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Editorial: Scalar fields and the dark universe

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Editorial on the Research Topic
Scalar fields and the dark universe

This Research Topic, Scalar Fields and the Dark Universe, is a Research Topic of five articles: three reviews and two papers that propose scalar fields as dark matter. Overall, we believe that this is a valuable contribution to the literature on alternative models of dark matter. Each article has value in its own right. Here we give a summary of the content.

A Machian model as potential alternative to dark matter halo thesis in galactic rotational velocity prediction by Walrand. This paper is well-structured and provides a comprehensive overview of the proposed axially symmetric metric and its implications for solving the Einstein field equations. The introduction effectively sets the stage by outlining the discrepancy between observed galactic rotational velocities and Newtonian predictions. It then transitions smoothly into the proposed solution, providing context for the reader. Here logical progression from the problem statement to the proposed solution and its implications is clear and easy to follow. This paper provides a thorough historical and theoretical background, including discussions of Mach's principle, modified Newtonian dynamics (MOND), and dark matter theories. This helps situate the proposed solution within the broader scientific discourse. The inclusion of Einstein's views on Mach's principle and the Lense–Thirring effect adds depth and historical perspective. The acknowledgment of the controversial relationship between Mach's principle and general relativity, as well as the historical debates surrounding it, adds nuance to the discussion. The proposed solution challenges the prevailing dark matter paradigm, offering an alternative explanation for galactic rotation curves.

A review of the basic results on the Bose-Einstein condensate dark matter model by Chavanis. This is a review of the Bose-Einstein condensate dark matter (BECDM) model is well-written and covers a broad range of key aspects of the theory. It provides a thorough overview of the BECDM model, including its core-envelope structure, the role of the Gross-Pitaevskii-Poisson (GPP) equations, and its potential to address the core-cusp problem of the cold dark matter (CDM) model. The discussion of the core mass-radius relation, halo mass-radius relation, and core mass-halo mass relation is particularly insightful and adds depth to the review. The distinction between the quantum core (soliton) and the approximately isothermal envelope is well-explained, and the analogy with the Navarro-Frenk-White (NFW) profile is effective in bridging the gap between BECDM and CDM models. The discussion of gravitational cooling, violent relaxation, and the formation of granules in the envelope is clear and concise. It successfully connects the BECDM model to both astrophysical phenomena (e.g., flat rotation curves, core-cusp problem)

and cosmological implications, providing a holistic view of the theory. The emphasis on the maximum mass of dilute axion stars and its consequences, including the potential collapse due to general relativity or attractive self-interaction, is a strong point. The analogy between the evolution of BECDM halos and globular clusters is effective in helping readers understand the secular evolution of these systems.

Primordial Black Hole formation during slow-reheating by Padilla et al. A review. In this paper we review the possible mechanisms for the production of primordial black holes (PBHs) during a slow-reheating period in which the energy transfer of the inflaton field to standard model particles becomes effective at slow temperatures, offering a comprehensive examination of the theoretical foundations and conditions required for each of formation channel. In particular, we focus on post-inflationary scenarios where there are no self-resonances and the reheating epoch can be described by the inflaton field evolving in a quadratic-like potential. In the hydrodynamical interpretation of this field during the slow-reheating epoch, the gravitational collapse of primordial fluctuations is subject to conditions on their sphericity, limits on their spin, as well as a maximum velocity dispersion finally we show, through an example, how PBH production serves to probe both the physics after primordial inflation, as well as the primordial power spectrum at the smallest scales.

Short review of the main achievements of the scalar field, fuzzy, ultralight, wave, BEC dark matter model by Matos et al. This text provides a concise and informative overview of the Scalar Field Dark Matter (SFDM) model, its historical context, and its potential as a solution to the dark matter problem. The text is clear and concise, effectively summarizing the core idea of the SFDM model and its various names (Fuzzy, BEC, Wave, Ultralight, Axion-like Dark Matter, *etc.*). The explanation of the Klein-Gordon (KG) equation and its non-relativistic, weak-field limit (Schrödinger-Poisson system) is straightforward and accessible. It provides a historical perspective, which helps situate the SFDM model within the broader context of dark matter research. This is particularly useful for readers who may not be familiar with the evolution of the model. Highlighting the KG equation and its transformation into the Schrödinger-Poisson system is a strong point, as these are the foundational equations of the SFDM model. The mention of comparing the model with observations is important, as it underscores the empirical relevance of the SFDM model and its potential to explain dark matter phenomena.

Static Axion stars revisited by Bautista and Degollado. This text provides a concise and informative overview on static solutions to the spherically symmetric Einstein-Scalar field systems with an axion potential. The text is clear and focused, effectively summarizing the key aspects of this topic, including the construction of axion star families, the role of the decay constant *fa*, and the discussion of stability regions, isotropy, and compactness. The mention of numerical construction of axion star families and the comparison with mini boson stars demonstrates technical rigor and adds depth to the discussion. It effectively highlights the main results, such as the richer existence diagram for axion stars compared to mini boson stars and the appearance of more massive, compact configurations as f*a* decreases. The text covers a wide range of topics, from the intrinsic properties of axion stars (isotropy, compactness) to the motion of test particles around these objects, providing a comprehensive overview of this topic.

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