Generating high fidelity phase screens using the structure-based method

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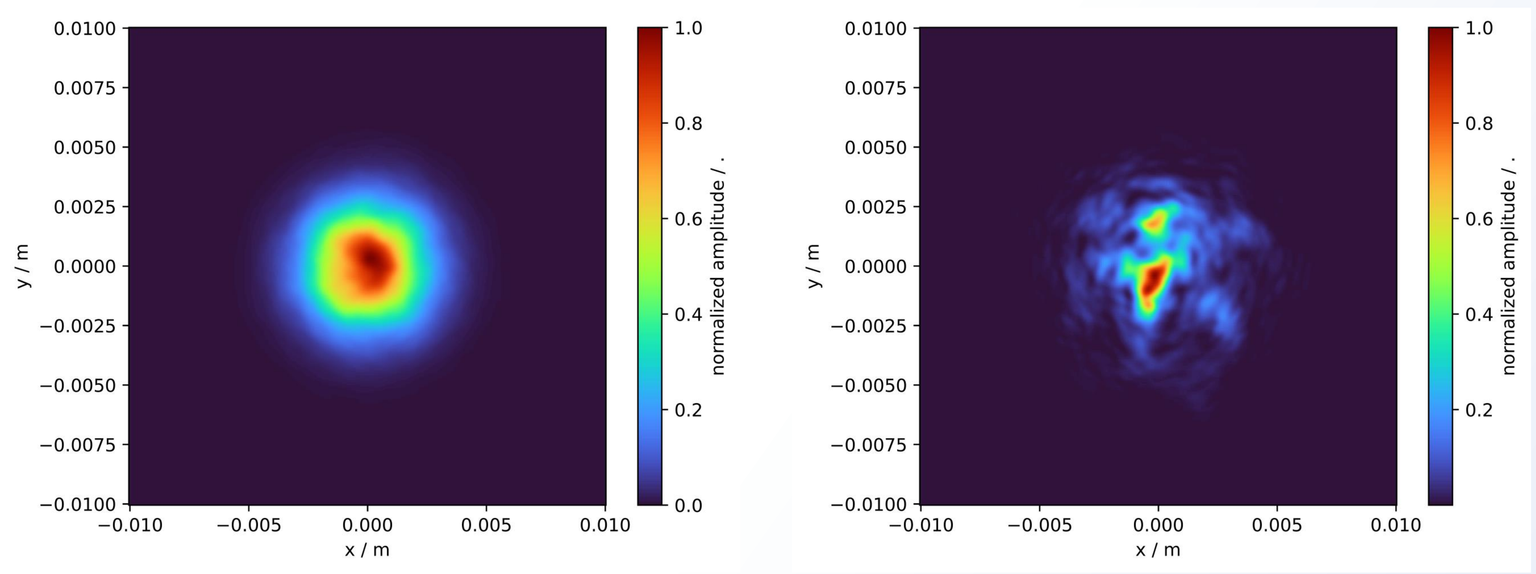
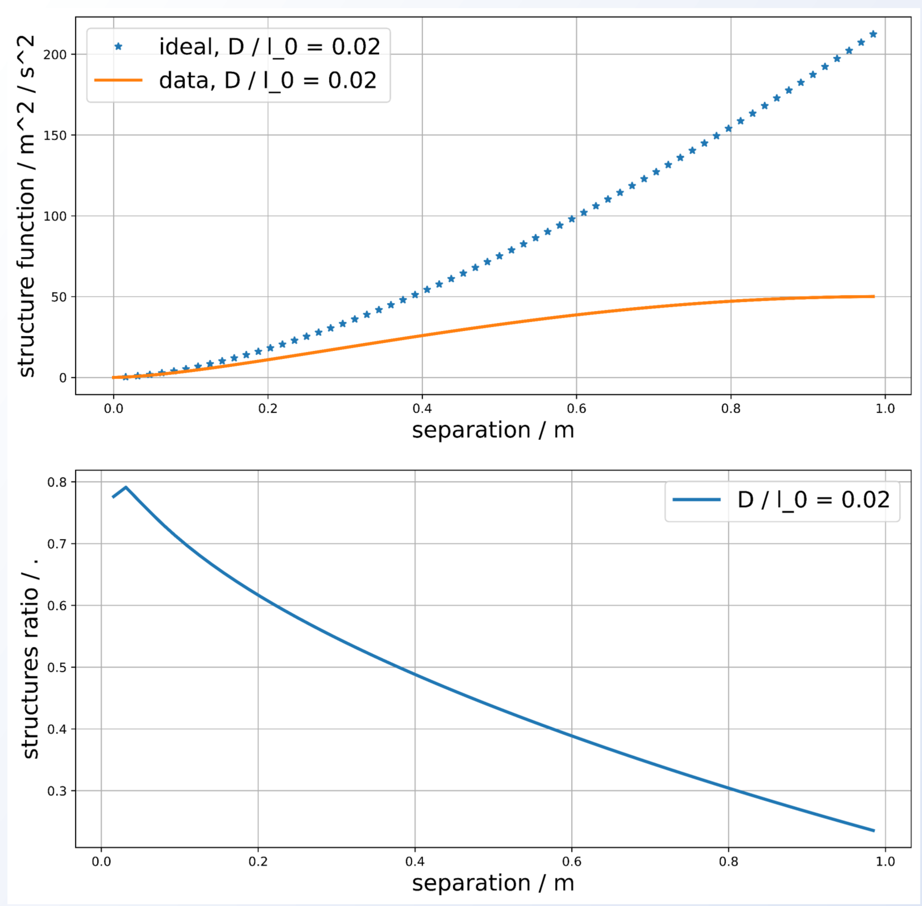
Modelling the beam propagation through the turbulent atmosphere using the phase screen method

The turbulent atmosphere makes the index of refraction of air to fluctuate, inducing a phase fluctuations that act on the beam as multiple lenses with different optical powers and inclinations.
Following a statistical approach [1] [2], this effect can be simulated using the phase fluctuations power spectral density (PSD) Φ_θ.



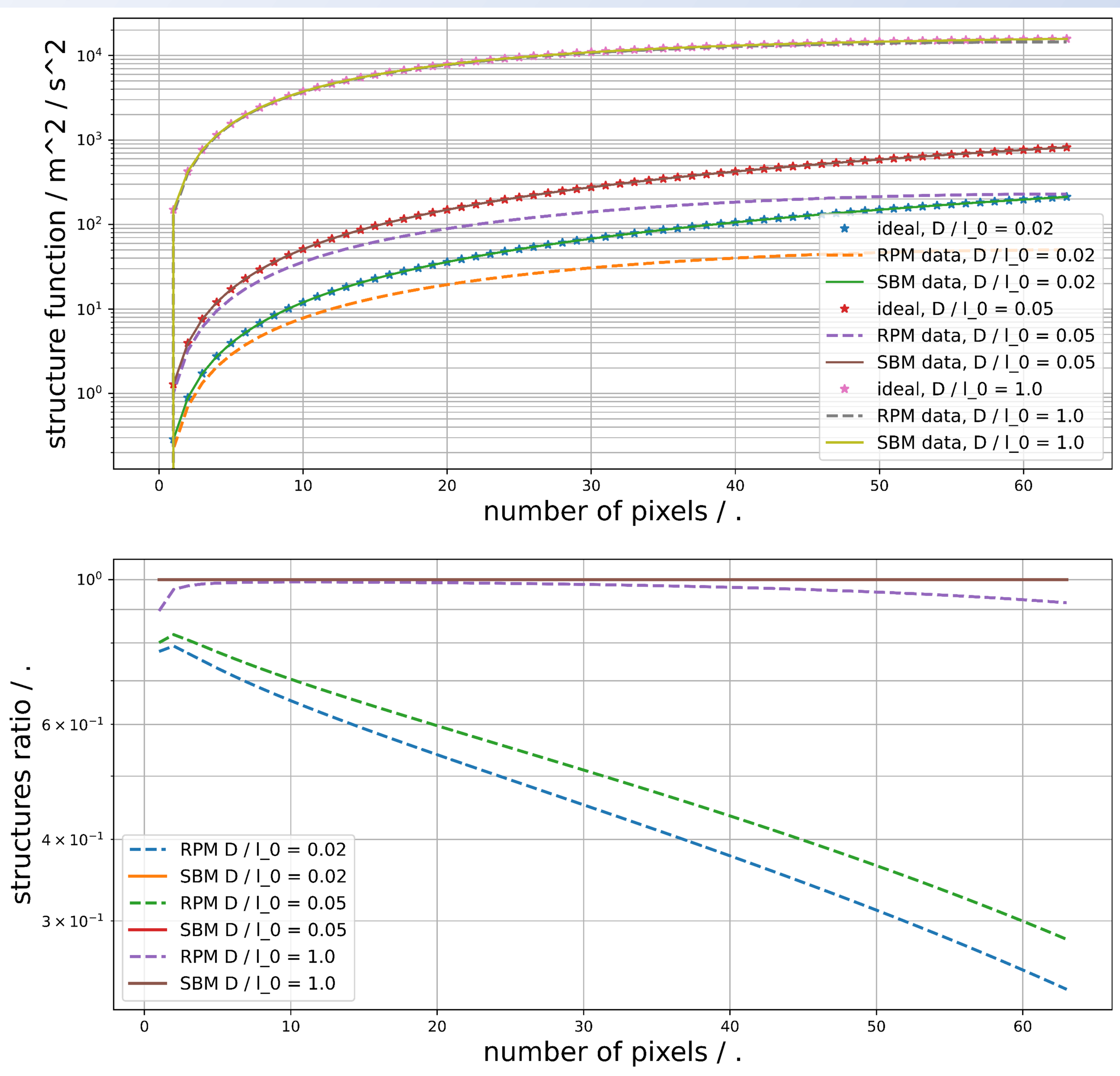
The random phase method discretization errors

By using the Discrete Fourier Transform (DFT), the wavenumber domain of the PSD is determined by the spatial resolution on which the dataset is reconstructed. This can lead to an underestimation of the power in the dataset.



Comparing the random phase method and the structure based method

The RPM and the SBM were compared for different spatial domain sizes. Although the SBM has not been compared with more accurate methods, such as the one implementing the sub-harmonics correction [5], the results show how the SBM is way more accurate than the RPM.



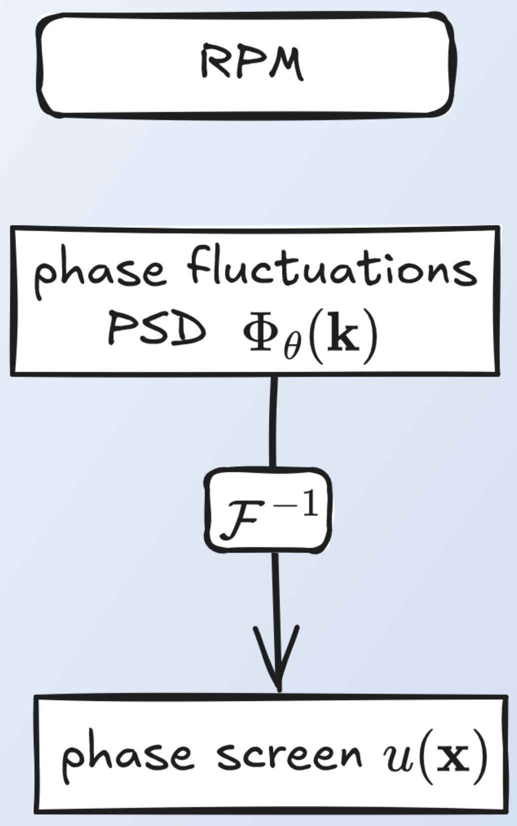
Generating phase screens through the random phase method

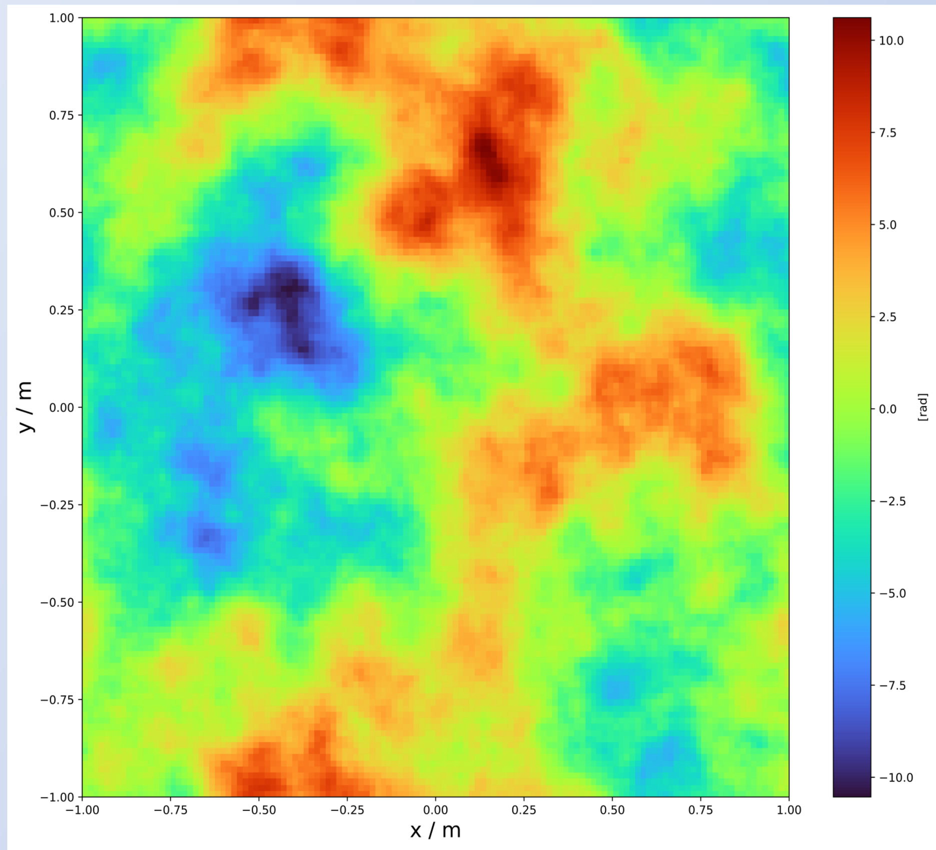
Implementing the random phase method (RPM) [3], the phase screen $u(\boldsymbol{x})$ is obtained as:

$$u(\boldsymbol{x}) = Re\left\{\mathcal{F}^{-1}\left(\boldsymbol{\mu}\frac{2\pi}{D_x D_y}N_x N_y\sqrt{\Phi_\theta(\boldsymbol{k})}\right)\right\}; \quad (2)$$

where $\Phi_\theta(\boldsymbol{k})$, in case of a 2D Von Karman spectrum, is:

$$\Phi_\theta(\boldsymbol{k}) = \frac{0.49\, r_0^{-\frac{5}{3}}}{(k^2 + k_0{}^2)}. \quad (3)$$



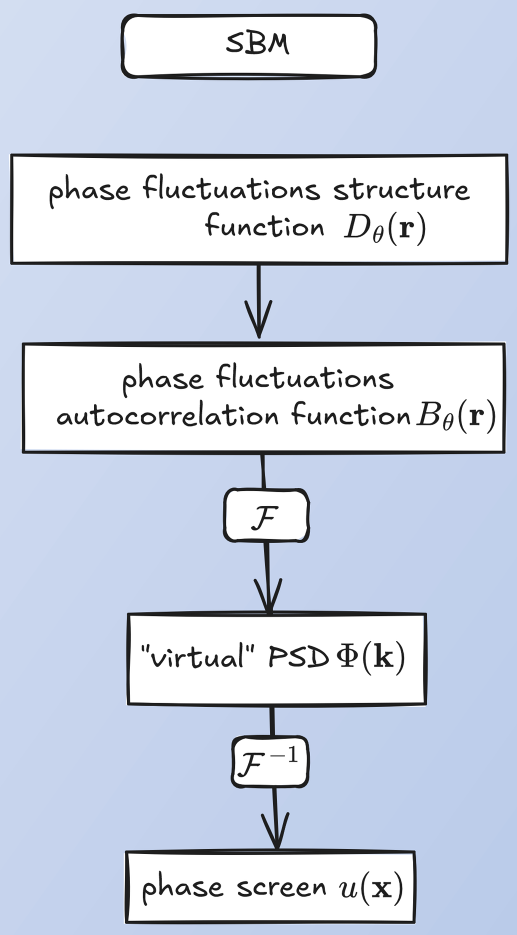


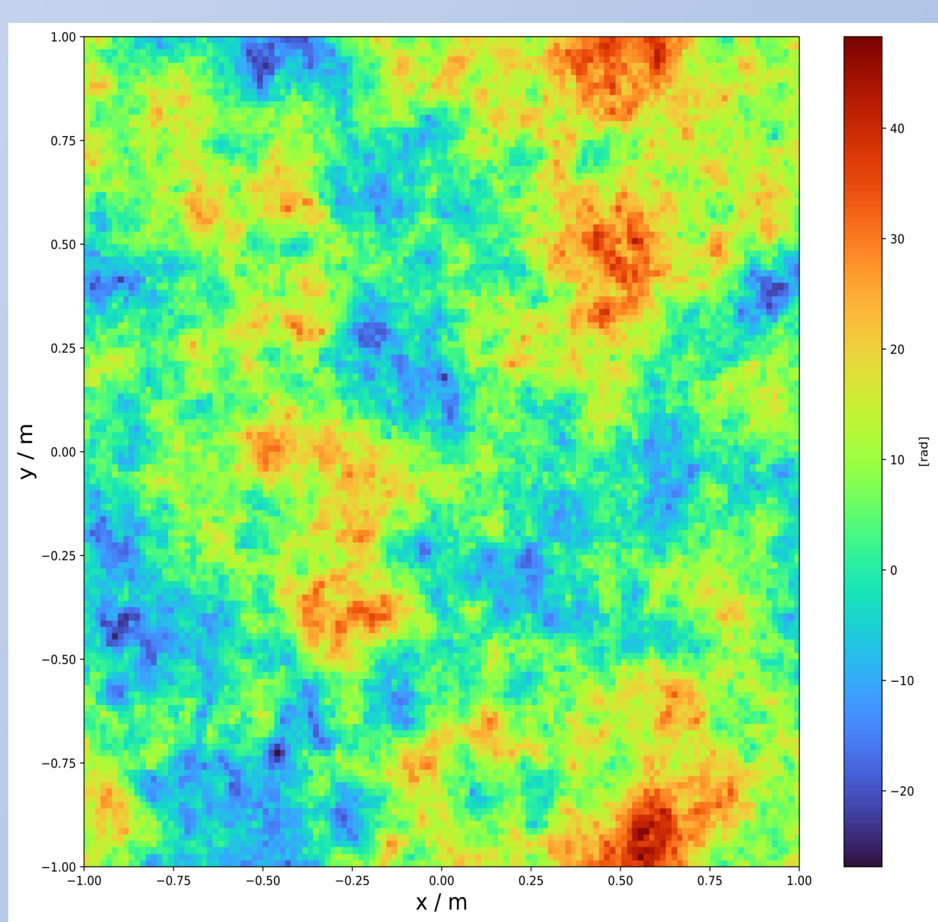
An alternative method: generating phase screens from the structure function

Implementing the structure-based method (SBM) [4], the phase screen $u(\boldsymbol{x})$ is obtained as:

$$u(\boldsymbol{x}) = Re\left\{\mathcal{F}^{-1}\left(\boldsymbol{\mu}\sqrt{\Phi(\boldsymbol{k})N_x N_y}\right)\right\}; \quad (4)$$

where $\Phi(\boldsymbol{k})$ is the PSD calculated as the inverse Fourier Transform of the autocorrelation function $B_\theta(\boldsymbol{r})$, computed from the theoretical structure function $D_\theta(\boldsymbol{r})$.





References

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*under review

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