PSF Modelling Errors for LSST

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Introduction

With the increase in precision and statistical power of LSST [1] measurements over previous surveys, systematic issues become more important to be well-corrected. Errors in PSF modelling can obscure the weak lensing shear signal by creating an additive bias due to incorrectly modelling the PSF shape, and a multiplicative bias due to incorrectly modelling the PSF size [2]. We study the effect of incorrectly modelling the PSF on the weak lensing signal and shear-shear correlations functions.

Method

We start by **(a)** generating a random star field in Right Ascension and Declination, in a large area the LSST covers in full depth, **(b)** finding all the LSST dither positions for a set constraint of time, RA and dec. **(c)** at each of those dither positions, we generate a realistically-motivated toy model of the star elipticities, PSF model, and the residual.

All of these are the same radial model differing only in magnitude, with the elipticities increasing towards the edges of the focal plane (qualitatively observed in recent surveys [3]. **(d)** We then study how the PSF modelling errors average down. We do this in 2nd moment space, where those moments add linearly, as follows:

From our model, we get, for small ω:

$$\Delta e_1 = \omega e_1^{PSF} = e_1^* - e_1^{PSF},$$

$$\Delta e_2 = \omega e_2^{PSF} = e_2^* - e_2^{PSF},$$

and σ^*, σ^{PSF}

By definition:

$$e_1 = \frac{M_{xx} - M_{yy}}{TrM}, \quad e_2 = \frac{2M_{xy}}{TrM}$$

$$TrM = M_{xx} + M_{yy} = 2\sigma^2$$

Moving into moment space, we get:

$$M = \frac{TrM}{2}\begin{bmatrix} e_1 + 1 & e_2 \\ e_2 & -e_1 + 1 \end{bmatrix}$$

We then take the arithmetic mean of M and move back to ellipticity-space. Although we use a toy model, the code can easily be ran through other, realistic models once they are available.

Analysis

Using this model with <e> ≈ 0.06, <Δe> = 0.03 <e> ≈ 0.0018, and FWHM= 0.7" (expected for LSST [4])

We use the ρ-statistics [5] to quantify the effect of the PSF modelling errors on the shear-shear correlation function.

$$\delta\xi_+(\theta) = 2\left\langle \frac{T_{PSF}}{T_{gal}} \frac{\delta T_{PSF}}{T_{PSF}} \right\rangle \xi_+(\theta) + \left\langle \frac{T_{PSF}}{T_{gal}} \right\rangle^2 \rho_1(\theta) - \alpha \left\langle \frac{T_{PSF}}{T_{gal}} \right\rangle \rho_2(\theta)$$
$$+ \left\langle \frac{T_{PSF}}{T_{gal}} \right\rangle^2 \rho_3(\theta) + \left\langle \frac{T_{PSF}}{T_{gal}} \right\rangle^2 \rho_4(\theta) - \alpha \left\langle \frac{T_{PSF}}{T_{gal}} \right\rangle \rho_5(\theta)$$

Where: $\rho_1 = \left\langle \delta e^*_{PSF}(x)\ \delta e_{PSF}(x+\theta) \right\rangle$

$$\rho_2 = \left\langle e^*_{PSF}(x)\ \delta e_{PSF}(x+\theta) \right\rangle$$

and assuming (for now) no PSF size modelling error means $\rho_{3-5} = 0$.

We use a 200°x50° slice of the `minion_1012` OpSim run (WFD only) with hex-dithers by default. Fig 1 compares these measurements. LSST estimated requirements are from rescaled HSC requirements [6] to account for the area difference.

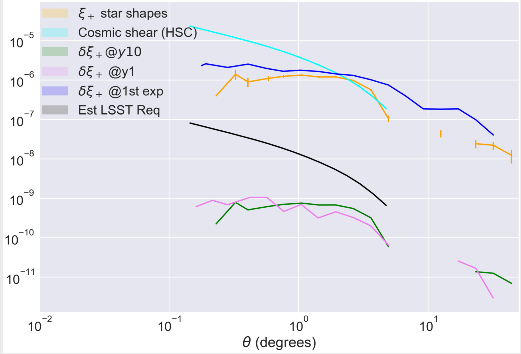

Fig 1. Comparison between PSF modelling errors, star shapes correlations, cosmic shear and estimated LSST requirements (from HSC)

Next Steps

- ✦ Test this for:
  - ✦ Other dither patterns (including rotational)
  - ✦ Other PSF models (including more realistic ones once they're ready
- ✦ Include PSF size errors (in addition to shape)
- ✦ Increase number density of stars to go to smaller scales
- ✦ Investigate lack of improvement in ρ statistics from y1—> y10, and consistency across dither patterns.

References

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[5] Jarvis, M. *et al.* DES Science Verification Weak Lensing shear catalogues (2016) arXiv: 1507.05603

[6] Mandelbaum, R. First-year shear catalog of the Subaru Hyper Suprime-Cam SSP Survey (2017) arXiv:1705.06745