Light as a metaphor of science: A pre-established disharmony

LUIGI BORZACCHINI

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> Who will solve all these not little problems, shedding light on light, will deserve well for such a brightness, which today for many people is surrounded by the great darkness of falsity.
> (Grimaldi 1665: prop. III, 25)

Light as a metaphor of knowledge, and darkness as a metaphor of ignorance and error are commonplace in every modern language. The first aim of this article is to show how profound this metaphor is and how far its roots stretch into the past.

The basic idea of this study is that our entire theoretical knowledge is caught up in a network of antinomies that we can define by their linguistic appearance. Thus we set out the antinomies shared by general knowledge and light theories. The second aim is to describe this common antinomical behavior.

At the beginning of Greek civilization, between Homer's and Socrates's times, something happened to change the history of mankind: the distance between divine truth, the *aletheia*, preserved by the Muses and echoed in the words of the poets, and human knowledge, empirical wealth of merchants, craftsmen and farmers, became less and less.

A new lexicon had to be created for this new 'philosophical' knowledge, a sort of bricolage, in which perceptual verbs in everyday language (*eidō*, *noeō*, *theoreō*)[1] had to deal with the ancient *aletheia*. The legacy of that ancient contamination is that ancient Greek words expressing 'sight' are the roots of modern words expressing 'abstract knowledge', such as 'theory/theorem' or 'idea'.

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That thesis, which seems more natural to us, was also supported by the Atomists. Leucippus and Democritus reduced all perceptions to contact, and wrote that the objects sent to our soul their representative eidola (*DK* 68 A 1): the interaction of such effluence with the senses caused knowledge. This point is relevant for our analysis, because the weakness of this approach was that it led to a knowledge theory in which thought had to be identical (or at least closely akin) to perception (*DK* 68 B 101). This meant ultimately developing a relativistic theory of knowledge, which was afterwards advocated by Protagoras (*DK* 80 B 1, 6), but actually Democritus somewhere (*DK* 68 A 9) maintained that relativism encompassed only perceptive knowledge, and that his theory 'atoms and void' held instead true.

Other problems linked to this approach were solved to a certain extent: Epicurus maintained that other particles take the place of those continually streaming off the surface of bodies, so that no diminution of the bodies was observed, and that, in order to account for the perception of the form, those given off retain the same position and arrangement of their atoms as when they were part of the solid bodies.

This approach, however, did not survive the Hellenic age, overcome by critiques such as Theophrastus's remark to Empedocles that his theory had to imply (and actually Empedocles' philosophy did) that also inanimate objects, having their own pores, should have perceptions (*DK* 31 A 86); or the remark to Democritus that, according to his theory, atoms' interaction with our senses had to be at the same time objective, because qualities are due the atomic patterns, and are subjective, to explain errors and relativity of perceptions (*DK* 68 B 135).

The opposite theory, advocating vision as an action starting from the eye (a fire coming out of the eyes to touch the objects and to reveal their forms and colors) was common to many ancient philosophers, such as Hipparchus, Parmenides, Hippocrates, Architas, and the Pythagoreans (*DK* 42 6, 28 A 48, 47 A 25). It is interesting to observe that also in this case, in the ancient Greek philosophy, the lack of a theory of the soul or mind as something not reducible to the senses, implied that knowledge, thought, mind, and personal behavior had to be natural processes deriving from the natural processes of perception,[3] so that the emphasis on the active aspects of knowledge entailed analogous active aspects of perception.

Only Aristotle and to a certain extent Plato, put forward a theory of knowledge showing a marked difference between prevalent 'active' (thinking) and 'passive' (senses) functions. After this distinction, purely subjective or objective theories about vision appear progressively outdated.

In fact, at the beginning of Greek civilization, we find a uniform use of perceptual and mental terms (seeing, hearing, thinking, saying) that in our modern culture play different roles, either more 'passive' ones (perceptual verbs such as seeing, hearing) or more 'active' ones (mental terms such as thinking, saying).

In addition, whenever we construct sentences in which these verbs have the object 'what is not', the effect of this uniformity is that the absurdity of 'seeing what is not', which is very near to the 'existence of what is not', extends to 'thinking/speaking what is not', thus creating the *negative judgement paradox*: 'given that an affirmative statement corresponds to a fact in the world, something that is, we have a negative statement that corresponds to something which is not, but a statement about what is not, is about nothing and hence is impossible', defined by Plato in *Sophista* (238 d2) 'the greatest and the first quandary'.[2] Plato eagerly fought against this paradox in almost all his works, and this reveals how far the *active/passive distinction* in knowledge was a crucial problem for the earliest Greek philosophers.

In early Greek philosophy it is not easy to find explicit theories on vision. The common premise was that there had to be some form of contact between the object of vision and the eyes, but it had to be embedded in the emerging subject/object opposition. As argued by Luther: 'According to Homer, light (*phos*) and eyes are intertwined. He describes the eyes as "lamps" (*phaea*). Light itself is not conceived as matter or an element, but as the Enlightening, the Clearing' (1966: 24).

Probably the first available fragments are those ascribed to Alcmaeon of Croton and Empedocles of Akragas, who both flourished in Magna Grecia in the fifth century B.C.: their interest in medicine brought both to recognize the fire in the eye as the basis for vision. However they had different opinions on the (at that time) crucial question: is perception due to interaction between similar or dissimilar entities? Alcmaeon took the latter position (cf. *DK* 24 A 5), Empedocles the former (cf. *DK* 31 B 84).

However, the answer they gave to another question is more important in the context of our analysis: is *sight actually an effluence from the objects toward the eyes*, or, vice versa, *something from the eye toward the objects*? Empedocles, as noted in Plato's *Meno* (76c), advocated that things 'give off a sort of effluence' which is perceived according to the size of the 'pores' of the perceiving body. Aristotle (*De sensu* 437b–438a) ascribes to Empedocles the opposite thesis of sight as a fire flowing from the eye, but this was credibly wrong (even according to Theophrastus' account [*DK* 31 A 86] of Empedocles' theory).

Contrary to the 'negative judgement paradox' Plato's theory of knowledge is centered on the role of the 'soul', which cannot be reduced to the senses, but it is difficult to find an explicit theory of vision in his dialogues. *Theaetetus* is a dialogue devoted to developing Plato's theory of knowledge, and here we find a theory of sight, which could be ascribed to Protagoras or Empedocles, where active and passive aspects seem to melt:

> When the eye and the appropriate object meet together and give birth to whiteness and the sensation connatural with it, which could not have been given by either of them going elsewhere, then while the sight is flowing from the eye, whiteness proceeds from the object which combines in producing the colour; and so the eye is fulfilled with sight and really sees, and becomes, not sight, but a seeing eye; and the object which combined to form the colour is fulfilled with whiteness, and becomes not whiteness but a white thing. (*Theaetetus*, 156 d–e)

Nothing exists in itself, nothing can be determined unless by this interaction: Plato fights Protagoras's relativism, but the dialogue does not seem to find an alternative, either for knowledge or for vision. In *Timeus* 45 c–d, 'sight' seems to require a double motion of 'fire', from the inside and from the outside as well, but the dialogue does not face the above crucial questions.

In general, a sine-qua-non condition for Plato's enterprise is the already underlined distinction of a set of functionalities more connected to the Self than to reality in the group seeing-thinking-speaking, which in the earlier tradition were linked together, in the absence of a precise distinction between 'reality' and 'mind'.

From this point of view the 'self' is the place where, by graduating those functionalities from a 'real' extremity in 'seeing' to a 'subjective' extremity in 'speaking', we have room enough to overcome the paradox: 'the soul knows, being is known' (*Sophista* 248d).

In Plato's *Republic* we find another implicit antinomy which will play a crucial role in modern physics. At the beginning of the seventh book, the 'myth of the cave' displays the basic themes of Plato's theory of knowledge. Here, prisoners can see just shadows of the real things. They must leave their chains to see them enlightened by the sun; however, this new vision is hard and painful, because they are not accustomed to the strong light. The sun is the idea of Good, and to see the 'ideas', we must first understand it. The problem is that, *since the sun, light and Good are preconditions for knowledge, how is it possible to know them*? What is the relationship between sight and the sun? Plato's answer is: the dialectical process fosters the reminiscence of ideas: the idea of Good is the source of the truth of objects and of the knowledge in the subject (cf. *Republic* 508e 1–3).

The problem can be expressed in other words: how can we know anything about light, if light is necessary for sight/knowledge? When we see something, do we see the thing or the light from the thing? And light plays a crucial role in the same Platonic ontology: in the tenth book of *Republic*, the myth of Er shows the role of light as structural ingredient of the cosmos. Light is the matter by which the cosmic fuses are built: maybe this is the first reference to light as a basic substance of the universe, which later will give birth to the idea of a coincidence between light and space.

The problems of knowledge in Platonism were thus shifted but not completely solved. In Neoplatonism being, light, ideas, good, and knowledge had to face not-being, darkness, matter, evil, and ignorance, thus leaving open the two basic problems: how can we characterize the *being of the negatives* (among which not-being: the eye can see also darkness, but if 'not-being' somehow 'is' and can 'be known' we find a contradiction with the 'positive' common nature of being and knowledge), and how can we *know something about 'knowledge'*: 'do we know the knowledge acts or the known facts?', that can be expressed as a metaphor in 'do we see the light or the lighted object?'.

Aristotle (*De anima* II 418–419) stressed the role of the diaphanous substance between the object and the eye, in order to embed the problem in his framework based on the pairs substance/accident and power/act. In fact color is a 'proper sensible', and thus is an essential aspect of the perceived substance, whereas the diaphanous matter is in a potential condition when in the darkness, and is modified toward an actual condition by the light. Lindberg (1978) underlines that the light is the act of the diaphanous as such; it is not a substance, but a state of the transparent medium resulting from the presence of some luminous body. Color is that which overlies the surface of the object and has the power to set in motion a medium. Ultimately, the medium moves the sense organ.

The role of the 'soul' to establish knowledge is crucial also in Aristotle's philosophy. In Aristotle, the perceiver's senses must be somehow changed according to the 'form' of the object, but knowledge cannot be simply determined by such interaction. In *Sophistici Elenchi* (178a 16) he remarks that 'to see' shows an active (*poiein*) aspect, such as 'to look at something', and a passive one (*paschien*), such as 'to be influenced by external perception' (*aisthanesthai*).

The development of the ideas of mind, soul, and self, connected to the transformation of old terms linked to sense or body terms toward mental connotations, as mentioned by Snell (1978), is the basis of the new theory of knowledge: 'the vision is contained in the eye as intuition is contained in the soul' (*Topica* 108a 12).

The soul is also 'the place of the forms' (Aristotle, *De anima* 429a 27), and the place where there is room enough between simple perception and its awareness/description, so that it becomes possible, for example, to see 'darkness', i.e., 'what cannot be seen' (*De anima* 425b).

The Atomists' approach did not consider the role of soul, the relativity of knowledge, and the subjectivity of behavior, and could not yield any non-relativistic idea of truth. After Aristotle, with the strengthening of the idea of soul, the 'mixed' solution somehow took the lead, enhancing the 'subjective' role also in perception. It was well-established in the Hellenic age, as underlined by Meyering (1989) when dealing with the most important optical theory of the classic antiquity: Aristotle, Galen, Euclid, to whom we can also add Ptolemy, as underlined by Ronchi (1983).

Thus Lindberg (1978) reminds us that Galen argued that visual spirit descending from the brain through the optic nerve to the eyes emerges from the eye for a short distance, and transforms the surrounding air, which thus becomes an extension of the optic nerve and an instrument of the soul. The crucial difference between Galen and Aristotle was that, whereas the latter made the medium an instrument of the visible object and assigned the observer a passive role in vision, the former made the medium an instrument of the eye and soul and ascribed activity to the observer.

Euclid's *Optica* based 'geometric optics' on the idea of straight rays from the eyes to the object (axioms 1–4) and the idea of sight as an exact representation (axioms 5–11). It is noteworthy that for Euclid these visual rays were not 'continuous', i.e., not absolutely close together, but separated by a certain distance, as mentioned by Heath (1921).

In Neoplatonic philosophy the universe was something organic and vision was the result of a sort of 'sympathy' between the eye and the object, so that the soul could see the objects themselves, without any material actions (cf. Plotinus, *Enneades* IV).

The Stoics ascribed to a visual 'pneuma' from the soul the function of producing a tension in the air by which the eye could get the impression of the external forms. However, among mathematicians, the Euclidean approach of simply subjective visual rays was dominant in the Middle Ages.

At the sunset of the classic world, these theories, different though they were, shared some basic arguments.

First, the presence of active and passive aspects bound together by the soul.

Second, the 'substantial' nature of colors, a quality of non-luminous objects, sharply contrasted with the 'accidental' or subjective nature of light, whose origin has to be found in fiery bodies. The first consequence of this argument was that color reflected a 'proper' attribute of the substance, whereas light had an ambiguous role (for example: condition for the transparency of the medium). The second consequence was that it was not clear whether darkness was to be considered as the lack of some substance, or light and darkness could both be 'seen' as such, as was common in ancient Greek culture.

Third, the 'holistic' character of vision, i.e., the idea that the image of the object was transmitted or revealed, and then represented, 'as a whole', an *eidolon* for the Atomists, a form for the Aristotelians, and that shapes and colors were just aspects of such a 'whole'.

To embed light (and analogously movement) in the Aristotelian framework was very difficult because Aristotle's physics was based on the ideas of 'substance', 'That which, numerically one and the same, is receptive of contraries' (*Categoriae* 5), as being strictly object-related, to account for fixed and passive being, and of 'property' as ranging between two 'contraria' (warm/cold, wet/dry), to account for change. Light (and movement) could be neither substances, due to their active behavior and their not being strict objects, nor properties due to their being absolute things, whose opposites, dark (and rest), were simple privative terms. Medium played an essential role in both phenomena, as mentioned by Maier (1955). For that reason Renaissance physics were first and foremost anti-Aristotelian mechanics and optics.

With Plato and Aristotle another aspect, and another metaphor, of knowledge emerges; it deals first and foremost with those contradictions of common-sense knowledge which were common-place in the Sophists's theories: a finger can be at the same time great and small, a man can be tall and short, and so on. Such contradictions appear when we deal with relationships and with becoming, and dialectics must face them.

That form of reasoning was called dianoia, 'the dialogue of the soul with herself', and this definition recalls the basis metaphor of this knowledge, 'signs, alphabet, and writing': the waxed board in Plato's *Theaetetus*, the book in Plato's *Philebus*, Aristotle's 'clean slate'; also the term employed to denote the first principles of a science ('elements', *stoicheia*) is the name of the letters of the alphabet. (These aspects have already been analyzed in Borzacchini 1995.)

If 'light' is the metaphor of perceptual and intuitive knowledge, positive, constructive, and unscathed by contradictions, 'writing' is instead the metaphor of theoretical and rational knowledge, facing the 'negative judgement paradox' and then the 'liar paradox', relational knowledge, natural becoming. Both are contained in the soul, but play opposite, complementary roles. Throughout the next two thousand years, until the Renaissance, syntactic metaphor (and formal knowledge) prevails in Aristotelian approaches, light metaphor (and the role of light in knowledge theory) in Platonic ones.

This is the great gift of Greek civilization to our culture: the encounter of divine 'truth' and human 'knowledge', a new generation of formal antinomies, the inexhaustible generative power of 'negative', the genesis of the philosophical lexicon, a new Indo-European linguistic province.

Light and knowledge were thus embedded in many different antinomies. In the ancient framework 'light' was amphibious between substance and accident, power and act, knowing subject and known object. The ambiguous state of light was strengthened when, at the end of the classic period, under the influence of both Christianity and Neoplatonism, the connection between light and space arose. In the religious framework light had to become ultimately the main attribute of God, as in the closing lines of St. John's *Apocalypse*: 'And night shall be no more; they need no light of lamp or sun, for the Lord God will be their light, and they shall reign for ever and ever'.

Maybe to save the substantial character of the biblical 'fiat lux et facta est lux', in the early Middle Ages it was common to distinguish between 'lux' (natural quality of the sources of light) and 'lumen' (derived light). The same terms were also, in more modern times, employed to distinguish between the natural (lumen) and psychological phenomenon (*lux*), as remembered by Ronchi (1983).

Light played a crucial role not only in Christianity, but in all the Semitic religions, most of all in their Gnostic tradition. The title of the basic book of Hebrew mysticism, *Zohar*, means 'light'. One of the most famous verses of the *Qur'an* is the 'verse of light', where light is the metaphor of Allah's knowledge and being as well, 'light on light'.

In St. Augustine's *Confessions*, Neoplatonic philosophy and Christian religion met, and ultimately darkness, as Evil, change, and falsity, became simply the lack of light, a privative term and a sort of not-being, opposite to the real substance, God, light, and being. This 'divine' light disperses the darkness, as God disperses Evil. In St. Augustine's theory of knowledge, the soul can grasp the eternal truths because it is illuminated by God, and this theme is easily adapted to Plotinus's view of creation as an emanation resembling the diffusion of light from a source of light. At the same time, light fills the space and is the queen of the colors.[4] However, light is also the door of temptation. This 'earthly' light, as 'matter', is a form of 'being', by which Sin and Evil, 'not-being', can enter the world of 'being'.

Religion preserves the double form of knowledge: faith revealed in the Book, source of the ecclesiastic hierarchy, and faith obtained by the mystic Light, wanted by monks and hermits. The universe is the realm of light and the place where the signs of God are written. However, in St. Augustine vision becomes the experience of created things and he preserves the two metaphors:

> Some people, in order to discover God, read a book. But there is a great book: the very appearance of created things. Look above and below, note, read. God, whom you want to discover, did not make the letters with ink; he put in front of your eyes the very things that he made. (*Sermo* CXXVI: 6)

For many centuries, during the Middle Ages, Islamic civilization preserved the remains of Greek culture. Actually Islamic scientists did something more: to Alhazen we can ascribe first, the idea of a finite speed spreading, second, a pointwise representation, with a 1–1 correspondence between points in the visual field and points in the eye, of the perceived object in the eye, overcoming the ancient 'holistic' approach, and third, the ultimate success of the idea of perception as passive, overcoming the ancient doubts, as pointed out by Lindberg (1978).

It is important to realize that for one thousand years, Islam and China were far stronger civilizations than Europe, not only from a military or an economic point of view, but also culturally and scientifically. Compasses, printing, gunpowder, which were changing European countries, came from the East, and so did new numbers and numerical algorithms. Slowly, however, sometime between the sixteenth and the seventeenth centuries, European civilization began to take the lead, in economics, in culture, on the battlefields, and, first and foremost, in science.

Optics in the Middle Ages was known as 'perspectiva', but its mathematical (from Euclid), physical (from Aristotle and the Atomists), and physiological (from Galen) aspects were regarded as distinct enterprises by the majority of scholars. A more unified approach appeared in Ibn al-Haytham (Alhazen) and the modern science of optics is usually ascribed to Kepler.

This foundation was intertwined with the birth of the new scientific method, which is the sine-qua-non condition for modern science and for us today is taken for granted, but is not trivial. Modern methodologists, ever since the eighteenth century, have always found great difficulty in founding de-jure the scientific enterprise, and have preferred a de-facto foundation, by the past scientific and academic practice or by the technological achievements: we believe in atoms (or in other 'strange things') just because we learn about them in school or because they mean cars, computers, and nuclear energy.

To make up a somehow 'objective, intersubjective, and theoretical truth', founded on empirical methods and mathematical language, the 'seeds' for continuous development had to be (i) faith in the mathematical expressibility of reality, and (ii) a sort of sociological and technological 'guarantee' that there are places (laboratories) in which to perform some pragmatical and perceptual activities (scientific experiments) in which some perceptual aspects (observations) are necessarily universally accepted, because they are intersubjective. The repeatability of such experiments, due to and granted by the modern industrial achievement of the idea of equality, has been thought sufficient, ever since the Renaissance, for scientific enterprise, though it was not an absolute philosophical guarantee, for it was based only on the equality in sign manipulation and therefore it was not 'sure' ground for the 'truth' enquiry.

A crucial point was the passage from 'experience' to 'experiment', and the new connection between 'eyes' and 'signs'. Slowly signs and symbols which played a great, and somehow 'final and causal', role in astrology and magic, began to be framed in the 'natural law', in which the causes lost their 'final' role and signs played a new barely representational role. The motion of the planets and the natural places of Aristotelian physics were connected in a framework which excluded sharp distinctions between (what we today call) ethic/finalist and material/causal aspects. Also the employment in astronomy of mathematical tools did not express consequences of natural laws, but was only an empirical way of representing a metaphysical being: the rationale was never to be found in purely physical causes and mathematical laws, but in the finalist structure of the world.

Before Galilee, 'experience' was a sort of real or likely everyday observation (motions on earth and in the sky, 'if a man and a fly carry the same weight ...'), whereas since Galilee 'experiment' has become a 'quantitative' and/or a 'thought' praxis (infinite smooth surfaces of infinitely decreasing slope, measurements of space and time intervals).

In the earlier works of Descartes (*Regulae ad directionem ingenii* XII) the experiment is not looking for the things in themselves (*res ipsae*), but rather for their geometrical representations (*compendiosae illarum quaedam figurae*), and this way 'extension' takes on a general role.

The passage from 'experience' to 'experiment' is the mark of the evolution of the idea of science as an 'asking' enterprise, as mentioned by Koyré (1966), in *which 'observing' is substituted by 'measuring'*, and the *physical entities are reduced to the numerical signs in the measurement process*, to *be matched with the signs occurring in the mathematical natural laws*. This can be clarified by recalling first that 'equality' does not exist among real objects, but is the basis of any 'sign manipulation', second that measurement can become the cornerstone of an empirical science only by the possibility of repetitions of the 'same' experiment under 'equal' conditions and with 'equal' experimental arrangements. Finally, to give a meaning to the word 'equal', measurements must be sign-based experiences.

The Renaissance and the age of the birth of modern mechanics are a 'sleeping' period for the antinomies of 'being' and 'light' which flourished in Greek culture. It is the time of Leibniz's 'preestablished harmony', granted by the role played by the soul and God in allowing a matching or a smooth distinction between natural causality and subjectivity.

In Descartes, the theory of light is not well established, but shows a strong mechanical aspect. The connection between light as a natural phenomenon and light as a subjective vision is granted by the 'pineal gland' where soul and matter meet. In addition, light plays a central role both in Descartes' cosmology and knowledge theory. Even the titles of his first masterworks are explicit: *La recherche de la veritè par la lumière naturelle, Le Monde ou le traitè de la lumière*. And the cosmological distinction among three kinds of matter (sun and stars, planets, skies) is based on their behavior with respect to light.

Newton's absolute space is at the same time God's sensorium and the reference frame of the application of the natural laws. In Leibniz, harmony is granted by the divine agreement between the two different worlds, the soul and mechanical nature. All different ways, free of antinomies, of overcoming the subject/object oppsition.[5]

This age of mechanical harmony is the background of an incredible development of physical optics from Grimaldi and Kepler to Newton, where light definitely gains a substantial and material nature, and at the same time its wave behaviors are recognized. Not only diffraction and interference, but also transmission through diaphanous matter and the very idea of continuity in the spherical distribution of light rays, together with the infinite propagation, are substantially incompatible with a purely corpuscular nature of light.[6] Colors are no longer simple properties of the object somehow carried by the rays, but begin to become aspects of light, of its particles or of its wave properties.

It is noteworthy that corpuscular phenomena are most of all connected with the interaction of light with matter and with human vision, whereas wave phenomena are first and foremost necessary to account for the spatial diffusion of light.

Whereas the 'negative judgement paradox' and the 'liar paradox' did not play a significant role till the end of the nineteenth century, when they flourished again with the paradoxes of set theory and with the metamathematical enterprise (Borzacchini 1995), the *ambiguous nature of light* *as source/object of knowledge will appear at the beginning of twentieth-century science under the headline of the 'measurement' problem.*

The role played by vision and writing as metaphors of knowledge throughout the Ancient and Middle Ages is played, in modern physics, by light as a basic tool for numerical measure and the measure as a base for syntactic knowledge. In fact *measure is just 'sign perception'* and then is based on light and signs as well. The link between light and measure is so strong that even if measurement is realized today by material particles, these have to behave as light. On the other hand *light is a basic constituent of reality* and must be described by syntactic natural laws. This other link between light and being is so strong that light rays must now behave as material particles.

Light must be at the same time an essential part of 'being' and a basic ground of 'sign-based measure', again object and source of knowledge as well.

Vision/writing and experience are substituted by *mathematical laws of nature, measurement, and experiment*, and the old *metaphor* becomes the new *method*. The last trace of the ancient metaphor is the name Enlightenment given to the eighteenth century, to mark the triumph of reason and scientific knowledge. However, visual and intuitive knowledge loses its earlier autonomy: *the ancient 'light' metaphor is absorbed in the 'sign' metaphor*, knowledge can be only scientific knowledge and must be progressively embedded in the 'realm of syntax'; God can know directly, but Man knows by signs.

This is Leibniz's *Ars Combinatoria* and the ancient philosophical lexicon becomes Algebra, Analysis, Logic, Computer Science, the earlier 'linguistic province' turns into a 'syntactic empire'.

At the end of the nineteenth century, light, as part of 'being', was an electromagnetic wave described by Maxwell's equations, by which it was possible to derive its constant speed; that is, the speed of light had to be the same in all the reference systems in which the equations held. This was impossible when assuming the physical laws as holding in all the inertial systems (i.e., those for which the inertial law holds), for there any speed is relative, according to Galileaian relativity. Hence Maxwell's equations had to hold only in an absolute space system.

However, this was excluded by the Michelson-Morley experiment, which made clear that there was absolute isotropy in the behavior of light, and therefore at last all the laboratories had to always be at rest in the 'absolute space' system, notwithstanding their embedding in the complex motions of the earth.

Fitzgerald and Lorentz then guessed a contraction in distances and a dilatation in times caused by the motion relative to the absolute space, in order to preserve the consequences of Maxwell's equation after the lack of experimental evidence of motion with respect to absolute space. Thus it was necessary to distinguish between the measured distances and times and the true ones, with the further embarrassment that the true measures could not be determined by experiments!

On the other hand, light, as a basic observation tool, was the basic ingredient of all the space and time measurements, due to their being centered on the idea of 'simultaneity'. An absolute simultaneity would require an infinite or a relative, but observable, light speed.

This opposition between the objective and subjective role of light was Einstein's starting point: he set out to show how Lorentz's transformations could be interpreted as giving the coordinates transformation rules of the moving reference system. Lorentz's and Einstein's relativity formulae coincide: the difference between them is that Lorentz's transformations, in Maxwell's tradition, describe the changes of absolute quantities, a pure ontology of light and moving bodies, whereas Einstein's approach deals with the epistemological role of light in the space-time measurements and relativity between inertial systems.

Special Relativity, by admitting the relativity of simultaneity, was suitable to match the natural features of light described by electromagnetism with the role it had to play in founding the measurement activity. The price to be paid was that the geometrical subject of classical mechanics could no longer be located in an absolute frame and could no longer distinguish between an empty geometrical space and the physical phenomena taking place there.

We recall that the epistemological connection between time and motion had been basic ever since Aristotle, who defined time as 'the number of motion according to before and after'. It is noteworthy that in the 'ontological' Fitzgerald–Lorentz theory the basic phenomenon was the foreshortening of the moving object (with respect to the ether), while in Einstein's 'epistemological' relativity the conceptual starting point was the relativity of simultaneity.

The Newtonian corpuscular model of light had slowly lost the battle against the wave model, and in nineteenth-century physics there was a sharp dichotomy between the 'wave' behavior of the light and, in general, of the electromagnetic radiation, and the 'particle' behavior of the material objects. Also other physical phenomena, such as the 'heath', had been reduced to this dichotomy, which appeared 'exclusive' and 'exhaustive' of the physical representation of nature.

Both models allow the representation of the temporal evolution of a light beam, but the 'wave' model is continuous, and the 'particle' model, conversely, is discrete; a 'particle' is 'substance', a 'wave' is a variable 'property' of an underlying substance. This difference and its effects can be illustrated by the classical 'two-slits experiment'. If a front of parallel waves hits a wall with two slits, beyond them there are two circular fronts centered on the slits, whose superposition produces interference phenomena, which are revealed on an intercepting screen as a succession of dark and light zones. If a beam of parallel particles hits the same wall with two slits, some of them pass through the slits, maybe deflected by local interactions, and can be revealed as individual events on an intercepting screen. Obviously there are no wave-interference phenomena between particles beams.

This harmony is broken in our century with the 'wave/particle dualism', which characterizes quantum mechanics. Experimentally, light and elementary particles display wave and corpuscular behaviors as well. That is, in quantum mechanics the dualism does not dichotomize the universe of the physical entities anymore, but, for any entity, dichotomizes its different phenomenical occurrences. Roughly speaking, both light and particles have a 'wave' behavior in their propagation and a 'particle' behavior in their detection. So, in the two-slits experiment, single detection events on the screen, for light and particles alike, are individual particle-like events. However, their statistical distribution, for light and particles as well, shows the typically wave-like interference patterns.

We could try to think that both light and electrons are some sort of little wave-packets, behaving like particles, but interfering as waves when in a very great number. This 'realistic' solution is actually impossible, for the two slits experiment achieved the same result, even when performed with a very low intensity, so that any individual wave-packets could not interfere with any other wave-packets. If our attempt to give a uniform, although mixed, model for light and objects were right, in this low-intensity version of the two-slits experiment, we should find on the screen the simple superposition of two single-slit experiment detection, which is not the case.

Hence, we have to stress that in quantum mechanics the dualism is not between different kinds of entities, but between different aspects of any entities. In the classical Copenhagen interpretation, more precisely, the 'wave' behavior characterizes the continuous evolution of the system in absence of observation events, and the wave features allow us to compute the probability of the results of a measurement event. The 'particle' behavior describes the discontinuous behavior of the system in a measurement event.

This is one of the most astonishing features of quantum mechanics: the 'autonomous' role of the 'observation', as a subjective event which cannot be reduced to a physical one. The very existence of a qualitatively different formalization for the observation process is something unthinkable in classic physics, where the observer can be completely ignored and completely amalgamated, pure 'soul' or another 'piece of matter' as you like, in the physical representation of the event, without affecting the natural laws, and this is the deep legacy of Leibniz' 'preestablished harmony'.

In quantum mechanics, on the contrary, we have two qualitatively different evolution laws for the system: the first is continuous, in absence of observation events, and the second is discontinuous, accomplishing a sudden 'reduction' of the wave-packet to one of the possible values/pure states of the observable magnitude, during a measurement event.

In classic and quantum mechanics, you can set the border between subject and object wherever you like. The difference is that in classic physics the two parts are *metaphysically different* (according to Cartesian body/mind opposition) but *physically homogeneous* (the same laws hold in the world and anywhere in the brain), whereas in quantum mechanics the two parts are embedded in *a homogeneous metaphysical approach* (neo-positivist reductionism), but are characterized by *different physical laws* (the Schroedinger equation and the wave-packet reduction).

This kind of complementarity between the wave and the particle behavior of the physical entities, between the 'spontaneous' and the 'measurement caused' evolution laws, is a basic feature of quantum mechanics, entailing also a set of relations between pairs of complementary physical magnitudes, such as position/momentum or time/energy, expressed in Heisenberg's 'indeterminacy relations'. According to these relations, the product of the errors in measuring two complementary magnitudes for the same system at the same time cannot be less than a quantity approximately given by the Plank constant.

In quantum mechanics the basic epistemological antinomy of light as object/source of knowledge extends its features to the whole measurement process, because *the role played by vision in the ancient theories of knowledge is now played by the sign-based measurement process.*

In the standard Bohr interpretation, 'complementarity' becomes a general principle, substituting the realistic, materialistic philosophy of classic physics. This had a certain effect on the physicists' community in the thirties. The most important criticism came from Einstein who claimed the 'incompleteness' of Quantum Mechanics in a renowned paper, containing the so-called 'Einstein-Podolski-Rosen experiment'. We refer to Jammer's reconstruction (1974) for more details, and here we give a short synthesis of the argument.

Einstein-Podolski-Rosen's necessary condition for 'completeness' of a physical theory is: 'every element of the physical reality must have a counterpart in the physical theory', while a sufficient condition for 'physical reality' is: 'if, without in any way disturbing a system, we can predict with certainty the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity'. It is noteworthy that the characterization of 'physical reality' is thus reduced to its epistemological acquisition without a measurement arrangement. It is interesting to confront such definition with the old Platonic one in the *Sophista*, in which the physical existence is characterized by its causal '*dinamis*', i.e., by its ontological, causal and potential behavior.

As well as these two 'explicit' conditions, many authors underlined the presence in Einstein-Podolski-Rosen's paper of other 'implicit' hypotheses, among which a 'locality' assumption, according to which anything done to one of two no longer interacting systems could not cause any changes in the other one.

Then, these authors outlined a thought-experiment which, in their opinion, proved the 'incompleteness' of quantum mechanics. A simplified version of the experiment is not difficult to sketch: let us suppose we have two particles scattered in opposite directions, and an observable A (for example, the 'spin' component along the x axis), whose knowledge for the first particle, for a conservation principle, allows us to know its value for the second particle. The same could be said for another observable B, that makes up with A an indeterminacy relation (for example, the 'spin' component along the y axis). The measurement of A for the first allows us to predict the value of the same observable for the second, which then must correspond to an element of the physical reality. The same could be done for B. Hence in the theoretical description of the second system there must be exact values of the two corresponding observables, for the second system cannot 'know' which observable has been measured on the first system. But this is impossible, because the second element, not disturbed by any measurement events and no longer interacting with the first, cannot have exact values of A and B simultaneously.[7]

In the 'EPR paradox' or in the 'two-slits experiment', the real trouble lies in homogeneously locating the measurement act in a mental image of the physical event. We see the particle behavior on the screen, and we cannot avoid imagining the particle flying before the impact through one of the slits, 'ignoring' the possible existence of the second slit. That is, the discontinuity of the 'knowledge' event in classic physics is 'saved' by its continuity in the 'mental' model. To deal with this 'mental' problem, most quantum mechanics theorists insisted on the 'wholeness' of the world, to avoid the necessity of a reasonable, functional mental representation (the 'physical reality') of the real world:

... the paradoxical results obtained by EPR ... will not be obtained if one avoids making their implicit assumptions ... that the world can correctly be analyzed into elements of reality, each of which is a counterpart of precisely defined mathematical quantity appearing in a complete theory. ... We assume that the one-to-one correspondence between mathematical theory and well-defined 'elements of reality' exists only at the classical level of accuracy. (Bohm 1951: 619)

It seems therefore impossible to define unambiguously the border between the observed system and the observer, although the measurement event must be described in 'classic' terms, while the observed system must be described in 'quantum' terms.

Bohm underlined that:

In fact, we can argue that the knowledge by measurement of the x-component of the spin for the first particle had, being accomplished in a classic arrangement, to allow us to compute, by classic arguments and correspondence principle, the knowledge of the same component of the second particle, which, in turn, had then to be also computed by the 'other', quantum-mechanical, way in the rectangle, for it commutes. But this is not the case according to quantum mechanics principle. If it were necessary to give all parts of the world a completely quantum mechanical description, a person trying to apply quantum theory to the process of observation would be faced with an insoluble paradox. This would be so because he would then have to regard himself as something connected inseparably with the rest of the world. On the other hand the very idea of making an observation implies that what is observed is totally distinct, from the person observing it. This paradox is avoided by taking note of the fact that all real observations are, in their last stages, classically describable. (1951: 584–585)

The 'critical' concepts of the EPR paradox concern 'locality' and 'individuality' principle in the syntactic reduction of our representation of the world.

Bohr's answer instead stressed the peculiar role of 'measurement' in quantum mechanics, as quoted in Jammer:

... the procedure of measurement has an essential influence on the conditions on which the very definition of the physical quantities in question rests. Since these conditions must be considered as an inherent element of any phenomenon to which the term 'physical reality' can be unambiguously applied, the conclusion of the above mentioned authors will not appear to be justified. (1974: 194)

The role of measurement is a crucial point in the 'Copenhagen interpretation':

The essentially new feature in the analysis of quantum phenomena is, however, the introduction of a fundamental distinction between the measuring apparatus and the objects under investigation. This is a direct consequence of the necessity of accounting for the functions of the measuring elements in purely classical terms ... the unambiguous account of proper quantum phenomena must, in principle, include a description of all relevant features of the experimental arrangement. (Bohr 1958: 310–311)

There is a sharp difference between Relativity and Quantum Theories, even though their flourishing ages are almost the same, and the philosophical aspects of this difference are only reflected in the Bohr-Einstein debate, and concern the thoroughly different relation of the two theories with respect to the measurement aspects involved.

The subject of Relativity is Cartesian, sharply distinct from the world, observed in a quasi-Cartesian 4-dimensional space-time framework, where light is the base of the time measurements. Measurement is based on 'clear and distinct' ideas and observations, and the physical magnitudes, though 'operative', are also the counterpart of ideas and concepts, whose center is a well-defined idea of 'reality'. The basic light antinomy is the idea of *light speed as 'substance'*, as described by Maxwell's theory, and its *Galileian relativity*, since it is a speed, i.e., a 'relative property'.

The subject of Quantum theory is phenomenological, part of a whole arrangement including measurement and physical systems, with a clear distinction of roles, but without definite borders between the two different systems. Here light displays its wave/particle duality, i.e., it is *part of reality and a basic ingredient of knowledge* as well. Consequently, the very idea of 'reality' and, more generally, models and ideas play no role at all.

Here we find the same antinomies we revealed in the classic Greek philosophy. The ancient subject was the *'seeing' and 'theoretically knowing' subject*. The subject of modern physics, in relativity and quantum mechanics as well, is the *'measuring' and 'syntactically knowing' subject*, i.e., a subject which knows by observing the signs on the measurement instruments, and by computing algebraic formulae, i.e., a subject which knows by manipulating the signs in the equations expressing the natural laws.

On the other hand it is also an object, a part of nature, and then its syntactic activity has a 'natural' aspect as well.

From Plato to classic physics these two facets did not interfere at all. A sort of transparency and neutrality of the observer was a postulate, and this was necessary to avoid skeptical arguments. The same nature laws hold throughout the whole knowledge enterprise. In modern physics, as in pre-Socratic philosophy, the observer is a mouse in the cheese: he cannot be indifferent.

The old mutual autonomy between the subject and natural law, granted by the soul, saved the epistemological coherence, which breaks down in quantum mechanics in two different laws: the first, Schroedinger's equation, describes the continuous evolution of a physical system unscathed by measurements, the second, the wave packet's reduction, describes the discontinuous change of the physical system after a measurement process. The true distinguishing feature of measurement among the other physical processes is the presence of the knowing subject. It cannot avoid being a discontinuous description, because the knowledge act has always been an intrinsically discontinuous act reducing something to a word or a sign: 'Oh, now I see that the spin is $+1/2$!'

The last criticism of Einstein simply advocates that coincidence between 'real being' and 'being knowable', which was safe in classic mechanics, because the soul was out of the cheese and shared, under Leibniz's syntactic proviso, a divine and absolute knowledge.

The subject is again where Aristotle found it: at the same time 'seer' of external objects and 'affected' by external sensations. Nothing strange, therefore it needs two different equations, one concerning the real world without subjects, the other concerning the subjective knowledge.

More than two thousand years ago Greek philosophers had difficulty placing vision and light between subject and object. After a few centuries of harmony and sleeping of paradoxes, again the ever-lasting antinomies and pre-established disharmony frame our knowledge enterprise. Our eyes are always the gates to the never-ending play between the subject and the world:

> Mine eyes have drawn thy shape, and thine for me/Are windows to my breast, wherethrough the sun/delights to peep, to gaze therein on thee (Shakespeare, *Sonnet 24*)

Notes

1. Snell (1978) stressed the frequent 'medium' aspect of these perceptual verbs used to express a strong involvement. Such an aspect can be found also in our modern languages in sensorial verbs like 'taste', which can mean either 'to recognize a flavor' or 'to have a flavor', or analogously 'smell'. In these uses, sensorial phenomena seem to be something in between the 'subject' and the 'object'. It is noteworthy that in modern languages this feature more easily affects 'secondary' senses, such as 'taste' or 'smell', than primary ones, such as 'sight' or 'hearing'. The progressive emergence of the subject/object opposition in light and knowledge theories is underlined by Luther (1966). It is noteworthy that in Chinese culture the subjective model of vision never appeared. This could be connected to the absence of sharp grammar categories in archaic Chinese and of a true subject/object epistemological problem in Chinese philosophy.

2. For example in *Theaetetus* 188e the paradox is compared with 'if somebody sees something, but sees nothing'. The problems were to be found in theoretical and practical aspects as well. Thus, there was great confusion among the different mental aspects, for example knowledge and behavior. In the dialogue *Gorgias*, the statement 'who knows justice is just' seems to be universally accepted (460b–461b). One of the most relevant related problems was the 'learning' or 'searching' debate. It showed a 'paradoxical' aspect, to be embedded in the general 'negative judgement paradox': if you do not know what you want to learn or search, you do not know how and where to learn or search, if you do know it, you need not learn or search; a question which is relevant not only theoretically but also from a more 'practical' aspect: can virtue be learned and taught? (*Meno* 80e).
3. In Alcmaeon, Homer, Xenophanes, 'to know' is basically 'to see'. Hyppocrates, as Galen states (*DK* 88 B 39), used *aisthainesthai* (to perceive) to mean *gnomé* (to know). Antiphon (480–411, sophist) says that: 'What is, is seen and known always, what is not, is neither seen nor known' (*DK* 87 B 1). Aristotle in *De anima* 427a21, and *Metaphysica* 1009 b12, says that the ancient philosophers reduced thought to sensation.

   In *Republic*, as well as many analogies between vision and knowledge (the myth of the cave, the idea of 'good' as the sun, ignorance as blindness, dialectics as sight) there are explicit identity statements (between existence and knowledge, 477a, between science and sight and hearing, 477c). Probably the *Theaetetus* is the first philosophical text where we can find a sharp difference between vision and knowledge.
4. This metaphysics of light will recur in the following centuries, as in Grosseteste's writings (twelfth–thirteenth century), where light was the first form to come to primary matter and all changes stemmed from this basic form. Light spreading was still Aristotelian in that it was a propagation of 'species', but was new in that it was based on a multiplication of geometric rays. It is noteworthy, that his disciple Roger Bacon gave a completely passive theory of light, of something psychological leaving the eyes in the vision process. According to Nicholas Cusanus vision is compared with knowledge at every step, preserves a mixed subjective/objective status and remains the basic antinomy according to which 'light's brightness overcomes vision ... therein light does not seem visible, but appears invisible' (*De apice theoriae*).
5. The ancient relativism of Protagoras concerning (perceptual) knowledge was based on examples such as drunkenness or illness. In Witelo's 'perspectiva' (thirteenth century), instead, the new sharp distinction between subject and object means that relativism is to be ascribed to the fact that perceived motion was only relative. Another aspect of the same change was underlined by Grosseteste who implicitly introduced as relative aspects of perception the new distinction between primary qualities (in which perception is substantially intersubjective insofar as it is passive) and secondary ones (in which relativism cannot be excluded and that must then be excluded in science).
6. In Kepler the 'infinite' appears in optics: infinite are the rays from any point, infinite is the length of the ray, infinite the speed of the light. It is noteworthy that Nicholas Oresme, at the beginning of the graphical representation of qualities in the fourteenth century, believed that the intensity of light (*lumen*) was a uniformly decreasing quality, and thus it had to vanish at some distance from the source, even though Johann Dumbleton was aware that the relationship had to be more complex.
7. We could compare the paradox with an ancient antinomy linked to the 'justification of evil'. When Christ forecasts that one of his Apostles is going to betray him, he cannot be wrong. So, either Judas cannot repent and change his mind, or, if he can because of his free will, suddenly another Apostle, wherever he is, must decide to betray Christ.

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