Unusual Rainbow. Images and Projections Between Art and Science

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Abstract. What do have in common a friar lived in the XVII century, a contemporary American artist belonging to the land art movement and an Italian structural engineer become famous between the two world wars? The answer can be certainly found in the common scientific approach of the three authors, but more precisely in their shared passion for the natural phenomenon of rainbow. The paper focus on the contextualization of studies relating to this atmospheric phenomenon - investigated since the classical period - considering its depictions in the history of science and art. Among the protagonists of this story, whose approaches are between aesthetic researches and natural philosophy, we find the friar Emmanuel Maignan (1601–1676), a scholar of optics and author of one of the most important gnomonic treatises of the Baroque period. From 1980 the artist Charles Ross had used big glass prisms, precisely oriented, to project the chromatic spectrum inside architectural scale installations. Finally the engineer Arturo Danusso (1880–1968) developed in the early decades of the 1900s a method for evaluating the tension stress of reinforced concrete structures based on photoelasticity. Beyond the examination of the heterogeneous uses of rainbow in art and science, the paper also intends to focus on the relation between light and optics assumed as an 'universal method' for investigating natural phenomena during the centuries.

Keywords: Optics · Knowledge Images Learning · Visual Simulation & Modeling Learning · Art and science

1 Optics and Rainbow in History

The first description about the functioning of rainbow phenomenon can be found in the III century b.C. in the work of Alexander from Afrodisia (200 b.C.), he considered the rainbow as a combination of light and colors, but he didn't established a precise law. Aristotle (384–322 b.C.) was the first who suggested to consider the formation of rainbow directly connected to the optical laws. In his treatise Meteorologia the philosopher affirmed that the sight, compared with all other senses, is the only one that permits the perception of colors; other elements perceived by our sight, such as the shape of objects, could be known by using our touch as well. He studied the reason of the second rainbow - sometimes visible in the sky - and at the end of his analysis he concludes: first the center of rainbow is always between the observer's position and the sun, second its shape is an arch of circumference never bigger than an half-circle and third the rainbow is caused by the reflective power of rain drops, able to show only three colors [1]. Seneca, who lived in the first century a.C., in his book *Naturales Quaestiones* explains that the rainbow comes from a reflection of sun rays on the rain drops. He affirms also that is possible to see it within a cylinder of glass crossed by a ray of light. Even if the theories of these authors were not precise about the difference between reflection and refraction, they influenced the researches about this topic until the 18th century, highlighting the relation among optics, light and rainbow.

During the Arabian Middle Age some researchers like al-Fārisī who lived in the 13th century, start to consider the colored arch in the sky as the product of reflections and refractions, according to the theories exposed by the mathematicians Alhazen in the 10th century in his treatise about Optics. Well known is the work of Alhazen, published by Friederick Riesner (1533–1580) in Basil in 1572 under the title *Opticae Thesaurus*. In its frontispiece, among many optical phenomena, it is represented even a rainbow in the background. The Arabian science influenced the middle ages latin culture, for example Roger Bacon (1214–1292), following the theories of Robert Grosseteste (1175–1253) about reflection and refraction, affirmed that the rainbow can be considered the basis of an imaginary cone whose vertex is the sun and whose axis is the line connecting sun, the observer's eye and the center of the arch. Finally, in the same period, the most precise description of this phenomenon is given by Teodorico von Freiberg (1250–1311), similar to the one assumed in our times: using a big sphere filled with water - like a big drop of rain - he experimented that the colors were produced by two refractions and one reflection. In the Renaissance period the rainbow was studied by other authors like Giovanni Battista Della Porta (1535–1615) or Marco Antonio De Dominicis (1560–1624). Moreover it started to appear in the frontispieces of treatises about optics and physics (Fig. 1) or in the engraving *Melancolia I* by Albrecht Dürer (1471–1528) because of its symbolic and mystic implications [2].

Teodorico's experiment was carried out in the baroque period by René Descartes (1596–1650). Using the sphere filled with water he was able to calculate that the colors appeared when the angle between the axis and the generatrix of the imaginary cone of light is around 42°. Descartes became famous for the codification of the refraction law, today known as Snell-Descartes law. Thanks to an instrument of his own invention, composed by a board with a hole covered with a glass prism, he was able to observe the appearance of different colors depending on the inclination of the source of light. Descartes was really fascinated by the magnifying power of lenses so that the last chapter of his treatise *La Dioptrique* is completely dedicated to the description of grinding machines for the production of these tools. In a letter written to an artisan, a lenses maker, he expresses his will to demonstrate the existence of alien life in the solar system using telescope or the possibility to project messages on the surface of the moon by employing light and lenses. More generally Descartes was able to develop a theory about light, reflection and refraction using a geometrical and experimental method.

Less than one century later Isaac Newton (1642–1726), with the experiment of the prism, demonstrated that the white light is composed by the seven colors of the rainbow, each of them characterized by a different wavelength [3].

Fig. 1. J. J. Scheuchzer, *Physica Sacra* (1731), tab 46: Iridis Demonstratio.

2 Emmanuel Maignan. A Rainbow for a Sundial

In a recent research I focused on the digital reconstruction of an unrealized project for a scientific villa designed by Francesco Borromini (1599–1667) around 1644 for Cardinal Camillo Pamphilj [4]. I'm referring to the actual Villa Dorja Pamphilj, that was finally built following a totally different project conceived by Alessandro Algardi (1598–1654) and Francesco Grimaldi (1606–1680). The documents on this topic are gathered in the Vatican Library and in the National Archive of Rome. These sources are both graphic and written: the graphic materials are constituted by the blueprint by Francesco Borromini, a plan and a symmetrical façade in two solutions. The literary documents include a handwritten in Latin by the monk Emmanuel Maignan (1601–1676), where 21 scientific games are described and conceived to decorate the villa. The games by Maignan represent investigations on Optics, Gnomonics, Void existence, Acoustics, Astronomy and so on with the typical geometrical approach of that time. The French friar Maignan, belonging to order of Minims, spent a part of his life in the convent of SS. Trinità dei Monti in Rome from 1637 to 1650. In the corridors at the first floor of the cloister he traced the portrait of S. Francesco di Paola in anomorphosis and a catoptric sundial. In 1648 Maignan realized a similar clock for Bernardino Spada (1594–1661) in its palace Capo di Ferro. Thanks to a small mirror positioned on the windowsill is possible to read the time observing the reflected sunray moving on the ceiling where the hours line have been previously calculated and traced. In point 6 of Maignan's handwritten for Villa Pamphilj, reconstructed with digital tools combining Borromini drawings and Maignan's description, the monk refers to the realization of a catoptric sundials on the vaults of two angular towers, the same solar clocks he really built in Trinità dei Monti and in Palazzo Spada.

The monk writes: "On both the vaults of the northern towers and the wall around, through the art of catoptrics it will be put a device indicating whatever concerns both the motion of sun and stars, thanks to the reflection of a sunbeam. Likewise, in the same place two mirrors will be arranged so that on the wall or on the vault a perpetual iris will be produced. The rainbow will have to indicate the parallel where the sun will be and thus it will show single places, such as cities or regions where the sun will reach its zenit that day" [5].

Maignan thinks to align the geographic places of the world where it is possible to know the astronomical midday, along the projection on the spherical vault of a perpetual arch of light obtained through a tool called *Iride Horariae Dioptricae*, shown in the fourth book of his treatise about gnomonic entitled *Perspectiva Horaria* (1648) [6]. In other words, the position of the arc points out the parallel where the sun is located, it changes in the course of the year, indicating each day the places where the star is at its zenith. In the clocks of Trinità dei Monti and Palazzo Spada, these locations are more simply arranged along a line marked in a dark color. Book IV of *Perspectiva Horaria* is therefore entirely dedicated to the explanation of how to achieve these refraction sundials, but not only: Maignan speaks about the theme of the *iris*, produced this time by an instrument called *Iride Horariae Dioptricae*, the Father states: "The reflected light shows only the whiteness that is typical of its nature, instead when it is refracted according to the way and the amount of refraction, it becomes yellow, green, purple and blue, …".

The digital simulations necessarily lead back to point 6 of the manuscript for Villa Pamphilj (Fig. 2). Fixed the planar gnomonic mirror on the windowsill, we will see an arc of a refracted circle of light, decomposed in the rainbow colors, intersecting the cone of light refracted with a cylinder of a transparent material (Fig. 3). Briefly it is once again a problem due to the conical sections, already explained by Apollonius of Perga in the II century b.C., no more connected to abstract geometrical object but to astronomical phenomena. Maignan uses his devices to create sundials but also to study the nature of light and the way it spreads around.

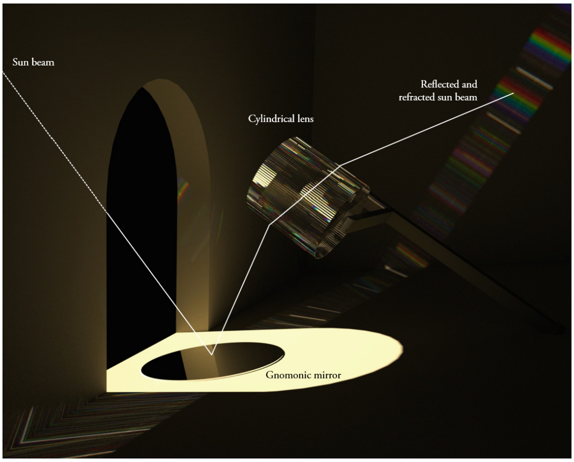

Fig. 2. Explanation of Iride Horariae Dioptricae by Maignan (digital reconstruction by A. Bortot).

For Maignan the value of *Iride Horariae Dioptricae* is not only related to scientific experiment or to the art of wonder, but also to symbolic and religious interpretation of light, as it will be explained in the conclusion of this paper.

Fig. 3. The projection of the rainbow using the device described by Maignan (digital reconstruction by A. Bortot).

3 Charles Ross. Tangible Rainbow

Charles Ross is an American artist born in 1937 with a bachelor of arts and mathematics. He belongs to a generation of artist, defined minimalists, whose works are based on natural phenomena and interaction with the landscape in order to produce precise perceptual effects. Among the artworks we can quote Larry Bell's vacuum chamber, Donald Judd's Plexiglas boxes, Robert Morris's mirrored cubes; Robert Smithson's inverted mirrored pyramid, John McCracken's fiberglass sculptures, Dan Flavin's fluorescent light bulbs, Robert Irwin's white circular aluminum discs, etc.

Since 1971 Ross has been creating in New Mexico desert an earthwork known as Star Axis, which is a naked eye observatory, a huge sundial and an architectonic sculpture. The Star Tunnel is the central element of Star Axis and it is precisely aligned with the earth's axis. In 1993 he realized *Day Burns: Solstice to Equinox*, a series of canvas obtained with some magnifying lenses able to burn the support thanks to the exposition to sun rays. Starting from the end of the Sixties, fascinated by the refraction of light, he started a series of sculptures called Prisms. These geometric transparent objects produce into the observer effects of reflection, distortion, fragmentation and dislocation. According to Klaus Ottmann "these objects do not refract light as much as they provide an experience of relativity by containing or presenting various perspectives. Through them the world can be observed simultaneously from several sides or moving at different speeds" [7].

His relation with architecture is highlighted by the installation with large-scale glass prisms used by him to project rainbows. The spectrums continuously evolve throughout the day, expanding into bright white light or contracting into brilliant bands of solar color moving through the space. For example in 1996 he realized the Dwan Light Sanctuary, in collaboration with the architect Laban Wingert (Fig. 4). The building is provided with 24 large scale prisms specifically aligned with the sun to project different and precise spectrum events for every season. The inner circular white plaster space is aligned not only with the sun, but also with the moon and stars in order to focused on specific seasonal events like winter and summer solstice, equinox, midsummer, midwinter, etc. The 24 prisms produce changing solar-spectrum events that circulate across the walls and floor during the day, and lunar spectrums at full moon. The relation between architecture and artwork offers to the visitor not only the experience of color and light, but also time. The aim of the artist is to connect human beings with the laws of the universe, that's why

Fig. 4. Rainbow projections inside the Dwan Sanctuary. © 2021 Charles Ross Artists Rights Society (ARS), New York

Ross's ultimate goal is to create a nexus of solar spectrum artworks around the globe so that as the spectrum sets in one location, it is always rising in another.

Considering the aforementioned sundials by Maignan some unexpected analogies rise up with the work of Ross: first a common will of transporting an open air phenomena - the one of rainbow - inside a close chamber and second the idea of using the solar spectrum as a witness of time passing. It is also significative the use of rainbows for a Chapel, according to his thought in fact, light is able to elevate spirits, regardless of a specific religion.

4 Arturo Danusso. The Rainbow of Structures

Arturo Danusso (1880–1968) have been an Italian engineer and one of the protagonists of the history of structural engineering in 20th century. The specific history of construction is quite interesting because, before the two world wars and then during the reconstruction, there was a prolific generation of engineers able to achieve a world celebrity. To support this statement we can say that the peak of this success is well represented by the great number of Italian project exposed in 1964 for the "Twentieth Century Engineering" exhibition at the Museum of Modern Art in New York. The Italian structural engineering was a part of the Italian Style trademark, widely recognized thanks to the ability of producing technologically advanced object with a handcrafted characteristics. It also significant the huge number of patents requested during the reconstruction of Italy after the second world war, for example the one by Pier Luigi Nervi (1891–1979) for his invention of ferrocement [8]. In the same topic of patent we can also mention the researches by Gustavo Colonnetti (1886–1968) about the elasticity and the application of prestressed concrete. The importance of this 'Italian school' is not only connected with realization of innovative structures (bridges, big domes, hangars, dams, skyscrapers, etc.), but also to original methods for the calculation of the projects. Colonnetti had an analytical approach, while Danusso preferred an empirical one. More in detail Danusso developed a theory formulated at the beginning of 1800 by the physicist Dawid Brewster (1781–1868) and later applied to structural calculation by Augustin-Charles-Marie Mesnager (1862–1933). The method, called Photoelasticity, experimentally determine the stress distribution in a material under mechanical deformation. Illuminating with a polarized light a semi-transparent (i.e. made of polycarbonate) maquette of a structure with loads applied is possible to observe the tensional states of stress in form of colored isostatic curves [9], (Fig. 5). Danusso preferred this optical approach to the analytical one because he thought that mathematical methods at that time were unable to evaluate all the forces in a reinforced concrete structure. In 1931 he founded the 'Prove modelli e costruzioni laboratory' at the Polytechnic of Milan and ISMES (Istituto Sperimentale Modelli e Strutture) in Bergamo in 1951, until the seventies these laboratories became a worldwide reference for structural analysis. Beyond the technical application of Photoelasticity, it is interesting to consider the role of light in this approach explained by Danusso: "The method uses the most subtle and attentive of observers, giving it the task of inspect the stress tensor in every point. The structure is represented by a transparent model: the light polarized ray, obeying to our orders, penetrates it; it puts in contact for a moment its own vitality with the most intimate parts of model, tormented by efforts comparable to those that the real construction will have to sustain; then the ray goes out and loyally describes on the screen, with an elegant succession of shades and hues, everything that he has seen" [10].

The passage highlights a humanistic approach to science, Danusso in fact, like all his colleagues of that period, was influenced by the neo idealistic philosophy by Benedetto Croce. He was also a fervent catholic and in its lectures he usually refers to the physical order as an analog mirror of the moral order and outlines suggestive analogies between mechanics and life [11].

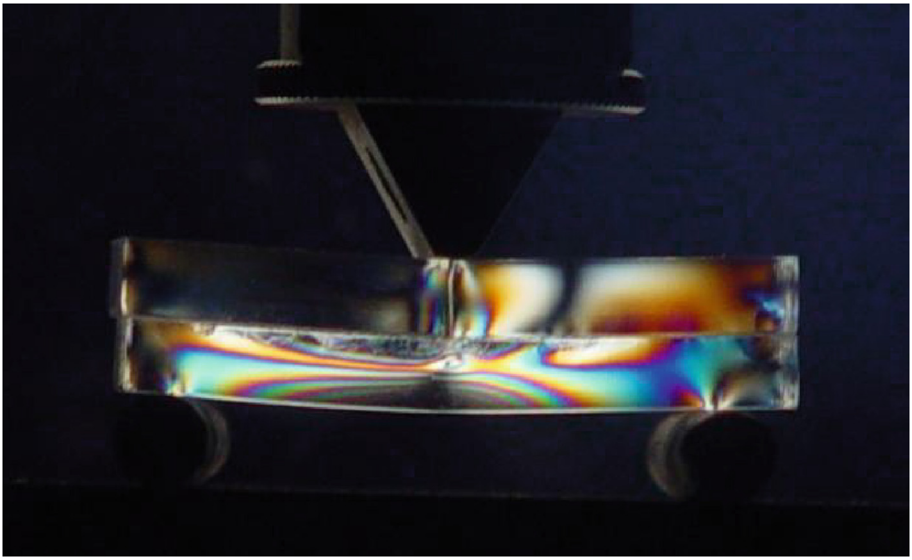

Fig. 5. Example of isocline on a prism made of plexiglass (Photoelastic stress test by Elena Sperotto).

5 Conclusions

The essential history of rainbow, described at the beginning, highlights the great curiosity for this meteorologic phenomenon, but also the complexity of its explanation considering the relation with the nature of light and to refraction law. We didn't mention the great fascination for rainbow reflected by mythological tales and literal works during the centuries. We can observe that the historical experiment and researches about light have a strict relation with the concept of projection before this method became a form of geometrical representation. The relation between light and optics is also highlighted by a similar physical behavior of light and visual rays, probably is not for chance that the studies about rainbow have been geometrically conduced combined with sight perception. The investigations in this field start to become artwork - and no more experiments - in contemporary time reproducing a physical phenomenon thanks to the control of reflection and refraction laws. The three protagonist of this story, even if belonging to different historical period and with completely different personal interests, are joined by the unveiling role of light. It looks like a religious man, an artist and an engineer recognized the value of light as a primordial element and a spiritual representation. Another monk belonging to the order of Minims, father Marin Mersenne, quoting San Paolo, affirms "everything that appears is light" but "as our eyes are too weak to bear its glow, colors are offered to us to appreciate its perfection" [12]. This affirmation underline the divine nature of light and the inability of man to tolerate its image if not broken down in its spectrum of color.

We can state that light - and so rainbow -, is one of natural phenomena that most attracted scientists and artists, marking in this way the short distance between these two areas of research and expression. In Greek mythology the goddess Iride was born from the relation between Taumante (son of Earth and See) and Elettra (daughter of Ocean); Iride is symbolically considered the intermediary, the one able to connect Night and Day, Earth and Sky, Gods and man.

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