

GalSim atmospheric PSF

Josh Meyers (Princeton West)

Why simulate the atmospheric PSF?

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- The point spread function (PSF) affects everyone's science; integral to many measurement algorithms.

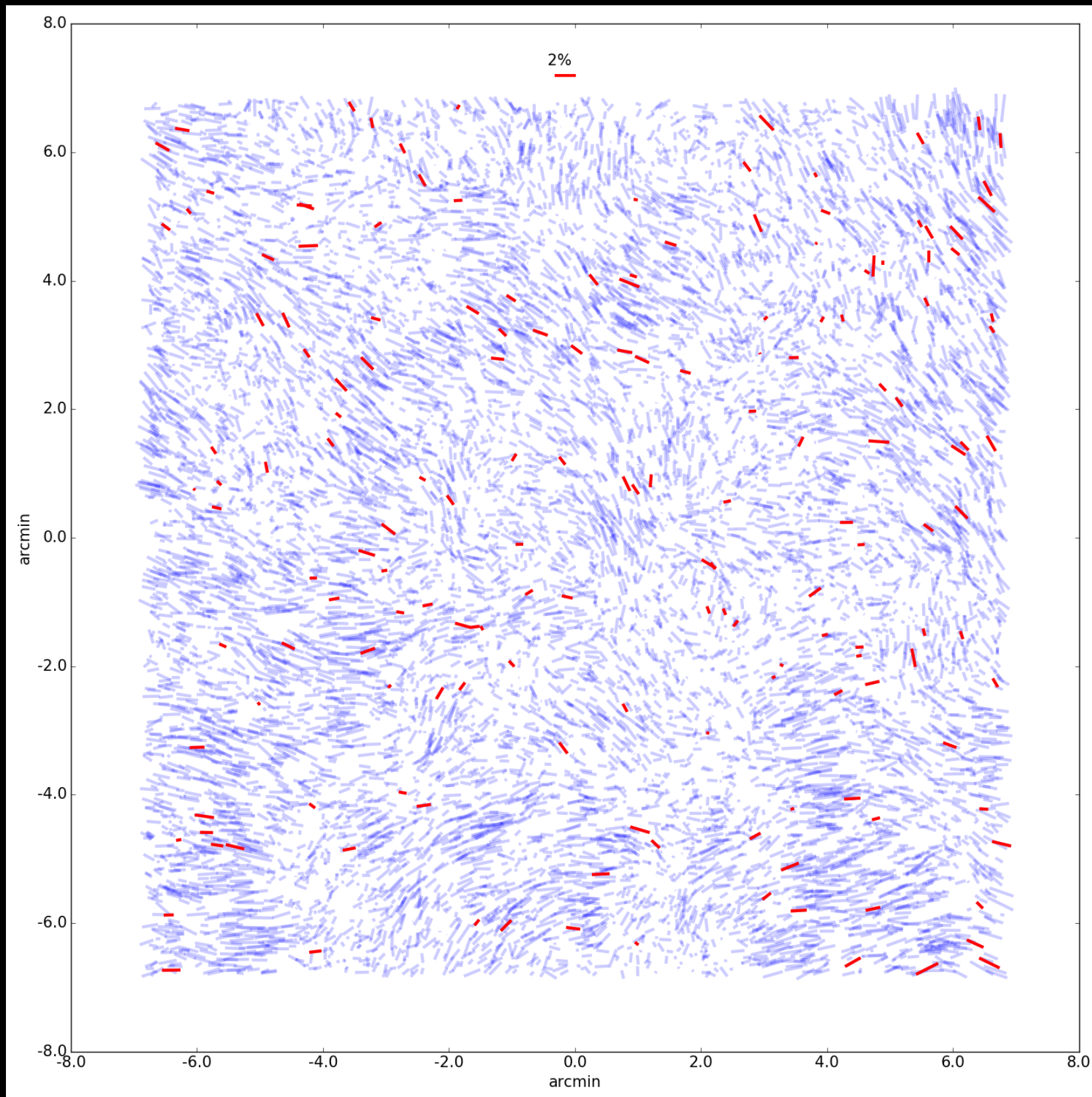
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- The atmosphere is the dominant contributor to the LSST PSF.
- The atmospheric PSF varies stochastically even over relatively short scales - a challenge for PSF inference.

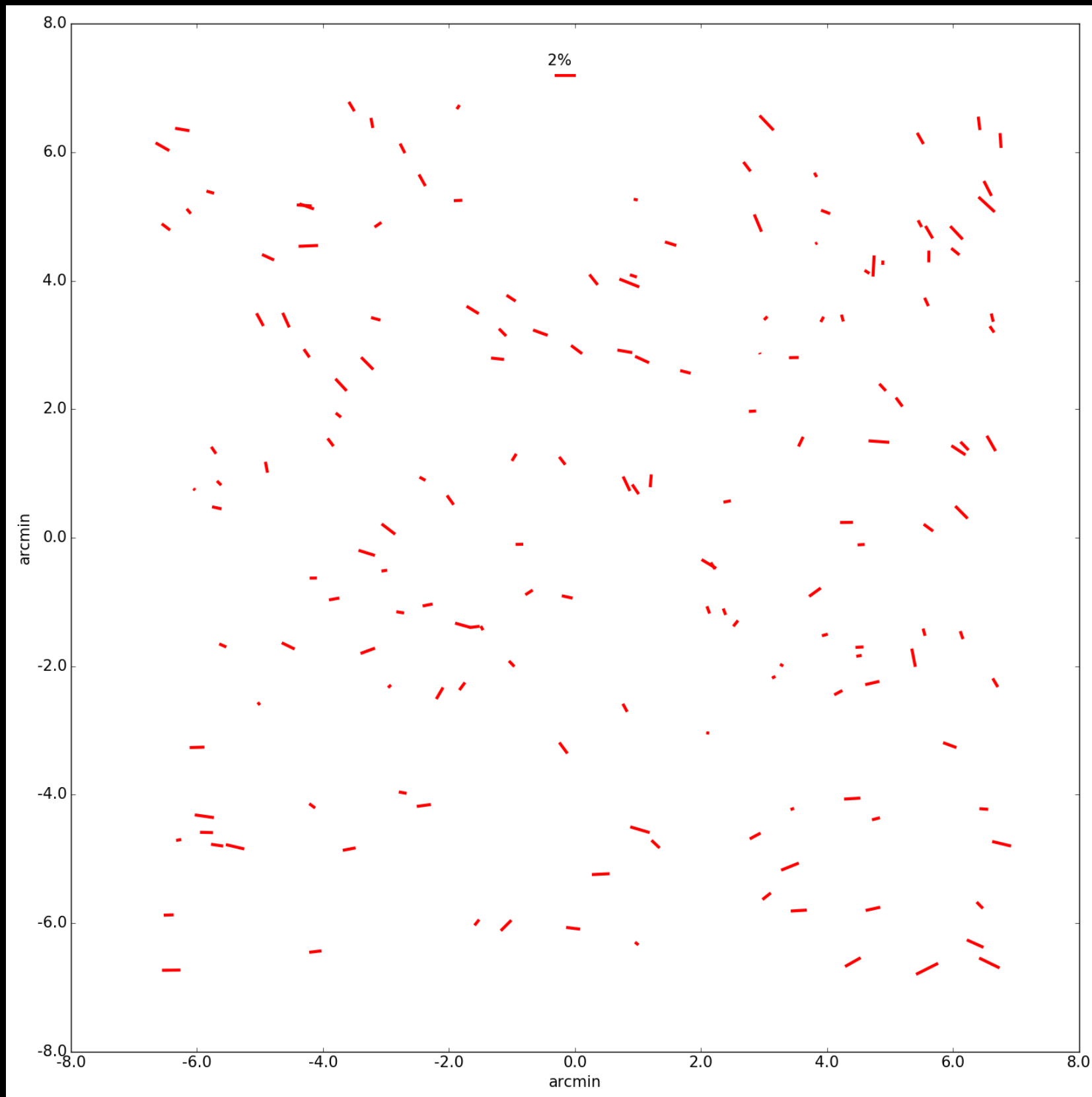
PSF ellipticity over one CCD



red = stellar density
blue = galaxy density

We want our sims
to be as
challenging as
data; preferably
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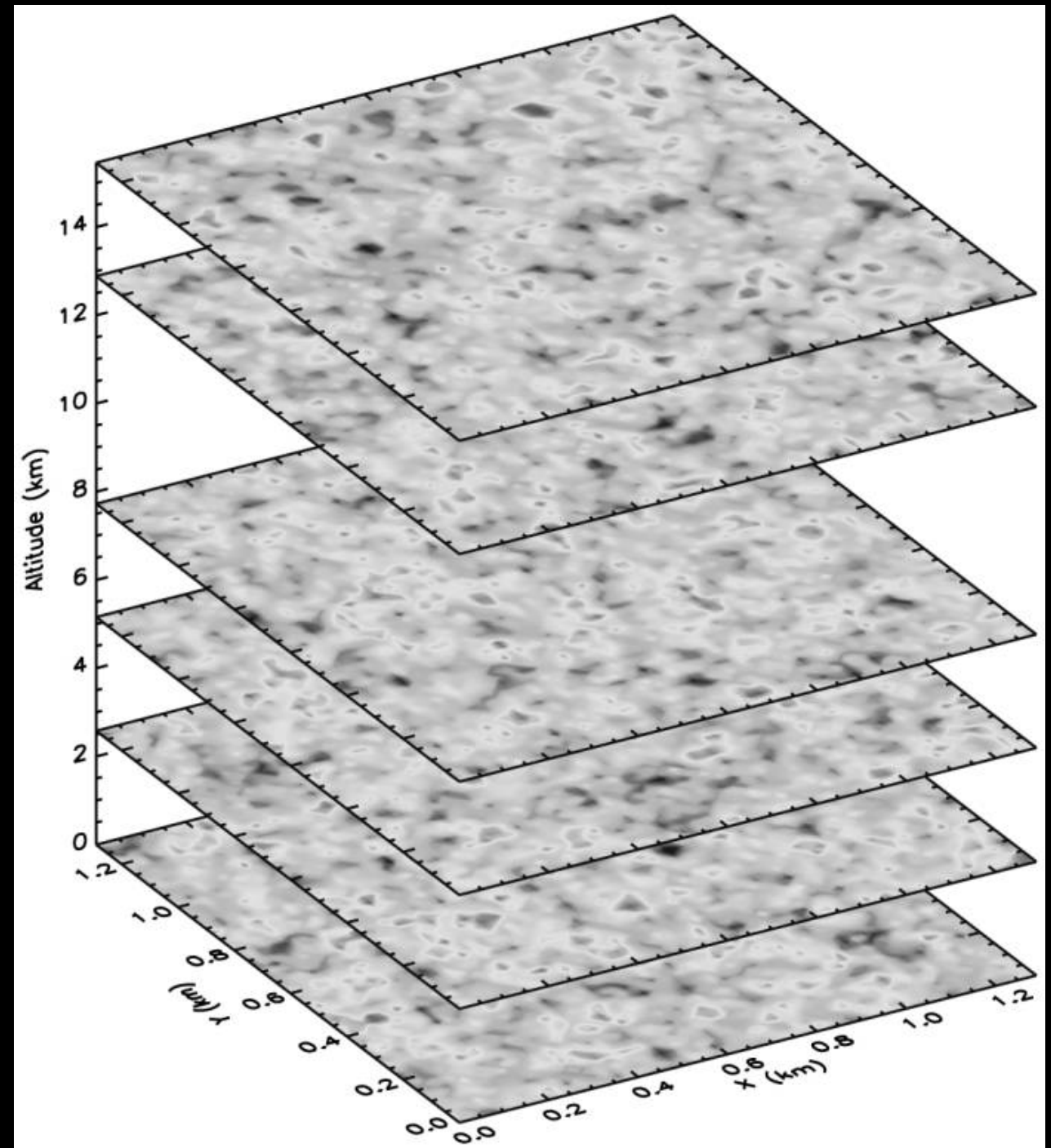


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Atmospheric PSF model



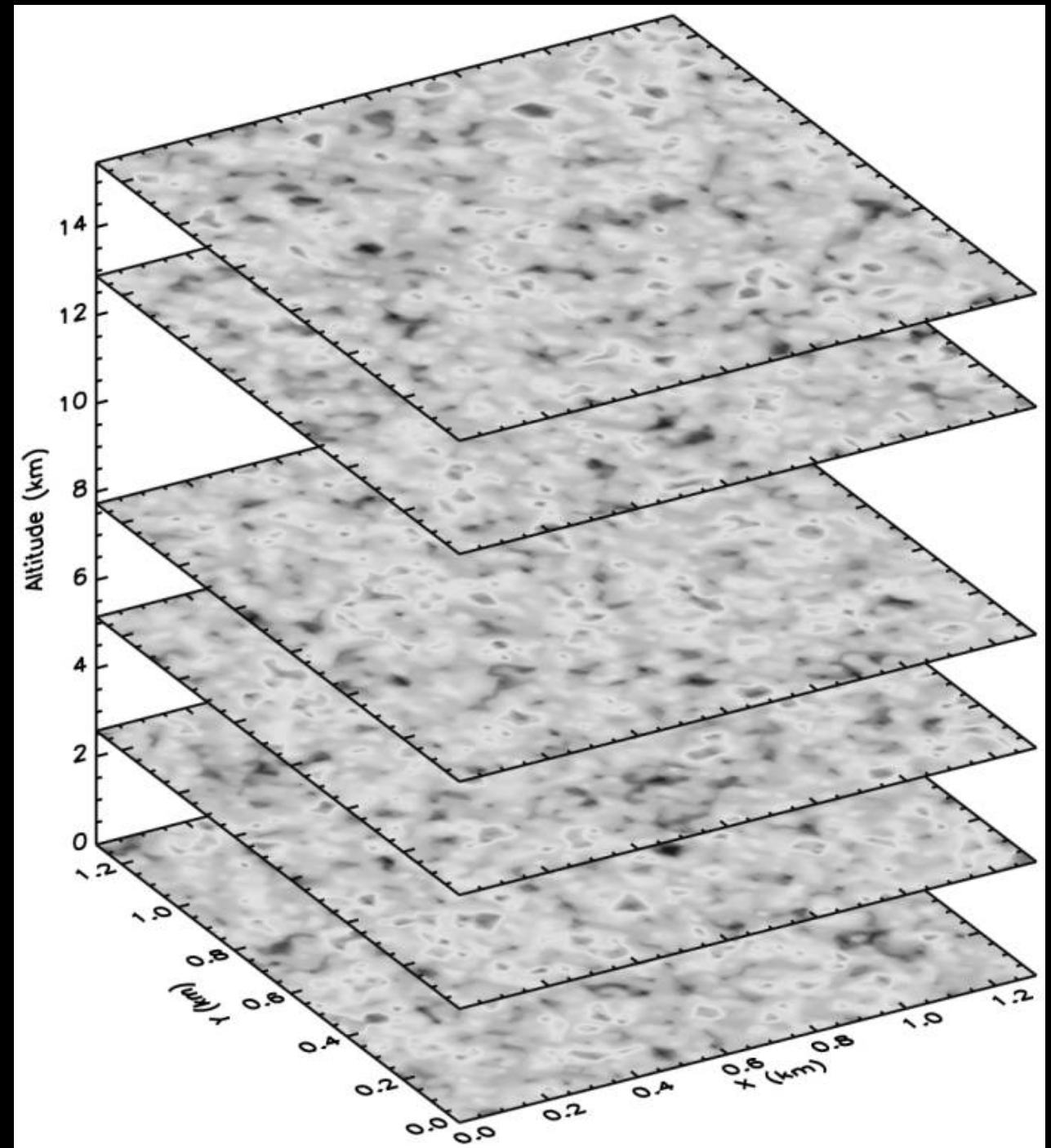
Jee+Tyson11

Peterson++15

Also a long literature from AO community

Atmospheric PSF model

- Model the 3D turbulence as a series of 2D phase screens.



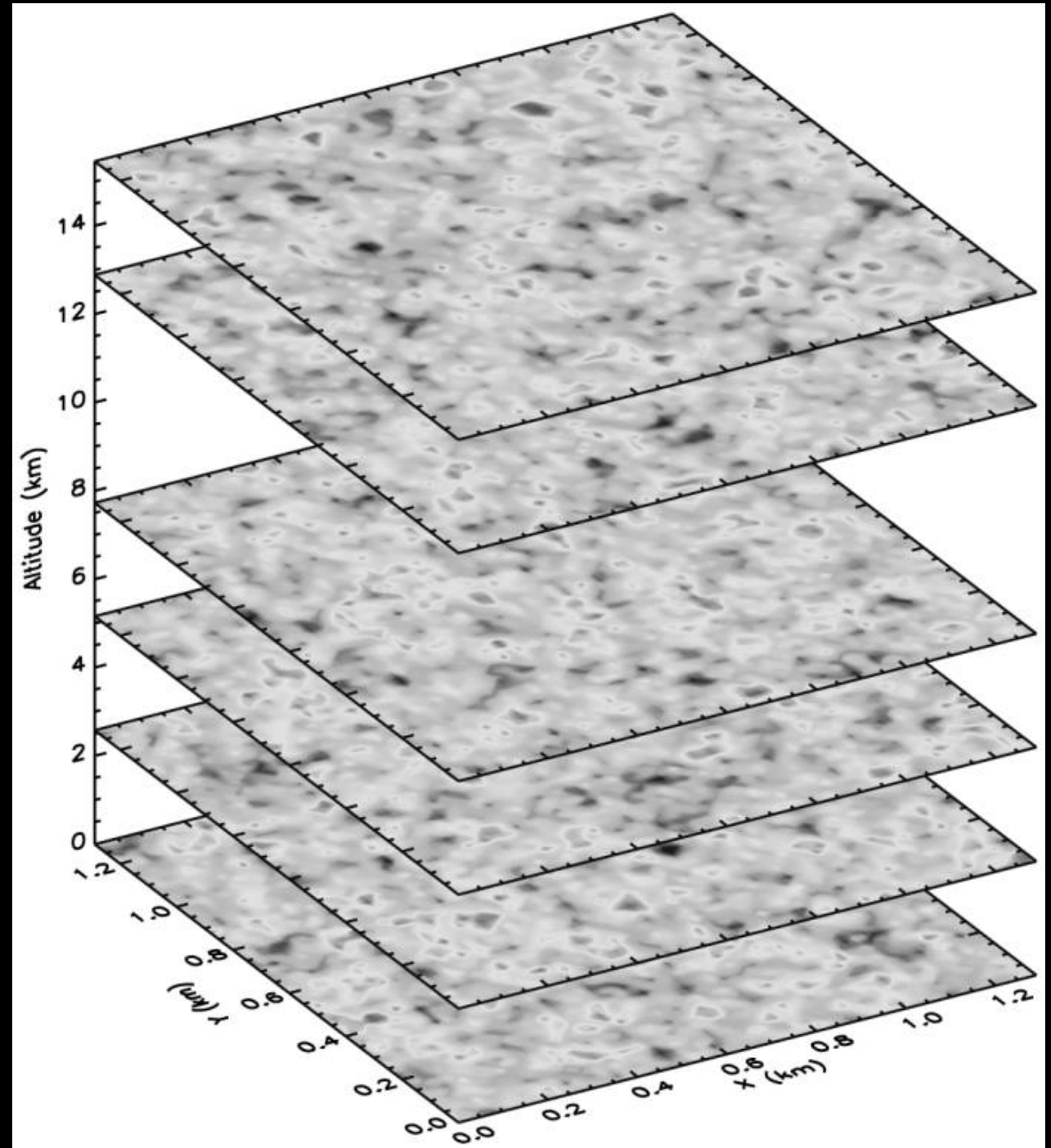
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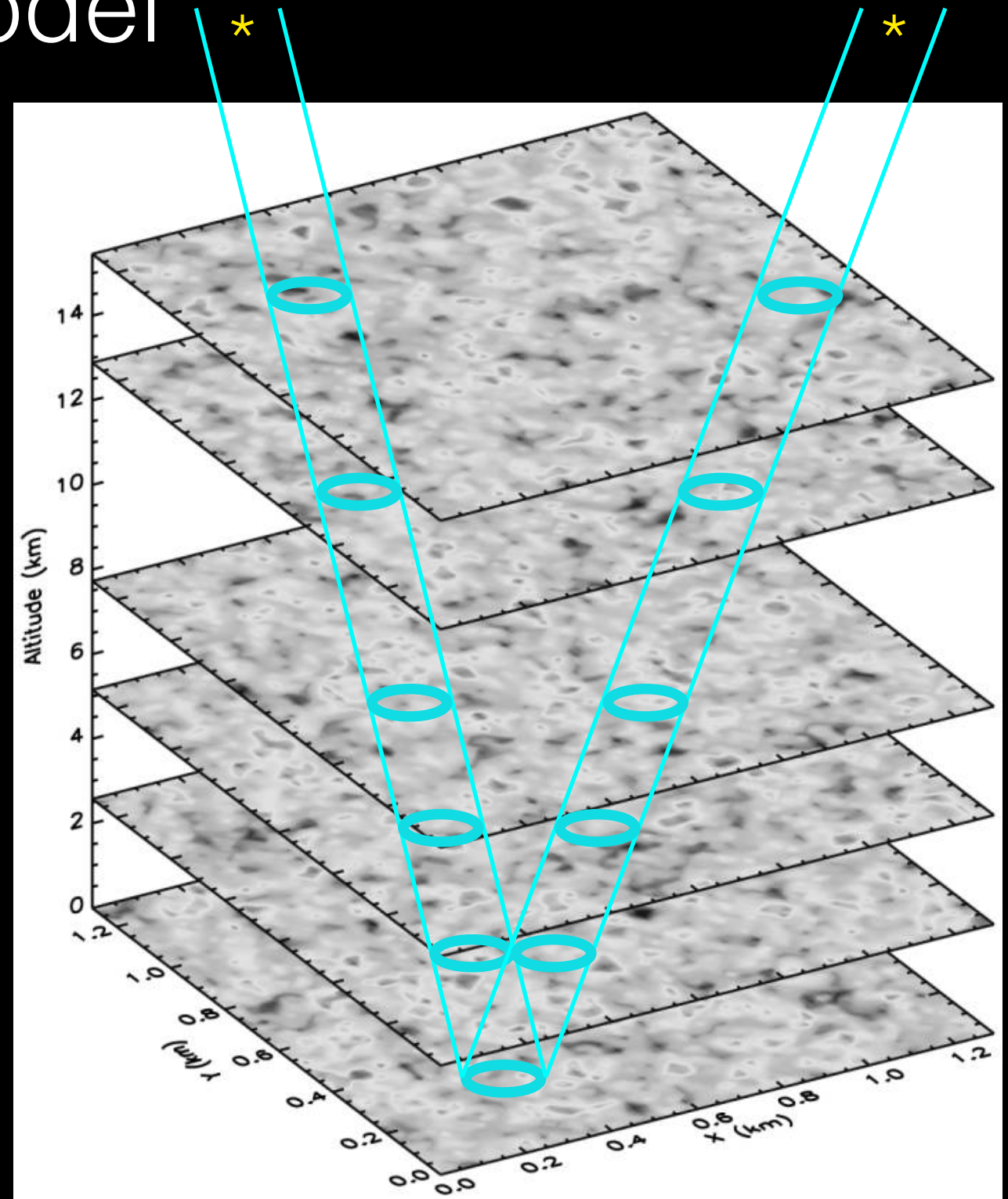
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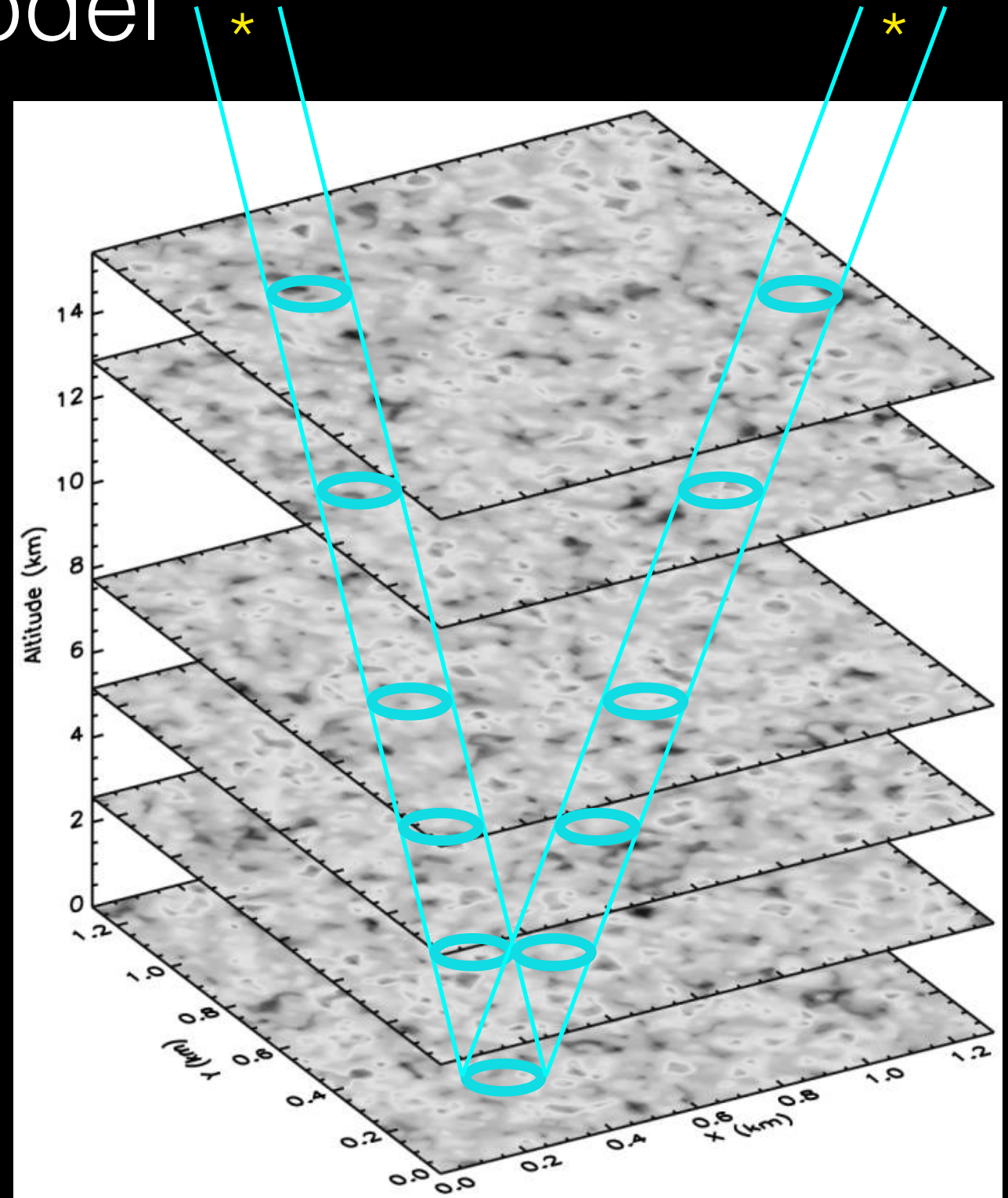
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Atmospheric PSF model

- Model the 3D turbulence as a series of 2D phase screens.
- Screens can blow around in the wind during an exposure.
- Project telescope aperture through the layers.
- Use either Fourier optics or geometric approximation to model the PSF.



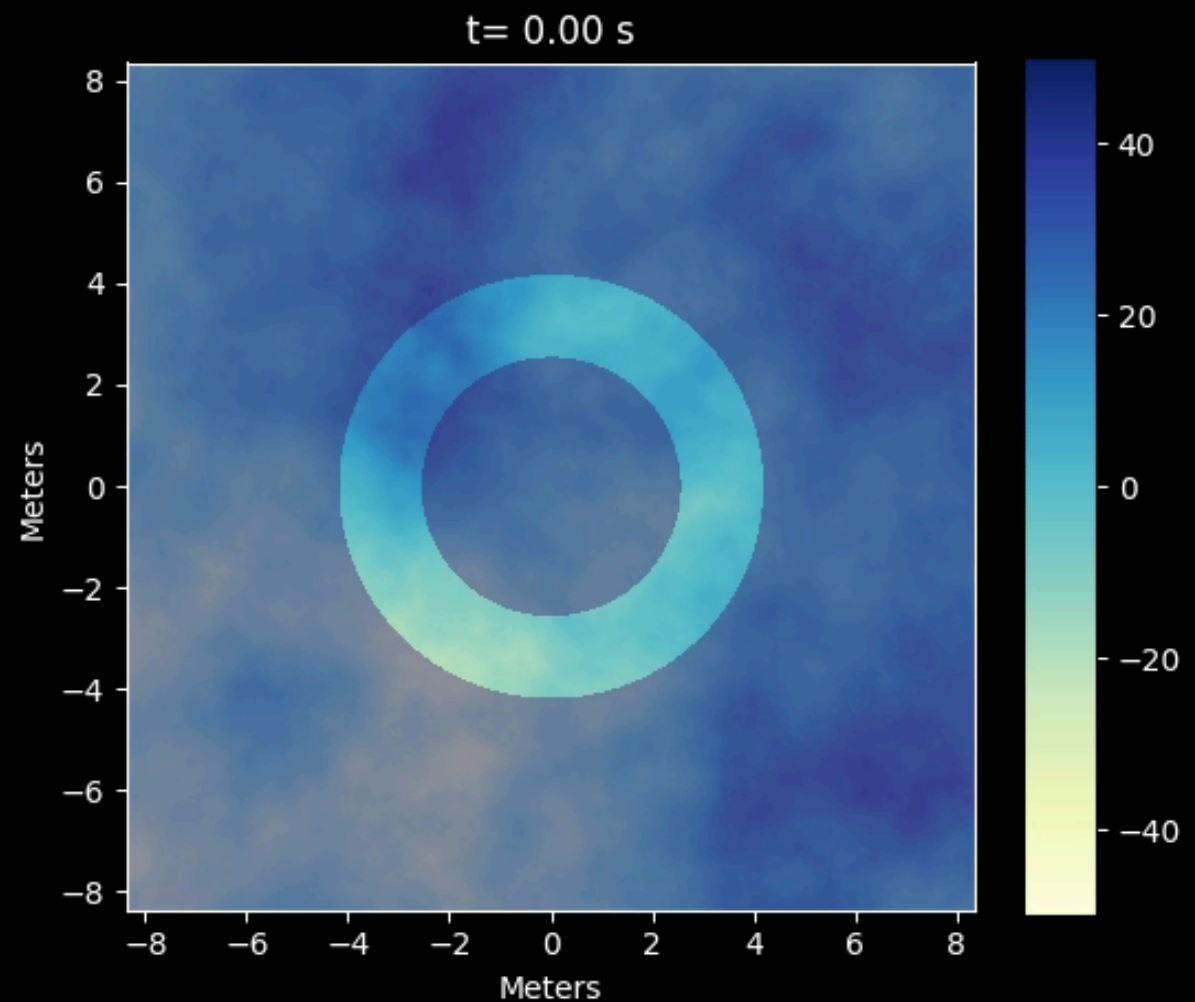
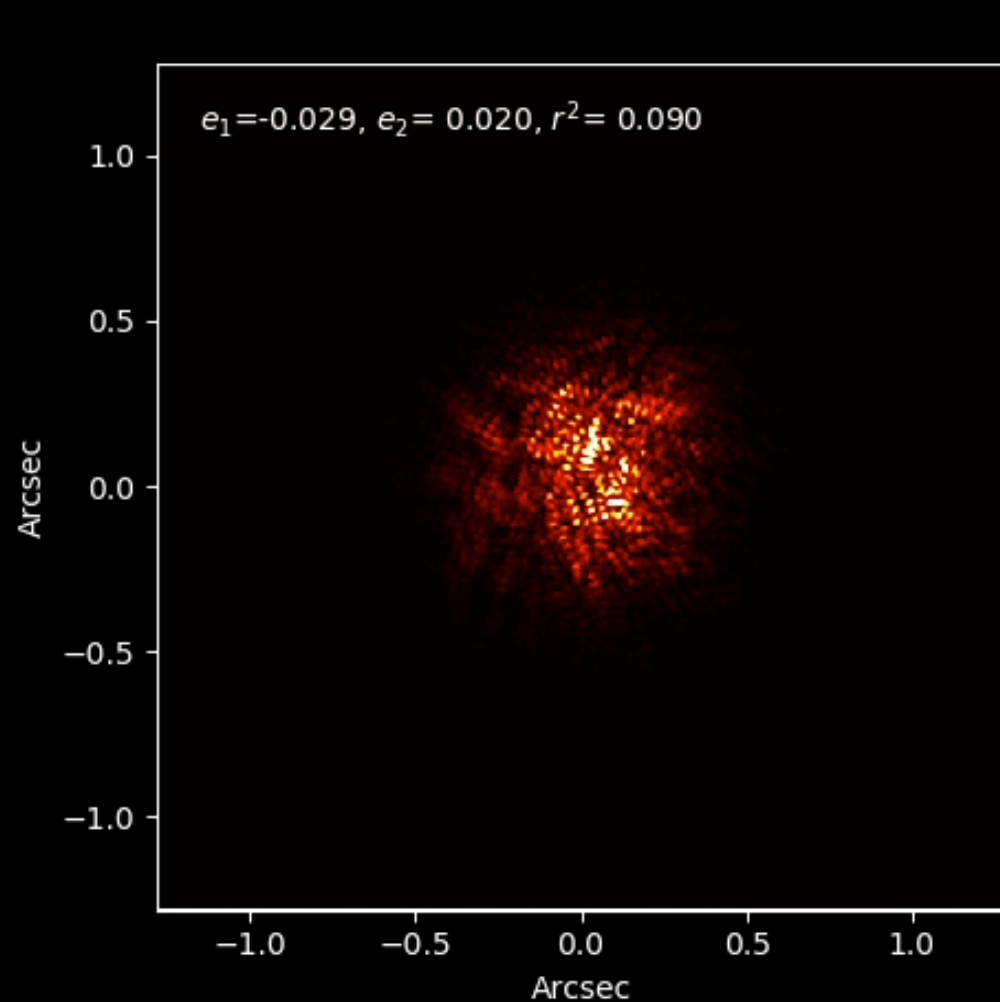
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Fourier optics

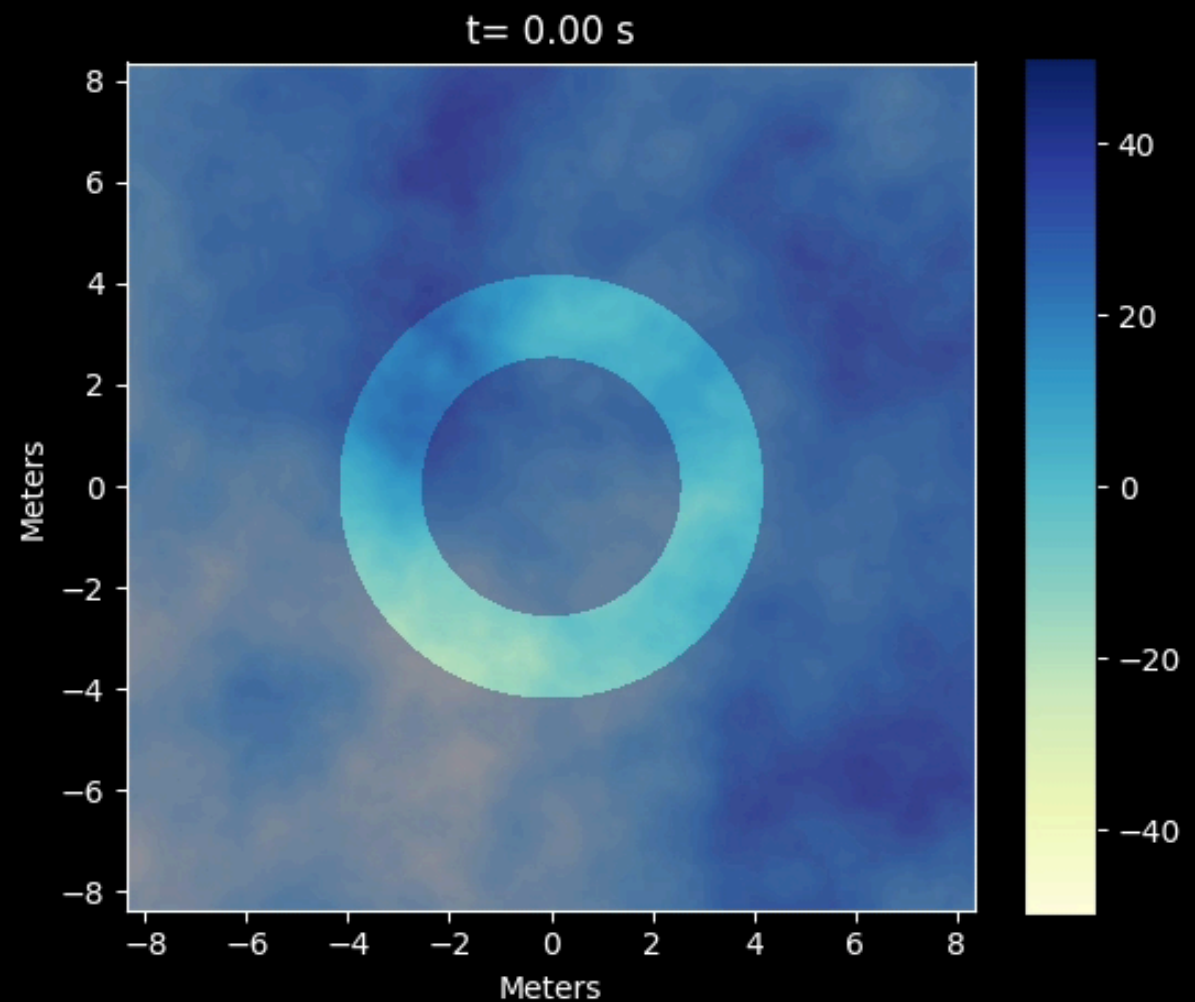
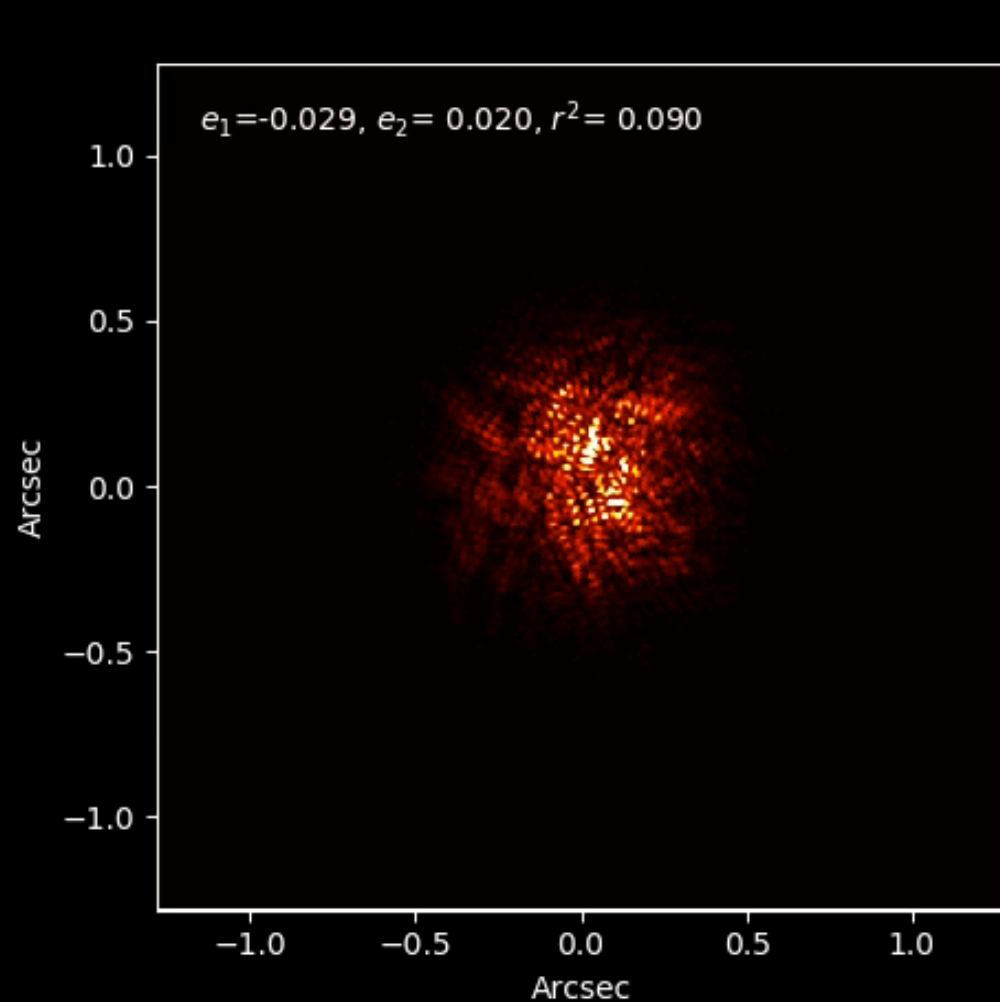
$$I(x, y) \propto \left| \mathcal{F} \left[P(u, v) \exp \left(\frac{-2\pi i}{\lambda} W(u, v) \right) \right] \right|^2$$



Broadly established, but very slow.

Fourier optics

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Geometric approximation

Geometric approximation

Pioneered in PhoSim. (Peterson++15)

Geometric approximation

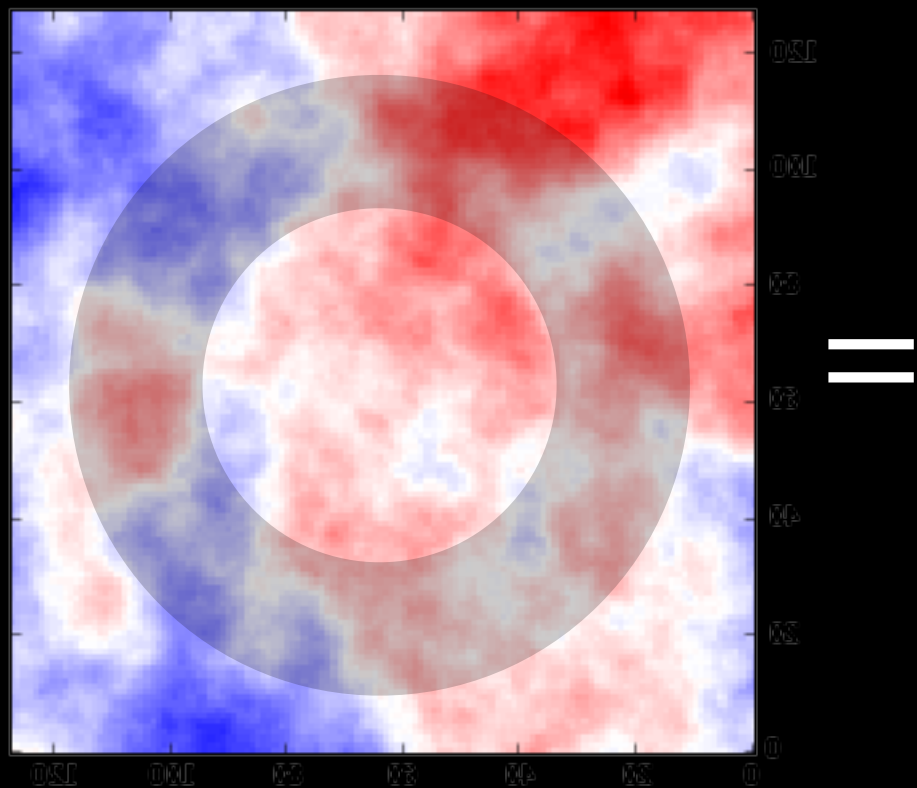
Pioneered in PhoSim. (Peterson++15)

Simulate discrete photons. Build up PSF by Monte Carlo.

Geometric approximation

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Fourier optics

Slow

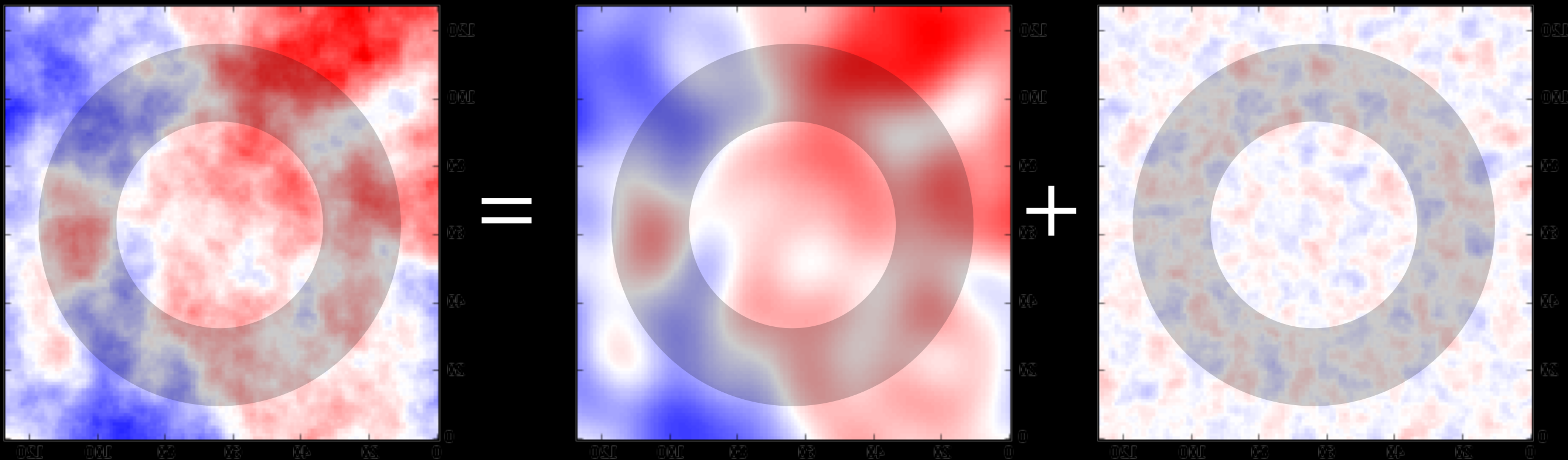
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$K < K_{\text{crit}}$

$K > K_{\text{crit}}$



Fourier optics

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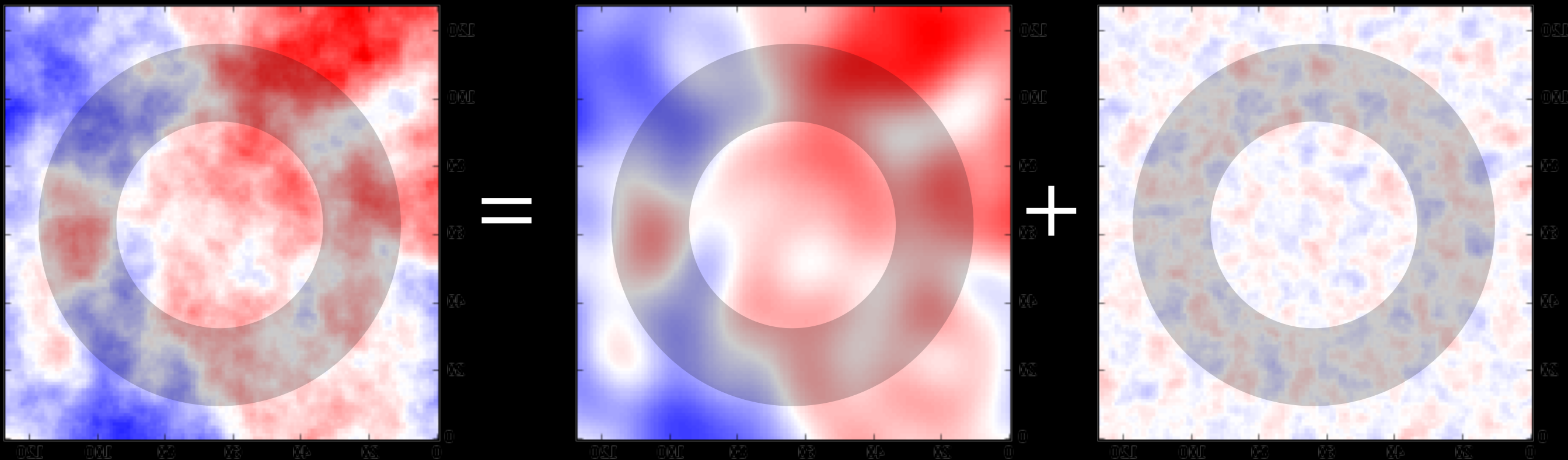
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Fourier optics

Geometric approx

“1st kick”

Slow

Fast

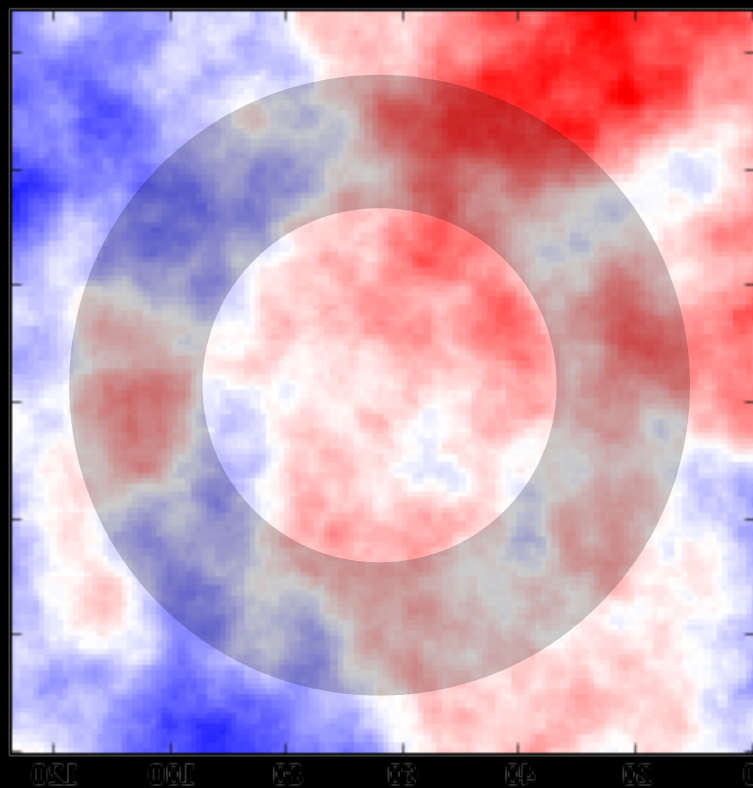
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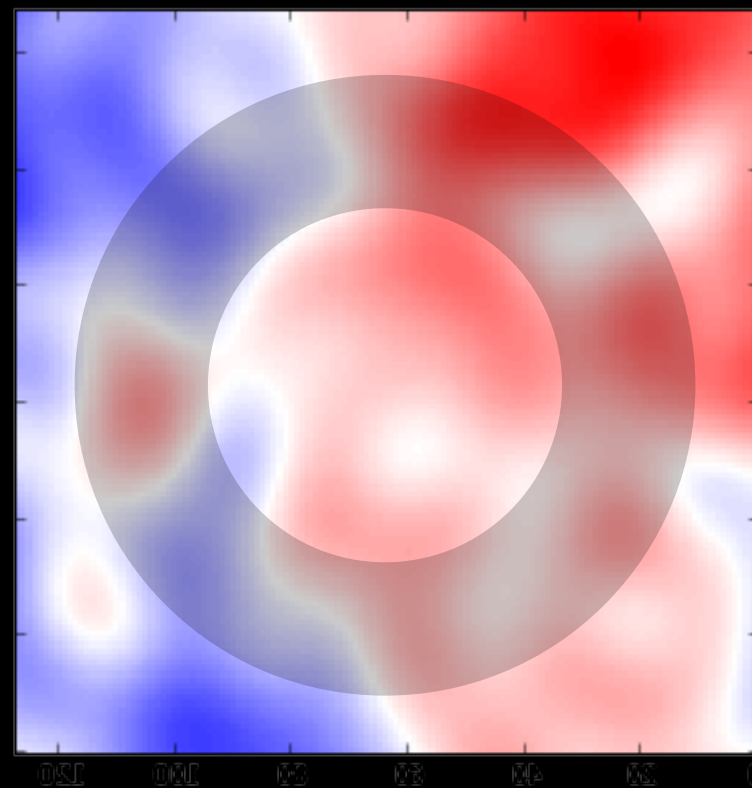
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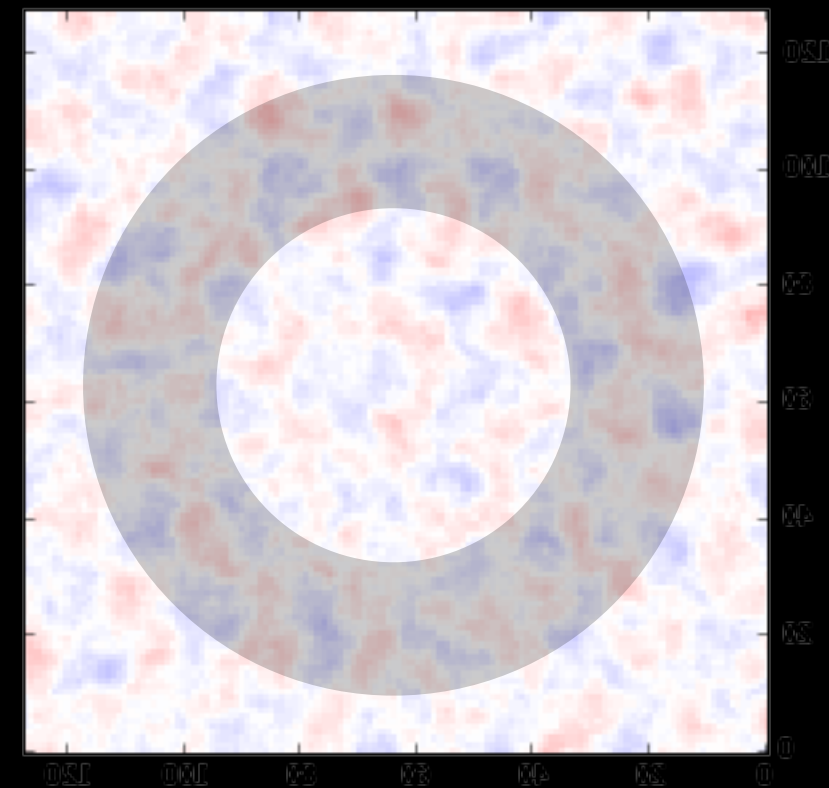
$K > K_{\text{crit}}$



=



+



Fourier optics

Geometric approx

Statistical expectation

“1st kick”

“2nd kick”

Slow

Fast

Calculate only once

Fourier optics validation

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- Reproduce analytic results: (obscured) Airy, von Karman

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 - **sampling** of original phase screens

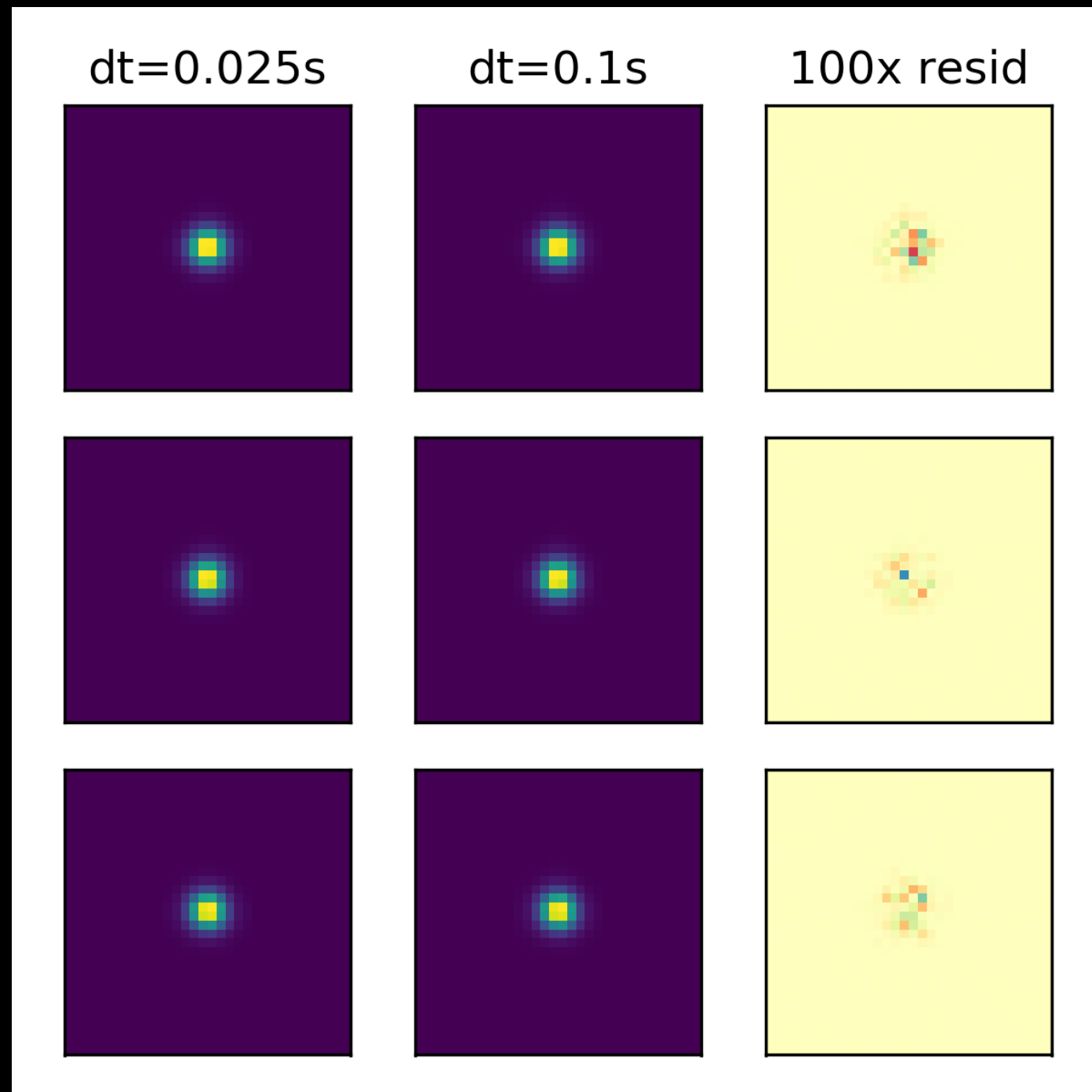
Fourier optics validation

- Reproduce analytic results: (obscured) Airy, von Karman
- Check for convergence in tunable parameters:
 - sampling of original phase screens
 - time step

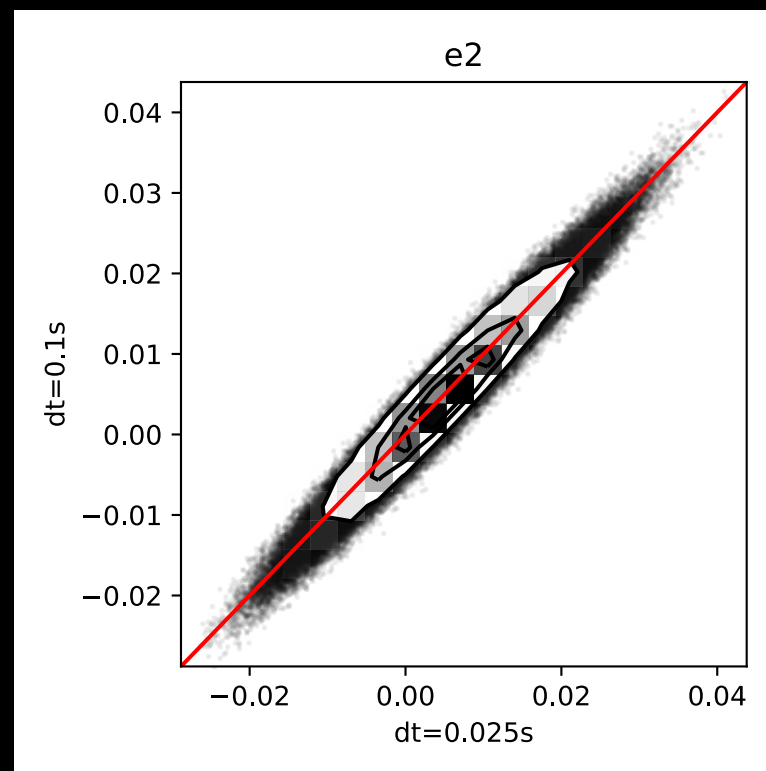
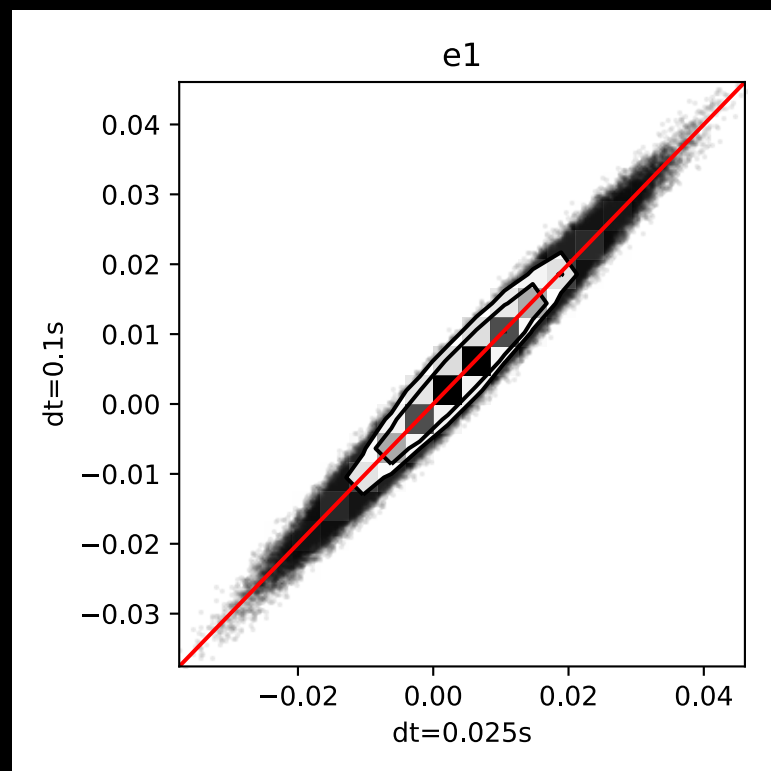
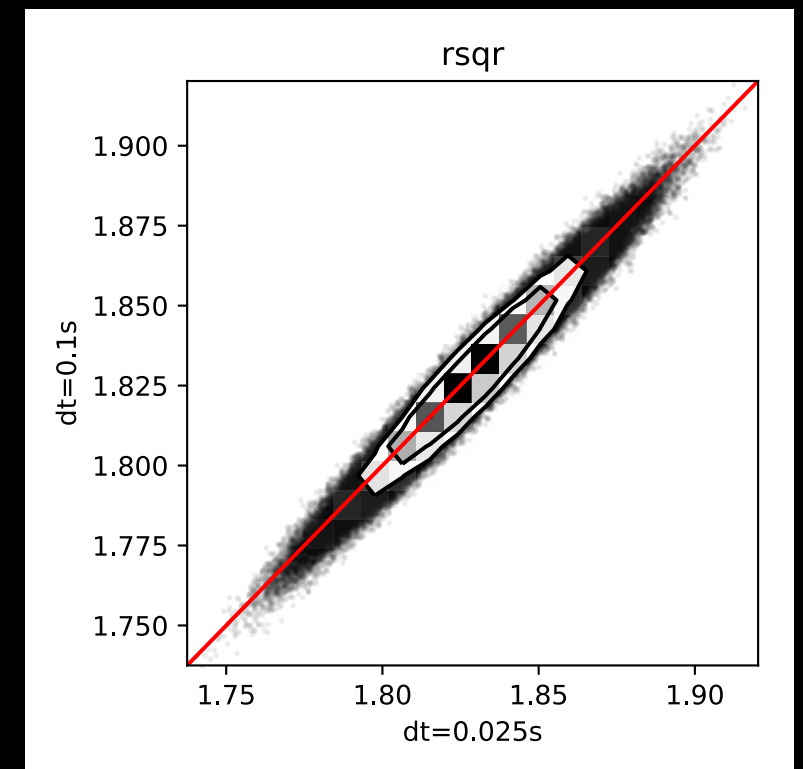
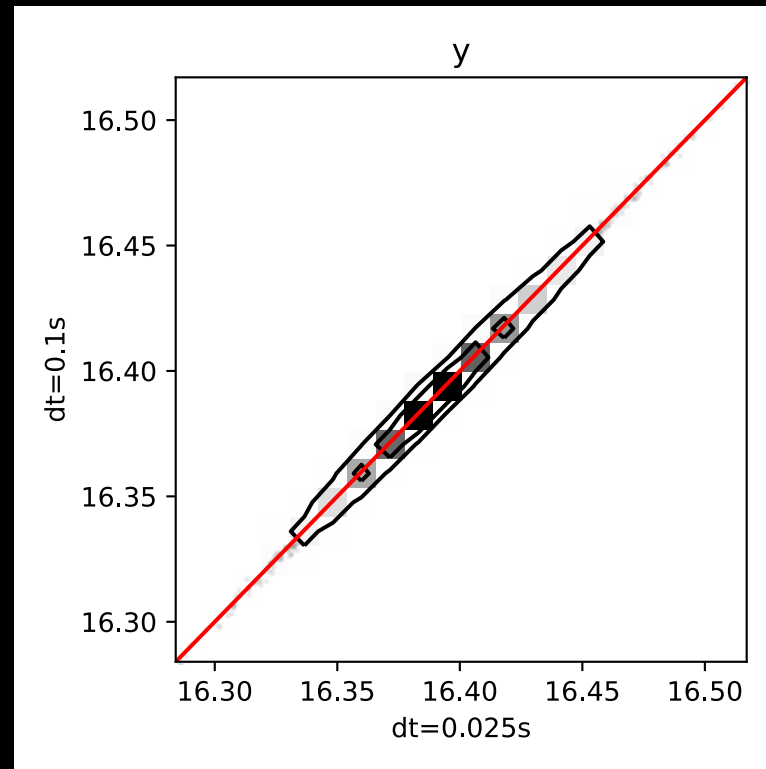
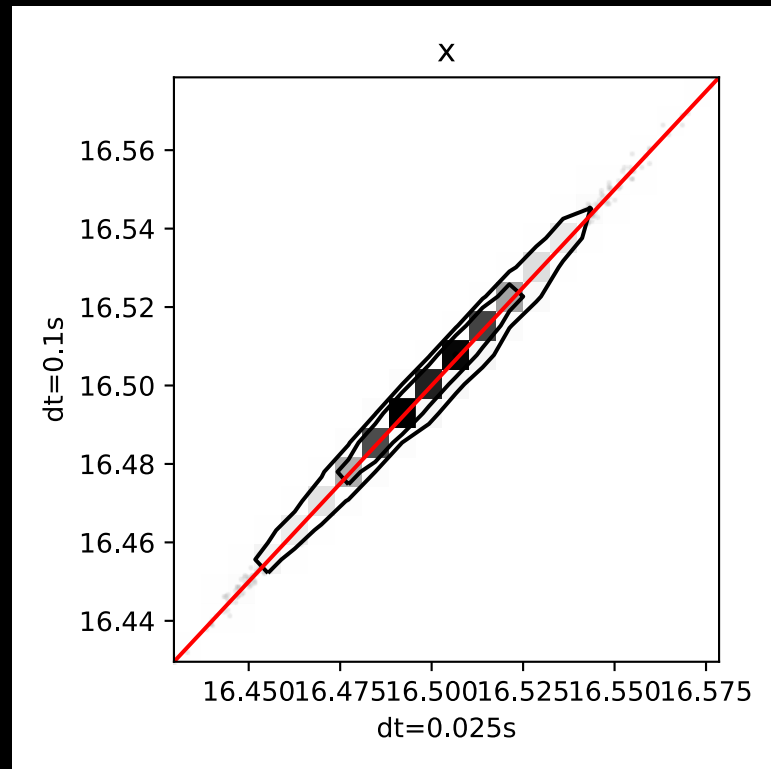
Fourier optics validation

- Reproduce analytic results: (obscured) Airy, von Karman
- Check for convergence in tunable parameters:
 - sampling of original phase screens
 - time step
 - sampling & zero-padding of pupil before FFT

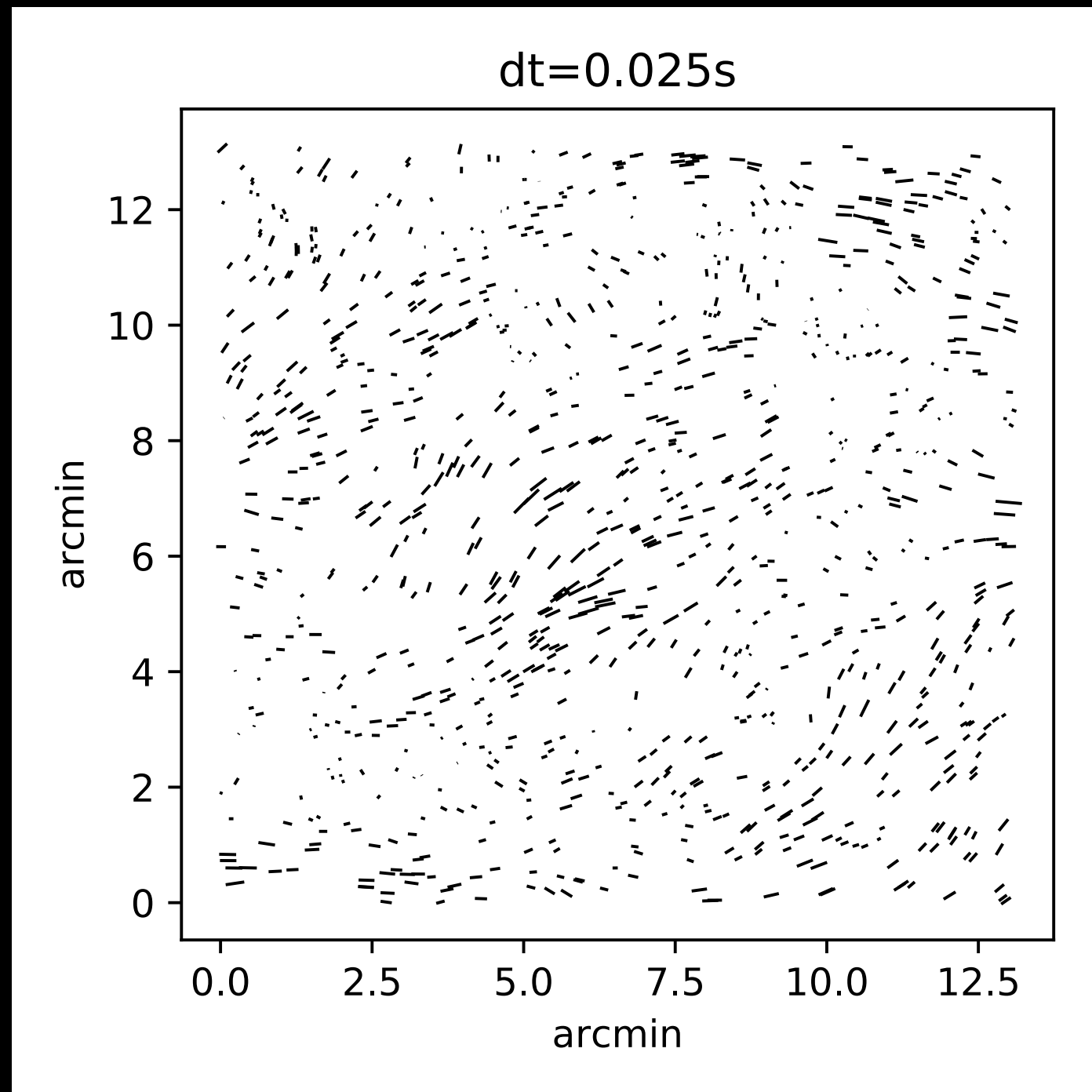
Visual inspection (time step)



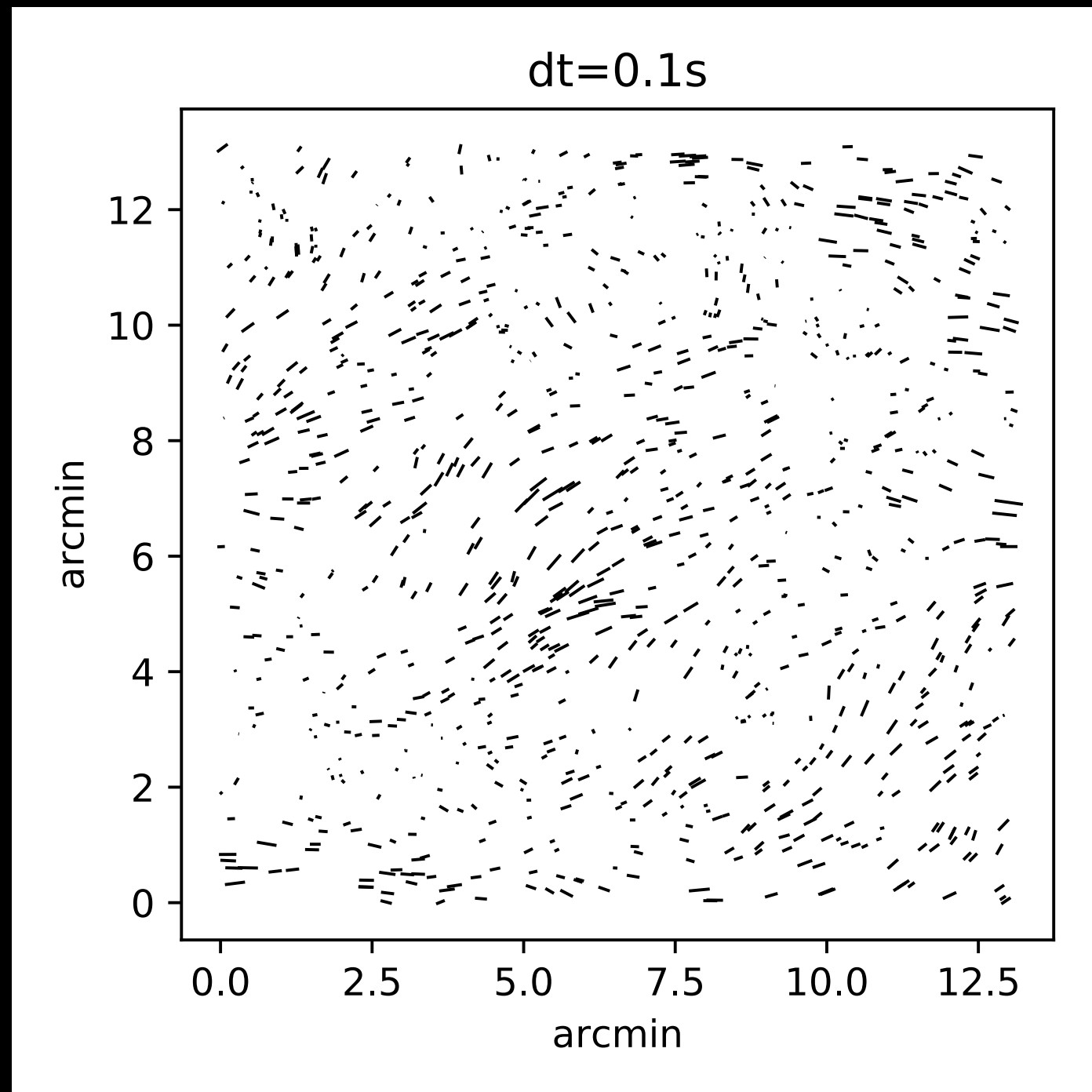
Comparison of moments (time step)



Comparison of whiskers (time step)

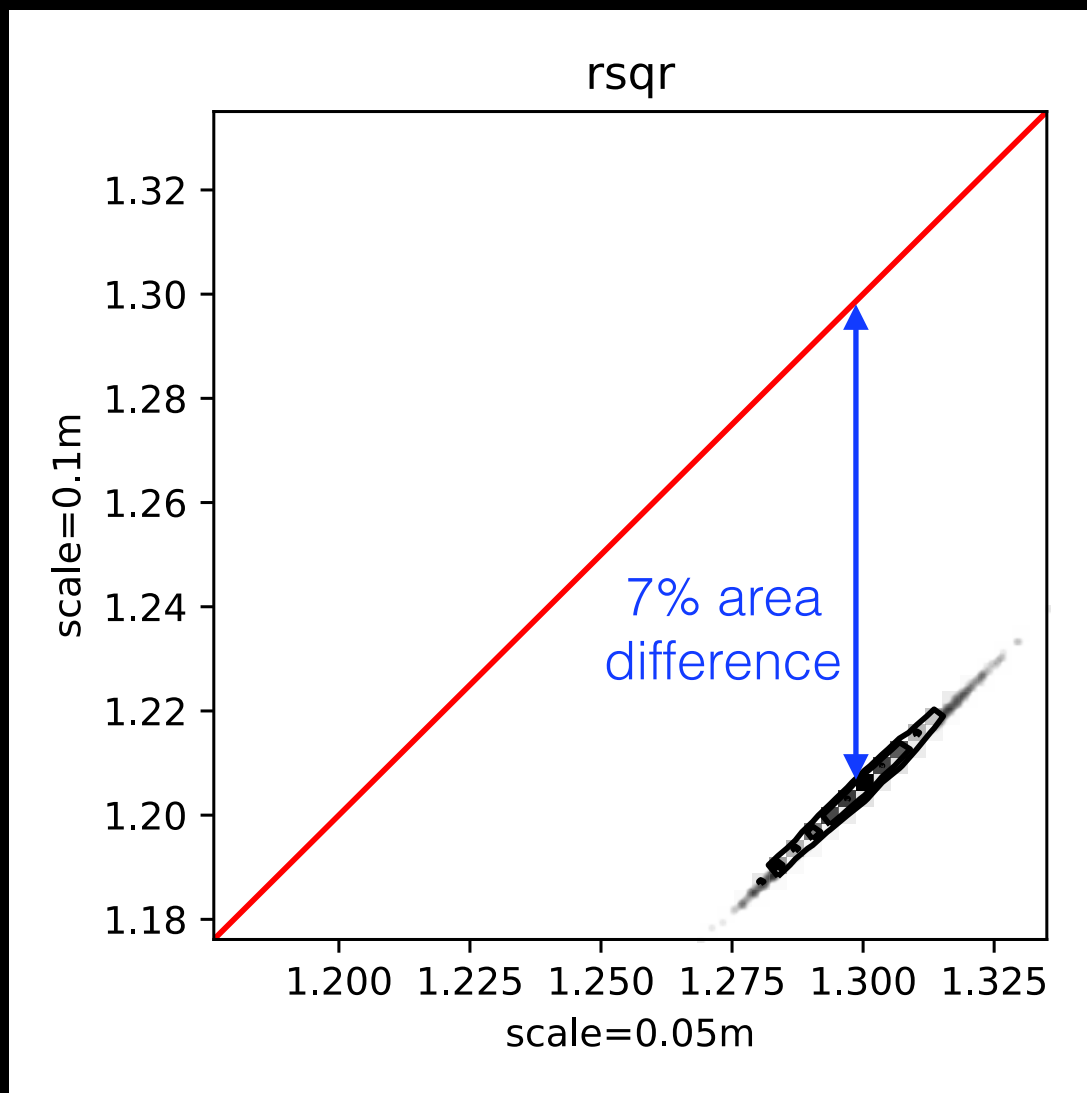


Comparison of whiskers (time step)

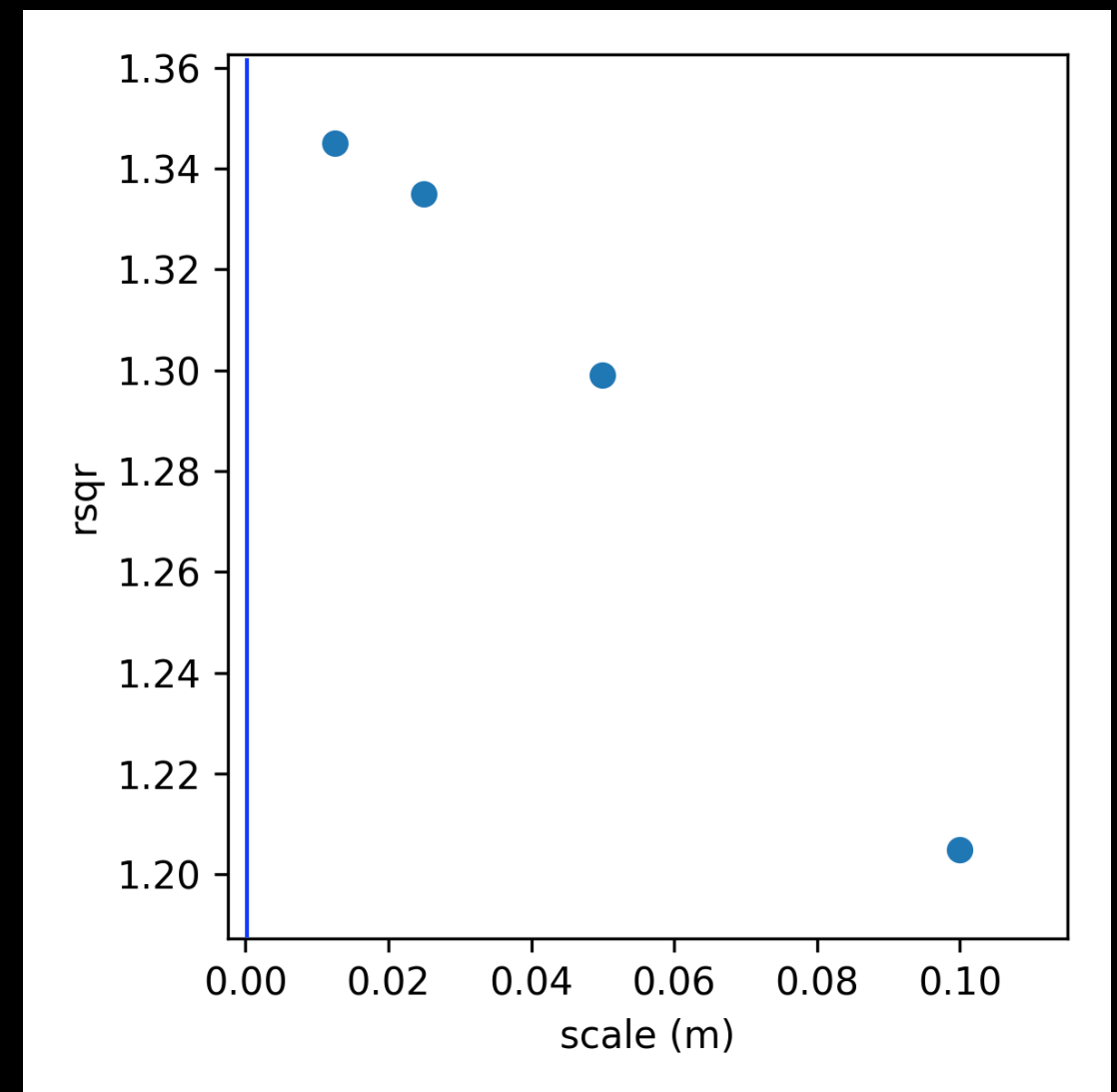
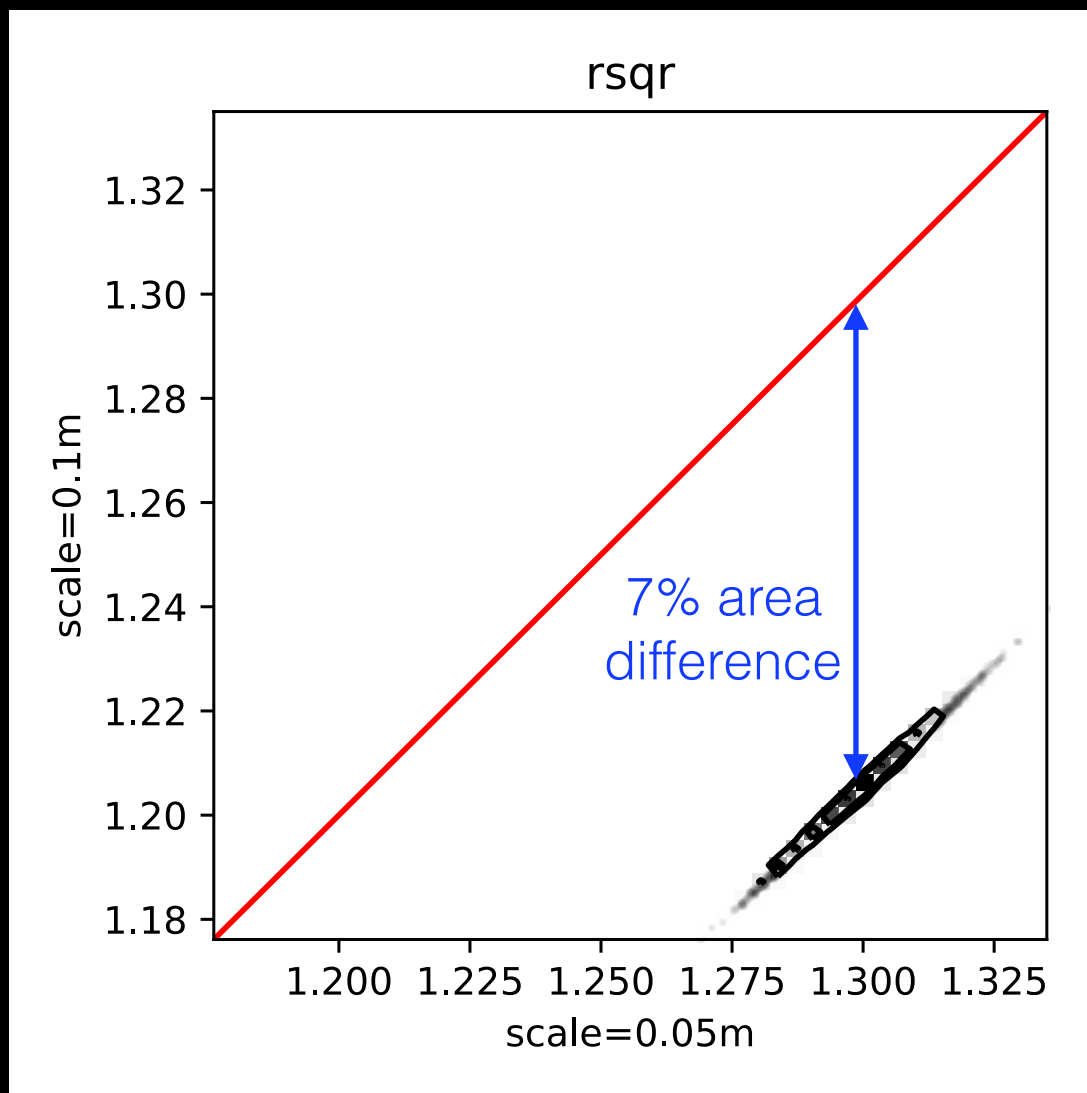


- time step is converged
- sampling and zero-padding of the pupil also converged

PSF size depends on original phase screen sampling



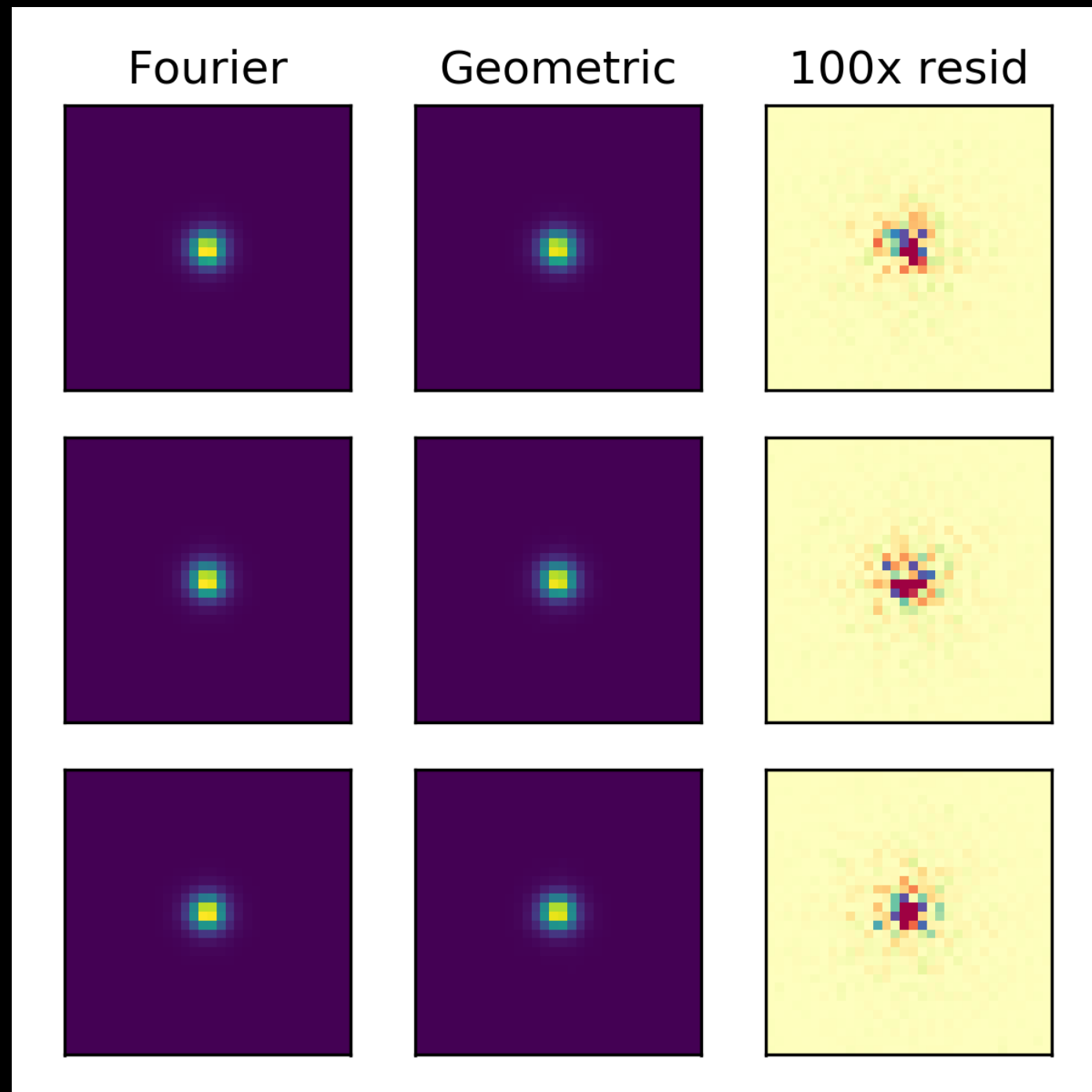
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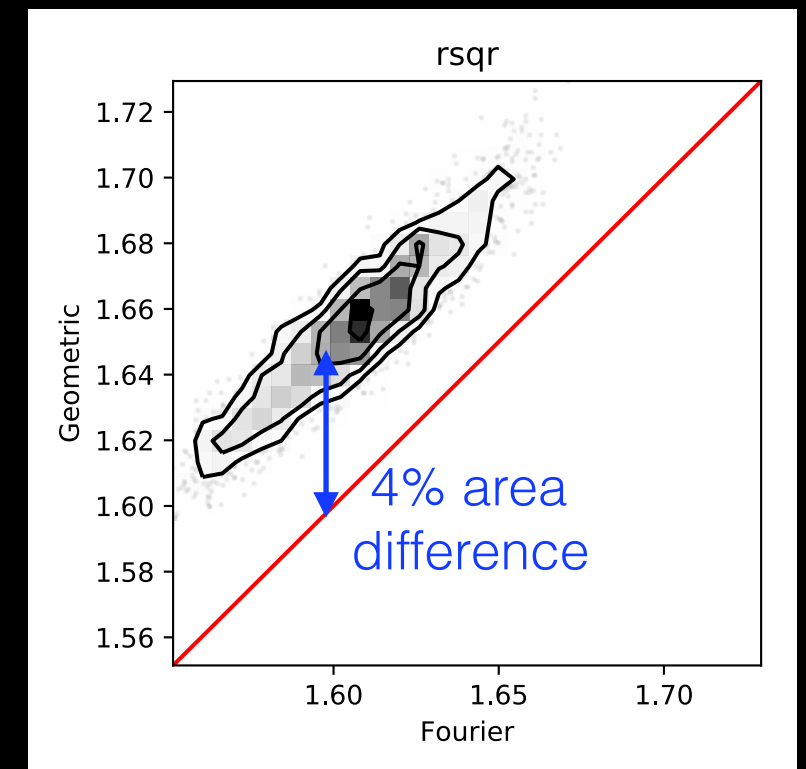
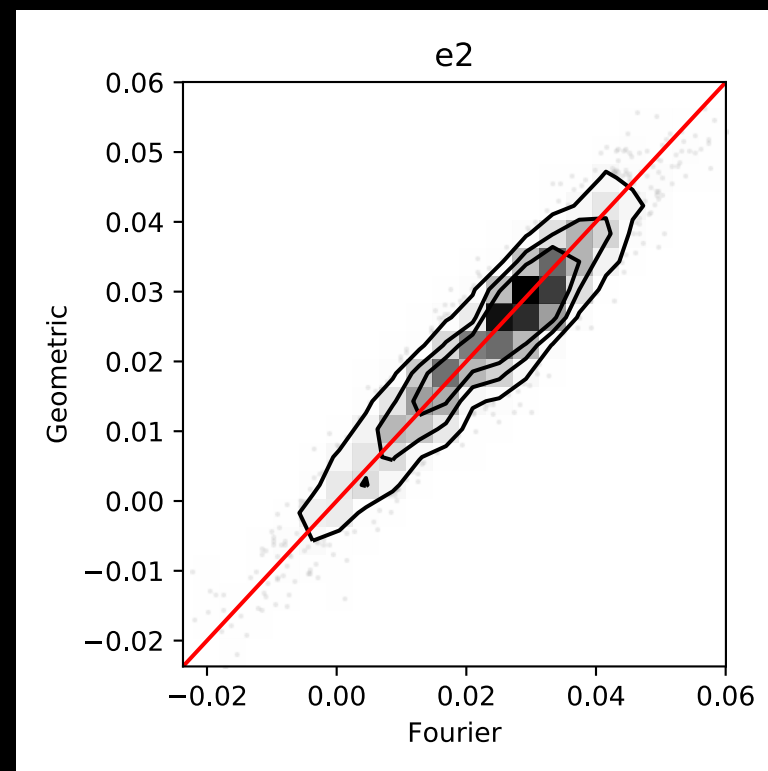
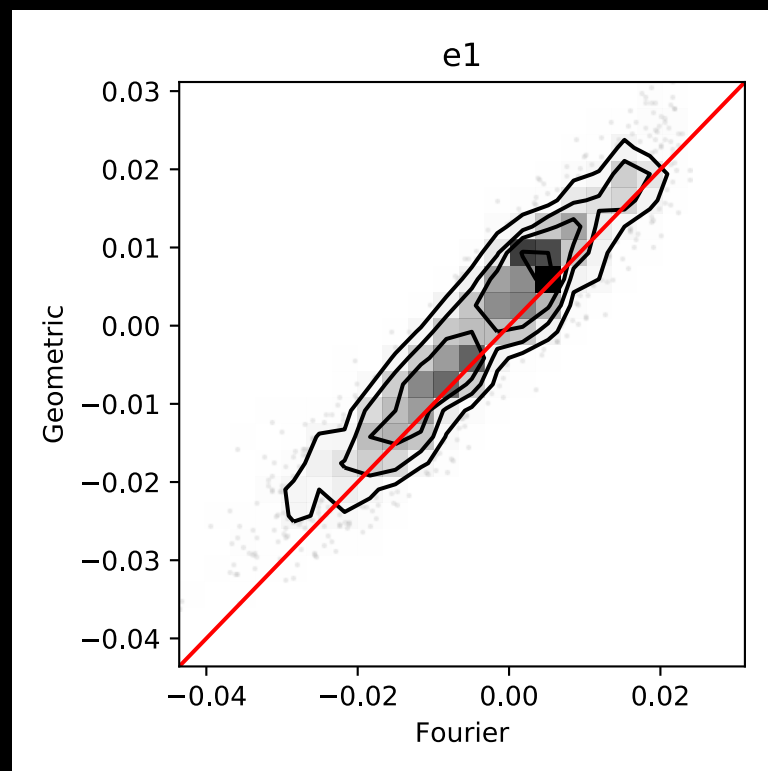
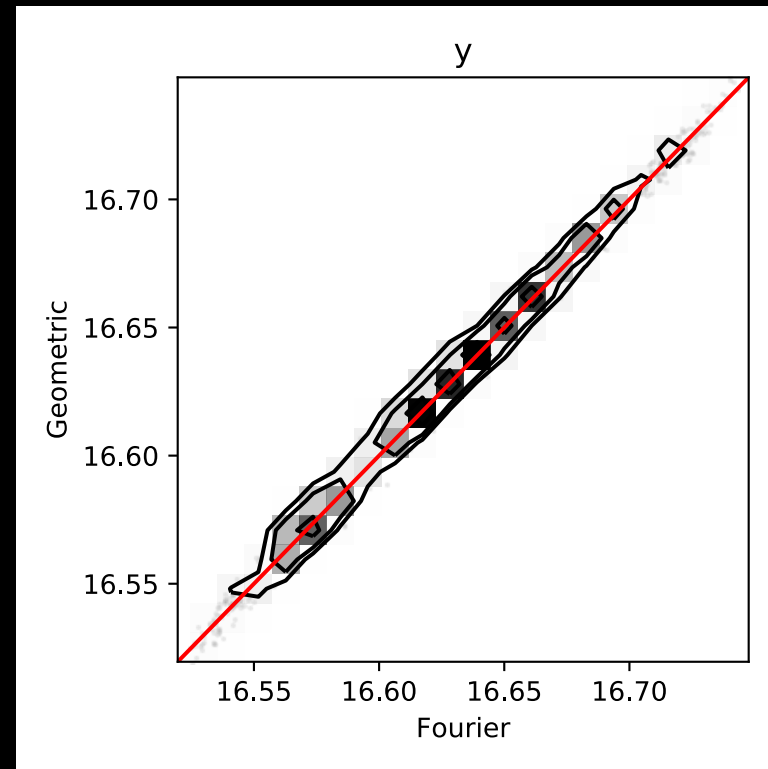
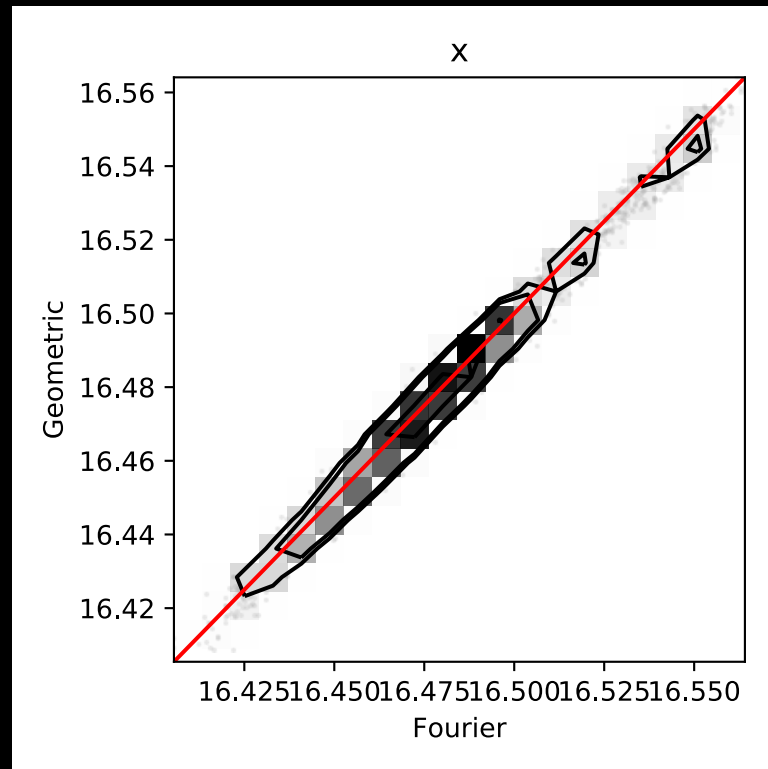
Geometric optics validation

- Compare against (mostly converged) Fourier optics

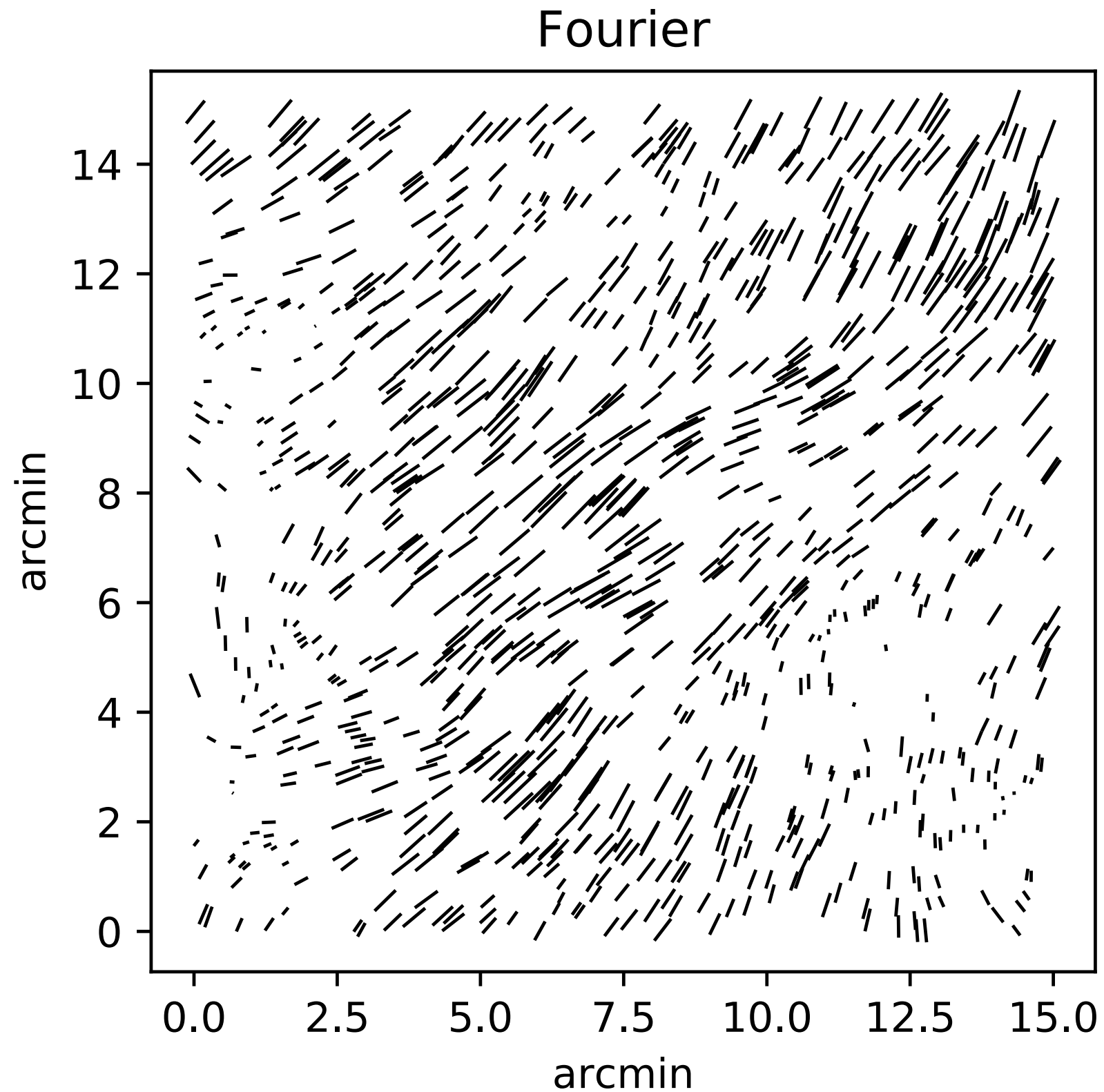
Fourier vs Geometric comparison



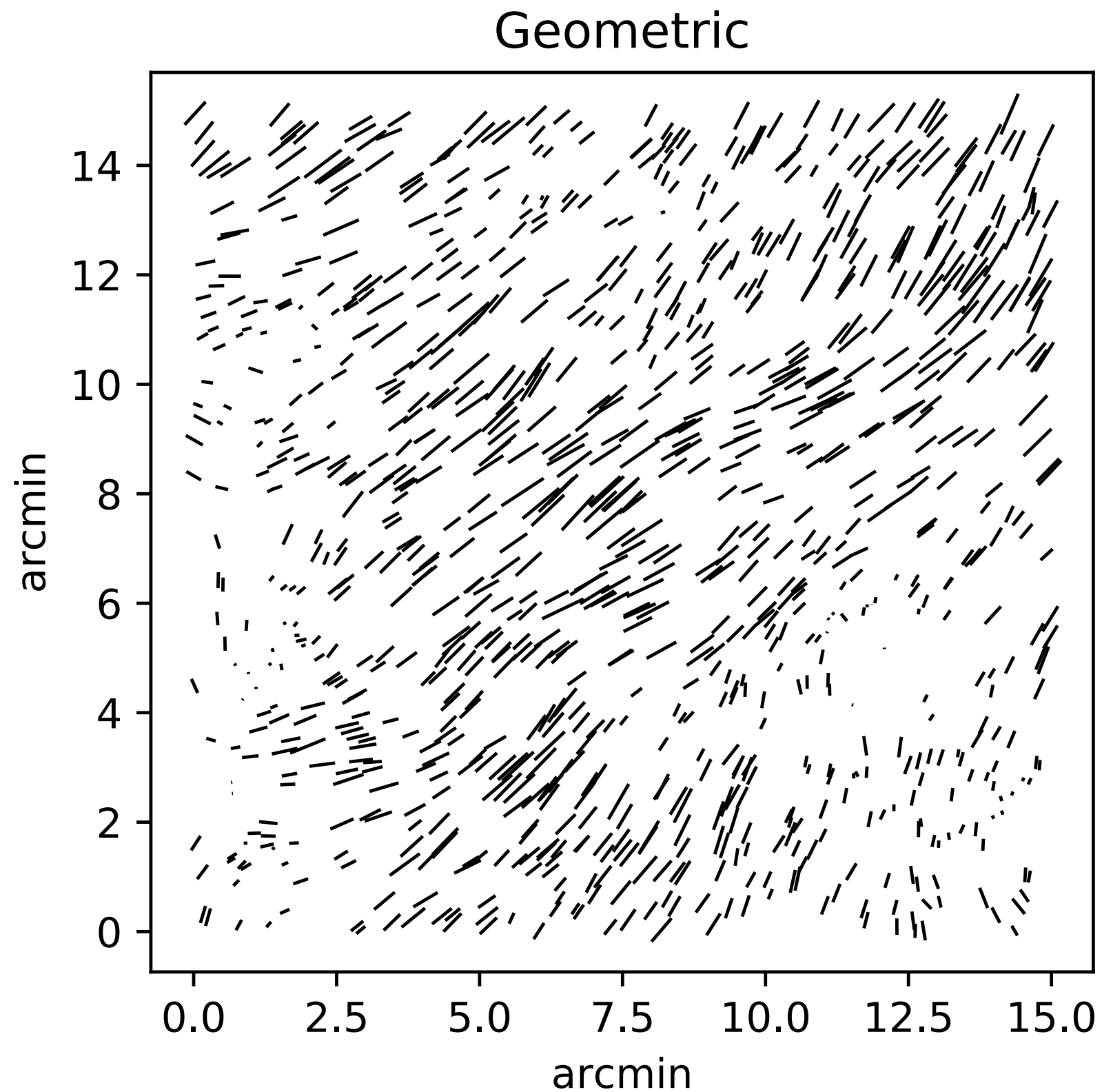
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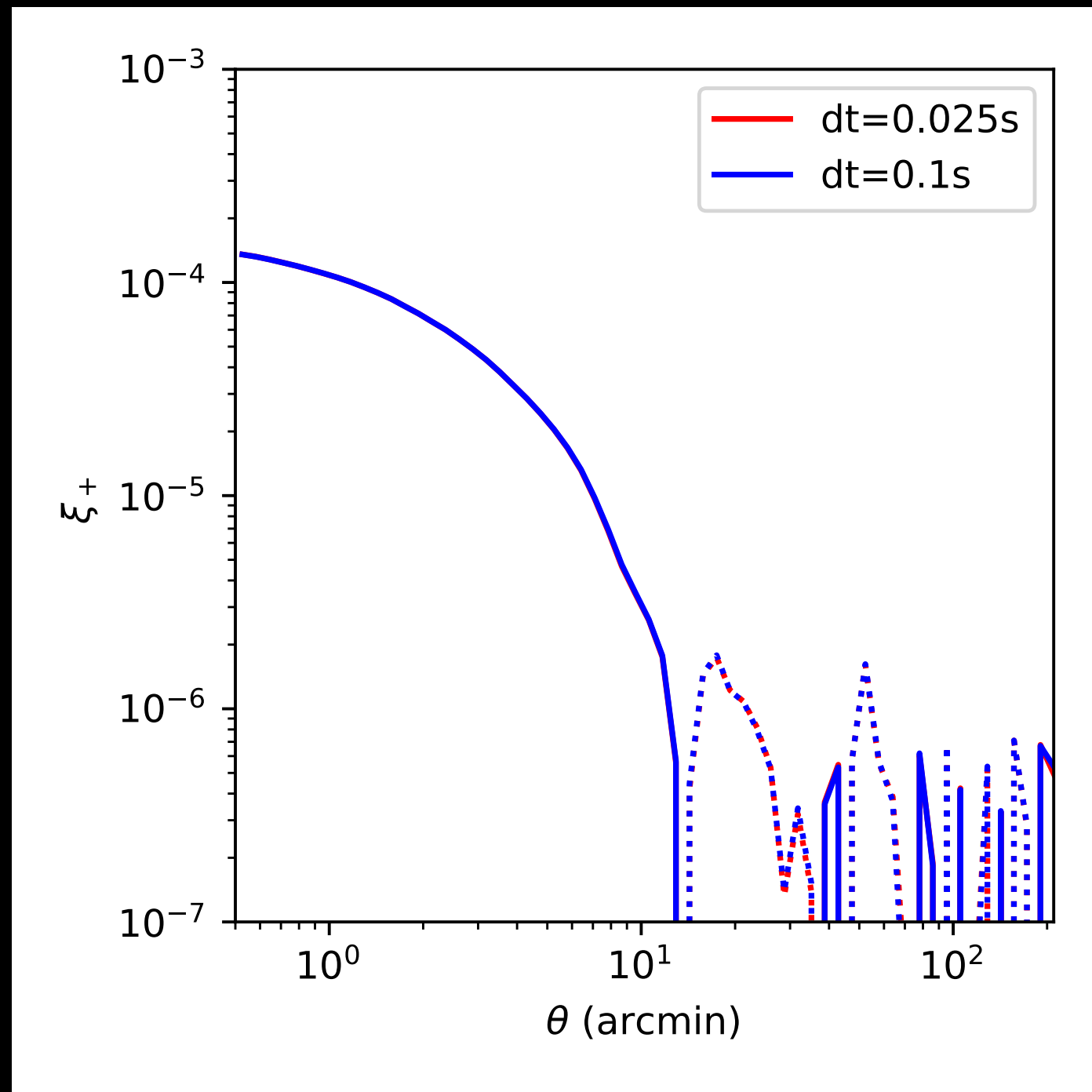
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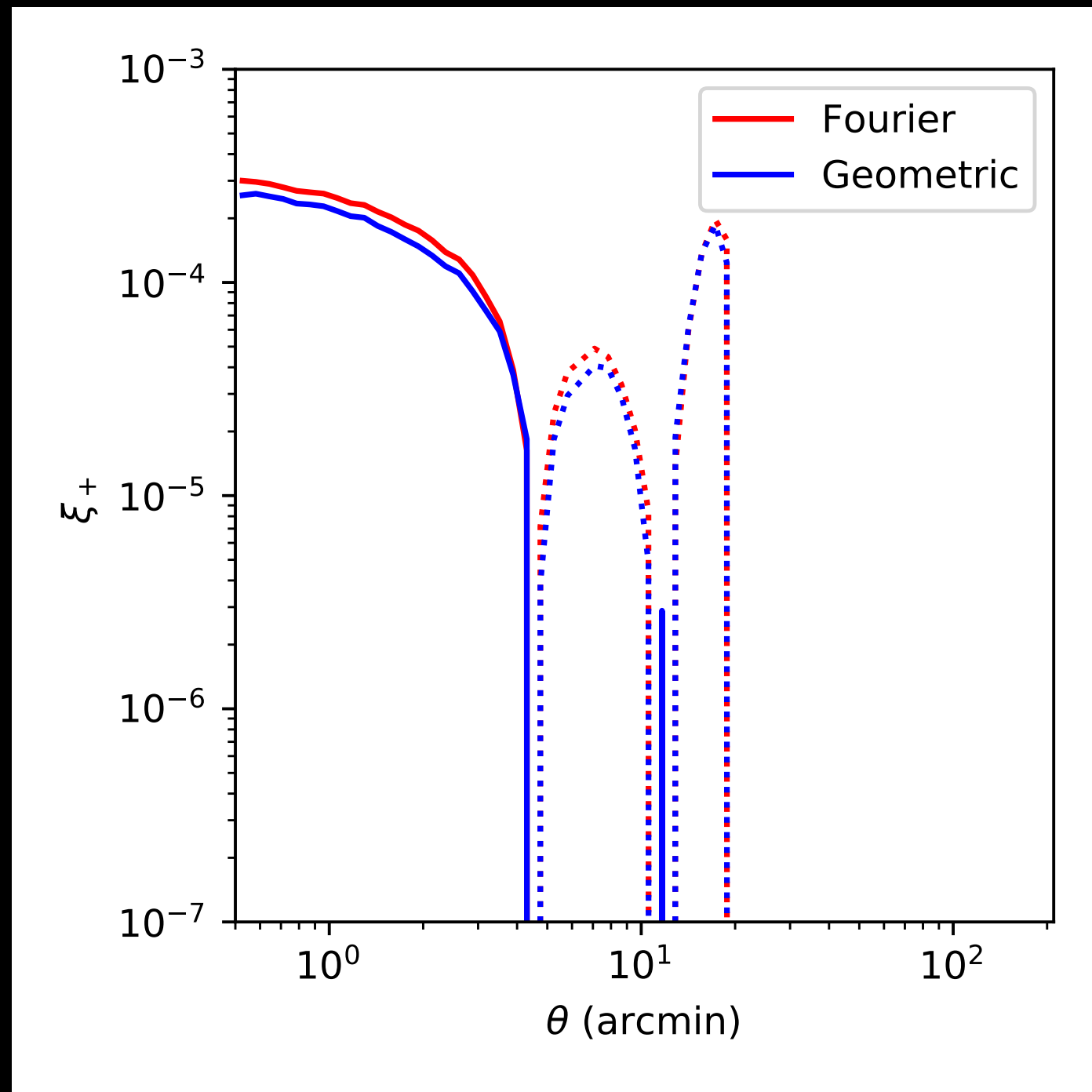
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- In the process of validating over a range of seeing, wavelength, random seeds. Look for a DESC Note soon.

Bonus plots

Correlation function (**time_step**)



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Changing the cutoff scale

