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The multi-axion toybox and black hole superradiance

Randomised landscapes of the string axiverse offer an inviting approach to probing the complexities of multi-field potentials in a self-consistent but ultimately simplified manner, where axion physics can be understood using ideas of maximised entropy of the Lagrangian matrix space and canonical random matrix theory. We will briefly introduce a series of random matrix theory axiverse models based on axion field alignment and central limit theorems of free convoluted measure spaces for the canonical fields. We will also present an overview of an effective approach to the axion spectrum arising from the superpotential in the M -theory axiverse, using stochastic parameters of the model used to suitably stabilise the moduli. Such models are susceptible to test the viability of axion contributions to the cosmic history using hierarchical Bayesian inference models on simplified parameter spaces.

In order to demonstrate how these models can be used to draw inferences on the axion parameter space, we will consider astrophysical spin measurements of black hole systems and the superradiance phenomenon. We will explore how these measurements are used to constrain properties of the universal statistical distributions in effective axiverse models, specifically the mass ranges and allowed numbers of fields present in the spectrum. Such a methodology generally excludes $N \geq 30$ axion-like fields with a range of mass distribution widths and central values spanning many orders of magnitude, covering axion phenomenologies important to the dark sector of cosmology, grand unified theories and particularly for the recently imaged M87*, models of fuzzy dark matter.

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