

Historical, Philosophical and Theological framing of General Relativity for High School students

Costantino Sigismondi (ICRA/Sapienza and Roma Ferraris Institute), Tiziana Pompa (Pescara Galilei Lyceum), Daniele Impellizzeri, Simone Tricase, Giorgia Alberelli (Roma Ferraris Institute)

Motivations: from wave optics to quantum behavior

Most of Italian students do not choose STEM curricula after school.

Among the reasons there is lack of experimental activities especially for the last year of physics.

An approach to Quantum Physics is recommended through spectroscopy, thanks to the wave-particle behavior of the photon, the availability of a LASER and the simplicity of many diffraction experiments [1].

Nevertheless the historical process through selection rules and suspected extraterrestrial elements like Helium and Coronium is also important. [2]

Gravitational Waves and Interferometry

In General Relativity the interferometers of Michelson e Morley (1881-1887) have been adapted to gravitational waves in LIGO/VIRGO (2015) using the same principles and the same geometry [3]. Also this interferometer can be realized and studied at school, as in 2018 at Pescara Galilei Lyceum.

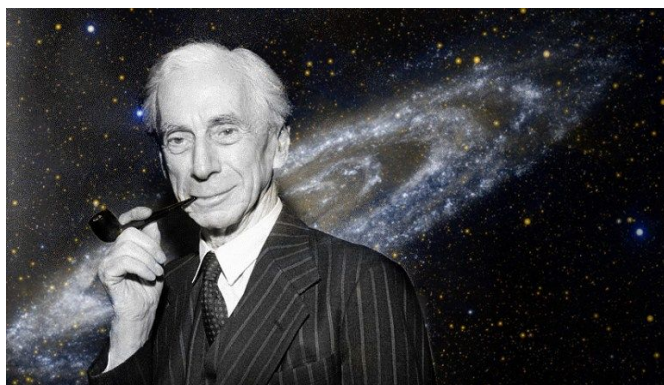
The utilization of Magneto Optical Filter in Gravitational Waves detection was proposed by the late Alessandro Cacciani (1937-2007). [4]

Relativistic light bending

Other effects like light gravitational bending are very difficult to be observed, even if the GAIA astrometry satellite is now able to measure it at 180 degrees from the Sun and the major planets [5]. This effect shows clearly the difference from Newtonian and Einstein gravity upon light (sir **James Jeans**, The Growth of Physical Sciences, 1948).

[6] The great project Gravity Probe B on the Lense-Thirring effect of Earth's frame dragging is also far from experimental level without using analogies (Ruffini and Sigismondi, The Lense-Thirring effect, WS 2002).

The Solar figure, spherical within few parts in a million, was measured by Dicke [7] to assess the possibility of a scalar-tensorial theory beyond Einstein and now is measured to understand the physics of solar secular variability, so important for our climate (C. Sigismondi 2011, High precision ground-based measurements of solar diameter in support of PICARD mission, <http://adsabs.harvard.edu/abs/2011PhDT.....372S>); C. Sigismondi, 2005, [2005NCimB.120.1169S](http://arxiv.org/abs/2005NCimB.120.1169S))



General Relativity and the view of the World

General Relativity was important to the view of the World as much as Quantum Physics. **Bertrand Russell** was one of the most relevant divulgators of Einstein's theory (L'Abc della

Relatività, Longanesi, Milano 1974), he contributed to spread the basis of Special and General Relativity, but the relevance of the new cosmological view of the World is left too often to the University specialistic studies, to avoid also to fall into 'unpleasant metaphysical questions' [8]. While right these questions can drive more students to STEM.

Cosmology, a new science with proper identity after Einstein

With Einstein the Physical Cosmology was born, because the Universe's behavior was comprised as a consequence of the matter's distribution (Peebles, Principles of Physical Cosmology, 1990). The Galileian idea of same physics on the Earth and across all Universe reached in this way its maximum extent.

Einstein by introducing the Cosmological Constant and later Hoyle, Bondi and Gold [8], and finally Hawking and Hartle tried to obtain a static or stationary Universe, conceptually not different from Aristotle's one, while Lemaitre proposed an evolutionary Universe, finding the observational proofs. The hot big bang theory was confirmed by the Cosmic Background Radiation discovery (1965) even if Zeldovic (1965) [9] theorized a cold one, based upon Fermi energy.

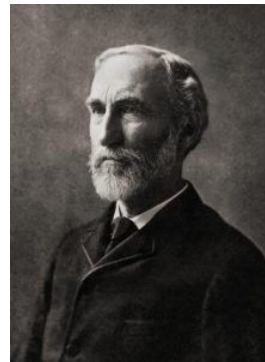
Ether and eternity of the Universe from Aristotle to Hawking

The role of Cosmic Ether, object of the studies of Michelson and Morley, is now played by the Dark Energy, which behaves exactly as the Cosmological Constant, and produces an accelerating Universe.

Framing philosophically the Physical Cosmology helps the students, also the ones far from STEM, to understand the present debate on the view of our World. Comparing the theories of expanding Universe, eternal Universe, oscillating Universe with the ancient ones, made by Aristotle and object of a condemnation by Etienne Tempier bishop of Paris in 1277, is also important.

The beginning of science and the possibility of confutation for a theory

According to **Pierre Duhem** (Système du Monde, 1913-58), the act of Etienne Tempier was the starting point of the modern science. [10] The construction of the theory, moreover, is based upon some principles, and the speed of light in vacuum-the veritable "celeritas"- cannot be surpassed [11]. The recent (2011) debate of OPERA results in Gran Sasso National Laboratories and CERN of Geneva can be studied in this optics. Provided this frame, there are plenty of motivations to know the essence of General Relativity and its contribution to the view of our World.



References and notes

[1] This not help to understand how interference and diffraction phenomena are studied before the advent of LASER. The Michelson Interferometer was used to study the vectorial composition of the light with the orbital Earth velocity, or the cosmic ether existence. The result was that the modulus of velocity c was conserved, while the direction followed the vectorial composition traditional rule.

A. H. Andrei, C. Sigismondi, V. Regoli (2014) <http://adsabs.harvard.edu/abs/2014arXiv1412.6096H>

C. Sigismondi (2008) <http://adsabs.harvard.edu/abs/2008mgm.conf.2470S>

[2] Quantum Mechanics verifies the Heisemberg principle for the matter, the diffraction of light is already the Heisemberg principle for photons.

Vavilov, L'Occhio e il Sole, Feltrinelli, Milano 1959.

At the Italian Ministry for Education, MIUR, a course in Spectroscopy is already organized for the high

school teachers <http://ls-osa.uniroma3.it/documents/98> (2018) but the general vision given by the historical perspective is lacking. The selection rules found in spectroscopy $\Delta L, \Delta m=0, \pm 1, \pm 2$... were interpreted later as permitted quantum gaps, and their violations as 'prohibited rules' upon which many fundamental discoveries have been done (e.g. 21 cm line of neutral Hydrogen and all galactic structure). The 'rarity' of some transition were obtained directly from quantum mechanics density function, as tunnel effect...

[3] The interference of Michelson experiment <http://adsabs.harvard.edu/abs/1882USNAO...1..109M> (1882) and <http://adsabs.harvard.edu/abs/1887SidM...6..306M> (1887) was with white light, a situation which is different from monochromatic LASER light. Similarly at Mount Wilson Observatory the interference between the stellar light received at opposite parts of the diameter of the 100 inches reflecting Hooker telescope (the technological marvel of its time) permitted the evaluation of the stellar diameter of Betelgeuse and the first stellar surface images. S. Metchev (2013) http://www.astro.sunysb.edu/metchev/PHY517_AST443/solar_diameter.pdf

[4] Paolo Rapex, 10 anni con Alessandro, in a Special Solar Day, Symposium in honor of A. Cacciani, Rome Sapienza 2008, Feb. 29.

[5] see M. T. Crosta and F. Mignard, <https://arxiv.org/abs/astro-ph/0512359> (2005). The gravitational light bending can be simulated only by the analogy photon-glass ball on the elastic carpet made by lycra, with a big mass at the center. This similarity (used e.g. at Rome 3 University, Physics dept.) is not completely satisfying because of the photon is massless. The apparatus is good for showing N-body simulations with friction, to show e.g. the onset of King profiles in galactic clusters... in a few seconds, instead of billions of years.

[6] Unless not evident from Mitchell 1780 approach of escape velocity, which gives correctly the value of Schwarzschild Radius, but considers light gravitating as matter, even if we know the photon is massless.

[7] see Damiani et al. <https://hal.archives-ouvertes.fr/hal-00519433/document> A Brief History of Solar Oblateness. A review (2010)

[8] B. Russell, L'Abc della Relatività, Longanesi, Milano 1974, p.173 The continuum model of the Universe has been the same at all times, in order to agree with cosmological expansion a continuum creation is required, which is not against the physical laws. This last part, being not comprised, was not present in textbooks like M. Parotto, E. L. Palmieri, il Globo Terrestre e la sua Evoluzione, Zanichelli Bologna 2017. The 'unpleasant metaphysical questions' are indeed more stimulating than increasing precision for saying anything about the truth [Martin Heidegger]. Russell in this respect says that 'the consequences of Relativity are neither grandiose nor surprising as believed' (p. 218-219). The differences between classical and relativistic physics are usually very small, and the mass of 4 weights of 1 Kg is smaller than 4 Kg, but the evidence of this effect of the equivalence of mass - binding energy in percentage four nuclei of H are lighter (0.7% less) than one nucleus of He.

Russell explains that events instead of coordinates are the essence of Relativity, and the action [Energy*time] is its natural unit of measure (p. 156-7). The action which fulfilled some aesthetic, almost

theological principle of symmetry with Maupertuis, Lagrange and Laplace, and become crucial in Quantum Mechanics with Planck constant in 1900 (J. Jeans, *Il Cammino della Scienza*, Bompiani, 1953, p. 318-328).



[9] Zeldovich, Ya. B. 1965, *Adv. Astron. Astrophys.*, **3**, 241 and A. Aguirre, 1999 <http://iopscience.iop.org/article/10.1086/307534/pdf>
Photo of Zeldovich, Ruffini and the Pope John Paul II

[10] Instead of blocking science this act stimulated it, because always Christianity has considered God as Creator. He is not a liar and the man can know Him from Revelation, but also from the Creation itself (as S. Thomas of Aquinas few years before Etienne Tempier taught in

Paris University).

‘God does not play with dices’ used to say Einstein and this debate is nowadays extremely far from the current main stream. [Alessandro Giostra

<http://www.upra.org/evento/pierre-duhem-la-nascita-della-scienza-nel-mondo-occidentale-cristiano/>]

[11] Einstein did know well that only one contradictory fact on the speed of light in vacuum would destroy all General Relativity theory. This characteristic of a scientific theory is the Fälschungsmöglichkeit, possibility of confutation, theorized by Karl Popper.

https://it.wikipedia.org/wiki/Principio_di_falsificabilit%C3%A0

Nowadays we are facing more and more with dogmatic theories like the anthropogenic global warming or the OGM vs organic food with respect to human health or the gender theory on the sexual differentiation induced by the environment and the cultural background... whatever fact has an explanation pro that theory, and no disproofs are possible, and we are in a scientific, post-galileian era.



This note may appear unappropriated either in a scientific congress either in the school, but the paralysis of autonomous thinking starts from the school and spread to all parts of the society. If the most influential theory of Physics is subjected naturally to the possibility of confutation, why there should be *theories* that cannot be falsified?

A *theory* since Ptolemy and before is a representation of the reality, which can be changed with a better one, when it is available.

Photo: The cover of “Sozein ta

Phainomena” of Pierre Duhem.