

ADAM ŚWIEŻYŃSKI

SOME REMARKS ON THE SIGNIFICANCE OF PARADOX FOR SCIENCE IN THE CONTEXT OF PHOTOMETRIC PARADOX CASE

Abstract. A paradox is an argument that produces an inconsistency, typically within logic or common sense. Most paradoxes are known to be invalid arguments but are still valuable in promoting critical thinking. In astrophysics and physical cosmology, Olbers' paradox (photometric; "dark night-sky"), named after German scholar Heinrich Olbers, is the argument that the darkness of the night sky conflicts with the assumption of an infinite and eternal static universe. If the universe is static and populated by an infinite number of stars, any sight line from Earth must end at the bright surface of a star, so the night sky should be completely bright. This contradicts the observed darkness of the night. Modern research on the essence of the photometric paradox (and attempts to neutralize it undertaken in the history of science) lead to the conclusion that its paradoxicality is resulting primarily from the precedence of human thought (ideas, theories) in relation to the possibility of its proper empirical verification. Therefore, the paradox of "dark night-sky" and attempts to overcome it may be instructive proof that something so plain and obvious, as available to anyone look at the starry night sky, sometimes, for respectively keen observer, give an opportunity to look ahead much further (and sometimes more accurately to reality) than empirical research allow at the moment. The photometric paradox created an opportunity for the unveiling of a new cognitive horizon by exceeding the existing scheme of thought and thereby acquiring new scientific knowledge, enriching the knowledge gained so far and deepening our understanding of Universe.

Keywords: paradox; photometric paradox (Olbers' paradox); scientific knowledge; cosmological models

1. Introduction.
2. The outline of history and attempts to resolve the photometric paradox.
3. Paradox and scientific cognition.
4. Conclusion.

1. INTRODUCTION

As the colloquial saying goes, “the world is full of paradoxes”. Each and every one of us sees the truth of this statement in everyday life.¹ We face paradoxical human decisions and statements, paradoxicality of so-called coincidences and of religious faith. In science (in scientific cognition) situations also occur which are called paradoxes.² Thus, it can be said that paradox is a truly ubiquitous and multidisciplinary phenomenon since it occurs in such a variety of domains of human activity.

Paradox (gr. *parádoxos* – unexpected, improbable; gr. *para* – opposite to something; gr. *doxa* – opinion, notion, knowledge) is a situation or statement leading to an unexpected, surprising, or contradictory conclusion. The contradiction may be the result of errors made in forming a statement or of erroneous assumptions but it can also result from disagreement with so-called common sense. When it turns out that a conclusion is paradoxical, it means that – according to the person forming it – the conclusion is discordant with what is universally considered to be recognised as true. Frequently, paradoxes are deemed to be the result of lack of proper knowledge or acceptance of an improper cognition model. Thus, in each case, a paradox is something closely connected to the human cognition and thus reveals its nature.³

1 By way of illustration, a few exemplary formulas which perceptively, accurately, and humorously reflect paradoxes of everyday life are: the paradox of doing – *I’m constantly doing something, yet nothing is done*; the paradox of women’s wardrobes – *nothing to wear, yet nowhere to hang more*, etc.

2 Examples of famous scientific paradoxes: Banach-Tarski paradox; the twin paradox; Monty Hall Problem.

3 On the genesis and the essence of paradox see: N. Rescher, *Paradoxes. Their Roots, Range, and Resolutions*, Open Court, Chicago – La Salle 2001; A.R. Sorensen, *Brief History of the Paradox: philosophy and the labyrinths of the mind*, Oxford University Press, Oxford 2005.

The most general classification of the paradox could be a division into mathematical, physical, statistical, philosophical, and humorous⁴ paradoxes. Surely this is not the only possible, exhaustive, and fully separable classification, however, it shows the basic categories of paradoxical statements and the spheres which they are relevant to. A simpler classification of paradoxes may also be used, one that divides them due to their “depth”, that is, significance for the enrichment of human thought in the specific area of cognition.⁵

When considering the philosophical statuses of paradoxes, on the other hand, they may be divided into: 1) ontological paradoxes – relevant to real phenomena occurring in the physical world (so-called real paradoxes); 2) epistemological (or semantic) paradoxes – related to explaining real phenomena which may be theoretical or observational (imagined, apparent paradoxes).⁶ These divisions show a basic quality of paradoxes, that is, the dilemma of their “realness” – whether a paradox is something that exists regardless of our way of regarding and understanding reality, or is it always relativized to human cognition and a certain aspect of its limitedness.

In science, paradoxes often appear in so-called crisis situations, when a new scientific paradigm is forming – in the crisis of a previously accepted scientific approach which occurred due to the necessity of its modification and making fundamental improvements in the face of contradictions revealing themselves (e.g. observational). In the case of physical paradoxes, they are usually divided into two groups: 1) theoretical paradoxes, which occur when the theoretical explanation

4 An example of the last kind of named paradox is the “battered cat” paradox, which also triggered scientific discussion. See more: J.C. Verley, *More on Alternate Theories – No Plurals*, APS News (2001)10, 4.

5 On the different types of paradoxes and the analysis of particular paradoxes see: R.M. Sanisbury, *Paradoxes (second edition)*, Cambridge University Press, Cambridge 1995; M. Clark, *Paradoxes from A to Z*, Routledge, London 2002.

6 F. Ramsey, *The Foundations of Mathematics*, in: *Foundations*, ed. D.H. Mellor, Humanities Press, Atlantic Highlands 1978, 171–172.

of a real physical phenomenon was not phrased precisely enough (may be caused by the difference between theoretical predictions and their mathematical verification or when mathematical speculation does not explain physical phenomenon); 2) experimental paradoxes, which occur when results of conducted laboratory experiments do not provide scientists with a satisfactory explanation.⁷

Yet another classification of paradoxes relates to their meaning, which is dependent on the way in which the paradoxes and their solutions are treated by the community of scientists in the scientific context in which they were revealed. Thus, each paradox may be classified as one of the following: 1) a paradox resulting from insufficiently proven scientific theory; 2) a paradox resulting from commonly accepted scientific theory; 3) a paradox resulting from general knowledge on the process of physical phenomena.⁸

One of the best known and longest discussed paradoxes in the history of science (astronomy, cosmology, and physics) is so-called Olbers' paradox (also referred to as dark night sky paradox or photometric paradox), a paradox related to a specific scientific paradigm of modern pre-relativistic cosmology.⁹ The history of attempts at resolving it and the current understanding of its nature show, however, that it can't be unequivocally classified as one of the paradoxes that disappear only when the prevailing scientific paradigm is completely changed. In the case of this type of paradox, in which the experience

7 D. Cucić, *Paradox in physics, the consistency of inconsistency (long version)*, 2008, 25, <http://arxiv.org/abs/0812.2541>; (download: 30.09.2017).

8 D. Cucić, *Types of Paradox in Physics*, <http://arxiv.org/abs/0912.1864>; (download: 30.09.2017); D. Cucić, *Astrophysical paradoxes*, <http://arxiv.org/pdf/0812.1679>; (download: 30.09.2017).

9 On complete approach to photometric paradox see: S.L. Jaki, *The Paradox of Olber's Paradox*, Herder and Herder, New York 1969 (new, extended edition: S.L. Jaki, *The Paradox of Olber's Paradox. A Case History of Scientific Thoughts*, Real View Books, Pinckney 2000); E. Harrison, *Darkness at Night. A Riddle of the Universe*, Harvard University Press, Cambridge – London 1987; A. Stinner, *Why is the Sky Dark at Night? Teaching the Evolution of Our Models of the Cosmos*, *Interchange* 45(2014)3–4, 123–131.

negates prevailing scientific theory, a change of the accepted, crucial, explanatory rule changes the explanation of the observed phenomenon. In consequence, the explanation desists negating the observed data. Contemporary research on Olbers' paradox (as well as attempts made during the course of history) leads to the conclusion that paradoxicality results primarily from the antecedence of human thought (concept, theory) over the possibility of its proper verification (confrontation with a result of an empirically advanced experiment). Therefore, the dark night sky paradox and attempts at resolving it are an enlightening proof that even something as banal and obvious as an available to anyone glance at a starry night sky may become an opportunity for a sufficiently insightful observer to reach much further (and sometimes much more accurately versus reality) with a thought than is possible with empiric research of the moment.

Presentation of the dark night sky paradox (as it was understood at the time of its phrasing) and the ensuing attempts at resolving it in the history of cosmology, as well as current cosmological facts reducing the occurrence of the aforementioned paradox, create an exemplificative background for contemplation on the subject of the significance of paradoxes revealed in scientific cognition and of the character of scientific cognition and generally, human cognition. The analysis of issues of the photometric paradox leads to the conclusion that what is called a paradox in science is relevant only to human cognition, not the reality experienced by humans itself. Thus, the paradoxicality in this case is not an ontological, but rather an epistemological category. The purpose of this article is also presenting some conclusions of methodological and philosophical type on the nature of scientific cognition and intuition in scientific research.

2. THE OUTLINE OF HISTORY AND ATTEMPTS TO RESOLVE THE PHOTOMETRIC PARADOX

Probably no one who currently looks at the starry night sky and admires its charming vastness asks themselves the question “Why is the night sky not light?”. The situation does not seem problematic in the slightest. The darkness of the night sky – only slightly weakened by the light of the sun reflected by the moon and tiny light points of stars and galaxies many light years away – seems obvious and not requiring of any in-depth justification. And yet that question, phrased for the first time several centuries ago, became one of the most crucial questions of modern cosmology and, in a way, influenced its current development.

The paradox is usually associated with the German doctor and astronomer Heinrich Olbers, who in 1823 (as another scientist to do this) took notice of the problem of darkness of the night sky and proposed a solution.¹⁰ However, the issue had bothered scientists much earlier than this. It can be presented as follows: if the universe is static, spatially and temporally infinite and contains infinite amounts of star matter (infinitely old universe with an infinite number of stars distributed in an infinitely large space), spread evenly through its whole space (uniformity and isotropy of the universe), then, looking in any direction, we should observe not spots of light, but even starlight. Admittedly, the stars that are further away give weaker light (from the point of view of the observer), however, with the increase of distance from the observer, the number of stars increases, which makes up for the weaker intensity of light emitted by more distant stars. Consequently, we should observe even lightness of the sky during the day and the night, which, however, is not the case.

10 H. Olbers, *Über die Durchsichtigkeit des Weltraums*, *Astronomisches Jahrbuch für das Jahr*, C.F.E. Spaethen, Berlin 1826, 110–121.

The disagreement between the theoretical prediction and the practical observation is the essence of the night sky paradox.¹¹

Mathematical and physical conceptualisation of the photometric paradox allows a more precise presentation. Assuming that the stars emit light of even strength, called absolute brightness of a star (L), we may consider a thin round layer of radius R and thickness ΔR (smaller than R) surrounding the Earth. Stars in this layer are all of the same distance from an observer on the Earth. Light from a star whose distance from Earth equals R spreads evenly through a sphere of radius R , so amount (intensity) of light l (where l is so-called apparent brightness of a star) emitted from the star in 1 second into a telescope mirror (used for night sky observation) of area S equals the product of S and L divided by $4\pi R^2$. In a unit of volume, there are n stars and the number of stars in the tested layer of volume V equal $N = nV = 4\pi R^2 \Delta R n$. The telescope registers the combined apparent power of stars in the layer equal to $Nl = nL\Delta R$. Since the combined apparent power of stars depends on R , then despite the fact that the apparent power of a singular star decreases as R^{-2} , the number of stars in the layer increases as R^2 . Thus, each layer containing stars, regardless of its distance from Earth, emits the same amount of light towards it. Since there is an endless number of the aforementioned layers in the endless universe, then an endless amount (intensity) of light should arrive on Earth from the night sky, therefore, the night sky should be light.¹²

11 The graphic presentation of the dark night sky paradox is a group of trees growing in an endlessly vast forest. While inside such a forest and looking in any direction, one sees only a unitary image of tree trunks, a wall of trees, since the space would be closed in any direction by the growing trees. Otto von Guericke was first to use this comparison in 1672. See more: E.R. Harrison, *The dark night-sky riddle, "Olbers paradox"*, in: *The Galactic and Extragalactic Background Radiation. Proceedings of the 139th Symposium of the International Astronomical Union Held in Heidelberg, F.R.G., June 12-16, 1989*, ed. S. Bowyer, C. Lienert, International Astronomical Union – Kluwer, Dordrecht 1990, 6.

12 Cf. E.R. Harrison, *Cosmology. The Science of the Universe*, Cambridge University Press, Cambridge – London – New York – New Rochelle – Melbourne – Sydney 1981, 251–253; H. Knutsen, *Darkness at night*, European Journal of Physics 18(1997), 295–302.

Slightly more poetic, but just as accurate, is the wording of the aforementioned paradox proposed by Agnes Mary Clerke at the end of the 19th century. “But the probability amounts almost to certainty that star-strewn space is of measurable dimensions. For from innumerable stars a limitless sum-total of radiations should be derived, by which darkness would be banished from our skies; and the ‘intense inane’, glowing with the mingled beams of suns individually indistinguishable, would bewilder our feeble sense with its monotonous splendour”.¹³

It seems that the first person to notice the existence of the photometric paradox (although he didn’t name it as such) was Thomas Digges. Moving beyond the Copernicus model of the universe, he assumed that it is not limited by a sphere of constant stars, but stretches into infinity. Therefore, stars fill this endless universe, however, T. Digges noticed a problem worded later by H. Olbers and, in 1576, presented a proposition for a solution. He assumed that the light of distant stars (the number of which is infinite) may be too weak to light up the sky enough for us to be able to observe it.¹⁴ Nonetheless, he omitted an observation that even if the stars are too far away for the light of specific stars to be observed, collectively, the light should still cause an effect of light sky during the night.

The next solution was proposed by Johannes Kepler in 1610.¹⁵ According to him, the universe is not similar to an endless forest but rather to a group of trees, within which we observe dark and empty space. He considered the possibility of the universe ending

13 A.M. Clerke, *The System of the Stars*, Longmans, Green and co., London 1890, 380.

14 T. Digges, *A Perfit Description of the Celestiall Orbs according to the most aunciente doctrine of the Pythagoreans, latelye revived by Copernicus and by Geometricall Demonstrations approved*, in: L. Digges, *Prognostication Everlastinge (...) Lately corrected and augmented by Thomas Digges*, T. Marsh, London 1576 (L. Digges, *A prognostication everlastinge: Corrected and augmented by Thomas Digges*, W.J. Johnson, Amsterdam 1975).

15 J. Kepler, *Conservation with the Starry Messenger*, trans. E. Rosen, Johnson Reprint, New York 1965 (*Dissertatio cum Nuncio Sidereo*, 1610).

suddenly at a “dark wall”, which constitutes the edge of the universe. Therefore, the universe contains much fewer stars than needed to fill the entirety of the visible sky. The finiteness of a spatially limited universe explains the insufficient number of stars. The world of stars is closed and limited by some sort of wall or ceiling.

Another solution for the night sky paradox was proposed by Edmund Halley in 1720. He contemplated a situation in which the stars in the universe would be placed in a specific way which would cause the surface of part of the stars located closer to the Earth to block the sight of stars located further away. He assumed the possibility of the existence of concentric spheres of gradually larger radius, creating a row of containers of constant thickness. Within his calculations, he ascertained that the number of stars in the subsequent layers increases with squared distance, whereas the intensity of light emitted by particular stars decreases with the squared distance inverse.¹⁶ Thus, sufficiently distant stars are completely invisible from Earth.

Yet another solution was proposed by Jean-Philippe Loys de Chéseaux (in 1744)¹⁷ and the aforementioned H. Olbers.¹⁸ Their reasoning was as follows: if even the most distant stars emit light which we should be able to observe during the night, then the darkness could be explained by the opacity of the universe. They believed that between the stars there are giant clouds of dark dust or gas which absorb the radiation emitted by stars (interstellar absorption). This argument was nevertheless disproved by the dependence of thermodynamics laws which state that energy absorbed by gas or dust will gradually heat up the substance until it reaches a temperature at which it will radiate the same amount of energy it absorbed. Therefore, after

16 E. Halley, *Of the infinity of the sphere of fix'd stars*, Philosophical Transactions (1720–1721)31, 22–24; E. Halley, *Of the number, order, and light of the fix'd stars*, Philosophical Transactions (1720–1721)31, 24–26.

17 J.P.L. de Chéseaux, *Traite' de la Comete*, M. M. Bousequet, Lausanne 1744.

18 H. Olbers, op. cit.

the proper amount of time, a cloud of dust or gas will start to emit light, causing the observed night (and day) sky to be evenly lit.

In 1849, British astronomer John Herschel (as well as R. Proctor in 1870, followed by F. d'Albe, and C. Charlier) proposed a solution based on the idea that matter creates a hierarchical structure in the universe, that is, it focuses around progressively bigger areas of space. In his opinion, dark areas visible in the Milky Way attest to the existence of fragments of space completely devoid of stars lying beyond it.¹⁹ As a result, the statement that looking at any part of the universe must, eventually, end in looking at the surface of a star, turns out to be incorrect. This argument should be considered to be generally consistent with our current cosmological knowledge, however, direct influence of the situation described in it on the darkness of the night sky is secondary.²⁰

German astronomer Johann Mädler, on the other hand, in 1861 expressed an opinion that the light from distant stars had not reached us yet since light has finite speed. He also advocated the finiteness of time of the universe's existence.²¹ "Finite amount of time has passed since the moment of Creation until today. And thus, we can only see celestial bodies from the distance which the light has travelled during that finite amount of time. (...) Instead of saying that the light from this distance is not reaching us, it should be said that it has not reached us yet".²² Therefore, the night sky is dark because the light

19 J. Herschel, *Outlines of Astronomy*, Lee and Blanchard, Philadelphia 1849.

20 Contemporarily, an interesting solution to Olbers' paradox appeared, one relating to concept of hierarchical structure of the universe – B. Mandelbrot's proposition of fractal distribution. G.S.M. More, *Resolution of Olbers' Paradox for Fractal Cosmological Models*, *Progress of Theoretical Physics*, 87(1992)2, 525–528.

21 See more: F.J. Tipler, *Johann Mädler's Resolution of Olbers' Paradox*, *Quarterly Journal of the Royal Astronomical Society*, 29(1988)3, 315–318.

22 J.H. Mädler, *Der Wunderbau des Weltalls, oder Populäre Astronomie*, Carl Heymann, Berlin 1861, 466. Interestingly, F. Engels was the only one among 19th century scientists who noticed the accuracy of argumentation of J. Mädlera and called it an amazing argument

of the distant stars has not reached us yet – assuming that the time of the travel of light is shorter than the age of the universe.

Another solution for the paradox was suggested in 1890 by the aforementioned Irish astronomer, A. Clerke.²³ Initially, it was proposed by Otto von Guericke in 1672 and then by the famous American astronomer Harlow Shapley in 1917. It is built on an assumption that the whole universe is an “island of matter”, drifting through the endless void of space (“islandic universe”). Thus, the area of stars reaches only finite size in the universe and is limited. This solution is similar to J. Kepler’s concept of a “dark wall”, with the difference being that the “dark cosmic wall” was replaced by a cosmic void. According to current cosmological knowledge, this is not a proper understanding of the structure of the universe structure.

In 1901, Scottish mathematician and physicist William Thomson (Baron Kelvin) conducted an analysis in which he stated, on the basis of performed calculations, that the solution to the paradox is the finite age of the stars. Invoking a finite age of specific stars, he decided there was no possibility they supplied enough energy to light up the night sky in accordance with the previous predictions of the scientists.²⁴ For the stars to light up the night sky, the beginning of their existence would have to be progressively earlier in time for the progressively more distant stars. In the opinion of W. Thomson, such a situation should be considered extremely unlikely. His proposed solution actually does explain the darkness of the night sky. Unfortunately, it was initially ignored by other scientists.

In 1922, William MacMillan proposed accepting an assumption that the universe is endless in terms of time and space but it is simultaneously in a constant state of transforming matter into energy

against so-called light absorption proposed earlier by J.-P. Loys de Chéseaux and H. Olbers. F. Engels F., *Dialectics of Nature*, International Publishers, New York 1940, 221.

23 A.M. Clerke, op. cit.

24 W. Thomson, *On Ether and Gravitational Matter through Infinite Space*, Philosophical Magazine, 6(1901)2, 161–177.

and vice versa.²⁵ This way, the aforementioned “self-transformation” prevents the light from reaching us from all directions in which the stars are located. The model turned out to be erroneous, which results mainly from the expanding of the universe.

It is necessary to note another solution, proposed by Hermann Bondi in 1955 in an era of relativistic cosmology, which took into consideration the expanding of the universe. This theory uses the effect of a moving light spectrum from stars moving away (galaxies) “towards red” (Doppler effect), which gives a decrease of radiation energy which reaches us from these stars.²⁶ An observer on Earth receives reduced radiation energy from distant stars, which, according to H. Bondi, reduces the paradox. If distant stars move quickly away from us, light emitted by them seems to become red and loses part of its energy.²⁷ A starry sky in an expanding universe automatically becomes dark because of the “reddening” of light arriving from distant galaxies. The solution was rather commonly accepted as up-to-date for all models of the expanding universe. It needs to be noted, however, that it is not the only cause of darkness of the night sky, which we will return to later.

When following the history of solutions for the dark night sky paradox, it is not difficult to notice that the paradox and its solutions have always been tied up with a certain cosmological context, that is, the issues of (spatial and genetic) infiniteness of the universe and its immutability. The paradox, after all, appeared within modern cosmology, shaped on the basis of the Newtonian image of the universe. Assumptions of post-Newton cosmology are as follows: 1) space is infinite and described by Euclidean geometry; 2) light emitting objects (stars) are spread through the universe in

25 W. MacMillan, *Some postulates of cosmology*, *Scientia* 31(1922), 105–113; W. MacMillan, *Some mathematical aspects of cosmology*, *Science* 62(1925), 63–72, 96–99, 121–127.

26 H. Bondi, *Theories of cosmology*, *Advancement of Science* 12(1955), 33–38.

27 H. Bondi, *Cosmology*, Cambridge University Press, Cambridge 1952, 23.

an isotropic way and their number is infinite; 3) each of the light emitting objects has the same power of radiation – emits the same amount of radiation energy in the same unit of time; 4) the universe is infinitely old, genetically infinite (has no beginning), and remains unchanged over time; 5) in space through which the light comes there is no dispersed matter which could dim the lightness of a light emitting object through light absorption.

In respect of the dark night sky paradox phrased in such a way, it is a common belief that its solution became possible only at the moment of change of the image of the universe, which happened as a consequence of the creation of relativistic cosmology and obtaining observational proof of the expanding of the universe. Thence, only due to: discovering the expanding of the universe, and as a consequence, the moving light spectrum of galaxies “towards red” (1929 – E. Hubble); proving, that the universe is not static and unchangeable; and assuming a genetic finiteness of the universe and age of stars, that is, that the time of universe (and stars) existence is not long enough for all photons emitted by the stars to light up the night sky; may the photometric paradox be eliminated.

However, as it turns out, also within post-Newton (pre-Einstein) cosmology²⁸ it was possible to resolve the paradox. To achieve this, one needed simply to assume that the universe has not existed “forever” but is temporally limited in the sense of genetic limitedness (such possibility was offered e.g. by the concept of the universe being created by God), since there is a solution for the dark night sky paradox which is independent of the assumed (static or expanding) cosmological model. Such solution was proposed contemporarily by Edward R. Harrison. According to his proposition, the universe,

28 The Newtonian theory and the post-Newtonian approximation are applied to homogeneous cosmologies and are compared against the fully general relativistic case. See: T. Rainsford, *Newtonian and Post-Newtonian Cosmology*, <https://digital.library.adelaide.edu.au/dspace/bitstream/2440/19818/2/02whole.pdf> (download: 10.10.2018).

due to its genetic limitedness (its finite age) does not possess enough energy to cause an effect of the light sky – starlight is too weak to fill the whole universe. This means that – according to E. Harrison’s calculations – a visible universe would need 10 trillion times more light energy than we currently see. Therefore, even if the entire matter within the universe was transformed into light energy, the night sky would become only a little bit lighter than it is now.²⁹ “(..) this means that the luminous emissions from stars are much too feeble to fill in their lifetime the vast empty spaces between stars with radiation of any significant amount” [to brighten the night sky – A. Ś.].³⁰ Moreover, E. Harrison proved that the correctness of the solution for the photometric paradox depends on the physics of a specific cosmological model, i.e. the solution proposed by H. Bondi is correct, but only within an assumed by him cosmological model, that is, the Steady State model.³¹

P. Wesson, in 1987, continued the argumentation of E. Harrison and decided that referencing the finite age of the universe (and of the galaxies and stars as well) is the best solution for the dark night paradox in light of the current knowledge on the structure and history of the universe.³² He ran computer calculations (in accordance with the assumed calculational model) which showed that the intensity of the galaxy’s radiation is low in the universe that is spatially endless

29 E.R. Harrison, *Olbers’ paradox and the background radiation density in an isotropic homogeneous Universe*, Monthly Notices of the Royal Astronomical Society 131(1965), 1–12.

30 E.R. Harrison, *Why the sky is dark at night*, Physics Today 30(1974)2, 36; cf. F.J. Belinfante, *Correction of a misunderstanding about Olbers’ paradox*, General Relativity and Gravitation 1(1975), 9–12.

31 E.R. Harrison *Olbers’s Paradox in Recent Times*, in: *Modern Cosmology in Retrospect*, eds. B. Bertotti, S. Bergia, A. Messina, Cambridge University Press, Cambridge 1990, 34–45. Currently, the Steady State theory of the universe has lost its actuality, thus, the solution of the photometric paradox proposed within standard “Big Bang” model remains the most up-to-date solution.

32 P.S. Wesson, K. Valle, R. Strabell, *The Extragalactic Background Light and a Definite Resolution of Olbers’s Paradox*, The Astrophysical Journal (1987)317, 601–606.

and homogenously filled with galaxies and it would stay low even if the universe was static.³³ This proves the argumentation of E. Harrison, who believed that the universe does not have enough energy to fill it with starlight. It should be noted that the position of E. Harrison and P. Wesson on the solution for the photometric paradox is often omitted in contemporary papers on astronomy and in cosmology textbooks.³⁴

In light of this briefly sketched history of attempts at solving the photometric paradox, it may be said that the solution itself turns out to be paradoxical since it does not require seemingly necessary change of all fundamental assumptions of the cosmological model. That is the paradox of the solution for the dark night sky paradox. "(...) the night sky is dark mainly because the galaxies are 'only' about the billion years old and have emitted only a limited amount of light – not because that light has been weakened by the expansion of the universe".³⁵

There is another paradox connected to the solution for the photometric paradox – the reasoning that eventually became the first correct solution of the paradox was proposed not by a scientist (astronomer, cosmologist, or physicist), but by an American Romantic poet, Edgar Allan Poe. In 1848 he published poem *Eureka* and claimed: "Were the succession of stars endless, then the background of the sky would present us an uniform luminosity, like that displayed by the Galaxy since there could be absolutely no point, in all that background, at which would not exist a star. The only mode, therefore, in which, under such a state of affairs, we could comprehend the voids which our telescopes find in innumerable directions, would be by supposing the distance of the invisible background so immense that

33 P.S. Wesson, *Olbers' Paradox and the Spectral Intensity of the Extragalactic Background Light*, *The Astrophysical Journal* (1991)367, 399–406.

34 As an example see: *The Cambridge Encyclopedia of Astronomy* 1977, 379.

35 P.S. Wesson, *The real reason the night sky is dark: Correcting a myth in astronomy teaching*, *Journal of the British Astronomical Association* 99(1989)1, 13.

no ray from it has yet been able to reach us at all. That this may be so, who shall venture to deny?"³⁶ The solution for the photometric paradox presented above is based on the finite speed of light – we cannot observe stars if they are so distant that their light can't reach us due to the distance. This is true even for a spatially endless universe since the universe observed by us at a specific moment is not endless (of course with the additional assumption of a genetic limitedness of the universe). It should be noted that E.A. Poe himself admitted in the aforementioned book that there is no clear empirical evidence on this.³⁷

In summary, there are currently two solutions for the photometric paradox which are considered correct: either the universe is too young, or/and the energy of the universe is too low for the starlight to light up the night sky. Other explanations (hierarchical structure of the universe, moving "towards red" light of stars/galaxies that are moving away from us) should be considered to be additional evidence of the darkness of the night sky (aside from visual observation), not its cause.³⁸

36 E.A. Poe, *Eureka: A Prose Poem*, Geo. P. Putnam, New York 1848, 100.

37 "I maintain, simply, that we have not even the shadow of a reason for believing that it is so." E.A. Poe, op. cit., 100. Perhaps E.A. Poe was inspired by A. von Humboldt, who in his work *Cosmos* (A. von Humboldt, *Cosmos: A Sketch of the Physical Description of the Universe*, vol. 1, trans. E.C. Otte, Harper, New York 1858 [1845]) mentioned that certain stars cannot be observed by us because of the imperfections of the observation instruments we possess. Cf. A. Cappi, *The Evolving Universe of Edgar Allan Poe*, in: *Cosmology through Time*, Mimesis, Milano 2003, 242. It is important to note, however, that not everyone agrees on the correctness of the intuition expressed by E.A. Poe and its usefulness in solving the paradox of the "dark sky". F. Tipler believes that "Poe may be given credit for originating the idea of an expanding universe (...) but not for the finite age resolution of Olbers' Paradox". F.J. Tipler, op. cit., 319. Therefore, he gives priority to the correct solution of the photometric paradox by J. Mädler.

38 H. Knutsen, after analysing various solutions for the photometric paradox, arrived at the conclusion that darkness of the night sky is conditioned by: 1) finite speed of light; 2) young age of the universe (and stars); 3) small size of stars and significant distance between them, all of which translates into a small density of energy in the universe.

Moreover, it is worth noting that the darkness of the night sky could have led scientists to a conclusion of a temporal limitedness of the universe (that the universe has its temporal beginning of existence in time $t=0$, regardless of the metaphysical or theological concept of the universe created by God), before relativistic models of the expanding universe appeared and its expansion was discovered. However, this did not come to pass, since the attachment of the scientists to the model of a spatially and temporally (genetically) endless universe was too strong. “The most fundamental observation in all of science is that night follows day. This simple fact is enough to show that the Universe has not always existed, everywhere, in the form that we see it today. There must be an ‘edge’ to the Universe (...)”.³⁹ Currently, the question of the physical beginning of the universe turns out to be much more complex than several centuries ago, therefore, it would be difficult to unequivocally predestine it merely on the basis of the darkness of the night sky.

3. PARADOX AND SCIENTIFIC COGNITION

There are three possible approaches to each paradox encountered by humans in everyday life. Firstly, one may adopt an attitude of acceptance towards the revealed paradox, assuming that “one has to live with it somehow” since we can’t find a way to eliminate the paradox. Secondly, one may look for the solution within the current life (existential) paradigm and avoid being discouraged by previous failures, that is, adopt a confrontative attitude towards the paradox and believe that in the name of one or other understood rationality, one does not

He also noticed that expanding of the universe has little influence on the solution for the photometric paradox. H. Knutsen, op. cit., 301; cf. J.M. Overduin, P.S. Wesson, *Dark Matter and Background Light*, Physics Reports Journal (2004)402, 278–280.

39 J. Gribbin, *Olbers’ Paradox: Why is the Sky Dark at Night?*, Astronomy Now 2(1988)3, 12.

agree to its presence. Finally, thirdly, one may assume that the only way to resolve the paradox is by any form of its transcending, which, practically speaking, means making a radical change of a standard, accepted life paradigm.

Each of the named strategies for dealing with paradoxes encountered in everyday life has its merits and flaws. Choosing any one of them is largely dictated by one's degree of resistance to the contradiction contained in the paradox. When regarding cognition of a strictly scientific character, it is difficult to accept the first of the aforementioned strategies, since science (or rather its representatives) should never give up seeking solutions for the problems faced by scientists. The second strategy, albeit conforming to the spirit of science, may remain ineffective and be destined to fail. The last of the possibilities, although the most scientifically creative, requires the scientists to show exceptional boldness, courage, and the ability to take risks connected to what is called a scientific revolution – a revolution in a former, established worldview.

In the case of the analysed photometric paradox, initially, a strategy of confrontation aiming to resolve the paradox within the existing paradigm (post-Newton cosmology) was used. Then, the development of relative cosmology enabled a new approach to the problem of dark night sky and, thanks to the change of cosmological paradigm that happened in the first half of 20th century, it was ultimately resolved. Only later did it transpire that the solution for the paradox did not require such huge changes in the cosmology and the paradox itself was apparent since it became obvious that observations made were consistent with the actual state of the observed universe. Additionally, the concept of a timely beginning of the universe (finite age of the universe), criticised and rejected on scientific grounds due to its theological connotations, turned out to be crucial in finding a solution to the photometric paradox, which, however, had not been applicable until the model of the so-called Big Bang was proposed. This proves that sometimes scientific progress is not as fast as it could

have been due to careless omittance and rejection of ideas which are not strictly scientific but may nonetheless be inspiring and useful for science.

The photometric paradox also reveals another feature of a paradox as a whole, being that the question of local character sometimes generates a problem of global character (i.e. the question of lack of lightness of the night sky above one's head is actually a question of the structure and origins of the universe as a whole). It needs to be remembered that the methodology of contemporary cosmology is different from that which was used by pre-relative cosmology. Formerly (in the 19th century and earlier), the starting point of cosmological research was observation of a phenomenon disturbing the researchers and often paradoxical in light of the knowledge they possessed. Now, the first certain cosmological model is constructed (i.e. a specific answer to Einstein's equations is selected), and then its cosmological interpretation happens. As a result, particular questions (including paradoxes, such as the photometric paradox) may be considered. Simultaneously, extrapolation of physical laws into cognitively unavailable areas and drawing of conclusions on the universe as a whole, nowadays, is a subject of more and more strict empirical control thanks to the richness of observational data. Nonetheless, a paradox occurring in science is always a paradox connected to a specific phenomenon or a group of phenomena. Within scientific cognition, however, the universe as a whole does not appear paradoxical. It may appear so only during a deep existential crisis. In contrast, an experience of the local paradoxicality in fragment of experienced reality inspires and encourages one to again contemplate the entirety of an image of structures, phenomena, and processes, creating one's worldview.

Reflecting on the history of solving the photometric paradox, one might risk the thesis that there are no paradoxes in the absolute sense: they are always relativized to a certain set of beliefs, knowledge, and the results of reasoning. In other words, it may be assumed that

the paradoxes are, in the most general sense, collisions between beliefs and facts, which demand, sometimes urgently, a reconciliation. Moreover, paradoxes are greatly relativized to the language used by those who form and resolve them, that is, to the language of a certain scientific field, used at a particular stage in its historic development. Finally, it needs to be noted that paradoxes are modifiers of our false intuitions, in respect of which, what stops being paradoxical starts functioning as actual knowledge. Consequently, paradoxes fulfil a creative role in science (and secondarily in the philosophy of science) and benefit its development. They can even be considered to “defend” scientific cognition from slipping into illusion and falsehood, since reality, causing feeling of paradoxicality in the researcher, forces them (albeit not always successfully) to verify previously accepted statements. Paradox and its reoccurring appearance is thus a certain kind of safety valve for the overconfident scientist, who unknowingly moved from cognition of reality to having only thoughts or notions of it. The peculiarity of cognition becomes visible when confronted with other conscious experiences similar to the cognition, such as thinking or imaging. About thinking, I can say that I “think about something “ or “think of something”. I’m thinking about something when I commit the act of thinking, which is always filled with content. I’m thinking this content but other than the fact that I know I’m thinking and what I’m thinking, I don’t receive new information on any object. I also don’t learn anything about the object that I’m thinking about when I’m thinking about it because I’m only presenting it to myself in my thoughts. Imaging, on the other hand, constructs the imagined object, which we get to know athematically with its construction. My knowledge of the imagined object does not exceed what I intentionally put in the object myself. Meanwhile in the cognition, I want to learn how are things that are independent of imaging them an act of cognition.⁴⁰ Thus, the paradox seems to be

40 J. Krokos *Odsłanianie intencjonalności*, Liber Libri, Warszawa 2014, 261–262.

what makes us realise the necessity of return from the attractive, charming world of idealism to the reality of cognitive toil. Scientific (and not only) cognition demands from the researcher honesty towards the subject of cognition through “letting it speak” and enabling it to “drop the cover”, also when the “voice” and the “sight” will be paradoxical for their interpreter.

Let us now ask what remarks arise about the role of intuition in cognition in the light of the cosmological paradox presented above. What is its function and meaning in human cognition? In general, we will say that the discussed paradox indicates that intuition is unreliable. We cannot rely completely on her suggestions. This forces us to be cautious in guiding our intuition and relying on her inspirational functions. Intuition should be controlled and educated. So we can and should control our intuition and educate it. Intuition is indeed a valuable heuristic tool, but it cannot be considered as one of the ways of proving claims. The more intuition is trained (in a given field of knowledge) based on facts based on the work of reason, the better it can give us services. It seems that realizing the exact state of affairs is important. This sheds light on many reflections on general philosophy. Let the problems arising from intuition emerge, such as the problem of its various types and their classification, or the issue of a test for error-free intuitive reality, etc. The issue is discussed in a significant way thanks to the existence of paradoxical phenomena in science. If we look at the paradox presented above, we notice that it appeared due to the lack of precision in the intuitive approach to the problem. Intuition could not present to us in a precise and precise way the content of concepts such as e.g. the universe, it could not – to put it somewhat more accurately – provide a sufficient basis on which the mind could formulate adequate definitions of the aforementioned concepts. The paradox always appears when (as it turned out later) rather “coarse” intuitions were confronted with conceptual refinements. It seems that this indicates in a sufficient way that you cannot stop at intuitive suggestions when defining concepts.

It is therefore necessary to clarify the concepts we first introduced in the act of original intuition. This remark is also one of the momentous conclusions stemming from the appearance of paradoxes. One cannot stop at the intuitive recognition of concepts.

Let us now consider the question whether and what relations exist between the paradox and our cognition of reality. Taking as a starting point the fact of intellectual “anxiety” caused by the appearance of paradoxes, which is thus a stimulus for more intensive scientific research, we can expect a positive impact of the paradox on the more adequate cognition of reality. Let us clearly emphasize that the term “reality” is understood here as broadly as possible, so it means every subject of scientific research. As we have seen, two main issues appear here. The first one concerns the relationship between intuition and discursive cognition, while the second is the problem of adequate cognition of reality. From the above it can be seen that the appearance of paradoxes is an excellent starting point for valuable insights regarding the issues discussed. Considering the relationship between discursive cognition and intuition, one can come to the conclusion: intuition is a valuable heuristic tool. However, it cannot claim to be a method of proof for any thesis. We must lead the discursive path. Well-educated, subtle intuition is a very desirable property in scientific work. It then sets the right course of action. It allows you to go in the right direction, do not wander your thoughts. The uneducated intuition of this condition cannot be fulfilled. The training of intuition, in general, is done in a classical way thanks to the appearance of paradoxical situations. A further conclusion, which arises here, refers to the precision of concepts. Thanks to the appearance of paradoxes, the path of approaching an increasingly adequate definition of the concepts originally given to us only intuitively opens before us. Two of these basic conclusions lead, in turn, to further ones. So first we can see a call for caution here. And in the most general sense. It is necessary to guard against the illusory “obviousness” which, after a more thorough examination,

does not seem so “obvious” at all. We believe that the paradoxes outlined above fully justify this conclusion. And the second conclusion is the occurrence of the dialectical connection between intuition and intellectual cognition. Scientific practice indicates that the development of human knowledge takes place through mutual intuition and intellectual approaches. And one and the other factor is necessary. Everyone in their place. Through the contact of both intuition and mind with reality and through the dialectic relationship that exists between them, we can reach a better, fuller, more adequate cognition of reality. It is the subject of scientific research and the final instance of the truth of our cognition.

On the margin of the above considerations, it is worth referencing another paradox, noted in the text of the *Gospel of Mark* (Mk 12:18–27). Quoted by Sadducees talking to Jesus *casus* of a woman marrying seven men in succession, none of whom had any children with her, raising the question which one of them will be her lawful husband in the eternal life, which may be called a theological (eschatological) paradox of “dark (misunderstood) sky (heaven)”. Jesus’s answer may be considered to be a paradigmatic response to all paradoxes we encounter both in everyday life and in scientific cognition: “It is because you don’t understand” (Mk 12:24). It shows the truth of how every paradox is proof of the limitedness of cognition which humans are capable of in the moment or in general. Simultaneously, a paradox gives one an opportunity (and motivation) to discover a new cognitive horizon by transcending previous thinking patterns and thus finding a new cognition method which will enrich previously gathered knowledge and deepen one’s understanding of the reality.

4. CONCLUSION

It is worth noting that even though the photometric paradox is currently resolved, it somehow turned out to be an “apparently apparent” paradox as a paradox of limited human perception. The apparentness

of its apparentness in the traditional sense is revealed in the light of contemporary observations of the universe connected to the phenomenon of so-called cosmic microwave background. The discovery of this radiation in 1965, and the subsequent proving of its presence in the universe and measuring of its intensity during spacecraft missions (COBE – 1992⁴¹; WMAP – 2003⁴²) leads to the conclusion that the night sky is dark, but not as dark as we think, since we observe it using only human eyes.⁴³ In truth, uniform electromagnetic radiation reaches the Earth from the universe on all sides, which, albeit invisible to human eyes, is real and registerable by proper devices. Thus, another paradox connected to the photometric paradox is revealed: what was considered paradoxical (a dark night sky which should be light but is not), has not been so paradoxical after all – the whole sky also “glows” at night after all, although much weaker than expected. It could, therefore, be said that it was a paradox of almost-dark sky which was resolved due to development of empirical cognition.

All this seems to be further proof of the fact that assumptions made in science, e.g. certain elements of a specific model of the universe, play a crucial role in the appearance and then potential resolving of scientific cognition paradoxes. Of crucial significance in the process is new observational data which influence development of a specific field of knowledge and thus a change of model. These data, however, may sometimes turn out to be the proverbial “two-edged sword”, since they may bring back to life ideas and concepts previously considered

41 *Cosmic Background Explorer* – an artificial satellite launched by NASA on November 18, 1989. It was equipped with a device for finding irregularities in the cosmic microwave background, the research of which was the main purpose of the satellite.

42 *Wilkinson Microwave Anisotropy Probe* – NASA spacecraft launched on June 30, 2001, the purpose of which was to measure cosmic microwave background and its rays scattering. It was the next cosmological mission after COBE.

43 N.V. Kosinov, V.I. Garbaruk, D.V. Polyakov, *Photometric paradox and relic radiation – two sides of one phenomenon?*, 2003, <http://www.zpenergy.com/downloads/photome.doc>; (download: 30.09.2017).

paradoxical and thus rejected – among them also the notion that sky at night should not be dark.⁴⁴

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⁴⁴ The discussion on a local explanation of the photometric paradox referring to gas clouds (resolution proposed originally by H. Olbers) is now again coming back in astrophysics. “We discuss the implications for these results for galaxy evolution, as well as compare our results with the latest models of galaxy formation. These results also reveal that the cosmic background light in the optical and near-infrared likely arise from these unobserved faint galaxies. We also show how these results solve the question of why the sky at night is dark, otherwise known as Olbers' paradox.” Ch. J. Conselice, A. Wilkinson, K. Duncan, A. Mortlock, *The evolution of galaxy number density $z < 8$ and its implications*, The Astrophysical Journal (2016)830, 1. Cf. G.A. Gontcharov, *Interstellar Extinction*, Astrophysics 59(2016), 548–579.

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ADAM ŚWIEŻYŃSKI

a.swiezynski@uksw.edu.pl

Cardinal Stefan Wyszyński University, Institute of Philosophy

Wóycickiego 1/3, 01-938 Warsaw, Poland

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