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EDGY COADDS

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ABSTRACT

Abstract here

1. INTRODUCTION

Intro here.

2. SIMULATIONS

We used two different simulations in this work. The first, which we call the realistic simulation, was a simulation of the full LSST focal plane, with semi-realistic PSF, galaxies and CCDs, noise and random sky pointings. Edges appear in the coadds naturally as part of the pointing pattern and camera geometry. These simulations should be similar to what we expect from real data.

The second simulation type, which we call the simple simulation, had fixed galaxy morphology, low noise, a simpler PSF model, and edges that were randomly inserted into the images with the desired statistical properties. This simulation does not reflect real data, but is useful for isolating any sources of bias.

We describe each simulation in more detail below.

2.1. *Realistic Simulations*

2.1.1. *Realistic Simulation Features*

The realistic simulations modeled a full LSST camera focal plane with 189 science CCDs and pixel scale 0.2 arscec. [ESS TODO: **show focal plane**]

The PSF for the realistic simulations was modeled as three separate components: an atmosphere, the optics, and local diffusion effects on each CCD.

For the atmospheric part of the PSF, we used the "power spectrum psf" from the `descwl-shear-sims` package (Sheldon et al. 2023). This PSF was tuned to have mean FWHM of 0.625 arcsec. [ESS TODO: **More description needed**].

The optical part was inspired by the realistic optical PSF produced by `imSim` package [1]. The spatial variations are modeled using order 6 Zernike (TODO cite) polynomials, constrained to have circulare symmetry. The profile is modeled as an elliptical Moffat (Moffat 1969). The model was tuned to give a mean FWHM of bout 0.35 arcsec. [ESS TODO: **show image, more description**]

Finally, each CCD was given a random gaussian diffusion kernel, with FWHM drawn from a normal distribution with mean of 0.2 arcsec and $\sigma = 0.02$.

These three PSF components were tuned to provide a mean seeing FWHM of approximately 0.8 arcsec and variations $\sigma = 0.06$ arcsec, similar to `imSim`. Note, due to the non Gaussian shape of the optical and atmospheric profiles, the individual FWHM quoted above do not add quadratically to give 0.8

For galaxies we used the models provided by the `WeakLensingDeblending` package (Sanchez et al. 2021)[2] [ESS TODO: **More description needed**]. We did not include stars in the simulation.

We used a sky background levels modeled to mimic the sky distribution expected for the LSST i-band data (TODO cite and show histogram)

We mimicked the LSST imaging survey by generating pointings across a region of sky with a specified density. For each simulated pointing observation, the camera geometry was orientated randomly to mimic rotational dithers.

2.1.2. *Realistic Simulation Images*

The year 10 LSST survey will have approximately 300 images at each point in the survey for the combined primary lensing bands (r, i, z). To produce a full set of such images, remap (a.k.a warp) them onto a common grid and coadd them would be prohibitively expensive.

However, we can make a number of reasonable approximations to speed up the simulations. We know from previous work that the warping and coadding process does not produce any bias for METACALIBRATION or METADETECTION (Armstrong et al. 2024; Sheldon et al. 2023). Warping does not need to be part of this test. As warping is the slowest part of the coadding process, we can save significant computing time by instead drawing directly into a coadd image.

We know that the detection process itself is well calibrated by METADETECTION (Sheldon et al. 2020, 2023), as is blending of multiple objects. Furthermore, shear dependent detection biases are significantly reduced compared to measurement biases (Sheldon et al. 2020). We expect that biases due to edges will also be reduced for detection compared to shear measurement. We thus avoid creating full images and focus on drawing small "postage stamps" for each galaxy with PSF and noise corresponding to the input observations. Choice of the postage stamp size for each object is left to the drawing code in `GALSIM`.

Each postage stamp image was given the same shear $\gamma = (0.02, 0.00)$.

[ESS TODO: **show histograms of various quantities**]

2.2. *Simple Simulations*

[1] https://github.com/LSSTDESC/imSim

[2] https://github.com/LSSTDESC/WeakLensingDeblending

The simple simulations employed a configurable but fixed galaxy profile with variable PSF and low noise. The galaxy was modeled as a round exponential profile with half light radius and flux chosen to provide high signal-to-noise ratio in the coadd. The half light radius was varied to examine how PSF errors propagate into the shear measurement as a function of galaxy size.

The PSF was modeled as an elliptical Moffat profile, with FWHM drawn from a truncted lognormal distribution (lower limit of 0.6 arcsec). The width of this was varied as part of the tests. The ellipticities were drawn from a truncated ($|e| < 1$) isotropic gaussian in e_1, e_2, with $\sigma = 0.02$.

As with the realistic simulations, postage stamps were used rather than full images, and each image was given the same shear $\gamma = (0.02, 0.00)$.

2.3. *Coadding and Edges*

We wish to produce a coadd of input images for analysis with METADETECTION. In the realistic simulation, the geometry of the CCDs and pattern of pointings on the sky result in non-uniform coverage and thus edges will naturally appear in the coadd images.

For the simpler simulation, we produce edges randomly with some specified probability, which is subject to experimental variation. We generate the edges by randomly choosing a line passing through the input image, possibly with an angle to represent camera rotations.

We used a weighted mean to produce coadds

$$C_{i,j} = \frac{\sum_k I_k(i',j') w_k(i',j')}{\sum_k w_k(i',j')} \tag{1}$$

where $C(i, j)$ specifies the pixel value in the output coadd, $I_k(i', j')$ specifies the pixel value in the observation to be added, and $w_k(i', j')$ specifies the weight assigned. If the coadd pixel i, j is not covered by the observation, a zero value is for the weight.

The above will result in a discontinuity in the properties of the coadd, such as the noise and PSF, when there is an edge. Thus a single PSF does not describe the image.

However, we need a single PSF estimate in order to perform the lensing analysis, which involves a choice of which PSFs from individual observations should be included in the PSF coadd. We choose to add the full PSF image from the input observations if the central pixel of the postage stamp coadd is covered by the observation. We exclude the PSF image from the coadd if the central pixel is not covered by the observation.

We expect that this PSF will be an adequate description of the PSF in the coadded postage stamp in the limit of a large number of input images or small variations of the input PSFs. In the limit of an infinite number of input images, a fair sampling of the PSFs is always available, and thus the final PSF can be made arbitrarily accurate. Similarly, in the limit of no PSF varations, any subset is a fair sample and the PSF will be accurate. In this work we will explore where these limits.

3. RESULTS

4. SUMMARY

Summary here

ACKNOWLEDGMENTS

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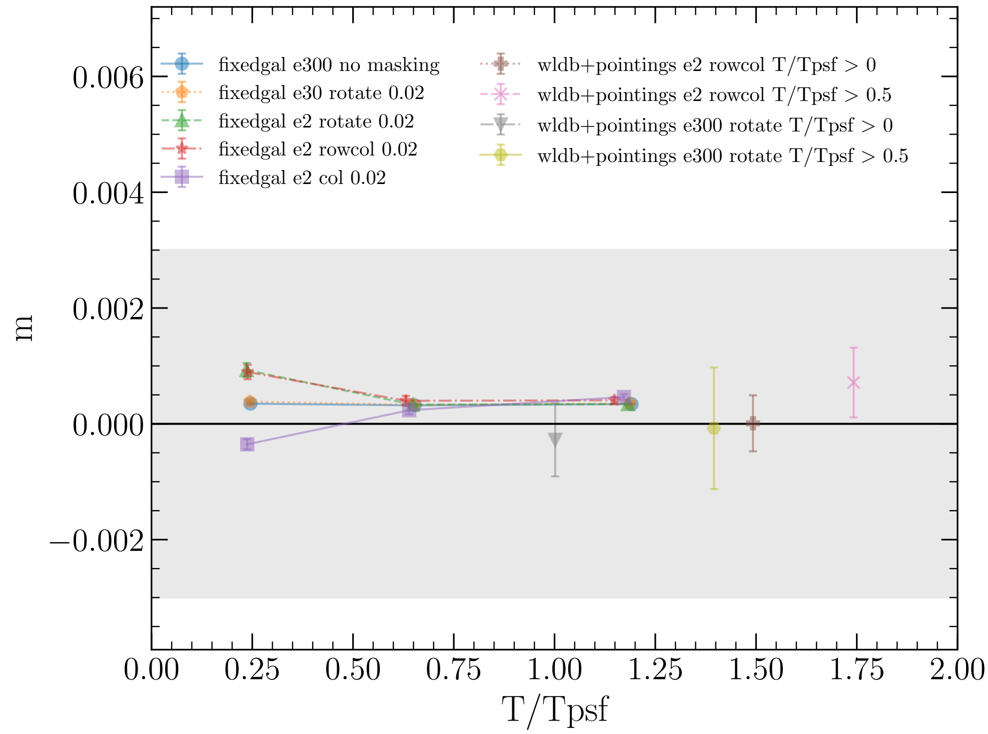

FIG. 1.— Multiplicative bias m as a function of area ratio T/T_{PSF} for various simulation settings. `e2` means two epochs, `e30` means 30 epochs etc. `fixedgal` is the fixed exponential model. Each point has a fixed size galaxy. `wldb+pointings` is the realistic simulation. `rotate` means the input images were rotated randomly, so edges are not purely in the row or column direction. `rowcol` means the images were not rotated. `col` means the edges were only allowed to be present in the column direction. For the fixedgal simulations, the area ratio is constant, whereas it varies for the realistic simulations.

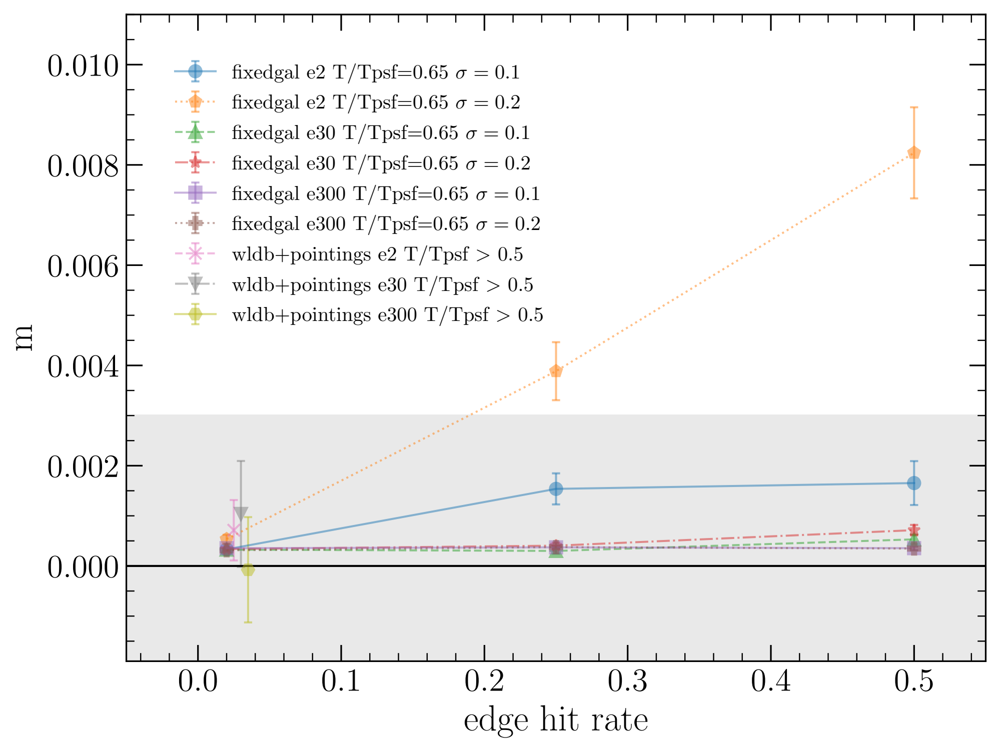

FIG. 2.— Multiplicative bias m as a function of the rate of edge hits in the coadd for various simulation settings. The `wldb+pointings` are artifically offset for clarity.