Preface

The idea of writing a book on "The Physics of Gamma-Ray Bursts" started in the summer of 2011, when I gave a one-week lecture series on GRBs at the National Astronomical Observatories of China (NAOC) to more than 100 students from several Chinese astronomical institutions. There were two considerations. First, even though there were several books on GRBs in the market, none of them had an in-depth discussion of GRB physics in a systematic manner. Second, with data collected from several NASA missions (especially *Swift* and *Fermi*) and ground-based telescopes, the GRB field has matured to the point that some basic physics of GRBs can be stated for certain, though many uncertainties remain. It thus became possible to summarize the knowledge in the field and come up with a book with a long shelf life.

After signing a contract with Cambridge University Press, I soon realized that writing a book is one of those ideas that takes minutes of excitement to conceive but countless hours to fulfill. The writing was pushed forward mostly in two semesters (spring 2012 and fall 2014) when I taught "The Physics of Gamma-Ray Bursts" twice to the graduate students in the Department of Physics and Astronomy at University of Nevada, Las Vegas (UNLV). The lecture notes were typed up during the first semester and the text was greatly enriched during the second semester. Yet it took a much longer time to finish the whole book, and Cambridge University Press kindly extended the deadline multiple times. The initial plan was a concise textbook, but as writing continued I decided to make the contents comprehensive and usable to not only new students in the field, but also experienced researchers. The delay in finishing the book was not regretful, since along the way we ushered in the multi-messenger era of GRBs, with progressively tighter high-energy neutrino flux upper limits placing meaningful constraints on GRB prompt emission models, the discovery of gravitational wave events due to double black hole (BH–BH) mergers, and, most excitingly, right before the delivery of the book, the detection of a double neutron star (NS–NS) merger system with an associated short GRB. These new developments undoubtedly make the book more complete.

As history has repeatedly shown, the GRB field evolves rapidly and is full of surprises. A book dedicated to GRBs may run the risk of becoming out-of-date quickly. For easy revisions in future editions, I tried to separate the contents of the chapters that describe robust fundamental physics and those that are more phenomenologically oriented. The former will remain intact regardless of future developments, while the latter may be improved or even significantly revised as more observations are accumulated. The structure of the book is as follows: Chapter 1 is the general introduction. The only part that will be improved in the future is §1.2 (brief history of GRB research), since it is certain that new observational breakthroughs and theoretical developments will be made in the years to come. Chapter 2 is an overview of GRB phenomenology. It summarizes available key electromagnetic observational data on GRB prompt emission, afterglow, supernova/kilonova associations, and host galaxies, and also discusses the global properties of GRBs, empirical correlations, and classification schemes. Most content will be permanent, although some mild expansion may be expected to include future breakthrough observations. Chapters 3 (relativity), 4 (relativistic hydrodynamics and magnetohydrodynamics), 5 (leptonic processes), and 6 (hadronic processes) describe fundamental physics, which can be applied to other high-energy astrophysical phenomena besides GRBs. They will remain intact in the future. Chapter 7 is an overview of the basic theoretical framework of GRBs, which includes the standard matter-dominated fireball scenario, the Poynting-flux-dominated scenario, and the more general hybrid scenario. Chapter 8 is dedicated to afterglow physics, which is quite mature. Little change is expected in the future. The next three chapters (Chapter 9 prompt emission physics, Chapter 10 progenitor, Chapter 11 central engine) are the subjects currently under active research. The best one can do is to summarize the parts that are more certain, and in the meantime introduce various ideas subject to uncertainties and debate. As an active researcher in the field, the author inevitably introduces personal preferences on some of the subjects, especially on the prompt emission mechanism as discussed in Chapter 9. These chapters may be subject to improvement in the future. Chapter 12 focuses on non-electromagnetic signals. As of the time of finishing the book, some interesting observations have emerged. Substantial expansion of the chapter is expected in the future when more data are accumulated. The chapter regarding cosmological connections (Chapter 13) is secure. Revisions, if any, may be made when high-z GRB observations become routine, and much about the high-z universe (e.g. reionization history) is learned from GRBs. Finally, Chapter 14 briefly touches broad impacts of GRBs on fundamental physics and life. These subjects may not significantly change in the long term. At the end of some chapters, some Exercise problems are provided for students who like to digest and derive some of the basic formulae related to GRB physics.

Many people contributed to this book more than they know. Peter Mészáros offered me a postdoc position at the Pennsylvania State University in 2000, which allowed me to enter the exciting field of gamma-ray bursts. I learned a great deal from him through numerous discussions and joint publications. Guo-Jun Qiao and Alice Harding guided me in conducting research in my early science career. Special thanks and thoughts go to the late Neil Gehrels, whose vision and leadership assured the success of the *Swift* mission, with which I am affiliated. A lot of the material in the book, including the multi-wavelength data and the developed theories, root from *Swift*. Many colleagues published important papers that I pleasantly coauthored, which are part of the contents of the book. The list includes (but is not limited to): Scott Barthelmy, Dave Burrows, Sergio Campana, Guido Chincarini, Zi-Gao Dai, Xinyu Dai, Abe Falcone, Dirk Grupe, Fan Guo, Kunihito Ioka, D. Alex Kann, Shiho Kobayashi, Pawan Kumar, Hui Li, Zhuo Li, Nicole Lloyd-Ronning, Yosuke Mizuno, Kohta Murase, Kentaro Nagamine, Yuu Niino, Ken-Ichi Nishikawa, Paul O'Brien, Julian Osborne, Kim Page, Asaf Pe'er, Rosalba Perna, Daniel Proga, Judith Racusin, Soeb Razzaque, Pete Roming, Antonia Rowlinson, Sarira Sahu, Takanori Sakamoto, Gianpiero Tagliaferri, Kenji Toma, Eleonora Troja, Xiang-Yu Wang, Richard Willingale, Huirong Yan, Yun-Wei Yu, Feng Yuan, and Weikang Zheng.

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