Preface

What is the physics behind getting a spacecraft to the nearest stars? How fast could it go? What would it encounter along the way? How can a spacecraft navigate autonomously? What science would it do at the target star? And how can we send back the data over enormous distances?

This book is about the physics of interstellar spaceflight. If a spacecraft is to get to even the nearest star within 50 years, it needs to travel at almost 10% the speed of light. This is well over a thousand times faster than the fastest spacecraft that has already left the solar system. For fundamental physical reasons, no chemical rocket can ever achieve anything close to this. We therefore need to look at alternative propulsion methods, such as nuclear fusion rockets and laser-propelled sails. These don't yet exist, but they are physically possible, and important steps are being been taken towards achieving them. Sending a robotic spacecraft is doable, and not so very far beyond our current technological reach.

The physics of interstellar travel is about much more than propulsion, however. In this book we will examine a broad range of topics, including how to navigate in deep space, the effect of high velocity particle impacts, the instruments needed to study exoplanets close up, how to communicate using individual photons, and much more besides. On this journey we will delve into many areas of physics, including classical mechanics, special relativity, optics, electromagnetism, thermodynamics, materials, nuclear and particle physics, astronomy, and of course rocket science. We will stick to established physics – I don't consider outlandish ideas such as warp drives and wormholes – but we won't be overly constrained by current technology or budgets.

Many articles and a number of books have been written about specific aspects of interstellar travel. Some of these are rather technical or assume a high level of background knowledge, so can be hard to connect to the basic physics. By looking at the fundamental concepts, and taking a broad view, I aim to give the reader a sense of the big picture and an understanding of the physical principles at work.

This book is targeted primarily at those who have completed introductory university courses in physics. By bringing together a wide range of topics and drawing on recent literature, this book should also be useful for researchers. I show how physics that has been learned in sometimes abstract ways can be applied in a practical setting with a clear goal. Many topics that I cover have a wider relevance too, such as the principles of rockets, Keplerian orbits, satellite navigation systems, relativistic optical effects, energy from nuclear reactions, and the basics of communication.

As the scope is broad, I cannot go into great detail in all topics, and I omit some potential technologies. My goal is to identify key issues and some proposed solutions, but without discussing every subtlety or giving a complete road map for how to achieve interstellar travel. Having read this book, the reader should be well equipped to dive deeper into topics covered

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by other books and articles. The appendix provides both a discussion of the literature sources I have used and suggestions for further reading.

In addition to being suitable for independent study, this book can serve as the basis for a full semester lecture course on interstellar travel, or parts could be selected for a shorter course. The content is modular, so chapters on specific topics could also be used to support other courses, for example on propulsion methods or relativity applications. Section 1.6 gives an overview of the chapters and their dependencies. Even if one is not particularly keen on interstellar travel, it is an excellent vehicle for learning about many topics in physics (excuse the pun). Learning is consolidated by doing, so I provide some exercises at the end of each chapter.

This project has grown out of a seminar course and a full semester lecture course I have taught to physics BSc and MSc students at Heidelberg University over a number of years. Their feedback and suggestions have been very useful in developing this work. For fruitful discussions and helpful comments on the manuscript I would like to thank Nora Bachmann, Werner Becker, Ian Crawford, Christian Fendt, Elisa Haas, David Hägele, Andreas Hein, René Heller, Tom Herbst, Ramon Khanna, Angelique Kahle, Pekka Janhunen, Les Johnson, Anne Jones, Lisa Kaltenegger, Laura Kreidberg, Stan Letchev, Richard London, Kelvin Long, Thomas Müller, David Messerschmitt, Carl Mungan, Kevin Parkin, Sabina Pauen, Markus Pössel, Bhavesh Rajpoot, Nick Sleep, Paul Steimle, Martin Tajmar, Ted von Hippel, Fabian Walter, and the anonymous reviewers. I thank colleagues and friends for their interest in, and encouragement of, this project. I am grateful to Roxanne Daruwalla, Vince Higgs, Zoë Lewin, and Aleksandra Serocka at Cambridge University Press (CUP) for their assistance in preparing the manuscript, and to Simone Kronenwett, the librarian at my institute, the Max Planck Institute of Astronomy (MPIA), for acquiring some of the literature. Special thanks go to the MPIA and Laura Kreidberg as well as to the Max Planck Society via the Max Planck Digital Library for supporting the publication of this book as open access.

Plots and sketches not credited to other sources were made by the author using R and inkscape. Artificial intelligence tools were not used to help write this book (other than to check a few commas). Despite my best efforts, there are no doubt some errors in this book. Notification of possible mistakes is welcome. Corrections, as well as additional information and extra exercises, can be found at www.mpia.de/homes/bailer-jones/pit.html or via the CUP website.

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