(BSM) is presented. This introductory chapter concludes by highlighting the role of ALPs as generic predictions in BSM theories and as compelling dark-matter candidates and is accompanied by a description of plausible techniques towards their detectability with astronomical sources.

Chapter 2 begins our discussion on astrophysical ALP searches by presenting the tightest bounds to date on the coupling of light ALPs to electromagnetism based on a spectral analysis of high-resolution archival *Chandra*/Grating observations of the luminous cluster-hosted quasar H 1821+643.

Chapter 3 provides an exploration of how the next-generation *Athena* X-ray flagship observatory will improve on the current most sensitive limits presented in Chapter 2. A promising technique to mitigate the effect of previously ignored systematic uncertainties is discussed. ALP projections from the *AXIS* probe-class concept proposed to NASA for a 2032 launch are also introduced.

The future of ALP searches with upcoming missions is encouraging due to advances in detector technology. These advances include improvements in effective area, spatial resolution, and spectral resolution when compared with current observatories. In future, probing light ALPs with observations of bright AGNs located at the centres of rich clusters may be the only plausible observational test of string theories and will complement the search for ALP dark matter at light ALP masses.

Chapter 4 presents the application of state-of-the-art X-ray reflection models on the *Chandra* spectral view of H 1821+643 introduced in Chapter 2, pointing out that its colossal, central SMBH is rotating at moderate speeds. This chapter concludes by presenting the observed population of SMBHs whose spin has been estimated from such models.

The observed population seems to feature two sub-populations: a population of low-mass SMBHs with maximal-to-extreme spins and a high-mass population of SMBHs whose spins cluster at moderate values. This notion is aligned with the predictions of semi-analytic and numerical models of hierarchical structure formation and black-hole evolution over cosmic time-scales. Therefore, assessing this hypothesis with Bayesian statistics may eventually help confirm what drives SMBH growth over cosmic time-scales and help distinguish between the relative importance of growth powered by coherent and incoherent accretion and SMBH–SMBH mergers.

Chapter 5 presents closing remarks and outlines possible future research directions. — *University of Cambridge; accepted 2024 July.*

Here and There

THE PANDEMIC WAS RESPONSIBLE FOR MORE THAN WE THOUGHT

A few weeks later, I flew to CERN for the first time after the pandemic had begun to present our results to the outside world. — *Space Oddities* (Picador), p. 193, 2024.