

Art and Physics

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This essay about art and physics is the result of self-education in the history of fine art due to my wish to understand why some artworks are masterpieces and others are not. Reading art history books, I have noticed that there is an inextricable link between art and science, which will be discussed here. Namely, the zeitgeist (spirit of the time) of a certain epoch is defined by the science, whereas art functions as its interpretation, provokes it and holistically sublimates in the artwork reflecting the narrative of a certain period, but also sometimes rejecting the current narratives and creating a new one. After delivering public lectures about the link between art and physics to art students and their professors, which were very well received, I continued to elaborate it further. One of the outcomes is the exhibition of the artworks done by the fine art students in Split, inspired by various physical concepts that I tried to explain through a set of lectures. In fact, the culture of a society is defined by science and art, through their intention to understand the world around us. Both art and science develop the ability of abstract thinking, so the most powerful tool of knowledge and creativity is common to both science and art. Science advances by developing a new mindset and novel abstract concepts, it requires thinking outside the box. Art teaches us to observe and perceive the world differently, free from the tyranny of answers, constantly challenging imposed narratives. Art tries to understand what we humans are governed by whereas science is concerned with what rules over natural phenomena. The intention of this essay is to point out that the knowledge of physics about the nature of space and time and the new scientific paradigms also influence artistic expression. Future will be shaped by new emerging technology advancing rapidly in an unpredictable way and there is jeopardy that deep emotion is replaced by a superficial impression and deep thinking is reduced to the use of "smart" applications. Science and art are the only guarantee to preserve these values of which our humanity and uniqueness of human beings are woven. The purpose of education should not be mere acquiring of skills under the pressure of labour market requirements. The main purpose of education is to teach people how to think and make conclusions, which leads to new knowledge and constant questioning of the current knowledge. Along that way art should be more present in future education. What should be the culture of the 21 century that should be taught to future generations?

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1. Introduction

Even before our predecessors learned to speak and developed the ability to articulate speech, they had started to paint on the cave walls. One could say that they wanted to convey a message to the other intelligent beings: "I was here in this cave", hoping that some other intelligent beings would be able to understand their images. A sort of 'message in a bottle' for future observers? Actually, to tell them: "You are not alone". This cave painting could be considered as an attempt to transfer knowledge. Modern humans also sent a drawing to the extra-terrestrial intelligent beings, mounted on the Pioneer 10 and Pioneer 11 spacecraft, launched in 1972 and 1973, respectively.

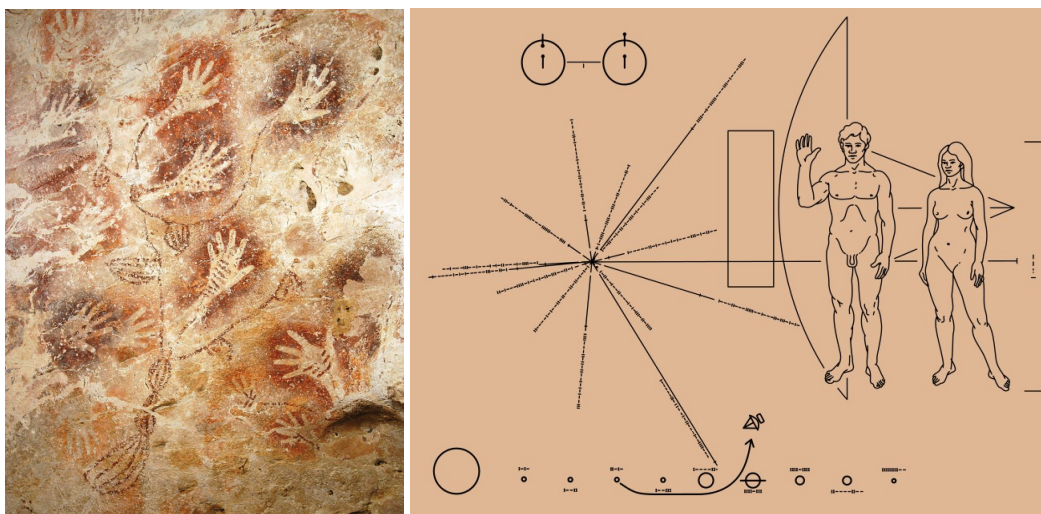


Figure 1: Left: The oldest cave painting (El Castillo, Spain), Right: The plaque attached to Pioneer 10

The plaques on Pioneer spacecraft show the pictorial message explaining that it was created by humans, living on the third planet around the Sun (a star), whose relative position in respect to the centre of our galaxy is encoded in the image and also conveying a message that we understand the structure of the hydrogen atom, the most abundant element in the universe. It is hard to understand why some people doubt the purpose of art, the need for artistic expression is a powerful evolutionary tool, simply because it develops the ability of abstract thinking. Actually, the alphabet could be considered the most useful abstract art ever, of course together with numbers. Namely, digging around, one can find gold, diamonds, oil ... but no one can dig up letters and numbers. The alphabet and number system are pure abstract art and the most useful abstract creation of mankind's mind. My education in the history of fine art and analysis of artworks discussed here is based on the review book written by an international team of artists, art historians and curators, tracing the development of art chronologically, with the illustrated text covering every genre, from painting and sculpture to conceptual art and performance art [1]. To end the introduction, let me state the simple equation: $\text{culture} = \text{science} + \text{art}$.

2. Hellenistic Art and Science

About 2500 years ago in Ancient Greece, people started using common sense and logic to understand nature. For the first time the subjective internal world of imaginations, dreams and fears was separated from the outside objective world. Thales of Miletus (624-545 BC) was the first one who boldly said, to understand the world/nature, there is no need to consult gods on the Olympus, it is enough to use reason and logic. This simple thought defined the spirit of the time, the mental framework which we, modern humans, have inherited, and I do hope still follow. This mindset is the legacy that has led us towards modern society. In antiquity, for the first time space and time were measured. Euclid published his textbooks "Elements" in which he used mathematics to describe the spatial relations, and thus he is considered as the founder of geometry, the first mathematical discipline. These books (13 in total) are one of the most influential works in the history of mathematics, serving as main textbooks for teaching mathematics for nearly two millennia. It is worth to mention that Eratosthenes measured with the astonishing precision the radius of the Earth only by using a stick and cord. The zeitgeist defined by the ancient Greek scholars is clearly embodied in the artworks of that time. The sculptor Polykleitos wrote a treatise ("Kanon") in which he defined proportions of the human body as an aesthetic principle, encoding them by using numbers/mathematics. Even to prove it, Polykleitos created his famous statue "Spear Bearer" and introduced *contrapposto*, to prove mathematically defined aesthetics principle in Classical antiquity (1000 BCE to 450 CE). The flat space and uniform time flow are our everyday experience and it is intuitively easy for us to accept and understand Euclidean postulates. Thus, the artworks of Classical antiquity reflecting this mindset, are very realistic, easy to understand and explain, since they respect the geometry of flat space defined by Euclid. In the flat Euclidean space two parallel lines never cross and the distant object is smaller. Classical antiquity, based on reason and logic, ended about 400 A.D. when the Alexandrian library was demolished and its last librarian, a female scholar Hypatia was killed. This event is considered as the beginning of the Dark Middle Ages which lasted for 800 years, till the Renaissance.

3. Middle Age Art and Science

The burning of the Library of Alexandria marked the beginning of the so-called Dark Middle Ages, whose zeitgeist is sublimated in the thought of Tertullian, the early Christian philosopher: "After Jesus there is no curiosity, there is no research after the Gospel. Believe it and want nothing more". The dominant narrative of the Middle Ages was to "save the soul", the body was not important. Sticking to this narrative (mindset), the burning of witches at the stake, actually meant their salvation. This is a horrible example, showing the extreme power of narratives, arising from the intellectual climate of a certain epoch. The art of the Middle Ages served the Christian religion to worship divine. Thus, artworks were dominated by spiritual and religious motives. In painting, the perspective and spatial relationship of the flat Euclidean space completely disappeared. Everything was subordinated to religion, art was used to worship god and promote religion, the skills to show 3d on canvas of 2d were lost and not used any more in painting. The dominant mindset taught that answers to all questions were to be found in the Bible, and the laws of reason

and logic were dismissed from A.D. 400 to A.D. 1250. St Augustine, the most influential thinker of the medieval mind taught: "It is enough for the Christians to believe that the only cause of all created things, whether heavenly or earthly is the goodness of the Creator, the true one God." Euclid's smooth space became fragmented in the medieval paintings, it lost its homogeneity and could no longer be measured, there was no more perspective showing proper spatial relationship between painted objects. It was impossible to comprehend proper spatial relationship, earthly space was unimportant, too profane to be shown on paintings. Also, the time was not properly shown, so it is impossible to see on the painting which part of the day is. In the medieval art, space and time lost their physical meaning as concepts that could be comprehended and measured and they used to express the spatial and temporal relationship according to common sense. Divine space and time were sacred, earthly space and time were profane and as such should not be a matter of an artwork. In Europe no layperson, from kings and emperors downward, could read or write and illiteracy was the norm for five centuries, from 800 up 1300 A.D. Although the masterpieces of the artwork, particularly in the architecture of the church buildings in the Middle Ages, show remarkable engineering achievements and some painting techniques and mosaic construction were perfected, it is justified to call this period of human history as the Dark Middle Ages, since it was the time when there were no new thoughts and knowledge, it was time of no curiosity.

4. Renaissance Art and Science

The first sign of a new mindset based on reason and logic, from which the Renaissance will evolve can be seen in Giotto di Bondone works of art, since in his paintings there is a hint of perspective, the distant objects look proportionally smaller. Giotto was the first one who started painting a scene as it is seen from a stationary point and in perspective, so that all lines of sight converge on the viewer's eye which is positioned in a stationary preferred location. This prospective technique creates the illusion of recession to the nexal vanishing point. Nichole d'Oresme introduced around 1360 a new tool, visual representation of numbers, where the horizontal and vertical axes are used to show numbers obtained by measurements, i.e. a graph - an unavoidable tool in science ever since. Horizontal and vertical axes are used by painters to organise space on the canvas in agreement with the Euclidean flat space. In 1435 Leon Batista Alberti published his book *Della pittura* in which he elaborated the drawing technique of the perspective using strict mathematics and Euclidean geometry. By painting a scene in perspective or observing a scene from one stationary point of view, it allowed the artist to arrange three axes of space in their proper relationships (perspective means "clear-seeing"). Renaissance paintings are realistic, almost as photographs, preserving the sizes, shapes and positions of various painted objects, relative to each other, as it is in the actual/real space. It is easy to understand and interpret the Renaissance paintings, everything looks reasonable, logical and does not contradict our intuitive understanding of the concept of space and time, which was mathematically described by Euclidean postulates. The Renaissance zeitgeist (mindset) is clearly visible in visual art, various techniques to show three-dimensional space on canvas two-dimensional space have been introduced and perfected by various famous painters. The mindset, which is seen in Renaissance artworks, rejecting the Middle Ages dogma that everything should be subordinated

to divine worshipping, paved the way for the birth of the modern scientific methods established by Galileo Galilei. Numerous Renaissance artists were also researchers, the most famous one, of course, is Leonardo, who struggled to understand various natural phenomena (vision, light, sound...) without divine interference. The Renaissance point of view is sublimated very clearly in Leonardo's masterpiece "Vitruvian Man" [2]. This remarkable Leonardo's painting clearly proclaims that the "human" is the hero, that we, humans, could make the difference. This is a strong artistic explanation of the meaning of humanism, which was born after a lot of struggle. Flourish of science based on observation, reason and logic in the Renaissance was achieved by the work of the most prominent scientists (Nicolaus Copernicus, Giordano Bruno, Galileo Galilei, Markantun de Dominis etc.) who taught us how to use scientific methodology to study nature and thus paved the way to modern society. The Renaissance artists and scholars showed that the humans, by using mind and its most powerful tool, abstract thinking, can take destiny in their own hands. The most fundamental understanding of the nature of space and time at that period culminated in Newton's laws of motion and gravity which dominated the scientific reasoning until the beginning of the twentieth century. Newton taught about space: "Absolute space, in its own nature, without regard to anything external, remains always similar and immovable ..." and about time: "Absolute, true and mathematical time, of itself, and from its own nature flows equably without regard to anything external ..."

5. Modern Art and Science

The invention of the photography by Joseph Nicephore Niepce in 1826 shocked the visual art community to that extent, that French painter Paul Delaroche declared: "From today painting is dead". At the same time, in the first half of the 19 century, mathematicians Gauss, Lobachevsky and Riemann developed new non-Euclidean geometry, the geometry of curved space. Although the great mathematician Gauss proposed a new non-Euclidean geometry already in 1824, he never published it, probably because of fear to be ridiculed by colleagues, simply because according to the mindset of that epoch the Euclidean concept of space was inviolable. However, Lobachevsky was brave enough to publish his theory of the geometry on curved space in 1840, stating, among other things, that two parallel lines could cross each other. The power of narrative arising from the zeitgeist was so dominant, that Lobachevsky lost his professorship, because of his blasphemy against Euclid. Relatively soon, Einstein will show that space and time are indeed curved and that the concept of the absolute space and time dominating for centuries is simply wrong. About 20 years after the theory of curved space had been published, Eduard Manet, made his seminal painting "The Luncheon on the Grass" [3], which is considered as the first modern painting. It is hard to understand it, since it does not provide a clear message and does not respect all the existing canons of painting established in the Renaissance. An educated physicist can actually see that this famous Manet painting encodes the geometry of the curved space. Namely, in the curved space the shape and size of the object depend on where the object is placed in space. In the back part of this painting, there is a lady figure which is huge according to the rules of the flat Euclidean space, illustrating the consequence of the curved space, that the size and shape of the object depend on where it is placed in space. Of course, it is not fair to claim that Manet was familiar with the geometry of curved space, but there is a reasonable doubt that

Manet could have been aware of non-Euclidean geometry. This fact suggests something worthwhile further investigating. This Manet painting is a clear example showing that breakthroughs in art and science are born when the existing mental concepts, thought and narratives, are questioned, challenged and mocked by artistic expression (mocking is the privilege of the artist and not of the scientists, who just have to show that the old working theory is an approximation of the new theory). The special (1905) and general (1915) theory of relativity entirely demolished the concept of the flat space and time ticking uniformly in the entire universe. Space and time are not any more untouchable stages at which physical phenomena take place. In fact, space and time are affected by physical processes. They are not two distinct concepts, but one entity, called *space-time*, adjusted in a way that the observer, who is standing still and the other one who is chasing the light, must measure the same speed of light. Also, the space-time is affected by the mass and energy which it contains. More massive body makes space-time "suffer" more, making it curve more. Regarding light, all the space is here and all the time is now, hence for light there is no space and time. The other amazing consequence of the new understanding of space-time is that there are regions of space-time so curved due to huge concentration of mass or energy, that it is separated from the rest of space-time and we cannot explain which physical laws work inside this region of space-time, called a black hole. This new understanding of the concepts of space and time created a new spirit of time, a new narrative and mindset present in the art movements at the beginning of the 20 centuries. In that short period, we invented new mental concepts of space-time and abstract physical quantities which make the foundation of quantum physics, like the quantum field. The quantum field is a pure construct of our mind, an abstract physical quantity that cannot be measured, but by using it, physicists are able to understand nature at the atomic and subatomic levels. Abstract concepts of quantum physics, which are anti-intuitive since they are not part of our everyday experience are the backbone of modern technology. These new abstract physical concepts show the power of abstract thinking, which has created the zeitgeist sublimated in various fine art movements like cubism, futurism, abstract art, conceptual art, performance, etc. The famous painter Kandinsky [4] began to explore the idea of art without an image. Similarly, as physicists look for the most fundamental building entities of the universe (atoms, elementary particles ...) painters also look for the most fundamental substance of the painting. This zeitgeist, looking for the most fundamental substance, could be seen in abstract paintings of Kazimir Malevich [5] and Jackson Pollock [6]. The Pollock paintings did not show "things" in the context of the homogeneous and linear space and time, but were trying to seize "now", aiming to show the process of painting creation. It is interesting to remark, that actually the world which we experience, in which we live, is the result of constant interactions of quantum fields, i.e. physical processes happening at the most fundamental level. The universe is in fact not made of elementary particles but of quantum fields, which are the most fundamental substance of the universe. The elementary particle is a simple concept, the particle has some position in space at a certain time, some mass, charge and spin. Quantum field, on the contrary, is not a localised entity, it exists everywhere in space at any time and we cannot measure it. Nevertheless, we know how to provoke it, to show its existence by exciting it to create an elementary particle which we are able to measure. Consequently, by doing experiments at the LHC accelerator and using detectors like CMS and ATLAS, we have measured a particle which is called Higgs boson. By detecting it we have proved

that Higgs quantum field exists together with other quantum fields associated with the already discovered elementary particles and that only those quantum fields associated with elementary particles having mass interact with Higgs quantum field. In the end, let me point to two artworks done by American artist Barnett Newman. One is "Vir Heroicus Sublimis" (1950), a huge canvas (2.5 m x 5.5 m) [7], covered with a single homogeneous colour of uniform texture and the only intervention on this monochromatic field are few thin strips of contrasting colours. Having been educated as a physicist I see in this painting quantum field and its excitations, i.e. elementary particles, illustrated by the strips. Also, the title of this painting is very intriguing. Newman loved art passionately and continuously questioned its mission. For several years he debated what should art be and claimed that: "The central issue of painting is the subject matter - what to paint". Looking at another Newman's painting having title "The Death of Euclid" (1942.) [8] it is obvious why he chose this title, as it is a beautiful visual illustration of the demolishing of the concept of flat space which had been done by physics many years ago.

Future education should combine an interdisciplinary approach to empowering students to learn quickly and understand new knowledge and skills. This could be achieved by combining scientific methodology and the arts from the very beginning of education for the purpose of acquiring abstract thinking skills to combine concepts from different fields. In fact, education in the future should aim to educate a Renaissance man who will think freely and undisturbed. The specialized education required in the labour market will soon become obsolete. In conclusion, learning is the most creative human activity, of course it is very difficult but it is also the most awarding, making human being to develop a sense of confidence, exaltation and fulfilment.

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