INTRODUCING THE BASIC CONCEPTS OF GENERAL RELATIVITY IN HIGH SCHOOLS

Marco Di Mauro[a] and Adele Naddeo[b]

Presenting Author: Marco Di Mauro (marco.dimauro@unitn.it)
[a]Dipartimento di Fisica, Università di Trento, Povo TN 38123, Italy
[b]INFN, Sezione di Napoli, Napoli NA 80126, Italy

KEYWORDS: Modern Physics, General Relativity, High school teaching

INTRODUCTION

Unlike the case of quantum mechanics, the teaching at the high school level of general relativity (GR) has been the target of relatively minor efforts by researchers in physics education (Kersting, Henriksen, Boe & Angell 2018), despite both subjects being included in the curricula in many countries. Although its foundations are not as controversial as those of quantum mechanics, GR also rests on some subtle conceptual steps, and, moreover, it cannot be probed using real experiments. Hence, teaching it at the high school level presents important challenges. However, the conceptual steps needed for GR are firmly founded in classical mechanics, electromagnetism, and special relativity (Sciama 1969), and when suitably presented and supported by adequate material, they can be within grasp of final year pupils.

In this presentation, we outline and discuss a proposal in which these basic concepts are gradually introduced as natural extensions of those that physics pupils know, in a simple yet nontrivial way, which goes beyond the current textbook approaches. The latter, indeed, usually present little more than a popular level account. Typically, they rely on the famous elastic sheet analogy, which in turn is based on the iconic fact that GR geometrizes the gravitational field. However, such a statement takes quite a long route to be established, hence without adequate motivation, usually results in students getting the impression that the theory comes out of the blue. Also, the analogy is not very accurate, failing to highlight the role of time in the theory.

FROM CLASSICAL MECHANICS TO GR: A PROPOSAL

Our proposal starts from a critical rethinking of the principles of Newtonian mechanics, focusing on the role of inertia and of inertial forces, and on the principle of equivalence of gravitational and inertial mass. This part can be supplemented by real experiments and simulations. The next step involves special relativity, discussing the apparently unrelated problems of extending the relativity principle to non-inertial frames, and of reconciling gravity with the universal speed limit. Then, the way in which the equivalence principle allows to extend the special relativity principle is discussed with the help of Einstein's elevator thought experiment. Crucial here is the discussion of how the equivalence principle is elevated from mechanics to all physical phenomena and how it is reconciled with the fact that special relativity teaches us that inertial mass is a form of energy. By means of some thought experiments, in fact, it is possible to quantitatively show that the same is true for the gravitational mass (Einstein, 1911). Then, by further thought experiments and simple calculations, some consequences of this principle can be explored: the gravitational redshift and time-dilation, the application to the Global Positioning System, and the gravitational bending of light. At this point, students should be invited to reflect on the special features that a theory based on special relativity and on Einstein's equivalence principle should have, in comparison with electromagnetism, and the consequences should be explored. Finally, the thought experiment of the rotating disc (Janssen, 2014) can provide a way of motivating the well-known geometric picture.

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Proceedings of the IUPAP International Conference on Physics Education, ICPE 2022 5-9 December 2022, page 76, ISBN: 978-1-74210-532-1.