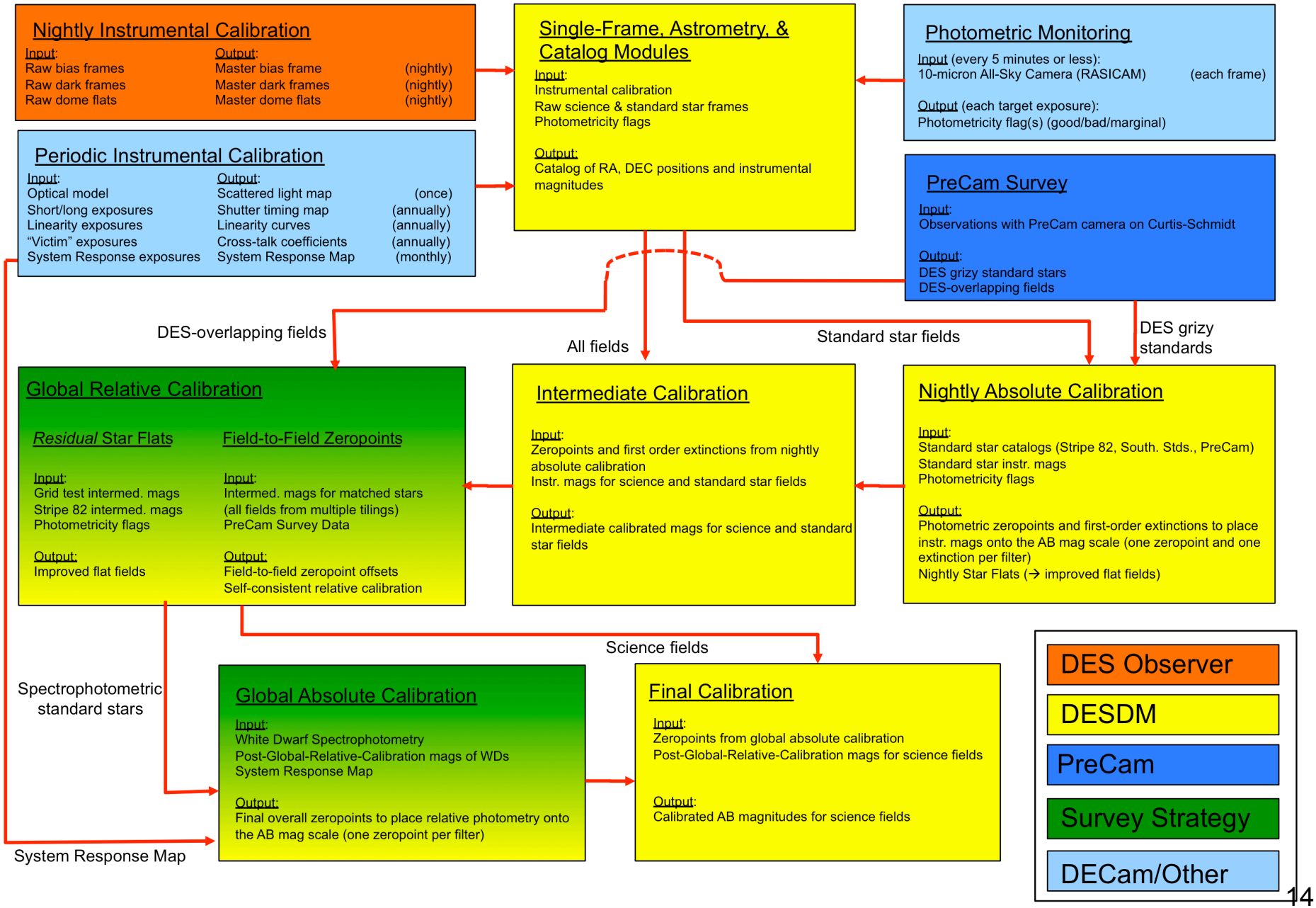
Survey Area

Credit: J. Annis

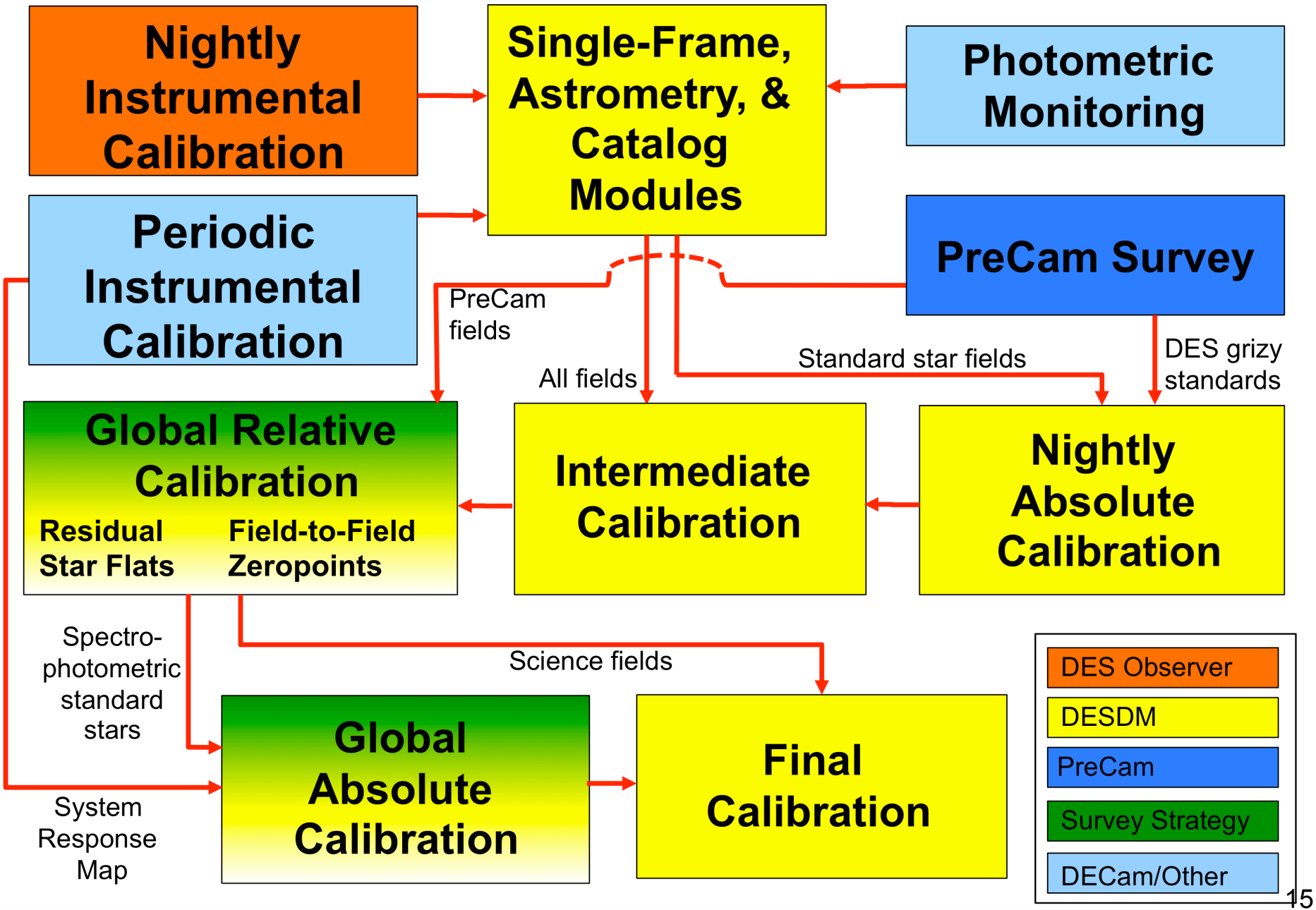


Total Area: 5000 sq deg

DES Photometric Calibrations Flow Diagram (v4.1)



DES Photometric Calibrations Flow Diagram (v4.1)



Periodic Instrumental Calibration: System Response Map

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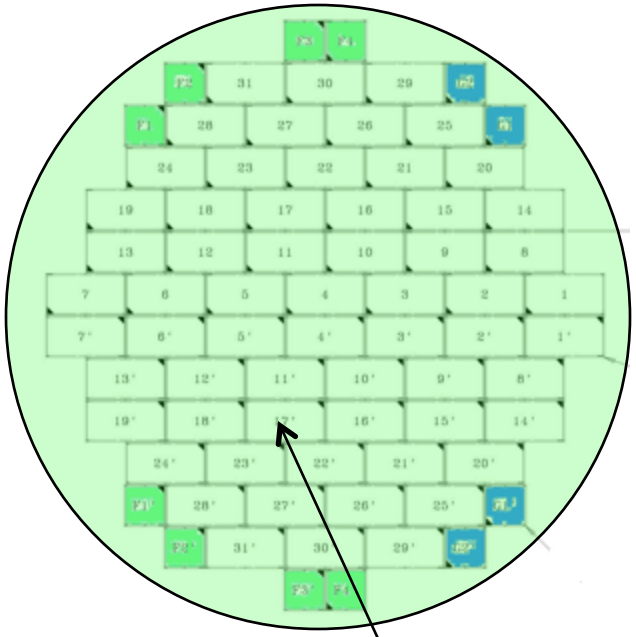

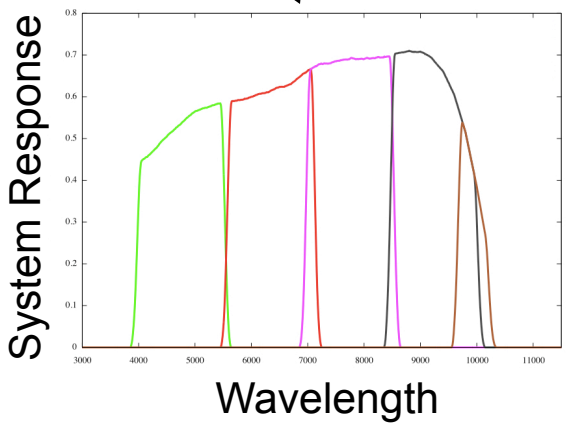

- There may be noticeable variations in the system response across the focal plane due to (1) CCD-to-CCD QE variations, (2) spatial non-uniformities in the coatings on C1-C5 optical elements, and (3) **spatial non-uniformities in the transmission curves of the filters**.
- Therefore, the shape of the system response response function will be a function of position on the focal plane.
- Therefore, the measured brightness of an object will depend on its position on the focal plane and on its color (shape of its spectrum).

  - Important for Global Absolute Calibration, for catalog and image co-adds, for enhanced calibration of specific classes of astronomical objects, and for tracking the system performance over time.
  - TBD: How coarse can the System Response Map be (pixel-by-pixel, CCD-by-CCD, or…)?

Global Relative Calibrations: Field-to-Field Zeropoint Offsets

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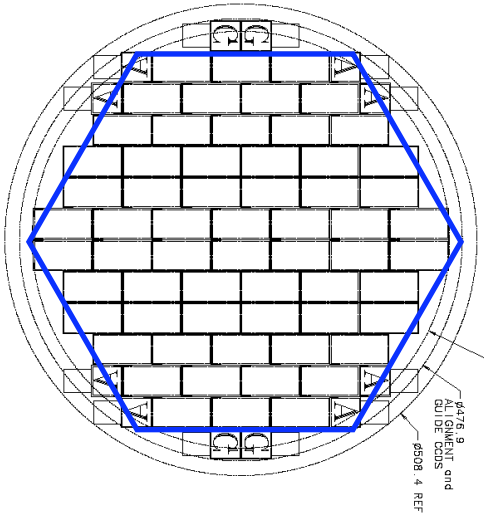
- DES covers the sky twice per year per filter. This is called tiling.
- It takes ~1700 hexes to tile the whole survey area.



DECam Focal Plane: "The Hex"

Recipe:

- Tile the plane
- Then, tile the plane with hex offset half hex over and up
- This gives 30% overlap with three hexagons
- Repeat, with different offsets
- Large overlaps provide very robust hex-to-hex relative calibrations
- Similar to PanStarrs strategy