Axion Physics from String Theory: Cosmological Signatures in Dark Matter and Inflation

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Abstract—The quest to understand the nature of dark matter and dark energy motivates a deep exploration into axion physics, particularly within the framework of string theory. Axions, originally proposed to solve the strong CP problem, emerge as compelling candidates for both dark matter and dark energy components of the universe. String theory, offering a unified perspective on fundamental forces, predicts a rich spectrum of axion-like particles (ALPs) arising from its compactifica- tion schemes. This paper provides a comprehensive review of axion physics within string theory, detailing their theoretical foundations, emergence from compactification processes, and roles in cosmological models. Key aspects covered include the Peccei-Quinn mechanism, the structure of ALPs, their moduli stabilization, and implications for observational signatures in dark matter, dark energy, and cosmological inflation scenarios. Insights from ongoing experimental efforts and future directions in axion cosmology are also discussed.

I. INTRODUCTION

The nature of dark matter and dark energy remains one of the most profound mysteries in modern cosmology. Axions, originally proposed to resolve the strong CP problem, have emerged as viable candidates for both dark matter and dark energy. String theory, as a leading candidate for a unified theory of fundamental forces, naturally predicts a plethora of axion-like particles (ALPs) arising from its compactifica- tion schemes. This

paper aims to provide a comprehensive overview of axion physics within the string theory framework and their potential roles in cosmological models.