Contemporary Engineering Sciences, Vol. 13, 2020, no. 1, 323 - 333
HIKARI Ltd, www.m-hikari.com
https://doi.org/10.12988/ces.2020.91599

Do We Live Inside a Complex Hologram?

Ideas and Theories About a New Perspective

Gastón Sanglier Contreras, Eduardo J. López Fernández,
Sonia Cesteros García, and Roberto A. González Lezcano

Universidad CEU San Pablo, Escuela Politécnica Superior
Área de Ingeniería de la Construcción, Campus de Montepríncipe
Boadilla del Monte 28660, Madrid, Spain

This article is distributed under the Creative Commons by-nc-nd Attribution License.
Copyright © 2020 Hikari Ltd.

Abstract

Albert Einstein was able to predict gravitational waves but assumed that man with his measuring instruments would never be able to detect them. He made the mistake of underestimating the curiosity and technological development capacity of the human race since interferometric laser detectors like LIGO have been able to detect them. This finding has been the beginning for scientists to start 'listening' to the universe. This opens a new paradigm to explain inflation, which is one of the unproven points in the cosmological model of the Great Expansion, and to understand what happened at the very moment the universe was created. This study is a small journey through our universe from the moment of the great explosion to the concept of the holographic universe, passing through gravitational waves, black holes, multiverses and other paradigms that provide an immediate future where interesting questions are raised (2). In our quest for truth, as a species we are able to make such great achievements and be proud of all that we are learning about the universe, but on the other hand, one might think that we are now destroying it, and perhaps leading to our own extinction.

Keywords: holographic principle, multiverse, string theory, Big Bang, black hole.

1. Introduction

The most accepted model today to describe how it all began is that of the Big Bang, in the beginning the universe was much denser, hotter and smaller. About 13.8 billion years ago our universe was beginning to expand and cool down until today. This model is based on very strong evidence that considers this theory proven today.

It is very likely that the universe after the Big Bang went through a brief period of very rapid expansion called inflation in which major gravitational waves occurred (16). Proving that inflation occurred is very complicated because the temperature of the universe, i.e., the energy of the elementary particles was billions of times higher than what can be achieved on Earth today (4,13). It is possible that these major gravitational waves still reverberate in the universe and their footprint can be searched for in what is called cosmic background radiation. Observing these gravitational waves could provide insight into the energy at which inflation occurred.

But all this clashes with a fundamental problem, since inflation is a quantum phenomenon and gravitational waves are more identified with Einstein's physics (14,19). This could be a bridge between the two theories, and could be the first evidence that gravity has a quantum nature, in the same way as the other four forces of nature.

Inflation is one of the unproven points in the cosmological model of the Great Expansion. If inflation occurred, then just for a few moments after the Big Bang, the universe expanded much faster than it would continue to do afterwards, and even faster than the speed of light (10,11,12).

If we use the metaphor that the universe was like a plate of hot water where approximately the temperature of the liquid is the same in all parts of the plate applying the principle of heat transmission since all the molecules of the water are in contact and transmit heat to each other. However, the edges of the known universe are almost 28 billion light years apart, while the age of the universe is only 13.8 billion years. This indicates that there has not been time for energy to be distributed evenly throughout the universe, as heat was transmitted in water. It could be said that light has not had time to connect and equalize the extreme regions of the universe and it is very unlikely that all regions have evolved independently (18,21).

It could be assumed that the universe in its incipient beginning went through a phase of expansion much faster than the speed of light and the problem would be solved. The extreme regions could have been connected in the past and that would explain their homogeneity.

Therefore, being able to detect the main gravitational waves would lead us to be able to demonstrate inflation. The theory indicates that inflation generated gravitational waves (vibrations) that could compress the space-time duo in one direction and stretch it in another.

It would be a matter of detecting the gravitational waves not by detecting the changes in space-time (what the LIGO observatory achieved and what the eLISA observatory aims at), but by reading the marks left by the movement of space-time in the background radiation.

On the other hand, we can talk about the multiverse which is one of the most controversial theories, there are scientists who do not want to talk about it because they consider it an unscientific subject, but we believe that everything should be considered in its right measure (31,32). Is the consideration of multiverse important to understand the universe and its laws? Only time and serious research will be able to answer this question.

In recent times, one of the most controversial theories about the universe is the one that physicists Gerard 'tHooft and Leonard Susskind proposed in the 1990s and is known as the Holographic Principle (30), which postulates the hypothesis that the universe can be interpreted as a hologram. This theory will be discussed later in this paper. Can we understand the universe as a hologram?

There are theories that remain in question, such as the theory that the universe is a virtual simulation, a kind of Matrix. Physicists think that this is more of an entertainment and not a specialty of the science of Cosmology.

Physicist Roberto Amparan comments that there can be a multiverse and there can be a universe in which the fundamental description of the universe is of the holographic type, and that in reality these three spatial dimensions and one dimension of time that we have are part of it, of a holographic illusion. Perhaps this is possible from the point of view of a way that we are not yet able to understand.

The same physicist says that there could be a multiverse, which is the possibility that our universe is part of a larger entity in which they have occurred, in the same way that you can have a liquid in which different bubbles can appear, and that each of those bubbles is like a universe, that there are different bubble universes in a larger structure, that's possible, but could we talk about multiverses and holographic universes independently? what particulars could that plurality of multiverse universes have?

One could look for a relationship that would unify quantum physics with the physics of gravity, which has a relationship to what is also known as string theory, superstring theory, and within this context, one has what is called the 'Holographic Principle', which says that a system where gravity exists, where quantum physics actually exists, effectively appears as a kind of hologram of something more fundamental. does a unification of the two theories seem possible? and if so, could one speak of a general formula for the government of the universe?

2. Methods and materials

2.1 What are gravitational waves?

Gravitational waves are invisible, though incredibly fast, waves in space. They travel at the speed of light (186,000 miles or 300,000 kilometers per second). Gravitational waves contract and stretch any body they find in their path.

For Spanish scientist Garcia-Bellido, gravitational waves are waves in space. They are like electromagnetic waves but instead of being in magnetic fields they are in space itself. They are wrinkles of space-time that propagate at the speed of light.

We have known about their existence for a long time. More than 100 years ago, Albert Einstein came up with many theories about gravity and space. He predicted that something special happens when two bodies, like planets or stars, orbit each other. He believed that this kind of motion could cause ripples in space. These ripples would extend like the ripples that occur in a pond when we throw a stone.

Scientists call these ripples of space gravitational waves. However, he said that the gravitational waves were produced at such a distance that when they reached our planet they were so weak that they could not be captured by any man-made instrument to date (14, 31).
The most powerful gravitational waves are created when objects move at very high speeds. Some examples of events that could cause a gravitational wave are:

- The asymmetric explosion of a star, called a supernova.
- Two large stars orbiting each other.
- Two black holes orbiting each other and merging.

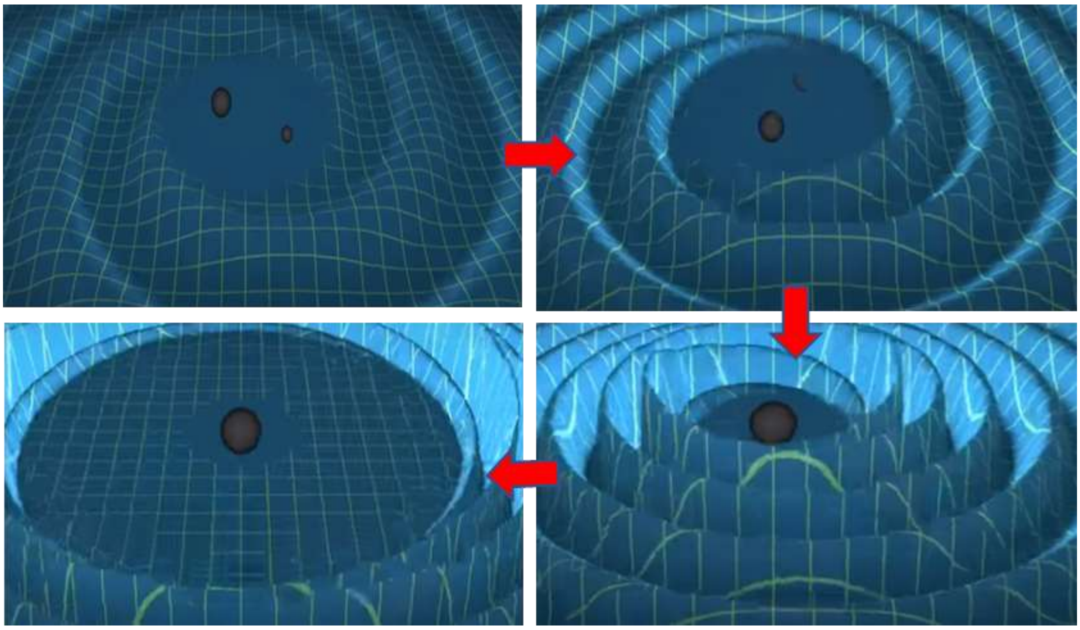

Figure 1. Animation created representing the gravitational waves created by the fusion of two black holes (15). Source: LIGO/T. Pyle

However, these types of objects that create gravitational waves are far away. And sometimes, these events only cause small, weak waves. By the time they reach the Earth they are very weak. This makes gravity waves difficult to detect.
Now, the question you might ask is how do we know that gravity waves exist?
The existence of gravitational waves was first demonstrated in the 1970s and 1980s by Joseph Taylor, Jr. and his co-workers.
In 1974, Taylor and Russell Hulse discovered a binary system formed by a pulsar in orbit around a neutron star. Taylor and Joel M. Weisberg in 1982 found that the pulsar's orbit was slowly decreasing over time due to the release of energy in the form of gravitational waves.
In 2015, scientists detected gravitational waves for the first time. They used a very sensitive instrument called LIGO (Laser Interferometry Gravitational Wave Observatory). These first gravitational waves were produced when two black holes

collided with each other. The collision occurred 1.3 million years ago, but the ripples did not reach the Earth until 2015 (2).

The first detection of gravitational waves was a very important event for the world of science. Before this, almost everything we knew about the universe came from the study of light waves. Now we have a new way to learn about the universe: by studying gravity waves.

In May 2019 a signal was detected on the screens of the laser interferometer at the LIGO US observatory and almost simultaneously, about 8,000 km away, it also occurred on the screen of the Virgo detector (in a town near Pisa, Italy). It is said to have been the strongest signal identified. The scientists translated the frequency of that signal into sound and heard, only for a tenth of a second, a very brief bump, or hum, which made it very difficult to identify where it came from and how it had occurred. This captured signal was produced 7 billion years ago. For George Simoor, Nobel Prize in Physics, this detail is the most important finding of the century.

The scientist Stephen Hawking celebrated the observation of the gravitational waves predicted by Einstein, commenting that thanks to this detection the relics of the Universe could be seen just after the Big Bang (17).

As announced by the team of the Gravitational Interferometer Wave Observatory (LIGO), the phenomenon that has been detected is the result of the fusion of two black holes in space.

Precisely, Hawking is an expert in black holes and showed his enthusiasm because the waves allow us to know the behavior of these objects throughout their lives with greater precision. In addition, he indicated that the information transported in the gravitational wave is exactly the same as when the system sent it in a distant time, something he said is rare in astronomy (17, 28). He indicated that you cannot see the light from whole regions of the Milky Way, because of the dust in the way, just as you cannot see the first part of the Big Bang because the Universe was opaque for a while. It is worth asking, if being able to detect the gravitational waves, could one overcome that opacity and make the beginning of the Universe transparent?

Gravitational waves will help us learn many new things about our universe and also about gravity.

2.2 How are gravitational waves detected?

When a gravitational wave passes through the Earth, it compresses and stretches space. LIGO can detect this stretching and compression. Each LIGO observatory has two "arms", each more than 2 miles (4 kilometers) long. A passing gravitational wave causes the length of the arms to change slightly. The observatory uses lasers, mirrors, and extremely sensitive instruments to detect these small changes.

American physicists have concluded that the gravitational waves detected were produced during the last fraction of a second of the fusion of two black holes to produce a single, more massive rotating black hole. It could be said that LIGO has opened a new window to the universe, the window of gravitational waves (26,27).

LISA (Laser Interferometer Space Antenna) was a project born at the beginning of this century involving the American (NASA) and European (ESA) space agencies.

Its objective was to develop and control an advanced detector of gravitational waves in space by changing the separation between reference masses on board three spacecraft located five million kilometers apart. LISA would monitor the sources of gravitational waves and adjust the position and distance of these phenomena, as well as facilitate their detection with other instruments in the electromagnetic spectrum. Due to a funding problem in 2011 from the U.S. agency, the European space agency is reviewing the project to fit it into another project it has named eLISA (Evolved LISA) that would be launched around 2028. This new mission would be made up of three ships that would fly in an equilateral triangle of one million kilometers on each side, describing an orbit around the sun similar to that of the Earth. This new mission will observe the gravitational waves by detecting changes of up to a pycrometer that may occur in the length of the sides of the triangle using laser interferometry. It may also detect some of the phenomena seen by LIGO.

The implications of being able to detect them are so many that they reach even our knowledge about the origin of the universe.

Physicists Gerard 'tHooft and Leonard Susskind in the 1990s proposed the Holographic Principle by interpreting the universe as a hologram.

A scientific study published in 2107 in Physical Review Letters (1) and supporting the holographic interpretation of the Universe raised a lot of awareness around the world. The idea that the Universe can resemble a huge hologram, as suggested by the title of a lecture by Stephen Hawking, is surprising to say the least.

Holography is an optical technique that makes it possible to create a three-dimensional image on a two-dimensional surface, which gives an impression of depth. That is why it gives its name to a series of mathematical tools that some physicists use to describe what happens in a Universe with three dimensions, from its border, a two-dimensional system. As an example of what is proposed, one can imagine that one wants to express with numbers what happens inside a room, and, for that, a mathematical model is made that describes what happens on the walls. The volume of the room has three dimensions, but it is explained from the walls, which have only two dimensions.

The relationship of the Universe with holography began because physicists observed that some properties of black holes depended on the area of the event horizon (the boundary from which nothing escapes the hole's gravity), and not on its volume (22,24).

As indicated above, it was the work of Susskind and Hooft, as well as Juan Maldacena, that contributed to establishing the idea of holography (20, 23, 25). Niayesh Afshordi, another of the researchers involved in this holographic study, indicated that the greatest achievement of their research is that they have been able to make a detailed comparison of the cosmological data (obtained by analyzing the microwave background radiation, something like an echo left after the Big Bang explosion) with a two-dimensional holographic model of the Big Bang. This suggests that the simplest way to understand the Big Bang is with one dimension less (1).

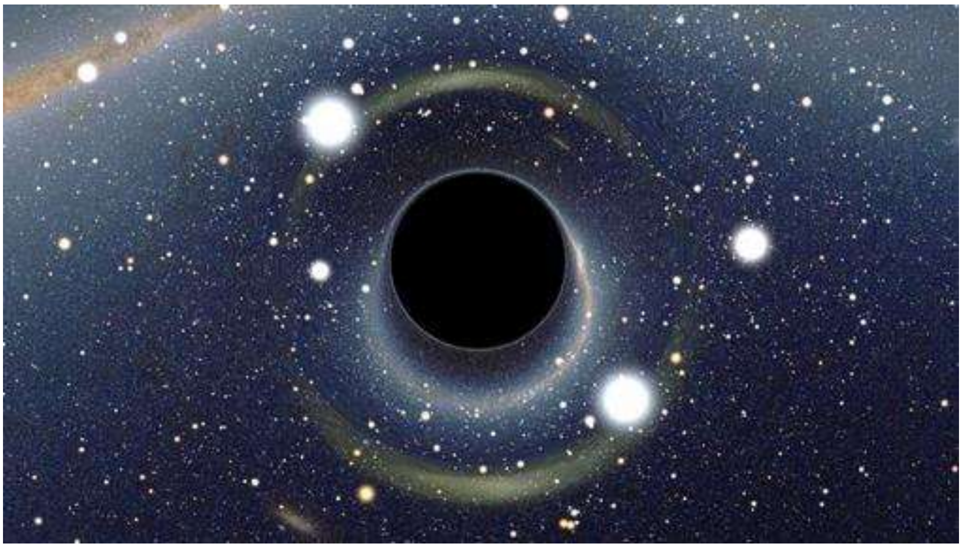

Figure 2. Simulation of a black hole in front of the Magellanic Cloud

This recently presented research offers what could be called a simple explanation of what happened after the Big Bang, but the truth is that there are many other alternative models, where the Holographic Principle has not yet been proven to be completely fulfilled (29). It could be thought that there is something left that we don't have and that something good language to answer the question of how the quantum speaks with gravity.

But let's be optimistic, and think like some scientists, who have suggested that in the next five years observations will rule out many of the alternative models that now exist on these questions. Gradually, we will have a better understanding of what happened after the Big Bang and how gravity and the world of Quantum Mechanics shaped the universe as we know it.

3. Conclusion

The scientific study of Afshordi and his collaborators supports the holographic interpretation of the universe, but contrary to what it may seem, neither this nor any other published study has ever concluded that the Universe is a hologram. Despite the media interest generated and the official press release issued by the University of Southampton (entitled "Study reveals substantial evidence of a holographic Universe"), the Universe cannot be interpreted as a hologram.

This is especially useful for studying black holes, the Big Bang, and gravity on a small scale, but in no case can the Universe be studied holographically or as a hologram. This holographic principle generally used by physicists, is only presented as a mathematical tool (based on conjecture and not yet proven valid in our Universe) in which the physics of a space is supposed to correspond to the information coded in its boundary (which is why it has one dimension less than that other space).

But apart from that, the holography of the Universe has nothing to do with the famous holograms of science fiction movies or the homemade experiments that help to understand this term. As scientist Kostas Skenderis points out, the purpose of Holographic Cosmology is to develop a theory for our universe that can be used more generally than the other theories we already have (1,3).

Why do we need a more general theory? It is necessary because the General Theory of Relativity (GRT) describes the Universe very well on large scales, but it fails on very small scales. Therefore, it is necessary to combine this theory with Quantum Mechanics (which describes the functioning of particles, of that microscopic world).

One way to combine both is to try to explain gravity by assuming it is holographic. According to this, gravitational theories can be understood as theories without gravity in a lower dimension.

Currently, physicists do this by using the knowledge of String Theory and applying it to the Universe immediately after the Big Bang, which holds the most mysteries about how energy and matter were structured (5,6,7,9).

4. Discussion

The problem with the holographic principle is that it uses a term that refers to a completely wrong idea: that our universe is actually a hologram. You may think that the universe is not a hologram but perhaps you could explain it as one.The holographic principle explains the force of gravity by encoding it in two dimensions, which would allow us to arrive at a universal model of physics and to study phenomena that we do not currently understand from a completely new perspective.

If the previous argument is seriously considered, a possible conclusion is to elevate this level to a fundamental principle, thus establishing that any theory that aspires to a candidate for quantum gravity must have a number of states limited by the exponential of the area of the region considered. Then a particularly attractive solution arises when considering that, perhaps what happens is that all the physics inside the box is completely described by a quantum system without gravity, but instead of occupying the three dimensions, it is limited to living on the surface of the box, thus saturating the proposed height. In this image, therefore, the three-dimensional world is a mere illusion, a hologram created by two-dimensional "pixels" whose complicated dynamics create the impression of the existence of new dimensions and gravity as emerging concepts. This idea, proposed by Gerardus 't Hooft and Leonard Susskind, is known as the Holographic Principle, and its subsequent refinements have spearheaded research into quantum gravity over the past two decades. But space and time are often presented as results of our way of perceiving, but we are so automated in accepting these concepts as absolute categories that we find it hard to even imagine them.

Naturally, these unsubstantiated ideas did not take true form until, years later, Juan Maldacena proposed a concrete model in which this principle can be carried out with precision: the so-called ADS/CFT correspondence. Without going into the details of this model, we can draw from it a lesson that ties one last loose end to our thought experiment. In particular, if all the physics of our box is described by pixels at the edge, it seems fair to ask what the typical states of those pixels are at different energies. The ADS/CFT correspondence relates several conformal field theories to the union of string theory and M theory in various numbers of dimensions. The theories involved are generally not viable models of the real world, but they have certain characteristics, such as their particle content or high degree of symmetry, which make them useful for solving problems in quantum field theory and quantum gravity.

Perhaps the almost universal tendency to fragment the world and to disregard the dynamic interconnection that exists between all things is the cause of many problems, not only in the field of science, but also in our lives and in our society. We believe that we can address various problems in society such as crime, poverty or drug addiction without studying the problems of society as a whole, and so on. Our current way of fragmenting the world into parts not only does not work, but can lead to extinction. The Holographic Principle could be that connection between all the theories of physics, but today it seems a bit premeditated to make this assumption.

Acknowledgements. The authors wish to thank CEU San Pablo University Foundation for the funds dedicated to the Project Ref. USP CEU-CP20V12 provided by CEU San Pablo University.

References

[1] N. Afshordi, C. Corianò, L. Delle Rose, E. Gould, K. Skenderis, From Planck Data to Planck Era: Observational Tests of Holographic Cosmology, *Phys. Rev. Lett.*, **118** (2017), 041301. https://doi.org/10.1103/physrevlett.118.041301

[2] A. Almheiri, D. Marolf, J. Polchinski, J. Sully. Black holes: Complementarity or firewalls?, *JHEP*, **1302** (2013), 062. https://doi.org/10.1007/jhep02(2013)062

[3] T. Banks, W. Fischler, S.H. Shenker, L. Susskind, M theory as a matrix model: A conjecture, *Phys. Rev. D*, **55** (1997), 5112. https://doi.org/10.1103/physrevd.55.5112

[4] J.D. Bekenstein, Black holes and entropy, *Phys. Rev. D*, **7** (1973), 2333-2346. https://doi.org/10.1103/physrevd.7.2333

[5] M. Brockman, *What´s Next? Dispatches on the future Science,* Vintage, Nueva York, 2019.

[6] D. Broderick, *Year Million: Science at the Far Edge of Knowledge*, Atlas, New York, 2008.

[7] J. Canton, *The Extreme Future: The Top Trends That Will Reshape the World for the Next 5, 10 and 20 Years*, Dutton, New York, 2006.

[8] J. Carey, *Eyewitness to Sciences: Scientists and writers illuminate natural phenomena from fossils to fractals*, Harvard University Press, 1997.
[9] E. Cornish, *Futuring: The Exploration of the Future*, World Future Society, Bethesda, MD, 2004.
[10] B. de Wit, J. Hoppe, H. Nicolai, On quantum mechanics of supermembranes, *Nucl. Phys. B*, **305** (1988), 545. https://doi.org/10.1016/0550-3213(88)90116-2
[11] G. W. Gibbons, Maeda Black holes and membranes in higher dimensional theories with dilaton fields, *Nucl. Phys. B*, **298** (1988), 741. https://doi.org/10.1016/0550-3213(88)90006-5
[12] M.B. Green, J.G. Russo, P. Vanhove, Non-renormalisation conditions in type II string theory and maximal supergravity, *JHEP* 0702 (2007), 099. https://doi.org/10.1088/1126-6708/2007/02/099
[13] B. Greene, *El universo elegante*, Editorial Planeta, Colección Booket Ciencia, 2012.
[14] D.J. Gross, E. Witten, Superstring modi_cations of Einstein's equations, *Nucl. Phys. B*, **277** (1986) 1. https://doi.org/10.1016/0550-3213(86)90429-3
[15] M. Hanada, J. Nishimura, S. Takeuchi, Non-lattice simulation for supersymmetric gauge theories in one dimensión, *Phys. Rev. Lett.*, **99** (2007), 161602. https://doi.org/10.1103/physrevlett.99.161602
[16] S.W. Hawking, Black hole explosions, *Nature,* **248** (1974), 30. https://doi.org/10.1038/248030a0
[17] S.W. Hawking, Particle creation by black holes, *Commun. Math. Phys*., **43** (1975), 199. https://doi.org/10.1007/bf02345020
[18] S.W. Hawking, Breakdown of predictability in gravitational collapse, *Phys. Rev. D*, **14** (1976), 2460. https://doi.org/10.1103/physrevd.14.2460
[19] S.W. Hawking, The unpredictability of quantum gravity, *Commun. Math. Phys.*, **87** (1982), 395. https://doi.org/10.1007/bf01206031
[20] G.T. Horowitz, J.M. Maldacena, The Black hole final state, *JHEP*, **0402** (2004), 008. https://doi.org/10.1088/1126-6708/2004/02/008
[21] G.T. Horowitz, A. Strominger, Black strings and p-branes, *Nucl. Phys. B*, **360** (1991), 197. https://doi.org/10.1016/0550-3213(91)90440-9
[22] Y. Hyakutake, *Quantum Near Horizon Geometry of Black 0-Brane*, College of Science, Ibaraki University. Bunkyo 1-1, Mito, Ibaraki 310-0062, Japan, 2013.
[23] N. Itzhaki, J.M. Maldacena, J. Sonnenschein, S. Yankielowicz, Supergravity and the large N limit of theories with sixteen supercharges, *Phys. Rev. D*, **58** (1998), 046004. https://doi.org/10.1103/physrevd.58.046004
[24] I.R. Klebanov, A.A. Tseytlin, Entropy of near extremal black p-branes, *Nucl. Phys. B*, **475** (1996), 164. https://doi.org/10.1016/0550-3213(96)00295-7
[25] J.M. Maldacena, The Large N limit of superconformal field theories and supergravity, *Adv. Theor. Math. Phys*., **2** (1998), 231. https://doi.org/10.4310/atmp.1998.v2.n2.a1
[26] J.A. Minahan et al., Review of AdS/CFT integrability, *Lett. Math. Phys*., **99** (2012), 33. https://doi.org/10.1007/s11005-011-0522-9

[27] J. Polchinski, Dirichlet branes and Ramond-Ramond charges, *Phys. Rev. Lett.*, **75** (1995), 4724. https://doi.org/10.1103/physrevlett.75.4724
[28] A. Strominger, C. Vafa, Microscopic origin of the Bekenstein-Hawking entropy, *Phys. Lett. B*, **379** (1996), 99.
https://doi.org/10.1016/0370-2693(96)00345-0
[29] L. Susskind, The world as a hologram, *J. Math. Phys*., **36** (1995), 6377.
https://doi.org/10.1063/1.531249
[30] G. 't Hooft, Dimensional reduction in quantum gravity, gr-qc/9310026, 1993.
[31] K.S. Thorne, *Agujeros negros y tiempo curvo: el escandaloso legado de Einstein*, Editorial Crítica, 2010.
[32] E. Witten, Bound states of strings and p-branes, *Nucl. Phys. B,* **460** (1996), 335. https://doi.org/10.1016/0550-3213(95)00610-9

Received: September 27, 2020; Published: November 14, 2020