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# Sterile Neutrino Dark Matter



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Morgan & Claypool Publishers

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ISBN 978-1-68174-481-0 (ebook)

ISBN 978-1-68174-480-3 (print)

ISBN 978-1-68174-483-4 (mobi)

DOI 10.1088/978-1-6817-4481-0

Version: 20170301

IOP Concise Physics

ISSN 2053-2571 (online)

ISSN 2054-7307 (print)

A Morgan & Claypool publication as part of IOP Concise Physics

Published by Morgan & Claypool Publishers, 40 Oak Drive, San Rafael, CA, 94903 USA

IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6HG, UK

*To Werner Maneschg—who predicted that years ago*



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# Preface

## Prerequisites

In order to gain something from this book, a potential reader should be somewhat familiar with the Standard Model of elementary particle physics. In addition, they should have some basic knowledge of cosmology. While we will not attempt to do very complicated computations, it will nevertheless often be very useful to be accustomed to certain notions used in both fields. For example, an ideal reader would know what ‘comoving momentum’ means, they should roughly understand how to read off an interaction from a Lagrangian, and certainly some background knowledge on WIMP Dark Matter would also be useful. Similarly, some very generic conventions used in nearly any text on the Standard Model, such as employing natural units (i.e.  $\hbar = c = 1$ ), will be used without further explanation. Finally, although not strictly necessary, some knowledge of neutrino physics can be of advantage. Nevertheless, I have tried to keep the text as basic as possible, keeping in mind that it is supposed to be a concise first introduction to a specialised topic.

Books that could be useful to have read are, e.g. *An Introduction to Quantum Field Theory* by Peskin and Schroeder for elementary particle physics or *The Early Universe* by Kolb and Turner for cosmology. Nevertheless, I will in any chapter point out useful references which treat the topics discussed in the respective chapter in greater detail. Given that there exist no textbooks for several of the aspects discussed, some of these references will be actual research papers. However, at least for some topics, excellent review articles are already available. While it is clear that, within the pre-determined format, no fully comprehensive discussion can be given, this text should nevertheless serve as an overview and hopefully an appetiser for the reader to explore the topic themselves. As for further reading, probably the richest document available, collecting information from all sides involved, is Adhikari *et al* 2017 A White Paper on keV sterile neutrino Dark Matter *J. Cosmol. Astropart. Phys.* [JCAP01\(2017\)025](#).

# Acknowledgments

First and foremost, my gratitude goes towards Nicki Dennis from Morgan & Claypool Publishers, for asking me to write a book on such a rather specialised subject. While this thought had not crossed my mind prior to that, the whole concept of writing a concise and pedagogical introduction to the field strongly appealed to me. Special thanks goes also to Karen Donnison, who took care of the permissions for some of the figures, which saved me a lot of trouble. Naturally, in the course of writing this book, I have drawn a lot from work I did with many great collaborators on keV sterile neutrinos and on related topics, among them Pasquale Di Bari, Marco Drewes, Steve King, Johannes König, Thierry Lasserre, Manfred Lindner, Nicola Menci, Susanne Mertens, Alessandro Mirizzi, Stefano Morisi, Ninetta Saviano, Daniel Schmidt, Matteo Viel, and Walter Winter. An even greater thank you, for several wonderful works done together on keV neutrinos and for being the most perfect collaborators I ever had the pleasure to work with, is deserved by Viviana Niro, Aurel Schneider, and Max Totzauer—and both Aurel and Max I also cannot thank enough for countless useful comments on the manuscript for this book. Finally, I am grateful to Kev Abazajian, Loredana Gastaldo, Thomas Tram, and Teja Venumadhav for sharing information on their work.

However, the greatest thank you of all, and all my love, is reserved for my family: my wife Martina, my son Atreyu, and my daughter Melissa. While I truly cannot claim that my kids have done very much to help me completing this book, they, together with my wife, are certainly responsible for the most joyful moments of my life.

*THANK YOU!!!*

# About the author

## Alexander Merle

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Alexander Merle was born in Arad, Romania, close to the famous region of Transylvania. After his emmigration to Germany at the tender age of two months, he grew up in the middle of Bavaria before entering the academic world. He is old enough to still hold the by now discontinued degree of a ‘Diplom-Physiker’ (Dipl.-Phys. Univ.) from Munich University of Technology in 2006. He obtained his PhD from Heidelberg University in 2009. He left Germany to be a postdoc in Stockholm, Sweden, before he progressed by securing a Marie Curie Fellowship with the University of Southampton, United Kingdom. He subsequently returned to Germany where he took on a Senior Postdoc position at the Max Planck Institute for Physics (Werner Heisenberg Institute) in Munich, Germany, where he is supervising a small group of PhD and Masters students.

Dr Merle’s main research fields are theoretical elementary particle physics and cosmology, with a particular focus on neutrinos, Dark Matter, and their inter-connections. He has written more than 60 papers on various topics, some even reaching out to neighboring fields such as mathematics or condensed matter physics, and some being cross-field collaborations with colleagues from, e.g. experimental physics or astronomy. He is an active contributor to the field of keV sterile neutrino Dark Matter, having discovered the production mechanism (FIMP scalar decay) that is currently in best agreement with data, having written a topcite review on model building aspects of keV sterile neutrinos, and having made several proposals on how to corner these particles with contemporary experiments. His reputation in the field is reflected by him being one of four main editors, section editor, and corresponding author of Adhikari *et al* A White paper on keV sterile neutrino Dark Matter *J. Cosmol. Astropart. Phys.* [JCAP01\(2017\)025](#), which is the most comprehensive document that exists on the topic.