Using Coadds for Photometry and Shear

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Outline

- Introduction to coadds: pros and cons
- Mitigating issues with coadds
  - Kaiser coadds
  - Coadd the PSF
  - Single-object coadds to deal with additional PSF issues
  - Dealing with correlated noise
- Simulation tests
  - Noise tests
  - Shear bias tests
- Future Work

Coadds: pros

- Large data compression: factor of about 100 for LSST
- Corresponding speed up for analysis
- Simplifies analysis, don't need to do multi-epoch fitting
  - But do still want simultaneous multi-band fitting. In DES we found this improves S/N significantly

Coadds: cons

- The variance of quantities derived from standard coadds is generally higher than those calculated using a multi-epoch fitting approach
- The PSF, noise, etc. discontinuous in the coadd at the location of edges in original images
- The noise is correlated in standard coadds due to interpolation

Example of Increased Variance

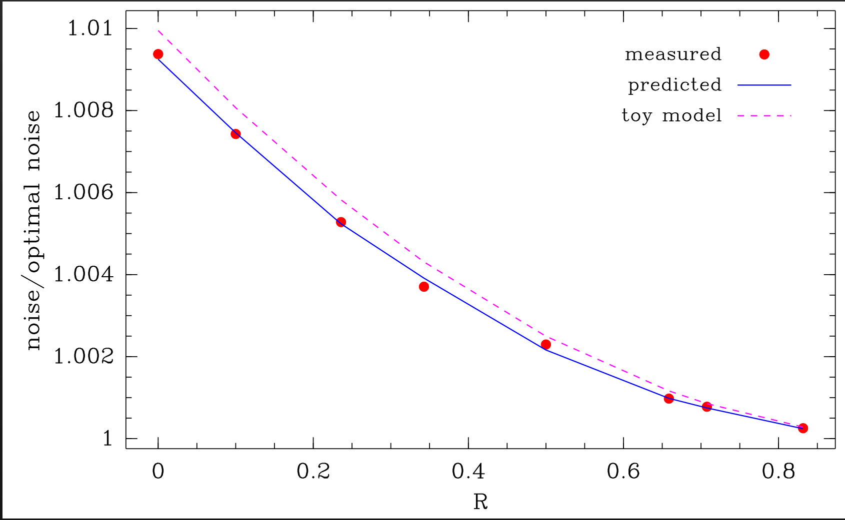
- Template flux, just fitting for an amplitude A
- We can calculate directly the increased variance
- Can also calculate a toy model with Gaussian PSF and object, assume Gaussian final image (Sheldon, Armstrong, Huff, et al. in prep)

$$\mathrm{var}\hat{A}_{\mathrm{coadd}} = \mathrm{var}\hat{A}_{\mathrm{me}} \left[1 + 2(1-R)^2 \left(\frac{\Delta\sigma_p}{\sigma_p} \right)^2 \right] \tag{1}$$

- g marks the object and p the PSF
- $R = \sigma_g^2/(\sigma_p^2 + \sigma_g^2)$ is 0 for stars, 1 for huge galaxies

Fluxes: comparison of formula with simulation

$\Delta\sigma_p/\sigma_p = 0.10$



(Sheldon, Armstrong, Huff, et al. in prep)

Mitigating increased variance: Kaiser Coadds

- For LSST, we expect a very minor increase in variance ($< 1\%$).
- For surveys with large seeing variation, we might care more.
- Kaiser derived a more optimal coadd for which there should be no increase in variance
- However in DES and LSST we currently use standard coadds
- From here on all the tests I show will be for standard coadds

Mitigating PSF issues: single-object coadds

- Overcome some discontinuities by coadding the PSF reconstructions also (e.g. SDSS coadd, Annis et al. 2011)
- However if an object straddles an image boundary in one of the epochs, the PSF will still not be correct
- Solution is single-object coadds: make a coadd for each object separately, only including epochs where the object does not straddlean edge (I heard the idea first from Jim Bosch)

Mitigating correlated noise issues

- Not a big problem for fluxes, but causes a bias for shear measurement
- One can whiten the noise, but in my experience it results in a significant increase in noise
- (Kaiser claims no loss of information if done correctly, but I don't understand this yet)
- Alternatively: determine the covariance and use it in analyses
  - Run noise images through the coadd process also
  - Feed this noise image into METACALIBRATION
  - For BFD, measure a covariance matrix and use it when calculating moments. Moments only taken once in BFD, so this is feasible.

Simulation Tests

- Tested realistic galaxy size and flux distribution, as well as fixed size and flux (to isolate any increase in noise).
- DES-like seeing distribution.
- Used typical DES WCS variations, including translations.
- Also ran tests with random rotations like in LSST.
- Ran in full multi-epoch mode and coadd mode.
- Blame: Coadd code by Armstrong & Sheldon. Simulation and METACALIBRATION code Sheldon. BFD code Bob Armstrong.

Increased shear variance

- Fixed galaxy size and flux to isolate variation in noise.
  - Want to avoid selections needed for realistic distributions: With correlated noise, quantities used for selection, such as S/N, are different
- DES-like seeing and PSF ellipticity distribution.
- METACALIBRATION for the smallest galaxies we would use ($T/T_{\mathrm{PSF}} = 0.5$) and typical $S/N = 15$ the noise in the recovered shear increases by

$$(0.65 \pm 0.02)\% \tag{2}$$

- BFD (B. Armstrong) Not sure exactly what size/flux distribution was used. Reported noise of 0.0007 for both (need an error bar)

Increased shear bias

- Realistic size and galaxy flux distribution. DES-like seeing and PSF ellipticity distribution.
- METACALIBRATION

$$m = (0.56 \pm 0.36) \times 10^{-3} \tag{3}$$

(expect $\sim 0.25 \times 10^{-3}$ due to breakdown of weak shear approximation)

- BFD (B. Armstrong)

$$m = (1.2 \pm 0.7) \times 10^{-3} \tag{4}$$

Future Work

- In DES edges are important due to the low number of epochs (~ 10).
- We need to create a code for the single-object coadds and corresponding PSF coaddition. May be able to work this into the MEDS maker. Need to run noise images through as well for correlated noise.
- For LSST exposures will be rotated randomly: coadds need to be done on the full images, or very large initial postage stamps, to avoid artifacts in the "corners".
- However, for LSST edges are less of a problem due to the large number of epochs (~ 100). It would be good to test in simulations if we need the single-object coadds at all.