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	DARK ENERGY SURVEY

Processing pipelines for LSST and its precursor at NCSA (DES)

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and the DES/DESDM Team.



- Evolution of DESDM Processing Model
- SingleEpoch \rightarrow Nightly Quality Assessment
- Coaddition
- LSST



DES Observing Strategy

- 10x90 sec exposures in griz, 10x45 sec in Y for wide-area survey, longer exposures in SN fields
- Bluer (redder) bands in bright (dark) time (the moon is blue)
- Multiple overlapping exposures for photometric calibration ("ubercal")
- Supernova fields when seeing is worse or when they haven't been recently observed
- Overlap with SPT, OzDES, VHS, SDSS, eBOSS, ACT,

DES Footprint



- Total area: 5000 sq. deg
- 10 Supernova fields (2 deep, 8 shallow), distributed within wide-area footprint
- Footprint is overhead at night from Aug.-Feb.



Operations: Pipelines Evolution

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Data Challenge 6B:

- Reduced 10 simulated nights (somewhat idealized)
- Problem: Single epoch processing required ~36-48 hours to reduce 1 night
- Problem: Calibrations, while regimented, required an ideal not generally present in a single nights observing
- Problem: SN pipeline already appeared to require calibrations with ~10 times fidelity achievable for those planned (e.g. 10 flats/band/ night)



Pipeline Parallelism



Crosstalk Block: X pipeline jobs Modules in pipeline: Crosstalk

CreateCor Block: Y pipeline jobs Modules in pipeline: mkbiascor, mkflatcor Note: mkflatcor is repeated for each band

Detrend Block: Z pipeline jobs (Z >> Y) Modules in pipeline: imcorrect

Example for Execution Paths

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Operations: Response to DC6B

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- Calibration requires a careful consideration.
- Pipelines were broken down to components and analyzed.
- Early plans sought to:
 - save intermediates products (analyze to obtain 2nd order calibrations (e.g., Illumination/fringe)
 - Reuse solutions (e.g. WCS) when possible





Astronomy Codes



Year 1 – Year 2 Time Line



- Y1N: nightly firstcut and SN processing
 - With early code changes from SVA1
- Y1P1: coadd of limited area using early Y1N data
- Y1A1: integrate changes from Science Working Groups and based on Y1P1 feedback from LINEA

Year 2/3/? (reality)



Current development is being made without significant feedback from the WGs or collaboration in general!

Again... I strongly propose Y3A1 code freeze at end of observing.



DECam (raw from the telescope)

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CR and Streak Masking

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Current assessment script evaluates each exposure based on single-epoch products. The goal is to determine whether each observations meets basic survey requirements.

Assessment is rendered based on calculation of the effective exposure time:

 $T_{eff} = (0.9 \text{ k / FWHM})^2 (Bkgd_{dark} / Bkgd) (10^{-2 \text{ cloud / }2.5})$ $= F_{eff} B_{eff} C_{eff}$ Current cutoffs used are $T_{eff} > 0.2$ (gY-band) $T_{eff} > 0.3$ (riz-bands)



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> Cloud/extinction measurement is made by comparison of Single Epoch Catalog with respect to APASS (gr-bands) and NOMAD (grizY-bands).



Current comparison with NOMAD is crude (but probably sufficient).



Year 1 (vs. SVA1): Breakdown T_{eff}

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Year 1 (vs. SVA1): Breakdown

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	SVA1		YEAR1	
Time period	11/01/12 - 02/15/13		08/31/13 - 02/15/14	
	# exposures	% accepted	# exposures	% accepted
All bands	10929*	60%	17605*	82%
g	1998	58%	4203	73%
r	2086	53%	2782	90%
i	2281	57%	2916	93%
Z	2375	65%	2965	96%
Y	1608	88%	4738	70%

Toward Release(s)





Y1 Observations Footprint





Y1(Y2?) COADD

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Typical survey Field

SN Deep Field







Y1(Y2?) COADD

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Typical survey Field

SN Deep Field





Y1(Y2?) COADD

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Typical survey Field

SN Deep Field







$\mathsf{DES} \rightarrow \mathsf{LSST}$

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> Telescope Field-of-View Survey Area

Camera Cadence

Raw Data Reduced

Catalog

DES	LSST
4 meters	8 met
π sq-deg	9.6 sc
5,000 sq-deg	18,00

500 megapixels 2 / yr / band

1 TB / night 2.5 PB

6 x 10⁸ objects

8 meters 9.6 sq-deg 18,000 sq-deg

3,200 megapixels ~100 / yr / band

30 Tb/ night Few 100 PB

2 x 10¹⁰ objects



Unspoken Thoughts

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Year 1: Single-Epoch Pipeline Overview

- <u>FINALCUT (Y1A1):</u>
- DECam_crosstalk: overscan, crosstalk, header-update
- Imcorrect: bias, linearity, flat, BPM, pupil, illumination, fringe
- Astrorefine: SExtractor + SCAMP
- Mkbleedmask: mask/interpolate bleed trails, bright stars, supersaturated crosstalk, edge-bleed)
- Maskcosmics:
- Streak-finder: Hough transform search for satellite trails
- create_catalog_modelfit: Sextractor w/ PSF model fitting
- Compress_files
- Photometric Standards Module
- QA assessment



DECam (raw from the telescope)

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Overscan and Cross-talk correction

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Astrometric Solution (Sextractor + SCAMP + UCAC4)



Typically σ=200-250 mas (external)





Bleed & Edge-Bleed Saturated Stars (Y1 included interpolation)

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Bleed & Edge-Bleed Saturated Stars (Y1 included detailed mask)

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CR and Streak Masking

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Detection and Masking of Streaks



Performance:

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~7/15 sec on 2.4 Ghz Core i7 MacBook Pro (includes I/O time)



- Iterate through each pixel of the thresholded image and count how many pixels lie at each possible angle
- Create a 2D histogram in "Houghspace" where lines accumulate as localized over-densities





Single Epoch Cataloging

- PSF modeling through AstrOmatic PSFex (has small issues with brighter-fatter effect in fully depleted CCDs
- Single Epoch model fitting using SExtractor provides single-epoch catalogs
- Currently, detailed analysis/monitoring of PSF (e.g. shape/whisker analysis) is not included
- After Global Calibration Module ~25 mmag rms



COADD

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- COADDITION of single-epoch images requires a global calibration based on single epoch photometry (~25 mmag).
- In Y1A1 an astrometric refinement step was added. Reduces the relative (i.e. internal) astrometric residuals:
- (internal) < 50 mas rms (all bands),</p>
- (external) ~150-200 mas rms (2MASS)

Cataloging is based on a detection image (currently a linear combination of *r*, *i*, and *z*-bands).





COADD

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Y1 (and Y2) depth is nominally 4 exposures per survey pointing.

Due to variations in PSF there are known systematic problems with PSF magnitudes. MAG_AUTO and MAG_APER are likely better choices for science in the near-term.

Detailed QA of COADDs has been implement within the Brazil Portal (see talk by Luiz de Costa).









Current Y2 pipeline upgrades

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- 1. Add Brighter/Fatter
- 2. Reorganize detrending to accommodate PCA template sky fitting.
 - Likely change from ADUs to electrons
- 3. Revamped handling of weights
 - carry ALL weights forward and adjust based on mask prior to steps that make measurements
- 4. More detailed masks that reflect artifacts that may be tolerated for some measurements...
- Framework/orchestration enhancement to improve throughput on OSG type compute resources
- Detailed provenance tracking
- Direct incorporation of afterburner production (extinction, Mangle, etc...) into COADD pipelines.



Unspoken Thoughts

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Detail level #2: The mask (right) does not capture the diffraction/edge-bleed spikes in the actual image (left):



Figure 1: Example of coadd image features in the i band DES2327-5248 image with companion mask.

Todo for Y1A1: Make the masks reflect this edge bleed effect. 5/27/15

Issue (Galaxy Clusters Group): Odd appearance of non-stars in grid like pattern (image boundaries).



Suggests poor modeling of PSF across coadd tile...possible astrometry problem.