

1. Background and Motivation

- Cosmology introduces spatial correlations in galaxy number density, shapes, and alignments.
- Atmospheric turbulence creates another layer of correlated aberrations in the shapes (ellipticities) and sizes of galaxy images.
- The point spread function (PSF) describes what a point source looks like on the focal plane. A distant star is considered a point source on the sky.
- We want to simulate the atmospheric PSF precisely to test and develop more robust PSF fitting models and thus mitigate aberrations and optimize weak lensing observations at Rubin.

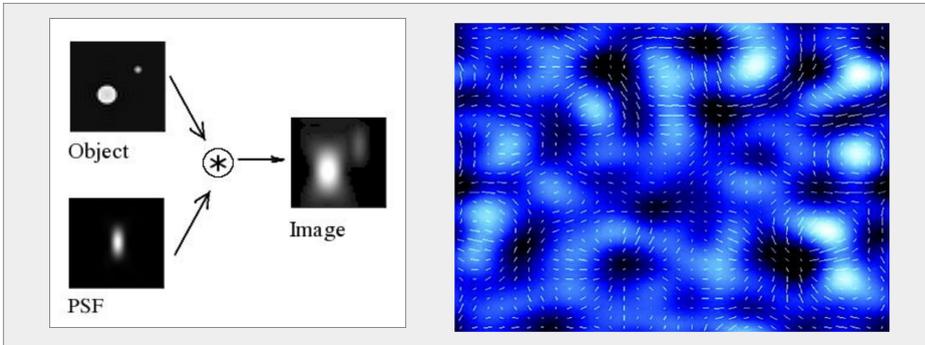


Fig 1. *Left:* The PSF describes the blurring of an object's image (Wikipedia). *Right:* Spatial correlation in the shear field due to non-uniform mass distribution (Ellis, 2010).

2. Simulation of a Single PSF

- In high resolution simulations of a single PSF, the instantaneous ellipticity varies rapidly in each time step, but the PSF integrated over an exposure is smoothed out and becomes rounder.
- The speckle effect is due to diffraction, where the size of each speckle is related to the size of the telescope diffraction limit.
- Simulation is implemented with GalSim.

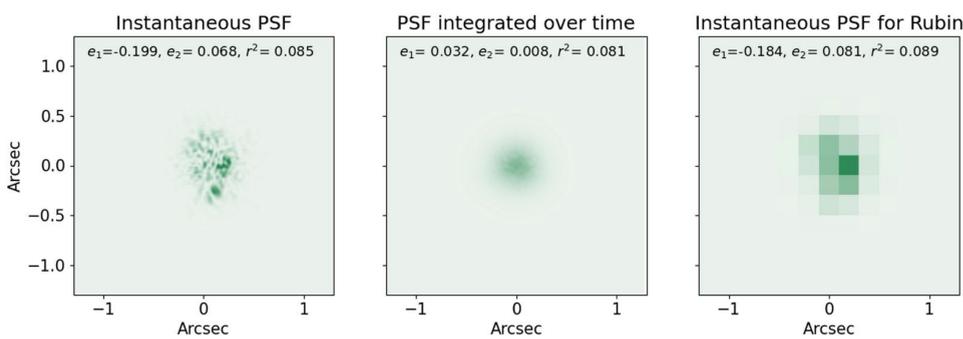


Fig 3. Simulation of a single PSF with high resolution (left and middle frame) and with Rubin pixel scale (rightmost frame).

3. Wide-field Simulation

- psf-weather-station (psfws) generates realistic input parameters (correlated wind speeds & directions, optical turbulence profiles) for psf simulations.
- We generate one set of 6 phase screens and simulate the resulting atmospheric PSF with both random and realistic environmental parameters: turbulence profile, wind speeds & directions, and phase screen heights.
- We then measure spatial correlations in PSF size and ellipticity.

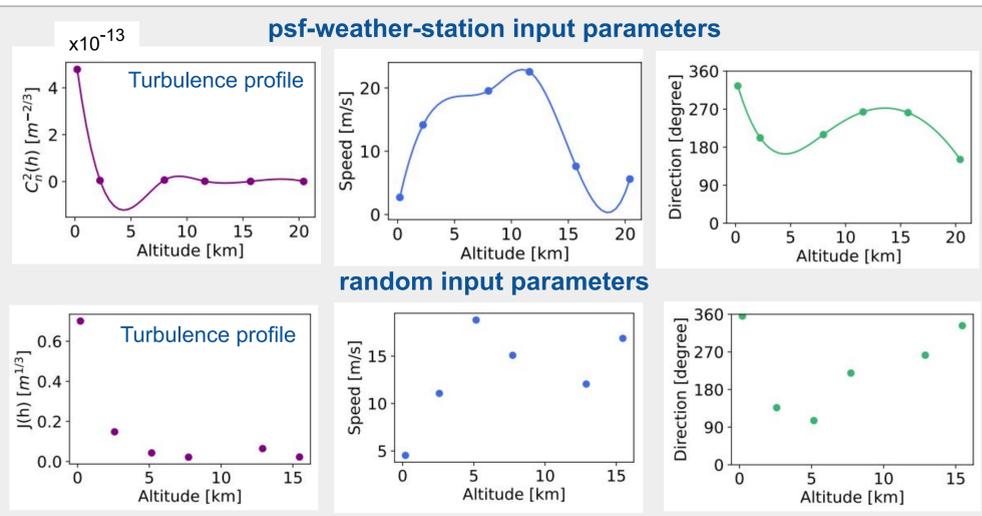


Fig 4. Input atmospheric parameters generated with psf-weather-station (top) and randomly selected (bottom).

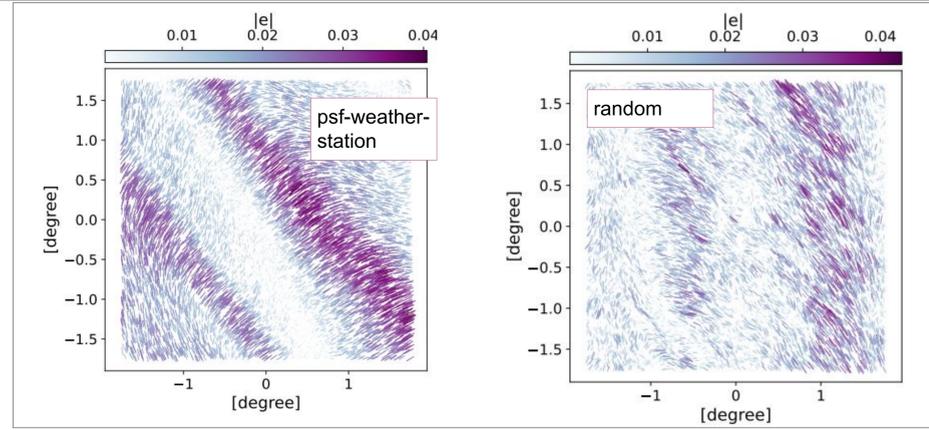


Fig 5. PSF ellipticity field. "Whiskers" show both magnitudes and ellipticities of PSFs.

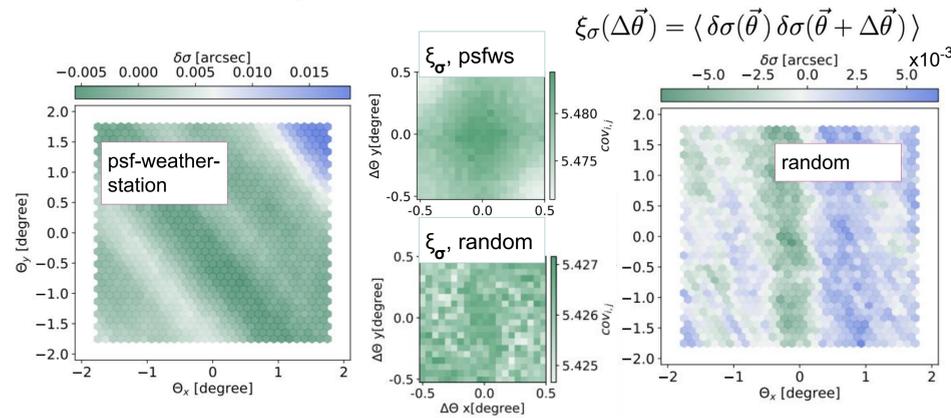


Fig 6. Distribution of PSF size variation (side panels) & correlation functions for PSF size (middle panels).

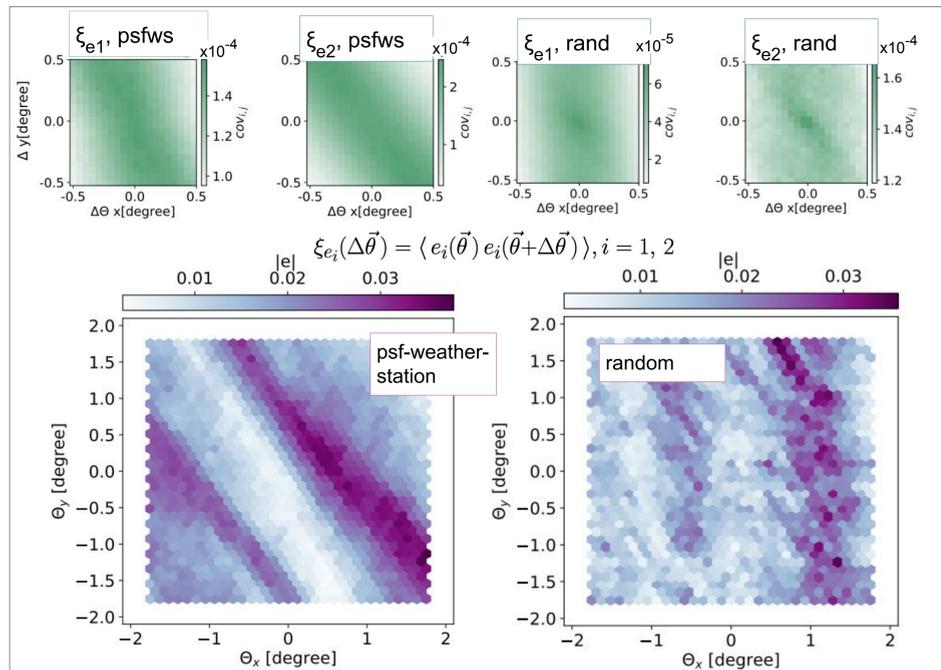


Fig 7. Top: Correlation functions of PSF ellipticities. Bottom: Deviation of PSFs ellipticities from the mean.

4. Multiple Wide-field Simulations

- We fit the correlation function to anisotropic Kolmogorov profiles and extract the ellipticities and directions of the profiles.
- With many realizations, we find that psf-weather-station yields PSF shape parameters whose correlation function has preferred directions.
- It is unclear whether there are preferred directions for the random simulations.
- We will study this by investigating the robustness of the profile fitting and by matching the range of random speeds to the range in psfws.

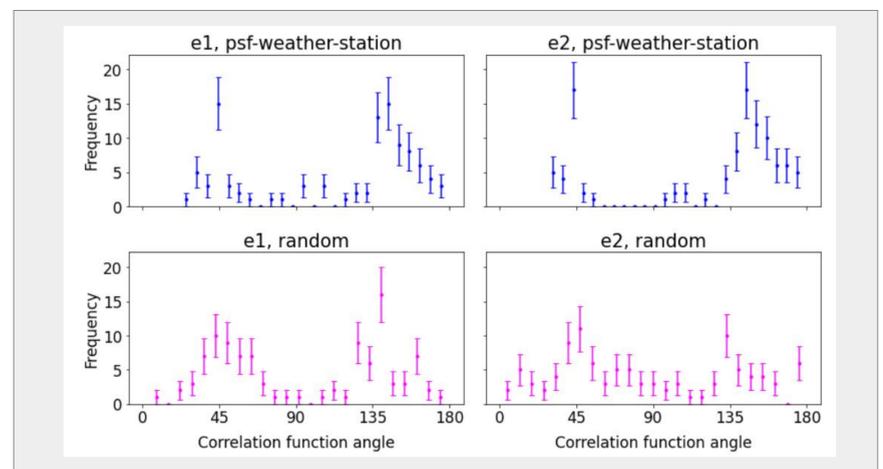


Fig 8. Distribution of anisotropic correlation function directions.