ARCHAEOLOGY OF THE POSTPHOTOGRAPHIC IMAGE. PHOTOGRAMMETRY, PHOTOMETRY, AND THE POST-OPTICAL REGIME (IN NINETEENTH CENTURY ASTRONOMY)[1]

Barbara Grespi

If we persist in thinking of photography as the recording of a visual act, we should surrender to the idea of its decline. Even the simplest digital snapshots, those taken with a smartphone, are no longer reproductions of the human gaze, but an enhancement of it beyond our perceptual limits; the High Dynamic Range system (HDR), set by default on the cameras of all mobile phones, is based on an algorithm which merges into a single shot three different photograms each with different "exposure" so as to obtain an image totally in focus, which has no correspondence with the physiology of the human eye. Sensors and algorithms, today at the basis of any photographic process, do not simulate our way of seeing but accustom us to a gaze that is less and less embodied in our corporeal specificity. Front cameras integrate depth sensors which, unlike us, see our face in infrared and use these "latent" images for facial recognition, while relying on an algorithm that simulates the variation of aperture of a diaphragm to adjust the blurring of the background and create "portraits" that enhance our perceptual parameters.

This is the photographic territory in which we operate every day as a result of the «second digitization», if the algorithmic turn that completed the digital revolution can be defined like this[2]. The term *postphotography* was used from the outset to signal the transition taking place[3], and even in the face of the current panorama, sharper and diversified, it continues to work, if only because it conceives the gap between the latest and earliest technical images within an underlying continuity.

Rather than construing the advent of algorithmic photography as a rupture in the history of technical images, the following pages explore a possible genealogy of the photographic

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2 This is the turn focused on by R. Eugeni, *Capitale algoritmico. Cinque dispositivi postmediali (più uno*), Scholé, Brescia 2021. On the idea of the second digitization see M. Carpo, *The second digital turn. Design Beyond Intelligence*, The MIT Press, Cambridge, Massachusetts/London 2017 (esp. pp. 70-71).

3 J. Fontcuberta, *La furia de las imágenes. Notas sobre la postforografia*, Galaxia Gutenberg, Barcelona 2016 (it. transl. *La furia delle immagini. Note sulla postfotografia*, Einaudi, Torino 2018).

as an act distinct from human vision, the parameters of which it does not simulate and which it does not aim to empower. This conception developed at the end of the Nineteenth Century with the appearance, in the realm of science, of photographs with special semiotic characteristics, and with the interest in the act of taking pictures, understood as a human gesture and image-making technique.

The role of the eyes, hands and body in the current photographic act is explored in the opening section, which examines the way in which the design of contemporary devices progressively uncouples photography from the gaze and ocular perception, while anchoring the image to the hands and other parts of the human body. This relationship between the corporeal, the technological and the iconic re-emerges from the deep history of photography, and in particular scientific photography, which since from the origin interprets the medium rather than as an extraordinarily accurate instrument of representation, as a technique for measuring and quantifying the entities and spaces of the world[4]. In late Nineteenth century, photography, or its fundamental principle, was used to obtain the exact dimensions of individual bodies (Alphonse Bertillon's anthropometry), of buildings (photogrammetry, perfected by Albrecht Meydenbauer), of stars (photographic photometry), of the human skeleton (X-rays). As Harun Farocki suggested in his *Images of the world and the inscription of war* (1988), the numerical conception of the image does not derive from the advent of the digital system, but appeared together with the first technical image, within a genealogical line that understands photography as a repository of exploitable data and practices it in order to extract them. Farocki alludes to photogrammetry but, as mentioned, this practice is part of a wider constellation of techniques that developed at the same time in different fields and are characterised by a common "photometrographic" vocation.

The second section delves into this territory by reconstructing the method of photogrammetry in its celestial context, that is astronomy, a field in which the gesture of taking pictures is integrated with the observation but at the same time profoundly transformed. Thanks to the online accessibility of the Harvard Observatory's archive, the first astrometric techniques based on photogrammetry can be traced back; there the hands measure the figure that the eyes perceive through the telescope, giving due weight to those factors which disturb perception.

Nevertheless, errors were reduced in a significant measure only when photography was associated with another astrometric practice, which belongs to a different "economy of light"[5]: photometry, the subject of the following section. Whereas photogrammetry has a male history (in which there also features the father of cognitive semiotics, Charles Sand-

4 The idea of the image as a measuring tool, based on Cassirer's idea («the principle of the "primacy" of the function over the object») is explored by Hoel, who connects it to Farocki's concept of *operational image*. See A. Sissel Hoel, *Images and measurement across art and science*, in 2014, "Cassirer Studies", V/VI-2012/2013, 2014, pp. 157-185. On photography as a descendant of metric procedures dating back to the Renaissance see T. Dvořák, J. Parikka, *Measuring photographs*, "photographies", 3, 2021, pp. 443-457, and T. Dvořák, *Beyond Human Measure: Eccentric Metrics in Visual Culture*, in T. Dvořák, J. Parikka (eds.), *Photography Off the Scale. Technologies and Theories of the Mass Image*, Edinburgh University Press, Edinburgh 2021, pp. 41-60.

5 R. Eugeni, *Capitale algoritmico*, cit., pp. 68-70.

ers Peirce), photographic photometry represents an all-female genealogy of the digital: in the hands of the famous women «computers», traces are translated into numbers, and care of the matter merges with calculation. This is the phase in which the human eye loses importance and stops being the major mediator of the photographic process. Finally, with the application of photography to spectroscopy, the way of understanding the film negative also changed: being no longer a scheme for the star's appearance, it becomes a mere archive of information not pertaining to the visible. Photography turns simply into a method for collecting the signal, fully equivalent to many others (based on acoustic, thermal, magnetic waves), and the translation of the negative into an image already sounds like a prelude to contemporary techniques of visualization.

Finally, beyond the "numerical" practices of the negative, the archaeology of the postphotographic may also include theories of the traces which matured in the same context. Peirce's trichotomy of sign, based on the distinction between index, icon and symbol and formulated at that very moment in time in which the forms of photography more distant from the mimetic idea were being experimented, reveals itself particularly useful to demonstrate the photographic nature of many algorithmic images. The concluding section is devoted to this, although it is limited to introducing the terms of a future reflection, towards a theory of postphotography as a sign which disconnects the iconic from the visual act.

Postphotographic gestures

The link between eye and hand in the act of taking pictures is an implicit question in many classical theories. According to André Bazin, photography is the «first image not made by a human hand»[6], because hands do not trace, mould, or inscribe figures into matter. It is clear what André Bazin meant at the time – the very possibility of a technical image – because, taken literally, his definition exposed itself to contradiction, since the hand in reality did play a role, albeit minimal.

In Bazin's time, the photographic gesture consisted of a specific articulation of the two organs: the eye aimed, selected, and framed, while the hand chose the instant in which to delegate agency to the device. The most creative aspect of the process was implicitly attributed to the gaze: "to shoot" meant being able to see, bringing the pupil closer to the lens to create full continuity between eye, glass, and image. This made photography an optical image, that is, based on a combination of lenses designed to model human sight and transfer its scheme to a fixation support[7].

For the last two decades now, i.e., since the camera was installed on smartphones, the gesture of taking pictures has changed significantly in the common practice of the medium.

6 A. Bazin, *Que'est ce-que le cinéma*, vol. I, Èditions du Cerf, Paris, 1959, engl. trasl. *The Ontology of the Photographic Image*, in *What Is Cinema,* vol. I, California University Press, Berkeley 1967, pp. 9-16.

7 Kittler recognizes a genealogy of optical devices, tracing for instance a continuity between camera obscura and microscope. See F. Kittler, *Optical Media*, Polity Press, London 2010, p. 72.

Now the hand adheres to the image instead of the eye: the image is contained in the palm of our hand, or between our hands, and is created through the movement of wrists and arms, which adjust the screen to set the borders of the frame, while the eye merely checks at a distance. With wearable technologies characterizing our narrow contemporary world, this gestural model becomes more pronounced with a further weakening of the role of the eye; photography becomes a mere manual gesture, almost a tic or an automatism. Ray-Ban Stories smart glasses, born of the encounter between the worlds of optics (EssilorLuxottica) and virtual (Meta), are a camera permanently worn on the face, like a pair of glasses. The two cameras set in the corners of the frame are activated simply by touching the right temple, thus without having to stop the flow of life to hold an instrument and concentrate on the shot. The conquest of the maximum "spontaneity" of the shot is associated with the loss of discipline of the gaze: in the absence of lens and display[8], the eye moves freely within the profile of the frame, while it is the body that has to discipline itself by learning the new gestures of photographing, such as bringing the right hand above the ear and pressing or tapping on the temple with the index finger. Despite the fact that eyes and lenses have returned to close contact, the reinterpretation of the photographic gesture in smart glasses confirms the subordination of the gaze to the hands that began with the use of the smartphone as a camera, and even accentuates it: the hand does not take action guided by the eye but chooses the instant on the bases of a mere reflex. Its instinctive reaction to the visible creates an initial iconic matrix, which then through software (Facebook View) is brought to resemble what the eye believes, or wishes, it had seen.

Finally, even in a project on the edge of the photographic such as *This Person Does Not Exist* by Philip Wang, based on the StyleGAN algorithm developed by Nvidia in 2008, the automatic, but ultimately "creative" gesture of the user's hand survives. On the popular website, photographic portraits which are perfectly believable, but do not correspond to any living being, are created by artificial intelligence as each visitor passes by: through the generative adversarial network system (GAN), the machine extracts *the codes* of photography from the database that feeds it, until it learns to "speak" that visual language[9]. The algorithm generates faces by drawing features that do not exist but represent a set of probabilities calculated by the database; the portraits thus exhibit a form of *potential resemblance* to real people, a resemblance derived from the mathematical analysis of a massive quantity of photographic traces; but beyond all this, it is not irrelevant that the composition of the faces still depends on a human gesture that "causes" the image, that is, on the click of the mouse that loads the web page generating the picture, one for each user, one for each press of the finger. The apparent spectator thus assumes the role of the photographer who activates the last and most extreme automatism of the machine with his finger, "shooting" a picture that freezes, ultimately, the instant of its passage on the page.

8 The lenses of the glasses become screens only in the augmented-reality version. In the simply photographic one, for example in the Spectacles model, they are only transparent surfaces with vision correction.

9 A. Somaini, *L'impact de l'intelligence artificielle sur la culture visuelle contemporaine,* in A. Pinotti, A. Somaini, *Culture visuelle. Images, regards, médias, dispositifs,* Les presses du réel, Paris, 2022, pp. 367-377.

Rather than interpreting the centrality of the hand in the postphotographic gesture as a symptom of the newly born culture of the fake, the following sections will present it as a possible re-emergence of one soul of photography overshadowed by the medium's historical trajectory[10]. Photography has always been a matrix to be brought into light and actualised in a memory of vision, because the collection of the trace has always been split from its visualization. The negative could produce many potential images, only one of which was made to appear, often precisely with the skilful, almost authorial use of the hands; hands shielded the light beam to distribute and refine contrasts, as in a corporeal archaeology of HDR[11].

Nevertheless, the figural homology between negative and positive undermined the idea of the print as an actualization of a virtual image and, at the same time, rendered it difficult to think of the positive as a visualization, one of many possible. In representational photography, the "visualization" in positive optimized the optical-visual scheme engraved in the negative, a matrix of an act of vision, while in the practice of scientific photography this scheme got weaker until it was lost or lost importance for the purpose of visualization.

The field of astrophotography offers key examples of this different way to understand the negative, the base of a genealogy of the postphotographic and proof of an already "digital" analogue practice.

Iconometry and photogrammetry: measuring the figure

Modern astronomy was born as a result of a famous human gesture: holding in his hands a telescope, an instrument designed to enhance vision from a distance, Galileo lifted his gaze and pointed that tube enclosed by two lenses straight up towards the sky (1609). The change in the direction of his gaze profoundly transformed the gesture of extending oneself to reach what is far away, and introduced the idea of tending toward the invisible, the unknown and the superhuman[12]. Photography that inherits the original gestural matrix of the telescope becomes a device for controlling and *capturing* an anthropocentric reality, while that which is grafted onto Galileo's act of lifting the gaze turns into a device for receiving and *intercepting* a reality that transcends the human.

10 See W. Strauven, *Touchscreen Archaeology*, meson press, Lüneburg 2021 for a deep history of hands-on practices and early touchscreens with reference to cinema archaeology. Indeed, hands have always been crucial for the cinematic, and perhaps also for the photographic (see the following note).

11 For example Arrigo Ghi, Luigi Ghirri's developer, whose ability to use his hands to shape the positive is legendary. For manual masking in analogue photography, see M. Fodde, *Mascherare o bruciare?*, "Fotografia Reflex", November, 2002, p. 63.

12 On the genealogical link between photo-cinematographic devices and weapons – and in particular the revolver invented by Samuel Colt in 1836 – see F. Kittler, *Optical Media*, cit., pp. 145-147.

The gesture we perform with a tool invented to enhance our senses contains a cognitive hypothesis formulated with the body and transferred to technology, which absorbs it and then transforms it with unpredictable feedback effects on the human[13].

Since it intensifies sight and at the same time drives it into an elsewhere not accessible with the body, the astronomic telescope reaches a point of decentralisation that transforms it from prostheses of the human, modelled on our senses, to an instrument of extension of natural phenomena; as if the objective and the eyepiece were exchanging their functions, as if it were the cosmos which watched and reached us through the telescope, and not *vice-versa*. This is why, when integrated into astronomical research, photography already develops that *non-human* character which often scholars attribute to it today[14].

This feature starts to emerge at the end of the Nineteenth century, and a way to grasp this is to follow the development of astrophotography at the Harvard College Observatory, whose archive has recently been made fully accessible online.

Harvard Observatory's identity is intimately linked to the use in astronomy of photography, in which the first directors, William Cranch Bond and his son George Phillips (1839-1865), firmly believed. Collaborating with the inventor and photographer John Adams Whipple (also a pioneer of night photography), the Bonds obtained the first celestial daguerreotypes, a corpus of around 300 photographs of astral bodies, which initially gave support to the graphic reproductions obtained from observation by means of telescope[15]. However, it was not until the next director, Joseph Winlock (1866-1875), that the photographic image began to be used as a research tool, thanks in part to the cooperation between astronomers and scientists from the U. S. National Coast and Geodetic Survey – the national office for chart-making, including cartographers, geodesists, physicists, and mathematicians – some of whom had been sent to Harvard to support the study of the imminent solar eclipse (1869). Among them there was the future father of cognitive semiotics Charles Sanders Peirce, hired at the Observatory as calculator and assistant from 1867 to 1975[16].

Winlock's faith in photography and the wide knowledge of the topographic techniques used for surveying the earth's surface, of which the geodesists were experts, were integrated at Harvard in a project not defined exactly as *photogrammetry of the skies*, but which was in fact inspired by the photo-cartographic methodology that was developing in Europe in the same period.

Photogrammetry, a technique for obtaining reliable information about the features of physical objects and the environment through the production of photographic images and measurement of the elements reproduced, has a long history, associated from its beginning with astronomy. In fact, the basic insight which paved the way to this technique dates back to the time of Galileo and, remarkably, is connected with his thinking. Pietro Accolti, a

13 A technical innovation prolongs a human gesture, according to a key branch of anthropology, but after its innervation, the tool starts to live its own life. Cfr. B. Grespi, *Figure del corpo. Gesto e immagine in movimento*, Meltemi, Milano 2019.

14 On the idea that "new" photographs are increasingly independent of human agency, and are produced not *of, by or for* humans see J. Zylinska, *Nonhuman Photography*, MIT Prees, Cambridge, MA 2017.

15 The first successful astro-daguerreotype (of the Moon) was obtained by John William Draper as early as 1840.

16 J. Brent, *Charles Sanders Peirce: A Life*, Indiana University Press, Indianapolis 1999, pp. 74–111.

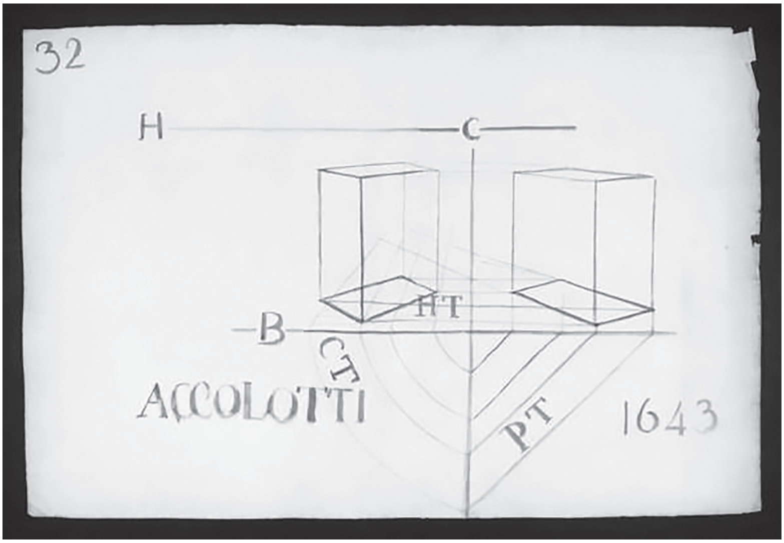

Fig. 1. Joseph Mallord William Turner, Lecture Diagram 32: *Perspective Method for a Cube* (after Pietro Accolti), 1810. The diagram shows the connection between projective geometry and perspectival calculations, attesting Acccolti's influence in Nineteenth century.

mathematician and military engineer at the Medici Court, first envisioned the possibility of "reversing" a perspectival image to extract some of the metric data it contains[17] (fig. 1). Accolti took inspiration from Galileo's method of parallel projections, by means of which the father of modern science interpreted the images of celestial bodies seen through a telescope[18]: given the incommensurable distance between the terrestrial observer and the stars, in fact, Galileo could consider the visual rays of the human gaze as parallel lines. Accolti based his theory of orthogonal projections on the complementary idea of images seen from the «eye of the Sun», that is with the observer located at infinity, and this was key to simplify his archaeo-photogrammetric calculation. Nevertheless, the potential of his reflection was not exploited until the invention of photography, which provided automatic perspectival constructions, considered more reliable and exactly reversible. Following this principle, between 1840 and 1865 European geodesists started using daguerreotypes for topographic surveys: the French astronomer François Arago promoted the use of the new technique as early as 1839[19], but the first to introduce it was the French engineer Aimé Laussedat. Initially, Laussedat resorted to the *camera lucida*, an optical tool which produced rigorous perspectival views projected directly on the drawing surface[20]; *iconometry*, as he

17 P. Accolti, *Lo inganno de gl'occhi. Prospettiva Pratica*, Cecconcelli, Firenze 1625.

18 This is he thesis of F. Camerota, *"The eye of the Sun"*: *Galileo and Pietro Accolti on orthographic projections*, in M. Carpo, F. Lemerle (eds.), *Perspective, Projections and Design. Technologies of Architectural Representation*, Routledge, London 2008, pp. 115-125.

19 As can be read in his *Rapport sur le daguerreotype* at the Académie des science of Paris (July, 3, 1939)

20 On the importance of Wollaston's *camera lucida* as a dioptric device allowing one to see the perceived image through a drawing surface see P. Valiaho, *Speculation, Providence, and Early Modern Optical Media*, Stanford University Press, Stanford 2022.

called this method, was completed by the translation of the drawing into a map. In 1850 Laussedat replaced the *camera lucida* with the daguerreotype and created the phototheodolite, a combination of a theodolite (a sort of spyglass for measuring angles) with a metric camera (that is provided with precision parameters concerning its positioning)[21].

In roughly the same period, the Prussian engineer Albrecht Meydenbauer applied the same idea to architectural surveying. His anecdotal story about the invention of photogrammetry – called *Photometrographie* in his original 1867 article – is well known thanks to the essay film by Harun Farocki, *Images of the World and the Inscription of War*, which connects the insight of surveying at a distance to the desire to avoid the risks run in scaling buildings to measure them directly.

Meydenbauer's technique was still based on the principles of projective geometry and on the reversal of perspectival calculations but took into greater consideration the optical component, which was regulated by designing a device with minimal distortion. His *Messbildkamera* (fig. 2) was provided with lenses that guaranteed negligible monochromatic aberration or produced errors which could be calculated exactly through calibration, and successively corrected in the post-production stage. Thanks to this tool, buildings could be reduced to their dimensional data and modelized as objects perceived by a human eye.

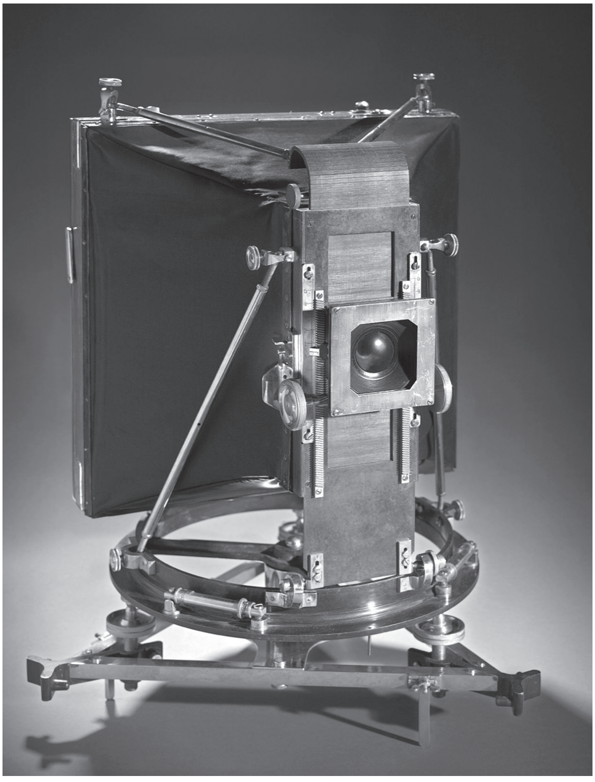

Fig. 2. Photogrammetrischen Messbildkamera, created by Albrecht Meydenbauer ca.1890.

21 L. Polidori, *On Laussedat's contribution to the emergence of photogrammetry*, "The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences", B2-2020, 2020, pp. 893-899.

Curiously, American geodesists resisted the adoption of photogrammetry in topography. They used this tool to map the earth from the sky only after a delay of thirty years[22], but on the other hand they were among the first to adopt it to measure, *vice versa*, the sky from the earth.

Already under Winlock's direction, almost all the hundreds of photographs taken were not intended as documents or precise illustrations of astronomic phenomena, but rather as instruments for the study of some portion of the sky. Precisely like his European fellow topographers or architects, Winlock wanted to test the potential of photography as a measurement device. In this attempt, he was assisted by the philosopher and scientist Charles Sanders Peirce, whose debut in the field of astronomy is today highly valued[23].

In 1869 Peirce helped Winlock to decipher the photographs of the eclipse, analysing the solar corona (which had been studied worldwide since 1860, fig. 3) and trying to deduce from it the distance between the Sun and the Moon. However, the difference between images of the Earth and the Sky was far from irrelevant and his conclusions were negative. Firstly: the objectives did not yet have sufficient resolution to produce images not needing dramatic and extremely distorting enlargements; secondly: the plates did not stay perfectly perpendicular with respect to the optical axis of the telescope and the tilt was too variable; thirdly: atmospheric factors interfered in the image-making process. For all these reasons, Peirce dismissed the scientific value of astrophotography, concluding that it was unfit for measuring purposes and could not furnish correct and usable data.

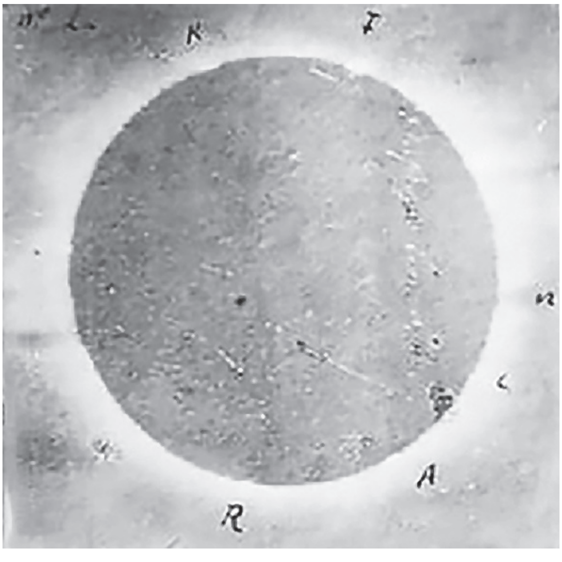

Fig. 3. Solar eclipse, 1860. One of the first photographs capable of reproducing on plate the solar corona, of which Father Angelo Secchi counted the prominences using letters of the alphabet.

22 S. L. Richardson, *Pioneers and Problems of Early American Photogrammetry*, "Photogrammetric Engineering and Remote Sensing", 4, 1984, pp. 433-450.

23 Hoel rediscovers Peirce's work at Harvard. See A. Sissel Hoel, *Measuring the Heavens: Charles S. Peirce and Astronomical Photography*, "History of Photography", vol. 40, n. 1, 2016, pp. 49-66l.

Nevertheless, Winlock was not disheartened and continued to experiment with photography until his death. To reduce optical distortion, he designed a sort of *Messbildcamera* for the skies: on the camera he mounted a fixed long focus lens and provided it with a micrometre, which he himself constructed. To avoid the use of the eyepiece, he tried to obtain the largest possible images, and constructed a gigantic telescope; finally, to overcome the problem of mounting and handling it, he placed his device horizontally and used a plane mirror to direct the light of the sun through it.

Winlock always claimed he devised the horizontal telescope autonomously, but in reality, a very similar model was created in France by Laussedat who already in 1860 applied the principles of his iconometry to the sky, seeking to take measurements of the sun with a horizontal refractor fixed in the plane of the meridian (the helioscope)[24]. Thus, Winlock's telescope was as a fully-fledged photogrammetric device in line with the invention of the French pioneer.

The horizontal telescope was used during the 1874 transit of Venus for yet another attempt to measure the value of the solar parallax (which provides the basis for calculating the average distance from the earth to the sun, the fundamental unit of measurement of astronomic distances). The US government assigned the monitoring of this celestial event to Simon Newcomb, a former Harvard researcher working at the Naval Observatory. Newcomb adopted Winlock's machinery – and was also in touch with the French astronomy station which was reviving Laussedat's device – but perfected the "astro-iconometer" placing a metronomic grid before the plate-holder and a fine silver wire in front of the plate; attached to the wire, a plumb bob was suspended. The squares of the grid were thus etched onto each plate, providing a stable measuring system (fig. 4).

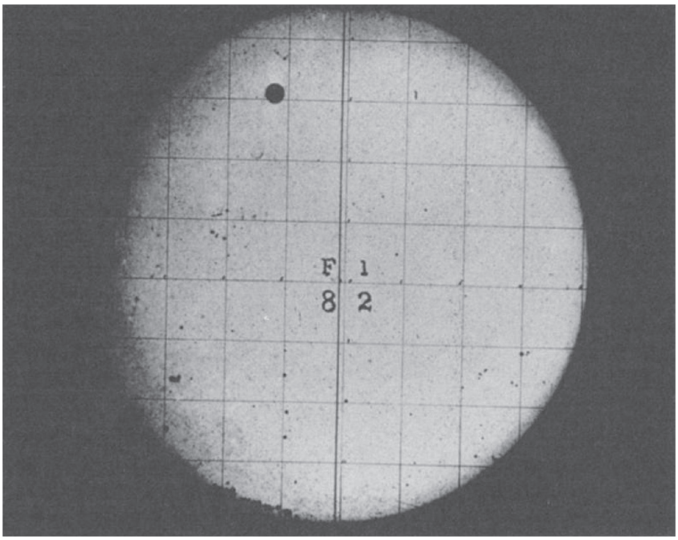

Fig. 4. U.S. Naval Observatory's wetplate photograph showing the 1874 transit of Venus through the grid and the plumb bob.

24 J. Winlock, *On the Horizontal Photographic Telescope of Long Focus*, "Nature", 12, 1875, pp. 273-75.

Newcomb's was probably the best possible measurement of the solar parallax obtainable with the photogrammetric method. But "astro-iconometry" continued to be liable to a considerable margin for error. After almost six years of collation and analysis of the observations made, the international astronomical community concluded that the use of astrophotography had not brought about any scientific improvement and only the Americans remained convinced of its potential, adopting it again for the following transit of Venus in 1882[25].

Measuring light: photometry and spectrometry (or, of a female genealogy of the postphotographic)

The scientific use of photography in astronomy was thereby limited as long as the medium was understood as a technique for recording an act of viewing from the earth. The translation of figures perceived through lenses into astral bodies with measurements and positions did not reach a sufficient level of accuracy.

Only with the use of photography within another process of studying celestial bodies, that is, photometry, was the impact of different variables minimized.

Originally, photometry, «the measurement of radiation in a way that characterizes its effectiveness in stimulating the normal human visual system»[26], was a technique entirely reliant on the act of observation. Since the sensation of a star's brilliance is a subjective experience, its translation into magnitude value was based on comparison with various light sources. Light from the star was placed side by side with light of known intensity and quantified according to a numerical scale (in which lower numbers mean greater brilliance, and *vice versa*).

The prototype photometer was invented in the mid-eighteenth century by the French astronomer Pierre Bouguer (1725); it was based on a standard candle illuminating a surface to be compared with that produced by the rays of the sun and the moon. A century later the photometer was combined with a refracting telescope, the lens of which was split into two parts. Each half of the lens independently focused on a different star, one of which was of known magnitude. In the mid-nineteenth century, German astronomer Johann Karl Friedrich Zöllner finally introduced polarization of light and created the first polarizing comparative photometer, with which the brightness of a star focused by the telescope could be compared with that of a model star. This latter was brought to a degree of brightness apparently equal to that of the real star to be measured; moreover, a quartz plate made it

25 J. Lankford, *Photography and the 19th-Century Transits of Venus*, "Technology and Culture", 3, 1987, pp. 648-657 (p. 656).

26 M. Bass (ed.), *Handbook of Optics*, vol. II, Mc Graw Hill, New York 2010, p. 34.37. For an evaluation of photographic photometry between analogical and digital see E. F. Milone, C. Sterken, *Astronomical Photometry, Past Present and Future*, Springer, London /New York 2011.

possible to vary the chromatic properties of the artificial light, and, hence, to match the apparent colours of the natural one[27].

At Harvard Observatory, photometric techniques made great strides precisely with the contribution of Peirce, who was the first to use Zöllner's photometer, purchased from Winlock in 1872 (fig. 5). Peirce introduced two fundamental innovations, namely the multiple repetition of observation of the same star under different atmospheric conditions and at different geographic locations, and, remarkably, the reduction of the scale of different observatories into a universal one through the application of a mathematical function[28]. By working out this method, Peirce was able to significantly reform the catalogue of stars' magnitude, bringing the results together in his first book, *Photometric Researches* (1878). Nevertheless, he was well aware of the limits of the photometer, both in its performance and operating principle: the kerosene lamp and the polariser (a Nicol prism) required constant adjustments, but the most critical factor was the difference in brilliance estimates (different observers could be differently sensitive to colours, differently resistant to eye fatigue, and disagree on the division of magnitude degrees)[29].

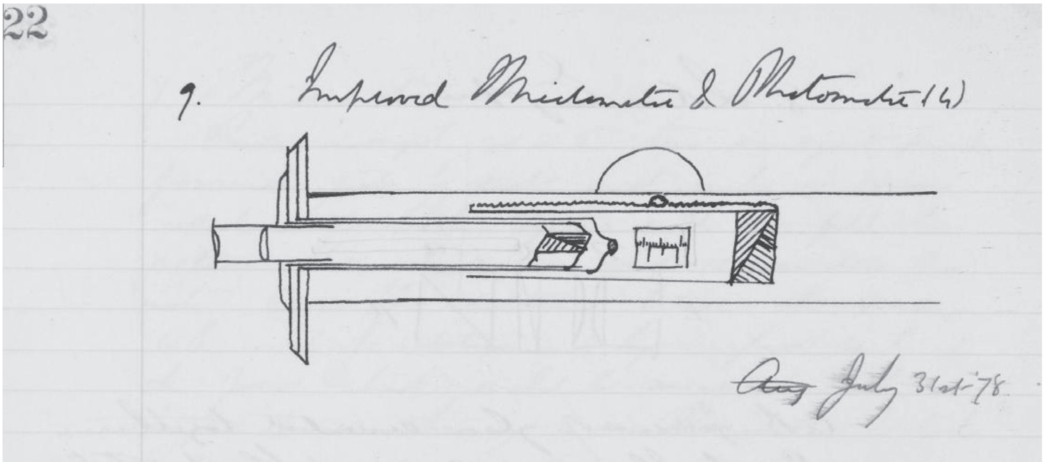

Fig. 5. Visual photometry. Zöllner's photometer reproduced in C. S. Peirce's *Photometric Researches*.

Precisely in an attempt to set aside the subjective components of observations, in search of that «mechanical objectivity» which characterises the century[30], Harvard astronomers resorted again to photography. The photographic turn in photometry occurred after Peirce left the Observatory, but his dual role as image analyst, or "iconometrist", and light expert paved the way for the experiments of the next director, Edward Charles Pickering (1877-1919).

In the early years Pickering experimented with different photometers to improve and extend the sky mapping begun by Peirce, until in 1885, taking advantage of the evolution

27 C. S. Peirce, *Photometric Researches. Made in the years 1872-1875*, Wilhelm Engelmann, Lepizig 1978, p. 8.
28 A. Sissel Hoel, *Measuring the Heavens*, cit., pp. 60-61.
29 C. S. Peirce, *Photometric Researches*, cit., pp. 90-92.
30 L. Daston, P. Galison, *Objectivity*, Zone Books, New York 2007.

of photographic chemistry, he combined photometry and photography. Wet collodion plates were replaced by dry plates, which brought many advantages. Invented in 1871 but in widespread use only at the end of the decade, dry plates were thin glass panes coated with a gelatine emulsion of silver bromide – a compound that possessed a greater light sensitivity and was much more practical than collodion, this latter having to be kept in a liquid state. Since preserving the fluidity of the emulsion was no longer necessary with bromide, protracted exposures became possible, and this revealed an important property of sensitive material: the plate proved to be capable of accumulating light impressions.

This physical characteristic of the support reintroduced the possibility of measuring stars through photography, though not in the usual way. The plates exposed for hours to the night sky concentrated faint light from the remotest stars and made them visible as spots on the silver pane. Full-night exposures also started to produce exciting discoveries, gradually revealing the existence of stars that no telescope had allowed scientists to see. On seemingly empty patches of sky, small spots appeared on the plates, blurred from the centre toward the edges. The Observatories equipped themselves to collect the traces of these stars, invisible to the telescope, over long periods of time: they mounted a guide clock that would mechanically rotate the device along with the rotation of the earth in order to keep the focus on the same portion of the sky[31].

The discoveries made possible by photography were interpreted as acts of extreme enhancement of our vision, and still thirty years later after Pickering's first experiments, James Stokley, astronomer and populariser of science, describes the enchantment of the appearance on a plate of entire unknown segments of the universe in this way.

> The retina of the eye bases its judgment of illumination solely on intensity, and we are not enabled to see a faint star better after looking at it for an hour than after a tenth of a second. In fact, the visual acuity is diminished because of fatigue. The photographic plate, however, does not get tired, and it is able to see more, the longer it looks [...] By simply exposing for longer and longer periods, therefore, fainter and fainter objects may be recorded, objects often too faint to be seen with the eye even when aided by the most powerful telescope [...] There is much in the sky of this nature that has never been seen, but the existence of which has been demonstrated photographically[32].

The metaphor of the plate as retina attempts to present the photography of the invisible still as a prosthesis of our perception, but in reality, the displacement of the "eye" elsewhere, that is, outside the human body, represents a far more significative leap: it is the moment when photography disengages from the visual act, renouncing human sight as a medium and reference system. This does not mean that it can disregard our position as "observers": invisible rays alter the sensitive substance in proportion to the brilliance and distance of the

31 S. I. Bailey, "Construction and guiding of astronomical cameras", in *The history and work of Harvard observatory*, cit., pp. 120-121.

32 J. Stokley, *Newest Ideas about Space and the Size of Everything*, "Oakland Tribune", 28 aprile, 1929, p. 374.

emitting star, so that the intensity and size of the spots produce reliable, but still *relative* dimensional data[33].

TABLE VIII.

CATALOGUE OF STARS.

Bond.	Vis.	Phot.	Bond.	Vis.	Phot.	Bond.	Vis.	Phot.	Bond	Vis.	Phot.	Bond.	Vis.	Phot.
8	9.7	10	43	14.8	15	78	13.1	14	134	10.2	10	175	13.9	14
9	13.9	14	45	14.8	13	79	11.5	14	136	11.3	12	176	10.8	11
12	11.5	15	46	9.3	7	81	9.7	8	139	14.8	15	178	11.5	—
15	13.9	15	49	10.8	11	84	13.9	14	144	11.5	11	179	13.1	14
21	13.9	15	50	11.0	11	88	13.9	15	145	11.0	11	181	14.8	15
22	11.2	11	51	11.0	13	92	11.5	14	148	11.0	10	187	14.8	15
23	13.1	14	52	13.9	14	96	13.9	14	151	13.9	14	190	10.7	11
24	9.5	10	53	14.8	15	97	9.7	8	152	10.2	11	191	13.9	14
25	14.8	15	54	11.5	13	99	12.3	11	153	13.1	14	193	13.9	15
26	10.8	11	55	11.3	13	111	13.9	—	156	13.1	13	197	13.9	—
28	9.2	9	56	13.9	15	112	12.3	13	159	13.1	12	199	9.7	9
33	10.8	12	60	13.1	15	118	9.7	10	162	11.0	11	203	13.9	15
35	10.4	10	64	10.8	12	122	10.8	14	163	14.8	15	206	14.8	15
36	13.9	15	66	10.8	12	123	11.7	13	164	11.5	11	208	11.5	11
38	10.2	9	69	13.1	14	124	14.8	15	166	9.4	9	211	13.1	13
39	10.8	11	71	13.1	13	126	14.8	15	167	10.8	12	212	13.1	13
40	10.2	10	72	13.1	14	130	13.9	15	170	9.4	10	215	9.8	9
41	11.5	14	76	10.3	10	132	13.3	14	172	13.1	14	216	13.9	14
42	10.8	11	77	13.9	15	133	14.8	15	173	13.9	15	218	12.3	13

Fig. 6. Comparison between photographic and visual magnitude (*Annals*, vol. XXXII, Part I).

The measurements obtained refer to what Peirce calls *phenomenal light*, light as a phenomenon that in one way or another reaches us, and as a magnitude that can be translated into a «function of a triple sensation»[34]. In the case of visible stars, however, there was a significant difference (understood as an increase in precision) between visually estimated magnitude values and those derived from photographs; the catalogue tables show data in two comparative columns (fig. 6). Most importantly, with photographic photometry the iconometric quantification of images is transformed into something else: while indicating the star as a point in the sky, long-exposure photographs were no longer measurable figures; nevertheless, they were repositories of exploitable and useful information for representing it (fig. 7).

33 S. I. Bailey, *The history and work of Harvard observatory, 1839 to 1927: an outline of the origin, development, and researches of the Astronomical observatory of Harvard college together with brief biographies of its leading members*, New York, London, McGraw-Hill 1931, p. 135.

34 That is, measurable through three independent variables that dialogue with our senses, *but not necessarily sight*. See C. S. Peirce, *Photometric Researches*, cit., p. 2.

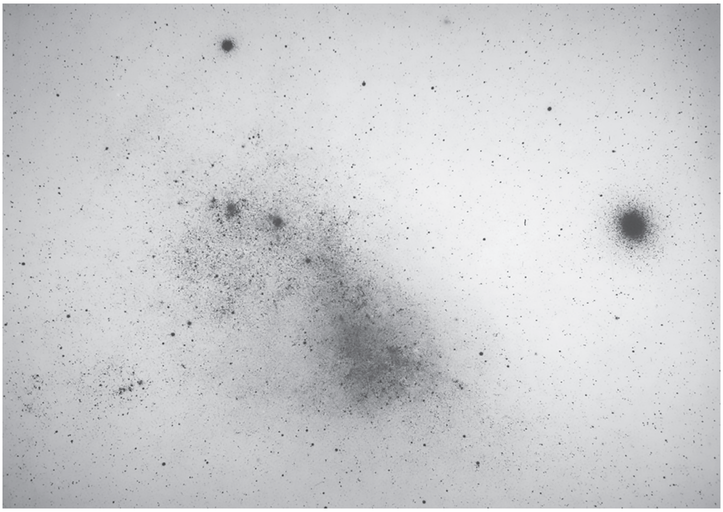

Fig. 7. Stars as black spots on a long-exposure negative (Small Magellanic Cloud, 1905).

However, the retrieval of information from the photographic trace was a far from trivial process. First, the negative had to be produced by locating the plate directly in the focus of the telescope, and not near the eyepiece[35]. The magnitude of the star was then determined by direct comparison of the negative with a scale of prepared imprints. In an 1885 report, William H. Pickering, Edward's brother, refers to this scale as the «standard square», a unit of measurement created by imprinted samples of various exposures on a plate. To obtain impressions corresponding to different exposures, a black mask, perforated by one-centimeter square apertures was placed in contact with the gelatine film so that light passed only through the holes and at different times. Finally, by comparing the negative with the sample plates, the magnitude was determined on a curve indicating the increase in intensity in proportion to the exposure time. When the trace of an invisible star reached an intensity and definition fully comparable to those of a visible star, its magnitude was considered lower (and thus its numerical value higher) the longer the exposure time had been (with the proportion of one magnitude lower for an exposure of two and a half to three times[36]). The numerical translation of the signal emitted by the star was complemented by map operations which, again in comparative terms, aimed to position that celestial body in the portion of the sky studied. The chart of the Orion Nebula, for example, was created through the composition of several long-exposure negatives (called «quantitative photography» by Pickering Jr.). The negatives were placed on a transparent shelf under which a mirror was hooked, and then were covered with a thin sheet perforated with a needle at the imprint of the star. A diagram thus took shape, a map of visible and invisible objects, whose existence and relative location was represented graphically on the basis of the photographs (fig. 8). By means of

35 S. I. Bailey, *The history and work of Harvard observatory*, cit., p. 5.

36 W. H. Pickering, *Investigations in astronomical photography* (*Annals*, vol. XXXII, Part. I), Harvard Observatory, Cambridge Mass. 1895, p. 31.

this process, the first cartography of the sky was produced at Harvard in 1903; albeit on a smaller scale, it predated that far more detailed and complete mapping at which Europe was aiming with the *Carte du ciel* project, launched in Paris in 1887.

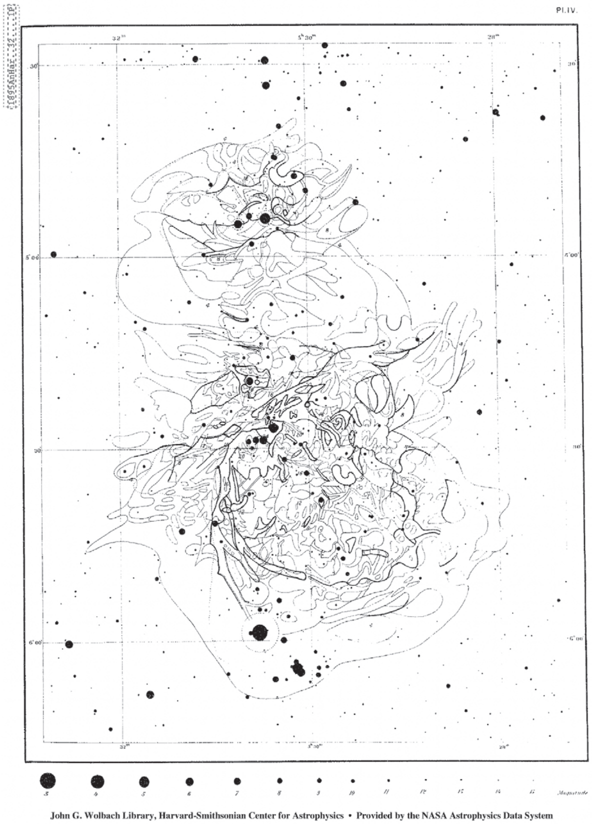

Fig. 8. Chart of the Orion Nebula obtained through negatives of quantitative photography, 1895.

Edward Pickering had decided not to participate in this and settled for a parallel but quicker and more modest enterprise, which was limited to stars up to the twelfth magnitude and to the study of fifty-five photographic plates[37]; nevertheless, its production required calculation and measurement efforts of the same kind.

In Europe as in the United States, a complex, meticulous and accurate work was necessary: it consisted in a massive conversion of analogue traces into data (dark spots translated into the position coordinates and intensity values of the stars), a labour that was done at all latitudes by female workers not yet recognised as scientists, but with considerable astronomical expertise.

At Harvard there operated the «computers», an all-female group tasked with calculating, like living machines, the "value" of images. As in a human, female gendered archaeology of the digital, the "calculators" were computers ante litteram, or flesh-and-blood scanners.

37 H. H. Turner, *The Great Star Map*, New York, Dutton & Company 2012, pp. 67-68.

In fact, in addition to excelling in mathematical calculation, those women had an excellent practical knowledge of images, which they were able to manipulate for comparative purposes; for example, by superimposing a negative and a positive related to the same portion of the sky at different times, to highlight the variability of the stars. Their story is today quite well known but still emblematic because it centred on genius, emancipation, and difference and on a feminine far from being denied. Williamina Fleming supported her own son working as a maid in Pickering's house, before being discovered by the astronomer's wife and put to the test at the Observatory; the others had studied at America's top universities, but two of them (Annie Jump Cannon and Henrietta Swan Lewitt) were afflicted by illness (deafness), which added an extra obstacle to their professional advancement (fig. 9)[38]. The Harvard case is not isolated: this female genealogy of the digital is confirmed by the work of many other women computers present in almost all the astronomical stations participating in the project *Carte du ciel*. The existence of a «Bureau des dames» at the Toulouse Observatory has recently come to light, while the case of the nuns assigned to this task at the Vatican Observatory is still almost entirely unexplored (fig. 10). The practical reason for using female personnel was quite prosaic – it was hard and underpaid work, which only those who had to fight to be part of the scientific enterprise, while having every right to do so, could have any interest in accepting; nevertheless, the exceptional nature of the outcome suggests that the ability to *care* for images – to be preserved, interpreted, valorized, and not simply computed – was a very important component.

Fig. 9. The Harvard Computers (including Henrietta Swan Leavitt, Annie Jump Cannon, Williamina Fleming, and Antonia Maury).

38 D. Sobel, *The glass universe. How the ladies of the Harvard Observatory took the measure of the world*, Viking, New York 2016 tells the story of the so-called «Pickering harem». More thorough but devoted to Leavitt alone is G. Johnson's *Miss Leavitt's stars: the untold story of the woman who discovered how to measure the universe*, New York and London: W. W. Norton & Company 2005. On the other hand, the case of the nuns of the Specola Vaticana is just mentioned by S. Sesti, L. Moro, *Scienziate nel tempo*, Ledizioni LUD, Milan 2018, but not yet explored.

Fig. 10. Sisters Emilia Ponzoni, Regina Colombo, Concetta Finardi and Luigia Panceri map the position and magnitude of stars at the Vatican Observatory.

The last nineteenth-century application of photography to astronomy is also the work of the women computers, particularly Annie Jump Cannon. The idea of using the negative as a matrix of data independent of ocular perception gradually shifts the focus from objects that can be reproduced through the medium of light, to light itself as a substance to be "reproduced" through photography with the telescope in microscope mode. To see the texture of the light, spectroscopy is utilised, and this technique, unlike photometry, treats radiation from the stars as matter, breaking it down by means of an optical prism into its multiple wavelengths of different colours (from infrared to ultraviolet).

The history of spectroscopy and the birth of astrophysics are intimately linked, and it is impossible to deal here with this point, which we merely recall, to complete the emancipation of the photographic from the visual. Spectroscopy was applied to the stars by Father Angelo Secchi, who made the first observations of astral light at the Roman Observatory between 1866 and 1877[39]. By the turn of the century, it had been shown that the electromagnetic spectrum contained indicators of the presence of chemical elements, which meant that the astronomer could use spectroscopy to learn about the chemical composition of stars. Secchi identified every star by its electromagnetic signature while recognising five major stellar classes with comparable spectral characteristics. In order to study them, he fixed graphically what he saw through the spectroscope (fig. 11).

39 For a recent evaluation of Secchi's contribution see I. Chinnici, G. Consolmagno (eds.), *Angelo Secchi and nineteenth century science. The multidisciplinary contributions of a pioneer and innovator*, Springer Nature Switzerland AG, 2021.

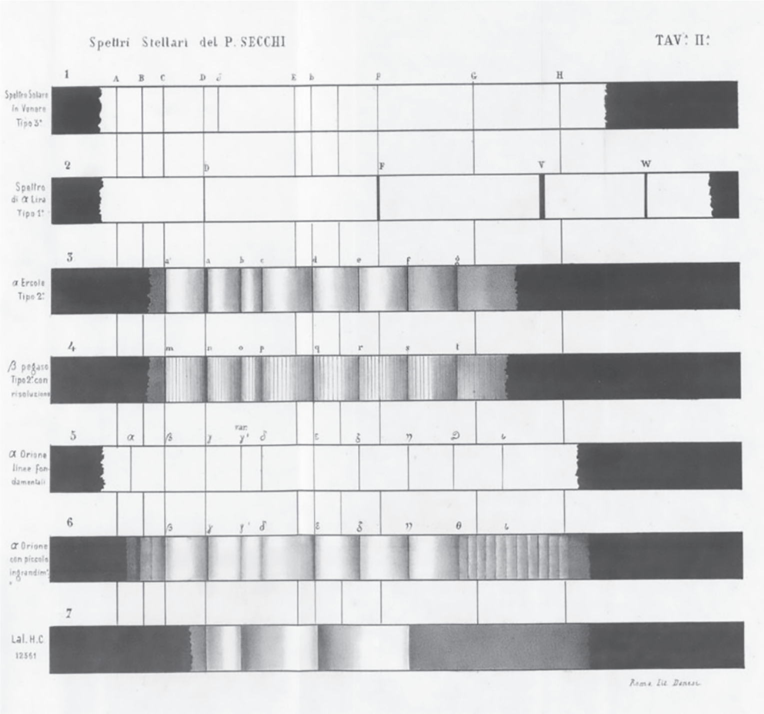

Fig. 11. Drawing of the electromagnetic spectrum by Father Angelo Secchi.

On this basic research the women computers intervened, determined to transform Secchi's manual transcriptions into automatic graphics. Annie Jump Cannon succeeded in photographing spectral bands and drawing up the Henri Draper Catalogue, which improved Secchi's classification. From the photographs, and particularly from the thickness and frequency of the absorption lines reproduced in the spectrum, Cannon deduced the chemical composition and temperature of the star, as she explained in a 1915 memoir[40]. Her "shots" were highly informative but gave no clue whatsoever to how the photographed star might appear to the human eye (fig. 12). Optics were still part of the process because it was a play of lenses that unpacked the light and gave us access to the data. However, this component was now completely divorced from our visual act. The whole electromagnetic spectrum, not just the visible light that constitutes a tiny portion of it, could now be exploited for data extraction, to produce a *virtual* perception of the star (its visualization.) This is what happens today with the latest infrared telescopes, particularly the James Webb Telescope, the furthest thing possible from an enhanced eye placed in orbit around the earth.

40 On a 1915 Christmas postcard, Cannon writes: «The photograph does not show the colour, but what is more important, it does show the presence of fine dark lines, few in some spectra and numerous in others». A. Jump Cannon, *The Story of Star Light*, 1915.

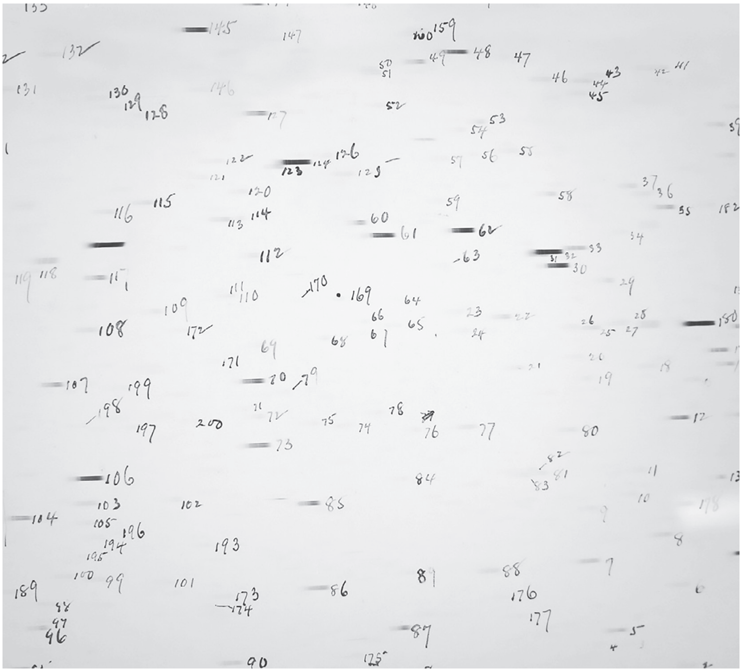

Fig. 12. Spectrometry by Annie Jump Cannon. A number is attributed to every spectrum on the plate.

Iconic act vs. visual act: postphotography as an indexical diagram

In the preceding sections an attempt has been made to argue that astrophotography, from the very outset, took on an epistemological function increasingly disconnected from its representational, or "documentary" character. In a first phase, astrophotography was decoupled from the act of vision with long-exposure negatives, translated manually into data; the consequent cartographic operations lost their earliest photogrammetric basis derived from optical-geometrical perspective and thus linked to our way of perceiving, to acquire a photometric value, that is to become a measure of the intensity of light. In a second phase, the transition from the use of photography for photometric purposes to its use for spectrometry shifted the focus to non-visible light, and to the non-optical information that they can provide. At that point our eye ceased to be the key reference and it became possible to consider (or better *theorize*) photography as something different from an act of vision.

After all theory also constitutes a historical "phenomenon" becoming part of the archaeology of a medium. In our case, not exactly a theory of the photographic, but a semiotics which elaborates its concepts by reference to photography. The triad index-icon-symbol at the core of Peirce's semiotics – being himself a historical protagonist of the first season of astrophotography – proves to be a key tool for conceptualizing the leap between photographic and post-photographic; or vice-versa, it is postphotography, precisely by virtue of its genealogy, that retrospectively enlightens those notions.

In the past decades Peirce's theory of sign was much used by theorists of the photographic, particularly attracted by the indexical sign, often exemplified by Peirce himself with the photographic image. «Index», he writes, «is a Sign which refers to the Object that it denotes by virtue of being really affected by that Object»[41], thus it sustains a merely "physical" or "existential" relation to its object to the point of being situated at the border of semiosis. A photograph derives from a concrete presence, and thus *indicates*, behaving exactly like such diverse signs as a footprint, smoke, thunder, weathervane, words like "this", "I" and "you", or the gesture of a pointing finger. This was the idea long stressed by Rosalind Krauss in the Seventies, a moment in which a non-representational current of art seemed to possess an indexical quality largely made to coincide with that of photography. Gordon Matta Clark's installation *indicated* a no longer visible reality by pointing towards its effects, just as a thermometer allowed one to infer temperature, or indeed a photograph the captured reality.

But as other commentators later added, a photograph is also very different from a weathervane: this latter provides certainty of the object being there (the wind) without visually describing it, while on the contrary a photograph is most often abundantly descriptive in visual terms. At least representational photography. Scientific photography – which is what Peirce had truly in mind, according to Robins – is more clearly a sort of reactional sign, because it presents itself as consequence rather than as evidence of a phenomenon, of which does not simply prove the existence but «provides usable data»[42]. Quantitative photographs and photographic spectrographs have strongly indexical qualities. But they are also iconic, or hypoiconic, if we understand this term correctly.

«A sign may be iconic», writes Peirce, «that is, it may represent its Object mainly by its similarity, no matter what its mode of being is [...] any material image, such as a painting, is largely conventional in its mode of representation; but in itself, without legend or label, it may be called a hypoicon»[43]. Representational photography is "trivially" hypoiconic, because it resembles its object with an unprecedented precision, while scientific photography is "sophisticatedly" iconic, because it is based on more complex similarities. In a pioneering article about Peirce and photography, François Brunet makes the concept clear, disentangling the idea of the icon from the idea of the sensible resemblance[44]. The *Likeness*, on which the hypoicon is based (just as the symbol is based on conventionality) may derive from simple qualities, that is graspable with the senses, as well as complex properties, of a logical kind. The diagram, one of the highest forms of iconicity according to Peirce, is based on the

41 C. S. Peirce, *Collected Papers*, The Belknap Press of Harvard University Press, Cambridge (Mass.) 1965-19671, 2:276.

42 A. Robins, *Peirce and Photography: Art, Semiotics, and Science*, The Journal of Speculative Philosophy, 1, 2014, 1-16 (3).

43 C. S. Peirce, *Collected Papers*, cit., 2:276. The icon is the quality of the Possible, of the Primity, while hypoicon is the sign which refers to the mode of Primity. "The icon does not inform, does not state; it just hints that something could be." See R. Fabbrichesi Leo, *Sulle tracce del segno. Semiotica, faneroscopia e cosmologia nel pensiero di Charles S. Peirce*, La Nuova Italia, Firenze p. 34.

44 F. Brunet, *Visual semiotics versus pragmaticism: Peirce and photography* (1996), in V. M. Colapietro, T. M. Olshewsky (eds.), *Peirce's Doctrine of Signs: Theory, Applications, and Connections*, De Gruyter, Berlin//Boston 2011, pp. 295-314.

homology of the relations among parts, on a similarity of schemes and processes that does not gratify our eyes but provides maps capable of producing knowledge.

The Harvard sky maps are powerfully iconic because they synthetize the set of relational properties between the celestial bodies by arranging them on a surface[45]. But their scientific value derives from the indexical character of the original traces. This means that we can consider them already as an extreme form of postphotography, especially after the revision of Peirce's idea of the photographic proposed by Jean-Louis Schaeffer. Schaeffer argued that Peirce did not reduce, simplistically, the photographic to the indexical, but on the contrary, he conceives it as the sign in which the iconic and the indexical totally coincide[46]. The *likeness* between a photograph and its object is indeed the *consequence* of a physical force, or in other words, iconicity is structurally indexical in photography.

> Photographs, especially instantaneous photographs, are very instructive, because we know that they are in certain respects exactly like the objects they represent. But this resemblance is due to the photographs having been produced under such circumstances that they were physically forced to correspond point by point to the object in nature[47].

Nevertheless, depending on the accompanying human gesture, on its form and meaning, the similarity produced and the physical force causing it take on different characteristics. The traditional photographic act was a visual act, for all the reasons given in the first part of this paper, or better: it was an iconic act corresponding to a visual act. The postphotographic act, however, is an iconic act which is not a memory of anything actually seen, and therefore it retains a virtual character and produces a potential visible. As the faces of *This person does not exist* are similar to probable persons, since they represent a pure likeness on a logical level, so the maps of the late nineteenth-century skies, not unlike the galaxies which appear today for the first time thanks to the James Webb telescope, display a virtual visible; they are diagrams referring to a probable sensory accessibility. Browsable algorithmic photographs, or the digital photogrammetry at the basis of immersive environments, possess the same diagrammatic iconicity[48] created from indexes of various kinds, not necessarily optical (they can be also thermal, acoustical, biometrical).

Therefore, the leap between photography and postphotography might correspond to different degrees of iconicity, rather than to a presumed loss of indexicality. The iconicity

45 On an epistemology of the map, see B. D. Geoghegan, *An Ecology of Operations: Vigilance, Radar, and the Birth of the Computer Screen,* "Representations", 1, 2019, 59–95.

46 J.M. Schaeffer, *L'image précaire. Du dispositive photographique*, Editions du Seuil, Paris 1987, pp. 65-66.

47 C. S. Peirce, *Collected Papers*, cit., 2: 281.

48 Dondero interprets the visualization of black holes produced by calculation as a form of diagram. See M. G. Dondero, *La fotografia scientifica tra impronta e matematizzazione,* in *La fotografia. Oggetto teorico e pratica sociale, Atti del XXXVIII Congresso dell'Associazione Italiana di Studi Semiotici*, 2011, pp. 156-172. According to Dondero, we still can speak of photography because this kind of visualization functions as a «fixing of the possible plurals» a moment in which a stop is put to the calculations and mathematical hypotheses that diagrams keep in motion (p. 171). Important insights also in R. Bellour, *La photo-diagramme*, in Id., *La querelle des dispositifs. Cinémainstallations, expositions*, POL, Paris 2012, pp. 229-238.

of the post-optical regime, centred on the hands and body in place of the eye[49], is diagrammatic, and the corresponding image is an *iconic act* ceasing to be also a *visual act*. But as we have tried to argue, the coincidence of the two dimensions is not a *conditio sine qua non* of the photographic: from the very beginning there has also existed a practice of "blind" photography and it is to it that today's algorithmic pictures reconnect.

49 The idea that with the algorithms we enter the post-optical regime is suggested also in C. L. Kane, *Chromatic Algorithms: Synthetic Color, Computer Art, and Aesthetics after Code*, The University of Chicago Press, Chicago 2014.