Biased Moments of Undersampled Sources

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ABSTRACT: Spatial intensity moments computed on images can be used as a probe of the centroid, size, and orientation of an object. However, all measurements made on finite pixels suffer from errors due to undersampling. We show examples of these biases from lab measurements, simulations, and survey data.

RESULTS: We find several systematic errors relative to the pixel grid. Preference for centroids near the pixel center is common among both measurements and simulations of ^{55}Fe data and spots. Sizes measured via adaptive moments are also biased by sub-pixel location. Orientations computed from biased moments show a predicable angular preference.

METHOD: We present undersampling errors using several measurements typically assumed to be invariant: the sub-pixel distribution of object centroid and size and the invariance of object orientation. We illustrate the centroid and size bias using LSST stack measurements of Iron-55 photoelectron images and re-imaged sub-pixel Airy disks, as well as physics-based simulations of both. Centroid and shape measurement is provided via two LSST Stack methods: '*base_SdssCentroid*' and '*base_SdssShape*', which estimate bias-corrected centroids and adaptive moments, respectively. Orientation bias is shown using similarly-measured adaptive moments of elliptical Gaussians which mimic the ellipticity and orientation distributions seen in a variety of public surveys.

DISCUSSION: Undersampled sources need modeling to measure un-biased centroids, sizes, and orientations. Simulation of the observations and measurements can aid in the calibration of these nuisances and development of specialized algorithms. With un-biased measurements of undersampled sources in hand, further investigation of sub-pixel imperfections and astrophysical inaccuracies will be possible.

REFERENCES:

J. Bosch et al, HSC software pipeline, PASJ 2018, arXiv:1705.06766

R. Lupton et al, SDSS Photo Pipeline (lite)

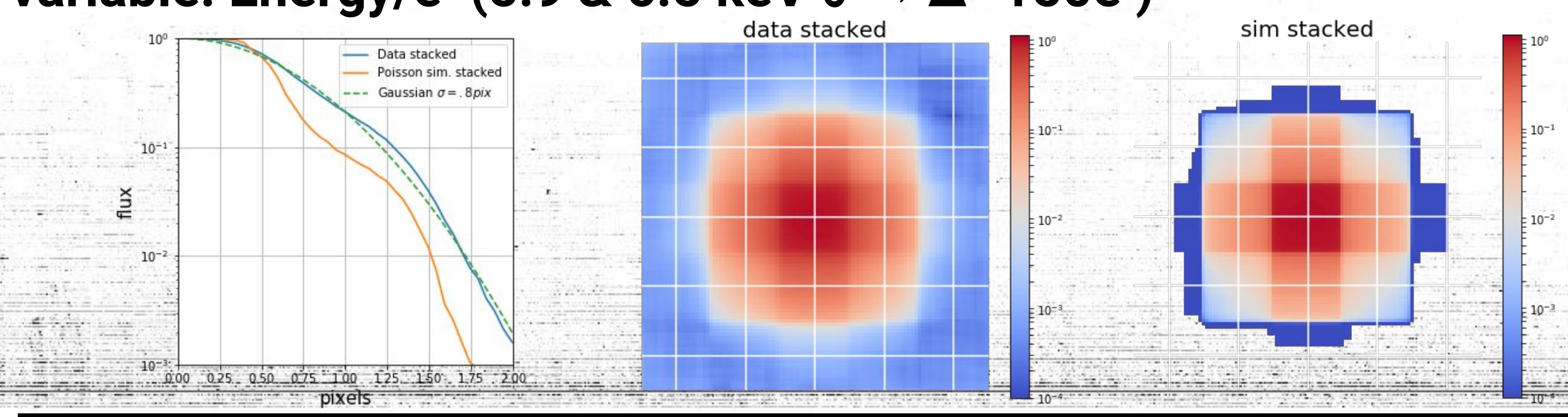
C. Teh, R. Chin, On digital approximation of moment invariants, CVGIP 1986, doi

J. A. Tyson et al, LSST optical beam simulator, SPIE 2014, arXiv:1411.5667

Iron-55 (^{55}Fe)

σ = sub-μm e^- cloud + diffusion < 10μm

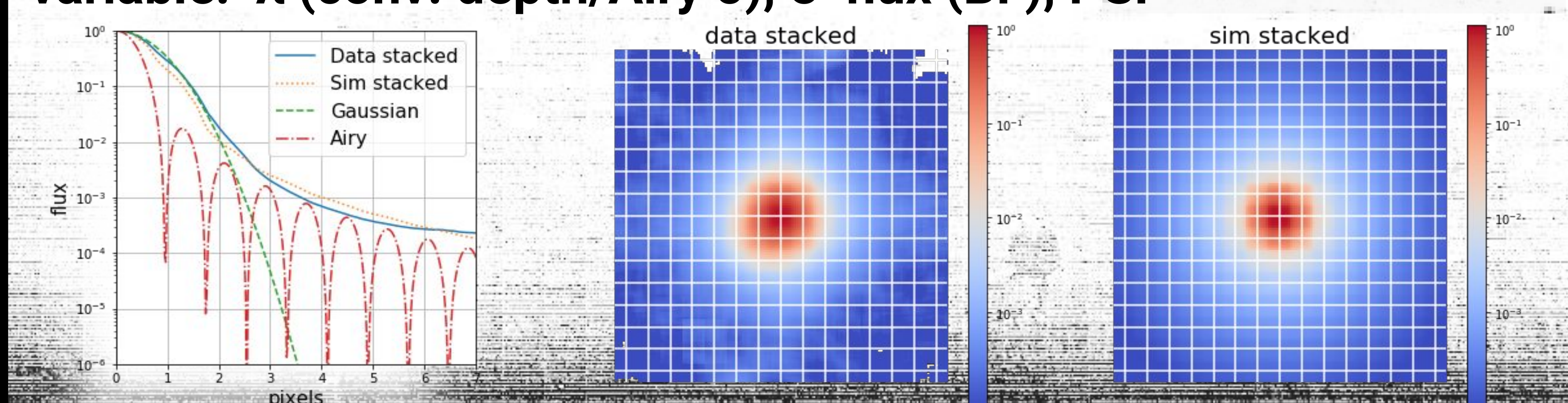
variable: Energy/e^- (5.9 & 6.5 keV ɣ → Δ~150e^-)



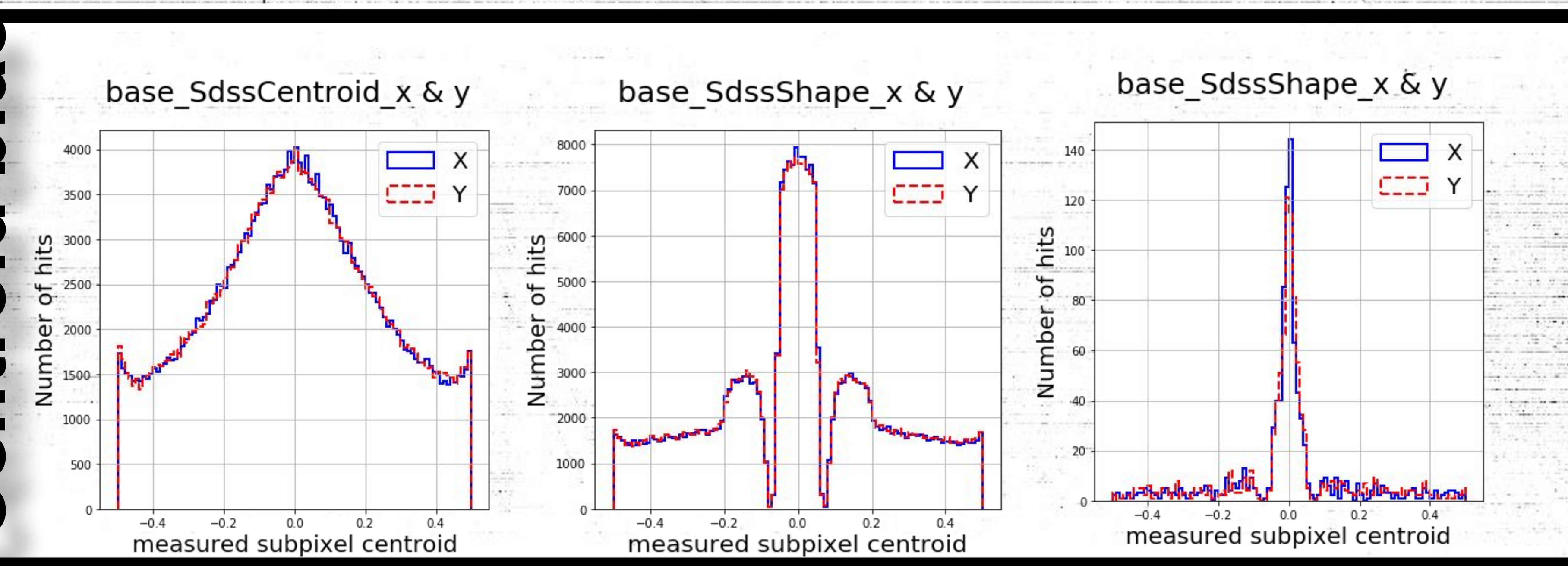
3μm pinholes

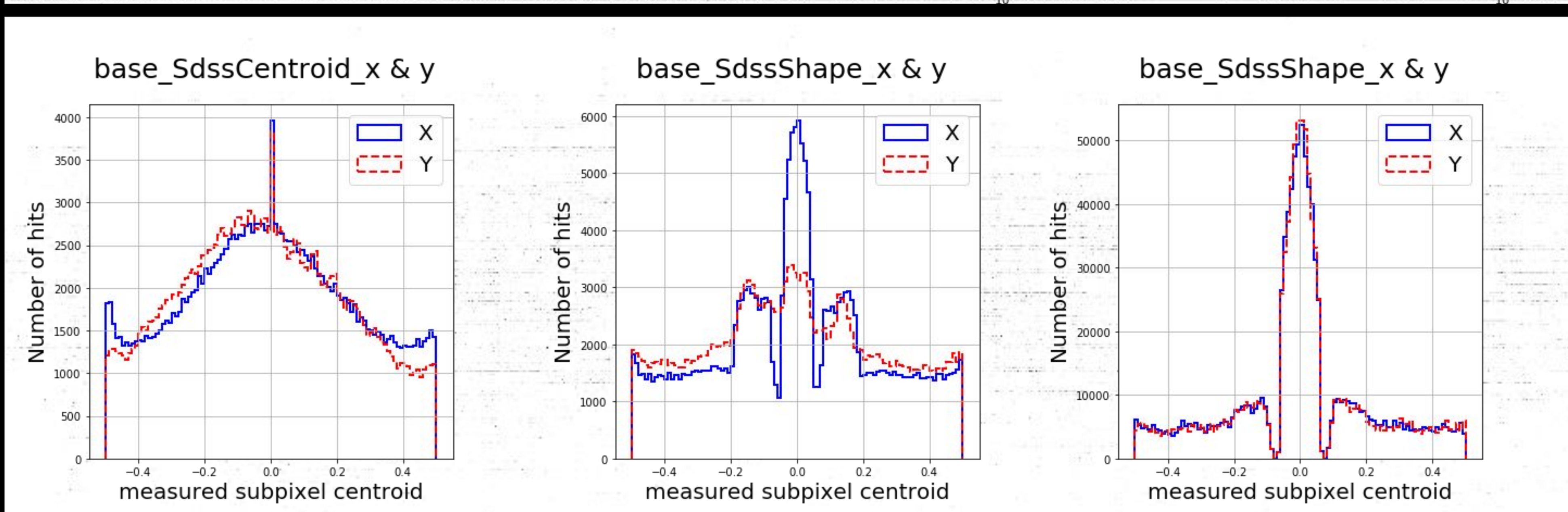
σ = 3μm Airy disk + diffusion + PSF < 10μm

variable: λ (conv. depth/Airy σ), e^- flux (BF), PSF

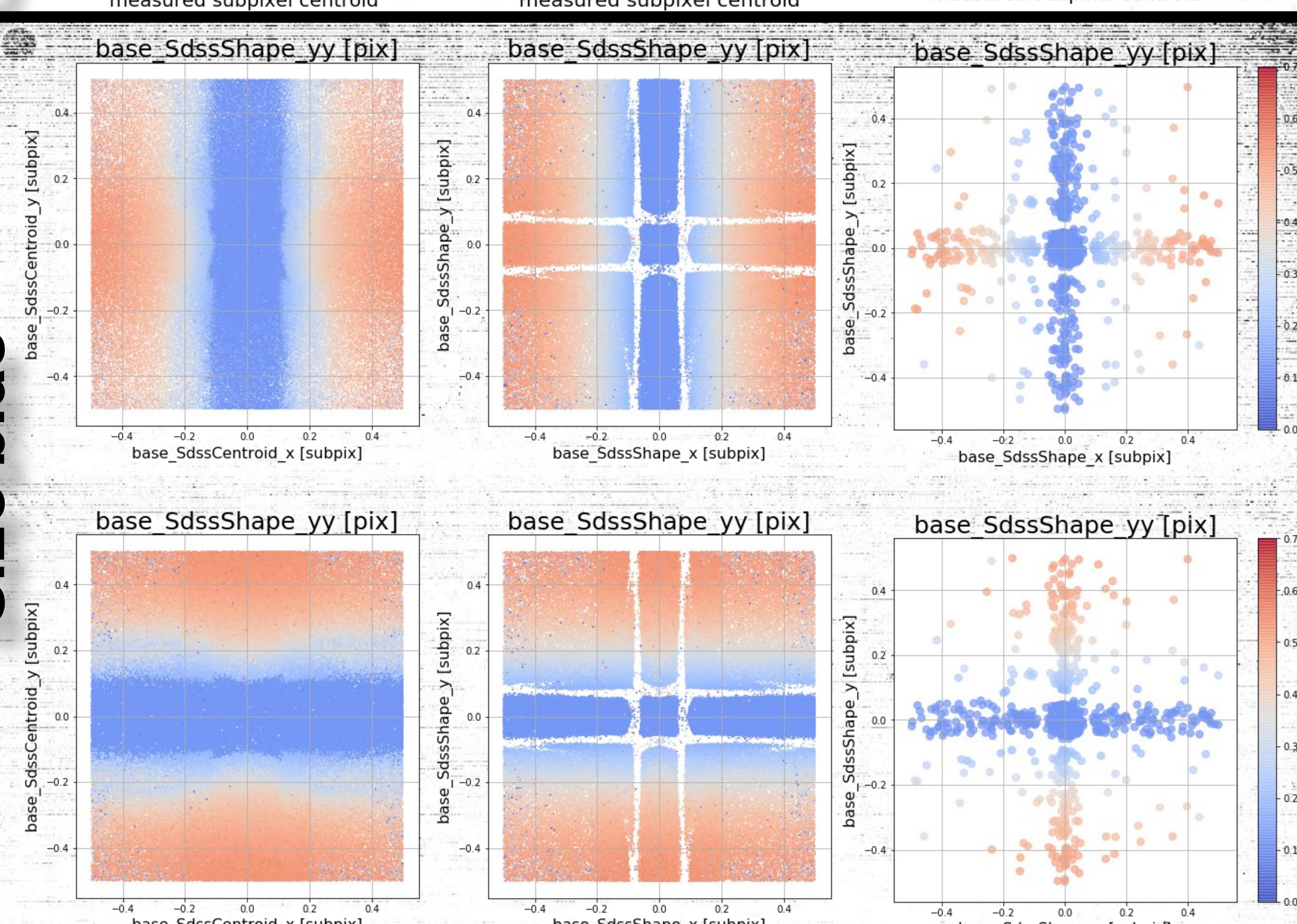


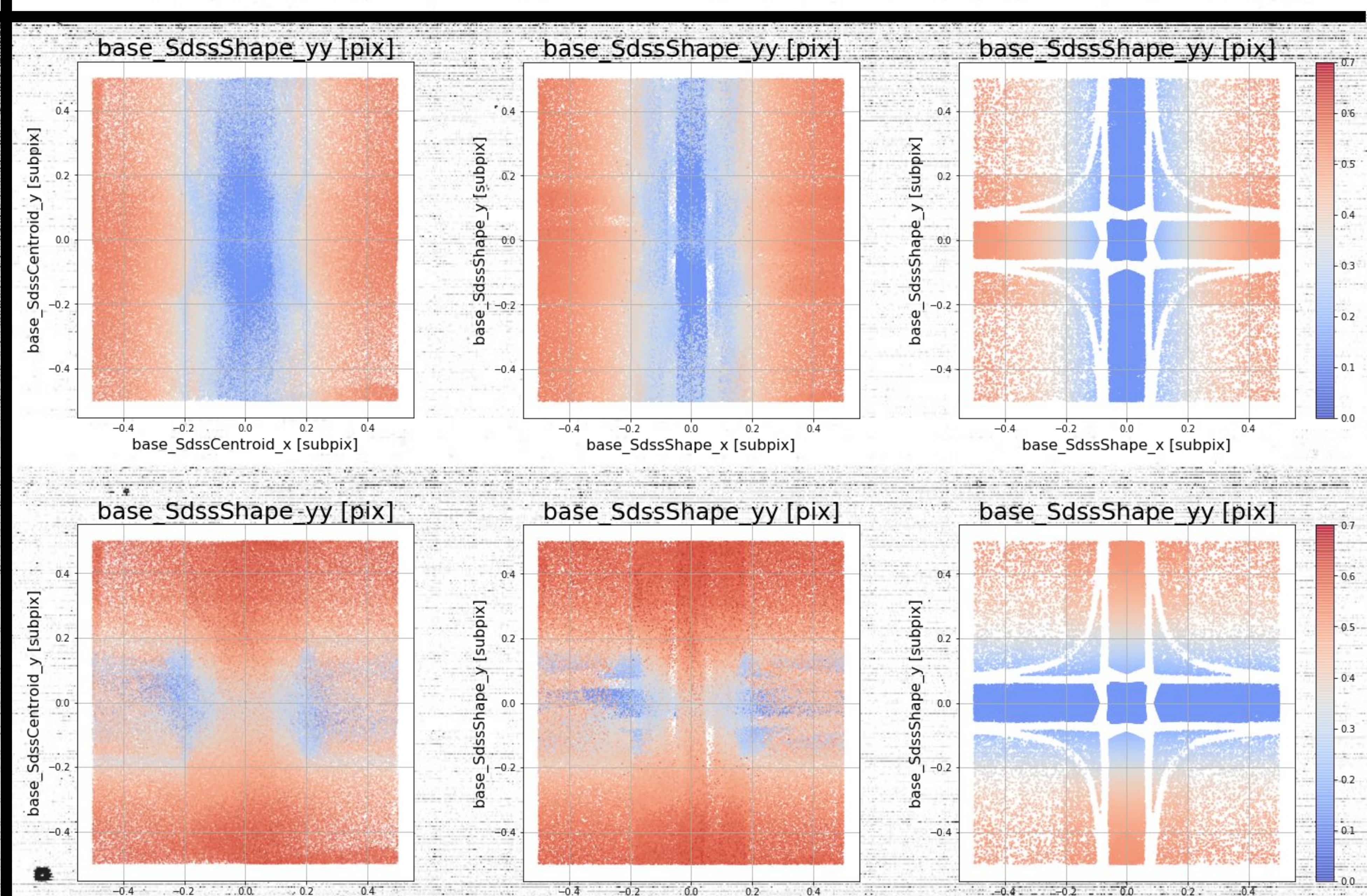
Centroid bias





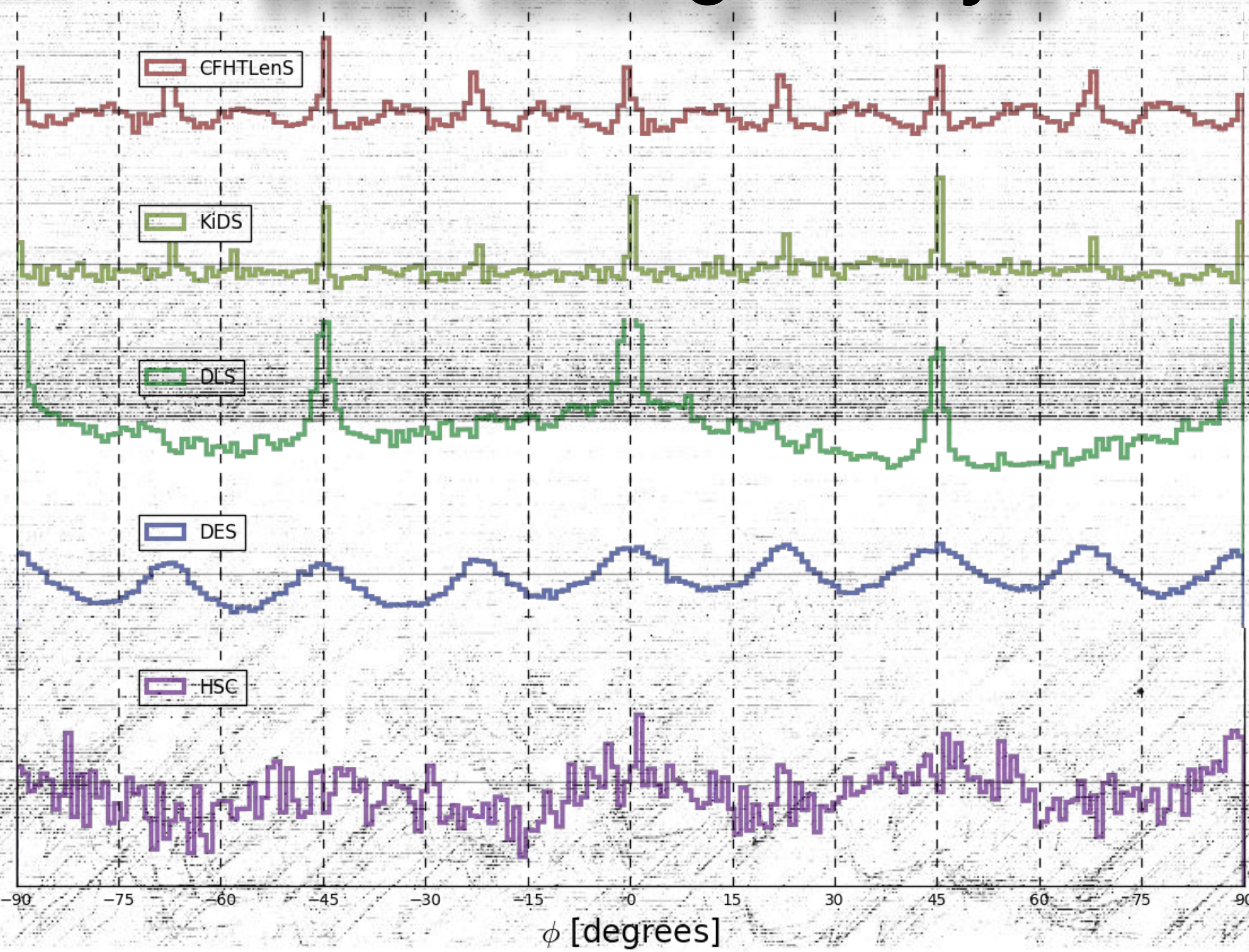
Size bias





Orientation bias

Weak lensing surveys



Gaussian simulation