Gen Relativ Gravit (2015) 47:3
DOI 10.1007/s10714-014-1839-3

BOOK REVIEW

Luciano Rezzolla and Olindo Zanotti: Relativistic hydrodynamics

Oxford University Press, Oxford, 2013, 752 pp, GBP 55.00, ISBN: 978-0-19-852890-6

Domenico Giulini

Received: 11 November 2014 / Accepted: 17 November 2014

The field of relativistic hydrodynamics, once thought to be a mere playground for mathematically inclined physicists and without much relevance for the "real world", is now of central importance for astrophysicists and cosmologists trying to understand objects like neutron stars and supernovae, and violent phenomena like star-collapses, deflagrations, and detonations. Such objects and their stability properties, as well as the associated phenomena, would be impossible to understand without taking due account of Special and General Relativity. But whereas the relativistic extension of, say, the laws of point mechanics is relatively straightforward, a similar extension is much harder, and can even be ambiguous, in case of hydro- and thermodynamics. The fundamental and conceptual issues associated with this extension are also the subject of this book.

The book is divided into three parts entitled "The Physics of Relativistic Hydrodynamics " (Part 1, Chapters 1–6, 313 pages), "Numerical Relativistic Hydrodynamics" (Part 2, Chapters 7–10, 172 pages), and "Applications of Relativistic Hydrodynamics" (Part 3, Chapters 11–12, 166 pages). This material is completed by 5 Appendices of a total of 23 pages, an impressive bibliography of 38 pages, and an exemplary index of 15 pages. Each of the 12 Chapter ends with suggestions for further reading and a couple of problems that should be doable by the attentive reader.

These basic data already suggest the tremendous effort that surely has gone into writing the book. This is nicely complemented by the appreciable effort that the publisher put into the arrangements and production: At a comparatively modest price of 55 £ the purchaser will get a very high quality hard-backed book printed in colour on high-quality heavy paper, copiously illustrated and with highlighted key equations.

D. Giulini (✉)
Institute of Theoretical Physics, Leibniz University of Hannover,
Appelstrasse 2, 30167 Hannover, Germany
e-mail: giulini@itp.uni-hannover.de

Published online: 14 January 2015

Quality of content, arrangement, and production happily match and make this book a really good buy indeed.

The whole approach of the book can perhaps be characterised by saying that it is written for the practising theoretician. As the authors state in their introduction (following a categorisation of approaches to hydrodynamics introduced by Richard Feynman), "fluids" in their book are definitely "wet" (not "dry", as for many whose focus is the mathematical structure alone). But this cannot, and in the present case fortunately does not, mean that the many conceptual and mathematical problems faced by relativistic hydrodynamics are swept under the carpet. Just to pick two examples: A well known mathematical issue is connected with the infinite propagation speed of disturbances allowed by the equations of ordinary hydrodynamics, which is due to their parabolic nature. This raises the problem of finding suitable "hyperbolisations" for the relativistic system. Another issue, this time of a more conceptual nature, arises when considering non-perfect fluids (as unfortunately rarely done in textbooks). Here an essential ambiguity arises concerning the definition of the fluid's four velocity and hence its rest frame. Here the authors mainly use the Eckart frame whenever possible, but also notice that it may fail to be well defined as, e.g., for systems with vanishing net baryon charge, in which case the Landau (or energy-) frame is to be preferred. Issues of that sort are abound and discussed with clarity and sense. Certainly, the issues themselves are well known and discussed at length in the relevant journal literature. But here the reader can study them nicely organised and presented in a form that is easy to understand and related to the actual physical problems. This, in my opinion, well justifies the more than 300 pages of Part 1.

Part 2 is a compendium of numerical methods, starting appropriately with a detailed discussion of the $3+1$ decomposition of the Einstein–Matter equations in order to put them into an evolutionary form. Discussions of finite-difference, high-resolution shock-capturing, and higher-order methods follow. Again this part is written in a fashion that makes it as accessible as possible without undue compromises.

Most interestingly for the researcher in this field are the applications contained in Part 3. They start with matter in external gravitational fields, like flows around black holes, accretion discs, jets, and also heavy-ion collisions. They continue with self-gravitating fluids in rotating stars, collapse of stars, and binary systems consisting either of two neutron stars or one neutron star and a black hole. Associated topics include gravastars and the emission of gravitational waves.

Despite the wealth of material already contained in this book it would, from the physicist's perspective (who ignores space constraints), not be unnatural to even extend it in future editions. As mentioned in the introduction, turbulence and fluid instabilities are not (yet) covered. Also, Part 3 can be easily imagined to be supplemented by further applications and perhaps slightly extended discussions on "hot topics", like the generation of gravitational waves.

This is a very informative and very useful book indeed, written with clarity and pedagogical skill by two of the leading experts in this fascinating field. The readership may range from the advanced undergraduate to the senior expert. The value-to-money ratio is exceptional. I am sure it will become a standard reference for many years to come.

Luciano Rezzolla (born 1967) is an Italian professor of relativistic astrophysics and numerical relativity at the Goethe University Frankfurt. His main field of study is the physics and astrophysics of compact objects such as black holes and neutron stars. It was announced in 2019 that he had been appointed honorary Andrews Professor of Astronomy at Trinity College Dublin (TCD). An Improved Exact Riemann Solver for Relativistic Hydrodynamics. By Luciano Rezzolla and Olindo Zanotti. SISSA, International School for Advanced Studies, Via Beirut 2-4, 34014 Trieste, Italy. (Received 5 April 2019).Â 2 L. Rezzolla & O. Zanotti. The numerical solution of a Riemann problem is the fundamental building block of hydro-dynamical codes based on Godunov-type nite difference methods. In such methods, the com-putational domain is discretized and each interface between two adjacent grid-zones is used to construct the initial left and right states of a â€œlocal Riemann problemâ€.