Preface

Gravitation stands apart among the four fundamental interactions of Nature. Its source is energy-momentum, a current every field or body gives rise to. It stands particularly distinctive in its description by General Relativity, in which the gravitational effects remain amalgamated with inertia. Furthermore, from the theoretical point of view, General Relativity is the only fundamental interaction theory which does not adhere to the gauge template. Teleparallel Gravity, the theory this book is devoted to, is an alternative description that, though equivalent to General Relativity, separates gravitation from inertia and meets the requirements of a gauge theory.

The simplest example of a gauge theory is electromagnetism, which is, for this reason, quite appropriate for understanding the basic tenets of the gauge paradigm. A fundamental piece of this paradigm is Noether's theorem. According to it, the electric current, the source of the electromagnetic field, is conserved provided the action functional of the source field be invariant under the transformations of the unitary group $U(1)$, the gauge group of the theory. In the same token, the source of the gravitational field is well known to be energy and momentum. Noether's theorem will say that the energy-momentum current tensor is conserved provided the source action functional be invariant under spacetime translations. If gravitation is to present a gauge formulation with energy-momentum as source, it must then be a gauge theory for the translation group. This is precisely Teleparallel Gravity.

Although equivalent to General Relativity, Teleparallel Gravity is, conceptually speaking, a completely different theory. In General Relativity, curvature is used to geometrize the gravitational interaction: geometry replaces the concept of gravitational force, and the trajectories are determined, not by force equations, but by geodesics. Teleparallel Gravity, on the other hand, attributes gravitation to torsion, but not through a geometrization: it acts through a force. In consequence, there are no geodesic equations in it, only force equations quite analogous to the Lorentz force equation of electrodynamics.

The reason for gravitation to present two equivalent descriptions lies in its most peculiar property: universality. Like the other fundamental interactions of Nature, gravitation can be described in terms of a gauge theory, which is just Teleparallel Gravity. Universality of free fall, on the other hand, makes it possible a second, geometrized description, based on the equivalence principle, which is just General Relativity. As the sole universal interaction, it is the only one to allow also a geometrical interpretation—hence the possibility of two descriptions. From this point of view, curvature and torsion are simply alternative ways of representing the same gravitational field, accounting for the same gravitational degrees of freedom.

The teleparallel structure was already known in the nineteen-twenties, and was used by Einstein in his unsuccessful attempt to unify electromagnetism and gravitation. The birth of teleparallelism as a gravitational theory, however, took place in the nineteen-fifties with the works by Møller. Since then, there have been many contributions from different authors to Teleparallel Gravity [see Sect. 4.1 for a brief historical review]. Although its foundations can be considered quite well understood by now, there are still some different interpretations for the role played by torsion in the description of the gravitational interaction. It is thus important to keep in mind that the ideas presented here are strongly biased by the authors' point of view on the subject, and are essentially based on the research developed by them along many years. In this sense this book is partially an expanded version of their relevant publications, and includes also many corrections to the original texts. Even though the authors are the solely responsible for the contents of the book, they owe much to some of their colleagues, as well as to their former and present collaborators: V.C. de Andrade, H.I. Arcos, T.V. Aucalla, A.L. Barbosa, P.B. Barros, T. Gribl Lucas, F.W. Hehl, L.C.T. Guillen, J.W. Maluf, R.A. Mosna, J. Nester, Yu.N. Obukhov, D.J. Rezende, R. da Rocha, G. Rubilar, K.H. Vu, P. Zambianchi and C.M. Zhang. The authors would like to express their deep gratitude to all of them. Finally, they wish to thank Aldo Rampioni, publishing editor of Theoretical & Mathematical Physics and Scientific Computation, Vesselin Petkov, member of the editorial board of the series *Fundamental Theories of Physics*, and Kirsten Theunissen from Springer for their friendly assistance and support during the completion of the book.

São Paulo, Brazil

Ruben Aldrovandi
José Geraldo Pereira

Springer

http://www.springer.com/978-94-007-5142-2

Teleparallel Gravity
An Introduction
Aldrovandi, R.; Pereira, J.G.
2013, XIV, 214 p., Hardcover
ISBN: 978-94-007-5142-2