

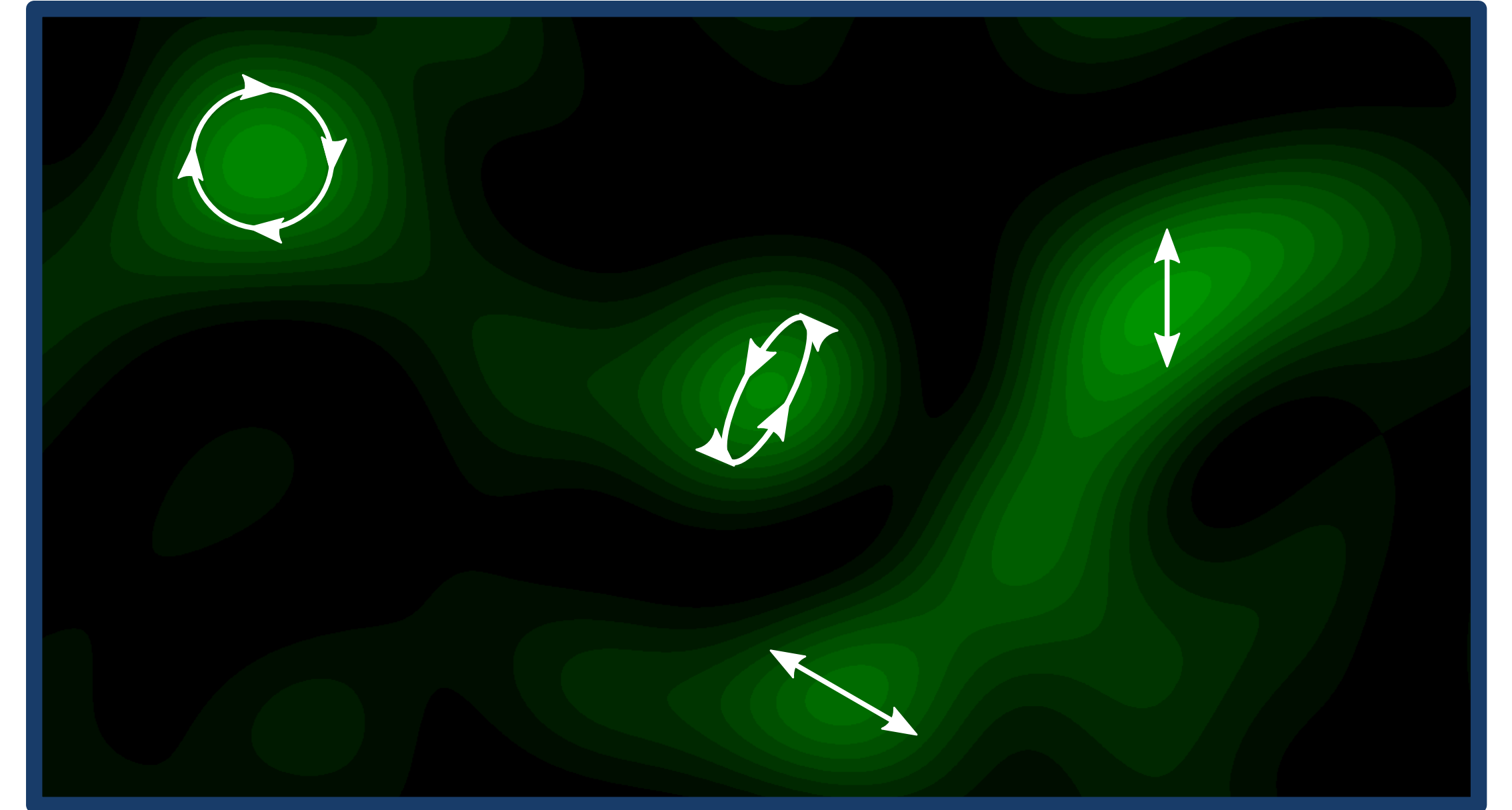
Polarised light scattering in disordered media: a random matrix model

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Introduction

- Polarised light is a useful tool for analysing structural properties of materials, e.g. thin films and surfaces, biological tissue [1] and astronomical bodies.
- Multiple scattering in disordered media is detrimental to information transfer due to randomisation of phase, intensity and polarisation state [2].
- Knowledge of the scattering matrix and its statistical properties has enabled precise wavefront control and imaging through turbid media [3].
- We have developed a numerical model for studying the statistics of random scattering matrices that incorporate polarisation properties of light.

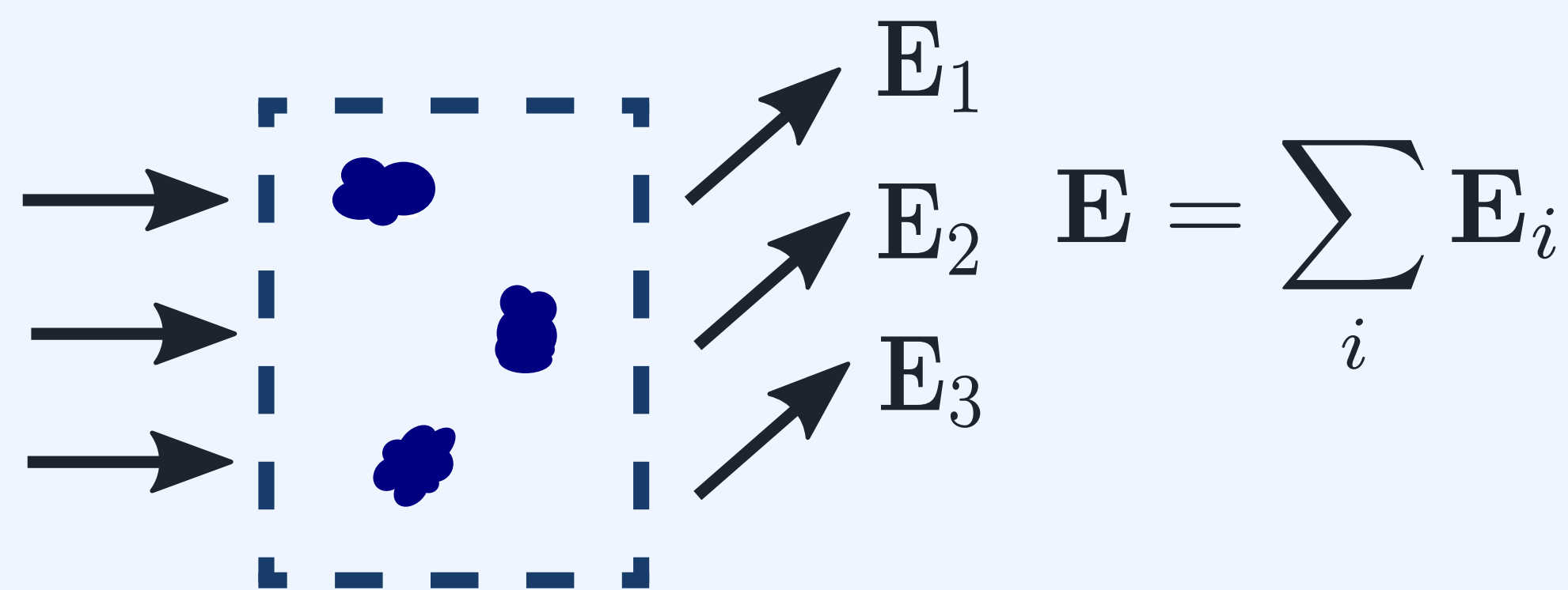


Randomly polarised speckles

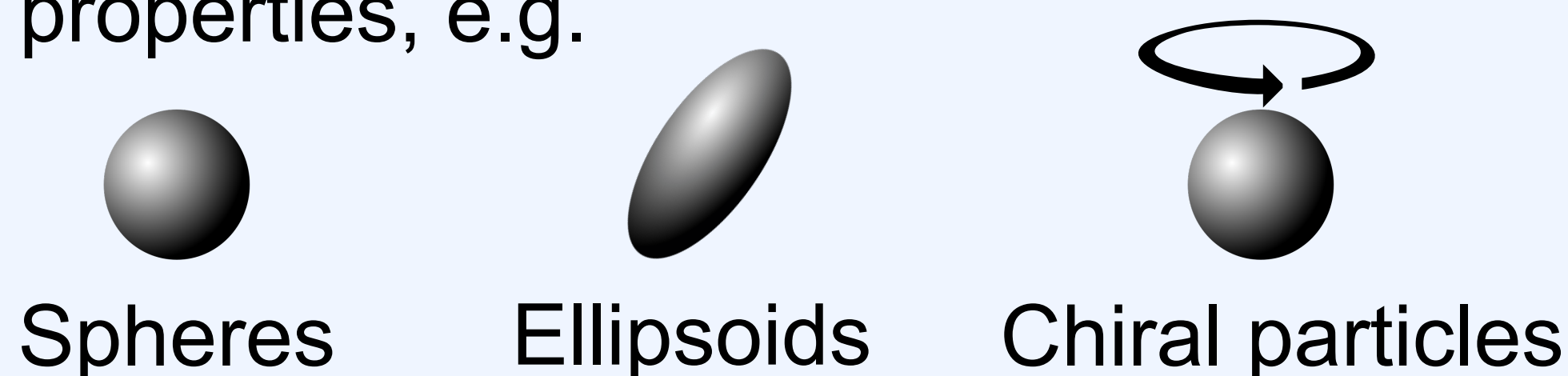
Model

1 Thin slab scattering

- Single scattering approximation.



- Total field given by complex phasor sum.
- Particles may have different shapes, sizes, orientations and polarimetric properties, e.g.



2 Random matrices

- Average Mueller matrix for thin slab determines covariance matrix for scattering matrix elements.

$$\mathbf{M} \rightarrow \Sigma$$

- Scattered field assumed to have joint Gaussian statistics.

$$p(\mathbf{z}) \sim e^{-\mathbf{z}^\dagger \Sigma^{-1} \mathbf{z}}$$

- Scattering matrix constrained by energy conservation + reciprocity [4].

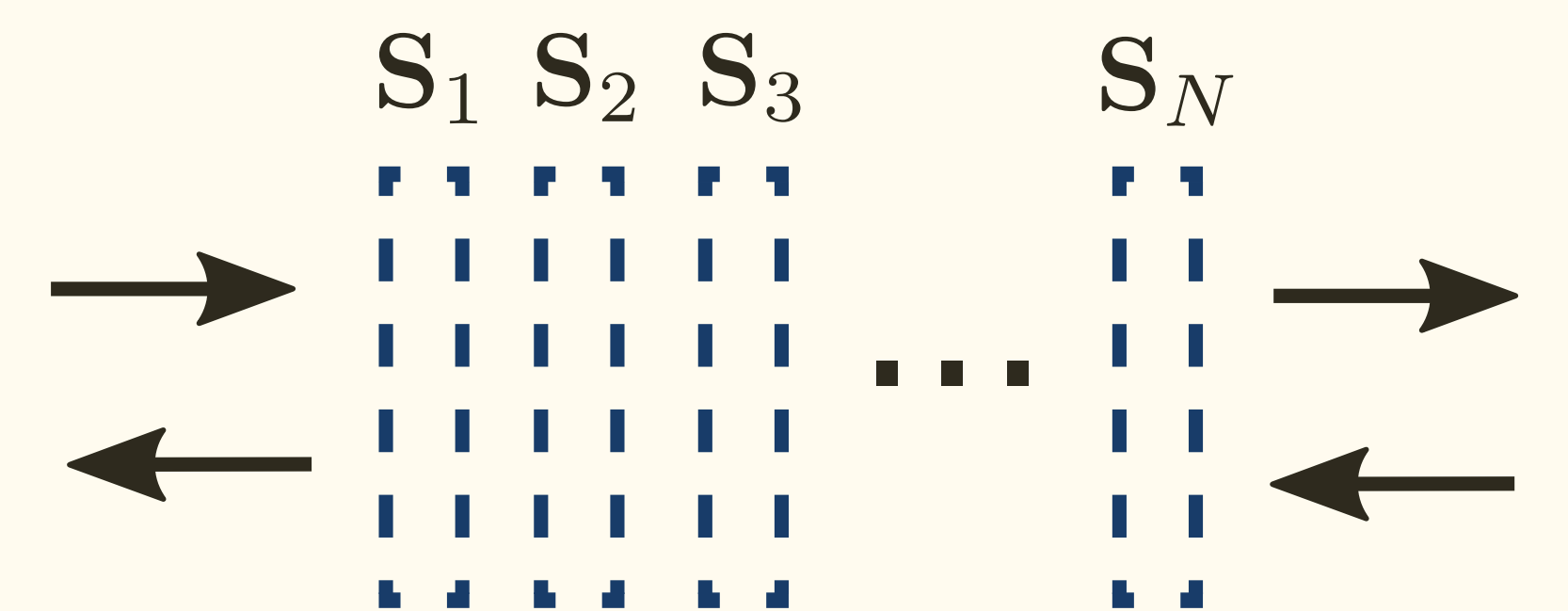
$$\begin{aligned} \mathbf{S}^\dagger \mathbf{S} &= \mathbf{I} \\ \mathbf{S} &= \mathbf{K} \mathbf{S}^T \mathbf{K}^{-1} \end{aligned}$$

3 Matrix cascade

- Generated scattering matrix describes transmission and reflection by single thin slab.

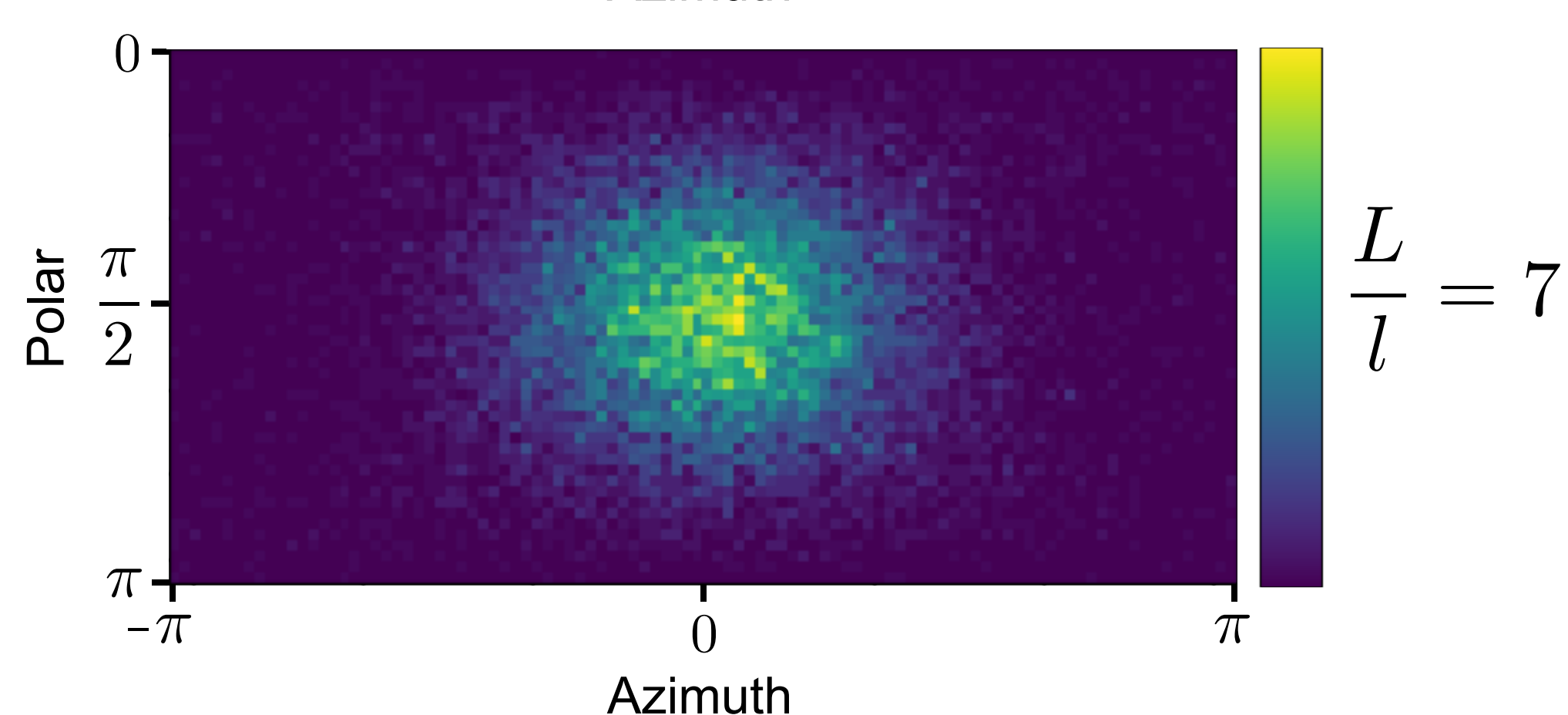
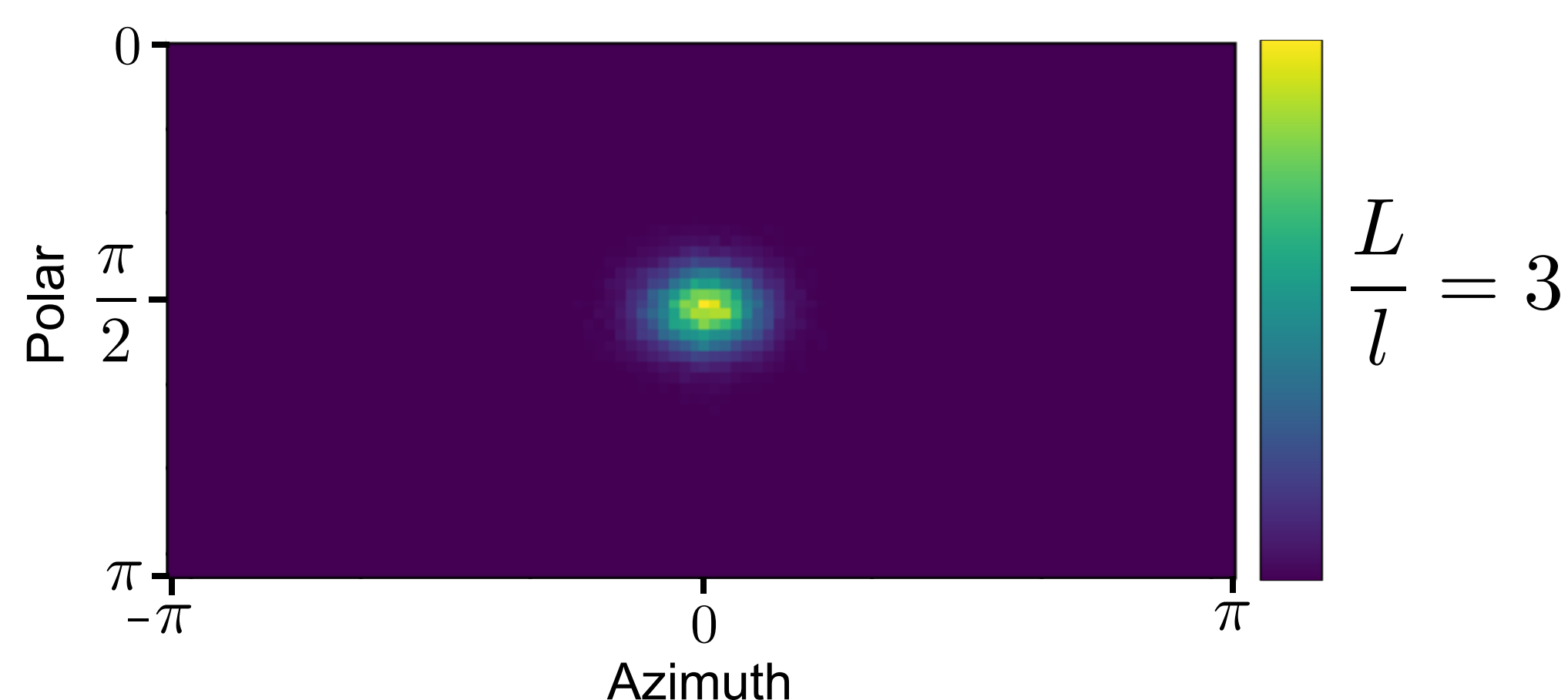
$$\mathbf{S} = \begin{pmatrix} \mathbf{r} & \mathbf{t}' \\ \mathbf{t} & \mathbf{r}' \end{pmatrix}$$

- Slabs can be cascaded to model thick, multiple scattering media.

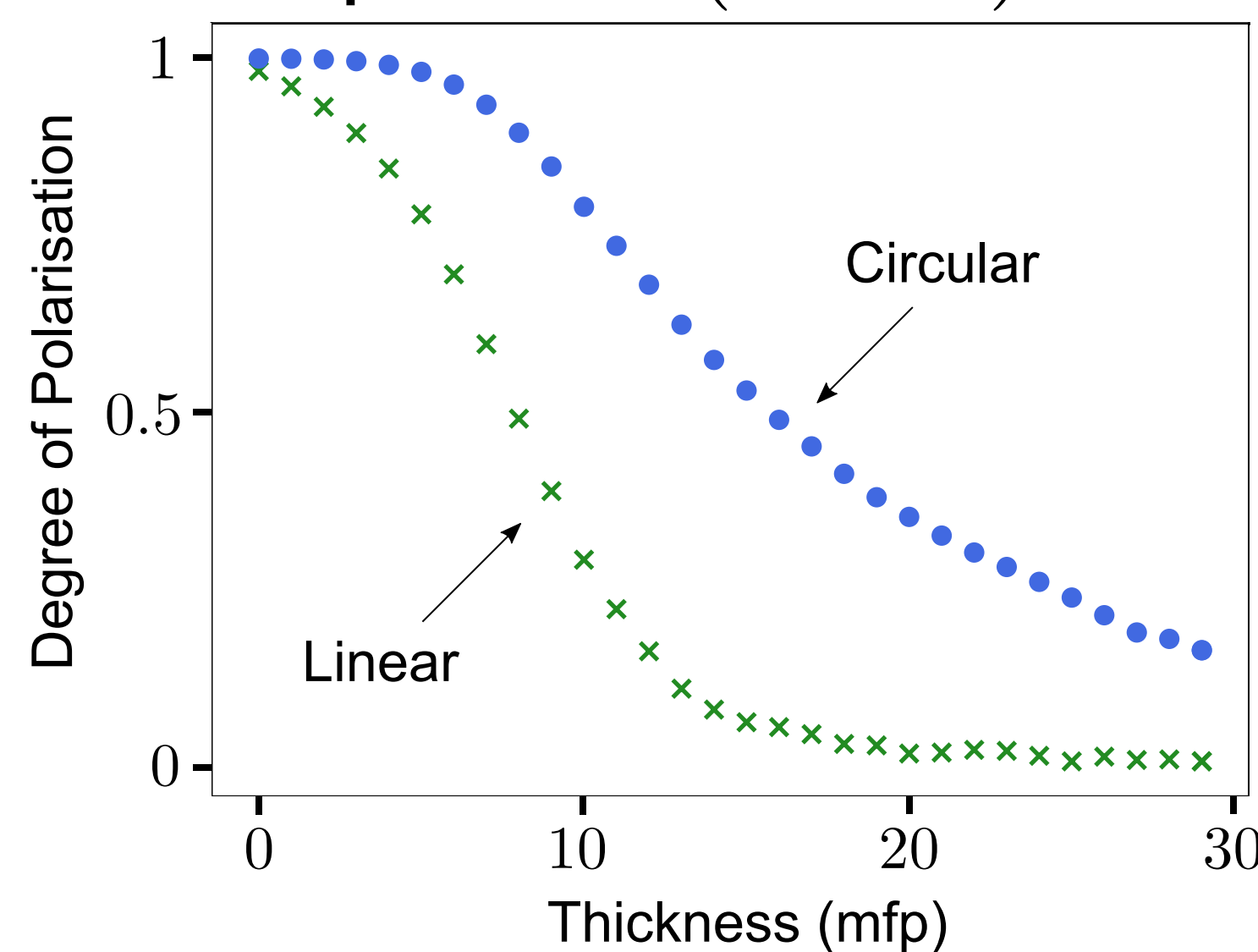


Results (Forward Scattering)

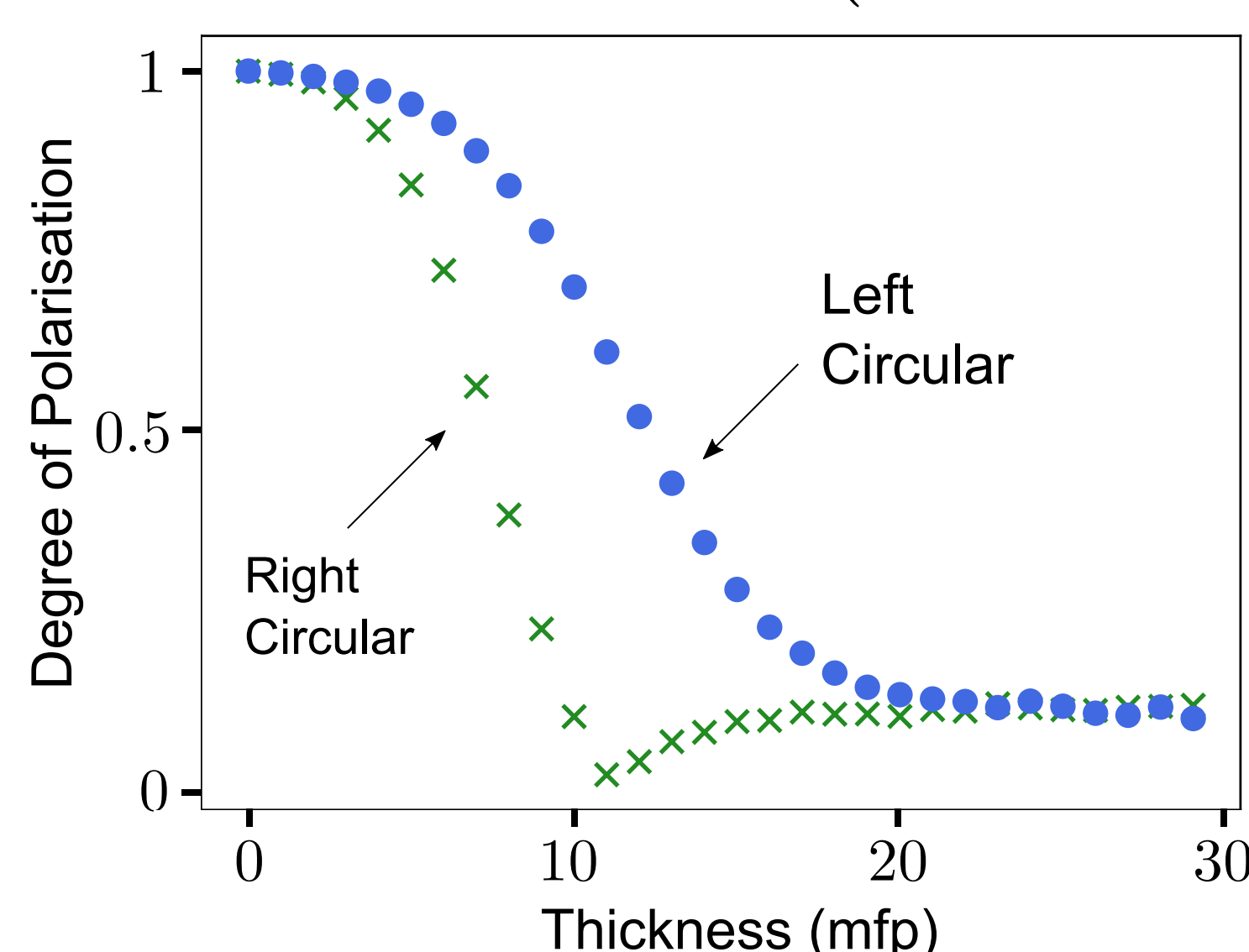
- Distribution of scattered field polarisation on Poincaré Sphere



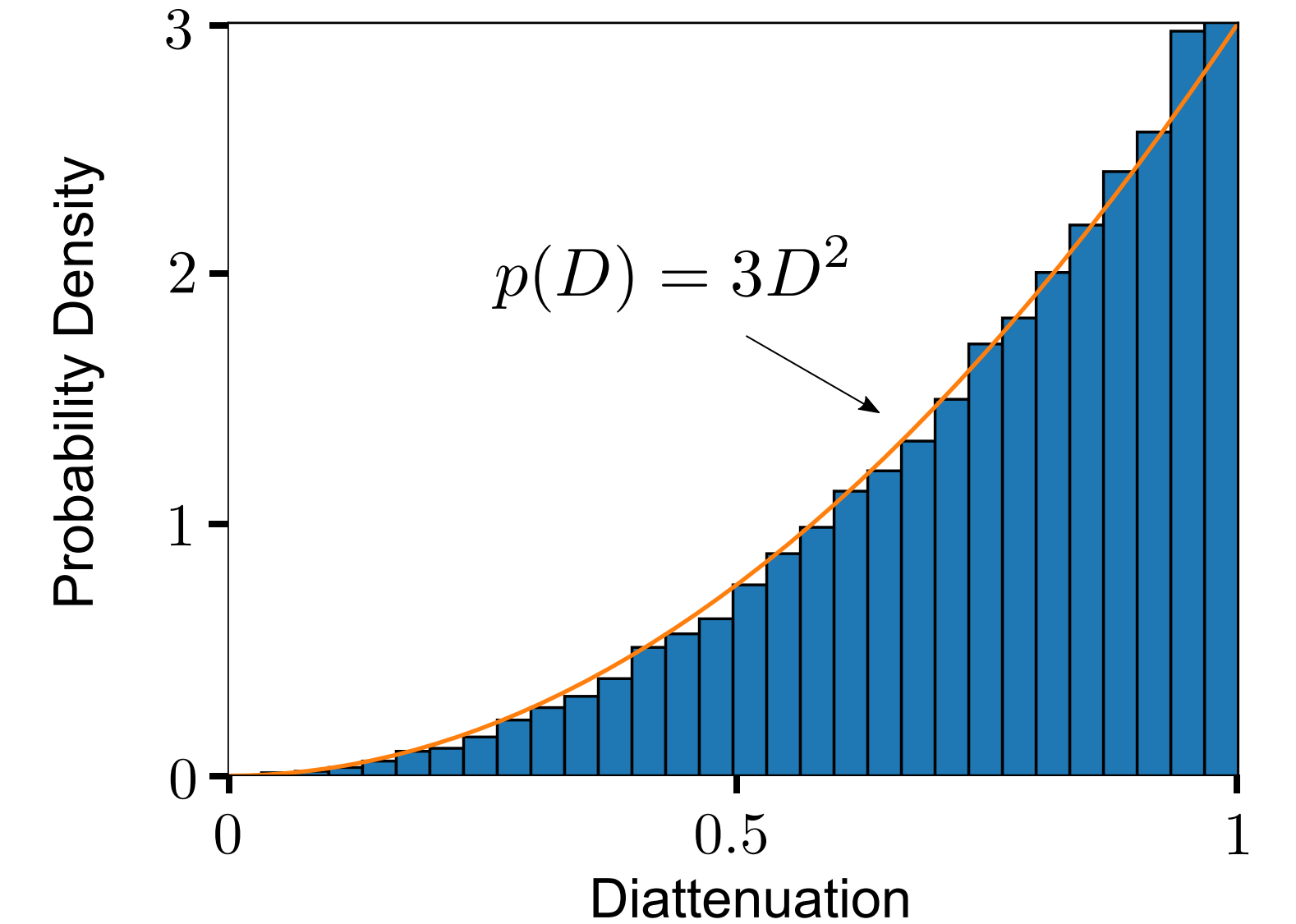
- Mie spheres ($x = 2$)



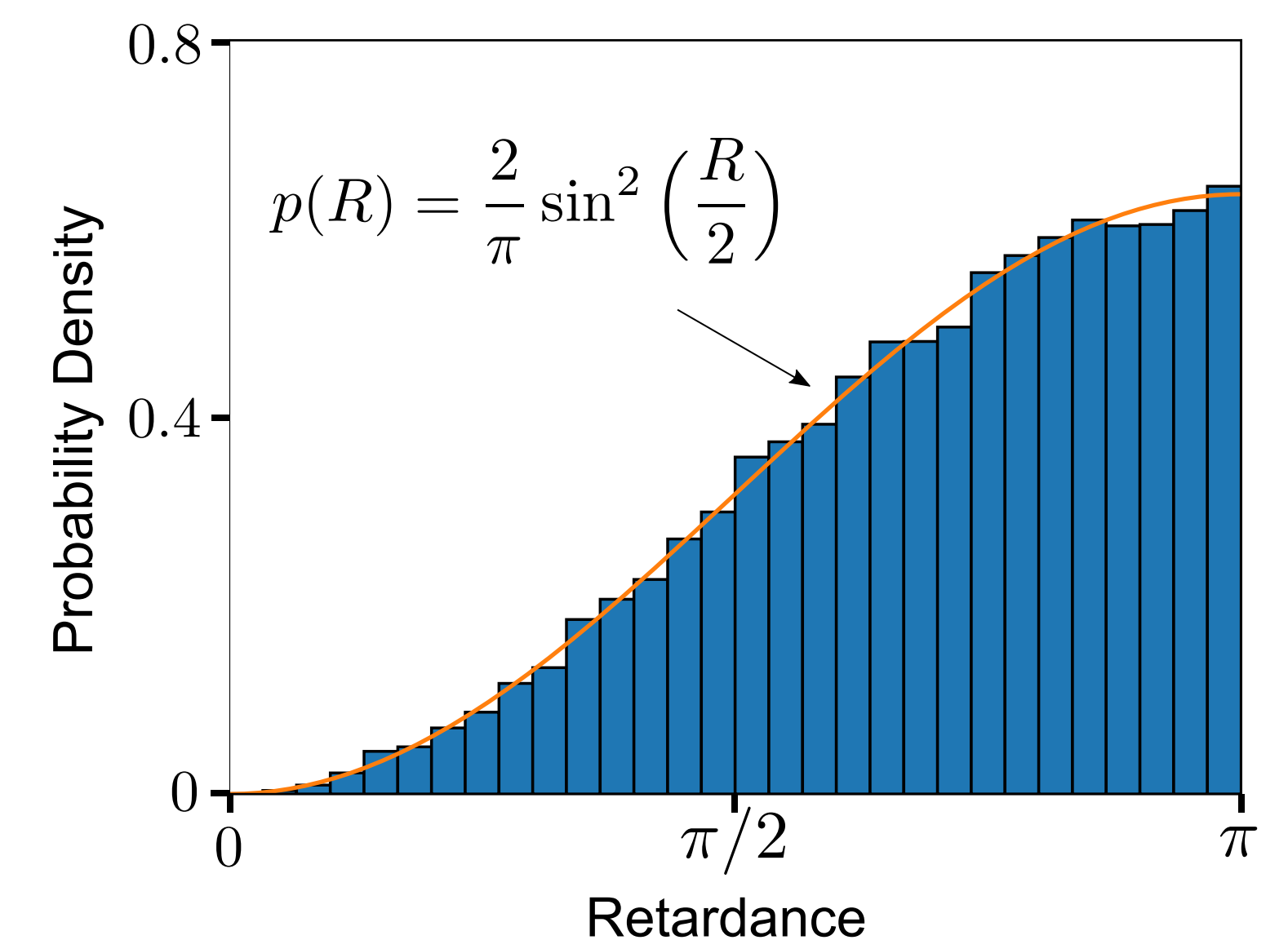
- Chiral particles ($\kappa = 0.05$)



- Diattenuation statistics



- Retardance statistics



References

- [1] Tuchin, V. V., Journal of Biomedical Optics 21(7), 071114 (2016)
- [2] Byrnes, N. et al., New Journal of Physics 22, 083023 (2020)
- [3] Katz, O. et al., Nature Photonics 8, 784–790 (2014)
- [4] Byrnes, N. et al., Physical Review Research 3, 013129 (2021)

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