

## EPISTEMOLOGICAL CONSEQUENCES OF GRAVITATIONAL WAVES DISCOVERY

*Associate Professor Bogdan Popoveniuc*

*University "Ștefan cel Mare" of Suceava*

*Abstract: The paper explores some philosophical and epistemological significances of the breakthrough discovery of GW. The event, compared with the moment when Galileo, four hundred years ago, directed a telescope to the sky, seems to promise equal cultural consequences. The revolutionary Copernican model would have been a simple peculiar model of Cosmos in the absence of Galilean observations. The empirical detection of GW, predicted 100 years ago by Einstein's Theory of Relativity, brings to the fore this hypothetical conception of Universe, with major consequences on the present conceptions of causality, space, time (space-time), the nature of determinism, and the relation of the human mind with the Universe. It proves once again the core function of interdisciplinary perspectives in contemporary science.*

*Keywords: Singularity, GW, Metaphysics, Philosophy of Mind, Interdisciplinary Stance.*

### **LIGO Detection**

"The Discovery of GW", "Einstein's GW found at last", "«It's Just Too Perfect»: Inside the First Gravitational Wave Detection", "Einstein's GW «seen» from black holes" are some of the titles which swamped the Internet in February 2016, after the announcement made by LIGO (Laser Interferometer Gravitational-wave Observatory). The GW were detected on September 14, 2015 at 5:51 a.m. Eastern Daylight Time (09:51 UTC) by both twin LIGO detectors, located in Livingston, Louisiana, and Hanford, Washington, USA. "This confirms a major prediction of Albert Einstein's 1915 General Theory of Relativity [GTR] and opens an unprecedented new window onto the cosmos," it is said in the official statement.

The paper focuses on the epistemological consequences of this experiment and its effects on the perspective on scientific activity. If we adopt a straight falsificationist perspective (or dogmatic falsificationism),<sup>1</sup> there is no experiment that could be a "proof" for the existence of Gravitational Waves [GW], but only a strong evidence which supports this model. In Science we have only the models and not depictions of reality. But the radical falsificationist limits are obvious. "If factual propositions are unprovable then they are fallible. If they are fallible then clashes between theories and factual propositions are not «falsifications» but merely inconsistencies. Our imagination may play a greater role in the formulation of «theories» than in the formulation of «factual propositions»,\* but they are both

<sup>1</sup> Karl R. Popper, *Conjectures and Refutations*, London: Routledge, 1963.

\* Incidentally, even this is questionable. (*authors note*)

fallible. Thus *we cannot prove theories and we cannot disprove them either*. The demarcation between the soft, unproven «theories» and the hard, proven, «empirical basis» is non-existent: *all* propositions of science are theoretical and, incurably, fallible.<sup>2</sup> Understanding the process of scientific knowledge requires a more complementary perspective that fusion both the falsificationist and verificationist dimension.<sup>3</sup>

### **Does the discovery of GW confirm GTR?**

But if the empirical settings could only definitely prove that a model is wrong and not the other way round, what is the purpose of this experiment? The detection of predicted GW is a strong evidence in which B-confirms the GTR.<sup>4</sup> The LIGO detections add new evidence, besides the already existing ones,<sup>5</sup> that the depiction of GTR could be suitable for explaining the physical phenomena observed. In 1974 Hulse and Taylor inferred from the hanging orbits of paired neutron stars observed, which comply with Einstein's general relativity prediction, that the other consequence, the existence of GW, should be also true. In the LIGO experiment, on the base of another fundamental postulate of GTR, i.e. the constant light speed, the scientists measured the changing laser time travel between mirrors, which correlates at that moment in two observatories, and inferred the existence of GW.<sup>6</sup>

The prior probability of GTR was based more on its success to solve the open problems left by classical theory of Universe. Some data could not have been explained in the classical theory framework and Einstein provides a new perspective where most of those observed data fitted: “anomalous” precession of the perihelion of Mercury, deflection of light by the Sun, gravitational red shift of light or light travel time delay testing, among other modern experiments. All these observations and experiments increased the probability of GTR, which accommodates better the existing evidence than the classical perspective. Until now the existence of GW was an unconfirmed direct consequence of GTR. Why is the detection of gravitational wave so important for the probability of GTR? In the Bayesian theory of confirmation the prior and posterior probabilities of a theory are formally related:  $P(T/E) = P(T) \cdot P(E/T) / P(E)$ : the posterior probability of T ( $P(T/E)$ ) is equal with the prior probability of T ( $P(T)$ ) multiplied by the ratio between likelihood of evidence given T ( $P(E/T)$ ) and the expectedness of evidence ( $P(E)$ ). GW was an evidence predicted on the base of GTR and not a fact previously known. GTR was made for “accommodating” the old

<sup>2</sup> Imre Lakatos, “Falsification and the Methodology of Scientific Research Programmes”, in *Criticism and the Growth of Knowledge*, eds. I. Lakatos and A. Musgrave, Cambridge: Cambridge University Press, 1970, pp 99-100.

<sup>3</sup> Bogdan Popoveniuc, “Falsificaționism, verificaționism și complementaritate (Falsificationism, verificationism and complementarity)”, in Sorin Tudor Maxim and Bogdan Popoveniuc (coord.), *Analele Universității “Ștefan cel Mare”, Seria Filosofie și Dicipline Socio-Umane (Annals of University “Ștefan cel Mare” Suceava, Philosophy and Social-Human Disciplines Series)*, Suceava: “Ștefan cel Mare” University Press, 2004, pp. 19-30.

<sup>4</sup> B-confirmation of a theory is a concept from Bayesian Confirmation Theory (BCT) which states that evidence affects the degrees of belief that people have about a theory in ways determined by theorems from probability theory such as Bayes Theorem. A certain evidence (would) confirms (in some degree) the T theory just if the probability of T conditional on E is greater than unconditional probability of T.

<sup>5</sup> The Royal Swedish Academy of Sciences has decided to award the Nobel Prize Physics for 1993 jointly to Russell A. Hulse and Joseph H. Taylor, Jr, both of Princeton University, New Jersey, USA for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation.  
[http://www.nobelprize.org/nobel\\_prizes/physics/laureates/1993/press.html](http://www.nobelprize.org/nobel_prizes/physics/laureates/1993/press.html).

<sup>6</sup> B. P. Abbott *et al.* (LIGO Scientific Collaboration and Virgo Collaboration), “Observation of GW from a Binary Black Hole Merger”, *Physical Review Letters*, 116, 061102 – Published 11 February 2016.

evidence as the “anomalous” precession of the perihelion of Mercury”. This was evidence which GTR was meant to explain. The GW is a posterior evidence “predicted” by GTR. However, the confirmation probability of a theory seems to be equal if it succeeds to accommodate some old fact, or it predicts new ones because they are symmetric: “both prediction and accommodation consist in the deduction of some facts; and that they apply the term «prediction» when the facts has not established, and the term «accommodation» when it has.”<sup>7</sup> As a rule, a theory is accommodating if it was designated to entails the datum, and theory correctly predicts datum when it wasn’t designed to entail it.

The GTR is a deterministic theory and the new predicted facts probability should be equal with 1:  $P(E/T)=1$ . In this case  $P(T/E)= P(T)/P(E)$ . In probabilistic theory of confirmation,  $P(E)$  should not be 1, because this will lead to the known problem of old evidence ( $P(h/e) = P(h)$ ). The question is: what will make this discovery more relevant for GTR, a low or a high value for  $P(E)$ ? In the Bayesian theory of confirmation it seems that low values for  $P(E)$  increase the probability confirmation of theory. Intuitively speaking, the more surprising the evidence is, the more confirming it is for that theory. For the scientific community working on verifying GTR the belief in E,  $P(E)$  was extremely high, almost 1, given the huge amount of investment made in LIGO and other facilities designed to confirm the predictions. For the public, the credibility was definitely very low, given the hard to imagine reality of GW.

The information that a theory correctly predicted certain facts enhances its credibility more than the news of the successful accommodation of the same data, only amongst those people who are not acquainted with the theory. Maybe they heard about it, as in the case of GTR, but they are unfamiliar with its principles. “But if, on the other hand, we grasp the theory and can rationally assess its plausibility, then no information about whether the entailed data were predicted or accommodated should have the slightest evidential value.”<sup>8</sup>

Does this mean that GW discovery has a minimum impact on the confirmation of GTR? This is not necessarily the case. Even in the Bayesian confirmation theory, it is asserted that the power to accommodate or predict are unequal relative with the probability of a theory.<sup>9</sup> Predictions which have high values for  $P(E)$  and for the likelihood ratio are decisive to determine that E is evidence for T and, also,  $P(E)$  must be high in order to justify the Bayesian conditionalization on E.<sup>10</sup> In other terms, the surprising evidences discovered are not raising the probability of a theory as much as (with high probability) expected ones because of its relation with the high probability of the likelihood of evidence given the falsehood of -T ( $P(E/-T)$ ), or other concurrent theories. “[P]rediction provides epistemic goods and additional assurance above and beyond accommodation at a number of points in scientific inference. For inferences from data to phenomena, from phenomena to theories, and from theories to framework, prediction provides distinct epistemic advantages. These epistemic assurances include: insurance against overfitting, evidential relevance to the explanatory structure of a

<sup>7</sup> Paul Horwich, *Probability and Evidence*, Cambridge: Cambridge University Press, 1982, p. 109.

<sup>8</sup> *Ibidem*, p. 117.

<sup>9</sup> Patrick Maher, *Betting on Theories*, Cambridge: Cambridge University Press, 1993.

<sup>10</sup> Sherrilyn Roush, *Tracking Truth: Knowledge, Evidence and Science*, Oxford University Press, 2006.

theory, and reliable production of successful theories. In addition, novel predictions provide other epistemic goods, such as uncovering new relevant evidence and new evidence/theory relations.”<sup>11</sup>

In the case of GTR and GW, the problem of confirmation is more special because we are dealing with a universal paradigm that represents a radical change from the previous one. The GTR is that sort of Universal Theory that neither the falsificationist one, nor even the pure verificationist one could account for its validity and development. Like the Newtonian theory of gravity, it does not forbid any “observational state of affaire” and could not be entirely rejected on the basis of any single evidence (not even more). A similar situation is found in Quantum Physics where scientists learned their lesson sooner than astronomers when they try to confirm their model for particles. They found that a particle is however it is measured. You may think it is corpuscular; hence your measurement device is set for particles detection and will discover a particle; you may think it has an undulatory nature, then you will build a device for measuring waves and this is all you have got. So is each and every model true? Both models are true? Or maybe there must be another solution?

The gravitation waves were inconceivable before GTR. In this case the theory predicts evidences which previously did not even exist as theoretical possibilities. Therefore, the detection of GW represents an example of godly power of mathematical language able to put order in the Universe. The efforts to accommodate past classical theory with observable data failed, and the human mind conceived a totally different kind of order, which implies a totally new understanding of physical reality. “Even if we know all the evidence on which a theorist based her theory, the fact that certain datum was predicted rather than accommodated, may provide further evidence for the theory.”<sup>12</sup> It is a big accomplishment of GTR model that we can get used with to understand the universe, it fits to a lot of observations, better than the previous ones, and it is more solid because it predicts in advance what should be discovered.

### **Competing theories**

We see that the combination of empirical falsifiability and confirmation with available and experimental evidence acquired makes out of GTR an epistemological superior theory. The detection of GW is less probable to be an “Einsteinism”: “correct prediction, wrong reason.” Most of the competing theories, at the GTR level of comprehension, are unable to provide testable consequence and make fallible statements. They are more metaphysical constructs based on a queer dogmatic verificationism. According to their authors’ personal beliefs, these “theories” have such a flexible hermeneutics, that it could adjust and re-interpret the event of GW detection in any desirable twisted ways. They could even become proofs that “Big Bang cosmology is not operational science. This observation in no way strengthens claims that the alleged Big Bang happened. The Big Bang necessarily still needs many unverifiable fudge factors. It is still unreasonable.”<sup>13</sup> GW are not a “proof” of Einstein’s

---

<sup>11</sup> P. D. Magnus and Heather Douglas, “State of the field: Why novel prediction matters” (2013), *Philosophy Faculty Scholarship*. Paper 23, p. 24, [http://scholarsarchive.library.albany.edu/cas\\_philosophy\\_scholar/23](http://scholarsarchive.library.albany.edu/cas_philosophy_scholar/23).

<sup>12</sup> Roger White, “The epistemic advantage of prediction over accommodation,” *Mind* 112 (448) (2003), p. 668.

<sup>13</sup> John G. Hartnett, “What impact does the detection of GW have on biblical creation?” Creation Ministries International, Published: 16 February 2016, <http://creation.com/detection-of-gravitational-waves-and-biblical-creation>.

“space curvature” as the “mechanism” of gravitation, but “it really would prove nothing more than that space is not empty and that it contains a material medium capable of transmitting motion over great distances.”<sup>14</sup> In such dogmatic interpretation the experiment confirms just the opposite: the dead of attraction gravity idea, that the space is not empty and the Aether must exist!\*

Other limits of GTR are also pretexts for contesting this amazing success. It predicts well the events and phenomena and the formation of black holes at a certain size. We also know that in time the black holes lose thermal radiation and shrinks reaching at the end a quantum size. TGR could not depict what happened with the final remnant, because it will depend on the way of how gravity behaves at Planck scales, and this is not covered by theory. Overall, the TGR gravity is not compatible with the gravity conception from Quantum Physics. For this is it necessary to upgrade the GTR to a Grand Unified Theory or to propose another model, like the EVTD<sup>2</sup> theory a model “based on the existence of an electromagnetic primary wave (EMW) that permanently format and animate by vibration these elementary entities having dimensions with values in the proximity of Planck dimension.”<sup>15</sup>

But a Physics of Everything as EVTD<sup>2</sup> that allows a great number of propositions for the understanding of physics phenomena, based on the main principles of simplicity and coherence of natural existence could prove to be, at the end, a Theory of Nothing as long as it could predict everything, hence nothing and make untested infallible assertions. In the harsh world of scientific progress, such theories are condemned to remain mere imaginative exercises, potentially viable as long as they fail to produce inter-verifiable and testable outcomes. In spite of the high level of abstraction and discourse involved in the modern scientific and metaphysical world, the rejection of dogmatic justificationalism makes the difference between a scientific theory and a purely metaphysical one. “The success of current scientific theories is no miracle. It is not surprising to the scientific (Darwinism) mind. For any scientific theory is born into a life of fierce competition, a jungle red in tooth and claw. Only successful theories survive.”<sup>16</sup> The epistemic competition between theories is not so much about on which theory is actually true, but on which theory adequately (accurately) describes the observable world.

In my opinion, the arguments in the debates on the superior value of predicting power over accommodation attribute are far from being conclusive, especially because the confirmation theorists strive to construct a mathematical demonstration for epistemic certainty. The mathematics is the most powerful tool invented by the human mind, but it is only an instrument that, like Midas hands, transforms everything it touches in quantitiveness. When we try to understand the human mind and everything which is related

---

<sup>14</sup> Glenn Borchardt, “Gravitational Attraction is Dead,” April 14, 2016,

<http://www.naturalphilosophy.org/site/glennborchardt/2016/04/14/gravitational-attraction-is-dead/>.

\* “Neomechanical Gravitation Theory” explains gravity through the rising of Aether pressure away from ordinary baryonic matter. Hence, the baryonic matter acts like a vacuum, making material objects to be pushed toward massive objects.

<sup>15</sup> M. Conte, I. Rosca, *Physique de Tout. Les EVTD2*, Braşov: Graphica Print, 2004.

<sup>16</sup> B. van Fraassen, *The Scientific Image*, Oxford: Oxford University Press, 1980, p. 80.

to it, we reach our limits. This also happens because the mathematic language could not provide its own explanation.

However, in Physics, it seems that scientists are speaking the language of rational God, that is mathematics. If “mathematics is the language with which God has written the universe”, as Galileo Galilei believed, we are able to comprehend it by using our minds when “thinking God’s thoughts after him” as Johannes Kepler asserts. Why people would build lasers and the mirrors in kilometers-long tubes, with fancy interferometers with electronics and hydraulic actuators and much more which cost many hundreds millions dollars if they didn’t believe in those equations? Nevertheless the psycho-social mechanism is similar in Science and Religion. People need to receive certitude from a comprehensive story of the entire world. They need to gain the feeling of knowing their place in the World. The scientific language is promoted in Science because it is the most clear and distinct of them all. But from here results an erroneous idea. “It is that in physics the ultimate reality is a mathematical prescription, an equation. In fact, the ultimate reality is a little story or myth.”<sup>17</sup> Unlike religious myths which imply a conformational hermeneutics in order to put the reality in accordance with the myth, the scientific myths are collectively constructed through a falsificationist process and changed according to the new data. The signs for the truthiness of a scientific myth consist in its predictive power. “[I]n science we have found out that when we know all about the adventures amid events of material physical objects and of scientific objects we have most of the relevant information which will enable us to predict the conditions under which we shall perceive sense-objects in specific situations.”<sup>18</sup> Any physical theory describing the ultimate limits of the Universe – as the unconditioned of the absolute totality of the series of conditions to a given conditioned in composition and division – is grounded in a myth which will eventually come to be taken as reality. This is true for GTR and Quantum Theory as well.

Unlike religious myths, the mathematics language seems to convey more hidden information about the World. If hermeneutics of religious texts reveal new meanings for old myths, the scientific hermeneutics for mathematical equation describing the Universe reveals a new way of understanding the Universe, which in turn, predicts new phenomena. Whilst people invest so much time in energy in these equations, it seems that more comes out from them than it goes in.

### **The Metaphysics of GW**

It seems that Newton’s warning for the generations of physicist to come: “Physics beware of metaphysics” was a faulty one. If we look at the famous “black-hole war” between Stephan Hawking and Leonard Susskind and proposed solutions, conservation of energy in a parallel Universe, the smearing of information in two dimensions around the edge of the black hole respectively, we found ourselves in a pure scholastic ardent debate about the nature of God and its creation. The holy texts which sustain the Universe are to be found in information bits on the cosmological horizon. According to Holographic Principle “at each level of space,

<sup>17</sup> Lewis C. Epstein, *Relativity Visualized*, Insight Press, 1985, p. 76.

<sup>18</sup> Alfred N. Whitehead, *The concept of Nature*, Cambridge: Cambridge University Press, 1971, p. 170.

everything enclosed may be described as a holographic image but when we go looking for the hologram it is always out at the next level.”<sup>19</sup> If we apply Susskind’s solution to the whole Universe, the physics of our known space-time universe (4-D) becomes a holographic reality working on an alternative set of physical laws, operating on a “real” 3-D boundary of space-time somewhere.\*

Physics was and will always be Meta-physics. Every physical model will have, sooner or later to address the cosmological Ideas of for the consistency of their ground. The Physics is the science of “the mathematical total of all phenomena and the totality of their synthesis — in its progress by means of composition, as well as by division.” The Universe is the World in its totality. The modern Physics dare to ask the question of its infinity in space, time and division and found there are legitimate question and not just Ideas of Reason.<sup>20</sup> By hesitating in front of the greatness of the Universe, the philosophers wanted to keep the Physics out from Metaphysics and assert these limitations on the legitimate questions areas. But the discovery of GW adds to the other proofs (i.e. the possible eternal Big-Bang, the quadri-dimensional spherical geometry of the Universe that makes it spatially finite but unlimited, the a infinite repetition of a finite number of possibility (or the incessant realisation of infinite possibilities) in Multiverse, and the quantic division of space) for the legitimacy of Kantian Cosmological Ideas and the unlimited power of human mind to conceive genuine meanings and comprehend the Universe. The contemporary models for the Universe, as a whole and at its fundamental structure, started from the need of explaining the existent evidence and it progressed by imagining experiments for proving the subsequent predictions. The GTR model of Universe and The Inflationary Model promise a consistent solution for the Kantian antimony generated by the cosmological Idea of the “absolute completeness of the *composition* of the given totality of all phenomena in space and time”. The quantum mechanics supports a consistent solution for the antimony caused by the cosmological Idea of “the absolute completeness of the *division* of given totality in a phenomenon.” The quantum causality reveals itself as a promising consistent solution for “the absolute completeness of the *origination* of a phenomenon.” And the Great Unified Theory, process physics or Theory of everything could resolute the logical conundrum rised by the cosmological Idea of “absolute completeness of the *dependence* of the *existence* of what is changeable in a phenomenon.”<sup>21</sup>

Kant wanted to prove that reason fails in insoluble antinomies when it rises the question of the Absolute condition of the existence in Universe. But GTR removed the Absolute and, along with Quantum Theory, set the problems at a new level, above the classical logic of intuitive apprehension. The Kantian conception was limited by its fundamental dogmatic justificationism, which does not accept any interference to its

---

<sup>19</sup> Leonard Susskind, *The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics*, Little, Brown, 2008, p. 301.

\* If we only take into account the cosmic space, the three dimensions we observe are in effective description only at macroscopic scale and at low energy, while the “real” Universe consists in two-dimensional information structure «painted» on the cosmological horizon.

<sup>20</sup> Immanuel Kant, *Critique of Pure Reason*, Harvard University, 1855, p. 260.

<sup>21</sup> Bogdan Popoveniuc, *Iluziile rațiunii. Antinomiile matematico-transcendentale și destinul lor în filosofia și știința contemporană*, București: Editura Didactică și Pedagogică, 2009.

assumption base from “external world”. But “if we accept the demarcation criteria of dogmatic falsificationism, *and* also the idea that facts can prove «factual» propositions, we have to declare that the most important, if not all, theories ever proposed in the history of science are metaphysical, that the most, if not all, of accepted progress is pseudo-progress, that the most, if not all, of the work done is irrational. If, however, while still accepting the demarcation criterion of dogmatic falsificationism, we deny that facts can prove propositions, then we certainly end up in complete scepticism: then all science is undoubtedly irrational metaphysics and should be rejected. *Scientific theories are not only equally unprovable, and equally improbable, but they are also equally undisprovable.* But the recognition that not only the theoretical but *all* the propositions in science are fallible, means the total collapse of *all* forms of dogmatic justificationism as theories of scientific rationality.”<sup>22</sup>

The detection of GW proves once again the power of the human mind and its collective masterpiece tool, the Science. Einstein knew nothing about black holes or even about lasers, but he laid the theoretical foundations for both. His theoretical and abstract conception reached to the fundamental basis of the things as far as the level of knowledge and technology allows at the time he lived in. His theoretical insights were tested one century later and proved to have a very strong predictive power. His work is no less than a highly creative metaphysical thinking strengthened with differential geometry and mathematical analysis which the same major aim of transforming the unfamiliar unknown and chaotic world in an organized, harmonious known Universe.

### **Future openings of Gravitational Astronomy**

The detection of GW represents the beginning of a new era where the field of gravitational wave astronomy became a reality. When the lasers were discovered, there were few those which believed in their practical usage, and nowadays they are one of the most and widely use application. This new field has no interest for many, but for researchers it could illuminate some of the fundamental mysteries of the Universe. For example, the GW astronomy is the only one that could give us information before 380000 million years from the beginning of the Universe, the time limit for standard astronomy based on other electromagnetic waves (light, X-rays, microwaves, radio waves).<sup>23</sup> In the last decades two major theoretical predictions, made by the two most successful theories of XXX century, i.e. GTR and Quantum Physics, were confirmed: the directly detection of GW and discovery of the Higgs boson. Using the new gravitational wave astronomy, other predicted physical phenomena wait to be revealed and questions to be answered: the direct observation of the dark matter, the inner workings of black holes, if neutron stars are rugged and how looks the actual dynamics of what goes on inside the supernova, what makes stars to explode, the evidence for inflation (e.g. tensor modes) in the cosmic microwave background (the oldest light in the universe, dating from shortly after the Big Bang) and how fast is the Universe expanding, if the GW travels at the speed of light, if there are gravitons, if space-time is made

<sup>22</sup> Imre Lakatos, “Falsification and the Methodology of Scientific Research Programmes,” p. 103.

<sup>23</sup> Until then the Universe was filled with hot ionized gas, i.e the electrons and nuclei were separated and only free electrons were flying around scattering wildly the photons of light and blurred the information they could carry.

of cosmic strings and, maybe, the discovery of particles which are not in the Standard Model.<sup>24</sup>

As one of founding member of LIGO, Kip Thorne said, the most important significance of gravitational-waves detection is the cultural enrichment brought for the future generation. “When we look back on the era of the Renaissance, and we ask ourselves, «What did the humans of that era give to us that is important to us today?» I think we would all agree it is great art, great architecture, great music. Similarly, when our descendants look back on this era, and they ask themselves, «What great things came to us?» ... I believe there will be an understanding of the fundamental laws of the universe and an understanding of what those laws do in the universe, and an exploration of the universe. (...) LIGO is a big part of that. The rest of astronomy is a big part of that. And I think that this cultural gift to our future generations is really much bigger than any kind of technological spin-off, than the ultimate development of technology of any kind. I think we should be proud of what we give to our descendants culturally.”<sup>25</sup>

#### **BIBLIOGRAPHY:**

Abbott, B. P. *et al.* (LIGO Scientific Collaboration and Virgo Collaboration), “Observation of GW from a Binary Black Hole Merger.” *Physical Review Letters*, 116, 061102. Published 11 February 2016.

Borchardt, Glenn. “Gravitational Attraction is Dead,” April 14, 2016. <http://www.naturalphilosophy.org/site/glennborchardt/2016/04/14/gravitational-attraction-is-dead/>.

Castelvecchi, Davide. “GW: 6 cosmic questions they can tackle,” *Nature*, 09 February 2016.

Cofield, Calla. “GW: What Their Discovery Means for Science and Humanity,” *Space.com*, February 12, 2016. <http://www.space.com/31922-gravitational-waves-detection-what-it-means.html>.

Conte, M.; Rosca, I. *Physique de Tout. Les EVTD2*. Brasov: Graphica Print, 2004.

Epstein, Lewis C. *Relativity Visualized*. Insight Press, 1985.

Fraassen, B. van. *The Scientific Image*. Oxford: Oxford University Press, 1980.

Hartnett, John G. “What impact does the detection of GW have on biblical creation?” Creation Ministries International. Published: 16 February 2016. <http://creation.com/detection-of-gravitational-waves-and-biblical-creation>.

Horwich, Paul. *Probability and Evidence*. Cambridge: Cambridge University Press, 1982.

Kant, Immanuel. *Critique of Pure Reason*. Harvard University, 1855.

Lakatos, Imre. “Falsification and the Methodology of Scientific Research Programmes.” In *Criticism and the Growth of Knowledge*, Lakatos, I. and Musgrave, A. (eds.). Cambridge: Cambridge University Press, 1970, pp. 91-195.

<sup>24</sup> Davide Castelvecchi, “GW: 6 cosmic questions they can tackle”, *Nature*, 09 February 2016.

<sup>25</sup> After Calla Cofield, “GW: What Their Discovery Means for Science and Humanity”, *Space.com*, February 12, 2016, <http://www.space.com/31922-gravitational-waves-detection-what-it-means.html>.

Magnus, P.D., and Douglas, Heather. "State of the field: Why novel prediction matters" (2013). *Philosophy Faculty Scholarship*. Paper 23. [http://scholarsarchive.library.albany.edu/cas\\_philosophy\\_scholar/23](http://scholarsarchive.library.albany.edu/cas_philosophy_scholar/23).

Maher, Patrick. *Betting on Theories*. Cambridge: Cambridge University Press, 1993.

Popoveniuc, Bogdan. "Falsificaționism, verificaționism și complementaritate" (Falsificationism, verificationism and complementarity). In Sorin Tudor Maxim, and Bogdan Popoveniuc (coord.), *Analele Universității "Ștefan cel Mare", Seria Filosofie și Dicipline Socio-Umane* (Annals of University "Ștefan cel Mare" Suceava, Philosophy and Social-Human Disciplines Series). Suceava: "Ștefan cel Mare" University Press, 2004, pp. 19-30.

Popoveniuc, Bogdan. *Iluziile rațiunii. Antinomiile matematico-transcendentale și destinul lor în filosofia și știința contemporană*. București: Editura Didactică și Pedagogică, 2009.

Popper, Karl R. *Conjectures and Refutations*. London: Routledge, 1963.

Roush, Sherrilyn. *Tracking Truth: Knowledge, Evidence and Science*. Oxford University Press, 2006.

Susskind, Leonard. *The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics*. Little, Brown, 2008.

White, Roger. "The epistemic advantage of prediction over accommodation." *Mind* 112 (448) (2003): 653-683.

Whitehead, Alfred N. *The concept of Nature*. Cambridge: Cambridge University Press, 1971.