«I therefore take the liberty of proposing for this hypothetical new atom, which is not light but plays an essential part in every process of radiation, the name photon.»
Gilbert N. Lewis, 1926
PROLOGUE
The notion of photon, as well as that of photonics is relatively recent and still debated. Conversely, the notion of light is thousands years old.

Nonetheless, the roots of this "granular " representation of what today we know as electromagnetic energy is faraway in time, while the idea of “particle of light” does not involve only physics.

The disciples of a sixth century BC branch of Hindu philosophy called Vaisheshika had a surprising physical intuition about light. Like the ancient Greeks, they used to believe the world was based on ‘atoms’ of earth, air, fire, and water. Light itself was thought to be made of such very fast-moving atoms called tejas.
European scientist in the 16th and 17th century or Persian mathematician and physicist al-Farisi (1260–1320) AIP Conference Proceedings 899, 849 (2007)

Known from the ancient times. The effects of diffraction of light were first carefully observed and characterized by Francesco Maria Grimaldi

Thomas Young's double slit interferometer in 1803 demonstrated interference fringes when two small holes were illuminated by light from another small hole which was illuminated by sunlight
The **PHOTON** is a type of elementary particle. It is the quantum of the electromagnetic field including electromagnetic radiation such as light and radio waves, and the mediator particle the electromagnetic interactions. **PHOTONS** are massless, so they always move at the speed of light in vacuum, 299792458 m/s. The **PHOTON** belongs to the class of bosons.

**PHOTON PROPERTIES**

**PHOTONS** have ZERO MASS and NO rest energy. They only exist as moving particles. **PHOTONS** have no electric charge but electric and magnetic fields. **PHOTONS** are spin-1 particles which makes them bosons. **PHOTONS** carry energy and momentum which are dependent on the frequency. **PHOTONS** can interact with other particles such as electrons. **PHOTONS** can be destroyed or created by many natural processes, for instance when radiation is absorbed or emitted. WHEN there are no PHOTONS in a “mode”, still there is some energy: the zero field energy.
Adaptive Detection of Arbitrarily Shaped Ultrashort Quantum Light States

C. Polycarpos,1,2 K. N. Cassemiro,3,4 G. Venturi,2 A. Zavatta,1,2 and M. Bellini1,2,8

1Istituto Nazionale di Ottica (INO-CNR), Largo Enrico Fermi 6, 50125 Florence, Italy
2LENS and Department of Physics, University of Firenze, 50019 Settimo Fiorentino, Florence, Italy
3Max Planck Institute for the Science of Light, 91058 Erlangen, Germany
4Departamento de Física, Universidade Federal de Pernambuco, 50670-901 Recife-PE, Brazil

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A quantum state of light is the excitation of a particular spatiotemporal mode of the electromagnetic field. A precise control of the mode structure is therefore essential for processing, detecting, and using photonic states in novel quantum technologies. Here we demonstrate an adaptive scheme, combining techniques from the fields of ultrafast coherent control and quantum optics, for probing the arbitrary complex spectrotemporal profile of an ultrashort quantum light pulse. The ability to access the modal structure of a quantum light state could boost the capacity of current quantum information protocols.
Despite the effort to make the modern science, and in particular the physics, "an objective knowledge", it remains anthropocentric.

2001: A Space Odyssey, S. Kubrick
Nonetheless, our **imagination and creativity** are not intrinsically part of the Universe. Is this what we use for modeling the Universe and the Nature?

2001: A Space Odyssey, S. Kubrick
In spite of all what we know, PHOTON is still an elusive particle, an insuperable sphinx.

It is enough to allude to the fact that photon has no mass but it is subject to mass effects, as an outcome of the mathematical singularities emerging from the general relativity field equations, today known as black holes, from which gravity even the photon cannot escape.
Eddington experiment that confirmed the prediction of Einstein's general relativity that provides the trajectory of light curved by the presence of a large mass.
The surface $r = r_s$ demarcates what is called the event horizon of the **black hole**. It represents the point past which light can no longer escape the gravitational field. Any physical object whose radius $R$ becomes less than or equal to the Schwarzschild radius has undergone gravitational collapse and become a **black hole**.
In the **FIRST LECTURE** I will provide a fresco of the historical and philosophical roots that give rise to the idea of photon. This period will extend from the ancient philosophers to the Newton’s Era.

In the **SECOND LECTURE** we will immerse ourselves in the crucible where classical physics evolved into quantum physics and the history of the photon will be our guide to review opposing ideas in comparison and ideological clashes between the giants of physics of '800 and '900.

In the **THIRD LECTURE** we will enter the world of the photon with its physical, epistemological, technological and social implications.

In the **LAST LECTURE**, as in the crescendo of a great polyphonic symphony, we will follow, step by step, what today we can define a fundamental mutation of quantum physics born from the head-on collision between two schools of thought on the completeness of quantum mechanics and therefore two ways of understanding physics. What will emerge is a physics bearer of the idea of zero point energy and then the idea of quantum vacuum, explaining the interference and diffraction produced by single particles (massive and massless) violating the principle of space-time superposition so far used to explain physical phenomena.

However, before starting we need to set some concepts, as a sort of guideline in order to argue on the same logical basis and with the same language.
SCIENCE
A possible definition is that Science is organized knowledge. In general, the knowledge base of Science is reproducible data, numbers obtained under controlled conditions. This simple but effective definition set also the boarder line between the ancient definition of science with its aphorisms and what today we call scientific knowledge.

THE SCIENTIFIC METHOD.
The set of procedures that involve not only logical consistency but falsifiable hypotheses (Falsifiability was introduced by the philosopher of science Karl Popper in his book Logik der Forschung (1934, revised and translated into English in 1959 as The Logic of Scientific Discovery), and their experimental testing as well as exploratory observations. «A theory is falsifiable if it is contradicted by possible observations”—i.e., by any observations that can be described in the language of the theory, which must have a conventional empirical interpretation. For example, the statement "All swans are white" is falsifiable because "Here is a black swan" contradicts it. »

PHYSICS
Concepts—models of nature—that can be translated into mathematical terms, i.e. into tractable equations. These equations, in turn, allow one to obtain mathematical formulas with which to predict numerical values that are expected to result from particular measurements (expectation values).
MATHEMATICS.

Photon is a physical concept, and physics relies on mathematics, so any understanding of photons must include some understanding of Mathematics. But math and physics, though linked, do not stand on the same foundations. Mathematicians are free to propose any set of axioms, any rules for their symbols, from which they then deduce theorems, corollaries and lemmas—and display their ingenuity. It is only necessary that their structures—the rules of algebras and groups and so on—be free of hindering contradictions. By contrast, physics is expected to conform to observations of nature, not just to be consistent within their mathematics.

Sometimes mathematics and science converge, but this is not a necessary condition. As I taught to my students of Electrodynamics, Physics is inconsistent with the idea of infinite, size-less objects, zero or empty space.
HISTORY OF LIGHT IN A NUTSHELL
Light is derived from the Latin "lux lucis" from the Indo-European root leuk-. The corresponding term in Greek is λευκός, "bright, white." A particular meaning of light in Greek occurs with φῶς (phaos/phōs) whose root corresponds to that of the verb phainō, meaning "to show," "to make manifest." The Greek word “φῶς” originally denotes not only light as a means of seeing, but also the light that emanates the truth attained through knowledge.

Aristotle (384 B.C.-322 B.C.) was the first to develop a concept of light that, despite its apparent immateriality, is fundamental to the corporeity of the universe. Thus, light is the basis of animate and inanimate physical being. Vision, and in particular color vision, was of great importance in the speculations of Greek philosophers. Two hypotheses were compared about the origin of images, one emissive, the other intrusive.

Credits: http://www.anisn.it/matita_ipertesti/visione/scienza%20greca.htm
Pythagoras (c 582 - c 500 B.C.) believed that the eye behaved like a beacon of the soul; that is, it emanated light to explore its surroundings and enable knowledge. On the contrary, the atomists, whose most significant exponent is Democritus, believed that light moves from the object towards the eye, causing vision.

Plato (427-347 B.C.) supported an intermediate position: there is a double direction of the communicative action of "heat" that impresses the eye, causing the vision; the external heat and the internal one coming from the brain impress the eye determining the perception.

Euclid (IV-V B.C.), in the book Optics formulated the hypothesis that the visual rays, which also according to his model came from the eye, propagated in a straight line and understood that the apparent size of an object could be calculated based on the angle formed by the straight lines drawn from the apex and base of the object observed to the eye of the observer. He also verified that closer objects appear larger and move apparently faster; and he was able to measure the height of distant objects by the length of the shadow cast by them.

Credits: http://www.anisn.it/matita_ipertesti/visione/scienza%20greca.htm
The study of vision and optics was of great interest in the Arab world. Avicenna (980-1037) and Averroë (1126-1198) deduced from Aristotle that light is not corporeal, because it does not occupy a space, but when it multiplies as a multiplicity of points then it materializes in a body. The universe itself corresponds to its brightness and since matter cannot be infinite, light too stops at a final term.

http://www.anisn.it/matita_ipertesti/visione/scienza%20greca.htm
The Englishman Roger Bacon, who had studied Arabic science, popularized the use of lenses and dreamed of a time when...images could be projected into the air, so that they could be seen by everyone....

Roberto Grossatesta (1168 - 1253), Referring to Genesis, according to which light gives form to matter, he stated: ...Lux est ergo prima forma corporalis ...

For the first time light is considered something material, so it is possible to assume that its characteristics, such as those that allow the vision, can be investigated through natural means. Towards the end of the 1200s spectacles appeared in Italy, the first models of which were perhaps imported by the Arabs. Slowly and laboriously, modernity was making its way.
THE BIRTH OF THE MODERN SCIENCE
Jesuit Francesco Maria Grimaldi discovered the diffraction, the problem between the objective "pictura" and the subjective world that man distinguishes remained open; hypotheses based on mysterious correspondences between microcosm and macrocosm continued to flourish; suffice it to mention Robert Fludd (1574-1637), a medical alchemist of the time.

Even the use of lenses was considered an artifact: who can say that the lens is not a tool to see things that do not actually exist? It is no coincidence that many Aristotelians refused to look into G. Galileo's telescope (1564-1642). In the debate also intervened Thomas Hobbes (1588-1679) that in his works argued that light propagated instantaneously in a medium through a wave front; according to the English philosopher vision did not consist simply in a response to mechanical stimulation that hit the eye, but involved a process of active learning.

Credits: http://www.anisn.it/matita_ipertesti/visione/scienza%20greca.htm
The Dutch physicist **Huygens (1629-1695)**, trained at the school of Cartesian mechanics, sketched a wave theory of light in the *Treatise on Light* (1690); the theory was based on the one developed by Hooke in 1665 and helped to open the debate on whether light was corpuscular or made of waves.

**John Kepler (1571-1630)** formulated the hypothesis that *the crystalline lens played a fundamental role in vision, allowing the rays of light to focus within the eye orbital cavity*. Kepler's work was fundamental for the subsequent development of modern optics, of which he can rightly be considered the founder.

**Galileo** made his earliest observations in 1609, thanks to improvements he had made to the first telescope, developed by Dutch opticians. In the space of a few months, he obtained much sharper images while increasing the telescope’s magnification power 30 times. In the autumn of 1609, he was able to contemplate the already known stars and planets in new and greater detail. He observed, for the first time, the Milky Way, the irregular surface of the moon, sunspots and the phases of Venus. Most importantly, he discovered Jupiter’s four satellites.

(*Christophe Roulet*, FHH Journal 2010)
Isac Newton in 1672, as author of OPTICKS. In a famous experiment he clarified the nature of colors from a physical point of view and pioneered of the theory that identified the light with corpuscular. The corpuscular theory of light, arguably set forward by Descartes in 1637, states that light is made up of small discrete particles called "corpuscles" which travel in a straight line with a finite velocity and possess impetus. This was based on an alternate description of atomism of the time period. He notably elaborated upon it in 1672.

The father of mechanicism, René Descartes (1596-1650), also brought fundamental contributions to the debate, although his ideas were criticized by many contemporaries, such as the great Jesuit Athanasius Kircher.

While the French philosopher had assumed that light moved at infinite speed, the studies of the Danish Ole Rømer (1644 - 1710) allowed to understand that it had a very high but finite speed; the scientist obtained his data in 1675, thanks to the study of eclipses of Jupiter's satellites.

This early conception of the particle theory of light was an early forerunner to the modern understanding of the photon. This theory cannot explain refraction, diffraction and interference, which require an understanding of the wave theory of light of Christiaan Huygens.
THE METHOD AND THE THEORY
behind the Glass at c, from whence any Rays AB, AC, AD, which flow from one and the same Point of the Object, do after their Reflection made in the Points B, C, D, diverge in going from the Glass to E, F, G, where they are incident on the Spectator’s Eyes. For these Rays do make the same Picture in the bottom of the Eyes as if they had come from the Object really placed at a without the interposition of the Looking-glass; and all Vision is made according to the place and shape of that Picture.

Fig. 2. In like manner the Object D seen through a Prism appears not in its proper place D, but is thence translated to some other place d situated in the last refracted Ray E F drawn backward from F to d.

Fig. 10. And so the Object Q seen through the Lens AB, appears at the place q from whence the Rays diverge in passing from the Lens to the Eye. Now it is to be noted, that the Image of the Object at q is so much bigger or lesser than the Object it fell at Q, as the distance of the Image at q from the Lens AB is bigger or less than the distance of the Object at Q from the same Lens. And if the Object be seen through two or more such Convex or Concave-glasses, every Glass shall make a new Image, and the Object shall appear in the place and of the bigness of the last Image. Which consideration unfolds the Theory of Microscopes and Telescopes. For that Theory consists in almost nothing else than the describing such Glasses as shall make the last Image of any Object as distant and large and luminous as it can conveniently be made.

I have now given in Axioms and their Explications the sum of what hath hitherto been treated of in Opticks. For what hath been generally agreed on I content myself to assume under the notion of Principles, in order to what I have further to write. And this may suffice for an 

PROPOSITIONS.

PROP. I. Theor. I.

LIGHTS which differ in Colour, differ also in Degrees of Refrangibility.

The Proof by Experiments.

Exper. 1. I took a black oblong fluff Paper terminated by Parallel Sides, and with a Perpendicular right Line drawn cross from one Side to the other, distinguished it into two equal Parts. One of these Parts I painted with a red Colour and the other with a blew. The Paper was very black, and the Colours intense and thickly laid on, that the Phenomenon might be more conspicuous. This Paper I viewed through a Prism of solid Glass, whose two Sides through which the Light passed to the Eye were plane and well polished, and contained an Angle of about Sixty Degrees; which Angle I call the refracting Angle of the Prism. And whilst I viewed it, I held it before a Window in such manner that the Sides of the Paper were parallel to the Prism, and both those Sides and the Prism parallel to the Horizon, and the cross Line perpendicular to it; and that the Light which fell from the Window upon.
AN EXPERIMENTAL PROBLEM
AND
A CONCEPTUAL QUESTION
In 1688 William Molyneux (1656-1698) entered the debate on the mechanisms of vision, sending a letter to John Locke (1632-1704) in which was formulated a crucial question: can a man blind from birth, once recovered the sight, distinguish objects with the sole help of this?
LIGHT DETECTION AND PHOTON DETECTION

Photonis Technologies S.A.S

Superconducting Nanowire Single Photon
JET Propulsion Lab. CALTECH

NATURE COMMUNICATIONS| 7:12172 | DOI: 10.1038/ncomms12172 (2016)
The concept of the photon
Marian O. Scully, and Murray Sargent
Citation: Physics Today 25, 3, 38 (1972); doi: 10.1063/1.3070771
View online: https://doi.org/10.1063/1.3070771

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biography

END FIRST LECTURE
To date, the earliest lenses identified in context are from the IV/V Dynasties of Egypt, dating back to about 4,500 years ago (e.g., the superb `Le Scribe Accroupi’ and `the Kai’ in the Louvre; added fine examples are located in the Cairo Museum). Latter examples have been found in Knossos (Minoan [Herakleion Museum]; ca. 3,500 years ago).