Imagining Reality:
Scientific imagery in the construction of perceptions of reality

Emilia Moisio

Table of Contents

Introduction

Scientific practices spring from the insatiable human curiosity to understand and master reality and the desire to impart knowledge, driven both by metaphysical quest to comprehend the mysteries of life and practical concerns for finding explanations and solutions for emerging issues (Bird 1998; Wilson 2010). Generally characterised as a progressive, regulated process utilising the scientific methodology of observation, formulation of hypotheses, experimentation, drawing conclusions, and formulating theories, scientific approach implies aspirations of revealing objective and absolute truths. Surges in scientific progress have characterised eras, contributing immensely to human knowledge and understanding, and shaping profoundly the prevailing assumptions about reality and existence, despite abundant well-known historical examples of exceedingly fanciful and misguided propositions and some of the once most eminent theories also later proven wrong by further discoveries.

There are, however, many powerful, often inconspicuous factors involved in the formation of the structure of the pervasive scientific hegemony, including historical conventions, social structures, the impact of the authority of the frameworks of production and display, and ideological and psychological factors. In this paper, scientific practices are considered through postmodern relativist, sociological, philosophical, psychological, and media culture theories reflexive of the widely assimilated contemporary humanist intellectual climate−although regularly disapproved of and heavily criticised by scientists−adapted for alternative, detached interpretations questioning the prevailing hegemony of the scientific structures of knowledge.[1]

---

[1] Although the widely harboured, traditional, positivist perception celebrates science as a uniquely, profoundly, universally true reflection of reality revealing hidden knowledge, philosophy of science challenges and problematises this scientific hegemony. Unlike the popularised preference for seeing science as a separate realm unaffected by social, ideological, cultural, economical, or political interests, postmodern relativism regards scientific practices, 'the purported objective knowledge' they produce, and thus also the resultant reality as socially and culturally relative, as well as entirely socially constructed (Latour & Woolgar 1979; Sokal 2008, p. 271; Davies 2010).

According to the relativist stance, scientific worldview is essentially another inherently precarious 'socially conditioned' attempt to construct and establish an authoritative, protective order responding to the universal human quest for an overarching, hegemonic metaphysical framework to cope with insecurity and anxiety by structuring, simplifying, unifying, controlling, and explaining the overwhelming, complicated, chaotic, and enigmatic existence, thereby resembling in some respects more of a belief system than any absolute manifestation of truth (Maslow 1966; Berger 1967; Latour & Woolgar 1979; Deleuze & Guattari 1994; Sokal 2008; Davies 2010, p. 68; Pfadenhauer 2013). On an individual level, the scientific worldview currently dominating Western society, is an acquired

Heidegger's theory of representational systems as tools for imposing structure and control over the chaotic experience of reality, and thus establishing and affirming our intellectual and emotional position of dominance over the surrounding reality—resembling stances expressed in several analyses on philosophy, psychology, and sociology of science—is applied here to propose that science can be considered such an artificial system devised to establish control and provide explanation as a means to cope with the overwhelming, sublime aspects of reality (1971; 1977). This approach provides illuminating insights into the subconscious influence that scientific models, and imagery, can have on our perceptions.

Due to the predominance of visuality in human perception and culture, visual representations have throughout history been crucial in recording, communicating, and comprehending information. Like Deleuze and Guattari formalise, scientific thought analyses reality by slowing down and isolating the scope of study to impose structure and control (1994, p. 118). Thereby images—photographs in particular—due to their ideal immobile, fixed nature, contribute centrally to scientific practices by suspending, recording, and preserving passing observations and samples for further study, and as diagnostic, methodological, classificatory,

---

conviction internalised and naturalised through pervasive sociocultural acculturation, excluding alternative doctrines and thinking (Schopenhauer 2009; Davies 2010; Pfadenhauer 2013). Such acquired and internalised metaphysical frameworks are neither logically inferred, reasoned, verifiable, nor disputable, but an intuitive matter of subjective personal conviction, thereby unconsciously guiding and restricting thinking and understanding of reality through inconspicuously defining the entities belonging to reality, but consequently also inversely limiting what is believed, trusted or even imagined (Schopenhauer 2009; Davies 2010). In stark opposition to the claims of absolute, infallible, universal scientific truths, the pluralist worldview further recognises incorporating aspects, explanations, and concepts founded on differing theoretical frameworks—forming a selective, partial, complementing combination of multiple scientific, spiritual, and philosophical approaches to approximating and explaining reality—as a valid approach adapted to the limited human perceptional capacity, allowing for understanding some explanations as varying levels of metaphorical rather than literal representations of truth and, crucially, appealing to the modern individualist mindset (Sokal 2008; Davies 2010). Conflicting the prevailing hegemonic discourse, the currently accepted scientific models are considered provisional, speculative, abstracted, simplified, and incomplete theoretical and cultural approximations formulated based on finitely accurate measurements and '[s]tatistical and probabilistic reasoning', effectively generating knowledge rather than uncovering it, even if currently yielding the most successful predictions and explanations for our observations and experiences (Maslow 1966; Kuhn 1970; Bird 1998, p. 187; Sokal 2008; Davies 2010). As a human attempt to construct a structured, unified, applicable, controllable, and essentially theoretical set of mathematical models operating by its internal rules and conventions, and striving for the scientific ideal of pure abstractness, elegant succinctness, comprehensiveness, independence, and internal coherence, the scientific system is essentially an artificial structure simplifying, classifying, controlling, and explaining complex and chaotic empirical observations through '[o]rganizing experience into meaningful patterns' and therefore actively creating and imposing meanings (Maslow 1966, p. 84; Wirth 1966; Bird 1998; Sokal 2008; Davies 2010). The holistical view further proposes that this culminates in perceiving merely our own imposed constructions and preconceptions instead of any actual real, paralleled for instance in Deleuze and Guattari's account of science effectively constructing the experiences of reality through establishing the structure for understanding it (Maslow 1966; Deleuze & Guattari 1994, p. 199).

and conceptualising aid (Robin 1992). This text focuses on the impact and role of generalised and popularised uses of scientific illustration in public contexts, not the purely scientific, expert uses of visual forms of scientific data.[2]

The central role that illustrations have acquired in relaying otherwise challenging, complex, and abstract information in conceivable form beyond scholarly circles to wider audiences raises problematic issues. Most contemporary research engages with elaborately conceptualised, intellectually challenging concepts and invisible phenomena ranging from subatomic to galactical, such as nanotechnology, particle physics, relativity, and gravitation, requiring complex theoretical inference (Kevles 1992; Wilson 2010). Only a diminutive portion of the currently known matter in the universe is visible to the human eye, yet scientific illustration has developed very specific, aesthetically highly alluring representational conventions utilising compelling purity of colours, crisp graphics, and prominent perspective in order to depict also directly imperceptible phenomena (Kevles 1992). By generating concrete presentations for incorporeal schemas and assigning form to innately formless things, illustrations facilitate relating to such unfamiliar matters, but also determining the general visual understanding of them, profoundly influence our perceptions of reality.

Photography, due to its unique technical abilities, has had a constitutive role as a scientific tool contributing to the development of observation, experiment, archiving, and illustration in widely varied fields. The persistently lingering powerful cultural metaphors and assumptions about the inherent aura of indexicality perpetually tinting the status of photographs, however, render the role and uses of photographic and subsequent digitally generated imagery complicated and highly debatable.[3] Despite the prevalent discourses on the

---

[2] Whereas visual representations function in sciences as a valid, useful tool for recording, expressing, studying, and analysing data, and thus phenomena in essential ways, scientists interpret the specialist images primarily as gathered data through the specific coding involved with an understanding of the nature and limitations of the processes and the theoretical models in question. Therefore, specialists may read invisible phenomena, such as temperatures, ranges of radiation, and chemical compositions and structures where a layperson sees wonderfully colourful, awe-inspiring sceneries.

[3] Characterised by the constitutive, historical assumptions of mechanical objectivity, guaranteed by automatic recording by an impartial machine producing unmediated, neutral, faithful, evidential, exact copies through the perceived, privileged, inherently indexical photographic relation to the referent and thus reality, and the unique superabundance of indiscriminate detail and clarity producing the common convincing and compelling illusion of transparency analogous with natural vision, photographs are—as extensively discussed and documented in art photography's struggles to free itself from these notions—customarily considered literal records, traces of their subjects (Edwards 2006; Price & Wells 2009). The inception of the medium during rapid industrialisation and expansion of capitalism requesting for reliable, efficient, and quick tools for documentation and reproduction

problematic status of photographs as alleged evidence in general, it is remarkable, fascinating, and at the same time unsettling how little the accuracy, validity, and implications of scientific illustrations as supposedly truthful evidences in public discourses is discussed, and how readily and unnoticed the use of imagery generated to illustrate, clarify, and even ostensibly evidence scientific information is accepted.[4] Further critical discussion and public familiarisation with the frameworks and techniques of scientific imaging, beyond the regularly publicly addressed concerns regarding the difficulty of visually differentiating various artificially generated diagrammatic illustrations from more representational imaging would, however, be important due to the profound impact that these visually compelling images have on our perceptions of reality.

---

further effectively established photography as a culturally privileged conveyor of reality (Edwards 2006).

[4] Disregarding the prevalence of mass practices and utilitarian imagery in social, cultural, and political uses, standard histories and critical reflections analysing photography−centring on art and documentary practices−tend to regrettably bypass these with inexplicably little attention. Typically framing the history of photography as a narrative of progress, rather than thoroughly addressing the abundant issues, technical problems, and inadequacies, which are particularly relevant to contesting its prominent role as a reliable tool in scientific imaging, they reflect instead strikingly unilaterally photography's uneasy struggles over identity, aspirations, and validity as art, deriving from the perceived inevitable indexicality for which the medium has been both hailed and discredited (Wilder 2009). Yet, the excessive emphasis on artists striving to distance themselves from the utilitarian functions has, in fact, perversely contributed to reinforcing the persistently lingering notions of mechanical fidelity (Wilder 2009).

The perils of referencing authorities and the trailing evolution of knowledge

Reorientation of scientific practices through major and partial revolutionary paradigm shifts, where the previous set of theories is replaced—thus transforming the contemporaneous worldview—renders many images pertaining to earlier eras poignant illustrations of the transitory, arbitrary, and relative nature of scientific truth.[5] An example from an era with a fundamentally different worldview, thereby, articulates some of the issues with scientific attempts to explain the world, as recognising the earlier stance, methods, and aberrations as products of the prevailing thought-structure is easier, as we are not inevitably enfolded in and indoctrinated by it.

[5] Thomas Kuhn famously formalised 'scientific paradigm' as the prevailing structure of standards, exemplars, canons of solution, and agenda for scientific practice (Kuhn 1970; Bird 1998). Paradigm prescribes the prevailing criterion for valid dilemmas, legitimate experimental procedures and solutions, the conception of, and entities in the scientific realm and thereby ultimately the contemporaneous conceptions of reality (Kuhn 1970). Paradigm shifts are inaugurated by the detected inadequacy of prevailing models or emergence of incompatible new theories, as well as the frequently touted scientific self-reflexive revising of theories (Kuhn 1970). Scientific paradigm shifts, also known as scientific revolutions, alternate with stretches of 'normal' science (Kuhn 1970). Remarkably conservative and intolerant of novel entities, developments, or theories, normal science focuses instead on consolidating the existing scientific structure by refining beings already recognised by the paradigm and thus striving to fit 'nature into the preformed and relatively inflexible box that the paradigm supplies' (Kuhn 1970, p. 24).

Fig. 1: Magnus, O. (1572) *Carta marina*

Medieval marine maps and scientific manuscripts populated by the most fantastical mythological creatures, such as dragons, sirens, mermaids, monsters, and most extraordinary hybrids like sea pigs and elephant-fishes, retrospectively poignantly illustrate the pitfalls of the evident erstwhile practice of simultaneous consultation of multiple expert sources for information.[6] The potential problems of the fundamental scientific praxis of citing,

[6] The production of generally educational, illustrational, and decorative maps flourished in the medieval and Renaissance Europe. The function of these maps was to impart broad knowledge about the world. They feature varying amounts and combinations of legends—providing information about the area, its assumed inhabitants, fauna, and curiosities of land and sea—and illustrations, including geographical features, flags, sovereigns, ships, and more or less exotic and mythological terrestrial and naval creatures. Although some of the elements appear to have been added simply to fascinate and increase the visual appeal—and thus the prestige—of these elaborate and ornate collectable status objects, there is clear evidence that some textual and pictorial elements derive from a mixture of the latest scientific publications and respected texts on natural history, such as contemporary bestiaries and illustrated encyclopaedias, and were included with the intention of recording and dispersing scientific information (Van Duzer 2013). Some sources became very influential and widely copied because—not unlike the current educational emphasis on studying fundamental disciplinary discourses—the study of treasured and rare manuscripts 'constituted one of the main [practices in] science' (Robin 1992, p. 21; Van Duzer 2013). It is further evident that many of the foremost thinkers of

referencing, and basing new work on contemporaneously respected sources—vividly evident here—do not, however, concern earlier practices alone.[7] It is essential to note that new discoveries and novel developments must be explained and reconciled with pre-existing knowledge and prevailing truths in every era.[8] Scientific practices must, therefore, always be understood in historical context instead of dismissing the worldview and scientific theories of

---

the era believed in the existence of such creatures, explained by the divine intentions of the edification of man (Barber 1992; Van Duzer 2013; Wright 2013).

Rather fanciful creatures, themes, scenes, and conventions of representation became highly influential and canonical through widespread repetition enforcing their status (Barber 1992; Robin 1992; Wright 2013). Some creatures and myths further gained imaginative dimensions through successive reiterations, rather liberal and artistic interpretations, embellishments, and misinterpretations, at times peppered with imaginative inventions capitalising on the contemporary curiosity for novelty value, exoticism, and interest in the natural world, further distributed by uncritical reproduction of such established knowledge (Barber 1992; Robin 1992; Wright 2013). Most fanciful imagery appearing side by side with ordinary motifs, rendered stylistically similar following the latest artistic representational styles, would further assert that the strange creatures may be equally true as the ones already familiar to the viewer.

[7] The system of basing scientific education and research on established knowledge has problematic implications due to the central role of studying earlier experiments, conclusions, and classifications in education, which will inevitably influence future work as we subconsciously look for affirmation of our preconceived beliefs (Robin 1992). In this structure of recursive values enforced through professional inculcation, and restricted by the preconceived criteria that predefine the scientific system and the reality it operates in, new observations, knowledge, and representations are conformed to and fitted within the frames of pre-existing understanding, inner images, and mental patterns by comparing the level of similarity to learned established concepts (Kuhn 1970; Robin 1992; Bird 1998). Familiarisation with specific interpretations thereby affects our ability to observe, recognise and perceive truly impartially, irreversibly transforming the recognition and interpretation of entities to conform primarily to paradigmatic standards (Kuhn 1970; Bird 1998). The extent of professional education reproducing scientific conventions through endorsing the recognised, eminent canon of professional texts and knowledge, exemplary practices, methods, and applications has further problematic consequences as training in the use of standard techniques, methods, instruments, experiments, language, and also imagery further informs and limits the future professional choice and preference of research orientations, approaches, methods, techniques, experimental arrangements, solutions, and interpretations and consequently the results (Kuhn 1970; Bird 1998; Davies 2010). These internalised preferences and customs potentially have a profound influence on the entire construct of science and the results it produces—and subsequently does not produce—as they pervade the entire training and thought-structure of scientists and society (Wirth 1966).

The accuracy of anterior knowledge also becomes crucial in the cumulative scientific system constructed from gradually accumulated and integrated separate pieces as new information is based on, evaluated against, and reconciled with the pre-existing, recognised theories and prevailing truths (Bird 1998).

[8] Medieval encyclopaedias and other accounts of the world, to provide an illuminating example, were constructed to combine, reconcile, and redefine in Christian terms the knowledge accumulated from the natural historians and philosophers of the ancient world (Barber 1992). Hence, the prevailing scientific outlook, enforced by several highly influential medieval authors—also responsible for the proliferation of the fantastic creatures in scientific accounts—was an amalgamation of symbolical, allegorical, moral, and religious interpretations rarely based on direct observation, but rather deriving from earlier respected authorities (Barber 1992; Wright 2013).

earlier eras from the modern perspective as inferior due to their different understanding of science.[9] Scientific imagery is similarly always generated in accordance with the prevailing conceptions and theories. It is, for instance, speculated that, not unlike the modern scientific illustration, the representation of pictorial monsters empowered the medieval viewer by privileged participation to generally unseen and unusual aspects of reality, thereby representing 'the revelation of hidden knowledge' (Van Duzer 2013, p. 12).[10]

Lacking unquestionable proof as to why modern era and current practices should drastically differ, remembering the legacy of various earlier erroneous stages in scientific progress should prompt healthy critical reflection and evaluation of the possible fallibility of current knowledge and the structures and communication methods supporting it, particularly when engaging with the alluringly resplendent modern scientific images.

---

[9] As the history of science is essentially a succession of not only new inventions and discoveries, but revision and overthrowing of earlier beliefs, conceptions, theories, and paradigms, it is, in retrospect, easy to remark upon major mistaken speculations, conclusions, and theories in nearly every branch of science, proposed by even the most notable scientists, such as the geocentric cosmology, and even altogether suspicious branches of science like physiognomy, the study of facial features in order to reveal inner character. Yet scientific approaches, methods, and theories, even when later proven misguided, are cogently formalised from the best available knowledge with sincere intentions and faith in their feasibility and accuracy, and supported, often most convincingly and impressively with equally sincerely intended illustrations. According to the relativist conception, the justifications and validations for each paradigm, and thereby the knowledge it produces, are, furthermore, relative to the paradigm and based on its internal standards, thus pre-empting any valid foundation for evaluating and comparing their validity across differing paradigms, also referred to as incommensurability (Kuhn 1970; Bird 1998; Sokal 2008).

[10] To medieval and Renaissance beholders, the monsters−typically located on maps at the most recently discovered, furthest perimeters of the known world−indicated possible real dangers, perils, and savagery, whilst also reflecting the increased general interest in exotic wonders and marvels, typical of the early modern period's scientific outlook driven by curiosity (Van Duzer 2013).

The imaginative new dimensions of fabricated vision

Science and photography are profoundly interlinked by a complex, essentially bidirectional relationship of functions, connections, and beliefs. The triumph of photography, rising in tandem with and as a celebrated, progressive, iconic, and ideal instrument of the powerful, pervasive Enlightenment emphasis on scientific observation and knowledge, derives largely from the trust in the seductive promise of photographic authority, stemming from the associated powerful and persistent notions of mechanical and optical passivity, objectivity, reliability, indiscriminateness, and veracity−notably absent from other types of images−which still fundamentally brand the notions, rhetoric, and interpretations of photography (Edwards 2006; Lister 2009; Price & Wells 2009; Sturken & Cartwright 2009; Wilder 2009).[11]

[11] Perceived to fulfil ideally the rationalist and positivist criteria of machine objectivity and reliability, free of subjectivity and error of the human sensory perception, crucial for successful scientific observation, photographic techniques with a varied range of capabilities for different purposes came to produce entirely new kinds of empirical evidence through mechanical methods of observing, measuring, and studying the world through their unique abilities of gathering wide ranges of electromagnetic radiation over time, separating, isolating, freezing, enlarging, and condensing, and thereby essentially generating images by rendering visible records of invisible entities (Sturken & Cartwright 2009; Wilder 2009). The age-old association of seeing to acquire knowledge−affiliated to photographic discourses through the prevalent and persistent eye metaphor−has been bolstered particularly by the growing numbers of mechanical observational devices and optical instruments for seeing more, further, and better (Sturken & Cartwright 2009; Wilder 2009). This started with the seventeenth century development of optical telescopes and microscopes benefitting several sciences, leading to remarkable discoveries and developments, and extending the conception and realm of visibly observable beyond the capability of unaided human vision, thus revealing hitherto unseen and unsuspected miraculous prospects in praised detail, accuracy, and objectivity (Sturken & Cartwright 2009; Wilder 2009). The sense of awe was further fostered by consecutive, emerging techniques, particularly the revolutionary discovery of X-rays in the 1890s, introducing a sensational, unprecedented penetrative method for observation revealing hidden structures and enforcing the notion of an underlying invisible 'scheme of things'−detectable through special equipment−generating magical sights of the previously unseen, advancing and revolutionising medical practices, and profoundly transforming and broadening the notions around photography in the process (Jeffrey 1999, p. 76; Sturken & Cartwright 2009; Wilder 2009).

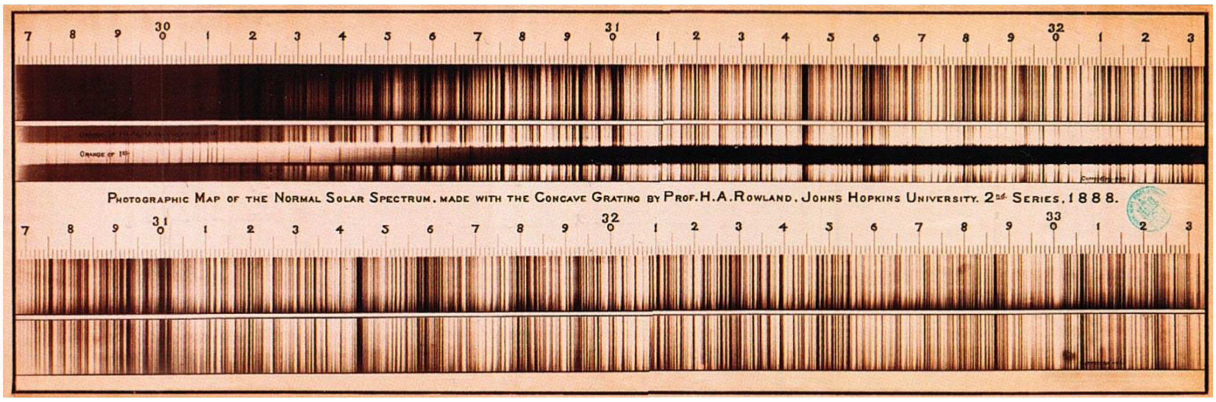

Fig. 2: Rowland, H. A. (1888) *Photographic Map of the Normal Solar Spectrum, Made with the Concave Grating, 2nd series*

The perceived faithful indexicality registering voluminous, minute, and even incidental detail actuated various scientific measuring practices to extract and generate non-visual data from photographic recordings and inspired even further experimental photographic methods producing abstract diagrammatic data for measuring, consequently generating highly specific and specialised information requiring expertise and acculturation to be ciphered (Wilder 2009). The scientific ethic of impersonality and objectivity, imposing passive voice on texts and graphic representations—typically released anonymously under institutional authority—both fails to acknowledge the inevitable influence of human factors and 'subjective and culturally informed decisions' and provides scientific imagery with added accreditation (Kevles 1992; Sturken & Cartwright 2009, p. 356). These evidential and authoritative uses photographs have been employed in under the positivist ethos have greatly influenced the general status of the photograph—habitually considered to be descriptive and truthful empirical proof providing reliable observations—thereby paradoxically further supporting the faith in photography as a scientific experimental method and an illustrational tool even despite its readily acknowledged deficiencies (Price & Wells 2009; Wilder 2009).[12]

Photography's widely remarked aptitude to evoke admiration and delight by magically transgressing 'the physical limits of scale and distance' and allowing us to participate in hidden secrets, further embedding it deeply in the social and institutional structures of phenomenological knowledge situating us in the world, is smoothly carried over to and furthered by the subsequent modern digital imaging techniques, even for rendering non-

[12] Numerous historical shortcomings and outright failures, obvious discrepancies, and several technical issues and limitations concerning manipulability, controllability, technical limits of photographic capability, reliability of chemical and mechanical components, and challenges in distinguishing interference from genuine results together with questions of how to actually interpret the visual outcome are often noted in association with scientific photography (Wilder 2009).

optical sensory data, such as acoustic and haptic information, into visual artefacts (Sturken & Cartwright 2009; Boyle 2013 p. 212; Palmer 2013).[13]

Fig. 3: '[The St Helens and Knowsley Teaching Hospitals] Maternity Ultrasound Department also offers the opportunity to purchase a 3D / 4D scan Package. This is a non diagnostic service that focuses on the baby’s facial features.' (St Helens and Knowsley Teaching Hospitals, NHS Trust 2015)

[13] Collecting, cataloguing, and delivering distant, rare, inaccessible, and alien views, and revealing 'underlying natural structures' through technological innovations enabling illustrating elusive and unobservable phenomena as visible renditions−perceived simultaneously miraculous, 'magical and truthful'−photographs consequently render them ordinary, thereby generating impressions of power, control, and possession of reality mediated by these images (Sontag 1979; Price & Wells 2009; Sturken & Cartwright 2009, p. 356; Wilder 2009, pp. 107‑108).

Paradoxically, despite the concerned debates about the acknowledged ambiguity, subjectivity and technical manipulability of photography, and the increased nominal awareness of the critically contested, questionable evidential value of photographs, intensified by the emergence of digital technologies, 'the widespread conviction that such non-human modes of sensing can provide unambiguous representations' and the casual acceptance of images as objective, transparent depictions of the real−termed *reality effect* in film studies−deriving from the historically accrued cultural and ideological naturalisation of the powerful positivist legacy, peculiarly persistently lingers and 'clings to mechanical and electronic images' 'particularly within the epistemic framework of science' (Edwards 2006; Lister 2009; Sturken & Cartwright 2009, p. 16; Boyle 2013 p. 212; Schuppli 2013, p. 22). As Susan Schuppli points out, the persistent indexicality association indeed 'still holds within many contemporary discourses [...] even if it fails to convince within critical photo studies' (2013, p. 26). Although the cultural meanings and expectations for digital images differ as computer-generated imagery has changed drastically the notion of photographic indexicality, subsequent, visually convincingly similar electronic imaging regimes still carry the irrational evidentiary authority of the photographic image by simulating the photographic truth through considerable continuity of photographic visual codes, even if in fact primarily referring to real through iconographic rather than necessarily indexical resemblance (Lister 2009; Sturken & Cartwright 2009).

Beyond the professional, clinical, informational meanings and functions, scientific imagery is invested with deep, inseparable social, cultural, and even emotional meanings, apparent, for example, in the cultural status of fetal sonograms (Sturken & Cartwright 2009).[14] While commonly understood 'as a kind of window into the body', ultrasound images are, however, factually visual representations of sound wave measurements, neither inherently nor necessarily visual, analysed by computers and rendered as images due to our cultural preference for visual representations (Sturken & Cartwright 2009, p. 365).[15]

Astonishingly different kinds of data, produced utilising multitudes of widely varying techniques measuring equally varied phenomena and entities, can in fact be visualised in deceptively similar ways.[16] While some scientific images still closely pertain to fairly traditional photographic recording, vast amounts of other types of pictorial representations also capitalise relatively inconspicuously on the powerful cultural assumptions of intrinsic photographic reliability, evidentiality, and truthfulness due to their deceptive visual resemblances to photographic images in clarity, detail and depth of field regardless of their methods of production. Utilising constructed perspective and artificial colouring, typically conforming to the Western pictorial tradition, further renders scientific views of widely varying scales and content attractive, intriguing, otherworldly, and even sublime landscapes of sort, yet simultaneous effectively alienated from any natural visual experience of the content, thus evoking awe and wonder, and enlisting the associated rhetoric of discovery, conquest, and domination.[17]

---

[14] Considered as 'a cultural rite' of the 'first "portrait" of the child-to-be', fetal sonograms, allowing for obstetrically acknowledged visual bonding with the future child and bestowing the fetus a personhood and a status as a social being, consequently also play an iconic role for instance in political abortion debates (Sturken & Cartwright 2009, pp. 365-366).

[15] Echoing the traditional accounts of images in general, scientific imagery is frequently understood through the powerful cultural metaphor of the picture as a window to the world, effectively suggesting a view through a transparent surface of the image (Edwards 2006).

[16] Even when the imaging techniques themselves may produce results fairly faithful to actuality, the procedures prior to the capture can modify the objects drastically. For the purposes of microscopic study and imaging, for example, the specimens are treated in various ways, including separating, isolating, slicing, flattening, dying, freezing, heating, drying, and peeling off layers both mechanically and chemically, to name but a few of the most violent techniques involved in standard preparation of samples. Although resulting in visually fascinating micrographs revealing internal structures and other features, the methods often also drastically alter the appearances of the samples, effectively rendering the original visual characters unrecognisable in the process.

[17] When genuine colours may reveal information about a variety of phenomena and substances, artificial colours are often assigned not to replicate reality but to emphasise areas of interest and

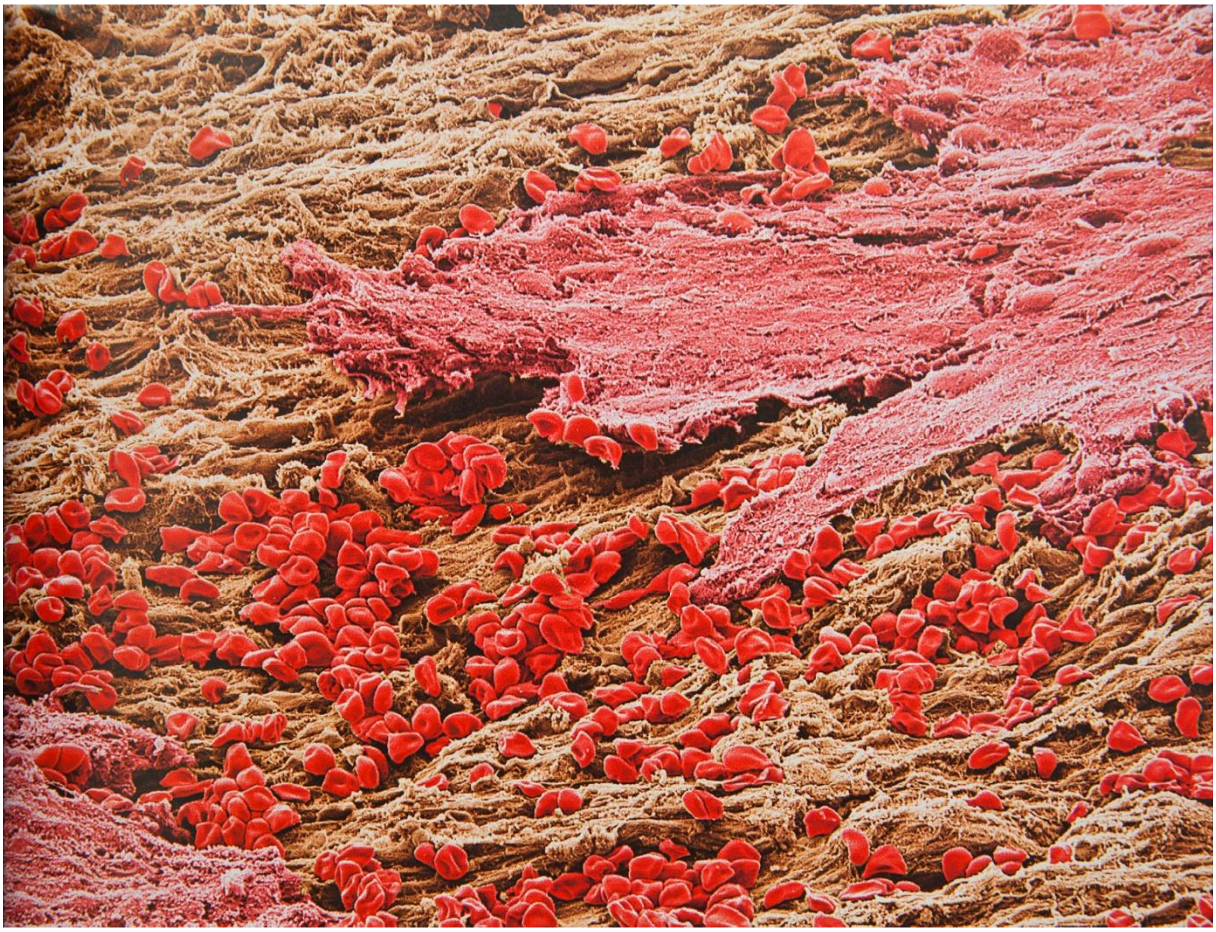

Fig. 4: Several modern scientific imaging practices produce awe-inspiring, attractive computer-generated images visually notably resembling photographic landscapes in clarity, detail, and the use of constructed linear perspective and artificial colouring.

Scientific imaging is part of the larger scopic and ideological regime of Western visuality, founded on the dominant Western mindset based on the Enlightenment philosophy, Cartesian dualism, and the mathematical rational and rationalising model of linear perspective, securing and addressing the humanist viewer as the dominant, rational, observing centre of the world, seeking 'objective knowledge through a disinterested and rational method of enquiry' and thereby establishing an order to reality (Kember 1998; Lister

enhance readability (Wilder 2009). A treatment can serve both genuinely diagnostic and visual purposes, like staining samples with reagents to discover or clarify their structures. The use of polarising, cross-polarising, and gradient filters, for example, not only reveals important information about the compounds and physical attributes of the objects examined, but also habitually produces visually intriguing and appealing spectral colours. However, to the vast array of scientific imagery algorithmically generated from innately non-visual data, colouring is added afterwards subjectively and arbitrarily without any universal code both for genuinely useful and informative reasons to differentiate details, but also purely to create more aesthetically appealing and lucid false-coloured images largely because 'the lay viewer of the later twentieth century, attuned to a world of colour representation [...] expects colour' (Ewing 1996, p. 14).

2009, p. 322).[18] Seconding Heideggerian representationalism, imaging allows for the desire of being positioned as a subject in a power relation to the appropriated, represented objects, thereby empowering the viewer and objectifying and enframing the world as a subordinated, simplified resource (Heidegger 1977). Such representationalist conception of the world, Heidegger suggests, further structures, enframes, and limits our understanding of the confines of legitimate reality through predefined scientific knowledge (1971; 1977).

Underlying the current epistemology emphasising advanced technologies uncovering invisible secrets—notably supported by modern imaging techniques generating representations ostensibly revealing hidden knowledge—is the historical Western notion that 'truth lies beneath the surface' and 'needs to be seen to be fully understood', stemming from the early Greek philosophy (Sturken & Cartwright 2009, p. 369–370). The resulting imposing status of vision as the primary means of obtaining, analysing, and ordering knowledge has been pivotal in not only formulating the modern, positivist understanding of existence as a primarily visual concept and centring scientific practices around observation, but through our reliance on visual proof enforcing the status of images in asserting veracity, conferring importance, and defining reality (Sontag 2008; Sturken & Cartwright 2009). Imaging has a particularly prominent role in Western medical practices where, cultural theorist Lisa Cartwright suggests, torrents of specialist imaging techniques, perceived superior and more authoritative and reliable than direct observation, have supplanted sensory perception (1995, p. 23).[19] The scale and ways of understanding and experiencing reality, and our own bodies,

[18] Descartes's profoundly influential mechanical conception of nature, and the subsequent, increasing mathematisation of scientific knowledge, profoundly shaping Western thinking, is the pivotal foundation of the dominant modern scientific perception of the ultimate nature of reality as a unified structure, enabling its reduction to arbitrary, abstract, artificial, theoretical mathematical schema or regime, internally coherent, but potentially entirely divorced from the perceptual reality (Maslow 1966; Heidegger 1977; Sorell 1987; Kevles 1992; Davies 2010; Wilson 2010). Shaping the correspondent conception of the essence of reality towards ultimate abstraction, structured through and understood as representations—essentially ordered and thus controlled by man—this mathematical outlook simultaneously implicitly supports the regime of representing knowledge with images (Heidegger 1977).

[19] A multitude of useful, non-invasive diagnostic techniques have been developed for medical purposes. Whereas the traditional X-ray shadowgrams are still based on recording radiation on a radiation-sensitive sensor—even if coloured afterwards to facilitate interpretation—later non-photographic inventions often rely heavily on computer processing of the data to generate the visual outputs. In computer axial tomography (CAT and CT), a beam of X-rays traces around the section studied at various angles, generating recordings of data which can be combined to create three-dimensional representations of opaque structures. Magnetic resonance imaging (MRI) computers generate colour-coded two- or three-dimensional representations of radio waves temporarily released by atoms inside structures when excited by the presence of high energy magnetic fields. Positron emission tomography (PET), in turn, produces computer-generated, colour-coded images of the

have shifted due to the emergence of the invisible level of molecular, atomic, nanoscale, and genetic concepts and entities (Sturken & Cartwright 2009). Along with the proliferation of digital imaging, cultural concepts and understanding of scientific entities have further 'begun to reflect concepts of the digital' (Sturken & Cartwright 2009, p. 370). Genetics has emerged as the primary biological paradigm assimilating the human being to digital code through a network of interconnected molecular, genetic, and digital concepts and metaphors, represented and perceived through clinical visual rendition techniques as organised systems of neat units, conceivable, manageable, modifiable, and transformable at the detailed molecular level (Sturken & Cartwright 2009). Beautifully supported by the clean-cut imagery offering a sense of possession and command of these invisible universes, this appealing conception of the reducibility of organic entities to systematic containable, controllable, and classifiable digital data, coded and thus mastered by science, underpins the shared, rather optimistic but highly appealing belief in the imagined control and power over the sublimity, uncontrollability, and complexity of nature (Henning 2009; Price & Wells 2009; Sturken & Cartwright 2009).

According to Sturken and Cartwright, the proliferation of visualisation processes, producing representations of a variety of scientific data and thus generating novel observable entities, throughout the twentieth century, suggests 'a worldwide shift toward the visual means of representing knowledge and evidence in science and a growth in the area of expert images' legible only to specialists trained to interpret the relevant codes (2009, p. 348). Information visualisation processes have thus shaped not only the general notions of science, but also scientific disciplines and practices towards visual ways of knowing, as 'images and visual inscriptions of data [have become] more important aspects of conducting experiments, rendering information, and communicating ideas in science and medicine', changing 'not only how scientists pursue knowledge but also what scientists seek to know' (Sturken & Cartwright 2009, pp. 348, 349; Wilder 2009).

---

distribution of a radioactive substance, injected into the bloodstream, from the radioactivity level measurements by radiation sensors positioned around the section studied. Ultrasound imaging uses sonic frequency measurements, whereas electroencephalography (EEG) is a computer-generated representation of electric impulse data generated by brain activity, to name but a few of these familiar modern practices authoritatively introduced to the general public in the name of scientific progress and unquestionable reliability. The resulting pictures are generated by computers interpreting, organising, and converting the collected, highly processed, statistical measurement data of scenes inherently imperceptible into graphic representations based on their programming. The output is a result of a combination of deliberate choices as the data is organised, processed to enhance desired detail, and assigned a range of colours to provide bold visualisations.

The habitually accepted bewildering array of new technologies, echoing the established positivist role of photography as an authoritative observation implement, have further turned out to be extremely productive picture-making tools that generate alluring, miraculous views of previously unseen microscopic and macroscopic universes in fascinating detail, sharpness, and perspectival depth (Henning 2009; Lister 2009).[20] Providing the principal access to these invisible realities, the omnipresent, popularised, highly processed, and often diagrammatic computer graphics illustrations carefully geared towards and selected for their visual impact, supposedly enabling seeing at these levels, create an acquired catalogue of visual notions 'constructed through aesthetic choices' and image-manipulation techniques (Sontag 2008; Sturken & Cartwright 2009, p. 371). Designating, assigning, and consolidating visual appearances to invisible entities, such imagery profoundly moulds how both laymen and experts see, experience, understand, visualise, and subsequently depict the world by facilitating, structuring, and transforming thinking of such unforeseen entities (Henning 2009; Sturken & Cartwright 2009).

Fig. 5: Ubiquitous, generic illustration of DNA

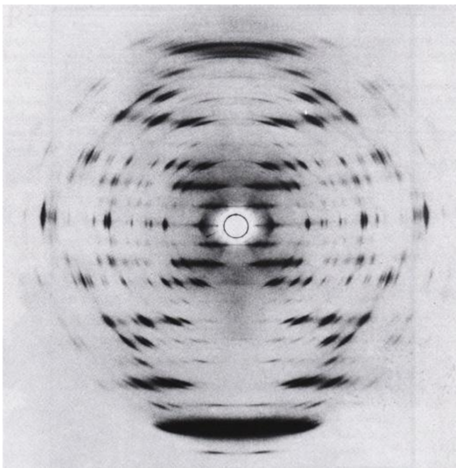

Fig. 6: Franklin, R. (1952)
X-ray photograph of a DNA crystal

The present ubiquity of generic, computer-generated illustrations of the double-helical molecular structure of deoxyribonucleic acid (DNA)−proposed in 1953 based on an X-ray

[20] In the twentieth century, non-optical imaging techniques were developed beyond the limitations of optical lenses and visible light, heralding 'a new frontier of corporeal knowledge' (Ewing 1996, p. 9). Now, scanning electron microscopes using streams of electrons controlled by electric or magnetic fields to generate captivating pictorial representations of astonishing magnification and depth of field are capable of depicting minuscule objects like cells and turning insects into those now so familiar scary monsters. The scanning tunnelling electron microscopes tracing the surface of the sample with a very fine needle recording the flow of electrons between the needle tip and the sample are even capable of generating recordings of individual atoms (Robin 1992).

crystallographic discovery−poignantly testifies to the influence that the dominance of a highly distinct scientific illustration mode can have on public conceptions.[21]

As abundances of scientific imagery acutely testify, despite their striking visual impact, these images are exceptionally dependent on the accompanying authoritative verbal information supplying, contextualising, and securing their reading and meanings due to the decontextualisation inherent in the faded sense of context and scale, crucial to interpretation, and not readily correlating with actual visible experiences other than similar illustrations. While contextualising and captioning imagery in more openly politicised contexts is frequently contested, scientific illustration seems to excite less passionate debates and concerns, rather leaving the recipients to rely on the accompanying information provided. Particularly in popularised contexts, the occasional negligent use of photographic terminology and metaphors, moreover, unjustifiably invokes the illusions of photographic origin, and thereby, associated notions of reliability.

[21] X-ray crystallography, also known as X-ray diffraction, where molecules are processed to form crystals that are subjected to X-rays to produce characteristic reflection patterns recorded on radiation-sensitive material, though somewhat based on genuine visual recordings, produces diagrammatic data of atomic structures, requiring considerable amounts of interpretation and construction of the actual visualisations. Although the crystallographic recordings are often somewhat misleadingly labelled 'photographic' in popularised publicity, it is, however, the subsequent, totally artificial computer-generated graphical illustrations modelling the hypothesised structures that have monopolised the public imagination.

Fig. 7: The visually captivating spectacles served by the modern scientific illustration are remarkably dependent on the accompanying verbal information supplying and clarifying their meaning, as is evident when trying to interpret these images without any further guidance.

Not all illustrations, obviously, are equally suspect, but in the modern media environment, visually captivating imagery seems to command easy public visibility. The modern scientific visual communication, notably paralleling the general representational conventions in cleanness, sharpness, minute detail, and the use of colour and linear perspective, blends effortlessly into the glossy, highly visual, contemporary consumer and information culture, where our lives are increasingly filled, illustrated, and advised by endless, bright, digitally enhanced, faultless publicity images representing an idealised, retouched reality. As the modern fascination with technological spectacle, simulation, virtual, and hyperreal creates an alluring space more real, perfect, and coherent than reality 'particularly amenable to fantasy or ideology', startling amounts of information, experiences, and thus sense of familiarity derive from this ubiquitous, established, and naturalised 'generalized image repertoire' stimulating our imaginations, but also levelling different types of experiences and entities through kindred output (Berger 1972; Barthes 1981, p. 118; Baudrillard 1994; Edwards 2006, p. 102). Ubiquitous scientific publicity images, devised and optimised to appeal and forward the notion of scientific research and development as progressive and intrinsically desirable by serving alluring scientific spectacles for the masses—largely motivated by political and funding interests—should demand similar caution and critical awareness of their questionable truthfulness.

The revolutionary, manufactured view of the cosmos

The alluringly popularised publicity surrounding the Hubble Space Telescope portrays excessively glorifyingly the widely circulating, popular, fascinating, and visually appealing iconic images as revolutionising our understanding of the space by 'revealing hitherto unsuspected secrets' in magnificent detail (Sparrow 2010, p. 6; Kessler 2012). Although Hubble discoveries have undeniably contributed formatively to astronomical knowledge, the highly detailed data produced is not visual—nor is it primarily intended for imaging purposes—but innately indexical, numeric radiation intensity measurements of physical properties exceeding the abilities of vision and representation (Sparrow 2010; Kessler 2012).[22]

[22] The radiation visible to human eye as light is a minute section of the electromagnetic spectrum, which consists of the range of electromagnetic radiation wavelengths from short wavelength gamma, ultraviolet, and X-rays to long wavelength infrared, radar, and radio waves all sharing the same physical nature, yet displaying very different properties. Modern imaging techniques, however, produce multitudes of visual representations of the invisible electromagnetic radiation, although for instance infrared—revealing information about temperature—would normally be perceived as a haptic rather than visual attribute. Although it is argued that—since invisible electromagnetic radiation forms parts of the same spectrum as the light visible to the human eye—generating visual representations of the data collected from these wavelengths results into images that are essentially similar to those the human eye can perceive naturally, the fact remains that the visual appearances of these images depend entirely on representational conventions rather than being based in any undisputable way on univocal existence.

As Hubble's imaging instruments, reaching beyond the spectrum of visible electromagnetic radiation, only detect intensities of radiation monochromatically, the data used to construct many of the released iconic, stunningly colourful, contrasty, detailed, and alluring images is collected from a range of different types of devices and detectors measuring different visible and invisible wavelength ranges, intensities, and radiation types during multiple separate successive exposures of varying exposure times and apertures through a plentiful array of combinations of filters, polarisers, and masks blocking out unwanted radiation according to wavelength ranges and other characteristics (Sparrow 2010; Kessler 2012). The data sets are separately calibrated, electronically overlaid, carefully enhanced, coloured, and altered through both automated and subjective elaborate image processing techniques to reveal and exaggerate the desired subtle, otherwise invisible features and distinctions before merging together to represent one combination of distinctly different types of phenomena in false-coloured layers in a single visual representation (Sparrow 2010; Kessler 2012). In addition to merely corrective calibration techniques—aiming to return the images closer to an ideal observation—the poor original technical quality of space telescope measurements further necessitates some very subjective, intensive, and interventive approximate restoration (Kessler 2012).

The highly complex processing that astronomical data requires lacks regulation and uniform protocols (Schuppli 2013). The false-colouring does not follow consistent codes, but colour ranges are assigned case-by-case to highlight varying, case-specific features and interests, and represent a variety of different aspects of the data, such as different radiation ranges of visible, infrared, ultraviolet, and X-ray radiation, radar and radio measurements, or inferred temperatures or presence of different chemical elements (Sparrow 2010; Kessler 2012). Some composite images even purport to present views of the elusive, innately invisible black holes, dark matter, and dark energy, speculatively generated through inference from distortion measurements and calculations, and depicted in colour renderings similar to other measurement results in such composite images (Sparrow 2010).

Although exhibiting valuable scientific information, the production of the visually impressive astronomical images, often labelled dismissively as 'pretty pictures' by astronomers, is secondary or even unnecessary in scientific projects (Kessler 2012). Instead, the images are considered central to communicating scientific notions more accessibly to wider audiences (Kessler 2012). Specifically dedicating valuable resources and a team of imaging specialists solely to crafting 'aesthetically attractive images' for regular public release−despite the permanent, deep ambivalence and complex disagreements manifested in the astronomic community about the acknowledged impossibility of accurately representing the precise numeric data visually−demonstrates shrewd understanding of the pivotal publicity role of visually appealing, startling images in communicating, promoting, and evidencing the significance and successfulness of the project to wider audiences, motivated largely by the interest in increasing the crucial public and political visibility, support, and funding of astronomy (Kessler 2012, p. 7).

Fig. 8: NASA, ESA, Megeath, T. & Robbertto, M. (s.d.) *Orion Nebula: colourful view*

Rather than reflecting or replicating any actual visual experience, the appearance of Hubble images is defined by the aspects of radiation originally chosen to be measured, and the subjective choices, intentions, and visual preferences in processing the data to emphasise desired visual features. Deliberately assigning colours, adjusting contrast, and choosing orientation, composition, and framing primarily in adherence to the intentionally developed, calculated aesthetic style and representational conventions favouring 'saturated colours, high contrast, and rich detail, [...] majestic compositions and dramatic lighting' maximises the aesthetic appeal and the visual potential of the data to gain 'the greatest attention and enthusiasm' (Kessler 2012, pp. 4, 111). The heavily constructive production processes in fact create artificial hybrid compilations, shattering the notion of photographic moment and thereby the associated indexical promise of truth that the visual photorealistic reference nevertheless subtly invokes (Schuppli 2013).[23] The perceived resemblances to familiar visual sceneries further enforce the deceptive perception of these images as mimetic reflections mirroring actual visual experiences rather than as abstract visualisations of manifold data (Kessler 2012).

Elisabeth Kessler proposes that intentionally inviting visual comparisons to the grandeur of the Romantic landscapes of the American West frontier by crafting formal resemblances to 'earthly geological and meteorological formations' through deliberate choices in colour scheme, framing, composition, and spatial orientation, which emphasise a sense of three-dimensionality, substantiality, and solidity, the Hubble images employ the culturally familiar iconography of the sublime (2012, p. 5). Not only does the evocative allusion provoke predictable emotional responses, purposefully conveying a sense of awe, mystery, grandeur, and overwhelming vastness of scale through the aesthetic impact, but the conflicting responses of imagination and reason, when confronted with extreme, overwhelming aesthetic experiences of magnificence and infiniteness of nature—central to the Kantian sublime—combine to assert humanity's potential through promising that the transcendent ability of human thinking and knowledge can reach an understanding of these remote reaches (Kessler 2012).

[23] Many astronomical images are composite mosaics merging data from copious aligned close-up images, constructed through a vast quantity of choices in combining imaging settings and processing interventions, collected over long periods of time by mapping the target with successive scans through consecutive satellites or probes in space and various separate telescopes based at detached locations on Earth, enhanced, and layered either fully or partially in selected areas and electronically stitched together to create artificially constructed visual representations (Sparrow 2010; Kessler 2012).

Fig. 9: NASA, ESA, and The Hubble Heritage Team (STScI/AURA) (2008) *Hubble Image of NGC 3324*

Representing these utterly alien sceneries neatly 'contained within the frame of an image' through culturally familiar, strikingly painterly aesthetic, iconography and a way of seeing—not intrinsic to science, but adopted from art—the Hubble images offer a tempting way to experience the cosmos, but also to position ourselves through formal, visual, and metaphorical similarities in a potentially empowering relationship to it (Kessler 2012, p. 226). In addition to the integral role of the apparent frontier rhetoric and the associated promise of possible future conquest and dominion in scientific discourses, particularly regarding space exploration, the metaphor, however, also participates in complex cultural and political discourses by carrying powerful cultural connections to the myths, ideals, and notions contributing to and celebrating American national identity, ideology, nostalgia, and goals (Kessler 2012). This poignantly exposes the complex cultural, social, historical, and political factors and interests operating in the field of science and its publicity images.

The conformity of astronomical images to conventions of canonical painting has drawn critical attention to the controversial and problematic aspects of designing digital images (Wilder 2009). Circulating in as wide and varied contexts as the Hubble images, imagery gradually loses the original contextualisation and accompanying verbal information disclosing the production processes, which are crucial for decoding the case-specific methods of representing information in the image (Kessler 2012). Instead, they accumulate new, potentially highly influential cultural interpretations, associations, and uses that may even override the original functions (Kessler 2012). Committed to representing the universe in this specific style, influenced by anterior science fiction and astronomical, cultural, and ideological conventions, the distinct appearance of these images has defined the public and specialist visual perception of the universe, conditioning us to imagine and expect to see the cosmos in a particular way—in brilliant colours—thus profoundly affecting subsequent specialist and popular cultural imaging and representations (Kessler 2012).

The Hubble images vividly demonstrate how fundamentally scientific imagery, assumed to be neutral and impersonal, is in fact infested with emotional, ideological, and political investments and meanings, shaping the collective consciousness, perceptions, and imagination.

Fantastical creations strike back at our gullibility in the artworks of Joan Fontcuberta

Joan Fontcuberta has become famous for his dialoguing, premeditated, and innovative artistic counteractions contesting the pervasive cultural faith in scientific knowledge and challenging the recipients to question the alleged reliability of photographic evidence, thereby illuminatingly exemplifying how art can contribute to such discussions.

Fig. 10: Fontcuberta, J. (1984) *Lavandula Angustifolia*

The *Herbarium* project (1982-85) consists of exquisite toned monochrome prints following the conventions of traditional botanical museum plant collection displays. Subtitled *Homage to Blossfeldt,* the images capitalise on the formalist, precise, and distanced style of the highly esteemed and influential plant photographs produced by Karl Blossfeldt in the 1920s.

Appropriating the conventions of traditional scientific archival photography with the neutral, systematic representation and titling of images with conjured botanical Latin naming, Fontcuberta utilises the cultural associations of scientific objectivity and credibility. Visually aligning the images with the history of influential photographic surveying and cataloguing projects further refers to the instrumental historical role of images—photography in particular—in collecting, depicting, analysing, and storing scientific samples, as well as categorising beings according to inherently contrived classifications, which are driven by human desire to master the world (Kevles 1992; Robin 1992).[24]

Only closer study reveals that the 'plants' depicted are in fact artefacts constructed from miscellaneous matter, including animal parts. The meticulous execution and painstakingly crafted details, however, invite an unquestioning acceptance of the first impression of an inventory of unforeseen scientific specimens, eloquently addressing the common human inclination to bypass familiar-looking elements as self-evident without closer scrutiny by resorting to recollection rather than attentive observation, particularly when presented within such an allegedly authoritative framework.

[24] Notably, the institutional prominence of photography, commended as an ideal archival tool for its perceived endurance, convenience of storing, reproducibility, and indiscriminate recording of infinite trivial and unlooked-for detail—potentially crucial for unforeseen future interests and purposes—has profoundly impacted the perceptions of photographs, as a result bestowing them with exceptional authority (Wilder 2009).

Fig. 11: Fontcuberta, J. (1986) *Alopex Stultus*

As a transition from solely photographs of fabricated objects, the subsequent project *Fauna* (1988) consists of an array of manufactured, intentionally aged archival material. Allegedly the entire archive of an invented mid-twentieth century scientist explorer—who discovered a staggering amount of peculiar animals during his expeditions—the installation proficiently adopts the bygone conventions of scientific documentation.

The purposely designed display of wealth of diverse, visually fascinating material contributes integrally to experiencing this artwork (Caujolle 2001). Despite being an altogether carefully constructed fabrication with excellent attention to detail and ingenious invocation of scientific authority, the work still gains most of its credibility from the included photographic evidence, as Christian Caujolle remarks (2001). Curiously, although the evident materiality of the purposefully aged, torn, scratched, faded, and stained photographs and documents accentuates their objectness, this treatment, producing archival appearances, simultaneously bestows evidentiality and consequent reliability, again by aligning the material with the institutional archival tradition.

Combined with wryly mimicking the conventions of scientific documentation, the astute strategy of initially exhibiting these projects in natural history museums—instead of galleries or art museums—crucial to the initial perception of the work, cleverly exploited and disclosed the predispositions implied by such authoritative frameworks.[25] Drawing attention to the centrality of context and accompanying information in influencing the interpretations and perceptions of meanings, content, and reliability, particularly in supposedly informative and factual contexts, the approach simultaneously discloses the role of structures of institutional authority in producing and disseminating knowledge.

Referencing the 19th century encyclopaedic approach to natural sciences, these projects poignantly address the human desire to control the reality through classificatory systems, and question the role and relevance of the concept of natural history museums in the modern day.[26] Alluding to how the selectivity of both historical archival and contemporary scientific knowledge accumulation, particularly the catalogues of images that often become public representatives of archives, thus forming pictorial canons of disciplines, is formative in shaping the boundaries and content of the prevailing worldview, profoundly influencing not only public perceptions but students and professionals alike, these projects further challenge the validity and accuracy of archival knowledge (Wilder 2009).

---

[25] As meanings never emerge solely from images, but are substantially constructed through surrounding meaning production processes, a major influence on the meaning, status, and presumed reliability of scientific images derives from the expert framework of production and the authoritarian context of usage, seeing as they are habitually represented as evidence (Suonpää 2002; Sturken & Cartwright 2009).

[26] The historically prominent Western practices of collecting and storing knowledge in encyclopaedias, administering structure and control over nature by organising ideal typological specimens in classificatory taxonomies—such as Carl Linnaeus's famous botanical system—and amassing, classifying, cataloguing, conserving, and displaying collections of vast quantities of samples have profoundly guided the scientific approach to knowledge (Robin 1992; Wilder 2009).

Rather than manipulating the photographic images, Fontcuberta constructed and manipulated the scenes before the camera to contests the perceived reliability of the photographic medium in *Herbarium* and *Fauna,* produced in an era when image manipulation was neither as easy and commonplace nor such a mistrusted and widely debated topic as it is today. In the digital culture with widespread facility and prevalence of digital manipulation, he approaches the topic with different tactics in *Constellations* (1993). In these photographs, insects splattered on a car windscreen glow against a dark background, plausibly resembling starry skies. Presented with impressive, assertive detailed notes imitating the authoritative and abstruse scientific language—shrewdly demonstrating how much modern scientific information escapes the understanding of a layperson—the work smoothly discloses the hazards of readily resorting to existing perceptions and mental images, easily resulting in preconceived erroneous interpretations.

Fig. 12: Fontcuberta, J. (1993) *MN 56 Lyra (NGC 6779) AR 19h 16,6 min/D+30° 11',*

These projects, antedating contemporary clean-cut, colourful digital graphics, adhere to a visually different regime of scientific imagery. They nonetheless efficiently contest the reliability of direct impressions, and utilise and consequently expose the lingering positivist myth of photographic objectivity in scientific contexts, where the customary neutrality foregrounding the content tends to effectively render the representations transparent (Wilder 2009). Provoking the recipients to question the common readiness to accept the veracity of photographic evidence and the resolute cultural faith in authoritative frameworks of scientific knowledge, Fontcuberta's creations serve as a valuable, smooth, light, and approachable caution against overlooking the authoritarian roles of science, institutions and images in not only recording but also centrally producing the real.

As the fabrication processes and the related intentions of Fontcuberta's sustained practice have been revealed over the years, his new artworks now trigger heightened suspicion, questioning, and awareness. Considering his work as 'a vaccination against more important fictions', the artist hopes to encourage extending similar levels of caution and suspicion to habitual encounters with mundane utilitarian imagery (Fontcuberta 2014).

Alternative views

Scientific imagery never simply illustrates. The cultural, social and political stakes are considerably high with scientific images, as—capable of affecting perceptions of reality through shaping and enforcing specific ways of seeing—they can convey and naturalise variously motivated notions (Edwards 2006; Sturken & Cartwright 2009).[27] The historical, social, cultural, and psychological investment in the prevalent regime of representation and knowledge—generating, supporting, and utilising the persistent notions of photographic reliability and veracity to justify the socially remarkable evidentiary role of images—is essentially informed by authoritative institutional and ideological interests in supporting and naturalising the social structures of knowledge to maintain the prevailing order and power (Edwards 2006; Lister 2009).[28]

Today, artists are frequently embedded in scientific projects and residency programmes at institutions to facilitate the distribution of research results to wider audiences due to funding requirements. Their usefulness in devising visually captivating, informative, and even provocative ways of representing scientific phenomena to engage the general public has been realised, as visual information has certainly proven highly influential in communicating complex concepts in approachable forms (Wilson 2010).[29] The artists unrestricted by

[27] Produced in and influenced by a complex network of cultural, social, ideological, institutional, and power structures and interests, visual renditions of the world reflect, reinforce, and produce prevailing ideologies and worldviews and the resultant social assumptions, beliefs, conventions, and fundamental values regarding reality (Suonpää 2002; Edwards 2006; Sturken & Cartwright 2009). The prevailing ideology is integrally produced and reflected by and affirmed and shared through both social institutions and constructs, such as science, and the socially and culturally constructed images, reinforcing specific values and influencing everyday lives, often in subtle, subconscious ways (Sturken & Cartwright 2009).

[28] Postmodernist sociological analysis, following the Foucaultian connection of producing information to power, has identified scientific practice as one of the structures producing dominant 'truths' through statements constructing and structuring reality, and thereby contributing to an underlying, popularised, unified belief structure in the vested political interest in maintaining the dominant social order and justifying and corroborating society's legislative choices, structures, and practices (Foucault 1980; Ross 1991; Sokal 2008; Schopenhauer 2009). Science is thus neither the neutral and uncontested nor the solely revelatory and revolutionary territory that it is often portrayed as. In addition to its traditional, complex internal hierarchies of preferences, research priorities and battles over professional prestige and power, due to its role as an instrument of political and social power, science is in fact a highly politically motivated practice, essentially channelled and regulated through funding, with ordering, stabilising, conserving, and defensive social functions (Maslow 1966; Sokal 2008).

[29] Seeking to refute the assumptions of science's difficulty and exclusivity, both independent and commissioned artists have indeed devised a great variety of mock, pseudo, and hybridised scientific installations, websites, performances, workshops, and other engaging interventions, incorporating

requirements for immediate institutional, utilitarian, financial, or commercial benefit, moreover hold a central position in generating and revealing critical aspects, as well as identifying and highlighting concerns scientists may overlook, prefer to omit, or dismiss as inconsequential (Wilson 2010). Moving beyond illustrating and visualising scientific information, some artists are utilising the framework, language, methods, and tools of contemporary science to explore and critically reflect on the social and ethical implications, possible dangers, fears, and shared assumptions that arise from the latest scientific research, and to address the limitations in the public ability to gain knowledge and understanding about the nature, safety, and beneficiality of modern scientific practices (Wilson 2010). While some projects celebrate science's accomplishments, other artists are, furthermore, joining the philosophers, sociologists, and critical theorists critiquing 'the idealized vision of science' and the beautification of scientific imagery (Wilson 2010, p. 12).

Mirroring the debates between realism and instrumentalism in the philosophy of science, it has been suggested that rather than bemoaning the compromised reliability of the modern scientific imaging practices, which spring from the traditional representational regime of photographic fidelity to visual resemblances and strive to digitally emulate the representational qualities of earlier pictorial forms, it should be considered whether they may actually even be ideally suited for understanding complex, conceptual, abstract, and multilayered modern information, concepts, and reality (Edwards 2006; Wilson 2010).[30] There is thus a considerable, acute demand for novel approaches that are more flexible, sustainable, and productive in representing and commenting on the varied emerging information and facilitating seeking out and perceiving new kinds of entities, knowledge and insights more clearly 'in order to [better] understand and represent the essence of reality' (Edwards 2006; Ritchin 2009; Wilson 2010, p. 14).[31]

---

educational, participatory, and interactive elements, to enable the public to engage with scientific techniques, processes, and concepts both physically and via responsive, interactive, local, and worldwide networked interfaces (Wilson 2010). By demystifying and increasing awareness of scientific practices and concepts, such projects 'empower the public to participate in debate' and stimulate critical reflection (Wilson 2010, p. 13).

[30] In the philosophy of science, the stances on the role and purpose of science vary between realism, considering the role of science to be uncovering absolute truths about the world, and instrumentalism, maintaining the realist goal is an illusion and advocating aiming at empirical adequacy instead (Sokal 2008).

[31] Devising alternative, unforeseen visual and non-visual methods for portraying scientific discoveries and processes, several contemporary art projects do experiment with information visualisation methods combining and converting data from one medium to alternative, unconventional types of

The particularly strong informational and authoritative role utilitarian scientific illustration holds 'as evidence of the real' in Western culture, however also pressingly advocates more critical attention to the considerable role of aesthetic choices and adherence to cultural representational conventions in shaping the imagery, which is habitually overlooked in commonplace encounters (Sturken & Cartwright 2009, p. 348; Wilson 2010). Unlike utilitarian illustration, predominantly reproducing established conventions, artistic approaches able to critically address, deconstruct, and question the conventions of scientific imagery can interpellate the viewer to participate in meaning production rather than imposing interpretations (Walsh 2013). Consequently, artistic methods may contribute crucially to seeking out repressed aspects, ignored by the dominant regime of scientific illustration, even if they−typically assumed restricted to the artistic sphere−are sometimes mistakenly perceived to have only limited ability to challenge the authority and conventions of the ubiquitous utilitarian representations. In exposing, deconstructing, and diverting underlying assumptions influencing the scientific paradigm, structures of information systems and conventions of conceptualising, visualising, and analysing information, creative projects can thus engage in postmodern questioning of the notions of objectivity and truth, the scientific belief in a deterministic natural structure and the pervasive optimism and faith in scientific progress and superiority (Wilson 2010).

---

sensory outputs to question and conceptualise the alleged knowledge derived from such representations (Wilson 2010). These experiments range from intriguing novel modes of visualisation, investigating the communicative abilities of new technologies, multimedia displays, and other digital applications, to multidisciplinary, multisensory, and non-visual hybrid approaches and immersive environments, contesting and proposing alternatives to the persistent cultural accustomisation to receiving and perceiving information of several non-visual phenomena as passive visual experiences (Wilson 2010).

Fig. 13: Miller, S. (2003) *Signal Relay*

In the *Protein* series, instead of illustrating science, artist Steve Miller reflects on how scientific and technological developments, approaches to visualisation in particular, can affect human perception (Miller 2014). Through layering scientific notes, diagrams and three-dimensional computer-generated models of cells and protein structures—originally produced and experimented with by the Nobel Prize winning scientist Roderick MacKinnon as visual tools in developing, structuring, and illustrating scientific study—the project highlights the substantial role that visual tools and visualisations can play in scientific practice. *Signal Relay* from Miller's series further alludes to the unfixed nature of representation of many scientific structures through morphing different-looking approaches together, while also subtly pointing to the apparent dependence on verbal elaboration to contextualise and expound scientific visuals. Representing cutting-edge scientific illustrations stripped of the usual sleek, digital clinicality through exquisite silk-screen printing points to their nature as products of the human creative imagination, similar to art, rather than as outputs of some impersonal, mechanical process guaranteeing automatic objectivity. The work thus suggests the inevitably limited ability of images to really represent scientific entities and also invites further consideration of how the habits and conventions of visualisation are born.

Conclusive prospective contemplations

In modern society, where knowledge continues to become increasingly sophisticated, intricate, and specialised, lack of requisite specialist acculturation renders deeper scientific information, together with most scientific imaging processes, unfathomable to the general public, leaving us to rely on the information issued by authoritative specialist sources in estimating the reliability and representational value of the plentiful, widely differing visual representations generated and frequently released by modern scientific practices. At the same time, the accounts advocating for the progressiveness, veracity, and superiority of science as the interpretative system for reality are centrally supported by images persuasively enforcing and securing our illusion of increasing dominance through control of these manageable, comprehensible units (Sturken & Cartwright 2009; Bolt 2011). How reality is structured, conceived, and represented is, therefore, of crucial significance because organising and classifying the initially chaotic 'experience into meaningful patterns' creates and imposes meanings, not only establishing order to the surrounding reality, but consequently establishing and securing the human position as the intellectually, emotionally, and ideologically dominant, empowered, rational, observing centre of the world (Maslow 1966, p. 84; Heidegger 1977).

Praising scientific techniques as revelatory of novel, miraculous vistas, the surrounding sociocultural rhetoric, deriving from the historical Western notion of visuality of knowledge and supported by the resultant shared faith in images to reveal truth, further strengthens the general faith in the supplied amazing visions of the numerous, otherwise unknown entities and phenomena (Sturken & Cartwright 2009). As the visual information about many scientific subjects originates solely from pictorial representations, rather than from first-hand observation, increasing the collective cultural awareness, understanding, and literacy of the evolving, self-generating system of conventions within the scientific imaging regime would be crucial in the current rapidly changing information culture, effectively naturalising and concealing the prevailing structures of knowledge production (Ritchin 2009). In addition to further critical discussion and public familiarisation with the frameworks and techniques, addressing the general 'tendency to conflate iconicity and indexicality' is particularly urgently advisable as the artificially constructed imaging conventions and practices profoundly impact public perceptions (Elo 2013, p. 96).

Far from infallibly delivering absolute truths, scientific imagery is, in fact, profoundly constructed by ideological, social, cultural, and political structures and interests specific to the contemporaneous prevailing paradigm. Sustained and naturalised by social, educational and publicity structures, the images are, furthermore, performing substantial roles in public and societal discourses. Particularly in the rarely critically addressed authoritarian institutional uses—easily perceived neutral and reliable—where the authoritative context of a highly esteemed specialist domain, together with the use of intricate techniques, generates assumptions of authority and credibility, images can indeed both purposefully and unintentionally construct and support desirable 'truths' (Sturken & Cartwright 2009).

Although cutting-edge scientific imaging has shifted from photographic towards purely digital, computer-generated imagery, public perceptions—embracing photography's prominent historical, instrumental, and specialist and public informational role—seem nevertheless persistently tinted by the relatively inconspicuous cultural, positivist legacy of the inherent photographic indexicality, the early rhetoric of mechanicality and automaticality, and the associated assumptions of transparency, objectivity, reliability, and evidentiality (Edwards 2006; Price & Wells 2009; Sturken & Cartwright 2009). The problematic, persistently lingering subconscious public trust in some level of indexicality, although refuted and discredited in modern photography theory and regularly dismissed in other contexts, however remains largely unaddressed with scientific imagery, perceived to originate from reliable sources, thereby underpinning the common, irrational cultural faith in their reliability.

Even scientists readily recognise the profoundly ambivalent role of images—considered essentially subjective, aesthetically motivated arbitrations—not optimally suited to the scientific ideals of exactitude and abstraction, perceived better fulfilled by fixed numeric data, impossible to perfectly translate or reflect visually (Kessler 2012). Elsewhere '[t]heorists warn that imaging systems do not provide unadulterated access to core levels of reality', producing instead insufficient, 'technologically mediated' representations providing fragmentary and 'selective access to unseen realities' based on the limited ability and restricted orientation of essentially culturally constructed imaging conventions and technologies, which are shaping and restricting the possibilities for all emerging presentations (Wilson 2010, p. 64; Boyle 2013 p. 220; Schuppli 2013). Yet, images play substantial and constitutive recursive roles in shaping the course of scientific development, as they affect perceptions, which in turn affect practices; practices then generate more images based on the prevailing conventions.

Despite the recognition of deficiencies of representations in relation to real, the common understanding of representation as a reflection of reality, and thus as the dominant system prescribing the way we understand the world, unquestionably still prevails (Baudrillard 1994; Bolt 2011). The exponentially expanding amount of information, furthermore, necessitates effective, accessible and simple communication methods to enable individuals to navigate the increasingly elaborate modern life, defending the otherwise questionable validity and justification of the use of scientific images in informational contexts, as visual representations facilitate relating complex and unfamiliar scientific concepts to everyday reality, thus contributing to both literal and metaphorical ways of understanding reality (Sturken & Cartwright 2009).

As theorists point out, we construct our perception of reality through reference on existing experience and meanings (Deleuze & Guattari 1994; Pfadenhauer 2013). All encountered images, thus, accumulate to add to constructing one's 'subjective reality', which in turn informs consciousness and imagination−integral to the ability to generate variant, divergent ways of thinking about and pre-visualising novel and prospective entities−and also produces the implicit, subconscious limits for what one can preconceive and expect (Boyle 2013 p. 231). The most pressing issue, particularly with innately invisible phenomena, where there are no direct visual reference points outside the prevailing, and thus internalised, regime of visualisation, is not that we would blindly assume the images unmanipulated, but that the prevalent practice of adhering to a single established mode of visualising a particular entity dictates perception and limits thinking in alternative ways.

As often noted in association with photographic seeing, once we have learned to see in a certain way, the impact cannot be undone, potentially limiting our ability to see and imagine alternatives (Boyle 2013). Thus, simply refuting an image will not reverse its impact or 'defuse its power' (Sturken & Cartwright 2009, p. 369). The compelling visual impact of characteristically aesthetically appealing scientific imagery, moreover, generates lasting, vibrant, subliminal 'emotional responses' even where the manufactured nature of the images is stated (Kevles 1992; Sturken & Cartwright 2009, p. 369). Experiencing the world through new kinds of representations, technologies and media profoundly alters our perceptions and experiences of reality, consequently shaping the reality itself through our resultant actions, thereby necessitating further evolving methods for exploring and expressing the constantly emerging new reality (Ritchin 2009; Wilson 2010). Here artists, free to explore alternative approaches to conceptualising and representing scientific information unprejudiced and unrestricted by current norms, can contribute substantially to public debate, understanding and imagination. Joan Fontcuberta's work, for example, proves that artworks can indeed increase public awareness and inspire questioning of prevailing, assimilated truths. Exploring the practices of scientific illustration both from the utilitarian and artistic perspectives is essential for my practice, as I consider it located in the intersection of questioning and deconstructing, together with exploring and proposing potential alternatives for the prevailing conventions.

Seeking to diversify methods for representation also in utilitarian contexts, such as simultaneously providing several differing suggestions for potential approaches to envisioning the represented entities, could potentially assist in imagining and developing further mental images and novel options for representations through enlarging and transforming our perceptual reality. Simultaneously enlarging understanding of the unfixed, unlimited visual nature of unseen realities, this could also benefit in reminding us that science is only capable of offering a reductionist account of only certain, limited aspects of human life (Davies 2010). With its internal system of representational conventions, scientific imagery would thereby indeed be better understood as an iconographic, rather than indexical, system of signs representing something possibly beyond our perceptual abilities.

List of Figures

Figure 11: Fontcuberta, J. (1986) *Alopex Stultus.* From: Caujolle, C. (2001) *Joan Fontcuberta 55* (p. 63). London: Phaidon.

Figure 12: Fontcuberta, J. (1993) *MN 56 Lyra (NGC 6779) AR 19h 16,6 min/D+30° 11',.* From: Dirección General de Bellas Artes y Bienes Culturales Subdirección General de Promoción de las Bellas Artes. (2000) *Joan Fontcuberta: twilight zones*. Barcelona: Actar. [no pagination].

Figure 13: Miller, S. (2003) *Signal Relay.* From: Wilson, S. (2010) *Art + science now* (p. 18). New York: Thames & Hudson Inc.

List of References

Barber, R. (1992) Introduction, in: Barber, R. ed. *Bestiary: MS Bodley 763*. Woodbridge: The Boydell Press.

Barthes, R. (1981) *Camera Lucida.* Translated from the French by Richard Howard. London: Vintage Books.

Baudrillard, J. (1994) Simulacra and Simulation. Translated for the French by Sheila Faria Glaser. Ann Arbor: The University of Michigan Press.

Publisher's note. (1998), in: Belanger Grafton, C. (ed.) Merian, M. The Younger. *1300 real and fanciful animals: from seventeenth-century engravings.* New York: Dover Publications Inc.

Berger, J. (1972) *Ways of seeing.* London: Penguin Books Ltd.

Berger, P. L. (1967) *The sacred canopy: elements of a social theory of religion.* Garden City, NY: Doubleday.

Bird, A. (1998) *Philosophy of science.* London: Routledge.

Publisher's note. (1985), in: Blossfeldt, K. *Art forms in the plant world*. Reprint. New York: Dover Publications Inc.

Bolt, B. (2011) *Heidegger reframed.* London: I. B. Tauris Co. Ltd.

Boyle, C. (2013) Eyes of the machine: the role of imaginative processes in the construction of unseen realities via photographic images, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 211-236.

Cartwright, L. (1995) *Screening the body: tracing medicine's visual culture* Minneapolis: University of Minnesota Press. Available from: ProQuest ebrary. [Accessed 28 January 2015].

Caujolle, C. (2001) *Joan Fontcuberta 55.* London: Phaidon.

Clancy, J. (2011) *The human body close-up.* London: Quercus Publishing Plc.

Davies, E. B. (2010) *Why beliefs matter: reflections on the nature of science.* Oxford: Oxford University Press.

Deleuze, G. & Guattari, F. (1994) *What is philosophy?* Translated from the French by Graham Burchell and Hugh Tomlinson. London: Verso.

Van Duzer, C. (2013) *Sea monsters on medieval and Renaissance maps.* London: The British Library.

Edwards, S. (2006) *Photography: a very short introduction*. Oxford: Oxford University Press.

Elo, M. (2013) The new technological environment of photography and shifting conditions of embodiment, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 89-104.

Ewing, W. A. (1996) *Inside information: imaging the human body.* London: Thames and Hudson, Ltd.

Fischer, A. (2013) Photographic scale, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 151-169.

Fontcuberta, J. (2014) From notes taken by Emilia Moisio at the artist's talk accompanying the *Joan Fontcuberta: stranger than fiction* exhibition. Science Museum, London, 27 October.

Foucault, M. (1980) Truth and power, in: *Power/knowledge: selected interviews and other writings 1972-1977.* Colin Gordon (ed.). Translated from the French by Colin Gordon, Leo Marshall, John Mepham, Kate Soper. New York: Harvester Wheatsheaf. pp. 109-133.

Heidegger, M. (1971) The origin of the work of art, in: *Poetry, language, thought*. Translated from the German by Albert Hofstadter. New York: Harper Perennial Modern Thought. pp. 15-86.

Heidegger, M. (1977) The age of the world picture, in: *The questions concerning technology and other essays.* Translated from the German by William Lovitt. New York: Harper & Row, Publishers. pp. 115-154.

Henning, M. (2009) The subject as object: photography and the human body, in: Wells, L. ed. *Photography: a critical introduction.* 4th ed. London: Routledge. pp. 167-204.

Jeffrey, I. (1999) *Revisions: an alternative history of photography.* Bradford: National Museum of Photography, Film & Television.

Kember, S. (1998) *Virtual anxiety: photography, new technologies and subjectivity.* Manchester: Manchester University Press.

Kessler, E. (2012). *Picturing the cosmos: Hubble Space Telescope images and the astronomical sublime.* Minneapolis: University of Minnesota Press.

Kevles, D. J. (1992) Historical foreword, in: Robin, H. *The scientific image: from cave to computer.* New York: Harry N. Adams, Inc.

Kuhn, T. S. (1970) *The structure of scientific revolutions.* 2nd ed. Chicago: The University of Chicago Press.

Latour, B. & Woolgar, S. (1979) *Laboratory life: the social construction of scientific facts.* Princeton: Princeton University Press.

Libbrecht, K. (2003) *The snowflake: winter's secret beauty.* Stillwater: Voyageur Press, Inc.

Lister, M. (2009) Photography in the age of electronic imaging, in: Wells, L. ed. *Photography: a critical introduction.* 4th ed. London: Routledge. pp. 311-344.

Maslow, A. H. (1966) *The psychology of science: a reconnaissance.* New York: Harper & Row.

Miller, A. (2014). *Colliding worlds: how cutting-edge science is redefining contemporary art.* New York: W.W. Norton & Company

Palmer, D. (2013) Redundant photographs: cameras, software and human obsolescence, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 49-67.

Peran, M. (2000) Reality, porous and besieged, in: Dirección General de Bellas Artes y Bienes Culturales Subdirección General de Promoción de las Bellas Artes. *Joan Fontcuberta: twilight zones*. Barcelona: Actar. [no pagination].

Price, D. & Wells, L. (2009) Thinking about photography: debates, historically and now, in: Wells, L. ed. *Photography: a critical introduction.* 4th ed. London: Routledge. pp. 9-64.

Ritchin, R. (2009) *After photography.* New York: W. W. Norton & Company Inc.

Robin, H. (1992) *The scientific image: from cave to computer.* New York: Harry N. Adams, Inc.

Ross, A. (1991). *Strange weather: culture, science, and technology in the age of limits.* London: Verso.

Rubinstein, D. (2013) The grin of Schrödinger's cat: quantum photograph and the limits of representation, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 33-47.

Rubinstein, D. & Fisher, A. (2013) Introduction: on the verge of photography, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 7-14.

Schopenhauer, A. (2009) *The horrors and absurdities of religion.* Translated from the German by R.J. Hollingdale. London: Penguin Books.

Science Museum. (2014) *Joan Fontcuberta: stranger than fiction.* London: Science Museum.

Schuppli, S. (2013) Atmospheric correction, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 17-32.

Sokal, A. (2008) *Beyond the hoax: science, philosophy and culture.* Oxford: Oxford University Press.

Sontag, S. (1979) *On photography.* London: Penguin Books

Sontag, S. (2008) Photography: a little summa, in: Dilonardo p. & Jump, A. eds. *At the same time: essays and speeches.* London: Penguin Books. pp. 124-127.

Sorell, T. (1987) *Descartes: a very short introduction.* Oxford: Oxford University Press.

Sparrow, G. (2010) *Hubble: window on the universe.* London: Quercus Publishing Plc.

St Helens and Knowsley Teaching Hospitals, NHS Trust (s.d.) [online]. Available at: http://www.sthk.nhs.uk/pages/Departments.aspx?iPageId=12470 [accessed 06 March 2015].

Sturken, M. & Cartwright, L. (2009) *Practices of looking: an introduction to visual culture.* 2nd ed. Oxford: Oxford University Press.

Suonpää, J. (2002) *Petokuvan raadollisuus (The unscrupulousness of the images of beasts of prey* [my translation])*.* Translated from the Finnish by Emilia Moisio. Tampere: Osuuskunta Vastapaino.

Pfadenhauer, M. (2013) *The new sociology of knowledge: the life and work of Peter L. Berger.* Translated from the German by Miriam Geoghegan. New Brunswick: Transaction Publishers.

Walsh, M. (2013) Oscillations between disciplinary and productive subjectivity in James Coupe's auto-generative online film project Today, too, I experienced something I hope to understand in a few days (2010), in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 171-189.

Wilder, K. (2009)*Photography and Science.* London: Reaktion Books Ltd.

Wilson, S. (2010) *Art + science now.* New York: Thames & Hudson Inc.

Wirth, A. G. (1966) Foreword, in: Maslow, A. H. *The psychology of science: a reconnaissance.* New York: Harper & Row.

Wright, A. E. (2013) *Curious beasts: animal prints from the British Museum.* London: The British Museum Press.

Bibliography

Arnold, K. & Kemp, M. (1995) *Materia medica: a new cabinet of medicine and art.* London: The Wellcome Trust.

Barber, R. (1992) Introduction, in: Barber, R. ed. *Bestiary: MS Bodley 763*. Woodbridge: The Boydell Press.

Barthes, R. (1981) *Camera Lucida.* Translated from the French by Richard Howard. London: Vintage Books.

Baudrillard, J. (1994) Simulacra and Simulation. Translated for the French by Sheila Faria Glaser. Ann Arbor: The University of Michigan Press.

Berger, J. (1972) *Ways of seeing.* London: Penguin Books Ltd.

Berger, P. L. (1967) *The sacred canopy: elements of a social theory of religion.* Garden City, NY: Doubleday.

Bird, A. (1998) *Philosophy of science.* London: Routledge.

Bolt, B. (2011) *Heidegger reframed.* London: I. B. Tauris Co. Ltd.

Boyle, C. (2013) Eyes of the machine: the role of imaginative processes in the construction of unseen realities via photographic images, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 211-236.

Cartwright, L. (1995) *Screening the body: tracing medicine's visual culture* Minneapolis: University of Minnesota Press. Available from: ProQuest ebrary. [Accessed 28 January 2015].

Caujolle, C. (2001) *Joan Fontcuberta 55.* London: Phaidon.

Davies, E. B. (2010) *Why beliefs matter: reflections on the nature of science.* Oxford: Oxford University Press.

Deleuze, G. & Guattari, F. (1994) *What is philosophy?* Translated from the French by Graham Burchell and Hugh Tomlinson. London: Verso.

Van Duzer, C. (2013) *Sea monsters on medieval and Renaissance maps.* London: The British Library.

Edwards, S. (2006) *Photography: a very short introduction*. Oxford: Oxford University Press.

Elo, M. (2013) The new technological environment of photography and shifting conditions of embodiment, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 89-104.

Ewing, W. A. (1996) *Inside information: imaging the human body.* London: Thames and Hudson, Ltd.

Fontcuberta, J. (2014) From notes taken by Emilia Moisio at the artist's talk accompanying the *Joan Fontcuberta: stranger than fiction* exhibition. Science Museum, London, 27 October.

Foucault, M. (1980) Truth and power, in: *Power/knowledge: selected interviews and other writings 1972-1977.* Colin Gordon (ed.). Translated from the French by Colin Gordon, Leo Marshall, John Mepham, Kate Soper. New York: Harvester Wheatsheaf. pp. 109-133.

Heidegger, M. (1971) The origin of the work of art, in: *Poetry, language, thought*. Translated from the German by Albert Hofstadter. New York: Harper Perennial Modern Thought. pp. 15-86.

Heidegger, M. (1977) The age of the world picture, in: *The questions concerning technology and other essays.* Translated from the German by William Lovitt. New York: Harper & Row, Publishers. pp. 115-154.

Henning, M. (2009) The subject as object: photography and the human body, in: Wells, L. ed. *Photography: a critical introduction.* 4th ed. London: Routledge. pp. 167-204.

Jeffrey, I. (1999) *Revisions: an alternative history of photography.* Bradford: National Museum of Photography, Film & Television.

Kember, S. (1998) *Virtual anxiety: photography, new technologies and subjectivity.* Manchester: Manchester University Press.

Kessler, E. (2012). *Picturing the cosmos: Hubble Space Telescope images and the astronomical sublime.* Minneapolis: University of Minnesota Press.

Kevles, D. J. (1992) Historical foreword, in: Robin, H. *The scientific image: from cave to computer.* New York: Harry N. Adams, Inc.

Kuhn, T. S. (1970) *The structure of scientific revolutions.* 2nd ed. Chicago: The University of Chicago Press.

Latour, B. & Woolgar, S. (1979) *Laboratory life: the social construction of scientific facts.* Princeton: Princeton University Press.

Lister, M. (2009) Photography in the age of electronic imaging, in: Wells, L. ed. *Photography: a critical introduction.* 4th ed. London: Routledge. pp. 311-344.

Maslow, A. H. (1966) *The psychology of science: a reconnaissance.* New York: Harper & Row.

Miller, A. (2014). *Colliding worlds: how cutting-edge science is redefining contemporary art.* New York: W.W. Norton & Company

Palmer, D. (2013) Redundant photographs: cameras, software and human obsolescence, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 49-67.

Price, D. & Wells, L. (2009) Thinking about photography: debates, historically and now, in: Wells, L. ed. *Photography: a critical introduction.* 4th ed. London: Routledge. pp. 9-64.

Ritchin, R. (2009) *After photography.* New York: W. W. Norton & Company Inc.

Robin, H. (1992) *The scientific image: from cave to computer.* New York: Harry N. Adams, Inc.

Ross, A. (1991). *Strange weather: culture, science, and technology in the age of limits.* London: Verso.

Schopenhauer, A. (2009) *The horrors and absurdities of religion.* Translated from the German by R.J. Hollingdale. London: Penguin Books.

Schuppli, S. (2013) Atmospheric correction, in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 17-32.

Sokal, A. (2008) *Beyond the hoax: science, philosophy and culture.* Oxford: Oxford University Press.

Sontag, S. (1979) *On photography.* London: Penguin Books

Sontag, S. (2008) Photography: a little summa, in: Dilonardo p. & Jump, A. eds. *At the same time: essays and speeches.* London: Penguin Books. pp. 124-127.

Sorell, T. (1987) *Descartes: a very short introduction.* Oxford: Oxford University Press.

Sparrow, G. (2010) *Hubble: window on the universe.* London: Quercus Publishing Plc.

St Helens and Knowsley Teaching Hospitals, NHS Trust (s.d.) [online]. Available at: http://www.sthk.nhs.uk/pages/Departments.aspx?iPageId=12470 [accessed 06 March 2015].

Sturken, M. & Cartwright, L. (2009) *Practices of looking: an introduction to visual culture.* 2nd ed. Oxford: Oxford University Press.

Suonpää, J. (2002) *Petokuvan raadollisuus (The unscrupulousness of the images of beasts of prey* [my translation]). Translated from the Finnish by Emilia Moisio. Tampere: Osuuskunta Vastapaino.

Pfadenhauer, M. (2013) *The new sociology of knowledge: the life and work of Peter L. Berger.* Translated from the German by Miriam Geoghegan. New Brunswick: Transaction Publishers.

Wagensberg, J. (2000) Fontcuberta: or the investigation of the intelligibility of forms, in: Dirección General de Bellas Artes y Bienes Culturales Subdirección General de Promoción de las Bellas Artes. *Joan Fontcuberta: twilight zones*. Barcelona: Actar. [no pagination].

Walsh, M. (2013) Oscillations between disciplinary and productive subjectivity in James Coupe's auto-generative online film project Today, too, I experienced something I hope to understand in a few days (2010), in: Rubinstein, D., Golding, J. & Fisher, A. *On the verge of photography: imaging beyond representation.* Birmingham: ARTicle Press. pp. 171-189.

Wilder, K. (2009)*Photography and Science.* London: Reaktion Books Ltd.

Wilson, S. (2010) *Art + science now.* New York: Thames & Hudson Inc.

Wirth, A. G. (1966) Foreword, in: Maslow, A. H. *The psychology of science: a reconnaissance.* New York: Harper & Row.

Wright, A. E. (2013) *Curious beasts: animal prints from the British Museum.* London: The British Museum Press.

Zabalbeascoa, A. (2000) Landscapes: corpses, words and genetic codes, in: Dirección General de Bellas Artes y Bienes Culturales Subdirección General de Promoción de las Bellas Artes. *Joan Fontcuberta: twilight zones*. Barcelona: Actar. [no pagination].