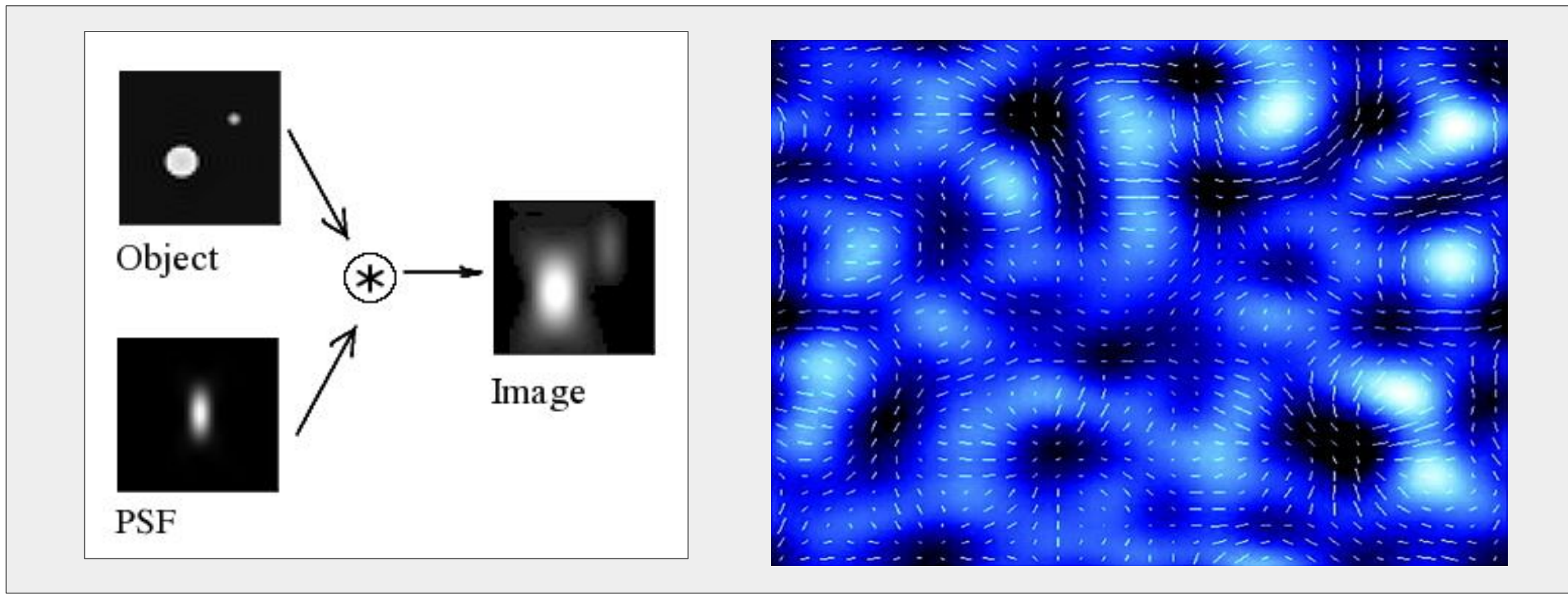


## 1. Background and Motivation

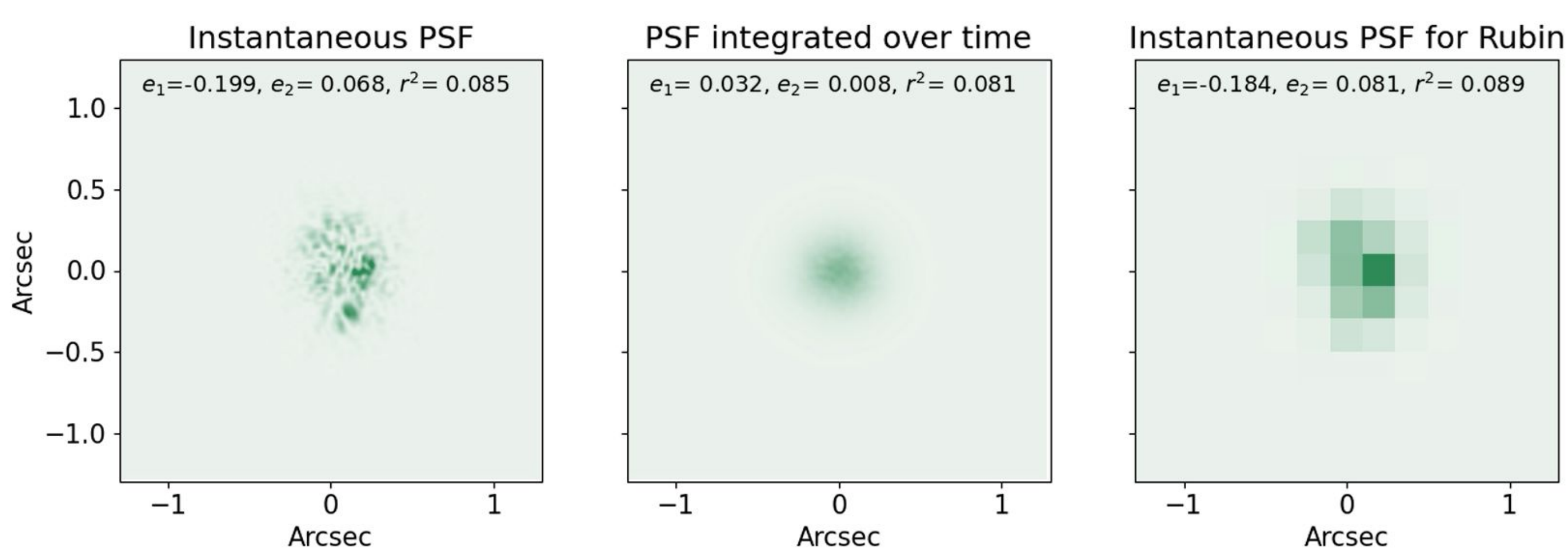
- Cosmology introduces spatial correlations in galaxy number density, shapes, and alignments.
- Atmospheric turbulence creates another layer of correlated aberrations in the shapes (ellipticities) and sizes of galaxy images.
- The point spread function (PSF) describes what a point source looks like on 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

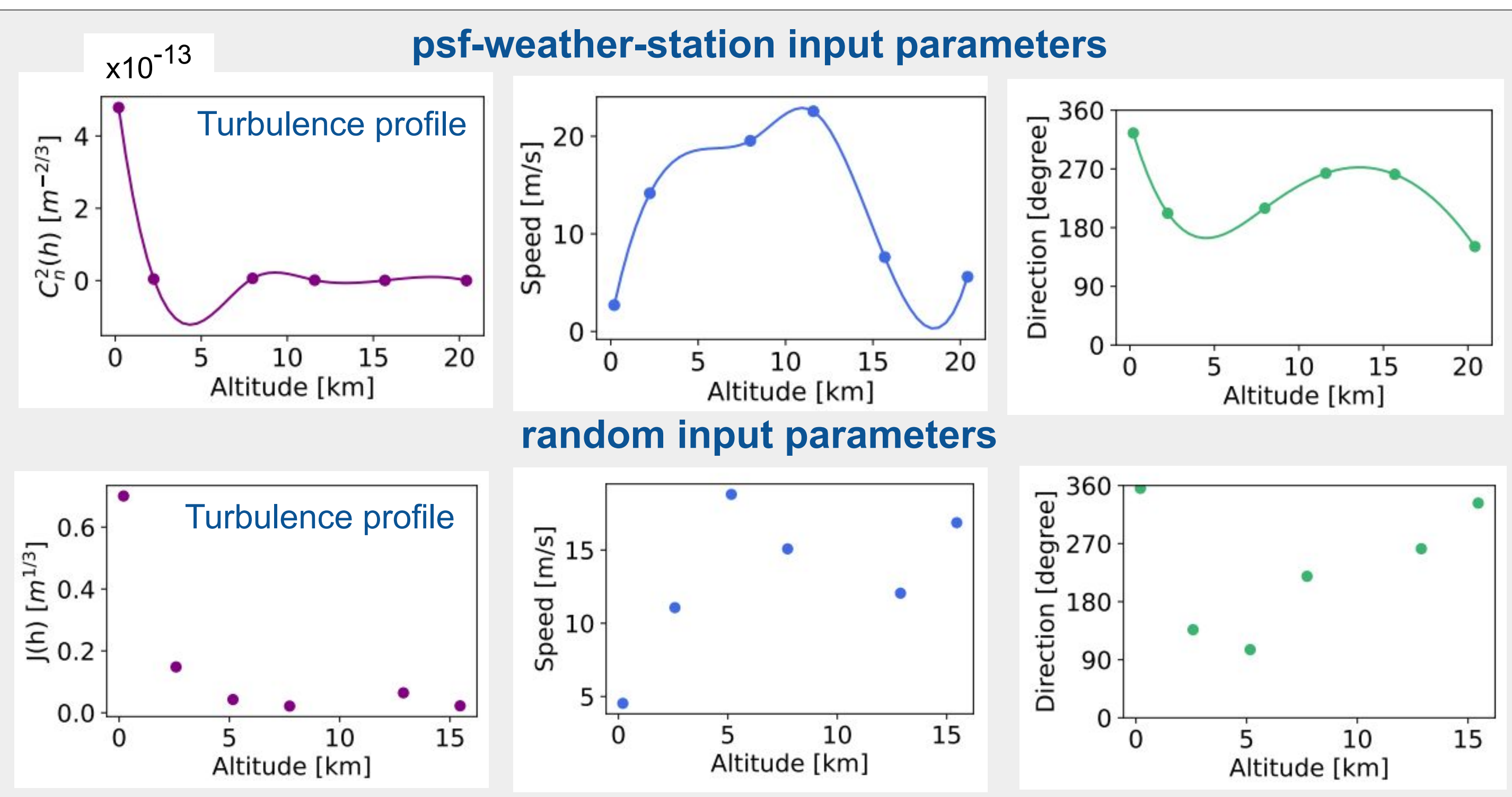
- In high resolution simulations of a single PSF, the instantaneous ellipticity varies rapidly in each time step, but the PSF integrated over an exposure is smoothed out and becomes rounder.
- The speckle effect is due to diffraction, where the size of each speckle is related to the size of the telescope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



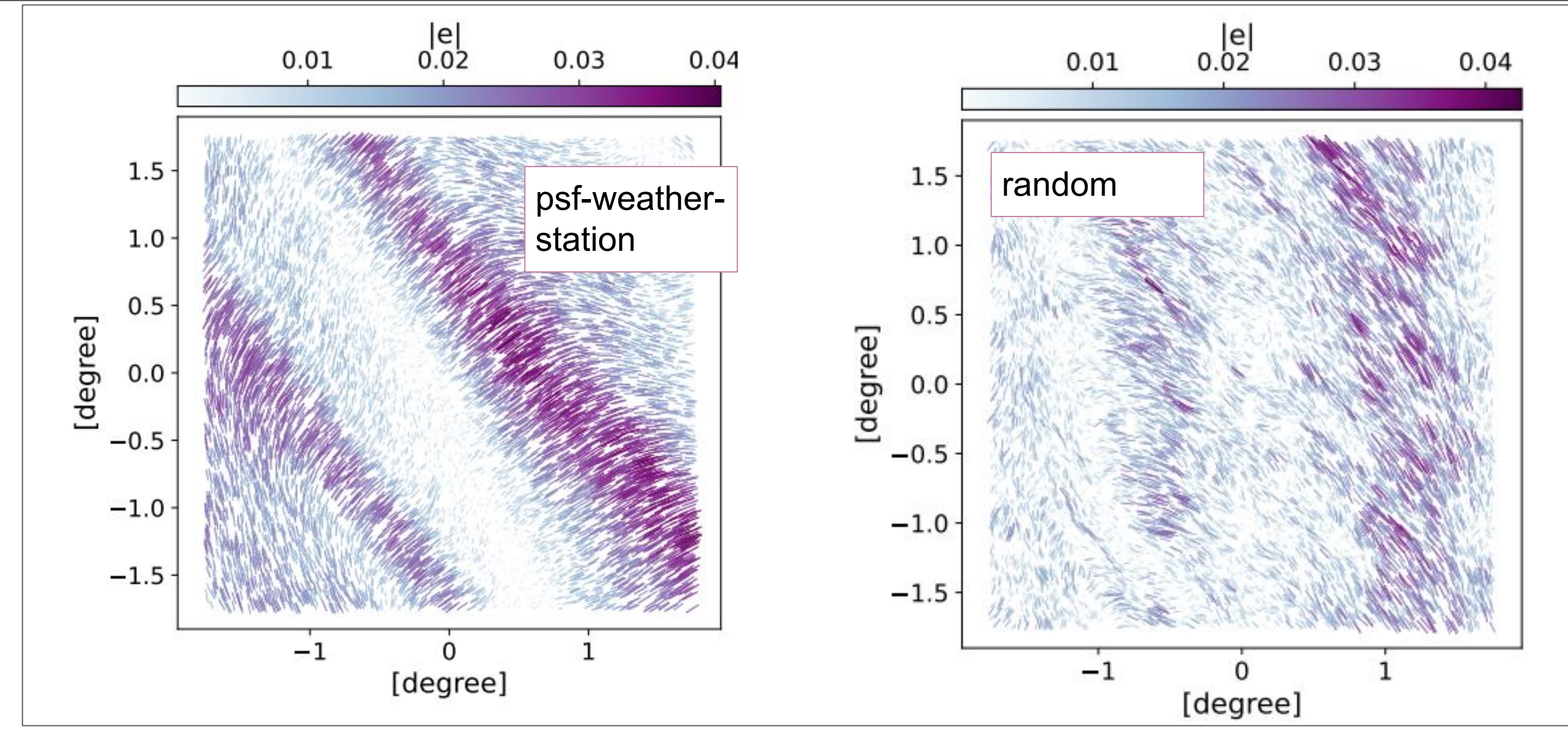
**Fig 3.** Simulation of a single PSF with high resolution (left and middle frame) and with Rubin pixel scale (rightmost frame).

## 3. Wide-field Simulation

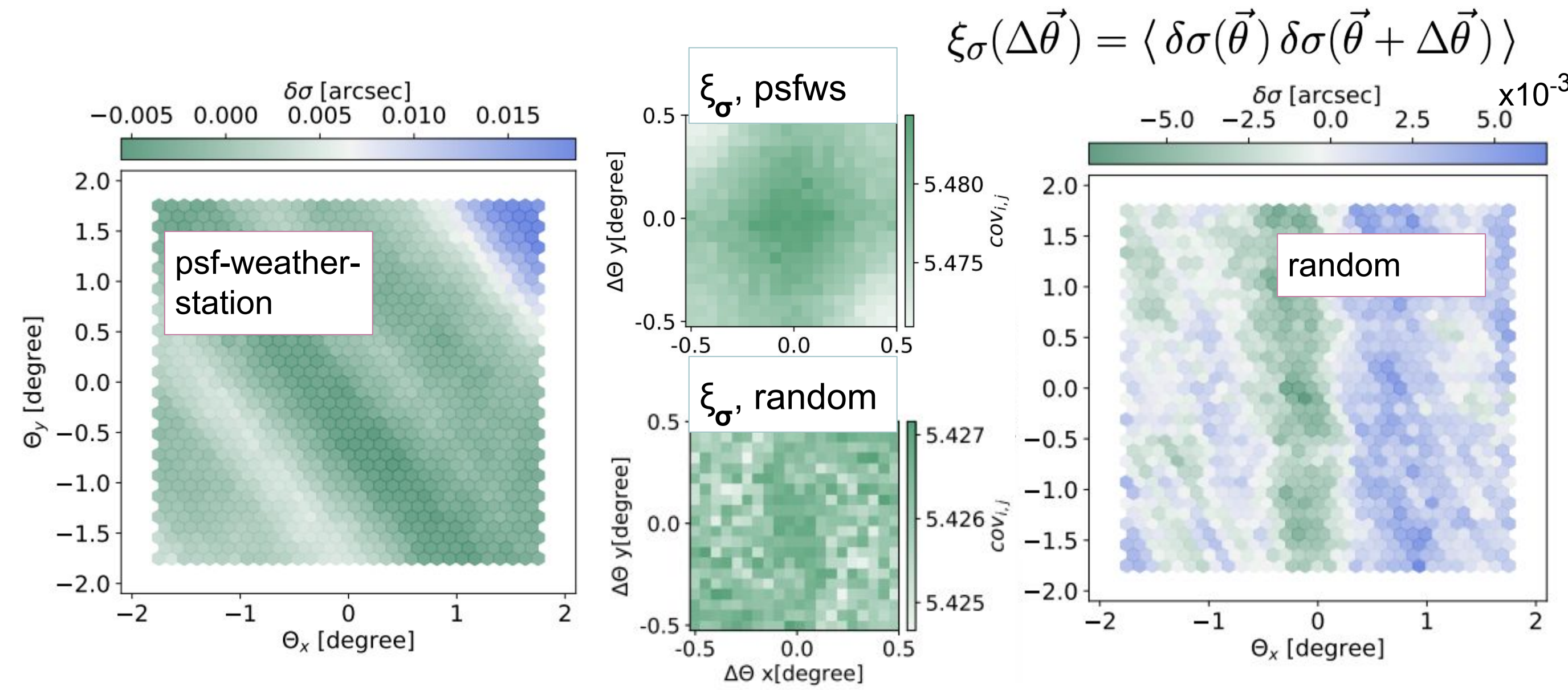
- psf-weather-station (psfws) generates realistic input parameters (correlated wind speeds & directions, optical turbulence profiles) for psf simulations.
- We generate one set of 6 phase screens and simulate the resulting atmospheric PSF with both random and realistic environmental parameters: turbulence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



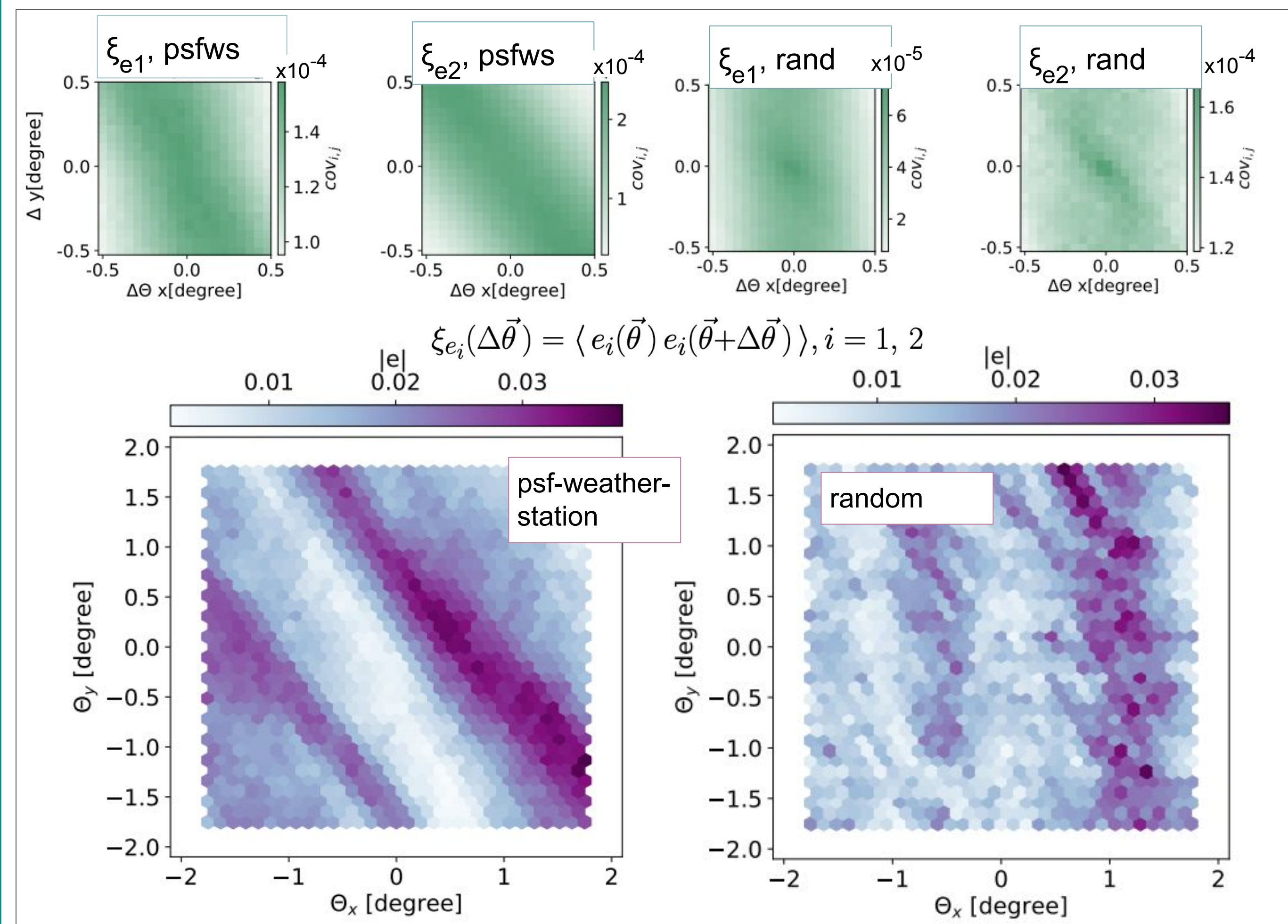
**Fig 4.** Input atmospheric parameters generated with psf-weather-station (top) and randomly selected (bottom).



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



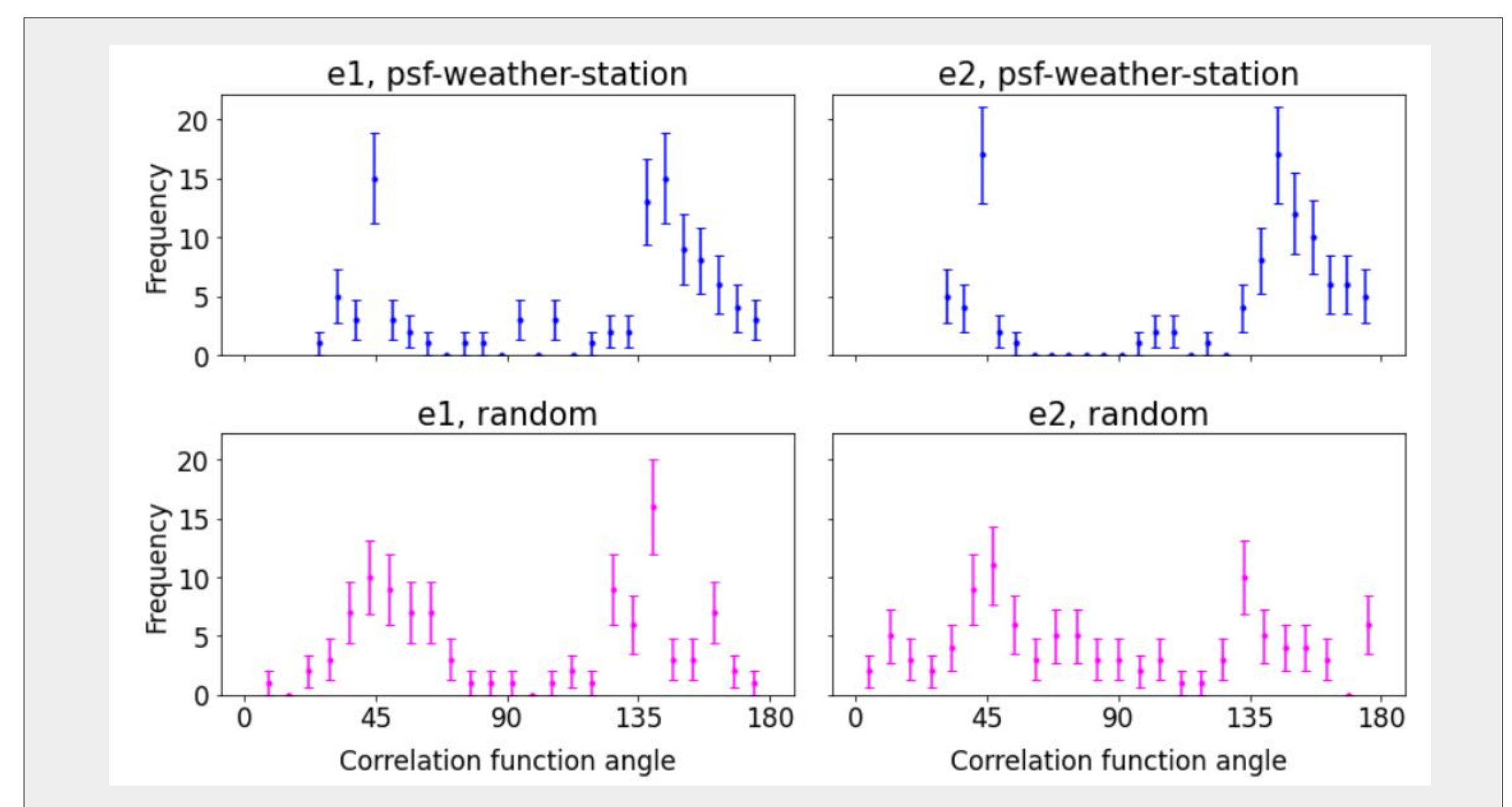
**Fig 6.** Distribution of PSF size variation (side panels) & correlation functions for PSF size (middle panels).



**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.