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Dr. Syed Salman Ahmad Warsi is an accomplished physicist, academician, and educator with extensive expertise in condensed matter physics. He currently serves as an Associate Professor in the Department of Physics at Integral University, Lucknow, and brings more than 25 years of experience in teaching, research, and academic mentorship.

Throughout his academic career, Dr. Warsi has taught undergraduate and postgraduate students, making significant contributions to physics education through his dedicated teaching and research guidance. He has successfully supervised numerous B.Sc. and M.Sc. dissertations and projects and is actively involved in mentoring doctoral scholars pursuing Ph.D. research in Physics.

His research interests include liquid-crystal systems, nanoscale materials, and contemporary topics in condensed matter physics. Dr. Warsi has published several peer-reviewed research papers in reputed journals and continues to contribute actively to scientific research and academic development.

In addition to his research contributions, Dr. Warsi has co-authored important educational books, including:

- *ICSE Physics for Class X (2025)*
- *ISC Practical Physics for Classes XI & XII (2021)*

He has also served as editor of the following scholarly books:

- *Characterization of Liquid Crystals and Photonic Crystals (2022)*
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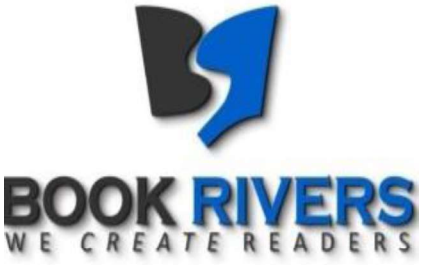

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CHAPTER - 4

COSMOLOGICAL NEUTRINOS AND THEIR IMPACT ON THE EVOLUTION OF UNIVERSE

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The thermal history of the Universe implies the existence of a diffuse neutrino component that has survived since the earliest cosmic epochs. While neutrinos are characterized by extremely small masses and very weak interactions, their collective presence becomes relevant on cosmological scales due to their high abundance. In this study, we focus on how this component emerges, which of its properties are most relevant for cosmological applications, and how it is incorporated into the contemporary concordance model of the Universe.

When neutrino mass is taken into account, the description of matter in the Universe is slightly altered compared to the idealized massless case. This alteration does not appear as a dominant effect but instead manifests as a consistent shift in model outcomes. As a result, the distribution of matter inferred from such models becomes less pronounced, indicating a reduced contrast relative to scenarios that neglect neutrino mass.

Neutrino effects are not treated here as a separate add-on, but as part of the working cosmological description adopted throughout the text. This choice is motivated by the fact that neutrinos influence several model outputs simultaneously, so their impact is best assessed within the full setup rather than through isolated statements. As new measurements extend both their precision and their scope, they can distinguish between small differences that are otherwise degenerate. In this sense, future data provide a practical way to check whether the adopted description remains adequate once neutrino effects are handled consistently.

INTRODUCTION:

The standard cosmological framework (ΛCDM) provides a consistent description of many observations, includingCMB anisotropies and galaxy clustering, BAO measurements. In this context, the total energy