Between physics and art: imaging the un-image-able

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September 2014

Volume **one**

Written thesis

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A thesis submitted in three components (two volumes and an exhibition of artworks), in partial fulfilment of the requirements for the degree of Doctor of Philosophy

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Abstract

This thesis explores the ways in which art practice can engage with science, and more precisely, how my own practice interacts with scientific knowledge. The theoretical underpinning and contextual position of the practice make it particularly suited to explore the concept of *visuality*, here deployed as a shared notion between scientific and artistic production. The artwork testifies to a deep interest in and fascination with the latest research in physics and the complex problems associated with the aesthetic visualisation of scientific concepts related to extreme scale, distance and mathematical abstraction. Through two volumes (a written thesis and supporting material) and an exhibition of artworks, the research asks: how can meaning be translated, transformed, and transfigured between one domain (science) and another (art), using the visual as its mode of mediation?

Following an opening survey of the broader field of investigation, looking at past and present literature and practices in the realm of science and art, the thesis analyses my art practice (considered as a hybrid between graphic design, illustration and visual communication) in terms of its immediate context, underlying motivations and methods for the production of art.

In its present form, my practice does not fit any of the current sub-domains identified in the landscape of contemporary art, and is often situated outside the dialogues and concerns of fellow practitioners. Nor does it fully belong to the realm of scientific visuality (or of an "aestheticised science"): the field has shown some limitations in relation to art's own domain of images, where modes of practice are not shared. In this instance the art is often reduced to explaining and communicating science in visual form. In contrast, my practice deploys a more sophisticated engagement with its referent, which needs to be positioned in relation to other practices, and its wider field of enquiry. To address this issue, findings from the initial investigation are reintroduced in order to conduct a reflective analysis through which the practice – argued as distinctive, and yet related to other visual traditions – exposes the problems that exist in the loosely defined domain of "Art and Science".

Taking the position of the reflective practitioner, the thesis demonstrates how the notion of research is intrinsically embedded in the creative process; therefore the enquiry also argues for the production of artworks as artistic research. Through the formation of a three-fold proposition – a *method-practice-discourse* – the investigation shows how this body of work can participate in, and question, the dominant dialogues in Art and Science. Furthermore, it serves to revisit the conventional views in the study of visuality by articulating an alternative form of engagement between two otherwise specialist domains. Ultimately, the research presents its proposition as a contribution to knowledge by providing a model for both practitioners and scholars.

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Author declaration

I declare that during my registration I was not registered for any other degree. Material for this thesis has not been used by me for another academic award.

Acknowledgements

I would like to thank my supervisors, Andrew Spicer, Paul Thirkell, and Brett Wilson for their valuable support and advice during my research, as well as Iain Biggs, Peter Walters Carinna Parraman, Barbara Hawkins, Arantxa Echarte and Paul Laidler at the University of the West of England; Gary Peters and Steve Purcell at York St John University; and Sir Michael Berry and Mervyn Miles at University of Bristol.

Special thanks to Jean Dalibard, Henning Schomerus, Gregory Ezra, Mark Dennis, Jonathan Keating, Jamie Hutchins, Brett Rubinstein and Tom Wilcox, for kindly providing testimonials used in the thesis and supporting material; as well as Robert Crease and Stephen Wiggins.

I am extremely grateful to my employer, IOP Publishing for sponsoring my doctoral research, and for the support from current Managing Director Steven Hall (2010-), his predecessor, Jerry Cowhig (1995-2010), as well as Olaf Ernst (Commercial Director) and Nicola Gulley (Editorial Director). Special thanks to all of my friends and colleagues across the organisation for their interest and encouragement (too many names to cite everyone!). I am particularly indebted to Adrian Corrigan for proofreading all of my work throughout the research and for assisting in writing the scientific captions for my art practice, as well as Andrew Malloy and Lisa Gibson.

Because of my limited knowledge in science at the level of expertise required to understand the wide-ranging content published by IOP, I have often sought explanation and advice from our publishers. I am particularly grateful to them for taking the time to discuss and explain scientific aspects, often with the added challenge of dealing with highly theoretical and obscure articles that I selected on numerous occasions. In particular, many thanks to Tim Smith, Antigoni Messaritaki, Lucy Smith, Christopher Wileman and Alex Wotherspoon.

Special thanks to my Art Director, Andrew Giaquinto, for his valuable advice, and for his unconditional support and patience during the time of my studies. I would like to acknowledge Andrew as an exceptional Art Director who I have been very fortunate to work with and learn from over the years. Andrew has been passing on and cascading down his design expertise after working closely with Swiss-German Creative Director Roland Schenk at Haymarket publishing, London (1979-1996), advocating for a strong design philosophy that defies trends and times, rooted in the legacy of the Bauhaus and the Swiss Rational Design. Andrew and I share a passion for graphic design and we have been fortunate to be working for an organisation that has enabled us to develop what has now become a distinctive design practice in the sector of STM publishing, not traditionally known for a strong design culture.

On a personal level, I would also like to thank: Dunstan Baker, Kurt Paulus, Nina Couzin, Frauke Ralf, Isabelle Auffret-Babak, Hanna Wirman, Tracy Johnson, Audrey Tsopanis, Isabelle Guihaire, Steve Gylphé, Philippe Nigro, Grégory Markovic, John Moran and all of my family back in France, for their support and patience, in particular my parents Gisèle and Claude Swist; Denise and Christiane Morelle; Hugues Dujardin; Céline, Sarah and Sylvain Baeriswyl.

Technical specification

Typopgraphy

- Body text: Minion from Linotype, designed by Robert Slimbach (1990)
- Secondary font: Helvetica Neue family, original version designed by Max Miedinger (1957)
- H&Js (hyphenation and justification settings) throughout the document: min. 70%, desired 80% and max. 90%.

Paper

Thesis printed on X-Per Premium White, from the Fedrigoni collection.
X-Per is PH neutral, chlorine-free and FSC certified, with a special treatment finish to enhance the surface and to allow a particularly bright and sharp printing.
Self-cover: 120 gsm.

Printing

Printed on the HP Indigo 5500, a high-definition digital press, with a print resolution of up to 230 lpi. Printed at Ripe Digital Ltd, Corsham, Wiltshire, UK (www.ripedigital.co.uk). Special thanks to George Penny and the production team at Ripe for their technical expertise and advice.

Chapter 1 | introduction

CHAPTER CONTENT

1 | 1 Introducing the research

From the early 1990s, commentators have attempted to provide a clear scope and definition as to what constitutes artistic research in the context of the university. In other words, *practice-led* or *practice-based* research continues to be highly debated in academic circles. Scholars such as Janneke Wesseling and Graeme Sullivan[1] offer positive ways forward in tackling the complexity of the issue, while a minority, in particular James Elkins, have been highly sceptical as to the necessity for artists to undertake this type of study; he argues that such intellectual scrutiny may be unecessary or even harmful to some art practices.[2] In response to a critical voice such as Elkins, I aim to demonstrate how my own artistic practice will benefit from theoretical discourse, and how embarking on a journey of exploration into my own work will make a contribution to knowledge for both academics and practitioners. First, I would like to begin with a brief background to what has led to this undertaking, and demonstrate why I think it is necessary.

I had already been working in the field of graphic design for five years before joining the in-house design studio at IOP Publishing (the publishing branch of the UK Institute of Physics) in 2000.[3] Immersing myself in the field of physics – the organisation's specialist subject – I was soon faced with the challenges in depicting scientific content in visual form to be deployed for branding, marketing and communication in a highly specialist environment of science, technology and medicine (also termed in the industry as STM publishing); but I also developed a fascination for scientific content and its imagery. Exploring the publications of the latest research in sub-fields such as condensed matter, nonlinearity, plasma physics or nuclear fusion, I identified an unfamiliar form of visuality (i.e. complex black and white graphs, diagrams and contour plots accompanying densely technical writing), in contrast to other branches of science, e.g. astronomy, medicine or biology, which are often illustrated with myriad colour-charged images (from long-exposure telescopes, X-rays, magnetic resonance imaging, to scanning electron microscopy and so forth).

Working closely with my Art Director, Andrew Giaquinto, we gradually developed a distinctive visual style, taking inspiration in these scientific graphs and diagrams from

1 Wesseling, J., (ed.) *See it Again, Say it Again: The Artist as Researcher* (Amsterdam: Valiz, 2011); Sullivan, G., *Art Practice as Research: Inquiry in Visual Arts* (Los Angeles, CA: Sage, 2010, 2nd edition).

2 Elkins, J., (ed.) *Artists with PhDs: On the New Doctoral Degree in Studio Art* (Washington, DC: New Academia, 2009).

3 Lewis, J. L., (ed.) *125 Years: The Physical Society and The Institute of Physics* (Bristol: IOP Publishing, 1999); also see chapter 3, pp. 87-93.

IOP's[4] scholarly journals, transforming them into new imagery, in order to respond to and develop the organisations's branding, marketing and editorial requirements. Over the years, this strategy has gradually become a more active part of IOP's corporate identity, with our design work often recognised and valued by peers, competitors and the broader scientific community as the distinctive branding image of the organisation.[5] Our design practice is influenced by the legacy of the Bauhaus and the Swiss Rational Design philosophy, which my Art Director advocated for the company.[6] This design strategy is dictated by the adoption of the grid system, typographical neutrality, a clear hierarchy and functional approach to layout, and a powerful use of imagery. Colours are deployed in more dynamic terms, *mediating* between visual and content, enabling us to express each brand and sub-brand's values in chromatic terms, from a high-profile corporate-level brochure to a full marketing campaign for an individual publication. This approach translates into the organisation's overall branding strategy: to convey a strong, coherent, authoritative and distinctive look-and-feel, supporting and reflecting the high quality of the content it provides to its specialist audience.

In creative terms, this approach showed potential for much further exploration, beyond the limitations of a brief, a client's requirements, or branding restrictions. Additional extensive visual research and experiment soon led to further possibilities for the creation of what is argued in this enquiry as a distinctive form of visuality – a methodological investigation that progressively developed into a body of work that has become an artistic practice in its own right.

From my involvement in both the design and the art practice, out of arguably a unique context (positioned at first hand, in direct access with the publication of scientific knowledge at the leading-edge of the field), questions and issues started to emerge from the making of art, from *within* the creative process. In turn these have been channelled to become research questions, driving the present enquiry. The rigour of an academic investigation into my art practice and its broader surroundings offers the challenge and the opportunity to interrogate issues on the very nature of representation, visualisation, and communication of science in visual form. It also allows one to question how art and design engage differently with scientific knowledge, and how these multi-faceted dimensions

4 Throughout the thesis I use the acronym "IOP" to refer to IOP Publishing, not its headquarters, the Institute of Physics.

5 See appendix 1, pp. 152-153.

6 See chapter 3, pp. 87-93.

in the construction of images are received, understood and positioned by an immediate audience as well as in the wider cultural context. The aim is to untangle what is seen from the outset as a complex web of concepts, notions and activities concerning images; to explore how they differ and relate to each other; and how a distinctive body of work can emerge out of this context in its current form. The particularity of my art practice is such that it does not seem to share concerns of fellow practitioners also engaged with science.[7] Therefore it engenders the difficulties of situating itself within or *between* its wider related cultural surroundings (more specifically, between theory/practice, graphic design/visual arts, and science/art).

As my art practice develops, is it also seen as an hybrid between graphic design, illustration and visual communication. Hence, the construction of a suitable theoretical framework is not only considered appropriate, but necessary in order to reach a deeper understanding of the intrinsic nature and motivations, as well as the mechanisms of creation, production and reception of the work of art. In one of his several configurations or "types" of enquiry into artistic research at the doctoral level, James Elkins proposes that one of the motivations for the researcher/practitioner could be to reach a level of sophistication with regard to his or her own artistic practice.[8] This is the case for the present enquiry, but it is also coupled with another motivation: to engage with its broader landscape, and to contribute to a possible reframing of the dominant dialogues in Art and Science.

1 | 1 | 1 Research title

The particular title of the thesis has been chosen because the research draws on a number of themes, and addresses issues that cannot always be clearly demarcated, but are located across disciplines, as well as between practice (the production of art) and theory (its contextual surroundings). What follows is a deconstruction of the thesis title, to convey the different dimensions or sub-themes for the investigation.

Between physics and art: concerns the issue of positioning my own art practice and particular engagement with physics in its related context. The word "between" implies

7 "Fellow practitioners" is meant here as a broad term, aiming to capture other artists with whom I share affinities and concerns in our individual engagement with science, rather than focussing on identifying common techniques or media. Examples of other practitioners discussed further in the thesis include mixed-media artist Peter Kalhkof (see p. 65), photographer Naglaa Walkers (see p. 70), or in reference to past models in modern art, strong affinities have been identified between my own art practice and those of Victor Vasarely and Richard Paul Lohse (see pp. 57-61 and pp. 101-102).

8 Elkins, *Artists with PhDs*, p. 152.

an issue of location in relation to science as a domain of enquiry; physics as my reference source; and art, both as the narrow space in which my practice exists, and as a wider domain of visual traditions in past and present practices engaged with science. The issue of situating my practice is significant, as it does not seem to fit with interests or concerns found in the dominant dialogues in Art and Science, that is to say the historical (or what I call *formal*) art-science connections as found in scholarly work such as those by Martin Kemp or Siân Ede, the movement Sci-Art, or ArtScience as defined by the MIT journal *Leonardo*.[9]

imaging: refers to the core of the investigation – the study of images, image-making, imaging techniques, image production and image critique. The research explores the concept of visuality in relation to scientific imagery, science modes and methods for the visualisation of knowledge, and how artists interact with science with an emphasis on the visual, rather than the conceptual.

"the un-image-able": aims to capture a strong interest in the threshold, the limits of (and what might lie beyond) the possibility of representing scientific concepts in visual form, where "objects or entities resist depiction".[10] This issue is found in the production of scientific imagery, and also in visual art, but here it is experienced differently, where the artist engages with concepts/fragments through the grasp or the apprehension of these abstractions, to produce and present art (as opposed to communicate science). The focus is often on the metaphor, appropriation, or conceptual interpretation of the source to become artwork. The term also draws on and questions the notion of uncertainty or impossibility in the production of a particular visuality, where tensions can be found between the artwork retaining a link from its source (science), but also departing from it to become something beyond – a process which is led by the manipulation of visuality itself, but which remains partly elusive, never to be fully explained as it is located at the core of the creative journey. The term "un-image-able" echoes and extends James Elkins' concept of the "unpicturable" (where he challenges the meaning presented in scientific imagery capturing events or phenomena beyond the threshold of the visible in terms of extreme scale or distance),[11] but here, the notion moves from Elkins' proposition to an alternative method of visual transformation, inherent in my art practice.

9 See glossary, p. 144, and appendix 2, p. 154.

10 Elkins, J., *Six Stories from the End of Representation: Images in Painting, Photography, Astronomy, Microscopy, Particle Physics, and Quantum Mechanics, 1980-2000* (Stanford, CA: Stanford University Press, 2008), p. XV.

11 Ibid., p. 191.

1 | 1 | 2 Context, background and identification of issues

Art and Science – a relationship between these domains has existed for much of our history, from Ancient Greece's first investigation of the atom and its visual depiction; the Renaissance's pioneering work on perspective and the camera obscura; medical and botanical illustrations of the era of natural philosophy;[12] or conceptual metaphor and artistic appropriation of scientific phenomena in modern and contemporary art. Art has been in many cases at the service of science, but science has also fed into art: connections and parallels are widespread and have been the subject of numerous artistic movements such as Cubism, Futurism, Constructivism, Kinetic or Optical Art – within modern art alone. In our contemporary landscape, practices engaged with science have become multidisciplinary, leading to the emergence of sub-movements such as Bio-Art and Nano-Art.[13] Artists and scientists are now collaborating on wide-ranging scientific and technological topics, making the art-science relationship vast, complex, dynamic, but also increasingly challenging to define (see appendix 2, p. 154).

What is loosely termed Sci-Art[14] tends to promote "artistic" imagery taken straight from scientific research, generally coming from an accurately representational and illustrative approach, and often generated and aestheticised by scientists themselves. MIT's resident science photographer Felice Frankel is well established in her field, with her visually charged photographs published in more than 300 articles and covers for leading publications such as *Science* and *Nature*.[15] Her work is often commented on as being "beautiful" and "artistic" – although Frankel herself resists these associations. A particular form of aesthetic is evident in this type of image (figure 1.1 and 1.2, p. 18), and is often acknowledged as such by its audience (testifying to the nature of misapprehension from Frankel's own motivations) but relates to a limited understanding of the notion of the beautiful – the concept is defined differently in art and philosophy from how it is employed in science. This type of "art" produced by science reflects a deep-seated misunderstanding of basic concepts that ultimately art and science do not share – an argument put forward

12 Kemp, M., *Seen/Unseen: Art, Science and Intuition from Leonardo to the Hubble telescope* (New York: Oxford University Press, 2006); Leibowitz, J. R., *Hidden Harmony: The Connected Worlds of Physics and Art* (Baltimore, MD: The Johns Hopkins University Press, 2008); Gamwell, L., *Exploring the Invisible: Art, Science and the Spiritual* (Princeton, NJ: Princeton University Press, 2002).

13 Wilson, S., *Art + Science Now: How Scientific Research and Technological Innovation are Becoming Key to 21st-Century Aesthetics* (London: Thames & Hudson, 2010); Wilson, S., *Information Arts: Intersections of Art, Science, and Technology* (Cambridge MA: MIT Press, 2003).

14 See glossary p. 147.

15 Frankel, F., *Felice Frankel* (2013). Available from: http://www.felicefrankel.com/ [Accessed 7 August 2013].

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Figure 1.1 (above): A 3-cm drop of ferrofluid on a glass slide. A slip of yellow paper sits below the slide and a set of seven small circular magnets under the paper affects the form of the drop, in Frankel, F., and Whitesides, G. M., *On the Surface of Things: Images of the Extraordinary in Science* (Cambridge MA: Harvard University Press, 2009), pp. 56-57.

Figure 1.2 (left): A detail of a very small motor. The 'blades' are half the width of one strand of hair, in Frankel and Whitesides, *On the Surface of Things*, pp. 58-59.

Figure 1.3 (below): An example of the (3,3)-soliton solution, in Kodama, Y. 'KP solitons in shallow water' in *Journal of Physics A: Mathematical and Theoretical* vol. 43, no. 43 (2010), 434004, p. 22.

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by Elkins that can also be applied to a critique of images.[16] In art, the science is often (deliberately) appropriated, interpreted, distorted, imagined, or metaphorised. Examples include Luke Jerram's series of virus glass sculpture, appropriating what can be understood as popular accounts in virology, to create visually arresting objects of the different types of viruses. Jerram engages with his audience through an area of science already highly charged with popular interpretations (i.e. images of viruses are often aesthetically colourised for public consumption as shown in figure 1.4, p. 20, while they are in actuality colourless, being smaller than the wavelength of light).[17] Keith Tyson is another artist who proclaims an interest in science (as discussed, p. 71), where he relies on loose connections with scientific notions to feed into his work. In these instances, it is popular accounts of science that serve as a creative trigger for the artist's work, as opposed to sourcing references from specialist content. Conversely, in science the aesthetics is frequently constructed using limited notions of beauty, elegance and harmony, mostly in relation to mathematics and the description of beautiful objects/pattern arrangements found in nature, or understood in relation to classical art.[18] This has been demonstrated with reference to Frankel's photography work (pp. 17-18), or with image competitions such as the Princeton yearly "Art of Science" initiative (discussed on pp. 52-56).

As regards the specificity of imagery, science has progressed to such an extent in the last fifty years alone (led by computing and digital technology) that only the current elite community of scientists can fully understand new knowledge in their respective highly specialised fields, as they deal on a daily basis with vast amount of data, algorithms, models and simulations, and their accompanying imagery (figure 1.3, p. 18). Work taking place at the leading edge of science does not generally feed into popular culture without being made more accessible. It leaves the broad audience to rely on these popularised accounts – i.e. a change of language or a process of "de-technicalisation" – which, at best, can be powerful for public debates and policy-making, but can also create issues of misinterpretation and distortion of the original meaning, thus leading to potential controversies and ill-formed judgements on societal issues. This concern not only applies to scientific writing but also to imagery, where popular pictures of galaxy clusters or microscopic living organisms are digitally manipulated to become more appealing for

16 Elkins, J., 'Aesthetics and the Two Cultures: Why Art and Science Should Be Allowed to Go Their Separate Ways' in Halsall, F., et al (eds) *Rediscovering Aesthetics* (Stanford, CA: Stanford University Press, 2009), pp. 34-50.

17 http://www.lukejerram.com/glass/ [Accessed 11 June 2014].

18 Also in reference to Elkins concept of "Pre-Kantian aesthetics". Elkins, J., *The Domain of Images* (Ithaca, NY: Cornell University Press, 1999), p. 11.

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Figure 1.4: Close up 3d render of a group of influenza-like viruses. Credit: iStockphoto.

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Figure 1.5: View of "Mystic Mountain" captured by the Hubble Space Telescope programme, showing a mountain of dust and gas rising in the Carina Nebula. Credit: Nasa, Esa, Livio, M. and the Hubble 20th Anniversary Team (STScI).

dissemination into a wider culture already saturated with images, hence contributing to a highly mediated *image* of science in the public sphere (figure 1.4 and 1.5, p. 20).

Professional science images are rarely seen in the media in their original format, so artists also tend to rely on popular accounts, to the extent that they often consider these as "true" fact-based scientific material.[19] Because of their complex nature, any attempt at engaging with specialist material – as a non-scientist – is significantly challenging, if not impossible, without undertaking a lengthy science education. As an art practitioner involved with the field, it entails tackling the technical language of science and negotiating different ways of reading and understanding imagery, where the dominant models of interpretation and critical analysis may no longer be sufficient or appropriate, because we are now dealing with specialist material such as graphs, diagrams, charts, models and contour plots, representing technical, abstract and mathematical notions of science in terms of meanings.

Considering all these issues, a potential way forward could be through the proposition of a particular method of engagement with science, through my artistic practice, which emerges from and exists within the context of science *itself*, but where the artwork proposes an alternative visuality that is located beyond existing scientific visualisation, illustration and visual communication. In dissecting and articulating my own artistic practice and involvement with science, I will not claim to resolve all the issues presented above, but I propose the possibility for a deeper interaction with science through art, with the transformation of meanings (science) in visual form (art), and argue for a shift of emphasis from understanding towards *apprehension* (in the sense of the direct experiencing/grasp) of these scientific notions, and from the *reception* towards the *production* of art.

1 | 1 | 3 Research questions

It is within the above context that my art practice and the present enquiry take place. The research asks: How can meaning be translated, transformed, and transfigured between one domain (science) and another (art) using the visual as its mode of mediation?

To address this central question, the investigation is organised around three core aspects: First, to establish a broad contextual landscape for my art practice and to identify the

19 Ede, S., *Art & Science* (London: I B Tauris, 2005).

relevant domains and sub-domains of visuality in science and art. Second, to understand more precisely the particular engagement between my art practice and science (specifically, physics) and to articulate what makes it distinctive in relation to those complex contexts. Third, to participate in and question the current dominant dialogues concerning the relationship between Art and Science.[20] In turn, these key concerns can be expressed as four research sub-questions, as follows:

- Where does my art practice sit within its wider multidisciplinary context?
- What makes my practice distinctive, a) in relation to its connection with science; b) in terms of creative process and method; and c) in relation to other art practices?
- What new insight and propositions can emerge from a study of my practice as artistic research?
- How can my practice and its underlying method participate in and contribute to the existing dialogues in Art and Science?

As this research is practice-led, it focuses on scrutinising my own art practice, combined with identifying a suitable contextual framework. The findings will serve to articulate an emerging proposition (termed *method-practice-discourse*) and to construct the critical space through which I also demonstrate the practice as artistic research. In this particular strategy of investigation, the reflective practitioner takes on the position of the *informed outsider*, questioning the field through offering an alternative model for the visualisation of science through art – hence directly addressing the main research question.

1 | 2 Methodologies and strategy for the investigation

1 | 2 | 1 Methodological models

Since the early 1990s, practice-led research has generated numerous debates as to what a suitable definition of artistic research might be, and the kinds of methods and methodologies that can respond to the individual nature and needs of such research. Different configurations have been proposed, the most established being the "research *into* art, research *through* art, and research *for* art".[21] The present enquiry places itself within both the first and second models, as follows.

20 For a reference to how the term "Art and Science" is defined in the context of the research, see glossary, p. 144.

21 Frayling, C., 'Research in Art and Design' in *Royal College of Art Research Papers* vol. 1, no. 1 (1993-94), pp. 1-5.

a) Research *into* art: here, the thesis is research that informs the art practice, although it is not restricted to a dissertation in art history, philosophy, art theory or art criticism, but borrows from all these domains.[22] More precisely, it emphasises a self-reflexivity component: "The purpose of the juxtaposition of art criticism and artwork at the doctoral level would presumably be to reach a pitch of sophistication in the description and evaluation of one's own art."[23] Additionally, the enquiry is not limited to the domain of art as it draws also from fields outside the humanities – this responds to another criteria that concerns researching in other disciplines: "If the function of the dissertation is to further the art practice, then the dissertation will necessarily be at least partly a matter of observing, adapting, appropriating, and critiquing the non-art discipline."[24]

b) Research *through* art: to some degree, the dissertation is weighted alongside the artwork, in the sense that both research and practice complement each other, that is to say "the dissertation is considered as conceptually or experientially equal to the art. The research doesn't support or inform the art, but complements it, with each one illuminating the other."[25]

1 | 2 | 2 Methodologies in relation to artistic research

A key aspect in considering the methodological strategy is that the very notion of research is embedded in my art practice on different levels,[26] thus adding to the complexity of clearly identifying suitable models of investigation, as well as the relationship between practice and theory:

- The concept of research is intrinsic to the practice's background, as it emerges from my graphic design profession, where substantial tacit knowledge in research methods has been acquired. It also testifies to research values such as "reflection *in* action" and "reflection *on* action",[27] i.e. skills in deploying (and refining) ways for the exploration, reflective critical analysis, and evaluation in the creative journey leading to the production of design or artwork, as well as a continual questioning of the meaning emerging from it.
- My art practice is driven by an underlying method in which the creative process is fully transparent: each stage is articulated, evaluated and recorded, thus demonstrating a

22 Elkins, *Artists with PhDs*, pp. 145-165.
23 Ibid., p. 152.
24 Ibid., p. 154.
25 Ibid., p. 156.
26 Wesseling, *See it Again, Say it Again*.
27 Schön, D., *The Reflective Practitioner: How Professionals Think in Action* (London: Temple Smith, 1983), p. 78.

process of rigorous research in itself. This confirms the suitability for this practice to be considered as artistic research, in the sense that the research component is highly active in the production of art, where the creative journey is fully transparent, hence particularly apt for academic scrutiny.

- My practice is central to the enquiry. It drives the investigation through an exploratory, reflective journey to establish its theoretical contextual framework; it participates in tackling wider problems of visualisation and representation in visual form; and it contributes to the formulation of an alternative proposition to challenge the findings.

Considering these dimensions, my approach to the methodology has been left to emerge gradually out of the core issues that drive the enquiry, rather than opting at an early stage for a particular model and shaping the investigation to conform to it. Specific components to the research adopt various mechanisms of investigation, that is, a combination of descriptive, explanatory and exploratory approaches.

1 | 2 | 3 Overview of key works

The research draws on a wide range of fields, cultural references and practices and their relevant scholarly work. The principal sources informing the investigation are identified as follows, clustered by discipline.

Visual studies: The domain refers to the study of images – all images – yet until recently, scholarly discourses have focused on themes located in art history and theory, media studies, social sciences and the humanities, leaving science and scientific images generally overlooked and under-researched. James Elkins discusses this issue at length in *Visual Studies: A Skeptical Introduction* (2003),[28] and in the aforementioned *Six Stories from the End of Representation* (2008) he proposes a scrutiny of imagery positioned at the limits of representation in fields ranging from astrophysics to quantum mechanics. An art historian by education, Elkins is among a small number of leading experts in the study of non-art and informational images. In his earlier work *The Domain of Images* (1999) – already cited p. 19 – he embarks on a literary experiment, bringing scientific visuality into the discourse of art history. His approach is significant, as he denounces the general lack of interest and inadequacy of art history in absorbing non-art imagery, and its reluctance to reconsider deep-rooted concepts such as the divide between expressive (art) and non-

28 Elkins, J., *Visual Studies: A Skeptical Introduction* (London: Routledge, 2003).

expressive (science) images. As a leading authority in this field, Elkins' work is used as a prominent reference in this research. I often refer to his claims throughout the enquiry, which I also extend, as I attempt to explore science's and art's respective domains of visuality with a greater emphasis on the production rather than reception of images, and with a clearer demarcation of their various dimensions (that is, their original context, role, purpose and immediate audience), against their displacement into the realms of visual culture and art history. Although Elkins addresses these aspects, he speaks primarily from an academic stance, while in contrast, the research adopts the stategy of deploying his arguments precisely from the perspective of the reflective practitioner in order to test his claims from the position of the producer, rather than the receiver/interpreter/critic/theorist.

Theory and history: Loraine Daston and Peter Galison are well-established scholars in the study of the history of scientific knowledge and more precisely the tensions between different modes of visual representation. In *Objectivity* (2007),[29] they investigate the evolution of epistemic models in the visual depiction of the physical and natural world, and propose a configuration of three: truth-to-nature (natural philosophers and artists depicting an idealised version of nature), mechanical objectivity (images generated by new mechanical devices, producing "accurate" depictions free from human interference), and trained judgement (contemporary imaging techniques, requiring specialist training to interpret the visual depiction). I borrow from and refer to their configuration in my own exploration of past and present scientific depictions. Daston and Galison provide a comprehensive landscape of concepts around image genre and their associated mechanisms of production and reception, also completing Elkins' numerous taxonomies of images.

One of the key discussions of popular science is Peter Broks' *Understanding Popular Science* (2006).[30] In this work he retraces the history of popular accounts, and the division between science as a professional community of experts, and its popularisation by journalists and cultural commentators. Broks' account serves to reinforce my claim for a working distinction between specialist imagery and their popularised counterparts in my survey of scientific visuality (chapter 2). In *Reading Popular Physics: Disciplinary Skirmishes and Textual Strategies* (2007), Elisabeth Leane argues that specialist text is often

29 Daston, L. and Galison, P., *Objectivity* (New York: Zone Books, 2007).

30 Broks, P., *Understanding Popular Science* (Maidenhead: Open University Press, 2006).

submitted to textual strategy, where the technical language of science is often re-written in a more accessible manner to become popular exposition, sometimes with the danger of over-simplifying key information or distorting the original meaning.[31] Using her claim, I draw a parallel between textual and visual representations in specialist accounts and their popularised counterparts.

The above references have been selected to construct a more complete landscape of different modes and practices around scientific visuality – a context crucial for the research to establish, in order to understand more specifically the visual traditions from which current practices in art and science emerge, including my own.

Past and present artistic practices: My work has been influenced by and often refers to key past practices, in particular with the work of the Hungarian-born French artist Victor Vasarely, which extends over three decades. It encompasses his early graphic design work in the 1950s, his prolific writing (*Vasarely: Écrits Divers 1947-1969*),[32] as well as a four-volume oversized series of selected artworks between 1965 and 1979, of which Vasarely designed and supervised the production. Each volume is extensively illustrated with sketches and colour research, but also includes complex folding and printing techniques of his artworks reproduced onto acetate, tracing paper, in metallic inks or spot-colour plates. These volumes alone expose a complex and prolific body of work. It presents the artist's rigorous underlying approach to geometric abstraction, in revealing through numerous studies or "programmes" the rationale behind his famous modular system *l'unité plastique*. Vasarely has always been a significant reference to my own practice, where I have identified strong affinities in both studying his work and developing my own approach to the exploration of form-colour relationship.

In a similar strand to Vasarely, I also discuss the work of Swiss-German artist Richard Paul Lohse. Lohse's exhaustive studies on colour-form relationships, and his systematic approach to grids and systems resonates with both Vasarely, and to some degree my own practice. His entire collection of work has recently been organised into a catalogue raisonné, *Richard Paul Lohse: Prints* (2002).[33] In this second volume (the first volume is

31 Leane, E., *Reading Popular Physics: Disciplinary Skirmishes and Textual Strategies* (Aldershot: Ashgate, 2007).

32 Vasarely, V., *Vasarely: Écrits Divers 1947-1969* (date and publisher unknown).

33 Albrecht, H. J., Lohse James, J. and Wiedler, F., *Richard Paul Lohse: Prints - Documentation and Catalogue Raisonné* (Ostfildern: Hatje Cantz, 2009).

dedicated to his graphic design work), consisting of 485 illustrations, the catalogue details Lohse's obsession with colours, and the organisation of simple geometric forms as modules and systems; it presents sketches and preparatory research alongside his larger scale serial work.

In studying both Lohse and Vasarely I explore a strong resonance with my own art and underlying approach to the complex problems of colour-form relationships. As I reveal the background and influences that have led to the development of my own practice, I refer to visual principles and rational systems first deployed in their work and I discuss affinities and shared concerns.

In contemporary art, the work of artist Naglaa Walker[34] and Peter Kalkhof[35] are of special interest; Walker's photographs are based on appropriating and creating new narratives from scientific fragments and equations, while in Kalkhof's work the visual plays a dominant role where it is constructed out of a rigorous underpinning situated in the legacy of geometric abstraction. A shared visual vocabulary and interest for colour are evident as I compare my own approach with Kalkhof's work; while a certain resonance for the expression of scientific remnants and the manipulation of meaning through the production of art are noticeable between Walker's narratives and my own engagement with science.

1 | 2 | 4 Chapter summary: trajectory of the thesis

Chapter 2: undertakes a literature survey in order to establish the theoretical context for the research. Central to this chapter, the concept of visuality is introduced and deployed as a shared notion between science and art. Through exploring selected visual materials, key scholarship and practices, this chapter investigates issues around imagery and image-making, but retained in their primary context of production (their process, purpose and usage) and reception (their primary audience). I demonstrate how they differ between artistic and scientific activities; I extract and discuss key notions around modes and methods of representation and interpretation of science in visual forms, as well as science-making-art (or an "aesthetics science"), and art's fascination with science.

Chapter 3: introduces my artistic practice, its background, immediate context, and

34 Craddock, S. and Gribbin, J., *Naglaa Walker on Physics* (Stockport: Dewi Lewis Publishing, 2004).

35 *Peter Kalkhof : Centre to Periphery* (London: Annely Juda Gallery, 2007), exhibition catalogue.

particular engagement with science. I demonstrate the individual nature of the work and its multidisciplinary dimension, as well as introduce its underlying method. I highlight the range of influences that have shaped and developed the artwork over the years, and more precisely, the close correlation between my art practice and my graphic design role in a science academic publishing environment (IOP Publishing). In addition to the background and range of influences that inform this practice, a distinctive relationship with science is revealed and articulated. Questions addressing issues of representation and visualisation of science through the production of art start to emerge in relation to the artwork and its underlying method. The method itself is presented through three sub-activities: *colour*, *form* and *medium*, and is illustrated with examples throughout the chapter, where each artwork and its accompanying rationale exemplifies how the method is implemented.

Chapter 4: now that the practice has been introduced, and its theoretical framework established, a reflective critical analysis can be undertaken. The findings from chapter 2 and 3 are re-introduced and deployed to formulate a hypothesis for a particular mode of engagement with science. My proposition focuses on three aspects:

a) a method that demonstrates the practice as research;
b) a practice that emerges from the method;
c) a discourse to articulate the implementation of the method for the production of art.

This chapter intends to address the issue of contextualisation of my practice within its broader related landscape. In the light of the findings from previous chapters, an emerging proposition has been articulated to define this practice as research, and to demonstrate how it may be located within – or more precisely between – the dominant dialogues in Art and Science. This three-fold proposition (*method-practice-discourse*) aims to participate in the current views on art engaged with science; it intends to highlight the inadequacy of the familiar models and surface issues in the study of the interrelation between the two domains, to the detriment of the possibilities for a deeper, more intricate engagement with science, where the creative process is no longer at the service of expressing, representing or communicating scientific knowledge, but is ultimately about the production and presentation of art. In essence, the proposition – representing a model of visuality, aiming to participate in existing dialogues in the field – forms the contribution to knowledge.

Chapter 5: the conclusion summarises the key findings from the previous chapters as it reviews what the research set out to do, revisits the research question, and demonstrates how the methodologies have served to conduct the investigation. Here, I articulate the nature of the contribution to knowledge, how and for whom the research may contribute and advance our understanding of the field. The enquiry has been centred on the study of the art practice, and has opened a range of themes and possible directions where further research may be undertaken. I indicate other perspectives or paths, and I identify specific under-studied domains that could extend the research. In terms of my art practice, potential directions have also been identified, and will prove of relevance for the development of artworks, looking at new dimensions yet to be explored that will complement and evolve from the work already presented in the enquiry.

1 | 2 | 5 Other components in conjunction with the thesis

The research comprises a number of components, where each tackles a specific aspect of the investigation, but is also integral to it. The written part of the enquiry is divided into two volumes, the main thesis (volume one), and the supporting material (volume two). Volume one also includes a series of appendices (pp. 149-199), which comprises published written work, visual essays and artworks from various contexts, demonstrating that both the theoretical research and the art practice are actively engaged in the field.

Volume two (supporting material) features a selection of artworks, which are discussed along with their accompanying stages of research and visual exploration. This document serves to reveal insights into the creative journey and to illustrate the extensive nature of the preparatory research (the underlying method), leading to the production of art. Volume two also aims to mediate between the main thesis and the art exhibition (see below), as it supports the theoretical investigation of volume one, and informs the display of artworks.

A number of artworks have been selected to form part of an exhibition, to be presented alongside the thesis as a core component of the research. The artworks are discussed at length in volumes one and two, but they also need to be seen in their intended context, at their actual scale and in their original form of production. Two artist's catalogues are also included as part of the exhibition.

Chapter 2 | context

CHAPTER CONTENT

2 | 1 Introduction

This chapter undertakes a broad survey of the field, and extracts key themes to establish the context and feed into the wider enquiry. Here, I introduce the concept of *visuality*, and approach it as a shared notion between two domains – science and art. Through the analysis of selected visual materials, literature and practices, this chapter investigates the issues surrounding imagery and image making, with a focus on their primary context of production (their process, purpose and usage) and reception (their immediate audience). I demonstrate how they may differ (or relate) between artistic and scientific activities, and identify some of the central notions in the various modes and methods of visualisation, representation and interpretation of science, as well as in the production of art engaged with science.

Two sub-domains are deconstructed: firstly, *scientific visuality*, which explores the production of knowledge in past models of visual depictions, contemporary laboratory work, popular accounts, and scientific visualisation. Secondly, past and present art practitioners also engage with scientific notions or ideas to construct their own domain of visuality. Here, *artistic visuality* is not intended to capture the whole of visuality found in the production of art; instead it designates a working distinction with its counterpart, as it focuses on a particular "infatuation" with science explored by a range of practitioners. In this domain, formal art-science connections are identified, but this study focuses on other modes of engagement with science that strongly resonate with my own art practice.

2 | 2 Scientific visuality

This section asks: how does science communicate through visual images? To address this, four genres have been identified: a) past models, or the history of images, b) professional science's production of images, c) the visual popularisation of science, and d) scientific visualisation. In each category I present my own taxonomy of images and discuss their associated concepts, namely in relation to their intrinsic nature, method of production, role and purpose; how they operate within their primary environment; and how they are understood or interpreted by their respective audiences.

2 | 2 | 1 Overview of past models

The history of scientific visuality has been the interest of much literature from wide-ranging fields and perspectives. To examine this would require an extensive study of the history of knowledge, going back from the first observations of the physical and natural world in Ancient Greece. This section limits itself to a number of relevant themes, mainly located in recent history. Figure 2.1 summarises the different perspectives identified in the literature survey.

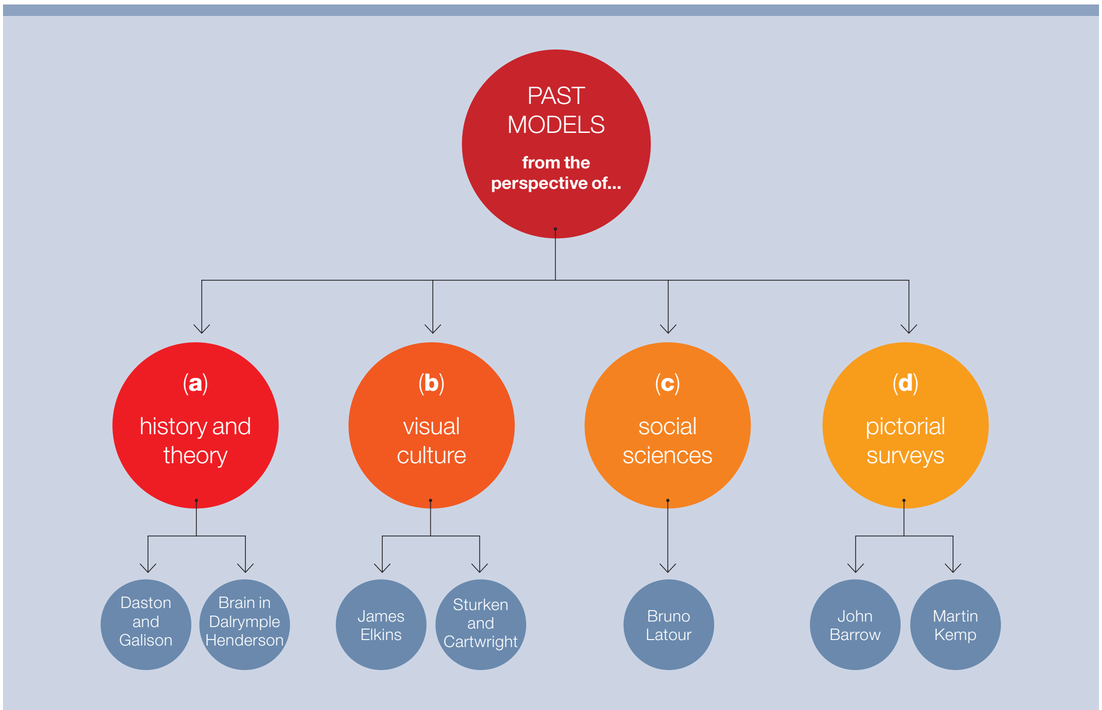

Figure 2.1: A graph showing the dominant (but not exhaustive) scholarly perspectives addressing the study of scientific images, in past and recent cultural moments and practices.

a) From the perspective of art/science history and theory

Loraine Daston and Elizabeth Lunbeck place observation as central to the history of science.[1] So the observation of natural objects and phenomena could be conceptualised as evidence, scientists and artists depicted such occurrences through schemata, drawing, watercolour, engraving and so forth. With the development of processes, methods and conventions around visual representation (meant in the sense of accurate depiction, mimesis), observations could be recorded and knowledge produced. Here the image serves exclusively as evidence for the investigation and classification of species, events and phenomena found in nature.

1 Daston, L. and Lunbeck, E., (eds) *Histories of Scientific Observation* (Chicago, IL: University of Chicago Press, 2011), p. 115.

In *Objectivity* Daston and Peter Galison uncover a more intricate relationship between the observation of nature and its visual rendition. They retrace western history through the evolution of modes and methods of depiction in atlas images.[2] Their study focuses on two epistemic strands[3] and their tensions between image modes: the subjectivity/objectivity dichotomy is captured in the concept of *truth-to-nature* (natural philosophers were concerned with depicting a typical, idealised version of nature, thus "modelling" or "improving" the species or phenomenon purged of its anomalies), and *mechanical objectivity* (with scientists advocating visual depiction led by photography and other mechanical techniques to produce "accurate" images free from human interference).

Robert M. Brain also examines the concept of mechanical objectivity with the development of instrumentation and the emergence of devices capable of drawing, tracing and plotting line graphs and inscriptions.[4] Apparatus such as self-recording dynamometers were among the first mechanical machines developed in the early 1800s.[5] Brain explains how scientists developed rigorous procedures to ensure the merit and "purity" of the measurements, unaltered by human intervention.[6] This newer machine-led pictorial mode indicates a clear contrast with the earlier generation of natural philosophers and artists, prolific at recording and classifying species, but often ruthless in their visual interpretation, "smoothing-out" nature from its imperfections.

b) Visual culture

Traditionally, visual culture is not a domain recognised for having a strong interest in science, where specialist scientific images are often left overlooked and understudied, until recently, where various perspectives on scientific visuality can be found.

In their second edition of *Practices of Looking,* Marita Sturken and Lisa Cartwright include a section on science – specifically medical imagery – which they approach "like any other images in culture".[7] Exploring historical accounts with materials ranging from paintings of dissection, taxonomies of the body with atlas images of skulls, to body X-rays in 1990s

2 Daston, and Galison, *Objectivity*, p. 23.

3 A third concept is also part of their study, *trained-judgement* in relation to contemporary imagery, discussed later in this chapter, see p. 40.

4 Brain, R. M., 'Representation on the line: graphic recording instruments and scientific modernism' in Clarke, B. and Dalrymple Henderson, L., (eds) *From Energy to Information* (Stanford: Stanford University Press, 2002), pp. 155-177.

5 Ibid., pp. 160-163.

6 Ibid., p. 164.

7 Sturken, M. and Cartwright, L., *Practices of Looking* (2nd ed., New York: Oxford University Press, 2009).

advertising, their analysis deploys (and limits itself to) the familiar models of image analysis (the gaze, psychoanalysis, gender identity or post-colonial theory). At no point in their account is a scientific image examined in relation to its initial purpose, context of production and primary sphere of reception, that is, within its original environment before its displacement to culturally informed interpretations and multiple readings.[8]

In contrast, James Elkins is a strong advocate for science's own domain of images. His deep interest in this genre takes us to the limits of representation (e.g. particle physics or quantum mechanics), what he terms "the threshold between the known and the unknowable", where specialist images capture objects or entities that resist depiction.[9] This can be exemplified with figure 2.2, an image showing light signals emitted by nano-particles. Interestingly, the scientist questions the very nature of the image in his article: "it should be noted that the term 'image' is used here somewhat loosely. The system does not image the particles in the sense of resolving them"[10] since the accurate rendering of the image is constrained by the limitation of the observing instrument. These notions – the questioning of the very nature of the image, its depiction, and the limitation of the apparatus – often conflict with the familiar models of image analysis as found in Sturken

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Figure 2.2: A 256 × 256 pixel frame of image data; the effective size of the pixels is approximately 1 µm. The particles are nominally 200 nm in radius polystyrene spheres; from Walker, J. G. 'Improved nano-particle tracking analysis' in *Measurement Science and Technology* vol. 23, no. 6 (2012), 065605, p. 7.

8 Although Carwright also offers a more sophisticated scrutiny of scientific imagery in the essay 'Imagination, multimodality and embodied interaction: a discussion, of sound and movement in two cases of laboratory and clinical magnetic resonance imaging', co-authored with Morana Alac in Hüppauf, B. and Weingart, P., (eds) *Science Images and Popular Images of the Sciences* (New York: Routledge, 2008), pp.199-223.

9 Elkins, *Six Stories*, p. XV.

10 Walker, J. G. 'Improved nano-particle tracking analysis' in *Measurement Science and Technology* vol. 23, no. 6 (2012), 065605, p. 7.

and Cartwright, which Elkins denounces as generally limited and inadequate; instead he argues for scientific images to be understood in terms of their intrinsic nature, purpose and specialist audience before they can be interpreted in the wider context of cultural references.

Other recent contributions of authority offer insights into new uncertainties about the relation between images and knowledge in contemporary science, and their impact on the construction of popular accounts. Scholars such as Peter Weingart, Bernd Hüppauf and Luc Pauwels, acknowledge the distinct nature of scientific images, call for their inclusion into a general category of images, and for an extension of past theories.[11] Rather than a demarcation between professional and popular science, they discuss a shift of context (and therefore reception) of scientific images from their specialist environment towards the realm of popular culture.

c) Social sciences

Sociologist Bruno Latour approaches images in science, religion and art through the concept of *mediation* where he questions the distinction between objective and mediated images.[12] He proposes the concept as an *iconoclash*, that is, an uncertainty regarding the role of the constructed image: on one hand, showing scientists in their laboratory prevents access to rational, objective knowledge, as it is seen as an obstruction on the part of a "socially constructed" science. On the other hand, describing an image as the result of human intervention (craftsmanship or technology) could increase its capability to grasp truth and objectivity, by offering deeper insight into the construction and production, but also the background, context and history of the image itself. Latour's questioning of scientific images raises issues of the role/purpose of the mediation itself: what kind of mediation? To what extent is the underlying meaning affected by such mediation? Does the image become less "objective", less meaningful as it becomes more visually appealing, more "substantial"? It could be argued that the popular image is embedded with more layers of mediation than its counterpart – the specialist scientific image – as it requires additional treatment and manipulation in order to be more evocative to its audience; but as the image becomes more visual, it becomes less scientific, therefore less useful to the scientist.

11 Hüppauf and Weingart, *Science Images and Popular Images of the Sciences*; Pauwels, L., (ed.) *Visual Cultures of Science: Rethinking Representational Practices in Knowledge Building and Science Communication* (Hanover, NH: Dartmouth College Press, 2006).

12 Latour, B. and Weibel, P., (eds) *Iconoclash: Beyond the Image Wars in Science, Religion and Art* (Cambridge, MA: MIT Press and Karlsruhe: ZKM Karlsruhe, 2002).

d) History of science through pictorial surveys

The history of science has been compiled through collections of images or "pictorial surveys" of past and present scientific discoveries. These highly illustrated titles provide interesting insights by mixing professional science and popular accounts, photographic material, technical graphs/diagrams, computer visualisation, and artist illustrations. In John Barrow's collection,[13] the image is focussed on illustrating the science; it is not in itself the subject of study, thus avoiding questions to do with the mode, method or nature of its visual representation. In this sense, the image is *passive*. In contrast, visuality is more central to Martin Kemp's survey, as he examines some of the mechanisms associated with the concept of representation:[14]

> **Analytical description:** refers to a form of representation in which aspects of appearance are remade—literally represented—on the basis of an intuitive or intellectual understanding of the nature of what is being seen, how it is seen, and how it may be depicted in such a way as to convey 'information' to an attuned viewer (...).
>
> **Abstraction:** high levels of remove and abstraction from the sensory parameters of our normal experience is a signal characteristic of modern science, using devices to see and often to generate emissions inaccessible to our eyes e.g. X-rays, infra-red, thermal radiation, sonar, electrons, other subatomic particles. (...)
>
> **Process:** this lack of determinism (...) has clear affinities with non-deterministic chaos and self-organized criticality—those fashionable kinds of computer driven analysis computation that have reclaimed the visual dimension for advanced mathematics. Chaos theory has shown the remarkable patterns behind unpredictable systems (...).

Kemp's analysis differentiates three specific image genres with their unique characteristics, but approached differently than Daston and Galison's earlier configuration; *analytical description* embodies conventional forms of visual representation from the era of natural philosophy. *Abstraction* concerns photographic and microscopic imagery, specifically modern means of depiction using the extended spectrum of light to capture aspects of nature otherwise invisible to unaided vision. Although Kemp addresses *process* in relation to artworks resulting from process-driven computing methods, in science, his definition refers to a third type of imagery, the data-generated modelling and simulation, or "scientific visualisation" (pp. 49-52).

13 Barrow, J. D., *Cosmic Imagery: Key Images in the History of Science* (London: The Bodley Head, 2008).

14 Kemp, M., *Visualizations: The Nature Book of Art and Science* (Berkeley, CA: University of California Press, 2000), pp. 6-7.

2 | 2 | 2 Professional science

This section is concerned with the type of imagery produced at the hard end of science, more precisely in contemporary physics. To understand this genre better, I focus on the origin of the imagery but I also address its reception. Here, I dissect some of their key features, through the device of my own configuration of eight activities:

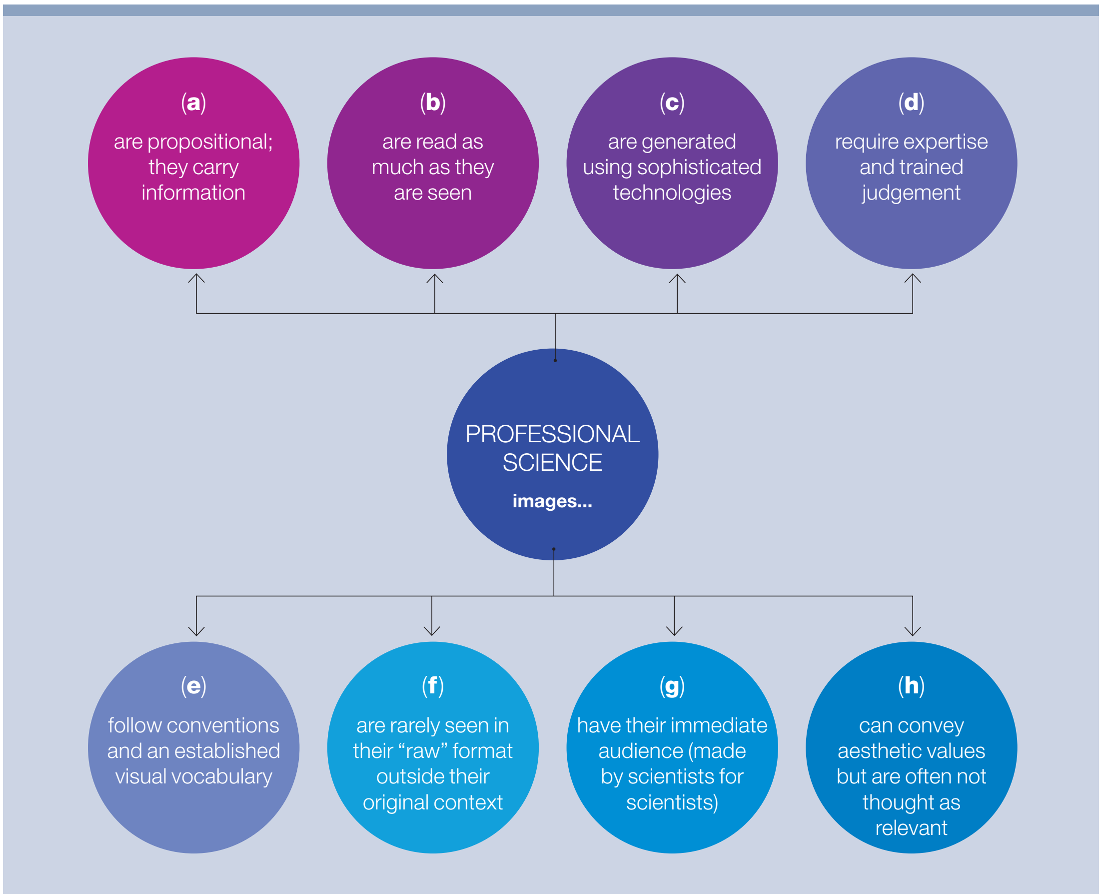

Figure 2.3: A configuration of eight strands in the study of specialist imagery found in professional science.

(a) Images are propositional; they carry information

Scientific images are functional, that is, they are produced to convey information. In this instance, the visual serves to support a theory, to reinforce the findings of an experiment or to translate the results of an investigation in visual form. Elkins discusses this characteristic as *propositional*: the image proposes meaning. Visual studies often scrutinise images through familiar mechanisms, focussing on their "expressive content".[15]

15 Rose, G., *Visual Methodologies: An Introduction to the Interpretation of Visual Materials* (2nd ed., London: Sage, 2007), p. 48; Elkins, *The Domain of Images*, pp. 3-67.

When it comes to scientific imagery, any expressive content may or may not be present in the image, but is thought of little interest (to the scientist), as the priority is in what meaning is being presented, what the propositional value of the image ought to be.[16]

(b) Images are "read" as much as they are seen

Specialist images are used alongside data. Peter Galison identifies a pattern of constant back-and-forth in the way images are used in combination with statistics and data analysis.[17] He discusses how astrophysicist Margaret Geller employed imagery to support new findings in the study of galaxies. Using images and statistical analysis, she and her team identified features in the way galaxies seem to cluster unevenly, with particular areas of concentration and vast voids in other places. Images alone could have not captured this information, so data are also used to plot a three-dimensional map of the galaxies' components. Equally, the gathered data would not be sufficient on their own. The combined data and imagery revealed new findings and were presented as evidence to back up their research.[18]

These images also work hand-in-hand with their accompanying explanatory captions; they generally need to be "worked at" and often involve an interruption in the reading of the main text. Figure 2.4 is a typical example of technical schemata and its explanatory caption. Not only is this set of figures accompanied by lengthy technical commentaries, but is also annotated with symbols, numbers, and words. Both Latour and Elkins argue that a scientific image can rarely be understood on its own, isolated from its scientific context.[19] Latour goes further, stating that the more images are produced, the more data are gathered, the more annotations are generated and ultimately, the more comprehensible and the richer the image becomes (as seen on p. 39).

16 Elkins accepts that scientific imagery can be expressive in a similar way that imagery in art is, but in its primary context of usage, the emphasis is on the functional aspect, the proposition rather than the expression that an image conveys. For instance, he captures the central position of calculation in this image genre as follows: "A 'useless' image, in science, can be defined as an image that cannot be used to calculate, because it has nothing quantitative in it." Elkins, J., 'Visual practices across the university: a report' in Grau, O., (ed.) *Imagery in the 21st Century* (Cambridge, MA: MIT Press, 2011), p. 157.

17 Galison, P., 'Images scatter into data, data gather into images' in Latour and Weibel, *Iconoclash*, pp. 300-323.

18 Ibid., pp. 238-239.

19 Ibid., pp. 34-35; Elkins, *Six Stories*, pp. 7-8.

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Figure 2.4: *In vivo* and *in vitro* field potential recordings from area CA3 of the ventral hippocampus of control and epileptic animals. (A1–B2) Representative electroencephalogram recordings from the ventral hippocampus of control and epileptic freely moving mice. (A1 and A2) Typical theta activity (A1) (peak frequency, 7.3 Hz) (A2 Left) in control mice during an exploratory behavior. (B1 and B2) Theta oscillatory activity (B1) was no longer seen in epileptic mice (B2 Left) during a chronic phase of TLE. (A1 and B1) Lower traces show time-expanded views of the region indicated by the bars in upper traces. (A2 Right and B2 Right) Band-path (30–80 Hz) filtered recordings from both animal groups unmasked the gamma-oscillatory activity (peak frequencies: 37 Hz and 39 Hz, in control and epileptic mice, respectively). (C1) Simultaneous expression of gamma- and theta-frequency oscillations in the control coronal slices after bath-applied KA (400 nM). (Inset) Schematic illustration of a coronal slice with the recording sites in ventral hippocampal CA3 region. (C2) (Left) Power–spectral density plots present two clear peaks at theta- (8 Hz) and gamma- (37 Hz) frequency range. (Right) Coherence spectra obtained from different recording sites. (D1 and D2) In marked contrast to control, coronal slices from epileptic mice demonstrate gamma, but not theta activity. (E) Averaged power–spectral density for gamma-oscillatory activity obtained from different recording sites. (F) Averaged gamma-coherence patterns during the network oscillations in the coronal slices (n = 8); from Dugladze, T. ‘Impaired hippocampal rhythmogenesis in a mouse model of mesial temporal lobe epilepsy’ in *PNAS* vol. 104, no. 44 (2007), pp. 17530-17535.

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Figure 2.5: SEM image of an AFM tip used for probing the surface of matter, magnification 3000 times; from: http://commons.wikimedia.org/wiki/File:AFM_(used)_cantilever_in_Scanning_Electron_Microscope,_magnification_3000x.JPG [Accessed 10 August 2012].

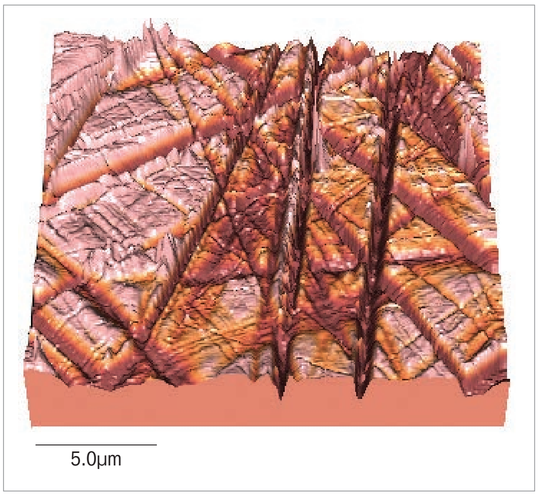

Figure 2.6: AFM topographical scan of a glass surface. The micro and nano-scale features of the glass can be observed, showing the roughness of the material; from: http://en.wikipedia.org/wiki/File:AFMimageRoughGlass20x20.JPG [Accessed 10 August 2012].

(c) Images are generated using sophisticated technologies

At the nanoscale, advanced technologies have enabled scientists to manipulate matter at the level of single atoms. Specialist imaging techniques such as atomic force microscopy (AFM) can reach significantly high resolution, involving a tip to probe the surface of an object at a resolution of fractions of one nanometre.[20] Figure 2.5 shows a close-up of the tip used to probe a surface, and figure 2.6 the topological visualisation rendered by the device sensing the sample. At this scale, traditional techniques of observation are no longer possible, as the entity studied is smaller than the beam of light; as shown in these examples, highly advanced technologies (aided by lengthy algorithms) have been developed to "sense" or "probe" the material and translate it into visual form.

(d) Images often require expertise and trained judgement

In their study of contemporary scientific imagery, Daston and Galison propose the notion of *trained judgement*, which they define as the combination of scientific intuition (developed through intense training and experiential work) and the deployment of particular modes of interpretation focussed on the depiction of patterns and signals from noise and artefacts. They present scanning electron microscopy (SEM) images or electroencephalograms (exemplified in figure 2.4) as typical specialist images that demand a high level of expertise in correctly reading and interpreting the information portrayed.[21]

Elkins also addresses the issue of interpreting such specialist imagery, and explains how scientists can be compelled to refer to a degree of intuition in interpreting the data. He concentrates on some of the technical characteristics in depicting pictures produced by different types of microscopes (optical, electron or phase contrast systems). These images are highly dependent on the manipulation of light and the setting of the apparatus in which the resolution and contrast are adjustable and can create shadows and effects that may not always belong to the object being observed.[22] Hence, they require trained judgement, that is, experience and expert knowledge to interpret accurately the information conveyed in visual form, and to distinguish important features or anomalies, from noise and background shapes.

20 One nanometre (nm) is equivalent to one billionth of a metre.

21 Daston and Galison, *Objectivity*, pp. 328-329.

22 Elkins, *Six Stories*, pp. 117-155.

(e) Images follow conventions and an established visual vocabulary

There is a rich visual vocabulary in scientific imagery, which is dictated by conventions for the representation of scientific measurement and data. For instance, scale bars are often found in graphs and schemata (figure 2.7). The colours themselves are generally arbitrary (led by colour palettes provided in the visualisation software), but the proportional variation of tone, hue or colour intensity is used to convey the scale of temperature change or a sequence of variables in relation to the phenomena under study.

Other images are produced by specialist software such as Openlab or Chimera (figure 2.8).[23] These programmes combine the ability to process complex algorithms and translate data into visual renderings. These include various settings, for instance, to enhance special features, colour-code elements, simulate three-dimensional effects, layers and structures, or render different levels of material from outer surfaces to inner structures. These modes of visualisation often become conventions, dictated by the tools provided in the modelling software, which in turn produce imagery that have become a familiar visual vocabulary, shared among scientists.[24]

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Figure 2.7: Contour plots of TCC on ϕ and τ are shown for different radii of the ring. $a =$ 100 nm, 200 nm, 300 nm and 400 nm in (a), (b), (c) and (d), respectively. The other parameters are $N = 100$, $\gamma = 0°$, $F_1 = F_2 = 500$ V cm^{-1}; from Zhu, Z. and Berakdar, J. 'Electromagnetic pulse-driven spin-dependent currents in semiconductor quantum rings' in *Journal of Physics: Condensed Matter* vol. 21, no. 14 (2009), 145801, p. 5.

23 Examples of imaging applications produced using specialised software Openlab are available at: http://www.apple.com/science/insidetheimage/skop/ and http://www.improvision.com/products/openlab/. Details and image gallery featuring imagery using molecular modeling program Chimera can be seen at: http://www.cgl.ucsf.edu/chimera/ [Both accessed 10 June 2012].

24 Newton, R. G., *The Truth of Science: Physical Theories and Reality* (Cambridge, MA: Harvard University Press, 1997); Brown, T. L., *Making Truth: Metaphor in Science* (Champaign, IL: University of Illinois Press, 2003).

Redacted due to copyright

Figure 2.8: Enolase superfamily sequence and structure. This example from Patricia Babbitt's research group at UCSF shows an alignment of three proteins in the enolase superfamily. The Babbitt group is characterizing superfamilies of enzymes whose member proteins perform a broad range of biochemical functions while sharing a common active site architecture. The color swatches behind the sequence names match the corresponding structures. Three residues from each protein are shown as ball-and-stick in the structure and highlighted with purple in the sequence alignment. These conserved residues bind a divalent metal ion (shown as a red ball) important for function; along with other residues (not shown), they provide the machinery for abstracting a proton alpha to a carboxylic acid. This partial reaction is the common feature of enolase superfamily members. The red serine in the sequence dialog indicates a mismatch between the provided alignment sequence and the structure sequence, which actually has a threonine in that position; from: http://www.cgl.ucsf.edu/chimera/ImageGallery/ [Accessed 16 August 2013]. Credit: The Regents of the University of California, USA.

(f) Images are rarely seen in their "raw" format, outside their original context

Generally this type of imagery is seldom seen outside the closed environment of technical publications or scientific conferences. As non-scientists, we rarely come across untouched, raw specialist imagery, such as figures 2.4-2.8, although some make their way into the realm of mass media and popular culture, as argued by Oliver Grau.[25] Some images may get elevated to become iconic as a result of scientific breakthrough, such as the double helix.[26] Other examples include a particle track image appropriated for a CD artwork for the American band The Strokes (figure 2.9); or an artwork produced for the British band Muse, using a visualisation of the brain (figure 2.10). Such images have been appropriated for a new context and audience, generally chosen for their stunning aesthetics, but also severed from their underlying scientific content.

Redacted due to copyright

Figure 2.9: *Is This It* (2001), album cover art for the American band The Strokes (album's second version), using a photograph of subatomic particle tracks in a bubble chamber from Cern. Credit: Patrice Loiez, Cern / Science Photo Library.

Redacted due to copyright

Figure 2.10: *The 2nd Law* (2012), album cover art for the British band Muse, using an image of a map of the human brain's neural pathways, supplied by the Human Connectome Project, Laboratory of Neuro Imaging, UCLA; from http://humanconnectomeproject.org/ [Accessed 10 July 2013].

(g) They have their immediate audience (made by scientists for scientists)

In science (as is true of any other field of enquiry), specialist images are produced for their primary audience. The more specialised the audience, the more information-charged and technical the image becomes, hence requiring the adequate knowledge and expertise to interprete the visual. As I discuss on p. 45, the aesthetics is generally considered redundant, as scientists focus their effort on producing imagery that conveys specific – and often complex – information. Felice Frankel and Angela DePage address the complexity of

25 Grau, *Imagery in the 21st Century.*

26 Barrow, *Cosmic Imagery*, pp. 474-477.

Redacted due to copyright

Figure 2.11: Instantaneous streamline patterns for free swimming fish; from Eldredge, J. D. 'Numerical simulations of undulatory swimming at moderate Reynolds number' in *Bioinspiration & Biomimetics* vol. 1, no. 4 (2006), pp. S19-S24.

Redacted due to copyright

Figure 2.12: Parameter space for the dissipative Fermi–Ulam model where panels (a, c) correspond to the parameter space colored according to the value of the Lyapunov exponent, while panels (b, d) correspond to the same parameter space colored according to the value of the average velocity. The structures observed in both figures for the same range of control parameters are remarkably similar, both qualitatively and quantitatively; from Oliveira, D. F. M. and Leonel, E. D. 'Parameter space for a dissipative Fermi–Ulam model' in *New Journal of Physics* vol. 13, no.12 (2011), 123012, p. 11.

the visual depictions and presentation of scientific content in *Visual Strategies*, a highly illustrated collection of imagery (from contour plot, schematic diagram, time sequence, X-ray to three-dimensional modelling and simulation), as well as case studies of image processes and good practice in visual conventions to their specialist audience.[27]

(h) Images can convey aesthetics values, but are often not thought as relevant

Within their primary purpose, technical images that display aesthetic qualities are generally not thought to be relevant or useful to scientists. Figure 2.11 is a contour map showing the patterns made by a swimming fish, here employed in the study of fluid dynamics. At no point in the article is the image commented on in terms of its visual substance, aesthetic values, or in relation to the shapes / patterns produced. Aesthetic qualities may be present, but are thought redundant to the scientific study – here the image only serves to convey the data and measurement in visual form.

Taken out of its context and removed from its notations, figure 2.12 (a) for instance could be suggested as an abstract expressionist pastiche. In its original context of production and usage however, the figure represents a set of computational images based on a mathematical model involving a series of interchangeable parameters. The article is highly theoretical, it addresses a very small audience of experts in the study of nonlinear mathematics, hence – despite several attempts at discussing the article with scientists – it is not apt to be reduced to a non-technical description. Likewise, the imagery is of a specialist nature, generated from complex data and computed by a visualisation software; colours indicate three levels of variables (the x and y axes coupled by the colour bar), which convey variations of parameters set by the underlying data. Again, in this article the figures are discussed in terms of measurements – as opposed to their aesthetics, composition, colour harmonies, medium, or expressive qualities.

2 | 2 | 3 Popular science

In our contemporary cultural landscape the process of popularisation is relied upon to translate the technical language of scientific knowledge into a more comprehensible form – this process also applies to scientific imagery. To some extent, we are all familiar with visually stunning, full-colour spacescapes, star clusters and galaxy photographs, produced

27 Frankel, F. and DePace, A. H., *Visual Strategies: A Practical Guide to Graphics for Scientists and Engineers* (New Haven, CT: Yale University Press, 2012).

by organisations such as Nasa or the European Space Agency (figure 2.14). In this instance, the conscious introduction of an aesthetic dimension to the visual information may be legitimised by the desire to render the imagery more accessible and essentially more attractive to a larger audience. Ultimately this type of visual treatment often distorts the underlying science, so the image itself becomes less meaningful scientifically, just as it becomes more visually evocative to the layman. That said, such a process of aestheticisation is crucial if science is to compete for our attention (and the funding that comes with it) within a culture that constantly bombards us with spectacular imagery from a multitude of sources.

As seen earlier with professional science's images, it is also important to capture the specificity of the process involved in producing popularised images; their key strands have been identified as follows:

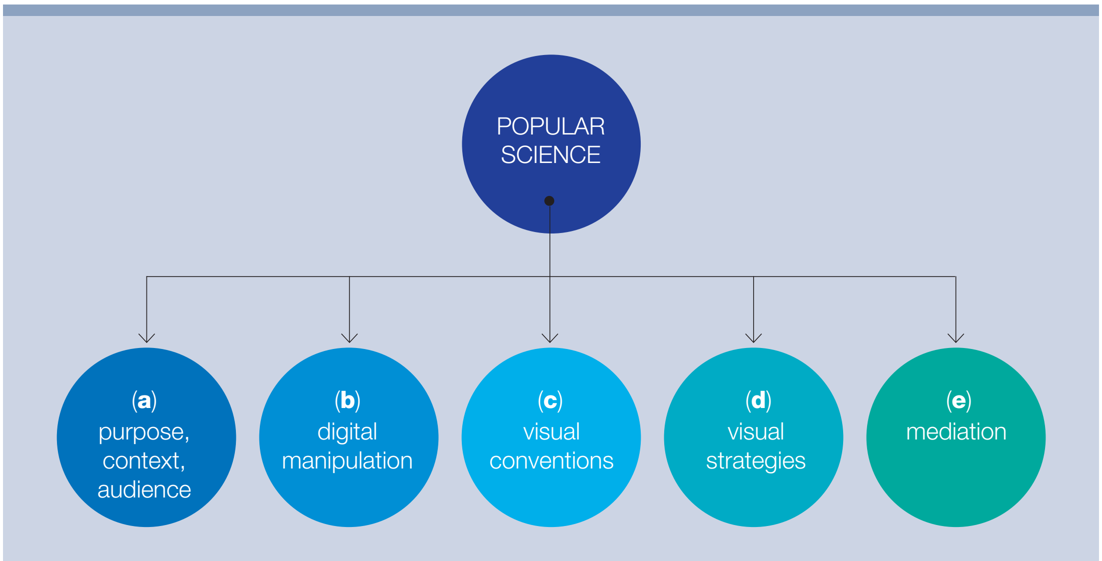

Figure 2.13: A graph showing the various strands and mechanisms in the production and usage of popular scientific imagery.

a) Purpose, context and audience

John Barrow said: "No area of science is more picturesque than astronomy".[28] However, browsing through recent editions of the prestigious *Astronomical Journal* and *Astrophysical Journal*, stunning and dramatic Nasa images of multi-colour galaxy clusters or cosmic events (figure 2.14) seem to be outnumbered by rather unappealing black-and-white

28 Barrow, *Cosmic Imagery*, p. 8.

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Figure 2.14 (above): Hubble Space Telescope image of the merging pair of Antennae galaxies, where the collision is giving rise to the formation of dense new superstar clusters. Credit: ESA/Hubble and Nasa.

Figure 2.15 (far left): Cover design for the coffee-table astronomy title *Stars: A Journey through Stellar Birth, Life and Death* (London: New Holland Publishers, 2008) by Raman Prinja, Professor of Astrophysics at University College London.

Figure 2.16 (left): Cover design for the science journal *Nature* vol. 457, no. 7225 (1 January 2009). The cover features an extensive graphic manipulation of the Antennae galaxies, here used as a conceptual illustration to celebrate The International Year of Astronomy. Credit: Hubble Space Telescope/Christian Darkin.

technical charts, graphs and diagrams.[29] This distinction in imagery alone highlights the different "types" of science taking place and how their accompanying images are being manipulated for dissemination to an audience beyond the closed circle of the scientific community.

b) Digital manipulation

The process of popularisation is generally achieved through extensive digital manipulation, such as layers of colourisation to create composite photographs. The transformation from raw monochromatic data into striking colourful imagery is often dictated by the software and digital techniques, but also by the image-maker himself, using his own expertise, experience and judgement towards a purpose (the communication to a wider audience), consequently limiting a whole range of decisions that would otherwise be part of the creative process in other fields of image-making.[30]

c) Visual conventions

There is an established visual vocabulary constructed around these images; for example pictures of viruses (figure 1.4, p. 20) are generally charged with false-colour rendering, while viruses are intrinsically colourless, as they are smaller than the wavelength of light. In these instances, colours are usually selected arbitrarily, and/or often dictated by the imaging sofware's colour palettes.

d) Visual strategies

An important parallel can be drawn between the manipulation of science in text and in image. In her essay on the popularisation of physics Elisabeth Leane discusses how scientific research is often submitted to "textual strategies" to transform the technical language of science into a more accessible form targeted to a lay audience.[31] This strategy involves abridging of complex concepts and translating jargon into plain language, which sometimes can lead to the distortion and oversimplification of meaning. This process of manipulation coupled with a shift of purpose and audience can also be found in scientific imagery, between the raw monochromatic specialist image and its popularised counterpart, charged with layers of colour and graphical enhancement. This

29 *The Astronomical Journal* and *The Astrophysical Journal*, both published in partnership between The American Astronomical Society and IOP Publishing are two prestigious titles that began in 1849 and 1895 respectively.

30 Not always restricted to the scientist, it can also include the specialist in computer imaging or the technical illustrator.

31 Leane, *Reading Popular Physics*.

transformation or de-technicalisation suggests that what leaves the laboratory to feed into the public arena – and therefore becomes a popular exposition of science – requires aesthetic augmentation of the visual to *better* communicate, in a similar way that technical writing may be simplified to become comprehensible to a lay audience.

e) Mediation

The popularised image can be regarded as a *mediator* – not between reality and its representation in visual form (as seen with Latour, p. 35) – but more precisely between its original source of production (professional science), towards a change of context, purpose and audience. This shift takes place through the process of aesthetisation: the image being subjected to extensive digital manipulation to appeal to a general public and compete in our visual cultural landscape already saturated with imagery.

2|2|4 Scientific visualisation

Alongside rapid developments in computer science in the last two decades, scientific illustration has become an interdisciplinary branch of science in its own right, referred to as "scientific visualisation". This new generation of images testifies to significant advancements for scientific knowledge to be visualised in increasingly sophisticated and innovative ways. The latest technology offers, for instance, the possibility to visualise how fluids, turbulence and magnetic field forces behave under simulated conditions; it allows for complex numerical data to be imaged; it provides the tools to generate predictions of behaviours and events (such as extreme weather patterns, or the circulation of blood flows) – none of which could easily be produced experimentally (figures 2.17 and 2.18, p. 51).

To generate these images, scientists are often faced with an unprecedented amount of data that is fully reliant on advanced computing to be processed. Visualisation techniques generally involve: a) an algorithm that creates a visual representation, and b) a rendering technique that displays it.[32] A wide range of tools is available, such as multi-dimensional representation, simulation of internal structures, complex patterns and rendering techniques, timelines and so forth.

The process of visualisation – the move from data to image – can be understood as a mode of translation between one language (algorithm) and another (visual rendition). In some

32 Graf, M. J., et al, 'To See is to Know: Visualization' in *SciDAC Review* no.10 (Winter 2008), p. 35.

cases "visualisation enhances the ability to see unexpected patterns and correlations", that is to say, it can direct the scientist to study further a particular anomaly or irregularity shown in the image, which may not be detectable in the data alone. But this process also presents challenges and limitations. Olaf Breidbach discusses modes and methods of visualisation used in bio- and neurosciences, more precisely the study of brain activity and its accompanying imaging techniques.[33] The algorithm used for the modelling describes complicated functions and variations; this is where conventional analytical solutions become impossible, especially with regard to the study of dynamic systems, as a large number of variables needs to be introduced to the coding for the simulation. In this instance, models are used so that scientists can produce estimates by testing different variables. Breidbach explains how these visualisations can indicate features that help researchers to understand more precisely the various functions in the brain, but they also show very complex networks and activities, which can be difficult to interpret. Such images look familiar (in terms of established conventions in their visual representation), but are also deceptive (they present unknown features, which may not always be reliable). Breidbach calls for scientific visualisations to be approached differently: to develop a more elaborate thinking around them that considers models and simulations not as representations of reality, but as their own reality, consequently requiring new ways of seeing and interpreting them.[34]

Studying similar issues, Daston and Galison introduce another important concept, as they explore images positioned at the nanoscale, at the edge of visuality in the familiar sense of observation: it is no longer about *seeing*, but about *making*:

> These images no longer *represent* a particular fluid at a certain place and time; they are products of calculations hovering in the hybrid space between theory and experiment, science and engineering. In some of them, making and seeing are indistinguishable (…)[35]
>
> Whether the patterns indicate natural kinds or not is a matter of indifference for most practitioners of judgement; for them, pattern detection is the preface to action, not just to classification.[36]

Here we enter another technology-driven image genre. This domain pushes the boundaries of the familiar concepts of imaging acquired from the legacy of historical scientific

33 Breidbach, O., 'Imaging Science: The Pictorial Turn in Bio- and Neurosciences' in Grau and Veigl, *Imagery in the 21st Century*, pp. 111-127.

34 Ibid., pp. 116-117.

35 Daston and Galison, *Objectivity*, p. 46.

36 Ibid., p. 370.

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Figure 2.17 (above): Instantaneous image of HO_2 and OH from direct numerical simulation of a lifted hydrogen/air jet flame; from Chen, J. H., et al, 'Terascale direct numerical simulations of turbulent combustion using S3D' in *Computational Science & Discovery* vol. 2 (January-December 2009), 015001, p. 17.

Figure 2.18 (left): Simultaneous visualization of pathlines and the angular momentum field obtained from a supernova simulation, performed by Dr. John Blondin. Credit: H. Yu and K. L. Ma, Ultrascale Visualization Institute/UC-Davis.

visuality yet further, reaching a new threshold: image-as-representation becomes *image-as-process*, where pictures are generated, viewed and altered simultaneously: their production and reception becomes one; the image is now a tool to manipulate the physical world, no longer limited to depicting and recording it as visual evidence.[37] Daston and Galison emphasise a shift from representation to presentation: "(…) nanomanipulation is no longer necessarily focused on copying what already exists – and instead becomes part of a coming-to-existence (…)".[38] The previous chronology in the visualisation process is no longer adequate: before, there was an ordering in the procedure, i.e. preparing the sample, setting the apparatus, capturing the image, analysing and recording the findings. Now, the image becomes an interactive part in the process of construction, manipulation, and alteration of atoms, which brings together the seeing and the making.

2 | 3 Artistic visuality

This section takes us beyond science into the visual arts, and from the visualisation of information (whether aestheticised or not) to the production of artwork. Having looked at the mechanisms, purpose, usage and limitations of the visual representation of science, could the artist propose a different way of grasping or sensing the un-image-able – not through visual representation – but as apprehended notions or meanings? This question is addressed as I explore selected practices in the following three sub-domains: science-making-art, modern art's infatuation with science, and how artists engage with science in contemporary art.

2 | 3 | 1 Science-making-art

There seems to be an inclination for a particular visual aesthetic found in the production of scientific imagery presented as art, that is most often sourced from within the scientific community: for example, well-established societies such as the ASCI (the Art & Science Collaborations Inc.) in New York, or the Wellcome Trust in the UK, actively support art, science and technology endeavours through educational programmes, exhibitions and grants. The imagery shown in figures 2.19-2.21 represents the type of visuals most actively disseminated to a wider audience by such organisations; they are generally produced by scientists in laboratories, not by artists or illustrators.

37 Ibid., pp. 382-383.

38 Ibid., pp. 383.

Redacted due to copyright

Figure 2.19: *Brainbow Rainbow* by Jess Brooks (2013), Esteban Engel and Lynn Enquist, Department of Molecular Biology and the Princeton Neuroscience Institute.

Vero cells are a particular kind of kidney monkey cells. Here they have been infected by a herpes virus that carries a "brainbow cassette," which makes cells express proteins that are tagged with a variety of fluorescent colors. This rainbow of colors helps us identify and analyze individual neurons (the core components of the body's nervous system), thus allowing us trace neural circuits.

Redacted due to copyright

Figure 2.20: *Fireworks* by Yunlai Zha (2013), Dept artment of Electrical Engineering.

Arsenic sulphide dissolved in a solution displays colorful random patterns after being spin-coated and baked on a chrome-evaporated glass slide.

Redacted due to copyright

Figure 2.21: *Microscopic Sea Creature* by Nan Yao, Gerald Poirier and Shiyou Xu, (2013), PRISM Imaging and Analysis Center.

This creature was captured by the 2010 FSS 114 class of 2010 and imaged using the PRISM imaging and Analysis Center Quanta 200f Environmental Scanning Electron Microscope, which allows us to see nanostructures in their native state with extraordinary three-dimensional clarity. ESEM images are originally black and white. But colors can be added subsequently (such as the green and orange in this image) by assigning a given color to a specific gray scale. The creature we see in this image is about 15 microns wide.

First, the notion of *hybrid* is introduced; these images can be understood as a hybrid between illustration, popular science photography and scientific visualisation. The issue here is how the science is being produced and manipulated to become more appealing visually, to become aestheticised. Often in these examples the science remains prominent and accurate, but in contrast to the popularised image as seen earlier, the visual is presented in the context of an art-science competition, online galleries, or in exhibitions. As art (understood from a scientific perspective), such images are linked to aesthetic notions of beauty and elegance, i.e. science's own (but often limited) definition of what constitutes art. Elkins discusses this issue at length in his essay "Aesthetics and the Two Cultures":

> There is, in fact, an intermittent conversation about aesthetics going on between art and science (…) but I would claim it's a 'drunken conversation' involving more or less drastic mutual misunderstandings of basic terms. (…) What I am aiming at (…) is the possibility that art and science are disconnected because they do not share some crucial common terms, especially regarding aesthetics.[39]

To summarise Elkins' extensive argument: his first claim is that even though there is an established narrative that captures the points of intersection between art and science (for instance the empiricism of the Renaissance, the 19th century infatuation for colour theories, or the 20th century exploration of computer-assisted painting),[40] it captures only a very small part of art's vastness, richness and complexity. His second argument is that the narrative tends to overestimate the scientific content to be found in art. Elkins exposes some serious issues and misunderstandings in past attempts to unify art and science, and goes against the general trend to "unify" them under a shared domain of creativity.[41]

Although I agree with Elkins's approach, and his desire to highlight the central position of the aesthetic in the art-science divide, I think that we should go further: the very notion of aesthetics needs to be re-examined, with the intention of arriving at a new working definition that would apply specifically to the problem of visualising or imaging science. Rather than seeking, with Elkins, an "expanded literacy",[42] which suggests only a more sophisticated model of reading and reception, I propose a more dynamic aesthetic, one that is rooted in the creation of the work of art: a *production aesthetic*.[43] This new concept could then be tested to consider the possibility of it underpinning and informing

39 Elkins, 'Aesthetics and the Two Cultures', p. 34.

40 Ibid., p. 35.

41 See appendix 2, p. 154.

42 Elkins, *Visual Studies*, pp. 83-94.

43 See glossary, p. 144.

the mediation between science and art. Such an aesthetic would take into account the scientist's own attempts to engage with art through the visual, but would also encourage and enable the artist to connect more profoundly with the complex nature of scientific ideas – prior to their artificial aestheticisation as seen in popular accounts – and to go beyond the accessible into the abstract, the unattainable, and the unpicturable (this proposition is articulated in chapter 4).

The issue of aesthetics becomes more apparent once the image is severed from its original context. Yet, naturally occurring phenomena can display astonishing aesthetic quality, but this is of little interest to professional scientists.[44] Beauty in the scientific image becomes important as it links to more familiar notions in image reception in popular culture, the arts and the humanities, but these images do not tend to integrate with the realm of what Elkins terms *serious art*.[45]

Art-science production of visuality has constructed its own territory and developed its own audience.[46] Here, artists and scientists work together to produce a visual sub-domain that draws directly from science's own production of images (thus constructing an aestheticised science), that often relates to issues of representation, where the balance between visual rendition and accuracy of the underlying science is often thought as fundamental to the creative process. In their concept of trained judgement, Daston and Galison make a claim for the scientific image of a nanotube, or an encephalogram *as* art. It is unclear under what criteria such material can be proposed as artwork: what kind of art, intended for what audience, challenged under which critical theory? They indicate a certain analogy between past models of image classification, the atlas, and the current digital picture gallery. Many leading science organisations, such as Cern and Nasa, offer extensive access to huge libraries of pictures from their research. Picture galleries have also been developed through the likes of Princeton University, who initiated an "art of science" yearly competition, collecting aestheticised scientific images, and hosting them on an online platform that may be understood as a scientific version of an art gallery, but again restricted/limited to its specialist audience (figures 2.19-2.21).

It is difficult to position this genre within our wider landscape of visuality – several factors

44 Elkins, *The Domain of Images*, pp. 10-11.

45 Elkins, 'Aesthetics and the Two Cultures', pp. 35-36.

46 See appendix 2, p. 154.

resist any clear position: a) the image is often less scientific, i.e. useless to the scientist in his research (in the sense that it has often lost vital information); b) it is the result of a "synthetic" aesthetics, a visual "augmentation", which does not draw from art traditions, but either from the observation of elegant/beautiful forms found in nature, or an aesthetics generated by computer imaging and its associated visual conventions; c) it is generally produced in the laboratory, not in the studio; d) the image is presented as art, but often retains its technical caption.

Rather than identifying a clear location, could this image genre assume the role of a bridge between science and art? This scenario raises a new concern: art is not accorded equal attention.[47] The imagery is the product and legacy of visual traditions found in science, and therefore remains excluded from the current dialogues in contemporary art practices. It would be more accurate to propose this sub-domain as a branch extending from scientific visuality feeding a wider landscape of visual culture and popular imagery. This genre contributes to define a powerful "aestheticised science";[48] but with limitations, as it does not engage enough with other modes proposed in the domain of artistic visuality, where artists have developed alternative and more sophisticated ways to approach science and which I also aim to demonstrate through my own art practice.

2 | 3 | 2 Selected practices in modern art

It can be argued that modern art is full of scientific references.[49] In particular, the 1960s Optical Art movement proclaimed enthusiastically its affinity with science and the study of scientific phenomena.[50] Op artists often demonstrated a rigorous and procedural approach to the construction of this new form of visual abstraction, while critics considered it as a possible revolution in aesthetics.[51] In this scenario, science can be seen as enabling or triggering this *new* aesthetics, where optical and kinetic phenomena were central to practitioners as they produced paintings and prints, three-dimensional artworks and large-scale installations.

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47 See appendix 2, p. 154.

48 Frankel, *On the Surface of Things*; Frankel, F., *Envisioning Science: The Design and Craft of the Science Image* (Cambridge, MA: MIT Press, 2002); Ameisen, J-C. and Brohard, Y., *Quand l'Art Rencontre la Science* (Paris: Éditions de la Martinière, 2007).

49 Dalrymple Henderson, L., *The Fourth Dimension and Non-Euclidean Geometry in Modern Art* (Princeton, NJ: Princeton University Press, 1983); Parkinson, G., *Surrealism, Art and Modern Science: Relativity, Quantum Mechanics, Epistemology* (New Haven, CT: Yale University Press, 2008).

50 Houston, J., *Optic Nerve: Perceptual Art of the 1960s* (Columbus, OH: Columbus Museum of Art and London: Merrel Publishers, 2007).

51 Ibid., p. 42.

In terms of context, the origins of Op Art can be found in the diverse influences and cultural references of the time and in particular with the Bauhaus, (the school of art, architecture and design founded by Walter Gropius in 1919). Despite its closure by the Nazis in 1933, the impact of the Bauhaus' teaching has been significant: its core values focussed on cross-disciplinarity and developing common rational principles to the organisation of form, space and colour, as well as to advocate a culture of industrialisation and mass production. This was in contrast to traditional craftsmanship, where workshops were to become "industrial laboratories" of research and experiment.[52] Bauhaus' philosophy spread and influenced European and American art, including the emergence of Op Art. Historians have also noted that movements such as Abstract Expressionism prepared the way for the complete abandonment of the representational in art, embraced later by Op artists, also aligning with Clement Greensberg's notion of "pure vision".[53] Op Art has been described by critics as an art form explicitly rooted in science, often seen at the time as assuming the role of a reconciler between science and art.[54] Artists experimented with scientific themes such as visual perception, kinetic movement, optical illusion, and colour theory. Some practitioners claimed to be scientists, while others to work in a scientific fashion. Not everyone approved of such associations:

> Bridget Riley (…) objected (…) to persistent suggestions by some critics that her work was the product of mathematical calculation and scientific theorizing. Other artists, such as the Hungarian painter Victor Vasarely (…), had published manifestos and given interviews in which they claimed to be researching visual effects in a scientific manner, and that their work was based on such 'research'.[55]

In this section I focus on practitioners who have developed a fascination for a scientific-like method in their approach to form and colour relationships: such methods were pioneered by Victor Vasarely and Richard Paul Lohse. In this instance, the art-science connection is of interest exclusively through the articulation of a potentially unique form of visuality – both in terms of construction and reception – but away from the familiar mechanisms of illustration, representation and visualisation. Here, we enter the realm of artistic expression through a sophisticated rationale for what can be understood as a visual grammar, itself based on logic, mathematics, systems, construction, rules, parameters, and programmes. In this context, the artist is at ease with the domain of pure abstraction, while he engages with a form of artistic research reminiscent of the scientific method. A

52 http://academic.chrissnider.com/bauhaus/pages/philosophy.html [Accessed 11 June 2014].

53 Greenberg, C., *Art and Culture: Critical Essays* (Boston, MA: Beacon Press, 1971).

54 Houston, *Optic Nerve*, p. 35.

55 Follin, F., *Embodied Visions: Bridget Riley, Op Art and the Sixties* (London: Thames & Hudson, 2004), p. 21.

Redacted due to copyright

Figure 2.22: *Lapidre Caruegue* by Victor Vasarely (circa 1970), serigraph, 63.5 × 61 cm. Credit: RoGallery.

Redacted due to copyright

Figure 2.23: *Folk-Lor* by Victor Vasarely (1973), medium and size unavailable. Credit: Fondation Vasarely.

Redacted due to copyright

Figure 2.24: *Gestalt (Nordex) No. 2* by Victor Vasarely (1970), serigraph on Schoeller Parole cardboard, 80 × 80 cm. Credit: RoGallery.

Redacted due to copyright

Figure 2.25: *Untitled VI* by Victor Vasarely (circa 1965), silkscreen, 67.31 cm × 67.31 cm. Credit: RoGallery.

shift of concern takes place, from the visual representation of the natural and physical world, to the presentation of an alternative form of visuality, where a scientific link has been transposed from being a source of inspiration or subject matter to become a mode of research. In other words, it is not so much science that serves to inspire artistic production, but more precisely, artists engaging directly with various modes of investigation rooted in the production of scientific knowledge, which are then deployed to become intrinsic to the artistic process: the creative journey becomes an analytical investigation into visual and aesthetic concerns.

At the forefront of the Optical Art movement, Victor Vasarely went even further, inviting scientists to his studio to share ideas and discuss his method. Spread over three decades, Vasarely's work and legacy is considerable, and testifies to a complex web of dimensions: influences rooted in the modernist era, the legacy of the Bauhaus; his background in graphic design; his obsession with grids, systems and modules to create what he termed *l'unité plastique* (a form of visual alphabet);[56] and his versatility with the medium (from small-scale editions of prints, to large public installations such as murals, metal work or tapestry). Evidence can be found that Vasarely had anticipated the new possibilities offered by technology.

> Much of Vasarely's work during the last two decades of his life (...) was devoted to extending his vision into new dematerialized forms. He created algorithmic systems that in many ways parallel the development of the computer. In fact, his early forms from the 1950s and 1960s can be seen as precursors to what artists today take for granted as computer-driven digital imagery. Vasarely made his own visual software in the form of mathematics, referring to the blueprints for his paintings as 'programs'. (...) He also understood that no program can extend beyond the parameters it is given.[57]

Figures 2.22-2.25 illustrate how Vasarely implemented his *unité plastique*. First, he devised a basic set of units (a combination of a square and a circle, each carrying a colour, as seen in figure 2.25), from which he constructed extensive series or "programs". Although very rigorous in their construction (each unit is referenced with a number), Vasarely often deliberately complicated his visual compositions, to retain a form of visual poetry and elegance, which could not always be achieved through a "cold" numerical approach, as shown with artworks such as *Folk-lor* (figure 2.23). He was also interested in exploring colour harmonies to convey the effect of gradient through flat surfaces, simulate three-dimensional effects (figures 2.24), or experiment with positive-negative arrangements (figure 2.25).

In a similar manner, Swiss Modernist artist Richard Paul Lohse's work expresses shared concerns:[58] texts on Lohse's work as a painter[59] often employ the terms "structural system", "logic" and "objectification" of colour. These are significant notions, distinctive to his practice but also indebted to the pioneers of geometric abstraction and the De

56 For Vasarely's *unité plastique*, see Morgan, R. C., *Vasarely* (New York: Braziller, 2005), pp. 32-34.

57 Ibid., p. 38.

58 *Richard Paul Lohse: Colour Becomes Form* (London: Annely Juda Fine Art gallery, 1997), exhibition catalogue.

59 Lohse started his career as an avant-garde designer.

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Figure 2.26: *Serial Elements Concentrated in Rhythmic Groups* by Richard Paul Lohse (1949-56), oil on canvas, 90 × 90 cm. Credit: Kunsthaus Zürich, Richard Paul Lohse Foundation.

Stijl movement to which he was drawn. Like Josef Albers,[60] Lohse was not interested in the physicality of colour, or in establishing a purely theoretical approach to it, but more precisely in the visual behaviour and interaction between colours. He achieved a better understanding of these complex relationships through extensive observation, experiment and analysis.[61] Lohse's own contribution to colour – suggested from the position of both the reflective practitioner and the theorist – leaves little to chance or accident. As exemplified in figure 2.26, with the piece entitled *Serial Elements Concentrated in Rhythmic Groups*, Lohse's logic of colour is based on three fundamental principles:[62]

(a) **Mathematical:** (but not geometrical) that is, not restrictive in determining the proportion of forms to carry the colours, or in stating a number of colour hues or values, but more specifically in expressing a particular interest for a procedure; a method for the allocation of colours.

(b) **Polarity:** here referring to the use of polar relationships in the sense of colour complementarities. Lohse also extended this principle further, through the use of contrast of value with tonal steps from dark to light and vice versa.

(c) **Equalisation:** Lohse often used a grid system (or matrix) from nine to nine hundred squares, which offered a modular space to allow him to explore serial structure and sequence. The notion of equalisation here means using equal "space" or "quantity" for each colour.[63]

Strong associations can be drawn between Lohse and Vasarely: their early careers in graphic design, background and appreciation for the Bauhaus philosophy and rational

60 Albers, J., *Interaction of Color: Revised and Expanded Edition* (New Haven, CT: Yale University Press, 1975).

61 Here the term physicality is meant in terms of "quantity of light", see *Lohse: Colour Becomes Form*, pp. 3, 4, 5, 28, 30.

62 *Lohse: Colour Becomes Form*, p. 4.

63 Lohse used the square as a perfect symmetrical surface in most of his work, but the principle of equalisation was presented in the artist catalogue *Colour Becomes Form* in relation to his compositions using the rectangle, see *Lohse: Colour Becomes Form*, p. 32. "Separation from the same colour and delimitation by other colours are the preliminary conditions of the homogeneity of the colour-square element. If a square structure is conceived in which the elements of one and the same colour touch at one or more corners, the integrity and the meaning of the colour square as an element as a value factor of the system of co-ordinates are impaired, the sovereignty of the colour square and its constitution as an active individual are annulled…" ibid., p. 30.

design, as well as their fascination (if not obsession) with order, system and colour. Both artists used coloured surfaces as "programmes" or "matrices" from which they constructed systems of various levels of complexity. They were using form and colour in the most abstract of terms. In Lohse's case, the dichotomy was said to be "anonymous" and "hierarchy-less". In Vasarely's approach, simple geometric shapes (such as a circle in a square) were used to define a two-colour unit (*l'unité plastique*). From this basis, Vasarely established a complete visual alphabet, where each colour-form unit was numbered. This attitude to colour goes beyond other previously established theories: here, colour has become *objectified*.

Alongside Optical Art and major exhibitions such as the *Responsive Eye*,[64] other groups of artists[65] pushed geometric and kinetic abstraction into new territory, challenging the very nature of the artwork, the audience and the role of the artist himself. Following on from the legacy already achieved by Vasarely, in 1960 his son Yvaral founded the *Groupe de Recherche d'Art Visuel* (G.R.A.V.).[66] The collective based its whole philosophy on a radical (and somewhat idealistic) stance, challenging the art institution and its elite cultural circle. The group devised its own manifesto, articulating its motivations as follows:[67]
a) the artist's studio is replaced by a research centre or "laboratory", while the myth of the lone Bohemian artist gives way to collective work by practitioners taking on the role of "engineers or "technicians" concerned with visuality as their field of research.
b) Instead of the deployment of a personal artistic genre or style, the group approaches art as research, aspiring to how scientists conduct their work, elaborating theories and experiments, and where the findings can be shared and used by others in the group to deploy a collective, anonymous response. c) The focus is on developing a universal, impersonal art form, underpinned by a deep intellectual dimension in its construction but that can be experienced purely on visual terms. d) The adoption of a scientific methodology favouring analytical and systematic research on problems concerning optical questions, such as moiré patterns, repetitions, multiplications, visual instabilities, plane-space relationships – all to be investigated through logic and mathematics.

Ultimately, the group aimed towards a deeper knowledge of the phenomena of optics, to be

64 Houston, *Optic Nerve*, pp. 57-59.

65 Ibid., p. 45.

66 Hahn, O., *Yvaral* (Paris: Le Musée de Poche, 1974), pp. 11.

67 Ibid., pp. 13, 22.

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Figure 2.27: *Interference* by Yvaral (1965), string and metal on wood panel, 60 × 60 cm, in Hahn, *Yvaral*, p. 25.

investigated like scientists but to be deployed as a "constructed" art form, as a fully articulated exploration that extends from Vasarely and other Optical Art practitioners. This resulted in an aesthetics entirely stripped away from any symbolism, or referential connotations – here the artwork is reduced to pure vision. The audience is expected to experience the work exclusively for its optical values. "It is a visual spectacle that requires no cultural knowledge of art to be appreciated".[68] Gradually, the viewer becomes a more active participant, as he or she is required to move around the artwork in order to experience its optical tricks and visual instabilities, as shown with Yvaral's *Interference* (figure 2.27), made from string constructed on wood and metal. Here, the relationship between the science and the art is well defined by their protagonists: G.R.A.V. practitioners borrowed from and aspired explicitly to a scientific attitude to artistic research. Implementing such methodologies in their own investigation, the creative process had to be fully controlled, leaving no space for chance or accident, as they analysed geometrical structures, planes and patterns to such an extent, aiming to produce a highly constructed visual vocabulary that exists solely in visual and neutral terms.

The group disolved in 1968; however, each member individually pursued the visual concerns they shared as a group, including François Morellet[69] who went on to study light through neon installations, or Argentinian artist Julio Le Parc,[70] who remained a significant figure in Optical and Kinetic Art, working with light, surface, movement and multiples – themes that were initiated by the G.R.A.V.

Although short-lived, the G.R.A.V. movement is an important example that testifies how a small group of artists aspired to transform visual art into pure research, seeking to reach something equivalent to how scientific investigation is conducted, but I argue that

68 Ibid., p. 14.

69 Lamouret, M., http://francoismorellet.wordpress.com/ [Accessed 26 August 2013].

70 The artist official website: http://www.julioleparc.org/ [Accessed 26 August 2013].

it also takes research too far into what can be described as a cold and detatched form of visuality, lacking the visual poetry and elegance that Vasarely for example negotiated so well with his own rigorous research, especially with the colour dimension to his geometric abstraction. In the G.R.A.V.'s approach, practitioners discarded colour altogether (which they considered as interfering with their pursuit of optical effects), instead focussing on the purity of high contrast between black and white. Interestingly, it was once the group disbanded, that Yvaral incorporated colour in his work.

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Figure 2.28: *Progressive Polychrome* by Yvaral (1970), acrylic on canvas 200.6 × 201.2 cm. Credit: Alon Zakaim Fine Art.

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Figure 2.29: *Structure Ambigüe Quadri Ben Positif No. 1072* by Yvaral (1971), acrylic on panel, 130 × 130 cm. Credit: Alon Zakaim Fine Art.

Remaining faithful to themes that he explored with the group, Yvaral turned to investigating the visual grammar of early computerised imagery that emerged in the 1970s, and soon became associated with the emergence of Digital Art (*l'Art Numérique*).[71] Combining his rigorous method of research with the possibilities offered by binary language resulted in a style exemplified by artworks such as *Progressive Polychrome* (figure 2.28) and *Structure Ambigüe Quadri Ben Positif No. 1072* (figure 2.29). Through the medium of painting he devised linear systems and abstract multi-dimensional geometrical landscapes, echoing a computer-generated aesthetics. Yvaral was also interested in small units or picture elements (pixels) making up imagery, which he introduced in a subsequent series of digital portraits, here linking back to Vasarely's anticipation of such a visual mode with his *unité plastique*, discussed earlier.

71 See glossary, p. 145.

The fundamental difference between the work of Vasarely and Yvaral is that in the former, a strong visual sensibility remains, a poetical dimension, which has also been acknowledged as such by curators and art critics.[72] As mentioned on p. 59, Vasarely himself intentionally complicated his own system to offer the viewer a certain visual elegance and more refined colour harmonies that might not occur in an otherwise systematised composition. Conversely, Yvaral wanted to encourage the viewers to deconstruct and analyse the artwork, and to be able to retrace for themselves the act of visual construction, stripping out any possible emotional response, in favour of a pure vision. He was committed to demonstrating "how any visual work of this genre could be subsequently decomposed and analysed empirically."[73]

2 | 3 | 3 Selected practices in contemporary art

In order to complete the construction of the domain of artistic visuality, a number of practices in contemporary art are introduced in this section, as I focus on a selection of particularly relevant artistic approaches and their engagement with science. The following examples will demonstrate other, often sophisticated ways to experience and interact with scientific concepts for artistic expression. These can be defined through three (non-exhaustive) sub-themes: image analogy / association; image / concept appropriation; and method / experiment (figure 2.30). This strategy contrasts with connections between art and science as seen in the previous section "science-making-art", where the artwork is positioned closer to its source, and has a more explicit explanatory role. Here, associations

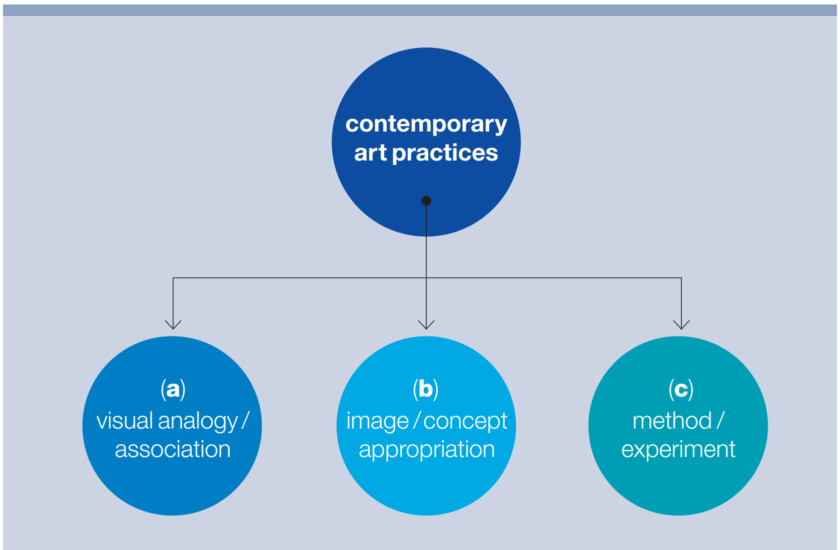

Figure 2.30: Graph presenting the various strands or sub-themes identified in the study of selected practices in contemporary art.

72 Morgan, *Vasarely*.

73 Hahn, *Yvaral*, p. 28; see also http://the-artists.org/artist/Jean-Pierre-Yvaral/ [Accessed 23 September 2013].

with scientific notions are more ambiguous and complex to uncover, as the artist plays on metaphor, analogy, appropriation, displacement, experiment, to the construction of an alternative form of visuality. In this section, we enter yet another domain, the presentation of art, as opposed to the representation of science.

Until recently, science has generally been left outside major themes addressed in contemporary art;[74] it does however trigger a steady stream of creative responses, often with an emphasis on digital technologies (soundscape, light, responsive media), life sciences (in particular, biology and medicine), or other areas such as kinetics and robotics.[75]

Established work from Olafur Eliasson (*Weather Project*, 2003) or Cornelia Parker (*Cold Dark Matter: An Exploded View*, 1991) exemplifies how, in these instances, the science is either sourced or manifested through different degrees of conceptual or metaphorical interpretation, transformation and infatuation with science and technology. Such art might be described as powerful, arresting, eloquent, articulate, and persuasive, both in terms of medium and dimension – where these large-scale installations impose their physical presence on the viewer – but more importantly in relation to the questions it asks and the experience it offers to its audience. However, these few examples alone also demonstrate how the science often becomes less scientific. The creative process in art favours wide-ranging means for expressing thought and emotion. It often prompts oblique ways for the artist to engage with his chosen theme/subject, where the rigour and accuracy in the representation of scientific concept and ideas often become redundant, as we leave the domain of scientific production; in other words, "to get at the science in art it is necessary to leave the science behind".[76]

a) Visual analogy / association

German-born artist Peter Kalkhof's artistic practice can be described as pure in its minimal visual grammar, but charged with metaphors and connotations, and a testimony to the reactivation of perhaps otherwise saturated themes, or at least this is how the work has been commented on by art critics.[77] It is not these metaphorical layers as such that are of

74 Robertson, J. and McDaniel, C., *Themes of Contemporary Art: Visual Art After 1980* (3rd ed., Oxford: Oxford University Press, 2012).

75 Wilson, S., *Art + Science Now: How Scientific Research and Technological Innovation are Becoming Key to 21st-Century Aesthetics* (London: Thames & Hudson, 2010).

76 Elkins, 'Aesthetics and the Two Cultures', p. 45.

77 *Peter Kalkhof: Centre to Periphery*, exhibition catalogue with an introduction by Peter Suchin.

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Figure 2.31: *Geometric Circles (Colour)* by Peter Kalkhof (2000), acrylic on canvas with CD, 165 × 147.5 cm. Credit: Annely Juda Fine Art.

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Figure 2.32: An enhanced colour view of Saturn's rings, available from: http://solarsystem.nasa.gov/planets/profile.cfm?Object=Saturn&Display=Rings [Accessed 8 February 2012].

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Figure 2.33: *Mathematical Nature Painting: Nested* by Keith Tyson (2008), mixed media on aluminium, 149 × 149 cm, (part of his series of nature paintings exhibited at the "Cloud Choreography and Other Emergent Systems" show at the Parasol Unit, London, 16 September to 11 November 2009). Credit: Prudence Cumming Association and Keith Tyson.

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Figure 2.34: Image of the Eagle Nebula M16. Credit: Keith B. Quattrocchi, available from: http://www.lostvalleyobservatory.com/page28m16nb/ [Accessed 12 February 2012].

interest here, but more precisely the visual, aesthetic exploration of the basic colour-form dichotomy deployed by Kalkhof. It can be said that he draws on an already familiar visual grammar and mixed media, reminiscent of geometric abstraction, minimalism and Optical Art. Yet, a highly structured approach to circles, squares, triangles, stripes of colours and patterns, confirms how these basic elements can be revived and produce fresh compositions. Figure 2.31, *Geometric Circles (Colour)*, was conceived in pure abstract terms, leaving the viewer to experience and work on the decoding of the piece. Perhaps in juxtaposing figure 2.32 – a picture of Saturn's rings produced by Nasa – it is forcing associations that are otherwise absent; nonetheless, visual resonance seems overwhelmingly present, especially through a shared colour rhythm, and yet, purely incidental.

Image associations between artworks and natural phenomenon have been the subject of the French book *Quand l'Art Rencontre la Science (When Art Meets Science)*.[78] Double-act images similar to Kalkhof's artwork and Saturn's rings, or Keith Tyson's *Mathematical Nature Painting: Nested* (figure 2.33) and a composite image of the Eagle Nebula M16 (figure 2.34) can be found throughout, often featuring the most astonishing resemblance in otherwise unrelated materials. These visual analogies can be identified (or constructed) between artistic work and that produced by nature, mainly in the sense of partial correspondence, visual likeness and similarities, but in these examples, the emphasis is on incidental associations, rather than a deliberate intention to mimic or portray nature. Here, it is the reception of the visual (as opposed to its production) that creates a strong correspondence between scientific visuality and artistic production.

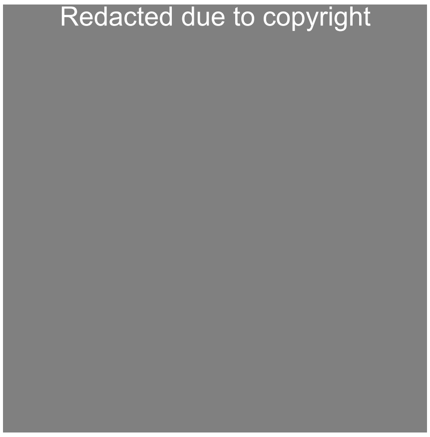

Figure 2.35: From the series *Micro Mundi (Small Worlds)* by Elaine Duigenan (2010). Origination: 5×4 black and white negatives, scanned and printed on fine art paper. Credit: Elaine Duigenan.

Figure 2.36: Photograph from Nasa mission STS-129. 171 orbits round the Earth, speed of 17,500 mph, distance 4,490,138 miles. Credit: Nasa.

In her series *Micro Mundi (Small Worlds)* (figure 2.35) Elaine Duigenan[79] explores visual associations between the microscopic and the cosmic scale. The artist is interested in the invisible, and the process of making visible. She plays on ambiguous meanings and connotations as she experiments with scale. In a collaboration with Nasa astronaut Leland Melvin, an image of her plates of snail paths was taken on board the shuttle

78 Ameisen and Brohard, *Quand l'Art Rencontre la Science*.

79 Contemporary artist and photographer, lives and works in London.

Atlantis on a 2009 mission. Placed by the engine's window, the image presents astonishing similarities with an outer space view of the Amazon River (figure 2.36). In her artist statement, Duigenan comments on her *Micro Mundi* series:

> These arterial wanderings are survival-led. The marks have been made by snails grazing on algae. The claw-like patterns are caused by the rasping action of the snail's spiky tongue. Year upon year they etch chaotic trails over abandoned surfaces, marking time and leaving us with rambling 'encryptions'.
>
> (…) I see a wonderful weaving of connections in the convoluted linearity. The patterns in Nature seem to replicate on both micro and cosmic scales. Small etchings on the side of a derelict building can look like entire swathes of earth from the air. Like the fingers of estuaries, the random dendritic markings attest to the presence of a vigorous life form.[80]

Duigenan's approach may be seen as a form of experimental work where she observes and investigates nature, recording and producing scientific-like imagery, executed in a way that resonates with artefacts produced by natural philosophers such as plates from early microscopes or astronomy landscapes. Here the visual is suggestive of an old fascination with uncovering nature and its hidden structures and patterns.

b) Image / concept appropriation

Other practitioners such as Gilles Barbier engage with metaphorical interpretations of scientific themes.[81] Figure 2.37, S*ans Titre (Bubble Chambre)* is a typical example of his interest in merging, combining and re-defining scientific ideas with other contemporary themes, here appropriating the traces of particle tracks as found in particle accelerator experiments with comic-strip characters and speech bubbles. In his practice, Barbier's "kitsch" and playful approach is intertwined with wide ranging science-related topics, from artificial intelligence, information theory, space discoveries, the Hiroshima bomb, but also societal themes such as the impact of plastic surgery on the anatomy.[82] He engages with these themes through creative metaphors and interpretative visual recomposition of fragmented meanings and images. The use of cloning and multiples, or the integration of text as enluminures,[83] are also part of his method for the construction of visual narratives, and demonstrate a constant need to return to borrowed and repurposed material.[84] The science here – although present in terms of visual and conceptual appropriations – is, in

80 Extract from Duigenan's artist statement, from her website http://www.elaineduigenan.com/ [Accessed 21 January 2012].

81 Gilles Barbier (1965-), French artist / plasticien, lives and works in Marseille, France.

82 *Gilles Barbier*, Carré d'Art, Musée d'Art Contemporain de Nimes (31 May to 17 September 2006), exhibition extract.

83 Enluminures, here in reference to medieval illuminated manuscripts.

84 *Gilles Barbier* (2006), exhibition extract.

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Figure 2.37: *Sans Titre (Bubble Chambre)* by Gilles Barbier (2004), gouache on paper, 120 × 190 cm. Credit: Fonds Régional d'Art Contemporain de Picardie.

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Figure 2.38: Naglaa Walker, double-spread page from *Physics*, captioned: "Strong Interaction: Quantum ChromoDynamics. The strong coupling parameter between two quarks depends on the flavours present – the particles must maintain some distance between them in order to retain their strong attraction".

truth, primarily only a pretext for a more reflective study of how the creative process, the thought, the reflection may emerge and develop, something that his preparatory notes and sketches indicate.[85] The aesthetic here is carefully considered, part of a visual and – more importantly – conceptual methodology of combined imagery and meaning. But again, the exactitude of the scientific content is no longer relevant: it has become a visual and conceptual remnant, after being submitted to a creative process of manipulation, displacement and transformation.

Naglaa Walker's *Physics* is a collection of photographic work, narrated through constructed human-object scenes, alongside captioned images of blackboard equations and laboratory apparatus (figure 2.38).[86] The series presents mathematical notations, graphs and diagrams, addressing scientific notions such as quantum tunnelling, Heisenberg's uncertainty principle, Doppler effect and so forth – highly technical subjects to the non-specialist, but which form part of the daily work of the scientist. The collection is both introduced by the art critic Sacha Craddock and science writer John Gribbin. Walker's body of work gives little away in terms of explanation of any scientific references. The artist proposes a journey into somewhat a surrealist or a constructed world, where a hidden conversation between the mathematical and visual day-to-day scenes takes place. The overall result suggests a form of investigation, a meticulous sequence of appropriation, as the artist collects concepts and images, carefully assembled to become the narrative, itself underpinned by a hidden logic resisting depiction. Of particular interest in this body of work is the duality between the language of mathematics – the charged yet impenetrable meaning carried by each equation – alongside a constructed / artificial / static visual world, seemingly familiar but equally inexplicable. The photographs are loud and intense in terms of visuality (colour-charged, carefully staged), but beyond the reach of a plausible elucidation; although clues are given with captions, but Walker also plays with the different dimensions between the real, the concrete, the ordinary image of our familiar surroundings (the park, the living room…), and the abstract, the mathematical, the theoretical, hiding behind the equation, the technical notation or the apparatus in the laboratory. It is left to the viewer to "make the connections between the abstraction of physical laws and the reality of experience".[87]

85 Ibid.

86 Craddock, S. and Gribbin, J., *Naglaa Walker on Physics* (Stockport: Dewi Lewis Publishing, 2004).

87 Ibid.

c) Method / experiment

British artist and 2002 Turner Prize winner Keith Tyson openly proclaims his interest in science: "I'm fascinated by science's dogmatic determinism: the belief that any event or action, however complex – a Mozart concerto, a terrorist attack – arises from hydrogen atoms bashing together after the Big Bang."[88] Perhaps more significant than his devotion for scientific themes, is the elaboration of a self-engineered pseudo-scientific apparatus: Tyson conceived the *Artmachine* (1991-), a sophisticated system using charts, books and computer programmes in order to generate "artistic proposals for him to implement".[89] Here, Tyson seems to adopt a particular method for the production of artwork: the experiment starts with a pre-defined set of rules and parameters which in turn serve to formulate a brief or a proposal for the artist to follow. This laboratory-like experimentation sets out the conditions for the creative journey but then opens up an infinite and unpredictable number of solutions for its realisation – an approach perfectly suited to the freedom in terms of expression, media and style required in Tyson's work, but dictated by the machine – not the artist – at the outset. Tyson parallels his method with experiment in laboratory work:

> The idea of failure, or the impossibility of achieving – or even managing – [what I am instructed to do] are all part of what's fascinating about working with *Artmachine*. I'm experimenting on myself, my own thinking and my own hand like a scientist would experiment with a frog".[90]

It is difficult to ignore the way Tyson discusses scientific themes, often referring to popular accounts, using lay terms and clichéd metaphors (as shown above, for instance, with the phrase "experiment with a frog"). He seems to experience science through the filter of popular culture and mass media, which is often charged with popularised and distorted views of scientists and work they produce. As illustrated with the *Artmachine*, Tyson's engagement, "experimenting" with such notions, seem particularly loose, skewed, and even playful, hinting on associations with the early twentieth-century art movement *Pataphysics* led by French writer Alfred Jarry.[91] While in strong contrast, Walker's body of work conveys a much more robust engagement and an eager to tackle often difficult material, in her selection of equations and theoretical fragments – an approach characteristic of her own background and education as a scientist.

88 Button, V., *The Turner Prize* (London: Tate Publishing, 2007), p. 184.

89 Ibid.

90 Ibid.

91 Hugill, A., *Pataphysics: A Useless Guide* (Cambridge, MA: MIT Press, 2012).

2 | 4 Conclusion

This chapter has attempted the ambitious task of surveying two vast and complex domains of images: each operating in different spheres of activities, spread among past and present practices, cultural moments, conventions and visual traditions, modes and methods of visuality, but also through the breadth of scholarly work already available on the subject.

In its first domain – scientific visuality – images have been submitted to a broad configuration or taxonomy of genres, in order to uncover various concepts, notions and mechanism addressing *the visual* – all of which have been loosely "mapped" as shown in figure 2.39. In this schemata, I have tried to position (approximately) each genre and its

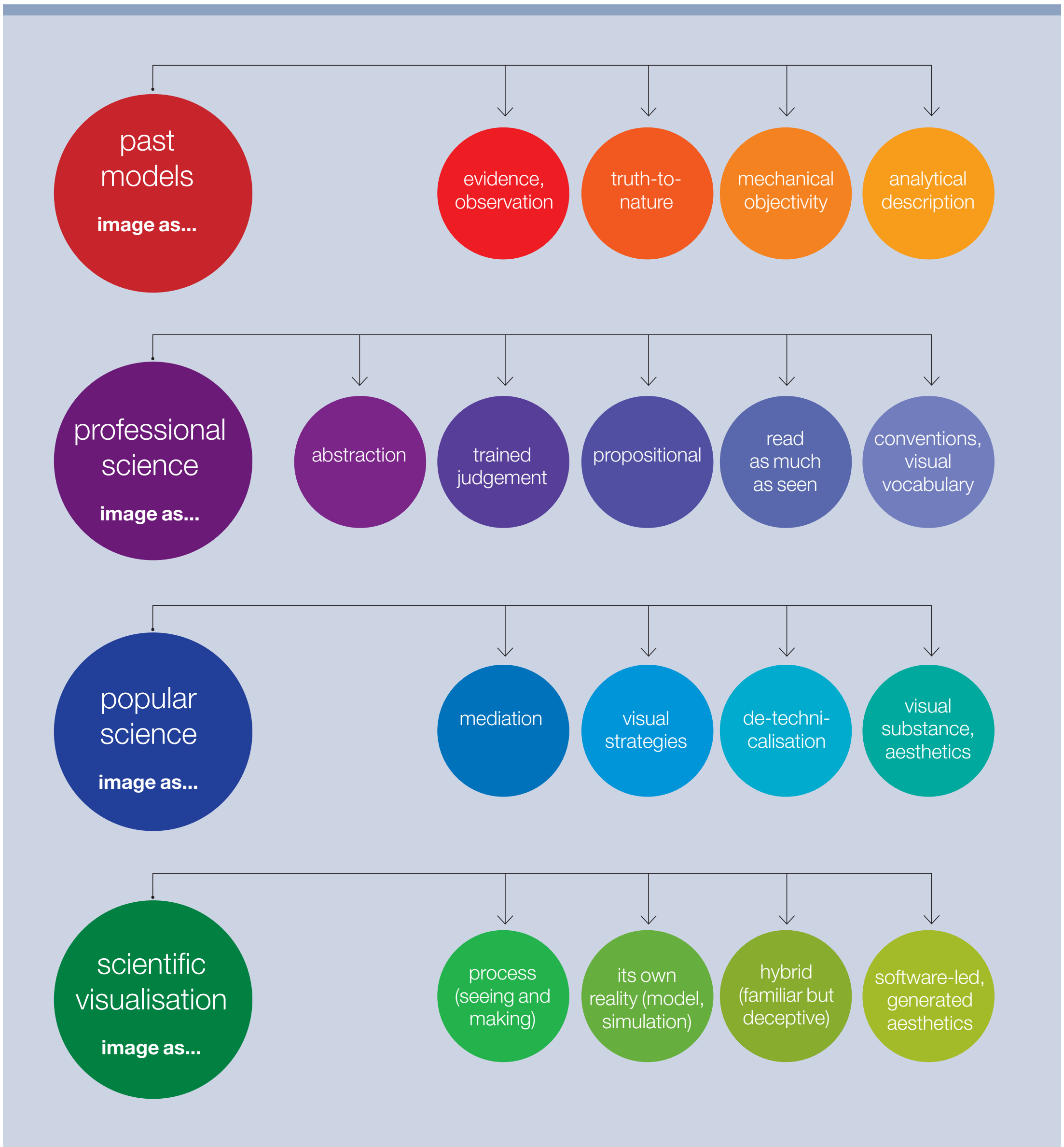

Figure 2.39: Visualisation of concepts uncovered in the survey, for each image group in the domain of scientific visuality.

associated concepts to construct a clearer landscape of the findings. A linear approach has its own problems of inaccuracy (as clear demarcations would be impossible to establish because each group involves a degree of overlap with others); nevertheless, it has been adopted here as I focus on a working distinction between groups and their sub-groups, and highlight how visuality operates differently in each of these specialist areas.

In its second domain – artistic visuality – the relation between science and art is more ambiguous to encover, where other concepts have been identified as follows: figure 2.40 adopts a triangular ordering (rather than a linear approach), aiming to capture the three main groups, where connections are more "organic", and where influences and visual

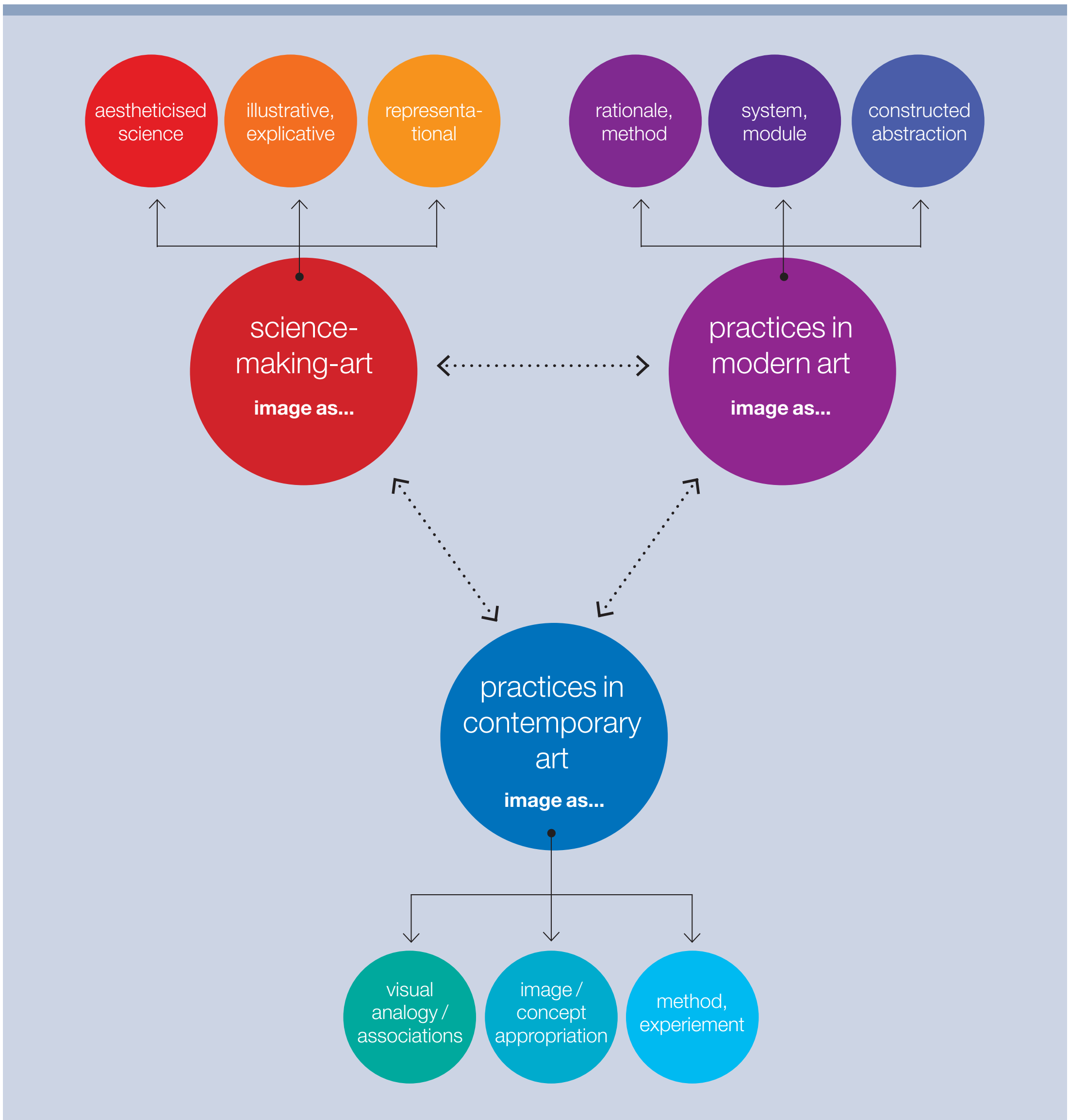

Figure 2.40: Visualisation of concepts uncovered in the survey, for each image group in the domain of artistic visuality.

traditions navigate from one field to another, ultimately making clear demarcations even more challenging to identify. Hence, figure 2.40, serves to indicate three principal domains alongside their respective sub-levels of image concepts as uncovered from the survey, but in this instance the data collection is centred on a smaller selection of particularly relevant practices, as opposed to the undertaking of a broader survey. The information captured (and loosely categorised) does not claim to be exhaustive, as it focuses instead on providing key concepts for further analysis against my art practice in chapter 4.

The findings from this survey will be therefore revisited in chapter 4, as the art practice is challenged against some of the notions highlighted here, and their specific mechanisms of image production and reception. This survey will also assist in demonstrating the distinctive nature of my practice, its particular position in relation to its wider contextual landscape, and will contribute to the dominant dialogues in Art and Science.

Chapter 3 | my artistic practice

CHAPTER CONTENT

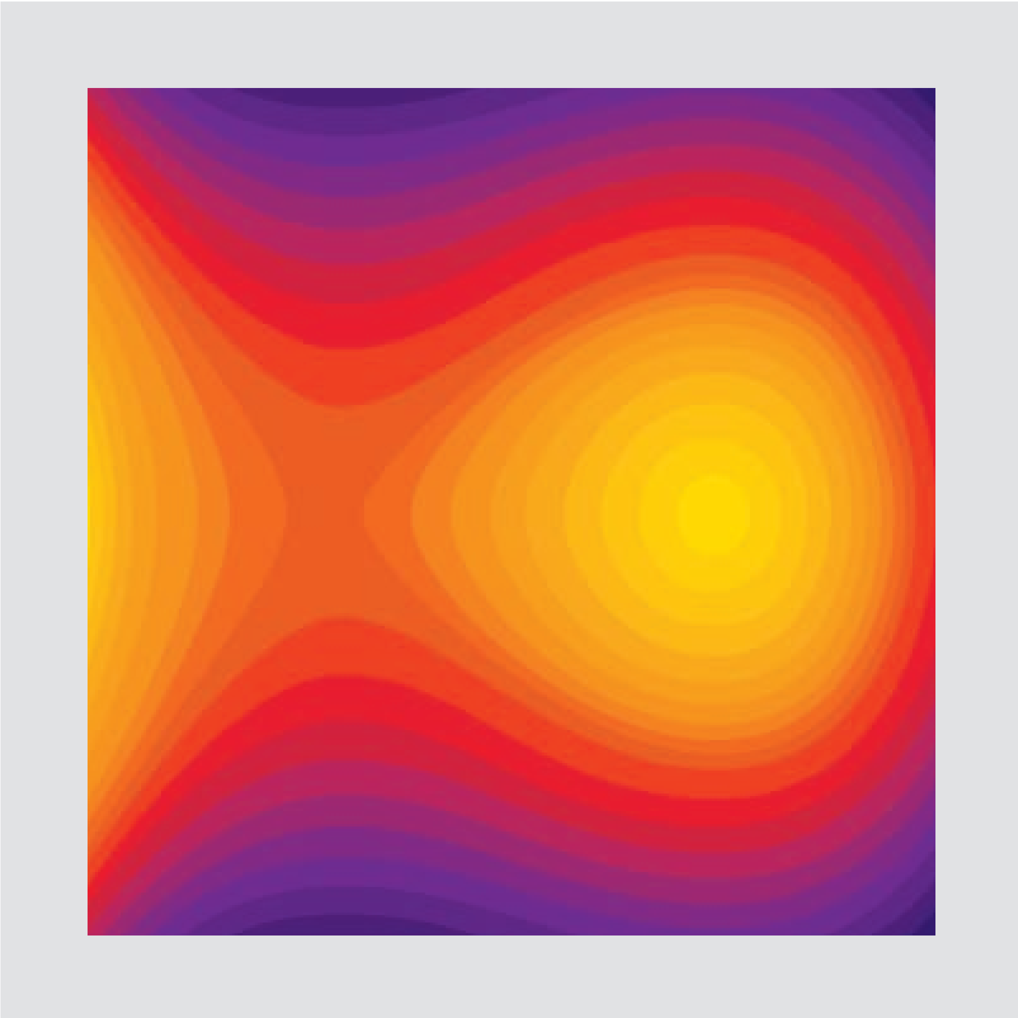

Figure 3.1: *Ionic Wave Propagation* (2008), archival pigment print, 800 × 800 mm, edition of 25.

3 | 1 Introducing the practice

From its outset, my practice testifies to a fascination with the latest research in physics, and the problems associated with the aesthetic visualisation (or transformation) of its source of inspiration. Its fundamental underpinning is centred on visuality, or to be precise, a particular type of visuality (figure 3.1), developed out of a complex web of influences and visual traditions. This section begins with an overview of how the work has been defined and presented so far, mainly in the context of the art gallery. Extracts from two artist statements provide early indications of its nature, how it is evolving, and the challenges in defining it in relation to its purpose, internal motivations and audience.

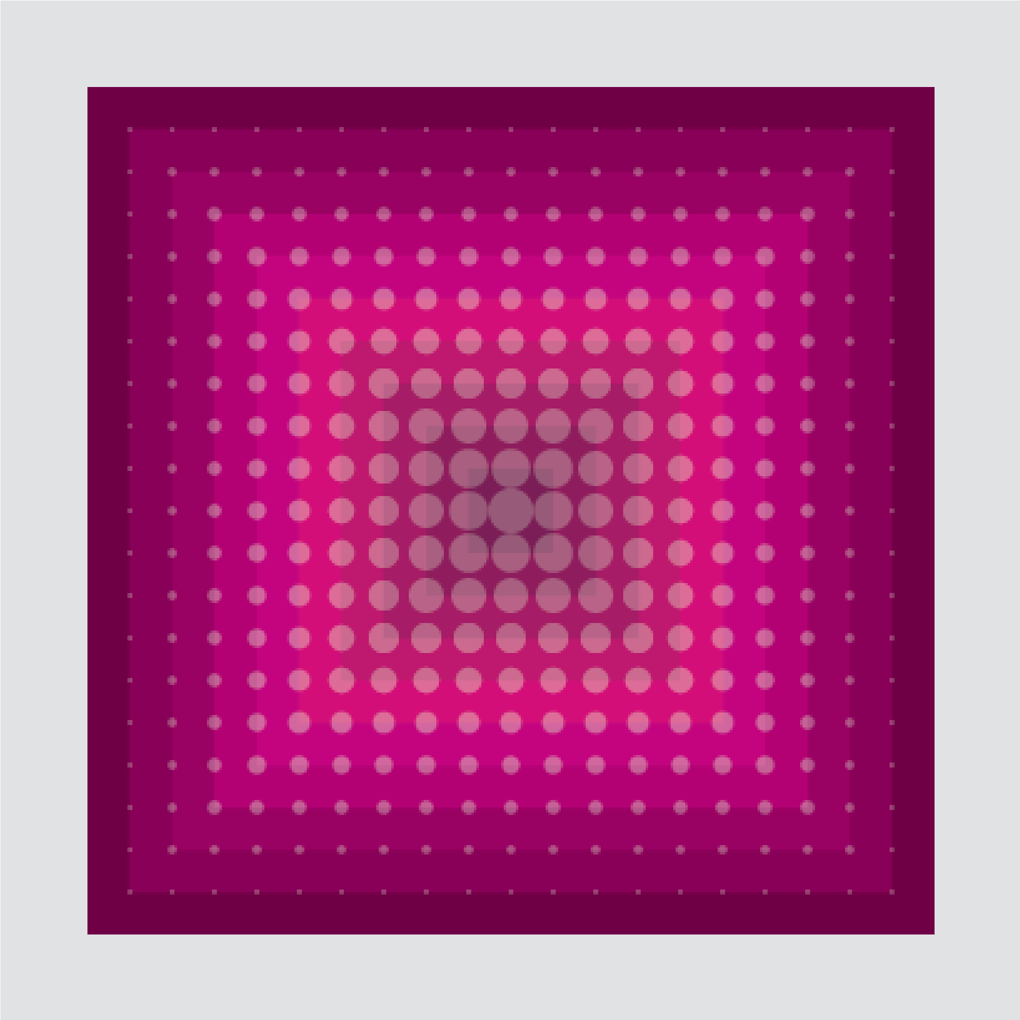

Figure 3.2 (above): *No. 6* from the series *10 × 361* (2008), archival pigment print, 800 x 800 mm, edition of 15.

Figure 3.3 (left): Artworks *in situ* at the group exhibition *Morphogenesis*, View Art Gallery, Bristol (2009).

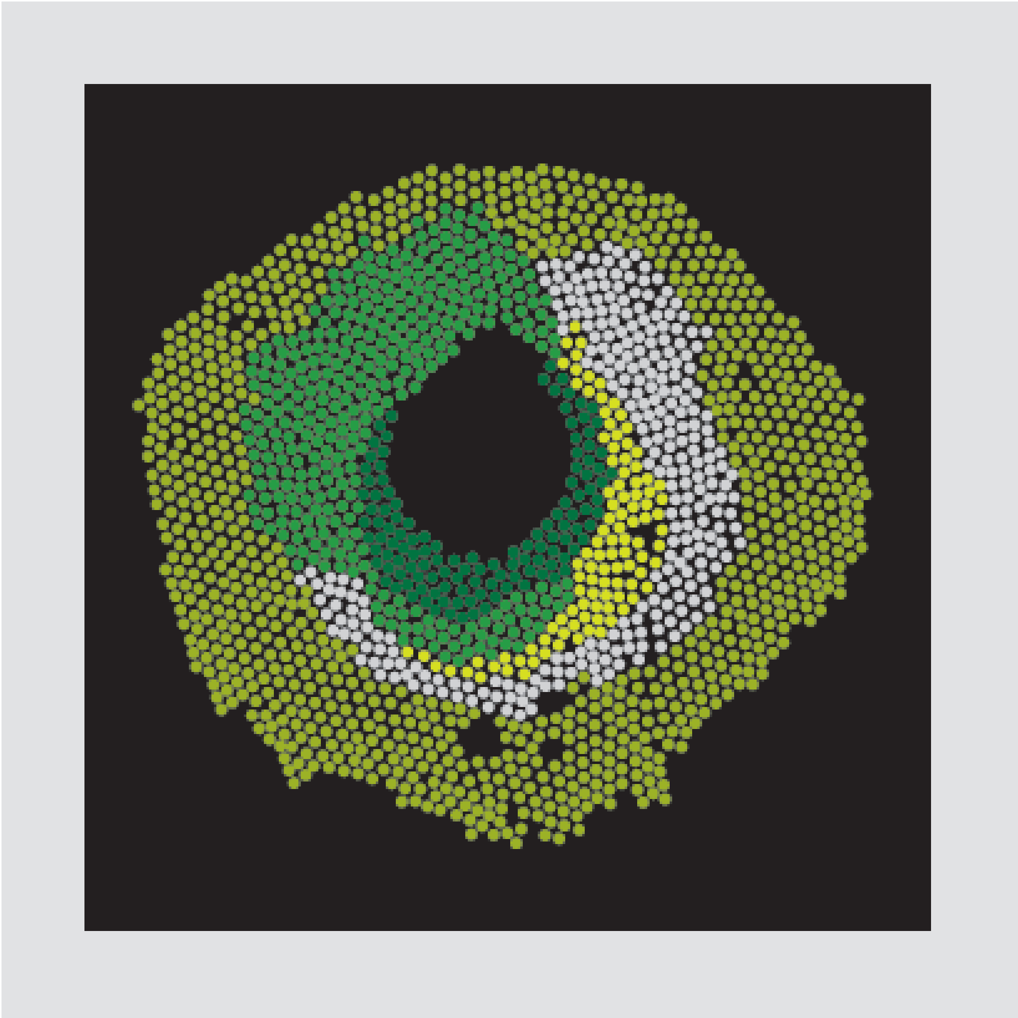

Figure 3.4: *Nanoparticle Gold Ring No. 4* (2008), archival pigment print, 700 × 700 mm, edition of 10.

Figure 3.5: Artworks *in situ* at the group exhibition *Morphogenesis*, View Art Gallery, Bristol (2009).

3 | 1 | 1 Artist statements

> My artistic practice focuses on the study of the relationship between art and science, and more specifically on the visualisation of physics through art. My attempt is to contribute to the communication of science from a visual approach, as I explore scientific concepts primarily from an aesthetic perspective. Taking inspiration from technical graphs, diagrams and models found in published scientific research, the artwork becomes colour-charged, highly visual new imagery in its own right, aesthetically distanced but never fully detached from its original meaning.
>
> My knowledge of physics is limited, which I use as an asset in my work. I approach my reference material by applying new functions to the forms and colours that I manipulate, while retaining the underlying scientific information. I often discuss with physicists the science that inspired the artwork and benefit from their expertise in explaining aspects of physics in a more engaging way.
>
> Each piece can be appreciated on different levels; from pure abstraction to material inspired by the most advanced physics research, it provides viewers with the opportunity to form their own interpretations, and to choose ways to engage visually and/or intellectually with the imagery.

This extract comes from an early artist statement that introduced the work at a group exhibition in 2009 (figures 3.2-3.5), and in the publication of my first art catalogue.[1] My initial attempt in describing the practice was based on notions of visualisation and representation of scientific material through art. Led by a strong aesthetics (or "visual substance"), the artwork could be defined as a hybrid between graphic arts, illustration and visual communication. In this early period (2004-2009), each artwork proposes an artistic interpretation of a scientific idea or phenomenon, as a new visual in its own right but one that always retains a close link to its reference source.

The practice began with a personal assumption of belonging to the so-called space of Art and Science,[2] with the belief that because I get my inspiration from scientific research, the work must belong to this domain. As it developed over the years, and as I became more aware of the broader spectrum of research on the subject, my position has gradually shifted.[3] I soon encountered difficulties in locating my own artistic approach among others engaged with scientific topics. My work did not seem to fit, affinities or shared concerns could not be easily identified, and my questions did not appear to match the preoccupations of fellow practitioners.[4]

1 Swist, F., *Science and the Visual: An Artistic Practice Engaging with the Visualisation of Scientific Concepts* (Bristol: Swist, F., 2009); Group exhibition *Morphogenesis*, View Art Gallery, Bristol (30 September-14 November 2009). During the course of the research I kept my art practice active; both this exhibition and catalogue were used to feed directly into, and inform the enquiry; this enabled me to discuss the work in these various related contexts.

2 See appendix 2, pp. 154.

3 While the production of artworks was perhaps less affected by this change.

4 Wilson, *Art + Science Now*.

The next extract, written by Gary Peters, comes from a subsequent publication, a brochure produced for the group exhibition *Sphere of Accuracies/Zone of Truth*, hosted at Bar Lane Studios in York in 2011:

> Her interest lies in the latest research in physics and the complex problems associated with the aesthetic visualisation of scientific concepts and phenomena related to extreme scale, distance and mathematical abstraction: the "end of representation".
>
> Not being a scientist, and thus excluded from the 'communicative community' of experts, she deploys this externality and alterity as a positive aspect of her work, prioritising the development of, and adherence to, a particular method of visualisation, intended to be analogous to, and thus capable of engaging artistically with, scientific notions such as the study of elementary particles, condensed matter, plasma physics, nano-science and quantum mechanics.
>
> Her artwork is inspired by graphs and diagrams encountered in technical publications which, through a series of negotiations, aesthetic judgements and visual transformations results in a vibrant body of work that inhabits the vestigial space between the representational and the non-representational.[5]

Fragments such as "end of representation", "method of visualisation", "vestigial space between the representational and the non-representational" are of particular significance: they demonstrate a shift from early concerns of visualisation, towards a deeper exploration of scientific visuality (specifically, the threshold beyond the visible) and the devising of a more sophisticated mode of engagement with its source. This external voice reflecting on my own practice has been a turning point: Peters' comments on my work has enabled me to crystalise artistic concerns that were already latent and has allowed focusing the creative journey around more explicit notions (discussed in further detail in this chapter).

3 | 1 | 2 Purpose

The purpose of my art practice can be addressed on two levels: through internal intentions (the production of art) and external motivations (the reception of artwork).

As to its internal purpose, the work is driven by a personal interest in both scientific and artistic visual domains. It is motivated by the deployment of a strong aesthetics as an alternative approach to the comprehension of its source material. The work takes place through lengthy research and extensive study of colour-form relationship; it is driven by a deep fascination for the construction of a particular form of visuality, rather than conceptual, symbolic, metaphorical or representational concerns.

5 Group exhibition *Sphere of Accuracies/Zone of Truth*, Bar Lane Studios, York (5-31 March 2011). The above extract, written by Gary Peters, is taken from the exhibition brochure. An online version is available at http://www.fredswist.co.uk/publications.html [Accessed 20 August 2012].

In terms of reception, my practice aims to participate in the current dialogues between art and science. In recent years, science's profile has been raised in the public sphere, through government policy, the media, and initiatives such as the Royal Society's public lectures and exhibitions, the Cheltenham Science Festival and the Wellcome Trust's programmes. In the arts, multidisciplinary exhibitions have generated interest in the connections between artistic and scientific activities. The *Design and the Elastic Mind* 2008 exhibition at the Museum of Modern Art, New York, Cern's art residencies with invited artists such as Antony Gormley and Keith Tyson, and the yearly Kinetica Art Fair are only three examples of a broader spectrum of events, exhibitions and conferences taking place worldwide. It is against this backdrop that I seek to locate the practice and to argue for it participating in an already established platform of discourses that continue to explore the complex relation between science and art.

3 | 1 | 3 Audience(s)

Over recent years in developing my practice, taking part in exhibitions and submitting works for publication, I have identified the potentially wide ranging audience that I am addressing as a practitioner. An indicative breakdown of audience and related context can be identified as follows:

- **Artists** – primarily the audience and participants at group exhibitions and in the context of art galleries[6]
- **Designers and illustrators** – work featured in trade magazines[7]
- **Collectors** – private sales and commissions[8]
- **Critics and commentators** – critiques, comments or citations in exhibition catalogues or academic essays[9]
- **Scientists and academics engaged with science studies** – scientists and academics have shown an interest in my work; they constitute the main audience when it has been presented in various science-related contexts.[10]

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6 Exhibitions and gallery contexts have been discussed pp. 76-79.

7 Such as *Decode* or *Novum* magazines, discussed p. 85; also see appendix 4, pp. 194-199.

8 A number of acquired work by institutions and private sales have taken place over the years. Examples of commissioned work are featured in volume 2, pp. 4-7 and pp. 14-21.

9 Examples include a short piece by Gary Peters for an exhibition catalogue (see p. 80), and a quote from Tom Wilcox, former Managing Director (2003-08) at the Whitechapel Gallery, London (see p. 85).

10 Discussed p. 83; also see volume two, pp. 8-13 and pp. 22-23.

Two series of artworks have been commissioned, giving me the opportunity to exhibit in a scientific context at the Centre for Nanoscience and Quantum Information, University of Bristol (2008),[11] and the Physics Department at the University of Birmingham (2009). In 2012, Robert Crease, Professor of Philosophy of Science at Stony Brook University, discussed the piece *Quantum Obstacle* (along with its scientific reference source), in his paper 'Art of the quantum moment' at the *Bridges Towson 2012* conference, where he addressed a multidisciplinary audience of scientists, artists and scholars.[12] Other works have been presented at open submissions, art gallery settings, and group exhibitions, both in the UK and abroad,[13] thus engaging with a broad and diverse public.

This plurality of receptions demonstrates the multidisciplinary dimension to the work but it also presents challenges to any attempt by a practitioner to engage more directly with the viewer. This has been and remains an issue in my practice, which I am continually questioning. In discussing any work of art, there are two important aspects to consider: the *production* and the *reception* of the artwork. Because the questions I explore have emerged from making artworks – therefore focussed on issues of production rather than reception – I was less concerned with identifying and engaging with an audience. In other words, my practice *assumes* its audience but temporarily resists a dialogue as it concentrates instead on the internal process of constructing its own form of visuality.[14] Nevertheless, the question of audience reception remains important if the art is to present itself to the viewer and engage with its broader related field. Janneke Wesseling captures the chronology between the production and reception of an artwork as follows:

> The work of art is not the end product of the artist's thinking, or just for a moment at best; it is an intermediate stage, a temporary halting of a never-ending thought process. As soon as the artist has allowed the work as object out into the world, he takes leave of it. His activity with regard to this specific work now belongs to the past, and at this point the beholder, the public, becomes involved in the work. The beholder picks up the train of thought as it is embodied in the work of art.[15]

The last sentence is of special interest: asking a section of my audience – scientists – to

11 See volume two, pp. 4-7.

12 *Bridges Towson 2012: Mathematics, Music, Art, Architecture, Culture* (Towson University, Maryland, USA, 25-29 July 2012).

13 See list of exhibitions, pp. 142-143.

14 In my art practice, the audience is assumed, hence it is not addressed as part of the work, or part of the research. I believe that a participatory approach would have affected or even influenced the creative process, and therefore could have informed the practice differently than it is in its current form. As a result, this would have generated new questions and a new direction for the practitioner, without necessarily addressing the current concerns proposed in this research. Questions to do with the reception of the work, the opening of interpretation and the manifestation of a plurality of readings – all encouraging the participatory role of an audience – therefore remain intentionally outside the current scope.

15 Wesseling, *See it Again, Say it Again*, p. 12.

comment on my practice, I have received compelling indications on how the artwork is being interpreted, in some cases with remarkable insights on their part as to how the creative process takes place and results in such artistic interpretation. This has been documented in volume two (the supporting material to the thesis): for example, Gregory Ezra (Cornell University, New York) commented that the artwork *Reaction Dynamics* was "somehow strongly and very correctly suggestive" of the underlying mathematical equation conveyed in the original graph, while in pure visual terms, the artistic interpretation looks significantly different; only the outline of the original graph has been kept (then duplicated and rotated) in order to construct the new composition (volume two, p. 13). Referring to the artwork *Quantum Obstacle*, Jean Dalibard (École Nationale Supérieure, Paris), captures accurately the creative process in the visual transformation between the original figure and the resulting artwork (volume two, p. 10). In particular, he comments on the back-and-forth between the two states, where my initial research suggests a "detachment" from the original, then a "closeness" again, in order to reveal patterns intrinsic in the imagery. Dalibard also draws parallels between the intentions embodied in the artistic process and his original motivations in the scientific research.

These remarks offers fascinating insights into how the artwork is perceived by the scientists from whose work I have taken inspiration. They demonstrate how the artistic interpretation remains referential to its source, often in an accurate and explicit manner (although this high level of accuracy is not always consciously or intended on my part) – and how it is acknowledged as such by the scientists who recognise the inherent scientific meanings retained in the visual. Since in these instances, they comment on artworks that have directly been inspired by their own research, consequently they are more aware of the effect of transformation, and are more apt to recognise remnants from the source than other sections of the audience. Jon Keating (University of Bristol) also made a comment that could be understood in a more general sense, about the art practice as a body of work:

> (...) Fred's work is interesting in this context because it is itself a transformation of our original figure; so a transformation of our transformations. Many of the articles in *Nonlinearity* relate to iterated transformations, and what Fred has done exemplifies that. Her art has become an example of the ideas that inspired it. It has captured the essence of the mathematics. Also, the way we visualise it relies on optics, so it is itself an optical transformation of the kind we imagined. In this sense the art and the science have become intertwined, or self-referential. (...)[16]

16 See volume two, p. 23.

Keating's remark resonates with my claim for a deeper and more intricate engagement with science, where the relationship between the two domains goes further than other practices, in the sense that it is not connecting through familiar models such as narrative, metaphor, imagination, appropriation or displacement. As I explain further in this chapter, my practice interacts at first hand with highly complex and theoretical research material that is positioned beyond my own understanding at an expert level, therefore I have devised an alternative form of interaction with it – a fascination with the visual and an aspiration for exploring and developing my own response, constructing my own form of visuality – a careful process of visual negotiation and transformation – but, as captured by these testimonies, retaining a level of (sometimes "intuitive") accuracy with the source.

In contrast, other sections of the audience, for instance, the graphic designer or illustrator, might interact and interpret the work differently, drawing on its other dimensions, or be particularly sensitive to my approach to colour and the work's distinctive aesthetics. To illustrate this, two examples are given: in 2008, a double-page article was featured in *Novum* magazine (appendix 4.3, pp. 194-196), and in 2005 an artist's profile was published in *Decode Magazine* (appendix 4.4, pp. 197-199). Both instances show how the design and artworks appealed to an audience already visually aware and sensitive to this image genre. These also demonstrate how the work is being interpreted by journalists, and how in some contexts, the design and art practice's own boundaries are seen as blurred, as the work is presented in a multidisciplinary environment. More specifically, *Novum*'s publication was part of a themed issue on information graphics, and the editorial team loosely linked the featured works to information-based design. *Decode*'s scope addresses wide ranging disciplines in the arts, from design and illustration to literature, poetry and performance work, here again introducing the practice on a broader platform of creative disciplines.

The art critic or theorist might be more interested in drawing on the strong visual connections with geometric abstraction or Optical Art – references that are explicitly articulated later in this chapter (see p. 85). From a curatorial perspective, Tom Wilcox, former Managing Director (2003-08) at the Whitechapel Gallery, comments on the practice as follows, as he situates it in relation to the broader contemporary art landscape:

> Science is frequently an uncomfortable subject for the visual arts world, which fears its rigour and absolutes. Frédérique Swist's work is both highly aesthetic and conceptual, rendering the clichéd differentiation between art and science almost obsolete. Swist's visualisation of concepts of physics creates a strong curatorial narrative in a gallery context – a characteristic too often absent from some forms of visual art – this is engaging for an audience; the viewer is compelled by a conceptual logic that contrasts with more ubiquitous arbitrary themes.[17]

Returning to Wesseling, her remark addressing the moment where the work of art enters the realm of public view is particularly relevant here: the above comments and experiences from different sections of my potential audience convey how they "pick up [and build on] the train of thought as it is embodied in the work of art", often in unpredictable ways, as they also introduce their own references to the reading of the artwork, hence leaving behind the original artist's intentions.

3 | 2 Background, context and historical traditions

My art practice emerges from a complex set of surroundings, involving a number of influences and visual traditions located in other disciplines such as Optical Art and geometric abstraction, graphic design, information graphics, and scientific visualisation. In this section I summarise these dimensions and provide a brief background to the practice's counterpart – my design vocation. I also explore the evolution or shift of concerns of the design towards the art practice.

3 | 2 | 1 Strands and dimensions

My practice can be defined through a number of components (figure 3.6), which influences, informs and opens to other sub-domains, directly feeding into the production of art. These serve as initial "signposts" to establish a broad landcape of relevant themes, while each aspect is discussed in more depth further in this chapter.

a) My art practice is rooted in its design counterpart

My professional role as senior graphic designer for a science academic publisher (IOP Publishing) has been the foundation from which my art practice has gradually extended. A shift from the design to the art practice progressively developed out of the limitations encountered in my design profession, where the creative process is deployed to specific requirements (pp. 87-93). My approach borrows both from a visual language already established in its design counterpart, but also extends it for further exploration (p. 93).

17 Personal communication, Wilcox, T., Email to Swist, F., (14 September 2013).

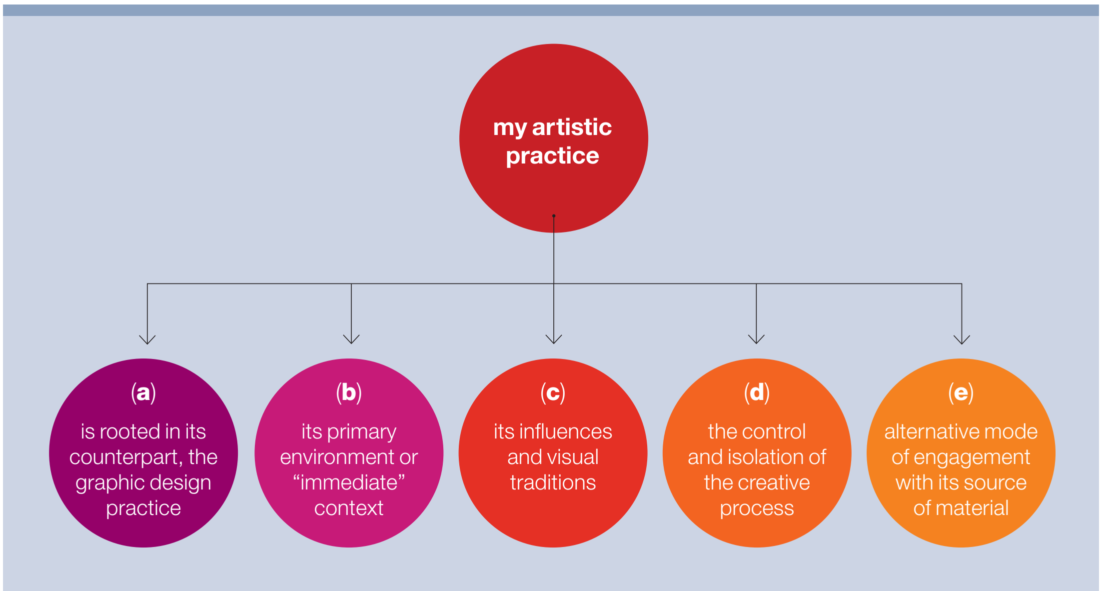


Figure 3.6: A configuration of five strands or dimensions to the art practice.

b) Its primary environment or "immediate" context

My design profession provides direct contact with specialist academic research in physics and physics-related subjects. This has allowed a growing interest in scientific content and specialist imagery mainly published in IOP journals, which I started to incorporate in my design work, then developed further to become artworks.[18] This unique environment, where I am situated "at first hand" in accessing specialist material, constitutes what I term the "immediate context" to my art practice.

c) Its influences and visual traditions

A range of inspirations and visual traditions (such as the Bauhaus, Johannes Itten's colour theories,[19] and geometric abstraction) can be identified in the work, sometimes with direct references to specific artists, such as a series I developed out of a study of Victor Vasarely's system *l'unité plastique* (pp. 101-102). In terms of visual vocabulary, the practice draws from principles rooted in the Swiss Rational Design (a design approach based on the rationalisation of information, grid and modular system, and a functional approach to typography), previously Principles previously deployed by modernist

18 My main source for scientific material is with IOP's portfolio of publications but also with other portals such as the arXiv platform, an open-access database of more than 600,000 articles hosted by Cornell University, at http://arxiv.org [Accessed 10 June 2011].

19 Itten, J., *The Art of Color* (New York: John Wiley & Sons Inc, 2002); Itten, J., *Design and Form: The Basic Course at the Bauhaus* (London: Thames and Hudson, 1975); Itten, J., *The Elements of Color* (New York: Van Nostrand Reinhold, 1970).

designers such as Wim Crouwel, Will Burtin or studio work by the corporate organisation Geigy.[20]

d) The control and isolation of the creative process

A deliberate sense of isolation is considered necessary in the conception of artwork, to avoid the contamination or compromise of the creative process, as it is focussed on an internal journey of research and experimentation. Demarcations can be made between my design and my art practice, as the former tends to operate more actively with participants (scientists, art director, clients, audience), while the latter deliberately distances itself, isolating the creative process from external factors. Here, a sense of discovery is replaced by a sense of construction, that is, of strict parameters in conducting the research, in order to fully control, test, evaluate and record the various stages (including failures) from initial idea through to the completion of the artwork.

e) Alternative mode of engagement with its source material

Using my limited knowledge of science at an expert level as an asset, I have been developing an alternative form of engagement with specialist scientific content, focusing on the "grasp" or "apprehension" of the raw material with an emphasis on its visual potential (as opposed to its explanatory values).[21]

3 | 2 | 2 My design practice, a brief overview

First I would like to briefly introduce my employer, IOP Publishing, and provide a brief background to the organisation. With its origins in the Physical Society of London formed in 1874, the Institute of Physics was created in 1918 in response to demands from physicists employed during the First World War for professional representation.[22] Now based in Portland Place, London, the Institute has become a scientific membership organisation devoted to increasing the understanding and application of physics. It has an extensive worldwide membership and is a leading communicator of physics, with an audience ranging from specialists, government, to the general public. Its publishing branch, IOP Publishing (IOP), located in Bristol, provides specialist publications through

20 *Wim Crouwel: A Graphic Odyssey* (London: Design Museum, 2011), exhibition catalogue; Remington, R. R. and Fripp, R., (eds) *Design and Science: The Life and Work of Will Burtin* (London: Lund Humphries, 2007); Museum für Gestaltung Zürich, Janser, A. and Junod, B., (eds) *Corporate Diversity: Swiss Graphic Design and Advertising by Geigy 1940-1970* (Baden: Lars Müller Publishers, 2009).

21 See volume two, p. 3.

22 Lewis, J. L., (ed.) *125 Years: The Physical Society and the Institute of Physics* (Bristol: Institute of Physics Publishing, 1999).

which leading-edge scientific research is disseminated worldwide. IOP is fully dedicated to supporting the scientific community and the advancement of science through its specialist portfolio of publications which includes journals, reference works, conference proceedings, e-books and specialist magazines, both in print and online.

Academic science publishing is generally not an environment known for supporting a strong design culture in its ways of communicating. A primary factor is the nature of the subject (science), in which the content is traditionally given much more importance than how it is communicated, in other words, when specialist technical and theoretical content is being primarily written by scientists for scientists. Researchers themselves can often be suspicious of branding and marketing interventions, because they claim, for instance, that enhancing the visual representation of scientific knowledge may endanger the credibility of their research, an issue discussed in the article 'Making visible the invisible'.[23] This remark highlights strong challenges for any designer engaged with such specialist content, but it also provides opportunities, as the field has not (yet) been saturated by the language of mainstream commercial branding, marketing and advertising consumer culture, hence opening alternative design and visual approaches for creatives to reflect and respond more appropriately to the specificity of the field and its audience.

Over the last fifteen years the in-house design studio at IOP has gradually developed, with its first significant change marked with the appointment of its current Art Director, Andrew Giaquinto, in 1997. Giaquinto brought with him a particular design approach from his background in magazine publishing, where he was employed at the Haymarket Group (London) between 1979 and 1996, working closely with the Swiss-German Creative Director Roland Schenk on titles such as *Campaign* and *Management Today*. Schenk was a strong advocate of Swiss Rational Design principles, which he developed further (including the use of the Golden Ratio for typography and colour), for a new generation of editorial content to serve a fast-growing service industry throughout the 1980s and 1990s. Strong layouts of large-scale numbers and letterings, well-crafted typography, high-contrast visuals and modular grid were particular to Schenk's designs, and implemented through the publisher's portfolio of titles.[24]

23 McKee, S., 'Making visible the invisible' in *Eye Magazine* vol. 15, no. 57 (2005), pp. 18-25.

24 *Campaign*, 'Haymarket 50 Years: 50 Glorious Moments', http://www.campaignlive.co.uk/news/763156/ [Accessed 3 September 2013].

Having joined IOP in 2000, my current role as Senior Graphic Designer is to support the Art Director in maintaining and developing the corporate identity of the organisation through editorial and marketing needs across its portfolio of publications and services.

Working closely with my Art Director, the design approach that we are focused on is driven by its content: *physics*. The organisation of text and imagery is deployed to support the editorial and marketing message, a strategy that translates into the following principles: information-led; visual clarity; legibility; authoritative; serial and systematic. These principles are implemented through:

Figure 3.7: Examples of design using a grid system for the organisation of information, the IOP corporate font Franklin Gothic and colours deployed for their functional values, i.e. to support the clarity and legibility of the content. Far left, brochure front cover, left inside double spread.

- **Typography:** Franklin Gothic was introduced to IOP by the Art Director in 1997, and has been the organisation's corporate typeface ever since.[25] Franklin Gothic offers similar characteristics to its counterpart Helvetica, as both are considered neutral, versatile and highly suitable to information-led design for their legibility value.

- **Grid:** module and proportional division in page layout is fundamental to IOP's design approach. Layouts tend to be divided between a main body area, narrow active columns, and modular spaces for the organisation of content (figure 3.7).

- **Colour:** Colours are also considered for their functional and legibility value. They support the clear presentation of the content, and are employed consistently to reinforce IOP's branding identity and associated sub-brands.

- **Imagery:** The visual strategy can divided into two categories: First, photographic images, often digitally enhanced and coloured. The image genre relates to general marketing

25 Franklin Gothic was designed by American type designer Morris Fuller Benton (1872-1948), between 1903 and 1912; Friedl, F., Ott, N. and Stein, B., (eds) *Typography: When Who How* (Köln: Könemann, 1998), p. 121.

Figure 3.8: Front covers taken from a series of subject-led brochures, promoting contents across IOP journals around a common topic. The cover design uses a more dynamic layout, to accomodate for each image, while the typographic style and header area remain static.

Figure 3.9: Front covers taken from a series of brochures, promoting content for individual journals. The design strategy for this project is based on a grid template using neutral colour and typography. Images are framed within the grid, and varying in sources, from materials taken from the journal (far right), to generic photo libraries (left and middle).

Figure 3.10: Example of corporate-level design, using a strong visually-led approach that combined the imagery with IOP's corporate colour scheme and branding values. Left: front cover design for IOP's yearly product catalogue for 2014, and visual variations developed for the pricing bulletins (top and bottom right). Each year, the catalogue requires a distinctive design, that reflects both the organisation's visual identity as well as its specialist content (physics).

Figure 3.11: Front covers for 2013's catalogue and pricing bulletins, following the same design strategy as seen above in figure 3.10.

Figure 3.12: EPL (formally *Europhysics Letters*) is a journal published in partnership with 17 European societies, covering the latest research across sub-areas in physics. The journal's front cover was re-designed in 2006, adopting a stronger branding of the EPL logo, and an image-led approach as seen above. Four volumes are produced every year, each requiring an individual image taken from previously published articles.

Figure 3.13: Examples of other titles from IOP's portfolio, with various visual approaches, all using imagery taken from articles published in the respective issue. Left and middle feature photographic imagery, colorised and graphically enhanced; the cover on the right presents an image that was redrawn from a graph; the original annotations have been removed to amplify the visual impact on the cover.

and editorial design such as journal covers (figures 3.7-3.9 and 3.13); they are often sourced from specialist suppliers such as the Science Photo Library. Second, artistic interpretations of technical graphs and diagrams from IOP journals, where the visual is redrawn, recomposed, coloured, and to various degrees, developed further away from its original appearance. They are often deployed for corporate-level projects that rely on a stronger design intervention (figures 3.10-3.12). Images are always accompanied by a full reference to their source material to differentiate them from "generic" abstractions (e.g. royalty-free picture libraries such as *iStock* or *Shutterstock*), and to provide an explanation of the scientific phenomena being represented.

3 | 2 | 3 Evolution of my art practice from its design counterpart

Because of their intricate relationship and areas of commonality, the evolution of the design towards the art practice can be difficult to establish;[26] nevertheless, shifts of concerns and priorities have become more evident, for instance:

My design practice	My art practice
Purpose	Non-purpose
Communication/information to an end	Self-expression
Given parameters (brief)	Self-established criterion (method)
Audience known (participatory)	Audience assumed (non-participatory)
Work in the context of a team (Art Director, stakeholders)	Work in isolation

Figure 3.14: Transition of concern, motivation, purpose and audience in the production of artwork between the design and the art practice.

In an interview in *Aesthetica*, designer Peter Saville is asked "Where does the line lie between art and design?" He replies: "A work of art is about itself, whereas design is about something other than itself."[27] Saville captures a key transition that applies here: in the design activity parameters are given by an external source, and their fulfilment considered to an end solution.[28] By contrast in my art practice, principles become self-established, towards an internal purpose: the creative journey is turning inward, where the focus is on the personal exploration of the problems of visuality with its own internal logic.

26 These issues are commonly discussed especially in relation to multidisciplinary practices, see Munari, B., *Design as Art* (London: Penguin Books, 2008).

27 Bache, P., 'Design: the changing face of the aesthetic environment' in *Aesthetica* (1 June 2009), pp. 38-41, available at http://www.aestheticamagazine.com/design-the-changing-face-of-the-aesthetic-environment [accessed 6 July 2011].

28 Noble, I. and Bestley, R., *Visual Research: An Introduction to Research Methodologies in Graphic Design* (Lausanne: AVA Publishing, 2005).

The art practice has evolved from its counterpart by freeing itself from a whole set of external, given limitations, to construct a new set of parameters which constitute the underlying method. This shift is defined as a move from externality to internality. Yet – for the practitioner, at least – this shift is insufficient. Reflecting both on my design profession and my art practice, the following questions arise: should each practice be considered as one common creative activity, or should they be clearly distinguished? Each side of this question can be argued: on the one hand, the design and art practice are both intricately connected; as discussed earlier, they share a common source of inspiration and influences; the creative process inhabits a common space between research and experiment in both art and design, often with the deployment of a shared visual vocabulary. On the other hand, design differs fundamentally from art, and these differences are defined by the very nature of their respective purpose and motivation, as shown in figure 3.14.

3 | 3 Engagement / relationship with science

Now that the background and immediate context have been established, I turn to how the art practice engages with science. This relationship is identified through two central aspects: a) in terms of subject matter / source of inspiration; b) in reference to the underlying method for the production of art.

3 | 3 | 1 How my practice engages with scientific research

Because my work takes its inspiration primarily from scientific imagery (graphs and diagrams) rather than text, its engagement is purely of a visual nature. The principal mechanism in the creative process is focused on the transformation of form, colour and composition, in other words, the construction of a *new* form of visuality. My practice is less concerned with expressing meanings as it is in exploring notions of the original scientific data in visual form. I approach my reference material through the "grasp" of features or fragments in my own limited understanding of the content that I manipulate. I employ various modes of visualisation and image construction as a substitute for this former deficiency, therefore focusing my concerns on the *visual* rather than the *conceptual*. Figure 3.15 presents a selection of source material from specialist publications, to show the preliminary research for the identification of potentially suitable imagery that will serve to trigger the creative process. A more detailed transition between my source material and the final artwork is presented on p. 100, and throughout volume two.

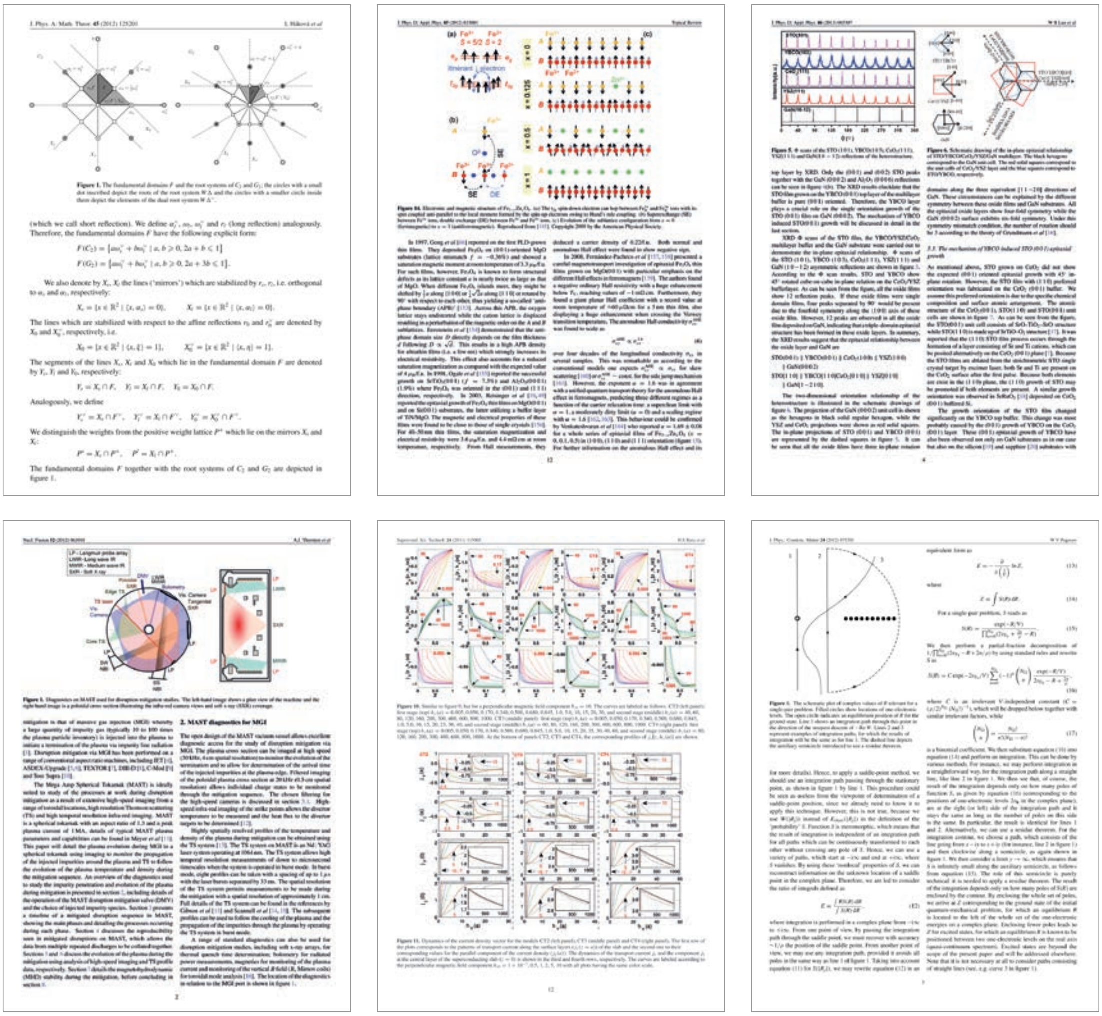


Figure 3.15: A selection of pages taken from academic journals published by IOP.

3 | 3 | 2 Concepts of rigour and accuracy in the scientific method

My interest in science is also aligned with a personal fascination and an "intuitive affinity" with the way science produces new knowledge. The rigour in the conducting of observations and experiments, the setting up of parameters and the recording of data prior to analysis is a method that aspires to precision, accuracy and the values of rational, logical, methodical thinking. These values respond to a prerequisite in my own method and resulting art form: the need to think and work creatively within the framework of criteria, conditions and parameters. The imagery is not created "freely"; there is a limited sense of discovery that is replaced by a stronger sense of control and construction. It is the outcome of a lengthy process, where each stage – each creative decision – is carefully negotiated among a series of pre-determined conditions, and where colour choices or compositional "failures" are also evaluated. These criteria borrow from a range of past methods and visual traditions (as seen pp. 85-87), which I transferred and developed to become in essence *the method*.

3 | 4 The underlying method to my practice

This section sets out to deconstruct the creative process, as it articulates the trajectory, different stages, components, and preparatory research leading to the final artwork. This approach is based on three core activities: colour, form and medium – each playing an equally fundamental role in the creative journey.

3 | 4 | 1 Colour

The colour model employed in my practice refers to the industry standard system found in graphic design, pre-press and commercial litho printing, which has been transposed to the digital medium.[29] The basis of this colour system is composed of four ink channels: cyan-magenta-yellow-black (CMYK). Every colour available in the CMYK space can be built upon, using percentages (figures 3.16-3.19).

Having studied and experimented with colours to significant depth for over fifteen years, I developed a rationale for their deployment in my work. Taking inspiration from the likes of Lohse and Vasarely, I devised my own approach to colours, following a series of principles:

- My practice is based on a subjective approach to colour selection, severed from any representational or symbolic role; instead, focus is given on establishing specific functions to colours in the construction of artwork. For instance, colours are chosen primarily to differentiate one shape from another, or to distinguish a particular gamut in relation to others.[30] Colour selection is often dictated by the principle of *visual legibility*, where each colour needs to be visible when juxtaposed with others.
- Extensive research is undertaken in exploring colour combination. Each chosen colour has a number of possible variations in terms of hue, darkness and intensity. This process involves the documentation of each modification (keeping a record of colour changes) and evaluating colour results with test-prints (p. 105).

29 Here, the digital medium refers to both the imaging and production systems through which the practice is fully dependent upon; see p. 103 in this chapter, dedicated to the medium.

30 This approach resonates with the way in which scientists employ colours in their work – often using different shades to highlight and isolate special features from others, or as a measurement device such as a scale bar. False-colour rendition is widely used in scientific imagery especially in modelling and simulations visualisations, as discussed in chapter 2, p. 49.

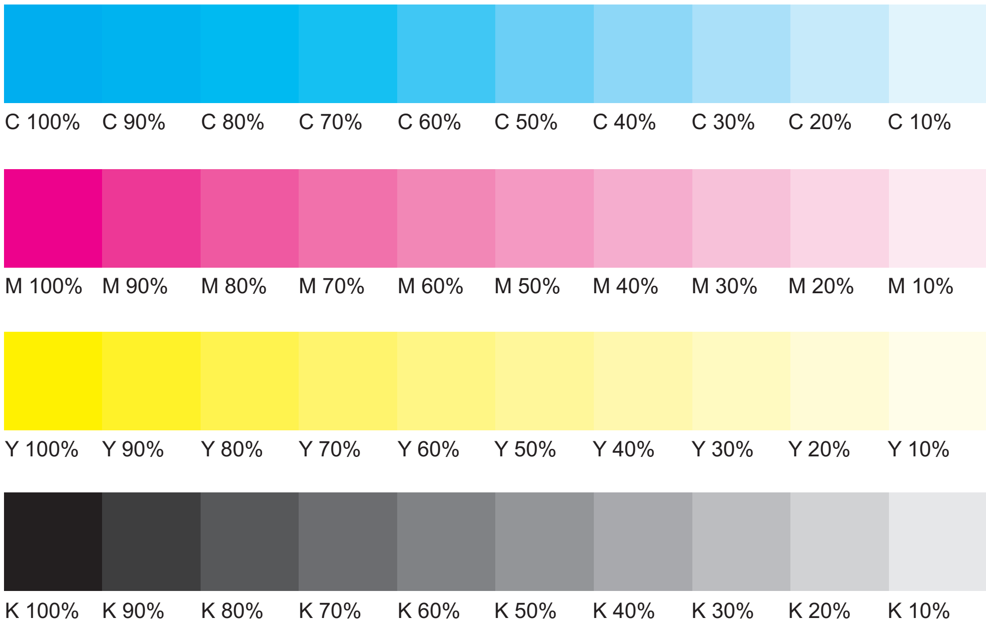


Figure 3.16: Basic colour breakdown in the CMYK colour space using the system of percentages.

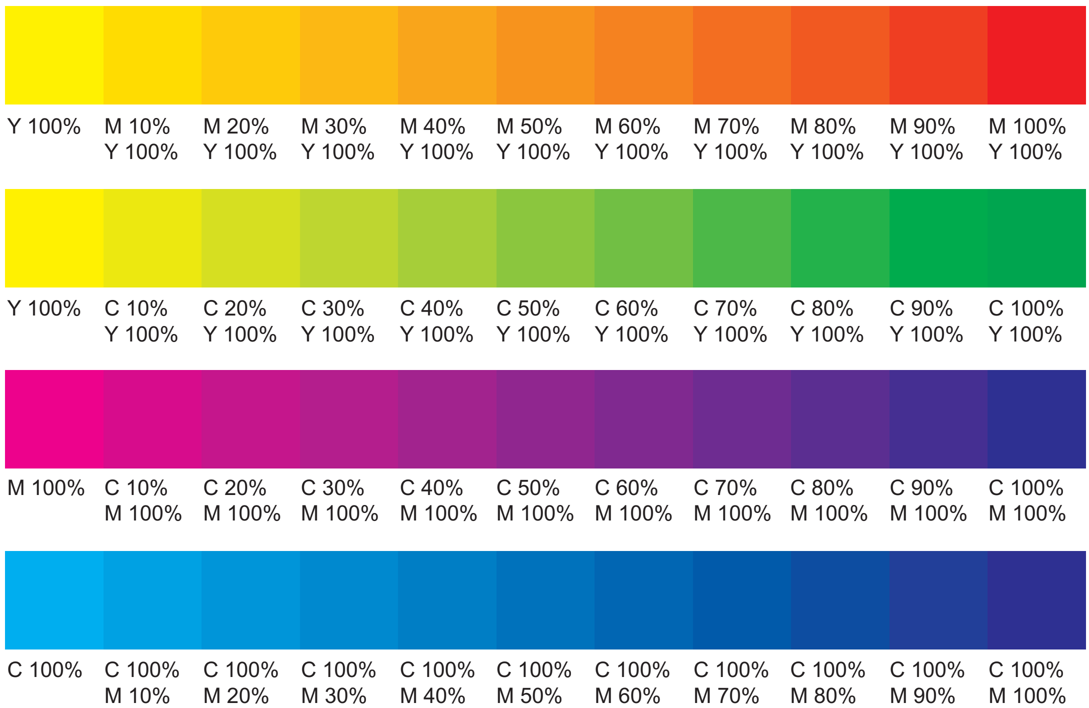


Figure 3.17: Example of families built from the four basic CMYK colours, including the percentage value for each channel.

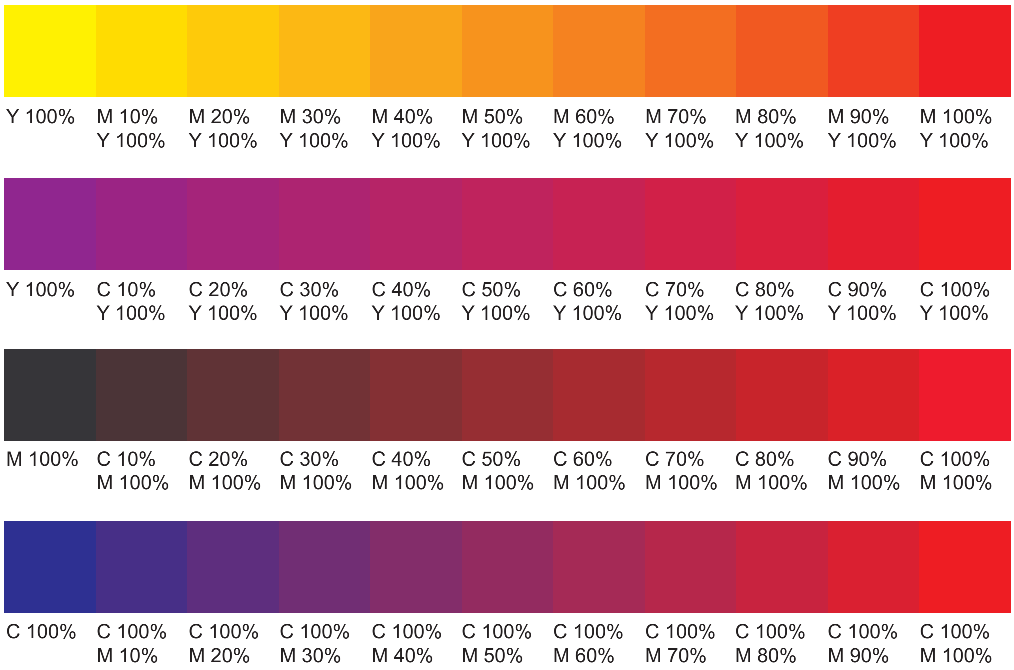


Figure 3.18: Colour strips with variations in colour vividness, using the four CMYK channels.

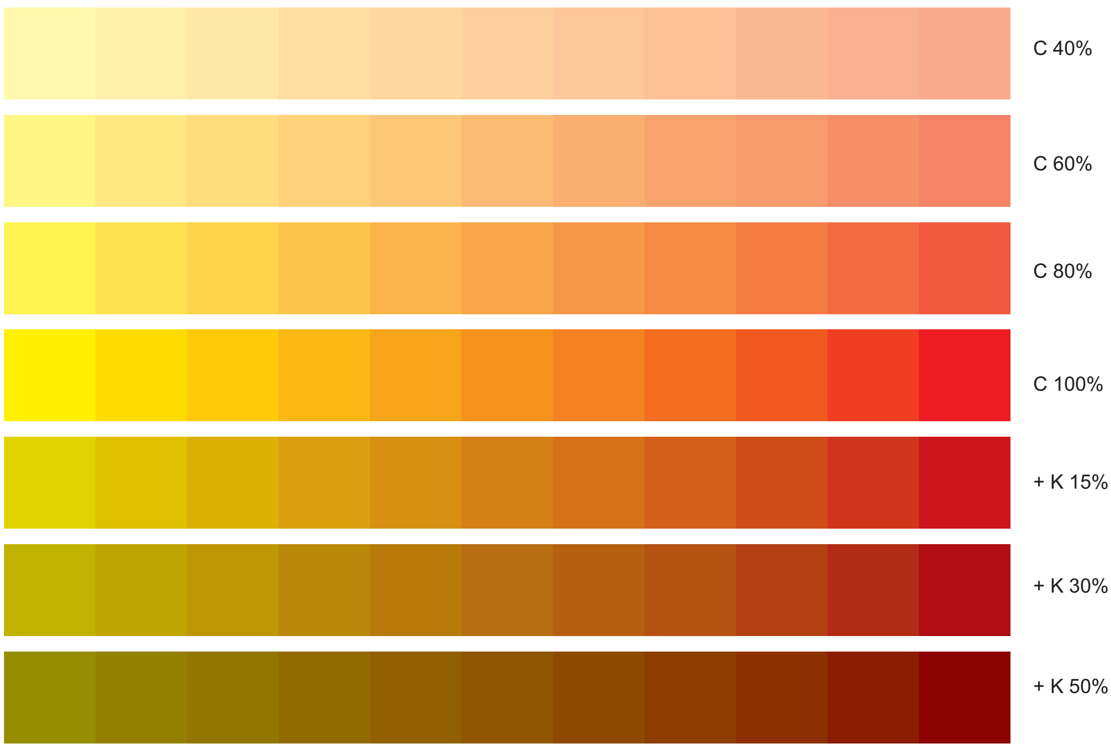


Figure 3.19: Colour strips with variations in lightness and intensity, using transparency (top four rows), and the black channel (bottom three rows).

- In the construction of colour palettes,[31] my method echoes the colour charts available in commercial litho printing which provide a significant level of accuracy in colour selection and reproduction, as illustrated in figures 3.16-3.19.[32]

Adopting a rationale for the deployment of colours contributes only partly to the method. Tacit knowledge, experience and intuition also form part of the creative process, where the device of particular harmonies cannot always be fully explained or justified. Generally, I approach colours with a focus on strong, vivid or pure gamuts rather than more restrained shades (such as coloured greys). I am particularly interested in the threshold between aggressive arrangements of colours (as seen for instance in computer fractal imagery), and more harmonious, yet visually arresting compositions. Colours are always considered as functional – they fulfil a particular task. Of special interest is the study of their optical behaviour: how they respond to their neighbouring colours, but also how rhythm, sequence, visual balance or instability can be expressed and controlled exclusively through their deployment and manipulation in a composition.

3|4|2 Form

In the earlier period of my practice, the transition between the original reference source and the final artwork was mainly motivated by retaining the integrity of its scientific content in visual form. In this scenario, the artwork was often considered illustrative (or even "explicative", especially to the scientist) rather than purely "artistic". This aspect is extensively illustrated in volume two, and offers comments from scientists regarding their own response to the visual interpretation of scientific content.

Figure 3.21 shows the artwork *Three-Particle Distribution Function*, alongside its reference source (figure 3.20).The manipulation of forms is visible as we compare the original (left) with the artwork (right). To some extent, the process of transformation remains faithful to the underlying science conveyed in the scientific graph, while a highly constructed aesthetic allows for its reconsideration, focussing on its intrinsic visual potential, thus

31 Among many colour theories available (from Newton, Goethe, Chevreul to Kandinsky and Itten) the colour wheel is arguably best known for the organisation of colours. Rules such as the use of primary and complementary colours are often employed, with the selection of a second colour positioned at the opposite location of its equivalent primary colour. For a list of key texts on colour theories, see bibliography, p. 134.

32 Homann, J-P., *Digital Color Management* (Berlin: Springer, 2009); Pipes, A., *Production for Graphic Designers* (5th ed., London: Laurence King Publishing, 2009) pp. 86-93. A detailed technical presentation of the colour method is available in Swist, F., 'CMYK: from graphic design to digital art – the transfer of colour manipulation from pre-press and commercial litho printing to a fine art digital practice' in Hoskins, S., (ed.) *Impact 6: Multidisciplinary Printmaking Conference Proceedings* (Bristol: Impact Press, 2011), pp. 60-65; also available in appendix 3.2, p. 162.

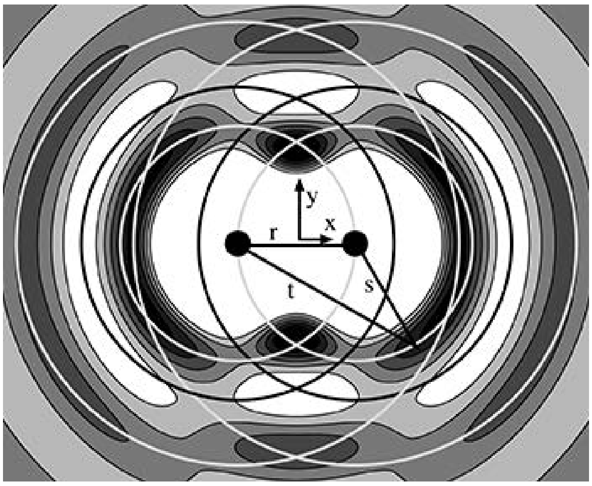


Figure 3.20: Distribution function of a third particle around two fixed particles in a two-dimensional colloidal liquid in Ruß, C., et al 'Triplet correlations in two-dimensional colloidal model liquids' in *Journal of Physics: Condensed Matter* vol. 15, no. 48 (2003), pp. S3509-S3522.

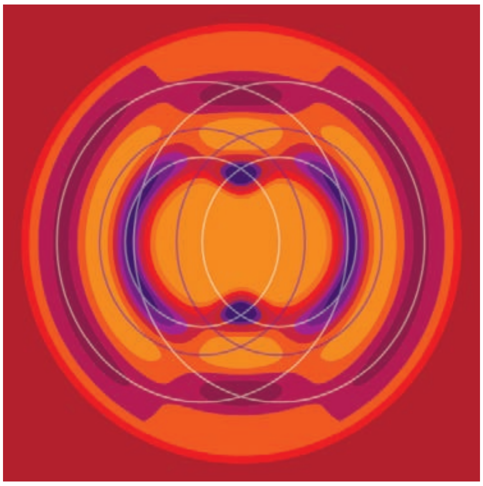
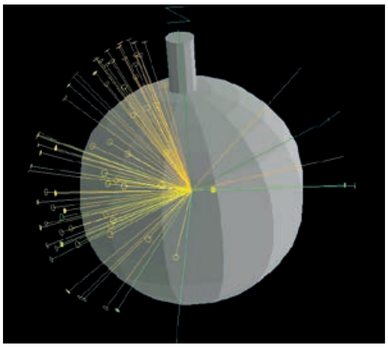
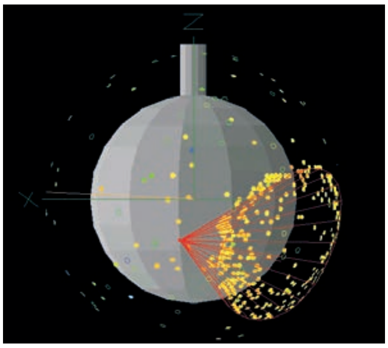


Figure 3.21: *Three-Particle Distribution Function* (2007-2009), archival pigment print, 700 × 700 mm, edition of 25.





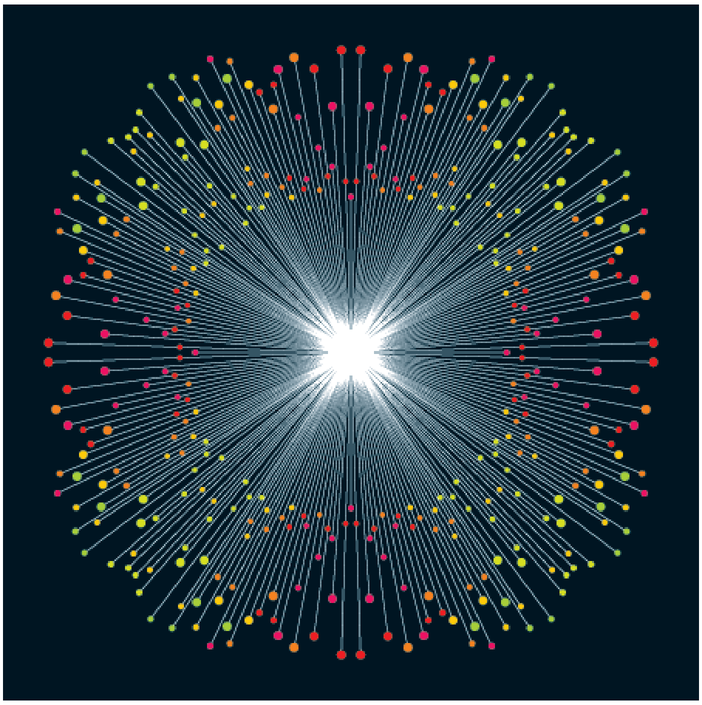


Figure 3.22 (top left): When a neutrino strikes the heavy water of the Sudbury Neutrino Observatory (SNO) detector, a faint cone of light spreads out from that point to SNO's light sensors which surround the spherical vessel of heavy water. In this neutrino event, 75 of the 9600 light sensors observed a photon of light. The lines indicate the direction from the neutrino strike to the sensors, from http://www.sno.phy.queensu.ca/event/event.html [Accessed 10 July 2011].

Figure 3.23 (bottom left): Neutrinos produced from cosmic rays, which strike the Earth's atmosphere, are detected at a much lower rate in the SNO detector. They carry more energy than neutrinos from the sun, and are distinguishable from them. Here more light sensors are involved, and the cone pattern of the light is clearly visible, , from http://www.sno.phy.queensu.ca/event/event.html [Accessed 10 July 2011].

Figure 3.24 (right): *Neutrino Trails* (2009), archival pigment print, 800 × 800 mm, edition of 15.

creating a new amplified version, or a new interpretation of it.

Over recent years, the creative process has developed, gradually departing from its source of inspiration to explore further and more freely, leaving behind the constraints of representing scientific notions in accurate forms. Here, only "fragments" of the underlying science remains of interest; the priority between concept and visual has shifted to focus on the exploration, or deployment of a more sophisticated aesthetics. Figures 3.22-3.24 illustrate this shift of priority, and the increasingly complex negotiation between content and imagery. The artwork is inspired by computer visualisation used to analyse the behaviour of neutrinos (figures 3.22-3.23). Neutrinos belong to a family of elementary particles, and are studied at leading-edge international centres like Cern.[33] They are so minute that they are virtually undetectable, other than through the tracks that they leave behind after collisions with other particles. The scientific depiction of this phenomenon – where lines and dots are in the form of cones of light – served to trigger an alternative "visual response". Inspired by elements found in the original material, fragments have been used to feed into the construction of a new artwork (figure 3.24). In this instance, the original material has not been traced or redrawn, but a strong visual correlation between the scientific source and the artwork remains, while an extended, amplified, freer interpretation took place.

It is not always the case that the construction of an artwork is rooted in specific scientific content; it can also result from being exposed in a broader sense to the visual language of scientific notation, graphs and diagrams where their visual arrangements trigger the creative process (see for example, volume two, pp. 24-25, where the artworks result from a study of pure geometry coupled with an underlying coding system, loosely inspired by scientific notations). In this scenario, the work evolves towards a rigorous study of forms, dictated by a series of self-established parameters:

- **Unit / module:** basic shapes such as the square and the circle are used as units for the exploration of visual possibilities. This approach resonates with Vasarely's work on his system *l'unité plastique*. Studying his method, I undertook to implement its principles as shown in figure 3.25: the artwork is composed of 100 background

33 Cern is the acronym for the "Organisation Européenne pour la Recherche Nucléaire" (the European Organisation for Nuclear Research), formally named "Centre Européen pour la Recherche Nucléaire". Cern operates the world's largest particle physics research facility. Its most recent development is the Large Hadron Collider (LHC), a tunnel infrastructure of 27 km circumference located under Switzerland and the French border. See www.cern.ch [Accessed 9 July 2011].

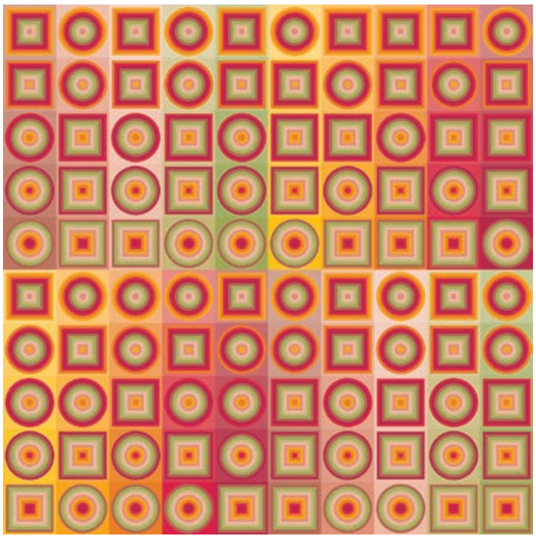


Figure 3.25: *Hommage à Vasarely: l'Unité Plastique No. 1* (2008-09), archival pigment print, 800 × 800 mm, edition of 10.

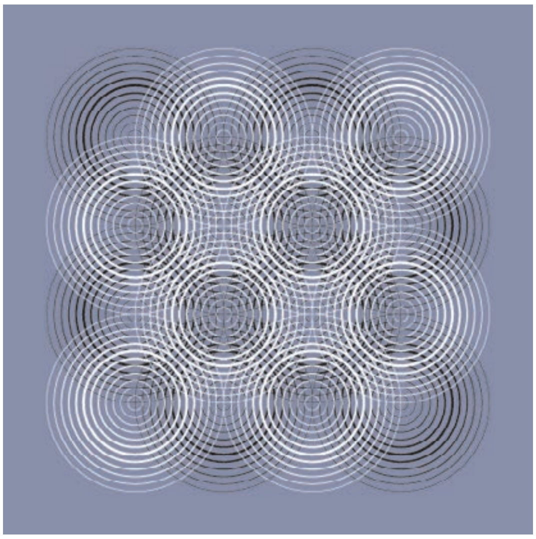


Figure 3.26: *Good Vibrations* (2010), archival pigment print, 800 × 800 mm, edition of 10.

squares, 900 geometric units, nine colours repeated sequentially across the pattern, and ten colours broken down into five proportional variations of shades, applied to the background structure.[34]

- **Sequence, rhythm and repetition:** geometric patterns and repetitions are deployed for instance to explore the notion of waves and oscillations, through a composition of circular shapes rather than through colours (figure 3.26).

- **Line / delimitation:** lines relate primarily to surface delimitation, but can also be part of the creation of effects, such as moiré patterns or the simulation of gradients (figure 3.26).

- **Grid / structure:** often employed as a blueprint for a later exploration of colour. Initially, the visual needs to "work" in black and white, before a colour study can be undertaken. The focus is on the relationship between space, form and proportion, in order to reach a perfectly symmetrical composition (figures 3.27-3.29).

- **Format, scale and dimension:** as a preferred format, 800 × 800 mm is dominant in the practice as it defines and frames the image within a pre-determined space.[35] Scale is also important to consider, as some artworks lose their visual intensity when printed in too large a format, while others lose detail when the output dimension is too small.

34 Swist, *Science and the Visual*, pp. 18-25.

35 Artists such as 2006 Turner Prize winner Tomma Abts welcome the limitation of pre-determined spatial restrictions in terms of format; she favours the 48 × 38 cm for all of her paintings; from http://www.tate.org.uk/whats-on/tate-britain/exhibition/turner-prize-2006/turner-prize-2006-artists-tomma-abts [Accessed 12 July 2011].

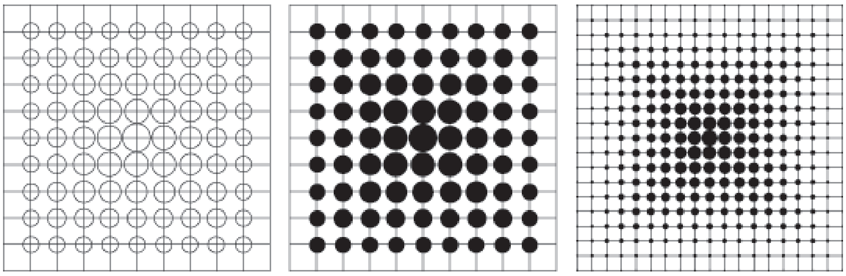


Figure 3.27: Shows the construction of an underlying grid / structure for the series *10 × 361*.

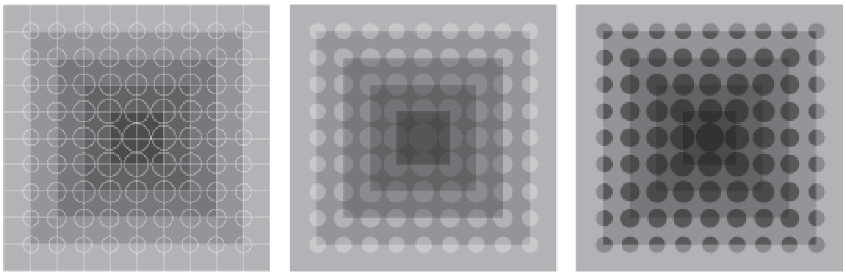


Figure 3.28: Presents the blueprint in preparation for colours. Interestingly, using proportional variations of grey, a three-dimensional effect appears.

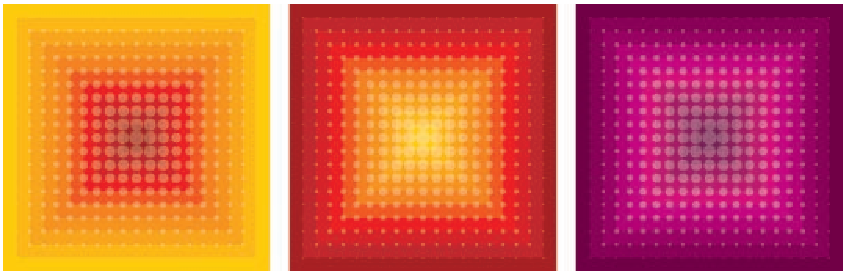


Figure 3.29: Final artworks for the series. Depending on the colour gamut, the three-dimensional effect may seem accentuated or diffused.

It is the complexity of the visual elements, colours and composition that often dictate the actual dimension.

3 | 4 | 3 Medium

My practice is fully dependent on its chosen medium: it dictates the graphic style, the aesthetics, the colour rendition and the way the artwork is produced as a physical object. The medium refers to both the means for the creation of the imagery and its output: the former relates to digital imaging techniques and the latter to the digital printing process. The imaging system adopted in the practice is the vector graphic format (resolution-free, as the visualisation is described by algorithm to represent points, lines and shapes, fully scaleable and editable), using Adobe Illustrator® for the creation and processing of the imagery.[36] The artwork is then produced using inkjet or laser technology to print digital images directly on the media without the use of plates (as found in traditional methods

36 The vector graphic format is based on the use of points, lines, curves and geometrical shapes, described by mathematical equations for their representation in visual form. A vector graphic image is resolution-free, fully editable and scaleable without affecting its visual quality (accuracy of representation). The leading specialist image-editor software used in the creative industries is Adobe Illustrator®; see www.adobe.com/products/illustrator.html [Accessed 3 July 2011].

such as commercial litho).[37] Both the imaging tool and printing medium complement each other, making the full process particularly consistent: the digital image is created in a way that is fully compatible with the subsequent processing software and the printer, also allowing a significant level of accuracy, unmatched by most of the earlier generation of digital and mechanical printing media.

As discussed earlier, the colour method has been developed by specifically taking into consideration the parameters and limitations of the digital image-processing and printing medium. I consider my approach to some extent conventional as I focus on exploring the full potential of known possibilities offered by the medium, rather than pushing the boundaries of what the system can already provide. For instance, a study of colour renditions exerted by the digital-processing chain – from choosing a colour on screen, through to its output on a test-print (figure 3.30) – involves an awareness of all possible variables, such as the numerous settings provided by the processing software. This aspect alone can be a complex and lengthy investigation, digital colour management being a specialist field in its own right.

The digital medium also offers the possibility to record and return to previous work with a significant level of accuracy and consistency. This allows for the different stages in the creative process through to production to be fully articulated, evaluated or "measured"; a rigorous methodology can be devised, where *fausses routes* can also be revealed and justified. *Fausses routes* and failed colour combinations are a part of the process (and remain in its documentation). Figure 3.31 illustrates an issue of colour imbalance, i.e. the purple in the central section is considered too dark. In this version, the such colour issue seems to "stop the gaze" abruptly, it interrupts the visual flow. In figure 3.32, the colour has been rectified to a lighter variation, so the central area better complements its surrounding section. Through this colour adjustment, the visual flow has been reintroduced, now inviting the eye to experience a more balanced colour arrangement. These decisions are partly taken by working "on screen" with the software; they are also backed-up with subsequent test-prints. Through a lengthy process and a significant level of precision, colour combinations are evaluated and adjusted, exhausting many possibilities, in order to attain what I consider the "perfect" visual balance for the final artwork.

37 Large-format printers from Epson®, Canon® and Hewlett-Packard® have become the industry standard for small print-runs, photography, fine-art printing, and large-format work.

Figure 3.30: Examples of test-prints, with colour variations printed in reduced size, before committing to the final artwork.

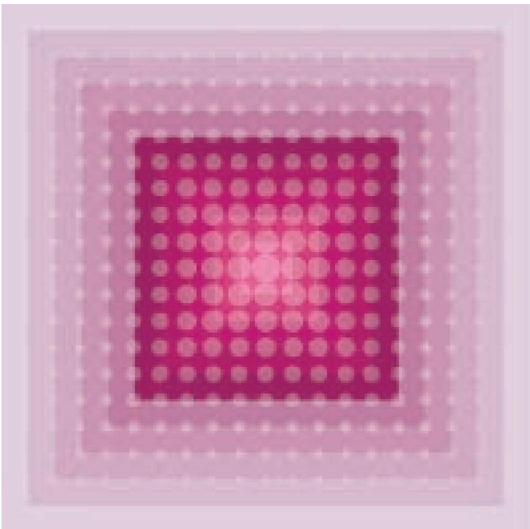


Figure 3.31: Example of colour disproportion or inequality; the second colour (located in the central area) is too strong, leading to a visual imbalance of the overall composition.

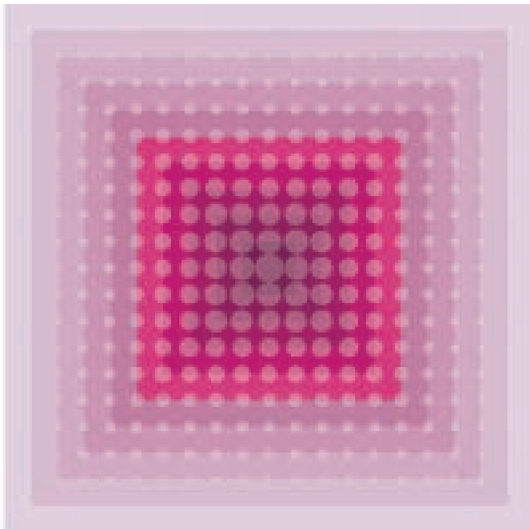


Figure 3.32: Final artwork, with colour adjustment completed: the two sets of colours are now more equal, therefore more visually balanced.

3 | 5 Further experiments: three short case studies

In the context of a publication or an exhibition, the work is seen as modular, as it is adaptable to its specific context and audience. Artworks tend to be accompanied by a short text to go alongside each piece, referring to its source of information and offering background to the science it relates to. This section presents various artworks and their captions; three scenarios are presented here to demonstrate the nature of this modular approach and how it evolves.

3 | 5 | 1 *Morphogenesis:* group exhibition, View Art Gallery

In preparation for the group exhibition *Morphogenesis*, hosted at the View Art Gallery (Bristol) in 2009, a discussion took place with the gallery regarding the accompanying text for the artworks. As presented in my first artist catalogue, the captions provide some background on the underlying science that inspired the artwork. The gallery owner indicated his reluctance to include the full captions for the show – there was some concern that the technical language of these descriptions might "alienate" the audience. Discussing this issue with scientists and science-trained colleagues, from their perspective, the captions are important and should be kept, as they articulate a deeper dimension to the work (often sourced in highly technical scientific research), and demonstrate why the image is not simply to be assumed as a visually pleasing abstract artwork. In their opinion, the scientists among the audience would particularly appreciate the text–image duality, and support my attempt to render complex scientific notions more transparent and approachable through the accompanying text. The full captions were displayed at the opening event, with the option offered to the gallery to remove them afterwards. They were read by a large section of the audience on the first night; subsequently, the gallery decided to keep them alongside of the artworks for the remainder of the exhibition.

This dilemma raises recurring questions in my practice about the audience: on the one hand, the captions are welcomed so an audience of scientists can experience the artworks on their own terms – on science's terms. On the other hand, a viewer with no scientific background may feel alienated by the technical wording, or may interpret the presence of the text as instructing or dictating on how to experience the work. In response to this concern, approaching the presentation of the work in terms of *modules* offers the possibility to choose to what extent the supporting material is needed, depending on its context and intended audience.

3 | 5 | 2 Artworks published in *Neutral* magazine

This project is based on the study of the concept of neutrality, and results from the interaction of three perspectives – art, science, philosophy – exploring this common theme: *the neutral*. I was asked to create a series of artworks to accompany an essay written by Professor Gary Peters for publication in *Neutral* magazine.[38] From the outset, the creative

38 Peters, G. and Swist, F., 'Sphere of accuracies, zone of truth: art, science and neutrality' in York St John University, *Neutral* no. 1 (May 2009), pp. 10-13. See also appendix 3.5, pp. 177-181.

process took place mainly in isolation (rather than with a sense of collaboration) from Peters' piece, and from discussing the concepts with scientists. I began searching through technical papers using keywords such as "neutral", "neutrally", "neutrality". Selected material triggered the creative process and allowed for the construction of new artworks, inspired by visual form and structures found in the reference source. It was only at a later stage that I consulted colleagues, who guided me through the scientific notions, and kindly provided the descriptions that I considered important to complement my artistic interpretation for the intended context. In the magazine, the imagery is accompanied by two types of caption: first the scientific explanation and then a short paragraph written by Peters, which re-connects the imagery to the main text (see appendix 3.5, pp. 181-185, for the full article and artworks presented in the magazine page layout).

In this piece different dimensions are proposed, again, demonstrating a notion of modularity in the work, how it can be presented and be adapted depending on its particular surrounding. Two sets of captions are presented in parallel, also echoing the way that each component was conceived in isolation from one another, yet resulting in a coherent overall response to the concept studied here.

a) *Ultracold Neutral Plasma* (figure 3.33)

> **Scientific caption:** Commonly occurring plasmas, such as the Sun's corona or lightning, are very high temperature gases or fluids of charged particles. But neutral plasmas with new properties can form at extremely low temperatures. A gas of atoms is ultra-cooled within a magnetic and laser trap and the photons of another laser ionize the atoms to form the plasma. This artwork is inspired by atoms captured in such laser beam experiments, and by the resulting distribution of electrons within the cooled ionized particle cloud (or neutrally charged plasma).
>
> **Alternative caption:** Let me try and be precise: I feel nothing when I look at this image. Not the absence of feeling but the feeling of nothing. To feel nothing is still to feel, but to feel what? To feel the inadequacy of feeling itself when confronted by an order outside of its own: outside of the empathic, the emotive, the communicative—outside of the human. It is not the darkness that threatens (a ridiculous cliché), nor the colour, which in its dubious aestheticism merely adds to the anxiety; no, it is the dull, dead neutrality of untraceable trajectories that leaves me feeling lost.

b) *Neutrino Trails* (figure 3.34)

> **Scientific caption:** Neutrinos are mysterious sub-atomic particles with no electric charge and almost negligible mass. They come in three types or 'flavours', rarely interact with other matter and race through the cosmos at nearly the speed of light. Only a few of the billions of neutrinos constantly passing through every point on Earth leave their mark in huge detector experiments. This artwork refers to a neutrino interacting with an atomic nucleus in which an electron is ejected. The charged electron speeds away, emitting cones of light which tell of the neutrino's energy, direction and flavour.
>
> **Alternative caption:** Let me try and be accurate: at the heart of the sphere of accuracies lies revelation, but not of the truth, only of the blinding light of accuracy itself. Every line in this image, so finely

figured, every point so purposive in its position, explodes from a shimmering absence that is utterly cold—arctic articulation. It is not the light that dazzles (a ridiculous cliché), nor the colour, which in its fragile ephemeracy only adds to the blindness; no, it is the cold, callous neutrality of an ever-expanding pointlessness that leaves me shivering.

c) *Neutron Stars Coalescing* (figure 3.35)

Scientific caption: Artwork inspired by density and temperature distributions as two neutron stars coalesce. A neutron star is born in an explosion when a large star, 10-30 times the size of our Sun, uses up its nuclear fuel and shatters in a spectacular supernova event. Much matter is expelled as the outer gases disperse and floods of neutrinos are emitted. Under intense gravitational pressure some of the remaining matter collapses into neutrons to form the core of a new neutron star. Rare pairs of neutron stars orbit each other in ever decreasing spirals as they radiate away energy as gravitational waves.

Alternative caption: Let me speak the truth: the zone of truth is a lie, all we have is accuracy. When I look at this image I see a grid and then I see a hurricane blowing out of the bowels of Hell. The grid is this Hell: the Hell of accuracy itself. It is not the grid that controls and structures the hurricane (a ridiculous cliché), nor does the colour, in its saturating intensity, sweep away the forces of order; no, they both together entice me so willingly into the sphere of accuracies where the neutral remains as that which allows everything but itself to burn. Leaving me…? No, the neutral never leaves me.

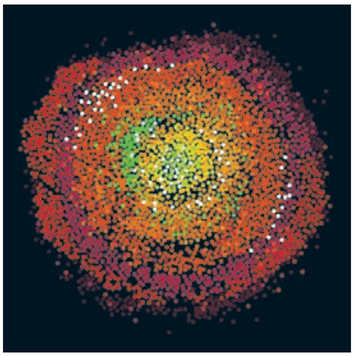


Figure 3.33: *Ultracold Neutral Plasma* (2009).

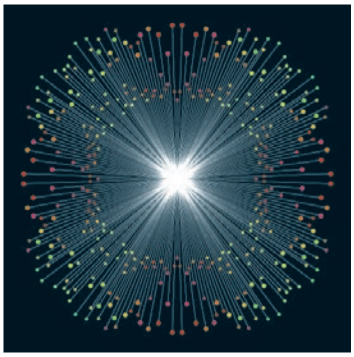


Figure 3.34: *Neutrino Trails* (2009).

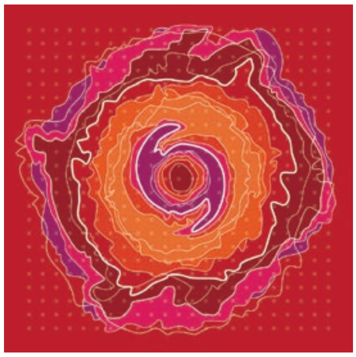


Figure 3.35: *Neutron Stars Coalescing* (2009).

3 | 5 | 3 Visual essay published in the journal *Parallax*

A subsequent project, again working with Professor Peters, took place with the visual essay 'The physics of positivity: visual affirmations' on the theme of affirmation, published in the academic journal *Parallax*.[39] We discussed the possibility of a shift from a descriptive wording to a freer exploration of emotion and interpretation in the reception of the artwork. The captions were written in two stages: first the accuracy of the scientific background provided an initial draft, composed with expert advice from scientists; then, the wording was transformed and manipulated beyond the initial technical explanation, adopting a different rhetorical voice that breaks away from science itself, toward art and philosophy. The captions were rephrased and refined, through several stages between

39 Swist, F., 'The physics of positivity: visual affirmations' in *Parallax* vol.16, no. 56 (September 2010), pp. 55-59. A reproduction of the published article is available in appendix 3.4, pp. 175-180.

Peters and myself. Pages from the published article are presented in appendix 3.4, pp. 175-180; the captions accompanying the images, from left to right, are:

a) *Good Vibrations* (front cover image, see figure A3.13, p. 175)

Good Vibrations refers to a system of a perfectly spherical and symmetrical grid to construct individual (but intertwined) sub-systems resonating and oscillating among one another. In this study, effects of resonance are associated with the concept of systematic arrangement which, as affect, takes on positive value as a visual rhythm intended to be experienced and 'felt' as a resonance that transcends the binarity normally associated with oscillation. The intention is to image an emergent affirmative rhythm that pulses independently of its positive/negative oscillatory source.

b) *Particle Remnants* (figure 3.36)

Particle Remnants references grid systems and dislocated geometrical forms as often seen in imagery produced by complex mathematics and computing methods in particle physics. Although substantially transformed, its underlying source is located in the study of elementary particles and the head-on visualisation of collision events. The visual aftermath of such barely visible impactions are sub-atomic remnants figured positively here as charged linear traces. Of particular interest is the manner in which the physical dialectic of obliteration and creation produces, through a double negation, positively charged particles (positrons). A confirmation of Hegel's speculative production of the positive from the negative– the negation of the negation.

c) *Positive Temporal Expansion* (figure 3.37)

Positive Temporal expansion is an attempt to think and configure positivity as an expansive spatio-temporal moment. It does this through the combination of elements drawn from graphs and diagrams studying the relation between the dimensions of the time and space continuum. Here positivity is rendered aesthetically as an expansive dynamic where temporal momentum and acceleration are mapped onto a delimited grid that, through the effect of framing, is intended to express containment while simultaneously affirming its overcoming.

d) *Positive Ionisation* (figure 3.38)

Positive Ionisation uses a grid to capture the concept of atomic structures losing particles that have 'freed themselves' from their original bounds, leading to an imbalance of electric charge (or ionisation). Here the concept of positivity is challenged by a positive 'freedom' that is rooted in imbalance and excess: a freedom-to rather than a freedom-from that has long been the goal (or dream) of "autonomous art practice".

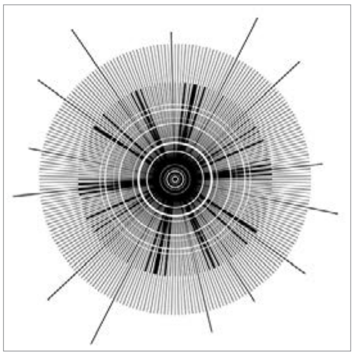


Figure 3.36: *Particle Remnants.*

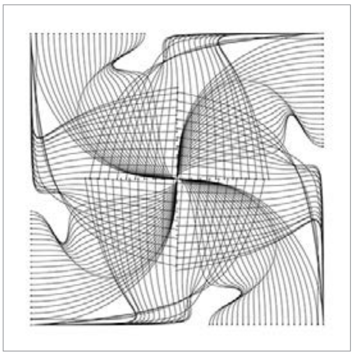


Figure 3.37: *Positive Temporal Expansion.*

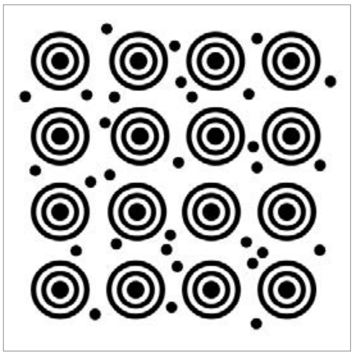


Figure 3.38: *Positive Ionisation.*

3 | 6 Conclusion

This chapter has introduced my art practice, its contextual surroundings, various strands, influences and visual traditions, and has offered significant insights into the creative process. A particular relationship with science has been revealed and important dichotomies have been identified: the evolution from design to art; the complex negotiation between form and colour; tensions and a shift of priorities between content and visual; and a duality of concerns between the production and reception of the artwork. This chapter has demonstrated the highly individual nature of the work, and articulated a rigorous underlying method for the production of art. In turn, this will serve in the next chapter to argue for this practice as artistic research, and to confront its unique strands against the landscape of more established dialogues and practices engaged with science, as seen in chapter 2.

Chapter 4 | proposition

CHAPTER CONTENT

4 | 1 Basis of evidence for the proposition

Now that both a survey of the field (chapter 2) and a dissection of my art practice (chapter 3) have been conducted, the findings from each chapter can be deployed as the practice is revisited and challenged against key relevant concepts, and used to define its contextual position. In turn, this strategy contributes to articulating an emerging proposition, and provides evidence for my claims as to the distinctive nature of the work and its engagement with science.

4 | 1 | 1 Summary of key concepts

Having investigated a wide range of image concepts in both art and science, I have identified how my art practice demonstrates affinities with other visual modes and artistic expressions. Starting with past models in the production of scientific imagery (i.e. based on images as *evidence*, *truth-to-nature*, *mechanical objectivity* and *analytical description*),[1] to some extent, these notions can be transposed and tested against my practice. Here, the artwork relates to the realm of an already well-established domain of images, sharing concerns with an aesthetic that does not compromise the communicative values of the underlying science inherent in the image, but supports and conveys these values – a strategy reminiscent of mechanisms found in past models of visual investigation. This commonality is particularly true in the early period of the practice, as highlighted in chapter 3, p. 79, or in an interview by Gabrielle Stackpool where she captures early concerns and motivations in my own attempt to define the nature of the work.[2]

However, my art practice conveys stronger connections with some of the image mechanisms identified in the study of present models of image production. Several sub-levels from the survey are of special interest, in particular those located in the sphere of professional science. First, referring to the concept of *trained judgement*,[3] I have established in chapter 3, pp. 94-105, how the underlying creative process takes place: the initial interaction with the source material, the lengthy process of visual exploration, and the extensive colour research – all resulting in a highly constructed aesthetics (a rationalisation of forms, systems, and modules). This trajectory leads to a new artwork being created, but still retaining (to various degrees) remnants of its source. In this scenario, trained judgement is argued to be a skill, inherent to the artist, that has been developed during the

1 See chapter 2, pp. 32-36.

2 See appendix 4.4, pp. 197-199.

3 As elaborated by Elkins and Galison, see chapter 2, p. 40.

creative process. In other words, I have devised a particular way of seeing, engaging with existing domains of visuality, and formulating a *new* one, that is driven by what has been identified as an "intuitive affinity", i.e. a personal mode of interaction with the reference source. The concept of trained judgement has therefore been identified as an active component in the production of art. However, returning to Elkins and Galison's original definition (i.e. a skill developed by the professional viewer/scientist in combining specialist training and experience so as to be able to interpret accurately specialist imagery), trained judgement can be absent in the eye of the lay audience, specifically if he or she is to interpret the artwork as intended by the artist. This is because the audience is not considered as a trained observer, in the narrow sense given by Elkins and Galison. Instead it is taking on the role of a cultural commentator and interpreter, as he or she introduces new references in decoding the work of art. Having said this, evidence has also shown how a particular section of the audience – scientists – have demonstrated remarkable insights into their understanding of the creative process and the move from hard science to the presentation of art. This aspect was discussed in chapter 3 (pp. 82-84), and is illustrated throughout volume two.

As my practice develops and the creative journey expands, new concerns focus on the exploration of more abstract notions, and less on the visual representation of meaning. A fine balance dealing with retaining the accuracy of the underlying science persists as a concern in the creation of artworks, but gradually less so, as another (more refined) form of engagement with the reference material takes over. Here, the notion of image as *abstraction* relates to such concepts found in scientific imagery: parallels are identifiable between the artwork dealing with a grasp/apprehension of the science, and specialist scientific imagery produced at the threshold of the limits of representation, leaning towards visual abstractions, and often requiring alternative ways to see, read, understand or interpret.[4] This resonates with Elkins' concept of the *unpicturable*, which I borrowed and extended, to become the *un-image-able*.[5] In its current, more mature period, my practice focuses on issues to do with visuality itself, as opposed to the expression of meaning through the visual. Led by the creative process, I have developed an alternative engagement with my source material, hence, moving on from Elkins' notion towards an extended concept of imaging, as expressed in the practice and deployed by its underlying method.

4 See volume two; chapter 2, pp. 37-45; and my review of *Six Stories*, in appendix 3.1, pp. 159-161.

5 See deconstruction of the thesis title in chapter 1, pp. 15-16.

Turning to another image concept uncovered by the survey, my practice can be argued to have a dual aspect: the artwork is both *propositional* (especially relevant to its early period, where the imagery retains a stronger link with its source), and *expressive* (relating to other influences and visual traditions, as seen in chapter 3, p. 86). Importantly, the notion of proposition arises because the artwork offers an alternative viewing or take on a scientific notion that inherently is not susceptible to be seen or imaged. Here, I argue that through its highly individual engagement with science and its method of visual reconstruction, my practice triggers its own *propositional* view of its reference source, where the visual/aesthetics takes over from the underlying meaning. The propositional quality of the artwork is transposed from proposing meaning through the visual (as seen with Elkins), to become a proposition for a particular visuality. This shows a move from the representation (or propositional logic) of science, to the presentation of art (an alternative visual response, or a propositional aesthetics).

In shifting from the idea of an image as a depiction/representation towards an image that becomes a part of manipulating visuality itself, the concept of *process* given by Galison[6] can be paralleled to mechanisms of visual construction in the practice. This is where the image becomes more active in taking on a new function (it contributes to making, producing, revealing or manipulating *within* the visual), extending from its previous role, which was limited to recording evidence. Here, the seeing and making are intertwined to become one activity: the image is at work in constructing "matter" (science), or aesthetics (art). In my practice, the notion of process is embodied in a combination of tacit knowledge, intuition and experience in dealing with such a form of visual construction.

Other concepts – found in the realm of art rather than science – are also of special interest: more precisely, the notions of *rationale*, *method*, *system*, *module*, in reference to two key practices in modern art – those of Lohse and Vasarely – where strong affinities have been made explicit with my own artistic research. These concepts can be understood in the practice as the construction of imagery led by a rigorous method, procedure or rationale. Visual mechanisms such as system, module, sequence, pattern, repetition are all present and contribute to a unified visual cohesion in the work. The image here again refers to a specific mode of construction: it is characterised by an approach for the deployment of its

6 See chapter 2, pp. 50-52.

visual qualities, which can ultimately be understood as a form of *constructed aesthetics*.[7] In turn, this has led to the formation of a personal artistic style – resonating and cascading from what Lohse and Vasarely pioneered – but which is also taken further. My own approach extends from theirs through the contribution of tacit knowledge, experience acquired in my design practice, and trained judgement developed over the years. Moreover, it is coupled with my chosen medium of production, also contributing to achieving precision and accuracy in my exploration of form-colour relationships, as well as dictating its particular aesthetics.[8]

Not limited to encapsulating the above concepts in addressing the question of visuality, my art practice also emerges from a rich landscape of visual traditions. Through a process of dissection, I have established how the creation of artworks materialises from a large sphere of references and familiar models of visuality that gradually feed and enable the work to develop. More specifically, I deconstructed the practice in chapter 3, identifying its various strands, and revealing its background, internal motivations and references.[9] I revisited its origins, situated in its counterpart, my design profession, again opening a wide spectrum of influences feeding into the formation of the artwork. Having explored and discussed this at length, in turn this enables me to argue for my practice to be both considered as highly distinctive, yet embedded in a complex environment where influences are made explicit. These characteristics also emerge out of the practice's particular engagement with its source of inspiration (science). This is explained both in chapter 3, pp. 98-102 and throughout volume two, where I detailed the mechanisms of interaction between my reference material and its creative response as artwork.

4 | 1 | 2 Situating my art practice

Attempting to situate my practice in relation to its broader related field of enquiry is a complex issue because – as seen above – the work draws from a number of (sometimes unrelated) concepts, without suggesting any potential location or positioning. In order to clarify the context, it also involves tackling the domain of Art and Science.[10] However, as I suggested in the introduction (pp. 16-21), such a field forms only a part of a larger and

7 See chapter 3, p. 86.

8 Ibid., pp. 103-105.

9 Ibid., p. 86, figure 3.6.

10 A more detailed account serving as additional background to the research in provided in appendix 2, pp. 154-158, where I attempt at defining Art and Science as a broad field of enquiry and practices.

more complicated environment. In this section, I briefly revisit key areas from the research, and adopt a process of elimination, indicating where my practice contrasts with others – a trajectory which then leads to clarifying its contextual position.

From the outset, it was made clear that it is not situated in the realm of scientific visuality, although it borrows a range of image concepts and mechanisms that contribute to defining the very nature of its engagement with scientific visual modes (as summarised in the previous section). My practice also differs significantly from the sub-domain of images discussed in the section "science-making-art" (pp. 52-56), as it does not seek to communicate, illustrate, or explain science through visuality. As exemplified by figures 2.19-2.21 (p. 53), I have established how these images present limitations for their consideration as artwork, and therefore share very little with my practice. Because discourse addressing this genre is often charged with what I call "surface" issues in the dialogues between Art and Science, this leads to the wider issue of (re)considering a suitable definition for what the term "Art and Science" might encapsulate in relation to the present research.

At first consideration, it could be described as a broad and diverse domain of enquiry (with its dedicated literature, audience and programmes), but one that is also characterised as fragmented, not yet described precisely by scholars. Surveys on Art and Science practices often capture only partly what I have identified as a potentially larger and much more complex field, as suggested by this research. In exploring this area, with the aim at situating my own engagement with science as a practitioner in relation to it, I have encountered challenges in identifying shared concerns and commonalities. I have often found that discourses seem restricted to these "surface" and "formal" connections rather than deep-seated interactions between each field. In other words, commentators seem to be concentrating (and limiting themselves) to obvious areas of commonalities such as the basic notions of creativity, or an already saturated line of investigation of historical parallels between artistic creations and scientific discoveries.

As stated in chapter 2, Elkins criticises the strong misunderstandings between science and art in their respective approach to aesthetics. I discussed on pp. 52-56 how an artificially aestheticised scientific image is not sufficient to be presented as what Elkins calls "serious art", that is to say, in the context of art criticism, gallery and art institution. As a possible consequence of this, the scientific community creates its own narrower platform, promoting an "Art of Science" (or an aestheticised science), which engages with its own targeted audience (opening science to a wider public), but also remains excluded from the authoritative voices in art theory, history and critique.

Turning to image domains explored in contemporary art, the research shows how my work does not easily identify with other practitioners engaged with science. Although some similarities have been discussed between a range of concepts and my art practice (pp. 112-115), they do not provide sufficiently robust evidence to draw strong connections and build a shared domain of artistic visuality. More specifically, my practice operates differently from those discussed in the survey (i.e. with artists such as Walker, Duigenam and Tyson). This is because it focuses exclusively on visual concerns in its interaction with science and the construction of its own form of visuality, as opposed to drawing on metaphors and narratives.

However, this aspect is not restricted to my own practice: the survey also suggests how peer practitioners encounter a distance from others engaged with scientific themes,[11] as well as a disconnection with the domain of Art and Science. Existing work does not acknowledge sufficiently the ways in which contemporary artists can engage more deeply with scientific themes. Generally with a motivation exclusively centred on the production and presentation of art, they do not consider themselves as participants in the current dialogues in Art and Science. This has been demonstrated for instance in the discussion of Naglaa Walker (chapter 2, p. 70), where it was argued that she elaborates a very sophisticated personal engagement with scientific concepts/fragments, but deployed exclusively as artistic expression, deliberately resisting what has been seen in other fields as more explicit and less refined art-science associations. Others, such as Keith Tyson and Gilles Barbier, appropriate scientific references in oblique and playful ways, elaborating their own artistic response – which ultimately is not *about* science, nor about portraying or communicating science.

In contrast to what can be seen as "weak" connections with other contemporary practitioners, it is through exploring selected artists in modern art that more meaningful

11 For instance, Walker's engagement with scientific notions has been argued as much more robust compared to Tyson's, whose infatuation with science takes place through the filter of popular culture rather than technical material. See chapter 2, p. 71.

affinities have been identified with my own work. Here again, these connections are located precisely at the core of artistic concerns, and have been explicitely acknowledged as strong influences in my work. Artists such as Lohse, Vasarely and the G.R.A.V. movement (to a lesser extent) have been studied in their relation to the relevant science (mainly optics and kinetics) by art historians and critics, as part of the wider context of 1960s Optical and Kinetic art. However, this line of critical discourse has been discontinued in current dialogues in Art and Science where these practitioners have not been positioned by scholars as participants or contributors in terms of the legacy of their particular (and pioneering) role in engaging with science.

Ultimately, my art practice contributes to questioning – through the concept of visuality – the relationship between art and science, and to challenging the limitations or inadequacies in the dominant dialogues between the two fields. More specifically, as the research demonstrated, a distinction between professional and popular science is necessary (an area rarely tackled in scholarly discourse). My practice, engaging at first hand with specialist material, offers insights into what is otherwise a closed domain as this image genre rarely transfers to the realm of visual culture in its raw, unmediated format. Professional science is overwhelmingly complex and often impenetrable to non-specialists in other fields and to the layperson. In visual terms, this has opened an opportunity, through my own interaction with such specialist content, to deploy an alternative viewing in engaging with the source. This is manifested through the construction of a highly distinctive form of visuality, which serves to challenge and reconsider afresh the relationship between art and science. In this instance, the engagement with scientific concepts is deeper and more sophisticated; it also serves to produce and present an art form on its own terms and own domain of visuality, rather than be limited to explain/communicate such scientific notions, or to present an aestheticed science. Consequently, my practice testifies to a deeper, more complex engagement or interaction with its reference source, that takes place through the transformation, and reconstruction of scientific remnants to produce art, using the visual for its mediation.

In conclusion, through the course of conducting the research, little evidence or indication have been found to demonstrate any significant affinities or connections with peer practitioners, or to identify the sharing of common concerns and motivations with other domains and practices. The research has also been confronted with issues related to the dominant dialogues in Art and Science, suggesting a fragmented field of enquiry which does not always engage with the deeper questions addressed by my own practice or by other practitioners offering alternative ways to interact with science. Far from enabling me to situate the work in relation to its wider context, these findings have instead reinforced the notion of uniqueness and isolation (already intrinsic to the practice). The research has shown how it is embedded and exists within a complex environment. However, despite this immersion, it remains excluded from the dominant perspectives in Art and Science, and outside other domains of visual practices, as it does not fully identify with them. This has been, and remains, a challenging issue to address. As a practitioner situated at first hand within direct contact with science, and equally positioned outside both the closed domain of scientific production and of other artistic practices, my willingness to contribute to the field led me to define my position as an *informed outsider*, participating and challenging its broader context, through what is argued in this study as a distinctive art form, its accompanying questions and concerns as a practitioner, and consequently its particular position *outside* its related domains of visuality.

4 | 2 Three-fold proposition: method-practice-discourse

Following from the above analysis, I now turn to articulating a three-fold proposition. This proposition has gradually emerged and evolved out of conducting the research, and now serves to define the contribution to knowledge.

4 | 2 | 1 Method

The research has articulated the deployment of an underlying method driving the production of art, and demonstrated it as integral to my practice. Unlike other research- or method-driven art practices,[12] in this instance the method is explicit: it forms a fundamental component in the creation of artworks. What distinguishes my practice from others driven by a method is that my own approach is more rigorous as it encapsulates a stronger degree of procedural and systematic principles; themselves translated into rules and parameters, consequently making the overall method especially responsive to dissemination. The method is considered as highly active, as it drives the creative process – again, in contrast to other approaches. In this scenario, the method is not left undefined, leading to "something being created".[13] It actively belongs and contributes to the work of

12 Boomgaard, J., 'The Chimera of Method' in Wesseling, *See it Again, Say it Again*, pp. 60-61.

13 Ibid., p. 61.

art, and is fully transparent and receptive to the scrutiny of its underlying processes.

The notion of research is embodied in such a method, thus arguing for my practice to be considered as artistic research in its most quantifiable sense; in response to what is considered as research here goes further than other claims that art is often linked to a degree of methodological thinking (implying a notion of research). Scholars such as Janneke Wesseling and Jeroen Boomgaard have argued that for artistic research to be considered as such in the context of academia, "more is needed".[14] In this instance, the "more" can be understood as being manifested in the practice through its inherent, transparent and explicit research process – *the method*. This establishes the practice as particularly receptive to a rigorous process of critical investigation. In this context, the notion of research inhabits two systems: firstly, at the core of the production of art (practice); secondly, as the practice opens itself to a critical investigation of its own discipline (theory).

4 | 2 | 2 Practice

My art practice emerges from the method, but has also been argued as distinctive while being embedded in visual traditions and explicit influences. This duality may not necessarily be in tension, but complementary, thus enabling a body of work to emerge from known surroundings and still express a degree of uniqueness in its artistic style. Moreover, the practice also raises the important question of knowledge: as artistic research, does it generate knowledge, and if so, what kind? Defining knowledge in art is a complex problem that has fuelled wide debate, especially since the academic requirement for artists undertaking doctoral research demands the art component produce knowledge. The way I would define or locate where and what kind of knowledge the production of artworks generates may be presented as follows: the practice offers an alternative way of interacting with its source, experiencing notions beyond my knowledge or understanding at an expert level, instead focusing on the grasp or apprehension (here meant as a "direct experiencing") of scientific notions. This triggers the creative process, and enables me to engage in a journey of transformation between one domain of visuality (science) toward another (art), developing my own aesthetics – in other words devising or revealing through the creative process my own form of visuality, and offering an alternative sensory

14 Ibid., p. 62.

experience to the viewer. Here "the materialisation of thinking"[15] expressed in the work of art refers to how the creative act (the reasoning) is partly achieved through the mechanism of knowledge (combination of tacit, intuitive and constructed knowledge), itself determined by the underlying method of the practice.

4|2|3 Discourse

The research has laid the foundation for a "detached" discourse emerging out of dissecting my practice. Taking the position of the reflective practitioner, the issue of positioning it within its wider related landscape remains an ongoing concern. This is addressed through opening a site for discourse, resisting and challenging the dominant dialogues in Art and Science. Such a discourse is instead focused on a narrower, well-defined line of concerns, as it explores and scrutinises my art practice on its own terms: the core concerns are located precisely in the questioning of the intrinsic nature of transformation between one domain (science) and another (art), using visuality as a vehicle for such a move. This position contributes to its broader related field in the sense that it introduces an alternative line of questioning (and creative response), where the practice bring forwards new concerns – hence opening a site for discourse. This *new*, or alternative, discourse invites the reconsideration of the intrinsic nature of visuality, to be explored from *within*, that is to say, in relation to its primary domain of production, purpose and audience before deploying familiar models of interpretation. Such a discourse also invites the practitioner to open his or her site of production, to express and articulate its creative journey, concerns and intentions, so as to re-address the balance between the viewer's interpretation and the original artistic intentions.

Chapter 2 (pp. 52-56) has identified some limitations in the loosely defined domain of Art and Science, where (aligning with Elkins' argument) art and science do not share similar understanding especially in relation to questions of aesthetics. An argument has also been made, calling for a clearer distinction between different "types" of science (professional versus popular) – an aspect that has often been overlooked in the relevant surveys and literature. In art, different engagements with science offer a rich but fragmented site for creative practices, which generally do not share a similar approach to mine; some have demonstrable affinities, but I argue that they do not go far enough, compared to my own position, situated at "first hand" in interacting with my source

15 Wesseling, *See it Again, Say it Again*, pp. 11.

of reference. These provide evidence for my argument to consider my practice in a highly suitable position from which to question the dominant views through opening an alternative path for discourse and by creating opportunities for new perspectives to emerge from the existing body of knowledge and understanding of the field.

4 | 3 Summary

To summarise, the proposed configuration *method-practice-discourse* can be understood as the embodiment of: a) A method for the production of art, testifying for my practice as artistic research, both intrinsically and in relation to the academic requirement. b) An art practice that emerges from the method, as it navigates between art and science, experiencing, transforming and reconstructing notions and fragments from one domain (science) through another (art), deploying its own visuality as a vehicle for such mediation. c) Opening a site for discourse, where dominant views are challenged as a series of dichotomies emerges: the focus is given in the production rather than the reception of art; my practice situates itself as an informed outsider in relation to its contextual framework, while charged with references to established visual traditions. Finally, my practice devises its own visual domain and detached voice in participating in and questioning the dialogues between Art and Science, hence opening a site for discourse that is transferable to other practices engaged with science.

Chapter 5 | conclusion

CHAPTER CONTENT

5 | 1 Summary of the investigation and outcome

In conducting this research, my aim was to embark on an in-depth investigation of my own artistic practice and to explore its theoretical dimensions as a vehicle to interrogate the concept of *visuality*, both in scientific and artistic domains of images – a theme situated at its core. This line of concern has been channelled to become the central question driving the investigation. The research asked: How can meaning be translated, transformed, and transfigured between one domain (science) and another (art), using the visual as its mode of mediation?

To address this, the research first undertook the challenge of defining a suitable methodological strategy and chronology for the investigation. As stated in the introduction on p. 22, the methodologies have been left to emerge gradually out of the research. Although early on in the study I briefly considered adopting theoretical models available from other established disciplines (such as the Postmodernist outlook on science for instance), it became clear that such models did not offer the flexibility and neutrality that I felt were necessary to address the questions I set out to explore. Turning to literature on practice-based research, I then found affinities with other reflective practitioners, who adopted a more personal approach to investigating the individual nature of their practice, often leaving the methodologies to be formulated directly out of the specificity of the art component of their research.[1] Taking a similar position, the present enquiry adopted the following trajectory: a) to establish the context for the research (chapter 2); b) to present and dissect my art practice (chapter 3 and volume two); and c) to revisit the findings from chapter 2 and 3 in turn to formulate a proposition (chapter 4). This chronology and its related mechanisms of investigation have been shaped and deployed in this way, to enable the articulation of the following outcomes.

Firstly, the research established a broad contextual landscape for the art practice, filtering and narrowing down relevant sub-themes from other areas seen as peripheral, devising a configuration of two domains – scientific and artistic visuality – and identifying a range of concepts in their respective sub-levels of image genres. This was achieved in chapter 2, through conducting a literature survey (the data collection was subjected to a broad classification and analysis), in order to explore the construction and interpretation of meaning in visual form, and to consider how it is produced, deployed and understood in

1 Wesseling, *See it Again, Say it Again.*

various contexts and audiences. Investigating some of the most influential scholarly work on the subject (such as Elkins, Daston, Galison, Kemp and Ede), I extracted key concepts and devised my own working taxonomy of images.

In the second part of chapter 2, this strategy turned to investigating how artists developed other ways to interact with scientific concepts to produce and present art, such as Lohse and Vasarely in modern art, and Walker and Kalkhof in contemporary art. Here, the research focussed on a narrower selection of material, chosen for their particular relevance (deployed in chapter 4 to challenge the practice), as opposed to conducting an exhaustive survey of the field which, after an initial consideration, was deemed too broad for the scope of the thesis. For example, artists engaged with scientific themes on a conceptual rather than a visual level, or practitioners interested in science and technology as a medium as opposed to subject matter, are two approaches bearing little relevance to the present research's concerns.

In terms of theoretical underpinning, this approach has provided the most appropriate setting from which to extract a number of concepts from my own taxonomy of image genres, and subsequently to challenge (or relate) other visual modes embodied in the art practice. The rationale behind this methodological strategy was to approach a study of images to be investigated in neutral terms. This means that the focus is on their primary environment of production, usage and reception, as opposed to their study through established theories and models of image critique/analysis as found in visual studies, which is often dictated by their interpretation through cultural references and multiple readings, mechanisms regarded as unsuited to this context.

Secondly, the research set out to examine my art practice's particular engagement with science (and physics as its principal reference source), and to articulate what makes it distinctive in relation to its complex surroundings. This aspect was addressed in chapter 3, where I dissected its various dimensions and investigated the move from its design counterpart. The study demonstrated how working as a graphic designer in an academic science environment presents challenges in developing a suitable visual response in terms of branding communication to highly specialist content that is not inherently visual in its nature. This challenge also offered opportunities to develop what has become a distinctive branding identity for the organisation, toward the further exploration of the creative process to produce a body of work. This initially extended from my design practice, then gradually became an art practice in its own right. Here, the investigation was driven by a more exploratory approach, adopting the position of the reflective practitioner. The process of dissecting my own art practice (both in chapter 3 and in volume two), has enabled me to reveal insights into the creative process, and investigate the dichotomy between the production and reception of artwork, with emphasis on the former. This strategy also led me to identify and articulate more clearly exactly what makes the practice highly distinctive, a) in relation to its own engagement with science (its immediate context), and b) in reference to the production of a particular (yet reference-embedded) form of aesthetics as expressed in the artwork and its underlying method.

Thirdly, in articulating the creative process and its wider theoretical dimension (here in reference to the image concepts identified in chapter 3, then transposed to define my art practice, as seen in chapter 4, pp. 112-115), the research argued for and demonstrated, the practice as *artistic research*. Not only is it driven by a rigorous underlying method for the construction of artworks, it also testifies to strong notions of research embedded in its internal logic and motivation. This has led to the conclusion that my practice is particularly apt to rigorous intellectual scrutiny and to dissemination. Moreover, in revealing its internal rationale, it provides a model for an alternative engagement with science through art.

Through the practice demonstrated as artistic research, the enquiry aimed to engage with the current dominant dialogues in Art and Science. This has been conducted by an exploratory and a more speculative analysis, deploying the findings from previous chapters, and channelling them to formulate a three-fold proposition or hypothesis – a *method-practice-discourse*, as discussed in chapter 4:

- A method that demonstrates my practice as research.
- A practice that emerges from the method.
- A discourse that articulates the practice and its underlying method, and opens a site for an alternative engagement with science.

Here, the methodological approach involved the distilling of the findings to construct a suitable landscape of key concepts in relation to my practice, to reach a more sophisticated understanding of its traditions and influences, as well as its motivations and creative processes. Chapter 4 also tackled the question of situating it within the broader landscape established by the research. This was addressed by identifying an issue of location, where the reflective practitioner is positioned as an informed outsider participating in the field by opening a site for discourse and offering an alternative perspective. Exploring and distinguishing both the immediate context and the wider cultural surroundings to my practice, the research concluded that the reflective practitioner is positioned at a distance, engaging in the current dialogues in Art and Science, outside the identified spheres of discourse and practices defining such a field, but with a first-hand access to specialist scientific material, that is not otherwise easily available to a broader audience. Ultimately, chapter 4 proposes that my practice be situated outside, or *between* science and art, as suggested in the thesis title and discussed in chapter 1 (pp. 15-16).

5 | 2 Contribution to knowledge

In contrast to more established disciplines, here the particularly dynamic nature of the practice-based format has opened opportunities for a more organic, explorative form of investigation, which situates the contribution to knowledge in different areas. More specifically, the contribution is expressed on both a visual and textual level; in other words, my practice is positioned centrally to the investigation, but the artwork also informs the research through its own visual contribution. The text-based component serves to explore, dissect, analyse and enlighten the practice, and through the process of self-reflection, clarifies its nature, role, purpose, and motivations. The text also feeds back and influences the creative process by increasing awareness of its broader related domain, and its key related concepts of visuality. Accordingly, both the visual and textual contributions are intertwined, as they feed and inform each other in a dynamic back-and-forward system of exploratory investigation.

Another dimension characterising how the research contributes to the field refers to the enquiry situating itself between theory and practice. The presentation and dissection of my art practice coupled with its contextualisation represent altogether the collection of data, from which a proposition crystallised. The proposition in itself emerges gradually out of the investigation, out of the production of art and its theoretical reflection, which can also be understood as the "intersection between theory and practice". In contrast to other long-established disciplines where the theoretical undertaking is often subsequent to and distanced from the topic under scrutiny, here the theory-practice dichotomy is seen as interactive with the shared objective to reveal insights and propose a hypothesis.

The contribution to knowledge can also be defined as a more distant meta-reflection on its subject of enquiry. The investigation identified an issue of location for my practice in relation to its broader related landscape; in response, the role of the reflective practitioner has been reformulated as an informed outsider, positioned at first hand in the context of scientific production, but left outside of the dominant dialogues in Art and Science. The research demonstrates how it is possible for the practice/practitioner to occupy a dual role, that is, to be equally embedded in its contextual surrounding, and at the same time to remain partly isolated, but still participating in the dominant dialogues, from its precise location *outside* such a domain. This has translated into adopting an alternative voice – a detached voice – not committing to a precise site of discourse, but located within a number of sites, models and practices. This position resonates with Wesseling's notion of "a distant meta-reflection"; the research is contributing to and advancing current engagements between both art and science, while at the same time opening an alternative perspective, through both the practice and its particular engagement with science, leading to a precise line of questioning – beyond current scholarly and practice-led investigations – or meta-reflection.

To summarise, it is through a visual and textual level, situated between theory and practice, and engaging in a more distant meta-reflection that the research indicates a new perspective to advance reflection of both its immediate discipline and its broader related field of enquiry. This distinctive position allows an opportunity to revisit afresh existing discourses on Art and Science. The practice offers a site for discourse: it is embedded within a larger domain from which it aims to participate and trigger new/alternative questions to those already addressing the relationship between creative activities in art and in science. Due to its distinctive nature, background and surroundings, the practice enables an alternative path to engage in an already established body of knowledge questioning scientific and artistic visuality as found both in past and current scholarly and practice-based investigations.

Hence, the practice and research combined, contribute to: articulating a particular engagement with its source, science; identifying its unique position both situated within a complex surrounding and isolated from it, leading to adopting the detached voice of the informed outsider in order to explore a line of questioning that opens a new site for discourse; in turn participating in an existing body of knowledge in the field; and ultimately, opening new directions for further investigation.

In terms of its impact, the research (which was initially driven by a personal motivation coupled with a desire to contribute to its broader field), has enabled me to reach a higher level of sophistication in my art practice and in the articulation of its intellectual underpinning. This has allowed the presentation of a body of work and its academic discourse as a particular model of engagement with science through art. Not only has the research enabled me to dissect the core of the creative process, it also represents a model for interpreting scientific visuality, or offering an alternative form of interaction with specialist scientific material.

As argued in chapter 3, the design and art practice are intricately connected (the latter emerging from the former); they are continually informing each other and contribute equally to the creative process. Through the rigour of academic research, the present enquiry has enabled me to scrutinise their wider contextual and theoretical dimensions, in turn constructing and reaching a stronger understanding of the relevant concepts, modalities and mechanisms of visuality in both science and art. It has allowed me to feed back into the creative process in my design practice for the organisation, resulting in a deeper understanding in the selection, manipulation and transformation of imagery for the purpose of visual communication and branding development. Such impact can be measured through the positive response and increased recognition that the organisation has received from its audience in recent years.[2] In relation to my art practice, with its artistic style developing into a more mature body of work, it has gained exposure through a number of exhibitions and publications.[3] It has generated interest from the scientific community (as documented in volume two), as well as produced a successful series of collaborations (featured in chapter 3, pp. 105-109).

5 | 3 Indicating new directions

The present research – although narrow and specific in its scope – has opened a wider spectrum of possible directions for further investigation. Two strands are discussed here: firstly, indicating potential new lines of enquiry for other scholars and practitioners to consider in relation to their own domains of study; and secondly, a series of new opportunities for the development of my own art practice.

2 See appendix 1, pp. 152-153.

3 See appendices 3 and 4, pp. 159-199.

5 | 3 | 1 Directions for further research

Although a number of surveys of artistic practices engaged with science have already been conducted by eminent scholars, such as Martin Kemp, Siân Ede and Stephen Wilson, this research has indicated that further investigation into deeper and more complex connections between Art and Science could be approached, through the exploration of contemporary practices that have shown a reluntance to be associated with the field, as exemplified by those of Naglaa Walker or Peter Kalkhof. To put this another way, an enquiry that would focus on practitioners who do not actively engage with, participate in, or position themselves within the domain of Art and Science.

In this research, my design practice has mainly served as a background, limited to introducing my art practice – it has not been part of the core themes driving the enquiry. Yet, further research could leave aside the art practice, and solely focus on the design component, which itself becomes a central area for an enquiry into the visual expression and communication of science. Although not well known outside their specialist field, design practitioners such as Will Burtin, Erwin Pœll, and the 1960s pharmaceutical company Geigy's, would contribute to questioning how science communicates in visual terms. This could be explored further, potentially opening out a rich visual sphere (very specific with its own visual vocabulary) and a domain that seems to be overlooked in scholarly discourse.

Although the present research has only touched on it, for an art-science debate to be addressed more fully, it would be necessary to revisit the famous two-culture divide, as identified by C. P. Snow in 1959. It has been said in various scholarly discourses that these questions have never been resolved mainly because the topic has lost interest for a subsequent generation of scholars in social sciences and the humanities. In hard science, very few scientists would have even heard of Snow's contribution. This offers opportunities to tackle this difficult area afresh, and bring a whole set of contemporary practices (in both art and in science) to participate and move the debate forwards, because Snow's divide arguably remains a core issue in the field.

As part of its claim for new knowledge, the research has argued its case through carefully positioning itself as an informed outsider, questioning the domain of Art and Science, and focusing on the artist's voice in exploring, dissecting and analysing my art practice. An interesting experiment would be to revisit the present enquiry, but this time constructing an argument for the practice to be positioned *within* the dialogues on Art and Science, with an emphasis on the moment of reception. That is to say, instead of a reluctance to invite the viewer to participate and engage with the work, the study would focus – through surveys, interviews and questionnaires – on reviewing and investigating the audience's reaction and the decoding / interpretation of the artwork. This would lay the foundation for the construction of an alternative domain of knowledge, and would constitute a parallel proposition to the present research.

5 | 3 | 2 Directions for my art practice

While the practice is continually developing, to the extent that it is now reaching a level of "saturation" in its current, deliberately narrow, site of exploration, it also opens a larger platform for further artistic research, where several possible directions are to be considered. Conscious decisions were made to define and retain a specific environment for the creative process to take place. For instance, focusing on two dimensions, both in terms of visuality and medium of production, was a choice motivated by the intention to "exhaust" all the possibilities within these parameters, before introducing new ones. After the process of extensive scrutiny of my practice in its current form, considerations for furthering the artistic production have identified the following areas of interest:

- **Sequence, narrative:** In exploring scientific material the notion of sequence is often recurring, where a scientific event/phenomenon is captured as a succession of frames or snapshots, to convey a form of evolution, transformation or motion through a chain of still images presented in chronological order. This concept has potential for developing or challenging my current approach to the form-colour relationship where, instead of framing a single concept/notion/phenomena into a highly constructed – and constrained – visual response, a series could be introduced, exploring the idea of motion, time and space through frames and sequences. In this way they could become more active components in the construction of the artwork, and leading such a construction towards the idea of a visual narrative. Here, the notion of sequence differs from my previous exploration of serial work,[4] which was restricted to the investigation of visual variations from a blueprint, as opposed to the construction of an evolving narrative.

4 Swist, *Science and the Visual*, pp. 22-23.

- **Pattern, repetition:** having developed a strong interest in the formal and structural qualities inherent in scientific graphs and diagrams, my own engagement with such material shows a deep resonance with imagery produced at the 1951 Festival of Britain. In this celebrated event although located in applied art and illustration, a similar interest with diagrams sourced in the scientific research of the time were appropriated and transformed to become patterns for textiles, wallpaper, interior design and three-dimensional displays at the Science Hall exhibition. Using the latest technology in digital imaging and printing, this approach could be replicated, deploying aspects of the practice, and adapting imagery to become patterns and graphics for such applications.

- **From two to three dimensions:** So far, my work has focused on constructing a form of visuality restricted to two dimensions, both in terms of imagery and medium. This intention has been dictated by the desire to explore all possibilities offered within this domain, investigating all potential combinations between form and colour within restricted parameters, before introducing new ones. Yet, the practice has always demonstrated the potential to develop into the realm of three-dimensional work, both in relation to its constructed visuality, and its medium of production. 3D printing would be a natural extension to further explore a new output medium; 3D software in the construction of imagery simulating three-dimensional space could also be a new area of investigation.

- **From colour to monochrome:** As seen earlier in this research, scientific imagery offers a rich visual vocabulary, with aesthetic qualities embodied in their forms, structures and textures, demonstrating significant potential as a source of inspiration for art – specifically *before* the dimension of colour is being introduced. Although colour is argued to be a fundamental aspect in my art practice, it has also been defined as a component of the method, as opposed to embodying the method in its entirety. At this stage in my practice, colour is beginning to show some limitations, in the sense that its exploration has now been extensively investigated, leaning towards a feeling of visual exhaustion and repetitiveness in the work. A new direction I wish to consider is to leave colour aside and focus on a series based exclusively on a scrutiny of formal, structural and compositional investigations, precisely located within the parameters of monochromatic tones. This would require reconsidering the current three-fold underlying method to my practice, and abandoning colour altogether in favour of further investigation exclusively into formal and structural visual concerns.

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In conclusion, the present research has enabled me to engage with complex questions on the very nature of visuality in both art and science, and to achieve a more sophisticated understanding of my art practice and its creative processes. It has enabled me to formulate a proposition that can now serve as a model for other researchers and practicioners concerned with related issues. Having completed the current study, both the theoretical investigation and the artistic work have indicated new directions, as discussed above, for further research to be undertaken.

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- Hoskins, S., (ed.) *Impact 6: Multidisciplinary Printmaking Conference Proceedings* (Bristol: Impact Press, 2011)
- *The Art-Science Divide: Myth or Reality?* (Project Dialogue, University of the West of England, Bristol, 26 Feb to 4 June 2010), series of seven extra-curricula postgraduate workshops.
- *The Artist under the Microscope: c. 1950 to the present day* (University of Durham, 14 November 2009)
- *Third International Conference on Preservation and Conservation Issues Related to Digital Printing and Digital Photography* (Institute of Physics and MATAR Research Centre of the University of the Arts London, April 2006)
- *Transdisciplinary Landscapes: Dialogues between Art and Science* (Project Dialogue/LAND2 Symposium, University of the West of England, Bristol, 3-4 November 2006)
- *State of Matter: Collisions and Connections in Art and Science* (University of the Arts London Central Saint Martins, 29 May 2013)
- *Visualising Science and Environment Symposium* (University of Brighton, 17-18 November 2011)

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- Peters, G. and Swist, F., 'Sphere of accuracies, zone of truth: art, science and neutrality' (York: York St John University, 2009), exhibition catalogue

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- Moosmann, C., 'Science + imagination' in *Novum* no. 1 (January 2008), pp. 50-51
- Pushkiskaya-10, *Sea-Level* (St Petersburg: Pushkiskaya-10, 2009), exhibition catalogue, pp. 72-73
- Reichert, S., (ed.) 'Artist profile: Frédérique Swist' in *Smartish Pace* no.19 (April 2012), p. 130
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List of exhibitions

- *Sphere of Accuracies/Zone of Truth*, group exhibition, Bar Lane Studios, York, 5 to 31 March 2011. Co-curated with Gary Peters
- *Picturing Science*, group exhibition, Riverside Gallery, Richmond, London, 4 December 2010 to 26 February 2011. Curated by Mark De Novellis
- *Ink-dot: Tonic*, group exhibition, Colston Hall, Glass Room, Bristol. 2 December 2010 to 2 January 2011. Fifth poster competition organised by Bristol collective Ink-dot
- *158th Autumn Exhibition*, Royal West of England Academy, Bristol, 24 October to 12 December 2010. Sculpture, painting, photography, printmaking and architecture selected by open submission
- *Ink-dot: Escape*, group exhibition, Howies, Bristol. 17 June to 11 July 2010. Fourth poster competition organised by Bristol collective Ink-dot
- *Sea-Level*, group exhibition, The Manege Central Exhibition Hall, St Petersburg, Russia, 24 October to 8 November 2009. International artists selected by open submission, in celebration of the 20th anniversary of the Art Centre Pushkinskaya-10

- *Morphogenesis*, group exhibition, View Art Gallery, Bristol, 30 September to 14 November 2009
- *7th Open Print Exhibition*, Royal West of England Academy, Bristol, 9 August to 19 September 2009. Contemporary printmaking selected by open submission
- *Science in Colour*, solo exhibition, At-Bristol, Bristol, 3 to 27 February 2008
- *Crossroads*, group exhibition, Mamü Gallery, Budapest, Hungary, 14 to 28 November 2008. Curated by Aranxta Escharte, University of the West of England. *Crossroads 2* was subsequently presented at UWE, Bower Ashton Campus, Bristol, 9 to 12 March 2009
- *Ink-dot: Spare Time*, group exhibition, Howies, Bristol, 27 November 2009. Third poster competition organised by Bristol collective Ink-dot
- *Symmetry, Harmony & Creativity*, group exhibition part of the Mind & Space seminar, Hedley Hall, Bath, 23 to 25 March 2007
- *6th Open Print Exhibition*, Royal West of England Academy, Bristol, 16 May to 12 June 2004. Contemporary printmaking selected by open submission

Commissions

- A series of limited edition prints acquired by IOP Publishing, Washington DC (2011)
- A limited edition print acquired by York St John University, York (2010)
- A series of limited edition prints acquired by Aston University, Birmingham (2009)
- A limited edition print acquired by Pushkinskaya-10 Art Centre, St Petersburg, Russia (2009)
- A series of five artworks commissioned for the Centre for Nanoscience and Quantum Information, University of Bristol; based on recent scientific research in the field of nanotechnology, project commissioned by the Department of Physics and funded by the South West Regional Development Agency (2008)
- A limited edition print commissioned by Jerry Cowhig, former Managing Director of IOP Publishing, presented to the Nobel Laureate Professor Zhores Alferov on the occasion of his 75th birthday (2005). The artwork is inspired by his Nobel Lecture 'The double heterostructure: concept and its applications in physics, electronics and technology', Stockholm University (2000)

Glossary of terms

Throughout the research, a number of terms have been introduced, often deployed in a narrow specific sense, thus delimiting what otherwise would be used more widely in other contexts. A clarification of key terms is provided below, also referring back to the various parts in the thesis where these notions are discussed with their intended meaning.

Aesthetics: the primary usage of the term generally relates to the visual qualities of an image, subject, object or entity, in relation to beauty or the appreciation of beauty. The term also refers to art history and theory, and a branch of philosophy (in particular with Immanuel Kant's *Critique of Judgement*, 1790). The present research carefully avoids philosophical discourse, as it restricts its investigation to the exploration of visual qualities, or what I also describe as "the visual substance" of an image. During the course of my analysis, I also extend the concept of aesthetics to a particular notion that I term a *production* aesthetics, or a *constructed* aesthetics (see definition p. 146).

Aestheticised science: refers to a type of scientific image, often artificially aestheticised through digital manipulation and colourisation in order to render it more visually striking. In chapter 2, pp. 52-56, I discuss how this image genre – generally produced by scientists – is also often presented as art.

Art and Science: (upper-case) the term has been adopted to designate in a broad sense a domain of practice where: a) artists and scientists collaborate; b) scientists manifest an interest in scientific imagery with aesthetic value, that can be presented as art; c) artists who have developed a fascination or infatuation with science, to produce art. The domain involves a wide spectrum of sub-activities and practices, from scholarly literature, conferences, exhibitions, grants, to public engagement initiatives. However, it is also fragmented, hence the term is used loosely, as opposed to defining an established discipline in its own right. While in the thesis I refer to Art and Science as a broad domain, I also attempt to define the field in appendix 2, pp. 154-158.

art and science: (lower-case) is also adopted in the text, here referring to each respective field – in distinction to the above.

***Between* physics and art:** the term is first deployed in the thesis title. It concerns the issue of positioning my own art practice and its particular engagement with physics in its related context. The word "between" implies an issue of location in relation to science as a domain of enquiry; physics as my practice's reference source; and art, both as the narrow space in which my practice exists, and as a wider domain of visual traditions in past and present practices engaged with science. The issue of situating my practice is significant, as it does not seem to fit with interests or concerns found in the dominant dialogues in Art and Science, that is to say the historical (or what I call *formal*) art-science connections as found in scholarly works such as those by Martin Kemp or Siân Ede, the movement Sci-Art, or ArtScience as defined by the MIT journal *Leonardo*.[1]

Digital Art: refers to art practices that use computing and digital technologies to produce artworks. The field comprises a wide array of sub-types, including algorithms, computer plotting, programming, image processing and so forth. This art form has its origins in the 1960s, with early experimental computing work, mainly led by scientists and mathematicians.[2] In August 1968 the first major international exhibition dedicated to Digital Art was held at the Institute of Contemporary Arts (ICA) in London. The exhibition, entitled *Cybernetic Serendipity*, introduced works involving robots, painting machines, plotters, cybernetics and early computer systems.[3] Developing alongside rapid technological advance, Digital Art has since grown into a well-established artistic genre, with its own aesthetics, and with new sub-genres constantly emerging (e.g. Net Art, Software Art, 3D, animation, virtual reality and gaming), where the artist-programmer is often positioned at the cutting edge of the latest technological possibilities.[4] Other practitioners, such as British artist Julian Opie, have embraced the medium in a slightly more restrictive form, using computer graphics to produce crisp, well-defined visuals, using thick lines and flat colours, a style unique to vector-based image processing.[5] Others, such as German artist Gerhard Mantz, use the hyper-realistic renditions that 3D software offers to construct large-scale, highly detailed fictional landscapes.[6] In the literature dedicated to Digital Art, Richard Paul Lohse and Victor Vasarely are not recognized as key

1 See glossary, p. 147-148, and appendix 2, pp. 154-158.
2 Lieser, W., *Digital Art* (Königswinter: Tandem Verlag, 2009), pp. 13-23.
3 The CompArt Database Digital Art (daDA), http://dada.compart-bremen.de/item/exhibition/3 [Accessed 11 July 2014].
4 Lieser, W., *Digital Art*.
5 Ibid., pp. 99-101 and p.108; http://www.julianopie.com [Accessed 11 July 2014].
6 Ibid., pp. 94-97.

figures; however I discuss in chapter 2, pp. 56-63, how some art historians have noted that they anticipated the principles subsequently realised in the processing of digital images, specifically with binary language (i.e. the underlying coding of a computed image), and the rasterisation process (i.e. the rendering of an image through pixels). In contrast, Vasarely's son, Yvaral, is specifically associated with the beginning of Digital Art in France (or *l'Art Numérique*), where he was particularly interested in the rendition of images in pixels, which he reproduced mechanically through a series of portraits during the 1980s.[7]

Image: a representation of a subject, object or entity in visual form. The definition for what constitutes an image has been extensively studied, among many other scholars, by James Elkins, who has been used as my principal reference in this research (chapter 1, p. 24). The study of image also relates to the academic disciplines of visual studies and visual culture (opening other concepts such as mental images and metaphors). These disciplines dissect images through various established theories, such as the gaze, simulacra, gender identity or feminist theories.[8] In contrast, the present enquiry is limited to concerns to do with the construction and reception of images (photographs, illustrations, data-generated images, artworks), with the exception of one instance in chapter 1, p. 21, where the word *image* refers to a general perception of science as a field of enquiry.

Imaging: taken from the thesis title, it refers to the core of the investigation – the study of images, image-making, imaging techniques, image production and image critique. The research explores the concept of visuality in relation to scientific imagery, science modes and methods for the visualisation of knowledge, and how artists interact with science with an emphasis on the visual rather than the conceptual.

Popular science: serves to describe a body of professionals (such as scientific journalists and commentators) whose task is to "translate" scientific knowledge produced by researchers, from its specialist technical language into a more accessible account, to address a broader audience of non-specialists (chapter 2, pp. 45-49).

Production aesthetics: the term has emerged from conducting the research, in response

7 http://www.yvaral.org [Accessed 11 July 2014].

8 Sturken and Cartwright, *Practices of Looking*.

to a scrutiny of my own art practice and its related issues of visual transformation and reconstruction of its reference material. A *production aesthetics* aims to describe a particular form of visuality – specific to my practice – but that is also rooted in other influences and visual traditions. It means that the aesthetic values or qualities in an artwork are particularly active, they are "at work" during the creative process, rather than limited to the moment of reception. I also use the term *constructed aesthetics* (chapter 4, p.115).

Professional science: refers to scientific knowledge conducted in research centres and laboratories, which is produced by a community of experts, within its primary specialist field and audience. *Hard science* is an alternative term, which refers more precisely to science as a subject matter (rather than a community of experts), mainly in distinction to the *soft sciences* (such as sociology, psychology or anthropology).

Physics: Although I refer to science in general terms throughout the research, I also discuss specific aspects in relation to the field of physics, primarily in the context of my art practice. I acknowledge how the principal source of inspiration in my work is located in scientific content in physics, and its related sub-fields. Other areas of science, such as biology and chemistry, may be implied in the investigation, when they share commonalities with physics, and thus are discussed under the term *science*.

Sci-Art: is employed here as a generic descriptor that aims to encapsulate a broad domain that investigates the connections between art and science, and encourages collaborations. Many variations in its terminology and spelling can be found, including:

- **Art of Science –** the term refers to online picture galleries organised by the likes of Princeton University, and University of Bristol. These platforms promote aestheticiesd images produced in the laboratory and selected through competitions. Imagery tends to remain technical and reflective of specialist fields in various scientific disciplines.[9]
- **Art|Sci –** a platform setup by the UCLA Art|Sci Center + Lab, devoted to "pursuing and promoting the evolving "Third Culture" by facilitating the infinite potential of collaborations between (media) arts and (bio/nano) sciences. (…) The center presents lectures and symposia to bring artists and scientists together in order to mesh these

9 Art of Science competition, Princeton University, http://www.princeton.edu/artofscience/; Art of Science competition, University of Bristol, http://www.bristol.ac.uk/fmvs/faculty/artofscience/about.html [Accessed 21 October 2013].

cultures and inspire individuals to think about art and science as already interrelated and relevant to our society." [10]

- **ArtScience –** the term has been adopted by MIT Press art and science journal *Leonardo*, as well as by writer David Edwards in his network of online platforms (the *ArtScience labs*), and his published work.[11] A Harvard University professor, Edwards encourages creativity in art, science and technology with a commitment "to social and cultural engagement through collaborative artistic and scientific discovery leading to remarkable arts partnerships, technological advances, and design solutions."[12]
- **art-sci-tech –** The US-based member organisations Art & Science Collaborations, Inc. (ASCI), founded in 1988, represents a wide networks of artists and scientists. The term art-sci-tech refers to a movement in the USA taking from the mid-1990s, echoing the UK Sciart programmes. The ASCI has a strong record of conferences and exhibitions on a wide spectrum of themes related to collaborations between art and science, including: Cyber Art, kinetics, light and interactive art, digital art, Bio- and Nano-Art.[13]
- **Sciart –** the term emerged in the UK in the early 1990s, from organisations such as the Wellcome Trust, in conjunction with government's initiatives linked with the public understanding of science. The Wellcome Trust launched its own programme to support "experimental projects that involved artists and scientists working collaboratively to explore a scientific subject matter using the arts. Sciart projects aimed to stimulate fresh thinking and debate in both disciplines, and to reach and engage with diverse audiences on the social, ethical and cultural issues that surround contemporary biomedical science."[14]

Science: The word *science* – in its modern usage – is generally defined as "the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment" (*Oxford* dictionary). In the thesis, science is employed to refer to (any or all of): a) scientific knowledge; b) the scientific field as a professional community of experts; c) a general descriptor for its related

10 Extract from the organisation's mission statement, from http://artsci.ucla.edu/ [Accessed 5 June 2013].

11 The ArtScience labs, http://www.artsciencelabs.org/ [Accessed 21 October 2013]. David Edwards, D., *Artscience: Creativity in the Post-Google Generation* (Cambridge, MA: Harvard University Press, 2008), and *The Lab: Creativity and Culture* (Cambridge, MA: Harvard University Press, 2010).

12 Extract taken from, http://www.artscienceprize.org/asp/david [Accessed 21 October 2013].

13 Extract from the organisation's mission statement, from http://www.asci.org/artikel384.html [Accessed 5 June 2013].

14 Wellcome Trust, Sciart programme, http://www.wellcome.ac.uk/Funding/Public-engagement/Funded-projects/Awards-made/All-awards-made/WTX035067.htm [Accessed 5 June 2013].

disciplines, physics, biology, chemistry and medicine. However, in this research, the term does not extend to other fields of knowledge using a scientific method of investigation, such as for instance the social sciences (e.g. *soft sciences*).

Un-image-able: first mentioned in the thesis title, the term aims to capture a strong interest in the threshold, the limits of (and what might lie beyond) the possibility of representing scientific concepts in visual form, where "objects or entities resist depiction".[15] This issue is found in the production of scientific imagery, and also in visual art, but here it is experienced differently, where the artist engages with concepts/fragments, through the grasp or the apprehension of these abstractions, to produce and present art (as opposed to communicate science). The focus is often on the metaphor, appropriation, or conceptual interpretation of the source to become a work of art. The term also draws on and questions the notion of uncertainty or impossibility in the production of a particular visuality, where tensions can be found between the artwork retaining a link from its source (science), but also departing from it to become something beyond. This process is led by the manipulation of visuality itself, but remains partly elusive, never to be fully explained as it is located at the core of the creative journey. The term "un-image-able" both echoes and extends James Elkins' concept of the "unpicturable" (where he challenges the meaning presented in scientific imagery capturing events or phenomena beyond the threshold of the visible in terms of extreme scale or distance).[16] In this instance, the notion moves from Elkins' proposition to an alternative method of visual transformation, inherent in my art practice.

Unpicturable: relates to James Elkins' study of scientific imagery, in particular those positioned at the limits of what can be depicted in visual form (due to extreme scale, distance and mathematical abstraction). This image genre is described by Elkins as "frail", "weak" or "empty", often characterised by blur and pixelated shapes, hence, lacking visual substance.[17] However they are significant to scientists, as they capture vital information for them to conduct their research (chapter 2, pp. 37-38). In this research I echo and extend Elkins' terminology, using the notion of *un-image-able* (as seen above).

15 Elkins, *Six Stories*, p. XV.

16 Ibid., p. 191.

17 Ibid., pp. 228-229.

Visuality: is deployed in a more active and inclusive sense than *image*. The term extends the notion of image as it refers to a taxonomy of image genres that have been constructed in chapter 2 (p. 31), where the term aims to capture all the characteristics around the construction, usage, purpose, production and reception of an image, in both scientific and artistic domains. In chapter 4 I also argue for my art practice to characterise a particular form of visuality (p. 115).

Visualisation: is limited to defining the modes and mechanisms of rendering information in visual form, that is to say, the move from data to image, in terms of a faithful translation, as opposed to a visual interpretation. The term also refers to an interdisciplinary branch of science, *scientific visualisation* (chapter 2, pp. 49-52).

Visual representation: in the research it is restricted to capturing two specific aspects: a) the representation of scientific knowledge in visual form; b) when discussed in relation to art, the term also serves to distinguish practices that engage with science through the *visual*, rather than the *conceptual*.

Appendices

A | 1 Appendix 1

IOP Publishing design strategy: record of evidence

This section offers a group of testimonials gathered as supporting information to back-up my claims from chapter 1, p. 14 (footnote 5). It provides a record of evidence on the impact of the design strategy adopted by IOP Publishing.

Since current Art Director Andrew Giaquinto's appointment at IOP in 1997, and with strong support from both former Managing Director, Jerry Cowhig (1995-2010), and current Managing Director Steven Hall (2010-), the in-house design studio has been continually developing and strengthening the corporate image for the organisation. The design strategy – as presented in the introduction (pp. 13-17), and in chapter 3 (pp. 87-93) – has been recognised and valued by its wider audience, including peers, competitors, authors and customers across the scientific community. Below is a range of extracts and comments that we have received over time, testifying to the impact and visibility that our design approach has benefited from.

> Excellent graphic design is a priority for our publishing company, but even in our most ambitious dreams we could not have anticipated the extra dimension that our design studio led by Andrew Giaquinto and Frédérique Swist, has brought to our journals, websites and promotional presentations. Combining Swiss Rational Design principles with Fred's ability to transform technical scientific diagrams into thrilling and dramatic images, this strategy has been deployed to enhance the design of our publishing output - journal covers, catalogues, and so forth - where they have become symbolic of our identity.[1]
>
> **Jerry Cowhig**
> *Managing Director, IOP Publishing (1995-2010)*

> I was given your brochure 'Introduction to refereeing' at Photonics West in San Francisco, and I have to say that I find the design and visual art of the brochure is the best I have seen in a long time. Please send my compliments to the responsible team. This booklet certainly can act as a standard for eye catching and pleasing print products.[2]
>
> **Junis Rindermann**
> *Laboratories for Hybrid Optoelectronics, University of Southampton, UK*

> Thank you very much for sending five copies of the promotional material. The cover image looks indeed very beautiful and I am very delighted for that. Please pass on my warm congratulations to your Design Department on the excellent interpretation of that figure.[3]
>
> **Professor Edson Denis Lionel**
> *Department of Physics, Lancaster University, UK*

1 Personal communication. Cowhig, J., Email to Swist., F. (4 August 2006).

2 Personal communication. Rindermann, J., Email to IOP Publishing (8 February 2012).

3 Personal communication. Edson, D. L., Email to IOP Publishing (circa. 2005).

I used to work at a very large publisher and, to put it mildly, product level branding there was probably the least of my concerns. Since joining IOP though, I have come to appreciate just how much our design studio reflects the importance of quality to this organization. Our brand is communicated through strong, vibrant colors and crisp, clean design. It helps us stand out at conferences and trade events. In a market in which most publishers offer very similar services, and as someone who spends most of his time trying to win new business, it is clear to me that our design studio is one of our strongest competitive advantages.[4]

Brett Rubinstein
Formerly Vice President of Library Sales at Springer, New York (2005-2012); joined IOP as Head of Business Development and Sales EMEA, in September 2012

For a publishing house of IOP's size, branding and design play an intrinsic role in maintaining our profile within the communities that we work with and offer us immediate recognition of our publications as belonging to our stable. The carefully crafted design ethos of IOP (itself the result of years of research and refinement) adds value to the content that we produce and importantly reflects its quality. It demonstrates our deep understanding of the material that we publish, and when providing an artistic interpretation of a scientific image, it allows the originator of the research further recognition for the hours of labour that goes into the research, authoring and publishing processes.

As a publisher who has been involved in the launch and relaunch of many titles over the past ten years, I have often struggled to convey the concept I have been looking for when briefing external designers. Often one feels as if they reproduce a favoured design pattern, simply adding a new title, in order to push through a greater volume of work. Now, having our design studio at the centre of our operation, it shortcuts any misunderstanding and reassures one of a professional opinion and approach to everything we do. High quality design is our most direct route to immediately convey the quality we aim to produce and to reflect the standing of the authors that we rely on for content."[5]

Jamie Hutchins
Formerly Head of Journals, Americas at Cambridge University Press, New York (2004-2012); now Head of Publishing at IOP, having joined the company in December 2012

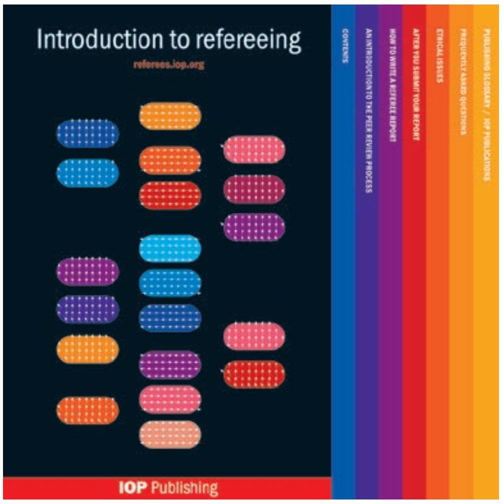


Figure A1.1: "Introduction to refereeing" brochure cover design (2012); see comment by Junis Rindermann, p.149.

Figure A1.2: Promotional flyer for *Journal of Physics A* (2005); see comment by Edson Denis Lionel, p. 149.

4 Personal communication. Rubinstein, B., Email to Swist, F. (10 September 2013).

5 Personal communication. Hutchins, J., Email to Swist, F. (26 September 2013).

A | 2 Appendix 2

Art and Science: defining a broad domain

From the outset it was made explicit that the central theme for the research is to explore the problems of visuality in both scientific and artistic production, as opposed to address Art and Science as a domain of enquiry. Consequently, the research has not provided a detailed survey of such a field, although I have referred to it in several instances, and more precisely in chapter 4, where I addressed the question of situating my art practice in relation to its broader related landscape. This appendix offers additional background and context to the problem of defining what has been mentioned throughout the thesis as *the domain of* or *the dialogues in* Art and Science.

"Art and Science" is a broad designation, found in wide-ranging literatures and practices. It is also often referred to under various terminologies and descriptors[1] – all addressing diverse contexts and purposes. Examples include the term "artscience" which was coined by both MIT journal's *Leonardo*,[2] and David Edwards, founder of the *ArtScience Labs*.[3] The latter is an international setup that brings together inventors, engineers, artists and scientists, offering them a platform for collaboration and experiment across disciplines. Another terminology, "Sciart", was proposed in the early 1990s by the UK-based Wellcome Trust,[4] centred on the public engagement with science. Numerous art-science programmes and art residencies have flourished internationally in recent years, especially with well-founded organisations such as MIT, UCLA and Cern.

The UK education system at the postgraduate level also reflects this emerging area of interest: in 2013, Central Saint Martins College of Arts and Design presented its first group of graduates from its inaugural Masters course in Art and Science. The college catalogue states: "As the only postgraduate course in the UK that is explicitly concerned with art and science, the students are pioneering an emerging field of interdisciplinary practice".[5] In contrast, in other countries such as China, Art and Science seems more established as an

1 See glossary pp. 147-148.

2 Peer-reviewed academic journal, published by the MIT Press, http://www.leonardo.info/ [Accessed 18 October 2013].

3 http://www.artsciencelabs.org/the-labs/ [Accessed 18 October 2013].

4 http://www.wellcome.ac.uk/ [Accessed 18 October 2013].

5 *State of Matter: Collisions and Connections in Art and Science* (University of the Arts London Central Saint Martins, London, 29 May 2013), p.13.

academic discipline in its own right, as demonstrated by Bing Liu in her essay 'Science and Art in China' where she offers a detailed review of the key conferences, exhibitions and published research in the field over the last fifteen years.[6]

Of course Art and Science is not exactly a new or emerging field; there is an abundance of scholarly work that retraces its connections and parallels throughout history, from Ancient Greece to the Italian Renaissance to name only two examples. Key texts include works by Miller, Kemp, Shlain and Leibowitz.[7] Other references include an essay by Jonathan Benthall,[8] which presents what can be seen as a contemporary survey of artists engaged with science and technology. His account was published in 1972, just over two decades after the optimism of the 1951 Festival of Britain,[9] and about thirteen years after C. P. Snow's famous Cambridge lecture on The Two Cultures in 1959.[10] This was also the year that saw *The Bulletin of the Atomic Scientists* release a special issue on Science and Art. The publication followed an exhibition held at the University of Chicago in 1954 "in which all of the works of 'art' were taken from the laboratory where they had been produced in the course of normal scientific research".[11] These provide interesting insights into what can be considered at the time already fully formed interactions between Art and Science and, more precisely, questions on the very nature of art produced *by* science.

The above signposts do not claim that these examples explicitly discussed Art and Science as a well-established field of enquiry in the way it has perhaps become today, but I argue that they laid the foundation for it. These instances show us that it is therefore not a *new* discipline. However, as Benthall remarked over forty years ago, the field was then, and remains today, very diverse, complex and elusive to define.[12] In current literature on the subject, different perspectives can be found: on the one hand, scholars such as Siân Ede overcome the issue by first offering insights into the specificity of science (as a

6 Liu, B., 'Science and Art in China' in Burguette, M. and Lam, L., (eds) *Art: A Science Matter* (Singapore: World Scientific, 2011), pp. 99-119.

7 Miller, A. I., *Einstein, Picasso: Space, Time and the Beauty that Causes Havoc* (New York: Basic Books, 2001); Kemp, M., *Seen/Unseen: Art, Science and Intuition from Leonardo to the Hubble Telescope* (New York: Oxford University Press, 2006); Shlain, L., *Art and Physics: Parallel Visions in Space, Time and Light* (New York: William Morrow, 1993); Leibowitz, J. R., *Hidden Harmony: The Connected Worlds of Physics and Art* (Baltimore, MD: The Johns Hopkins University Press, 2008).

8 Benthall, J., *Science and Technology in Art Today* (London: Thames and Hudson, 1972).

9 Jackson, L., *From Atoms to Patterns: Crystal Structure Designs from the 1951 Festival of Britain* (Ilminster: Richard Dennis Publications and London: Wellcome Collection, 2008).

10 Snow, C. P., *The Two Cultures: And a Second Look* (Cambridge: Cambridge University Press, 1969).

11 'Science and Art', special issue of the *Bulletin of the Atomic Scientists* vol. 15, no. 2 (February 1959), p. 50.

12 Benthall, *Science and Technology in Art Today*, pp. 9, 11.

body of knowledge and a community of professionals). She navigates between offering readers popularised accounts of complex scientific discoveries (such as Einstein's theory of relativity), to directing them to Martin Kemp's analysis of how artists often develop sophisticated ways to interact with their environment. She also argues that artists tend to engage with the cultural references of their time, making them particularly receptive to absorbing and distilling new scientific knowledge through art, so as to offer alternative views to the public.[13] On the other hand, in *Art + Science Now*, Stephen Wilson sees – perhaps ambitiously – the diversity of creative practices engaged with science and technology as "forging a new art for the twenty-first century".[14] In his introduction Wilson gives a pertinent summary of the key difficulties one encounters in any attempt to propose a clear articulation of how this *new* field might be outlined: firstly, an issue of definition for each term: in today's global multidisciplinary landscape, what *does* constitute science and art? Secondly, he acknowledges the recurring problems for many practitioners in locating their practice within such a field. Thirdly, and most importantly, Wilson reveals implicitly what I consider as another key issue:

> This book surveys artists, and *some* [my italics] scientists, who seek liberation from specialized compartments and definitions. (…) The scientists have been willing to undertake inquiries outside the arena of traditional research.[15]

Although there are many instances of artists and scientists collaborating successfully, it is generally the case that the relationship between the art and the science is not equal. Professor Sir Michael Berry describes it as *asymmetrical*.[16] Such art-science collaborations include *The Blue Morph* (an interactive installation that uses nanoscale images and sounds derived from the metamorphosis of a caterpillar into a butterfly), between nanoscientist Jim Gimzewski and visual artist Victoria Vesna,[17] or the large-scale installation *Covariance* by artist Lyndall Phelps, who worked closely with scientist Ben Still.[18] Both examples demonstrate how the science has explicitely fed and informed the artwork, while the latter is merely proposed as a piece of art for the public to engage with and experience as an artistic interpretation of science – not an artwork that directly participates in how scientific knowledge is produced. Here, if the art is connecting with the science, it is precisely to

13 Ede, S., Hesse-Honegger, C., Gilbert, M. and Oulton, T., *Words & Pictures: Explaining Science Through Art and Writing* (Carlisle: Cumbria Publishing, 2003), p. 6.

14 Wilson, *Art + Science Now*, p. 6.

15 Ibid.

16 Personal communication. Berry, M., with Swist, F. (30 January 2013).

17 http://artsci.ucla.edu/BlueMorph/main.html [Accessed 11 June 2014].

18 http://www.physics.org/superposition/ [Accessed 11 June 2014].

encourage a dialogue, an engagement between the public and a popularised interpretation of scientific research otherwise not easily accessible to an audience of non-specialists. It is usually done well, as the artist learns much working directly with an expert. However, in these instances, the art does not explicitly feed back into the science, in order to inform and contribute to scientific research. In other words, there seems to be a general tendency in which artists can learn and borrow from science (and from such collaborations), while scientists continue to make science regardless, that is to say, the art does not generally influence how science is produced.

This supports Berry's notion of an asymmetrical relationship between the two fields. Another example can be found in the article "Similarities and Contrasts in the Creative Processes of the Sciences and the Arts" by Roger Guillemin.[19] Interestingly, the author is a scientist by vocation and training, as well as a self-taught digital artist. He carefully and accurately describes his experience working in both fields, and discusses where strong affinities in working methods may be identified, while others remain clearly distinct. However, Guillemin avoids any suggestion that aspects in his art practice may feed back and directly inform his work as a scientist.

Art-Science interactions seem to be more successful when they operate within its own newly formed specialist field, often in the context of multidisciplinary programmes, with its own dedicated audience. Recent initiatives can be found with the *ArcheTime* conference,[20] involving over 70 participants, from a wide spectrum of disciplines ranging from visual and performing arts, writing and journalism, to science and technology, philosophy, photography and filmmaking. Taking place through an ambitious programme of talks, panel discussions, art exhibitions, performances and film screenings, the conference offered a strong sense of dialogue and exchange between the participants. However, it is also important to note that, as a complement to these strong interactions, each contribution was presented in such a way that it was able to coexist alongside others that were very different in nature (technical essays, journalism pieces, visual narratives, art installations, or laboratory experiments), and that each was allowed to retain its own specialist language and original context. Following the conference, a book was published,

19 Guillemin, R., 'Similarities and Contrasts in the Creative Processes of the Sciences and the Arts' in *Leonardo* vol. 43, no. 1 (2010), pp. 59-62.

20 Ast, O., (ed.) *Infinite Instances: Studies and Images of Time* (Brooklyn, NY: Mark Batty Publisher, 2001); Swist, F., 'Reviews: Reflections on time' in *Physics World* vol. 25, no. 8 (2012), p. 46.

featuring the diverse contributions, faithful to the format of the event, as each piece retained its own voice and inherent context. What can be seen as successfully echoing Elkins' view on how both the language of art and of science should be allowed to share a space while retaining their specialist language, has also been criticized by others, such as by Jack Ox in his review of the book, published in *Leonardo* book reviews online.[21] Ox is much more critical of such multidisciplinary undertaking, arguing that the submissions remain too isolated from one another, and too succinct, therefore leaving the exploration between art and science somehow predictable and superficially tackled. Ox called for a more in-depth scholarly and authoritative investigation. This difference of perspectives is yet another example of the challenges encountered by programmes and initiatives such as the ArcheTime at engaging between Art and Science in meaningful ways – as they tackle two specialist disciplines charged with their own histories, theoretical underpinnings and communities of experts.

21 http://leonardo.info/reviews/may2012/ast-ox.php [Accessed 18 October 2013].

A | 3 Appendix 3

A | 3 | 1 *Six Stories from the End of Representation* book review

Book review by Swist, F., of Elkins, J., *Six Stories from the End of Representation: Images in Painting, Photography, Astronomy, Microscopy, Particle Physics, and Quantum Mechanics, 1980-2000* (Stanford, CA: Stanford University Press, 2008), published in *Leonardo* book reviews online, January 2009, available at: http://leonardo.info/reviews/jan2009/swist_six.html [Accessed 25 August 2013].

> The images I am interested in show us things we can't possibly be seeing (…). They are pictures of objects that literally don't exist – that couldn't exist as they are pictured – but somehow do. They are abstractions of abstractions (…).

Six Stories from the End of Representation is a fascinating journey into the limits of representation in selected material from art and science. James Elkins explores the borderline between what can be observed and what can only be depicted, with a particular interest in the limitations and obstacles when the representation of meaning reaches such a place. Avoiding the predictability of re-visiting formal connections between art and science, Elkins successfully utilises both specialised languages in combining technical explanations and humanities literature, in an attempt to attract readers from both fields. In positioning his essay away from a philosophical discourse or simply a contribution to art history, he focuses on the exploration of imagery as opposed to its explanation and offers a distinct and more "open" perspective, allowing the reader to decide how to reflect on a fascinating and complex topic. In terms of historical framework, the material presented is from the period between 1980 and 2000 and comprises images from contemporary art and photography, followed by four specific scientific disciplines (astronomy, microscopy, particle physics and quantum mechanics).

Among the range of concepts explored throughout the book, the reader will find the concept of the sublime, mainly in reference to Kant, proposed in chapter one on painting. Elkins discusses the complexity of the inadequate verbalisation in our attempts to capture meaning in a non-representational artwork. This leads quickly to the central topic of the book: "(…) the negotiations of the limits of the verbal representation of pictures, and the limits of representation in pictures – the sequence leading from the known to the unknowable". From photographic material (chapter two), four key aspects are presented: blur, darkness, the ruined grid and the anti-optical. As the author explains, these notions are to be considered as "operative concepts" that will enable the reader to better understand the imagery as opposed to representing a full account of experiments with the limits of photographic representation. In their search for "a break in representation", artists are deliberately looking for ways to resist optical representation using techniques of under-exposure, smearing and shallow-focus in image manipulation.

Of special interest to Elkins is the relation with scale, from the infinitely large distances in astronomy (chapter three), to the extremely minute dimensions of particle physics and quantum mechanics (chapters five and six). At each end of the spectrum, it raises questions on how it has become possible to depict natural phenomena when traditional observation is no longer sufficient. Modern physics has enabled particles to be detected and "visualised" by their tracks as opposed to the "objects" themselves. The complexity of bubble-chamber images is such that they are accompanied by explanatory graphs, diagrams and mathematical measurements. These pictures are meant to be functional; they are measured as opposed to just being seen, which causes a relation between the way we "see" or "read" a painting or a photograph and an image produced by science to become increasingly unattainable.

Astronomical observation offers images representing entire galaxies at unimaginable scale and distance through light-travel. The material produced is often characterised by blur, pixels and shadowy shapes, which consequently compel scientists to refer to a degree of intuition in interpreting the data, but combined with the production of mathematical models. In microscopy (chapter four), Elkins concentrates on some of the technical characteristics in capturing and depicting pictures produced by different types of microscopes from optical, electron or phase contrast systems. Scale and resolution are paramount aspects to consider in this field, and he explains how images produced are highly dependent on the manipulation of light and the apparatus' setting in which the resolution and contrast are adjustable and can create shadows and effects that may not always belong to the object placed under the scrutiny of the microscope.

Quantum mechanics, in chapter six, reaches the very limits in the possibilities of representation, where imagery refers no longer to photography, microscopy or particle tracks but instead involves graphs and schematic diagrams. The author uses the notions of unpicturable and unconceivable to take us through the most complex section of the book. Significant obstacles hinder the process of visualisation, starting with the inadequacy of using metaphors, familiar analogies and "commonly identified intuition" for anyone studying quantum mechanics. Feynman diagrams are proposed to illustrate the interaction of particles as schemata, material that helps physicists to calculate the lifetimes of individual particles, the speed of a reaction, or the probability of a reaction taking place. However these figures should not be taken as visually realistic; they are misleading in that the distance or exact position of the elements for instance is not represented accurately. The author informs us that in quantum mechanics mathematics is used to describe "objects" that are permanently inaccessible to the senses. Therefore unless through highly complex equations, there are no longer objects to depict in the sense that is discussed in previous chapters.

Important questions are raised in this book, from the notion of interpretation of a concept already presented (i.e. re-presented, therefore producing a potential distortion of vital information), to questioning the adequacy of metaphors, or the way scientific imagery is highly dependent on the apparatus used in its production, leaving scientists the complicated task of reading the captured events. Elkins' essay stands out from other treatments in that he addresses the complex issues of dealing with "images of objects that resist depiction". Scientific imagery can be addressed through aesthetics and visual values (sometimes over its meaning) at one end of the spectrum, and meaning and representation (to the detriment of aesthetics) at its opposite. In this context, the latter seems to correspond to Elkins's intentions, as he deliberately resists a discourse on aesthetics. In his conclusion he acknowledges the selected imagery to be "frail", lacking any visual qualities. His intention to distance his survey from commercial false-coloured imagery as found in astronomy, medical physics or computer modelling for example is justifiable within the framework of the survey; nevertheless, does this strategy imply that aesthetically-enhanced and colour-charged imagery in art and science could not be considered as suitable material for an investigation in the limits of representation?

A | 3 | 2 'CMYK: from graphic design to digital art' conference proceedings

Swist, F., 'CMYK: from graphic design to digital art – the transfer of colour manipulation from pre-press and commercial litho printing to a fine art digital practice' in Hoskins, S., (ed.) *Impact 6: Multidisciplinary Printmaking Conference Proceedings* (Bristol: Impact Press, 2011), pp. 60-65.

Abstract

In today's traditional and digital printing technologies, two dominant colour spaces are used: cyan-magenta-yellow-black (CMYK) and red-green-blue (RGB). In graphic design, publishing and commercial litho printing, the CMYK colour mode is the industry standard, while in contemporary printing as adopted by creative disciplines involved with digital technology (such as photography and fine art digital printing) RGB is the most widely employed colour mode for image manipulation and output. In this essay, I will present my own colour method (as implemented in my artistic practice), and I will demonstrate the main principles in adopting the CMYK mode for application to digital imaging and output. I will also highlight some of the obstacles and challenges in relation to conversion in RGB colours and problems of accuracy in print reproduction. However, because my focus is on the making of colours prior to printing, I will be less concerned with the outcome of the printing process. Illustrated with a wide range of visual examples, this essay aims to offer an insight into the colour method applied in an art practice that is fully dependent on digital technology for its image making and printing, but that also borrows from graphic design for its colour manipulation and management in the CMYK space, as opposed to the RGB colour mode.

1. The CMYK colour space

The CMYK colour space is based on the mixing of the four basic colours used as inks in the pre-press[1] and printing industry: cyan, magenta, yellow and black. The mix of the cyan, magenta and yellow gives a black, but black ink is added to provide a purer, more intense black, which allows additional possibilities of altering the darkness of the three basic colours. In commercial litho printing, each of the four colours is separated as a plate

1 Pre-press is a collective term for the steps taken to prepare original artwork for printing. Also see www.prepressure.com [Accessed 10 August 2010].

or screen and once printed in superposition, can reproduce the complete spectrum of colours available in the CMYK space, using the process of half-toning (dots). To avoid moiré patterns, each colour plate is set up with a different screen angle.[2] With the use of dots (measured in dots per inch), colours can be defined or quantified as percentages, and once printed they can also be measured using a spectrophotometer.[3] Figure A3.1 shows the basic spectrum of the CMYK palette, with graduation steps of 10%.

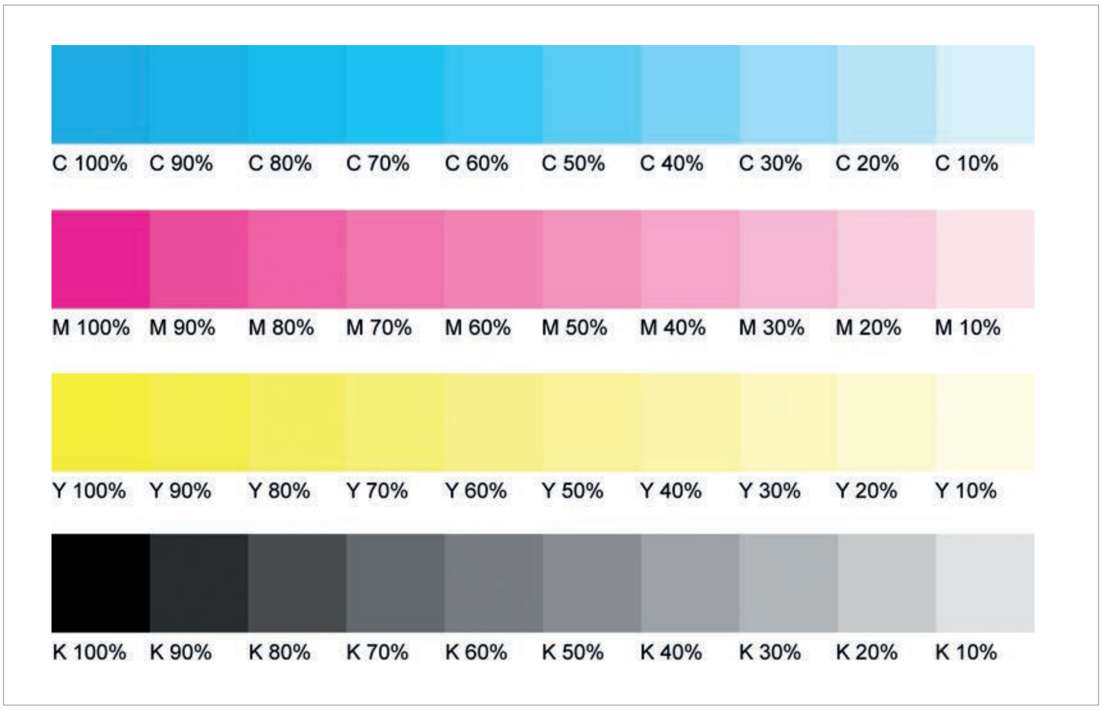


Figure A3.1: Basic colour breakdown in the CMYK colour space using the system of percentages.

From this basis, the whole spectrum of printable colours (available within the CMYK space) can be built upon. Colour families and gradual variations in hues and saturation can be established by mixing percentage values from the cyan, magenta, yellow and black. Figure A3.2 shows examples of a yellow > orange > red colour family; a yellow > green; a magenta > purple > dark blue; and finally a cyan > dark blue colour range. Each colour can be identified by its equivalent numerical value, defined in percentages as shown here, under each colour square.

2 A typical or default screen angle set for the CMYK plates is: cyan 105°, magenta 75°, yellow 90°, black 45°. Pipes, A., 2009 *Production for Graphic Designers* (5th ed., London: Laurence King), p. 91.

3 Homann, J-P., *Digital Colour Management* (Berlin: Springer, 2009), pp. 52-53.

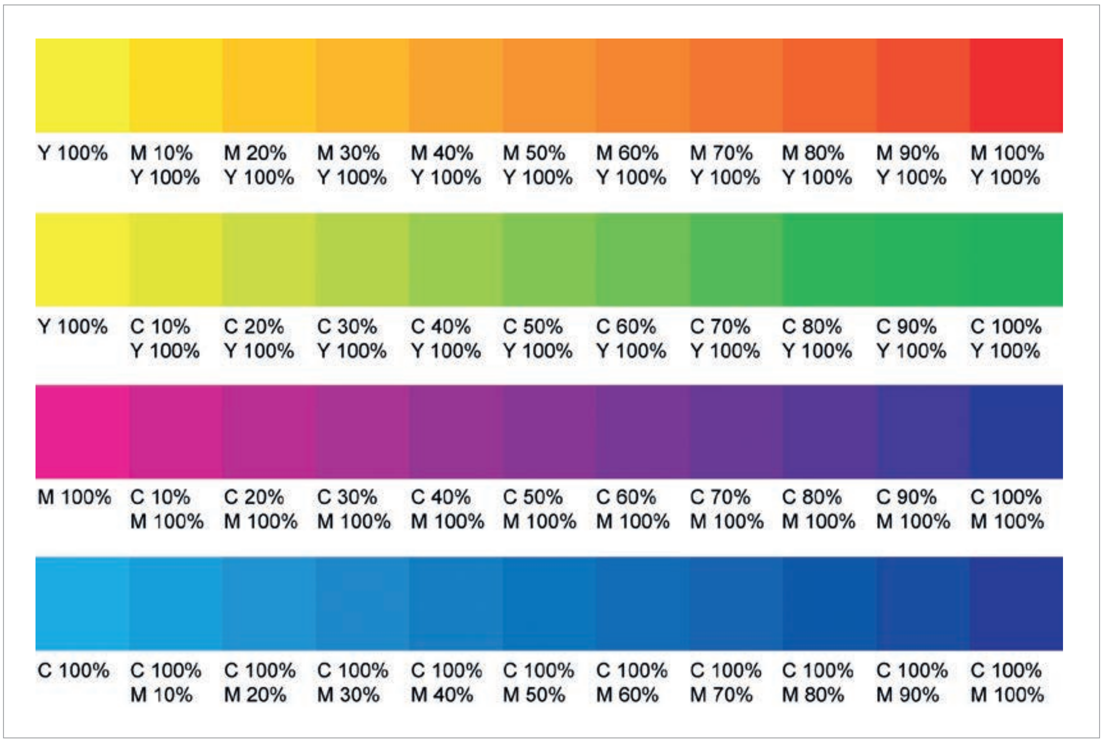


Figure A3.2: Example of families built from the four basic CMYK colours.

This method of colour mixing also allows replicating shades of grey without necessarily using the black. Figure A3.3 demonstrates how the mixing of percentages using cyan, magenta and yellow, may 'simulate' shades of grey that are otherwise made up in the black channel. This method is often used in graphic design, to create more subtle or warmer coloured greys, generally intended to be reproduced using the litho-printing process.

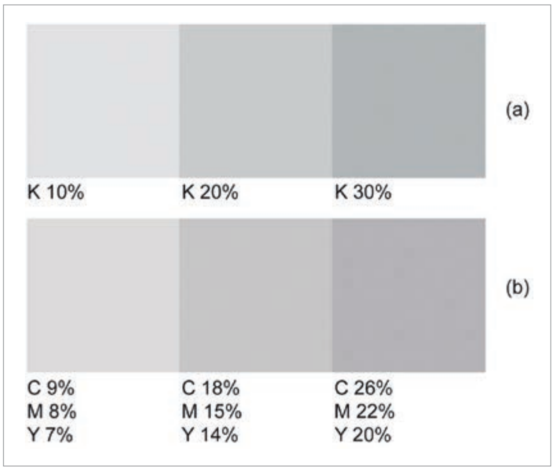


Figure A3.3: Example of a three-colour grey set (b), to simulate standard shades of grey using the black channel (a).

2. CMYK vs. RGB

The fundamental difference between CYMK and RGB relates to the subtractive (former) and additive (latter) systems.[4] In simple terms, we could consider CMYK as "physical" colours (i.e. using inks), and RGB as "optical" colours (i.e. with reference to light and wavelength). This distinction is not fully accurate, as all colours result from the process of vision but will be temporarily adopted for the purpose of this essay. Using this distinction, we can therefore define the mixing of CMYK colours – using percentages – as the process of specifying "quantities" of inks to be printed on paper.

In the RGB mode, each of the three colours is represented by a numerical value, from 0 to 255 (a digital representation used in computing, part of the digital imaging and data processing language). The major difference between the two colour modes is that with CMYK, a higher percentage of colour will add intensity or darkness (therefore adding a "quantity of ink"), while in RGB, specifying a smaller numerical value means obstructing light, resulting in darkening the colour towards black, with a value of R0, G0, B0 corresponding to a pure black. Because in the RGB space, each of the three colours is composed of a number from 0 to 255, the possible combination of colours is equal to 255 x 255 x 255, giving a total of 16,777,216 colours.

In the CMYK mode each of the four colours is represented using percentages, from 0 to 100% for each of the four channels. Exhausting every possible combination of percentages in order to build a complete colour palette would give a total of 100,000,000 colours (in absolute terms). However, in commercial litho as in digital technologies, printers can safely and "visibly" reproduce colours, up to 2% (litho) and 1% (digital). In optical terms, our vision may safely detect a difference between two juxtaposed colours up to approximately 3% (although it may vary depending on the colour mix) – beyond this range it will be more problematic. To illustrate this, figure A3.4 shows a very small variation of the percentages in one colour channel as follows:

- Colour (a) = 100% cyan, plus a gradual increase in the magenta from 0 to 2%, 5% and 8%.
- Colour (b) = 100% yellow, plus a gradual decrease in the magenta from 100% to 98%, 95% and 92%.
- Colour (c) = 100% cyan, plus a gradual increase in the magenta from 0 to 5%, 10% and 15%.
- Colour (d) = 100% yellow, plus a gradual decrease in the magenta from 100% to 95%, 90% and 85%.

4 Homann, *Digital Colour Management*, pp. 22-25.

In colour (a) and (b) the difference is hardly visible to the eye and may present similar challenges once printed. Because many variables are to be considered during the printing process (both in litho and digital), it is difficult to know with certainty what are the exact printable limits of colour percentages. Taking this issue into consideration, figure (c) and (d) proposes the setting up of a minimum gap of 5% between each colour variation, where the colour nuances remain proportional but also become slightly more visually noticeable.

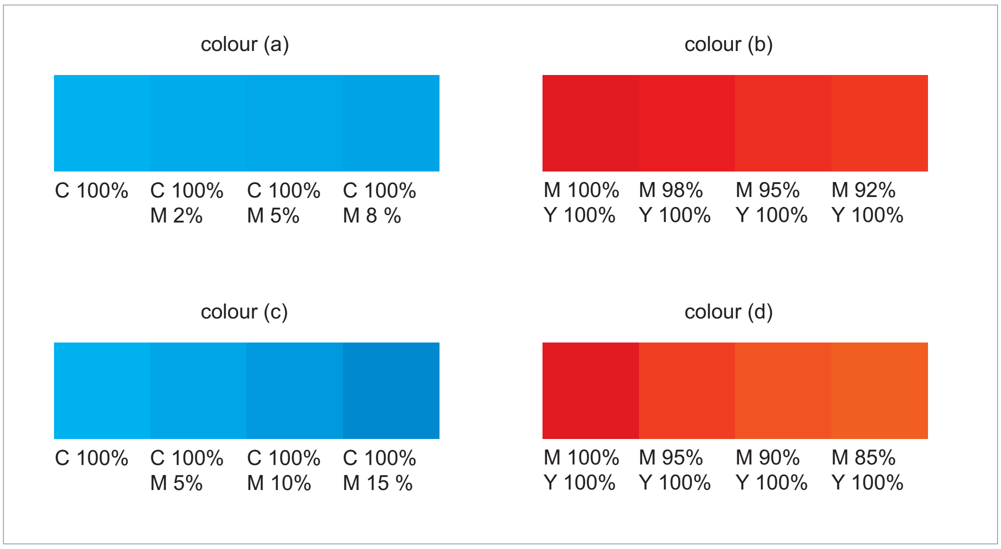


Figure A3.4: Examples showing small variations in percentages, where the changes in colour (a) and (b) are hardly visible to the eye, while by increasing the gaps at 5%, each colour is individually noticeable as shown with colour (c) and (d).

Considering the above, a more "workable" palette could be set up using an increase and decrease of 5% between each colour variation. Each of the four basic colours would therefore consist of 20 graduations, from 5%, 10%, 15%, up to 100%. A total range would result in 20 x 20 x 20 x 20, or 160,000 colours. This is the least extensive colour palette, compared with an absolute CMYK palette (100,000,000 colours), or the standard RGB colour space (16,777,216 colours). However, as demonstrated in figure 4 (c) and (d), a "safer" percentage gap between each graduation provides a more efficient and practical colour palette, where colour variations may be more noticeable to the eye but may also increase the prospect for more manageable print reproduction and measurement. I will demonstrate, in section 4 (p. 166), how a fairly restrictive palette on first consideration can still provide a wide range of colour variation and combination.

Also well known in the photography, pre-press and printing industry is the problem of conversion between the modes. Without discussing the process of photography here, I will restrict my examples to basic conversion issues, from RGB to CMYK and vice versa using two basic colours: the CMYK red (M 100%, Y 100%), and its equivalent in RGB (R255, G0, B0). Figure A3.5 illustrates the process of automatic conversion and the issue of conversion back to the original mode: the conversion between these two colours needs to be altered manually in order to get "pure" (rounded) numerical values, and cannot be converted back to its original colour mode and achieve its exact initial numerical value. Automatic conversion between each colour mode is a constant issue. Some colours will convert accurately, while others change more significantly, depending on their position in their respective colour gamut (see figure 6).

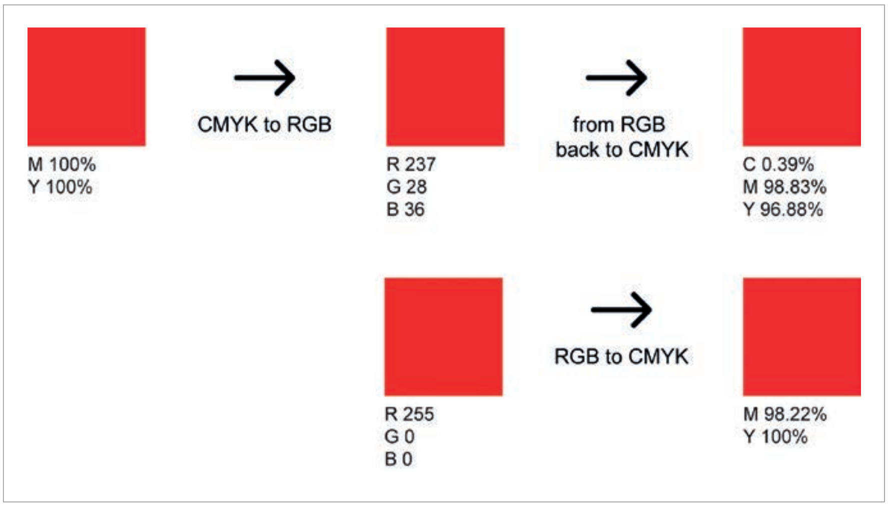
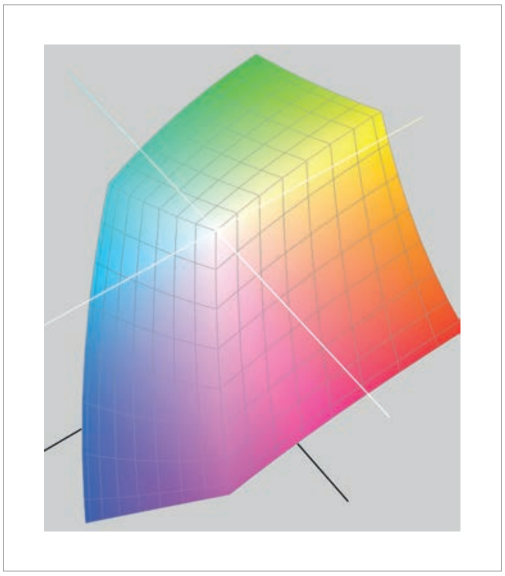


Figure A3.5: Examples of colour conversion between CMYK and RGB, and from RGB back to CMYK.

Because each mode is significantly different, exact equivalence in colour conversion is problematic and not possible for every single colour. This issue can also be illustrated with a visual representation of each colour gamut[5] as shown in figure A3.6. On the left, the graph presents the RGB colour gamut, while on the right, the CMYK gamut is superimposed. The main issue for colour conversion and reproduction is that many of the colours in RGB fall outside the spectrum of the CMYK gamut, which is much smaller; also, a small number of CMYK colours fall outside the RGB gamut, therefore making some colours impossible to convert and reproduce in print with an accurate numerical and visual equivalent.

5 For other examples for the visualisation of colour gamut, see Pipes, *Production for Graphic Designers,* p. 90; Lawler, B. P., *The Official Adobe Print Publishing Guide* (Berkeley: Adobe Press, 2006), p. 9; Bann, D., *The All New Print Production Handbook* (Mies: Rotovision, 2006), p. 45.



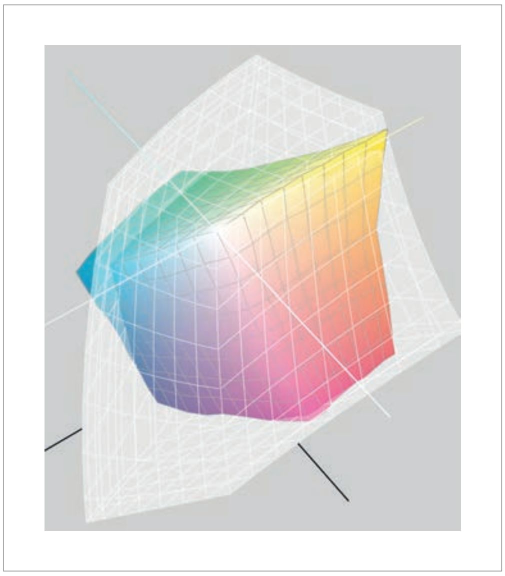


Figure A3.6: A 3-dimensional visualisation of both the RGB and CMYK colour gamut. The RGB colour space is represented on the left, and the CMYK space is superimposed on the right. Graphs produced using the ColorSync Utility on Apple Mac (version 4.5, Apple Inc.), using generic RGB and CMYK profiles.

3. CMYK and the Golden Ratio

The composition of colour families can also be established using a method employed by the Swiss-German art director Roland Schenk. Schenk used an abridged version of the Golden Ratio in order to divide each of the basic CMYK colours proportionally, also using the system of percentages (see figure A3.7). Very little documentation is available on Schenk's design work and legacy; nonetheless, in learning about his method from IOP Publishing's[6] current art director Andrew Giaquinto (who worked for over 20 years with Schenk), I tried to replicate the methodology by creating a series of colours using the Golden Ratio, following Schenk's system.

Schenk used a cut-down version of the Golden Ratio (1.618033) and divided each colour proportionally from 100% to 0%. Using this method, I propose here a basic set of 7 shades for each of the cyan, magenta, yellow and black, giving a total colour palette of 2401 (7 x 7 x 7 x 7). At first glance, this seems the most restrictive palette compared to the full colour range offered by the CMYK and RGB systems. However, as figure A3.7 demonstrates, this method of composing colours offers more subtle and finer colour families than provided by the basic CMYK palette. Schenk's method is logical, precise and rigorous, which is reflected by his cultural and educational background situated in the legacy of the Swiss

6 IOP Publishing (based in Bristol) is a leading science academic publisher, own by the Institute of Physics (London). The organisation is devoted to the dissemination of the advancement of scientific research in physics.

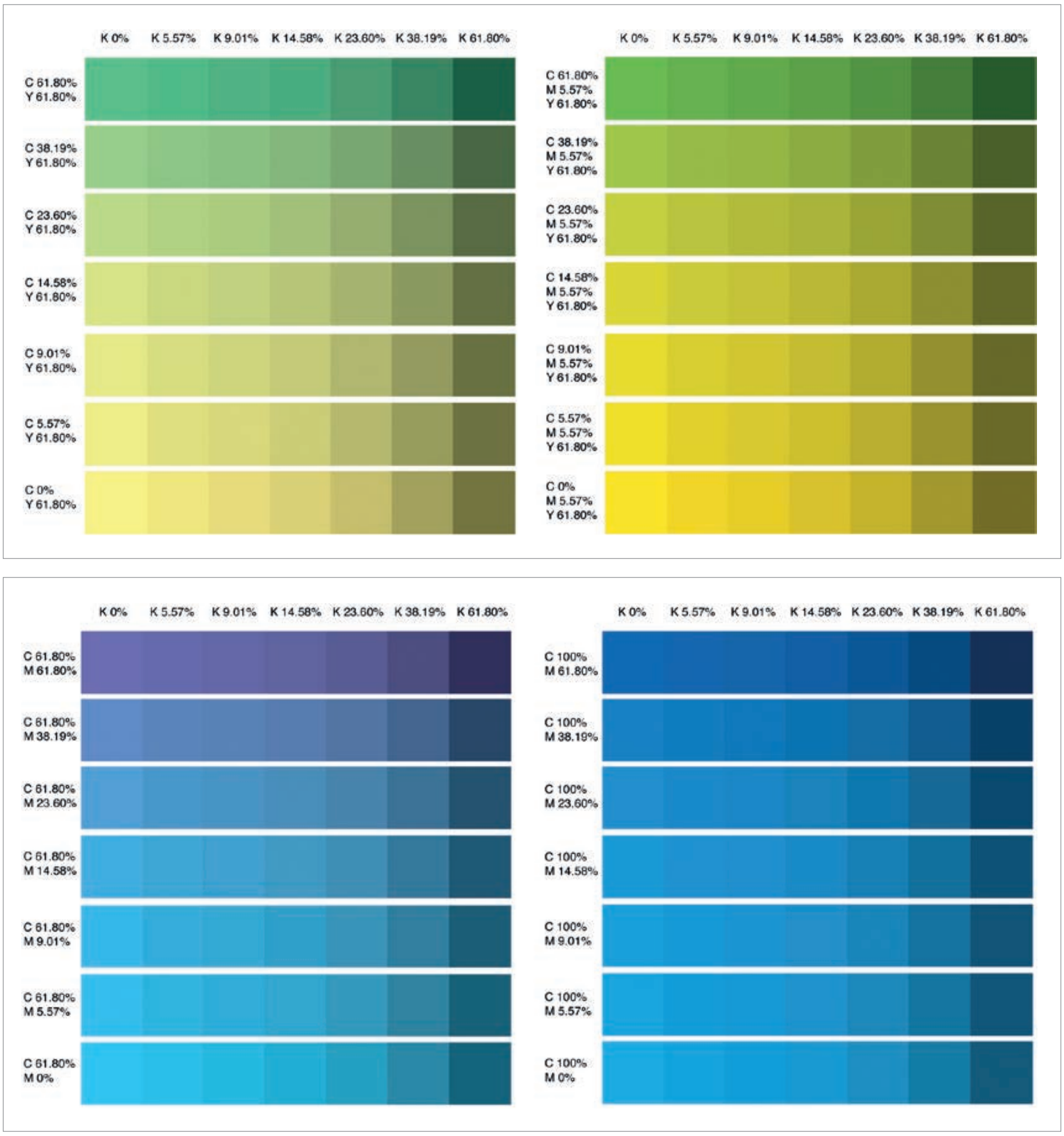


Figure A3.7: Examples of colour palettes demonstrating how sophisticated colour harmonies can be established using the Golden Ratio.

Rational design.[7] The Swiss Style (also known as the International Style) founded the main principles of design rationalisation, from the creation of standard paper size (such as the A4 letterhead), the grid system for editorial layouts, or the creation of highly functional typography like Helvetica. The influence of this design philosophy was still very much alive in Switzerland up to the 1960s, such that Schenk extended its key principles to his own approach to colour usage in his design work for the following three decades while working on high-profile editorial designs at Haymarket Publishing in London.

7 Hollis, R., *Swiss Graphic Design: The Origins and Growth of an International Style* (London: Laurence King, 2006).

As seen in figure A3.4, issues to do with technical limitations in the printing of colours need to be considered. Colour palettes using the Golden Ratio offer subtle variations and sophisticated colour harmonies that otherwise would not be possible to create using rounded percentages. However, their numerical values present challenges in the pursuit of accurate and measurable colour reproduction. A colour value such as 5.57% or 9.01% becomes impractical for the purpose of printing, as a value below 1% not only becomes imperceptible to the eye, but also in terms of print reproduction. Considering this issue, the building of colour palettes using rounded percentages (as seen in figures A3.1 and A3.2), therefore may better respond to the possibilities of accurate output and overcome the current limitations in both litho and digital print processes.

4. Brief presentation of my artistic practice and its colour usage

4.1 Background

My artistic practice is based on the creation of vector EPS imagery, composed in Adobe Illustrator®, using extensive colour combinations in the CMYK colour space. The choice of working in this colour mode results from my background in graphic design, where CMYK is the industry standard in print-design, pre-press and litho printing. I employed this method from my work in graphic design and extended its methodology and underlying rationale to my art practice, building extensive colour palettes based on the system of percentages as presented in section 1 (p. 163). The artworks I create are fully dependent on digital technology from their conception through to their output, using vector graphic imaging software and large-format inkjet printing for their production. It is however an on-going process, where I am exploring and testing printing outputs in CMYK and equivalents in RGB.

4.2 Method for colour usage

My own method for creating and using colours is driven by a need for a measurable and reproducible system in which my main requirements are: the possibilities to define, quantify, measure, record and, most importantly, re-use and reproduce each individual colour with an optimum level of accuracy and consistency. There are several key aspects to consider in this approach to colour:

- **Colour identification:** a colour can be identified, not only visually (variable and inaccurate), but also by its numerical value (in %).
- **Colour measurement:** a colour can be "measured" using its corresponding numerical value but also once printed, it can be measured using a spectrophotometer.
- **Colour adjustment:** a colour can be adjusted not only visually but also through its numerical value.
- **Recording of colour:** recording colours and organising them in sets or families, to offer a more effective method for colour identification and re-use.
- **Accuracy of reproduction:** a system that enables access to the colour numerical value contributes towards a better preparation for reproduction in print and anticipation of the output.
- **Colour legibility:** colour legibility is important on two levels, firstly in terms of vision (how we may see and differentiate two colours juxtaposed), and secondly in terms of printing (how a printing method is able to portray colours and "measure" them as a quantity of ink on paper).

Some of these aspects are illustrated in figure A3.8: the colour tools in Adobe Illustrator® allow for the visualisation of the colour mixing, the identification of their percentage values, and offer the possibility to organise and record folders of colour families or libraries.

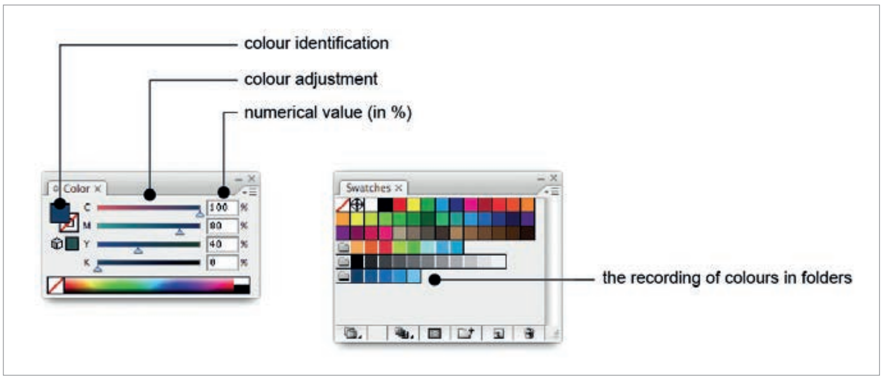


Figure A3.8: Tools used in Adobe Illustrator®, showing the breakdown of a colour in the CMYK space using percentages (left), and the recording of colour folders in the swatches tool (right).

Figure A3.9 shows an example of an artwork taken from my art practice, with the detailed colour breakdown used in the imagery. This colour palette results from preparatory research in possible variations for colour intensity, vibrancy, hue and saturation. The rationale behind each colour choice is established by my own requirement for "colour legibility": each colour needs to be visible against the black background, but also when juxtaposed with neighboring colours within the overall visual composition. Figure A3.10 shows the preparatory colour research and possible variations in terms of percentages. On the right-hand sides, colours are tested on the black background for legibility.

5. Concluding remarks

This essay has presented a particular method for using colours, giving insights into the use

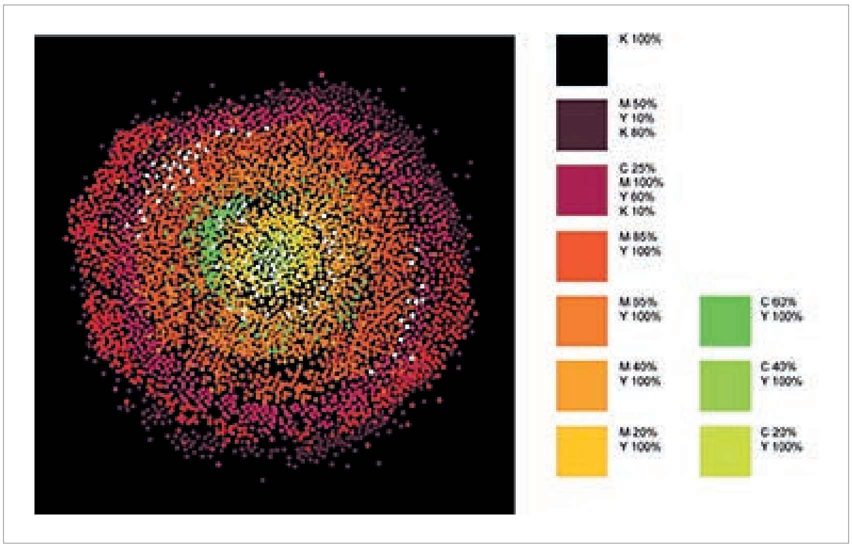


Figure A3.9: Artwork *Ultracold Neutral Plasma* (2009) shows an example taken from my art practice, with its accompanying selection of colours and CMYK breakdown.

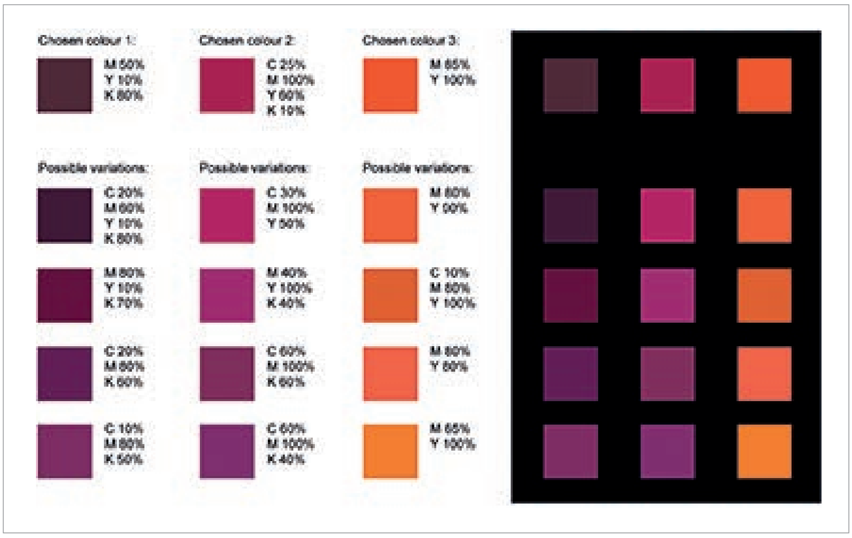


Figure A3.10: Example of preparatory work on colours prior to the final artwork, with percentage variations.

of the CMYK mode as opposed to the traditionally dominant RGB colour space in digital imaging and printing. However, issues and challenges between the CMYK and RGB colour modes remain dependent on current technologies and their limitations. The method presented here, in transferring and adapting the CMYK system from the environment of commercial litho printing to digital technology, can provide a certain level of control in the identification, measurement, recording and reproduction of colours, but addresses only part of the technical chain of production, and remains dependent on a number of other variables such as colour conversion, or rendering output related to printer settings, inks and paper used, and other intervening factors. Consequently, the present method offers an exploration and understanding of a small and specific area within the wider context of colour system and management, but contributes to on-going enquiries in the broader technical environment of digitally led image creation, production and output.

A | 3 | 3 'Reflections on time' book review

Book review by Swist, F., of Ast., O., (ed.) *Infinite Instances: Studies and Images of Time* (Brooklyn, NY: Mark Batty Publisher, 2011), published in *Physics World* vol. 25, no. 8 (2012), p. 46.

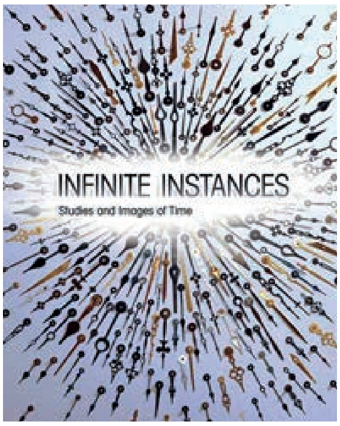


Figure A3.11: *Infinite Instances*, book cover.

Infinite Instances was published subsequently to the 2009 conference ArcheTime, held in New York, USA. I was asked by Margaret Harris, *Physics World*'s Section Editor to review the book for publication in the magazine. See p. 174 for the full review, published in issue 8 (2012). Subsequently, the review was translated into seven languages, including French, Russian and Chinese), all available online on the *Infinite Instances* website.[1]

1 http://www.infiniteinstances.com/ [Accessed 7 October 2013].

Reflections on time

Infinite Instances: Studies and Images of Time
Ed. Olga Ast
2011 Mark Batty Publisher £32.00/$50.00hb
224pp

The ArcheTime conference was completely unlike most meetings attended by physicists. Organized by conceptual artist Olga Ast, the June 2009 event brought together more than 70 people from a wide range of backgrounds, including artists, philosophers, writers, photographers and filmmakers as well as scientists. Alongside the programme of talks and panel discussions, an accompanying exhibition showcased artworks, installations and moving images by artists such as the award-winning percussionist, composer and improviser Jesse Stewart, experimental filmmaker Ken Jacobs and Ast herself.

Such interdisciplinarity was necessary because the subject of the conference was *time* – and in the words of the science writer (and conference attendee) George Musser, "our experience of time is so fundamental and so mysterious that it takes all areas of human endeavour to come to grips with it". Now, some three years later, Ast has produced a beautiful coffee-table book, *Infinite Instances: Studies and Images of Time*, which brings the numerous contributions to ArcheTime together in a single volume.

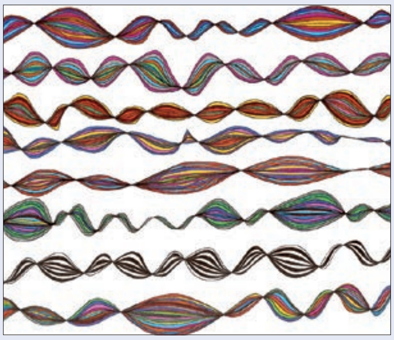
Like the conference itself, *Infinite Instances* tackles the subject of time from many angles, incorporating the technical voices of scientists as well as the creative responses of artists and the ingenious experiments of designers. The collection of visual essays and text-based pieces appears to be organized in no particular order, but as you flick through its pages, a dichotomy emerges. On the one hand, time seems to be experienced as organic, living, moving, growing – for instance in Catinca Tilea's *My Time*, which features a watch that contains living algae growing at different rates depending on the amount of heat and light it receives.

On the other hand, time can be represented through complex graphs and diagrams, measurement apparatus and data-visualization systems. One example of the latter approach is found in the essay "Space–time imagery in art and science". Here, the physicist Norman Zabusky shows how Eadweard Muybridge's famous chronophotographs of motion inspired not only Marcel Duchamp's painting *Nude Descending a Staircase, No 2*, but also the physiologist Étienne-Jules Marey's images of fluid flow and Zabusky's own work (carried out with fellow scientist Martin Kruskal) on "visiometrics", or the visualization and quantification of evolving amorphous objects.

For me, though, one of the book's most fascinating entries comes from a graphic designer, Camilla Torna, who carried out an "experiment" in which she asked subjects – aged between 3 and 72 years – to draw their own interpretation of time. Their responses were organized into the *Visualizing Time* database, and a selection of 25 entries appears in the book. Ranging from a single dot on a blank sheet to carefully crafted networks of waves, lines and circles, the drawings (accompanied by captions) give an interesting insight into creative, metaphorical and conceptual responses to the experience of time. Torna's contribution reveals both our tireless fascination with time and the complexity involved in grasping what it is in essence, and what it means as a concept.

In exploring the various approaches presented in this book, one thing becomes clear. The central question is not so much about searching for a suitable universal definition of time. Instead, it concerns how time is experienced and how we might engage with it from different perspectives. In bringing together voices from a spectrum of disciplines, the book invites readers to explore, investigate and reflect freely on the subject in a way that celebrates all of these different strands. *Infinite Instances* would appeal equally to the specialist and the general reader, but will particularly interest those involved in multidisciplinary work and in dialogues between art and science.

Courtesy of Mark Batty Publisher



The art of time Detail from *Untitled* by Jesse Stewart (above) and two of the drawings from Camilla Torna's *Visualizing Time* experiment (below).

Fred Swist is a senior graphic designer at IOP Publishing, which publishes *Physics World*, e-mail fred.swist@iop.org

Figure A3.12: *Infinite Instances*, book review published in *Physics World* vol. 25, no. 8 (2012), p. 46.

A | 3 | 4 'The physics of positivity: visual affirmations' visual essay

Swist, F., 'The physics of positivity: visual affirmations' in *Parallax* vol.16, no. 3 (September 2010), pp. 55-59.

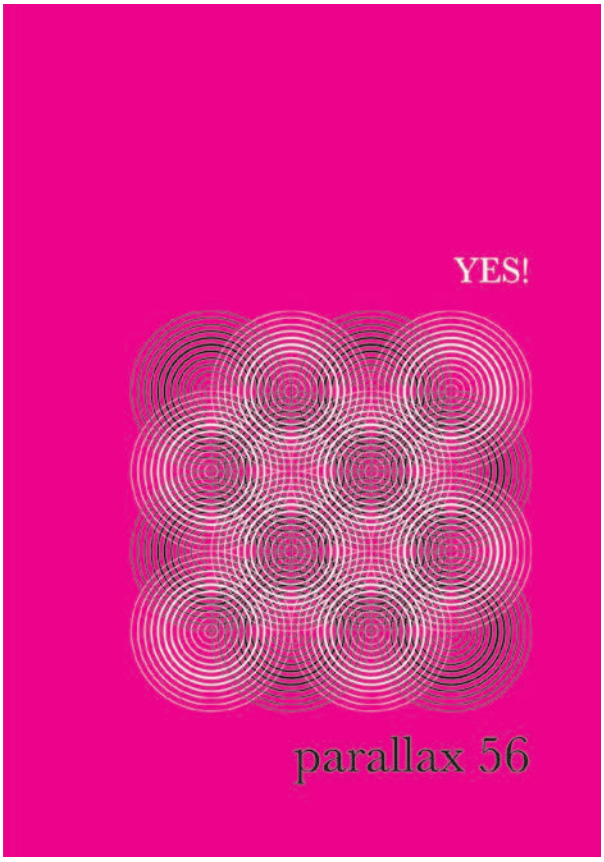
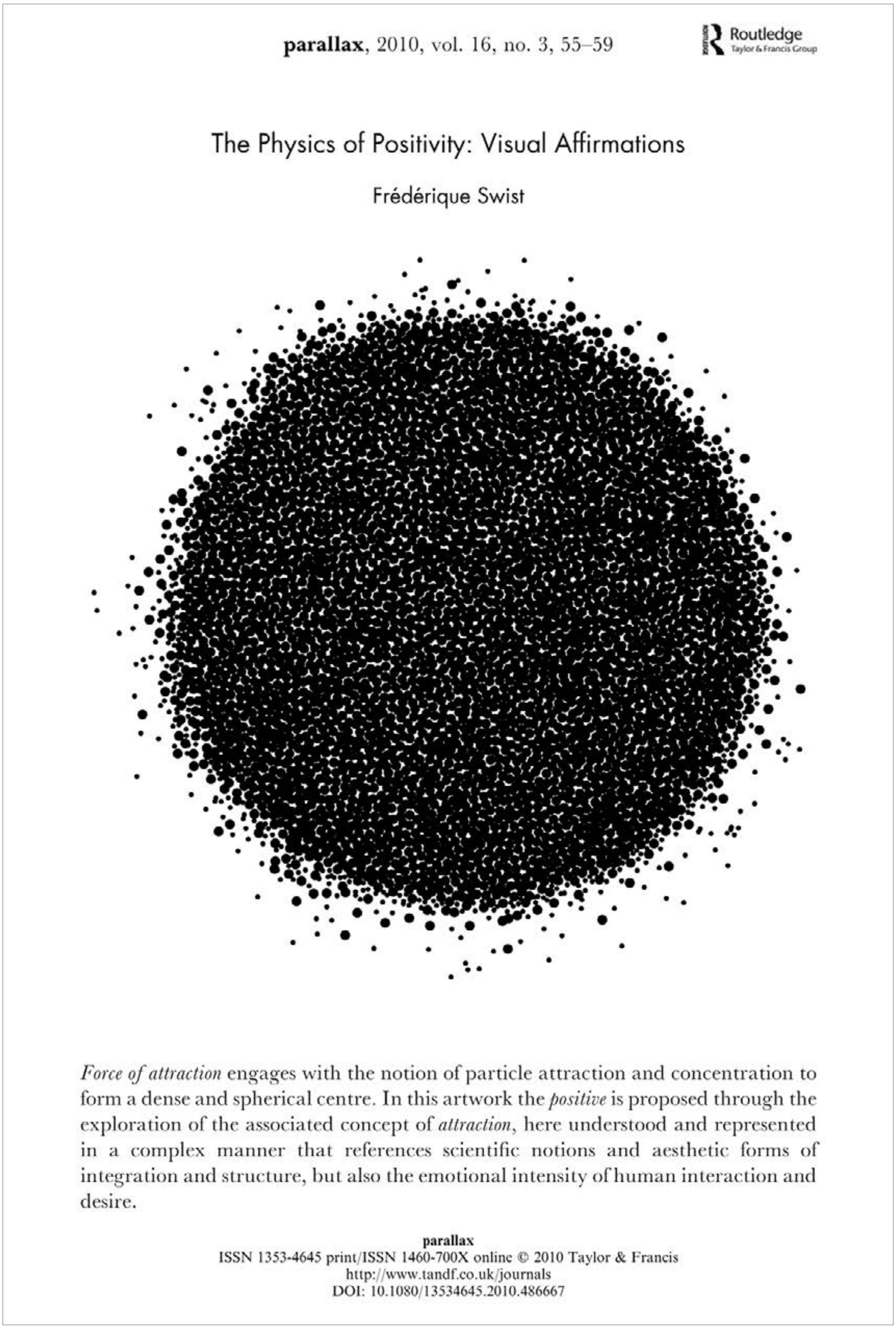


Figure A3.13: *Parallax* vol. 16, no. 3 (September 2010), front cover design.

Parallax is a peer-reviewed academic journal in cultural studies, critical theory and philosophy. Each issue is run by a Guest Editor and focuses of a particular theme. For issue 56, Guest Editor Gary Peters invited me to contribute to the journal, on the theme of "affirmation", as an extension to our previous collaboration with the artworks and essays published in *Neutral* magazine (pp. 176-180). Page 172-176 show my contribution with a visual essay entitled 'The physics of positivitiy: visual affirmations'.
I was also invited to suggest a cover image, using one of the visuals from the essay (figure A3.13).



parallax, 2010, vol. 16, no. 3, 55–59

Routledge
Taylor & Francis Group

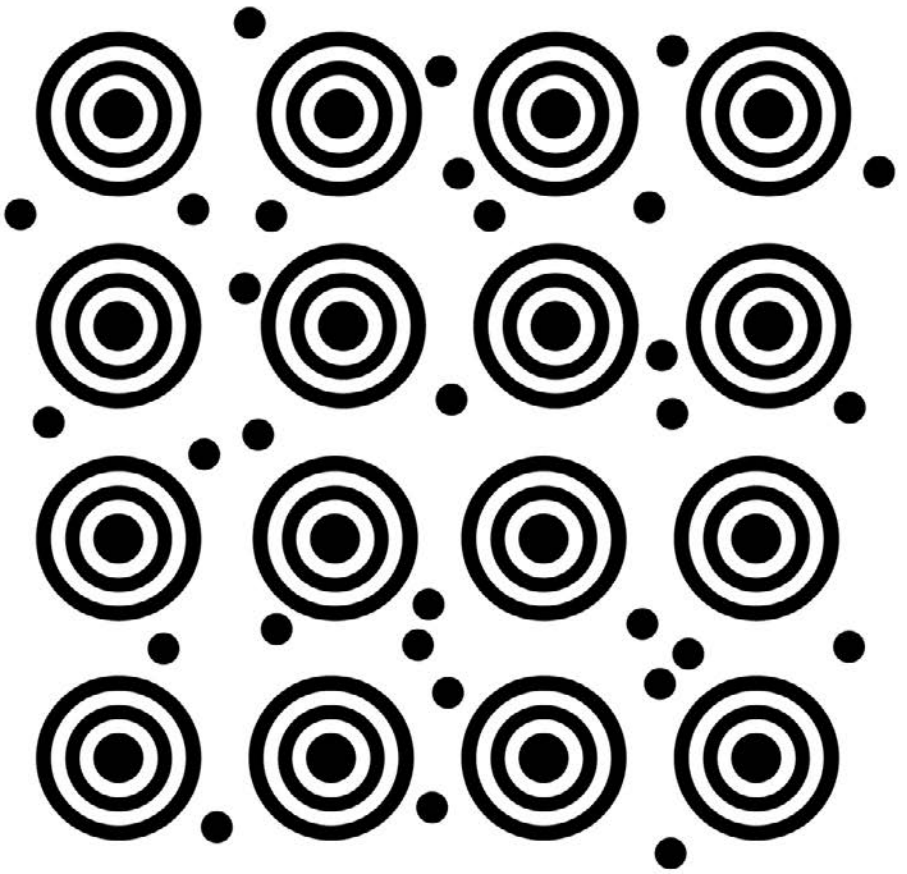
The Physics of Positivity: Visual Affirmations

Frédérique Swist

Force of attraction engages with the notion of particle attraction and concentration to form a dense and spherical centre. In this artwork the *positive* is proposed through the exploration of the associated concept of *attraction*, here understood and represented in a complex manner that references scientific notions and aesthetic forms of integration and structure, but also the emotional intensity of human interaction and desire.

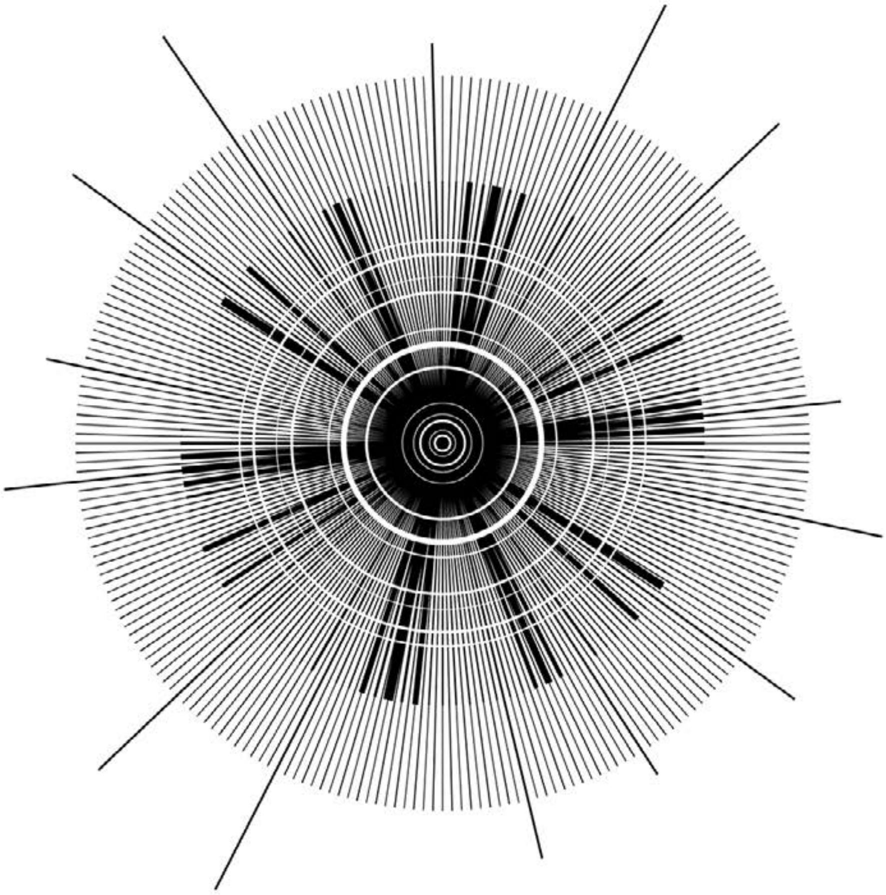
parallax
ISSN 1353-4645 print/ISSN 1460-700X online © 2010 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/13534645.2010.486667

Figure A3.14: *Parallax*, visual essay, p. 55.



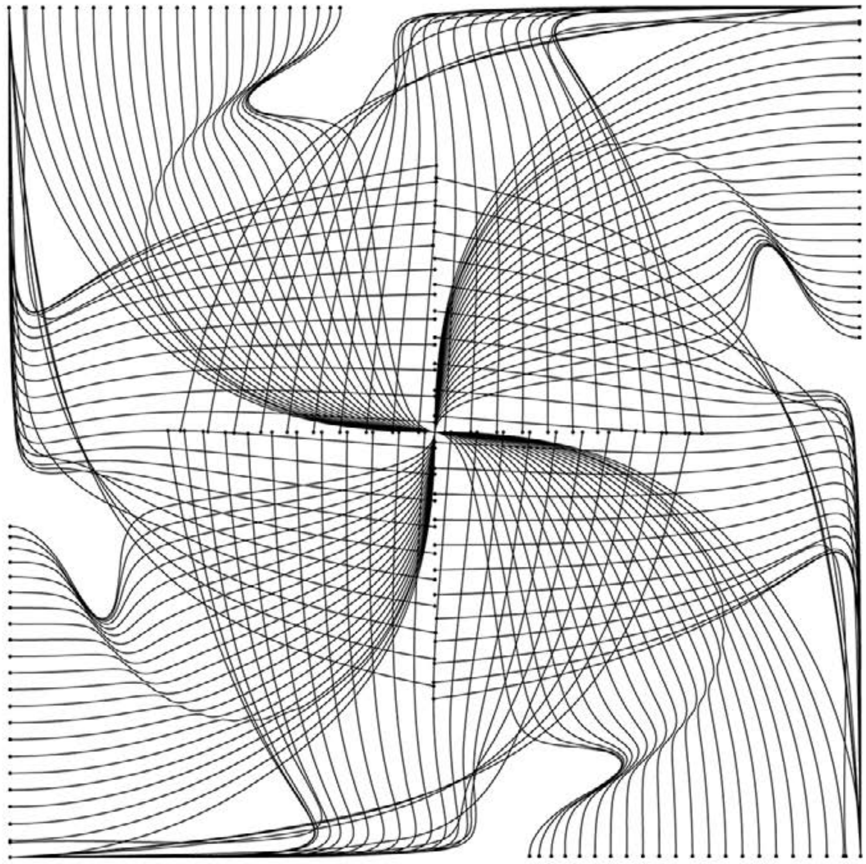
Positive ionisation uses a grid to capture the concept of atomic structures losing particles that have 'freed themselves' from their original bounds, leading to an imbalance of electric charge (or ionisation). Here the concept of *positivity* is challenged by a *positive* 'freedom' that is rooted in imbalance and excess: a freedom-to rather than a freedom-from that has long been the goal (or dream) of 'autonomous art practice'.

Figure A3.15: *Parallax*, visual essay, p. 56.



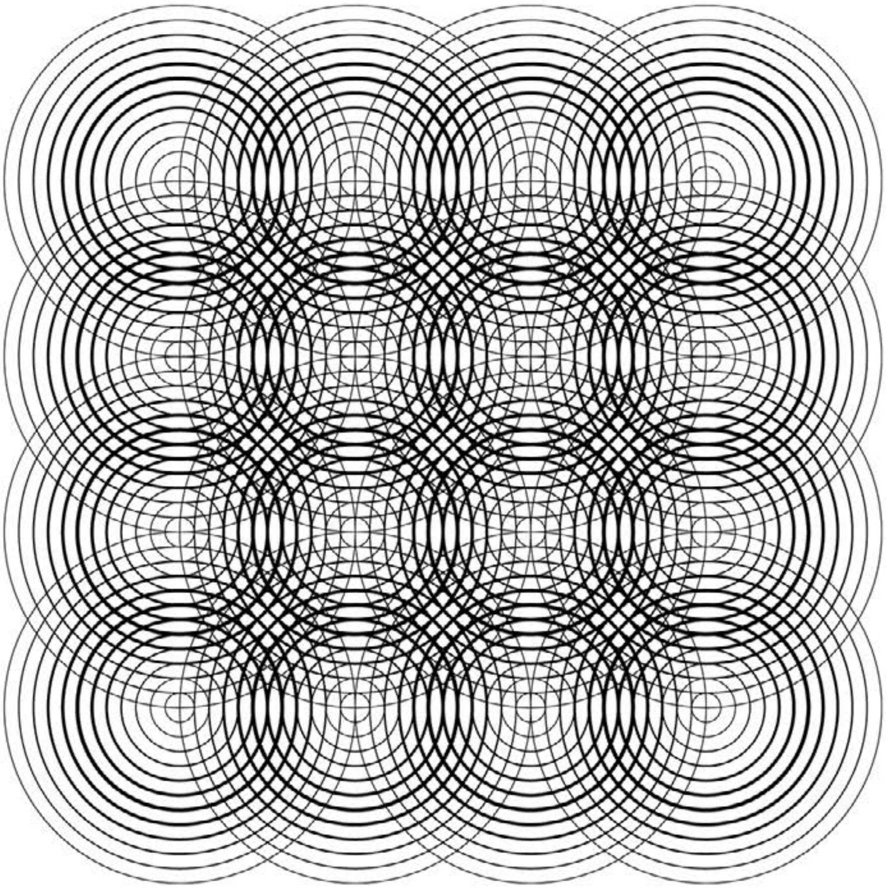
Particle remnants references grid systems and dislocated geometrical forms as often seen in imagery produced by complex mathematics and computing methods in particle physics. Although substantially transformed, its underlying source is located in the study of elementary particles and the head-on visualisation of collision events. The visual aftermath of such barely visible impactions are sub-atomic remnants figured positively here as charged linear traces. Of particular interest is the manner in which the physical dialectic of obliteration and creation produces, through a double negation, positively charged particles (*positrons*). A confirmation of Hegel's speculative production of the positive from the negative—the negation of the negation.

Figure A3.16: *Parallax*, visual essay, p. 57.



Positive temporal expansion is an attempt to think and configure *positivity* as an expansive spatio-temporal moment. It does this through the combination of elements drawn from graphs and diagrams studying the relation between the dimensions of the time and space continuum. Here *positivity* is rendered aesthetically as an expansive dynamic where temporal momentum and acceleration are mapped onto a delimited grid that, through the effect of framing, is intended to express containment while simultaneously affirming its overcoming.

Figure A3.17: *Parallax*, visual essay, p. 58.



Good vibrations refers to a system of a perfectly spherical and symmetrical grid to construct individual (but intertwined) sub-systems resonating and oscillating among one another. In this study, effects of resonance are associated with the concept of systematic arrangement which, as affect, takes on *positive* value as a visual rhythm intended to be experienced and 'felt' as a resonance that transcends the binarity normally associated with oscillation. The intention is to image an emergent affirmative rhythm that pulses independently of its positive/negative oscillatory source.

Frédérique Swist is a senior graphic designer for the science academic publisher IOP Publishing (owned by the Institute of Physics), and a PhD candidate at the University of the West of England, School of Creative Arts, Bristol.

Figure A3.18: *Parallax*, visual essay, p. 59.

A | 3 | 5 'Sphere of accuracies, zone of truth' visual essay

Peters, G. and Swist, F., 'Sphere of accuracies, zone of truth: art, science and neutrality' in York St John University, *Neutral* no. 1 (May 2009), pp. 10-13.

The following project was a collaboration with Professor Gary Peters, where I was asked to produce a visual contribution to his written work on the theme of *neutral*, *neutrality*. The project is discussed as a case study in chapter 3, pp. 106-108, while the following pages shows a reproduction of the published article (figures A3.19-A3.22).

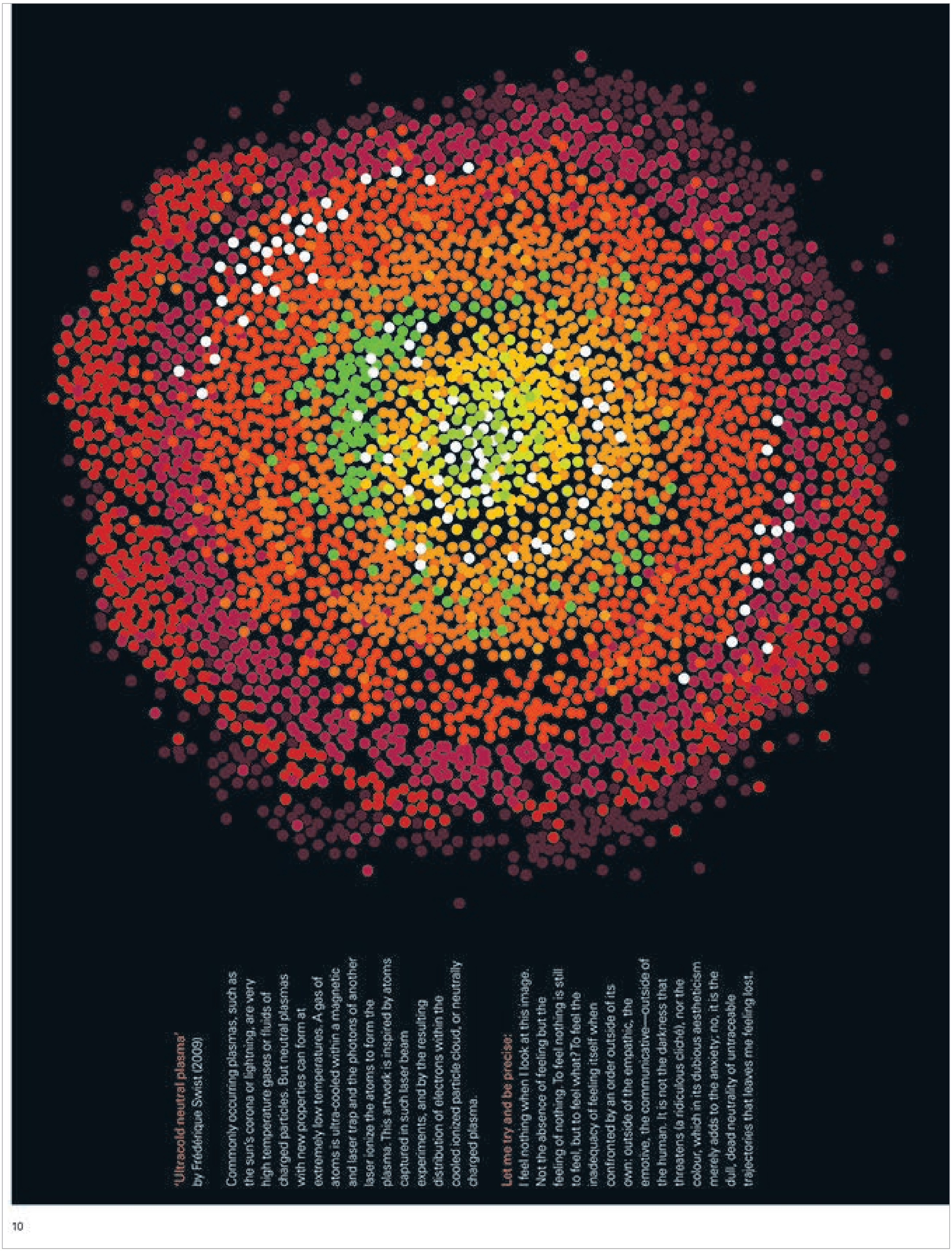
The final piece is presented in the form of four components:

a) The main essay written by Gary Peters: 'Sphere of accuracies, zone of truth: art, science and neutrality'.

b) The artworks: as a creative response or interpretation of notions to the given theme of neutrality, initially found in scientific research – however, not taking its root in a particular graph or technical diagram, but from the grasp of "remnants" of how neutrality is expressed in natural phenomena, such as cold plasma or the study of neutrinos.

c) The scientific captions to accompany the artworks: the accuracy of the technical description was carefully composed, giving some background and underlying connection to how the concept of neutrality is sourced in science and leads to the artwork.

d) The "alternative" captions: provided by Peters, from the perspective of the viewer, experiencing the imagery away from the concerns of the practitioner. These alternative notes offer the sense of a "liberated" interpretation, linking back to notions discussed in the main text.


'Ultracold neutral plasma'
by Frédérique Swist (2009)

Commonly occurring plasmas, such as the sun's corona or lightning, are very high temperature gases or fluids of charged particles. But neutral plasmas with new properties can form at extremely low temperatures. A gas of atoms is ultra-cooled within a magnetic and laser trap and the photons of another laser ionize the atoms to form the plasma. This artwork is inspired by atoms captured in such laser beam experiments, and by the resulting distribution of electrons within the cooled ionized particle cloud, or neutrally charged plasma.

Let me try and be precise:
I feel nothing when I look at this image. Not the absence of feeling but the feeling of nothing. To feel nothing is still to feel, but to feel what? To feel the inadequacy of feeling itself when confronted by an order outside of its own: outside of the empathic, the emotive, the communicative—outside of the human. It is not the darkness that threatens (a ridiculous cliché), nor the colour, which in its dubious aestheticism merely adds to the anxiety; no, it is the dull, dead neutrality of untraceable trajectories that leaves me feeling lost.

10

Figure A3.19: *Neutral* magazine, no. 1 (May 2009) p. 10.

Thought of the neuter or the neutral is a threat and a scandal for thought

Sphere of Accuracies, Zone of Truth: Art, Science and Neutrality

Gary Peters and Frédérique Swist

With a mission statement that commits not just to getting 'in amongst the debates of media and culture, but in between the spaces of debates', **Neutral** sets itself quite a task. Which media? Which culture? And what is the space between the spaces of debate? *Are* there spaces between spaces?

Are we talking about the culture that still seems to find a way of maintaining itself upon the shifting sands of cultural history, cultural studies and visual culture, or the culture that C. P. Snow saw as its other: the domain of science of, and to whom, it cannot speak? This is a different space, filled not with the noise of debate but the silence of the unknown.

Here (through lack of space) we are going to try to collapse these two spaces into one by heeding the advice of James Elkins[2] and interrupting the all-too-familiar textual and visual discourses of the literary and the aesthetic with the alterity of the scientific. Not, and here we part company with Elkins, in the name of an expanded 'visual literacy', but in pursuit of a radical *illiteracy* that, following Maurice Blanchot and his peculiar notion of 'research', will be associated with the neutral itself.

> *The unknown is neutral, a neuter...let us propose that in research—where poetry [art] and thought[science] affirm themselves in the space that is proper to them, separable, inseparable—the unknown is at stake; on condition, however, that it be explicitly stated that this research relates to the unknown as unknown...In other words, we are supposing a relation in which the unknown would be affirmed, made manifest, even exhibited: disclosed—and under what aspect?—precisely in that which keeps it unknown.*[3]

Perhaps, then, the opening of art to science should not be conceived in epistemological terms as the introduction of knowledge into ignorance - a Socratic prejudice as old as Western thought - but as the inauguration of a neutral space of unknowing that can be indicated, 'even exhibited', but not inhabited by either. Indeed, perhaps the undeniable explanatory power of science (so proudly waved in the face of art) has no ontological legitimacy at all. This is certainly how Heidegger sees it.

Propositions about "Science"

> *2. Accordingly, "science" itself is **not a knowing**, in the sense of grounding and preserving an essential truth. Science is a derived mechanism of knowing, i.e., it is the machinational opening of a sphere of accuracies within an otherwise hidden - and for science in no way question-worthy - zone of truth.*
>
> *3. What is "scientifically" knowable is in each case **given in advance** by a "truth" which is never graspable by science, a truth about the recognized region of beings. **Beings as a region** lie in advance for science, they constitute a **positum**, and every science is in itself a **"positive" science**.*

What and where is the space between art and science then if it is not to be located along the well-guarded borders between them as discrete disciplines? If science *itself* is 'not a knowing', then any 'debate' that might arise *between* its own inhabitants and the strangers from the aesthetic realm might be better re-staged not on the boundaries between the two, but, rather, in the neutral space that, it will be argued, inhabits both.

Heidegger considers two spaces, the 'region of beings' and the 'sphere of accuracies', the former a 'zone of truth', the latter a 'derived mechanism'. The intention is not to 'critique' science (pointless) but to remind it and us that the *difference* between explanation and knowledge is integral to, but ungraspable for, science itself. It could be argued, then, that it is precisely this absence at the heart of (or 'in advance' of) scientific self-presence that is obscured or concealed by the different 'mechanisms of knowing', including the institutionalisation of accuracy itself and all of its modes of operation and methods of articulation.

The felicitously named 'sphere of accuracies' describes a process of opening that is not only characterised by the 'machinational' governance of scientific method, experimental precision and institutionalised objectivity, but also, as the accompanying images and texts are intended to demonstrate, by what might be described as a hegemonic climate of rigour and, yes to say again, accuracy, one that leaves its mark on everything - including what you see before you, text and image.

11

Figure A3.20: *Neutral* magazine, p. 11.

As any marksman will confirm, the valorisation of accuracy concerns both an absolute respect for distance (the irreducibility of one space to another) and its obliteration. Here we are assuming or imagining a kind of intimacy (and perhaps this is true of all intimacy) that does not reduce the distance between this and that, but brings that distance to *life*. And to be alive to the irreducible distance between one place/zone/region and another is in effect to introduce a form of tactility into space that helps explain the common marshalling of metaphors such as 'feel' and 'touch' to articulate this apparent obliteration of the space between spaces. But to have a 'feel' for, or to be able to 'touch upon' the distance that differentiates one space from another is precisely *not* to grasp something and hold it firmly together. No, accuracy is a kind of discipline and training that does not hold together but, rather, allows those within the scientific community (whether scientists or not) to hold things steady, retain some stability and feel in touch with the neutral space that hollows out the different methodologies of their own self-articulation and legitimation, whether text or image.

Accuracy stabilises distance, what Heidegger would see as the distance between the derivativeness of accuracy itself and essential or founding truth, what scientists might see as the distance/difference within their own sphere, and the distance between science and its other - in this instance the aesthetic/art. Accuracy is not about truth but, rather, the ways in which different forms of communication within and beyond science strive to be true to the truth; an impossible fidelity that, like it or not, inevitably drives science towards the aesthetic. Scientists themselves acknowledge this to the extent that they accept the essential role played by metaphor in pretty much all human communication, scientific jargon included.

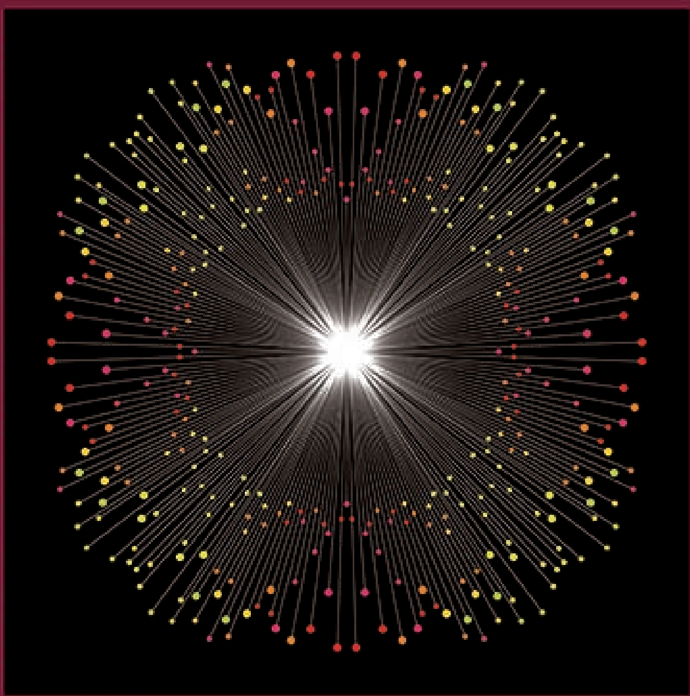
> *Scientists use metaphorical reason to interpret observational data, creating models to account for new observations and to reinterpret older data. Metaphors, once created and put to use in these ways, serve in communication between scientists and between scientist and the public. Metaphor is the vehicle by which ideas and models from one scientific discipline are transferred to another.* [5]

James Elkins has recently described such metaphors as 'wobbly'[6], 'feeble symbols'[7] that unsteadily stand-in for the virtually incommunicable data that distinguishes one branch of science from another and science from its surrounding (metaphor-happy) culture. Strictly speaking this may be true, but what is of interest for us here is not the wobbliness of individual metaphors but the discipline and rigour of metaphorical thought and practice within a sphere of accuracy that so effectively *conceals* its own feebleness. What is more, 'metaphorical reason', as Brown describes it, is not exclusively locked into its primary tasks of interpretation, translation and transference, it is also creative. Yes, a metaphor is a 'vehicle' but it is more than that, it does not only allow the traversing of spaces, it *creates* spaces - most of which are, at least in part, aesthetic. Paul Ricoeur rightly describes metaphor as the innovative 'power' to create new meanings, but it is not the new that concerns us here but the production of the new that leaves no trace in what is produced - the 'nothing' that he describes below:

> *As regards the metaphor itself, semantics shows with the same force that the metaphorical meaning of a word is nothing which can be found in the dictionary... So even if the metaphorical meaning is something more and other than the actualisation of one of the possible meanings of a polysemic word...nevertheless this metaphorical use must be solely contextual, that is, a meaning which emerges as the unique and fleeting result of a certain contextual action.*

'Neutrino trails' by Frédérique Swist (2009)
Neutrinos are mysterious sub-atomic particles with no electric charge and almost negligible mass. They come in three types or 'flavours', rarely interact with other matter and race through the cosmos at nearly the speed of light. Only a few of the billions of neutrinos constantly passing through every point on Earth leave their mark in huge detector experiments. This artwork refers to a neutrino interacting with an atomic nucleus in which an electron is ejected. The charged electron speeds away, emitting cones of light which tell of the neutrino's energy, direction and flavour.

Let me try and be accurate:
at the heart of the sphere of accuracies lies revelation, but not of the truth, only of the blinding light of accuracy itself. Every line in this image, so finely figured, every point so purposive in its position, explodes from a shimmering absence that is utterly cold—arctic articulation. It is not the light that dazzles (a ridiculous cliché), nor the colour, which in its fragile ephemeracy only adds to the blindness; no, it is the cold, callous neutrality of an ever-expanding pointlessness that leaves me shivering.



12

Figure A3.21: *Neutral* magazine, p. 12.

If, for us, the 'sphere of accuracies' is the context, then the 'unique and fleeting' metaphorical acts, that allow some form of communication to take place within an ever-emerging because ever-unstable textual or visual space, need to be prised-free from the metaphors themselves and the accuracy they aspire to, and recognised for what they are: the invisible, silent, absent movements across the neutral - the creation of the neutral.

This, perhaps, is where the 'two cultures' could and should become one. Not in the Heideggerian 'zone of truth' which, as a 'positum', is assumed by science and denied by art (Heidegger's ontology notwithstanding), nor in the negativity of sceptical reason that enjoys nothing more than to make everything wobble, but in the neutral space they share, where the neutral (the word/concept) is itself the (metaphorical) mark of its own absence, an otherness that cannot be reduced to the same, whether positive or negatively charged. In truth though the 'two cultures' will never become one, absolute estrangement is the fate and plight of the scientific and the aesthetic, not because of the space between them but, rather, the neutrality within them, the unknown that does not even allow them to know or be at one with themselves. But, having said that, perhaps the space between science and art, their difference, concerns above all the acknowledgement (or not) of the neutral. It is this difference that, to use Blanchot's words, marks the 'decisive importance' of art.

"literature"... sets itself apart from science... above all - here is literature's always decisive importance - by denouncing as ideological the faith that science, through an implacable allegiance and for its salvation, pledges to identity and to the permanence of signs

'Neutron stars coalescing' by Frédérique Swist (2009)
Artwork inspired by density and temperature distributions as two neutron stars coalesce. A neutron star is born in an explosion when a large star, 10-30 times the size of our Sun, uses up its nuclear fuel and shatters in a spectacular supernova event. Much matter is expelled as the outer gases disperse and floods of neutrinos are emitted. Under intense gravitational pressure some of the remaining matter collapses into neutrons to form the core of a new neutron star. Rare pairs of neutron stars orbit each other in ever decreasing spirals as they radiate away energy as gravitational waves.

Let me speak the truth:
the zone of truth is a lie, all we have is accuracy. When I look at this image I see a grid and then I see a hurricane blowing out of the bowels of Hell. The grid is this Hell: the Hell of accuracy itself. It is not the grid that controls and structures the hurricane (a ridiculous cliché), nor does the colour, in its saturating intensity, sweep away the forces of order; no, they both together entice me so willingly into the sphere of accuracies where the neutral remains as that which allows everything but itself to burn. Leaving me…? No, the neutral never leaves me.

1 Maurice Blanchot, The Infinite Conversation, University of Minnesota Press, 1993, p. 299.
2 James Elkins, Visual Studies: A Sceptical Introduction, Routledge, 2003.
3 The Infinite Conversation, p. 300.
4 Martin Heidegger, Contributions to Philosophy (From Enowning), Indiana University Press, 1999, p. 101.
5 T.L. Brown, Making Truth: Metaphor in Science, University of Illinois Press, 2003, pp. 184-5.
6 James Elkins, Six Stories from the End of Representation, Stanford University Press, 2008, p. 156
7 Ibid., p. xv.
8 Paul Ricoeur, Hermeneutics and the Human Sciences, Cambridge University Press, 1981, p. 180.
9 Ibid., p. 169.
10 The Infinite Conversation, p.312

13

Figure A3.22: *Neutral* magazine, p. 13.

A | 4 Appendix 4

A | 4 | 1 *Smartish Pace* poetry journal

Smartish Pace[1] is an independent scholarly journal, based in Baltimore, MD, USA, that celebrates contemporary poetry, publishing work from both up-and-coming and established writers. In January 2012, I was approached to contribute to the next issue with a visual for the front cover. Stephen Reichert, founder and editor of the journal, was introduced to my work through Jeff Lewandowski, a colleague publisher from IOP's editorial office, in Washington D.C.

An artwork from my catalogue was chosen for the front cover, but artistic differences soon emerged when the journal sent its proposed design. The imagery was applied into a particular style, which I was not expecting, having seen cover designs from previous issues. In my view, the suggested cover (see figure A4.1) seemed strongly reminiscent of the 1980s, where designers developed an early infatuation with large typeface databases newly made available to them in the first generation of Apple Mac's page layout software. Both the weak visual arrangement (there did not seem to be a justification for cropping the image in such as way, leaving it to run on the spine) and the poor typographic style (using up to four different styles), led me to negotiate a different design with the editor. After further discussion, I was offered the opportunity to refine and finalise the front cover. Revising the layout and typographical approach, I returned to the typography used inside, and adopted a sober visual arrangement. I then provided a new version (figure A4.2, p. 187) which was approved by Reichert in consultation with his team, and was adopted for no. 19 of the journal.

Figure A4.1: Initial cover proposal, suggested by the journal's in-house designer.

1 http://www.smartishpace.com/ [Accessed 3 October 2013].

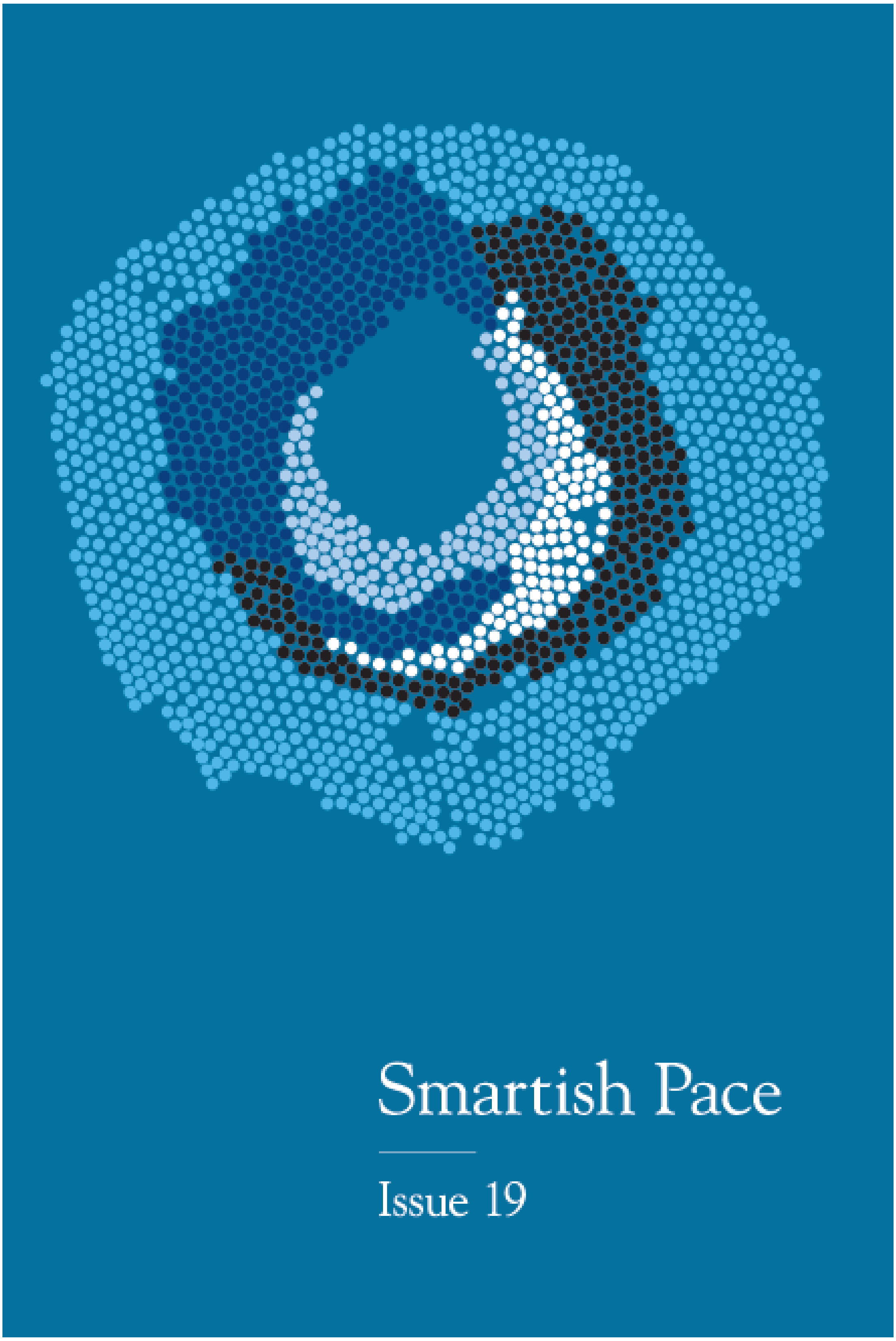


Figure A4.2: *Smartish Pace*, final cover design for no. 19 (2012).

Artist Profile

FRÉDÉRIQUE SWIST is an artist and a senior graphic designer for the academic science publisher IOP Publishing, owned by the UK Institute of Physics. She is also a researcher at the University of the West of England, Bristol, UK.

*Nanoparticle Gold Ring N*5* (2008) is an artistic interpretation of an electron microscopy image showing a ring structure of gold nanoparticles. This artwork is inspired by a figure from the article "Synthesis and Self-Organization of Au Nanoparticles."[1]

Over the years, Swist's artistic practice developed from her graphic design vocation. Her interests lie in the latest research in physics and the complex problems associated with the aesthetic visualisation of scientific concepts and phenomena related to extreme scale, distance and mathematical abstraction.

Excluded from the "communicative community" of experts for lack of a science background, Swist uses her unique perspective to prioritise the development of and adherence to a particular method of visualisation. This method, intended to be analogous to scientific concepts and phenomena, is thus capable of engaging artistically with them. Her artwork is inspired by imagery encountered in technical publications; through a series of negotiations, aesthetics judgements and visual transformations, Swist's process results in a vibrant body of work that inhabits the vestigial space between the representational and non-representational.

Swist has exhibited her work in Bristol, York, London, St. Petersburg and Budapest, and her pieces have been acquired by Aston University and York St. John University. In 2008, Professor Mervyn Miles of the University of Bristol's Centre of Nanoscience and Quantum Information commissioned Swist for a series, from which the cover artwork is a part.

1. Pyrpassopoulos, S., D. Niarchos, G. Nounesis, N. Boukos, I. Zafiropoulou, and V. Tzitzios. "Synthesis and Self-Organization of Au Nanoparticles." *Nanotechnology* 18.48 (2007): 485604. Print.

130 Smartish Pace *Artist Profile*

Figure A4.3: *Smartish Pace*, p. 130 with cover image details and artist profile.

A | 4 | 2 *Ink-dot* poster competitions

Ink-dot, founded by Steven Dawson, is a creative collective fully committed to graphic design and illustration. The group includes members from various sections of Bristol's creative industries. They organise regular exhibitions, promoting local (and connected) designers and illustrators, who all make artwork to a brief which is set by the group. The brief is designed to give the participants a starting point, from which they can then develop and interpret in their own style.[1]

The following set of posters (pp. 190-193) were created for submission to four subsequent *Ink-dot* competitions. Each poster responds to the set brief consisting of a keyword (providing the theme), a given number of colours and an output dimension.

The first design (p. 190), on the theme of "spare time", explores the notion of time and more precisely the absence of time in physics (i.e. time-independent phenomena found in quantum mechanics). The second poster (p. 191), based on the keyword "escape", investigates the behaviour of particles at the atomic scale, and the idea of particles "escaping" or releasing themselves from electro-magnetic forces. In the third poster (p. 192), with the given keyword "tonic", I slightly extended from the brief towards the related terms "tonal" and "tonality". Here, the idea of tonality refers to colours, proportional variations in their numerical values, and how a sequence within a grid may be constructed, using a set of six colours as a basis (located in white squares). In the fourth poster (p. 193), the brief was based on the theme of "resolution", and also required the use of an oval shape in the design. My interpretation is twofold: firstly, a decomposition of the keyword and its relation to a scientific concept (featured in the poster's caption). Secondly, I incorporated the oval shape in the design, after looking at scientific imagery of the universe (often mapped in an oval form), and the idea of a multiverse,[2] thus resonating with the notion of resolution. Each poster is accompanied by a caption or comment giving insight on how I interpreted the brief, as well as a list of related terms extending from the initial keyword.

1 http://www.ink-dot.co.uk/ [Accessed 3 October 2013].

2 http://en.wikipedia.org/wiki/Multiverse [Accessed 3 October 2013].

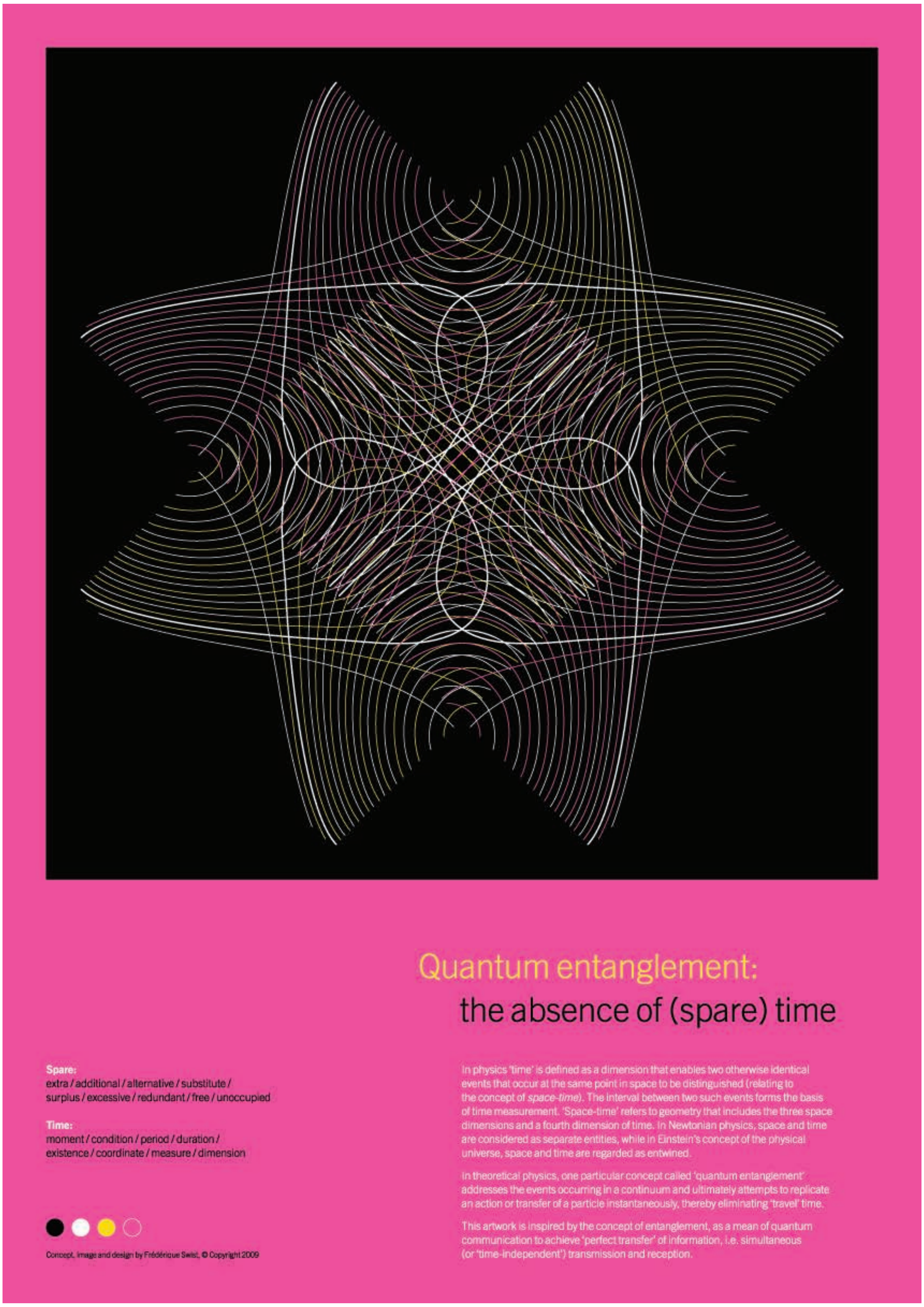


Figure A4.4: *Quantum Entanglement: The Absence of (Spare) Time* (2009), digital print, 594 × 420 mm.

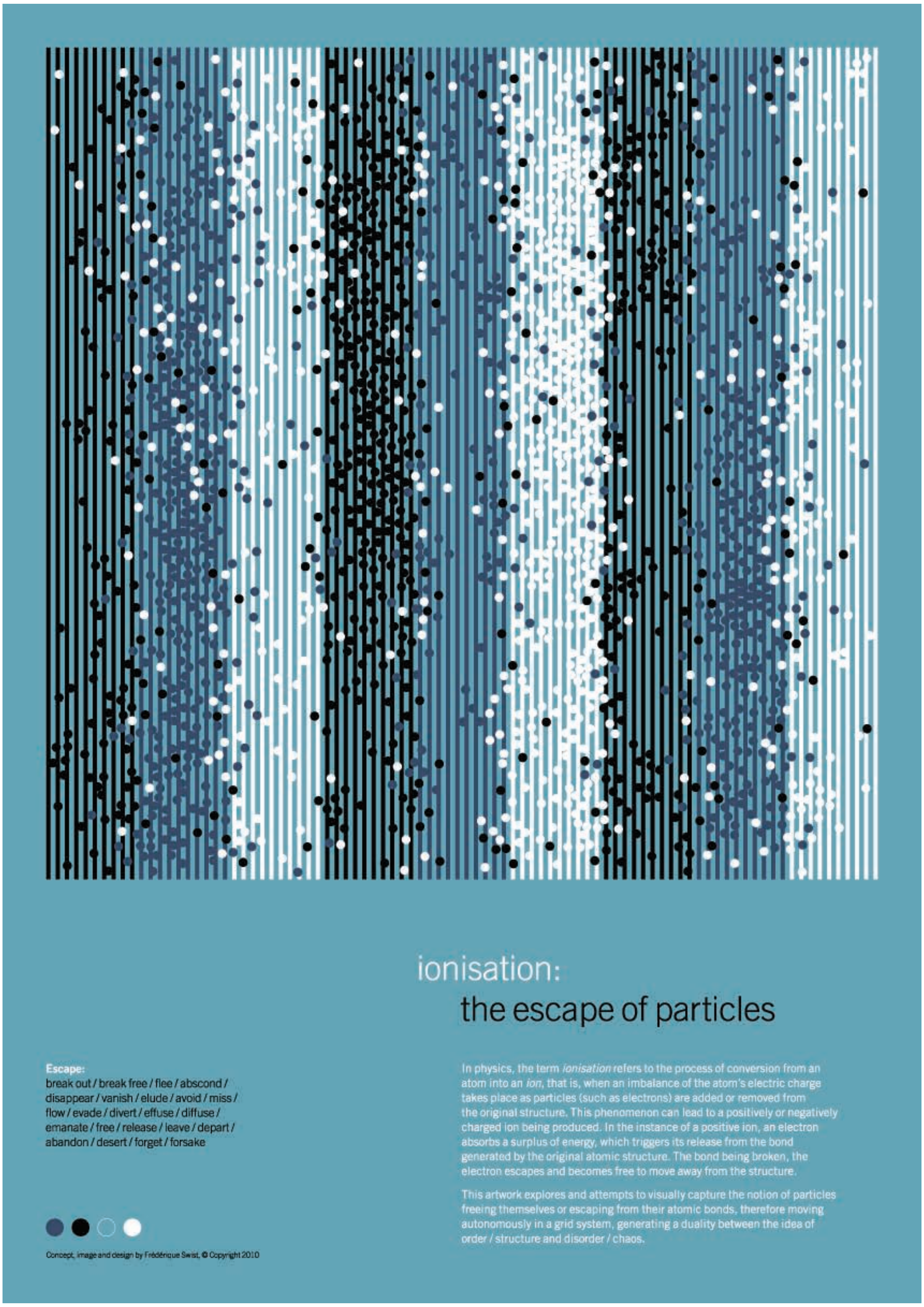


Figure A4.5: *Ionisation: The Escape of Particles* (2010), digital print, 594 × 420 mm.

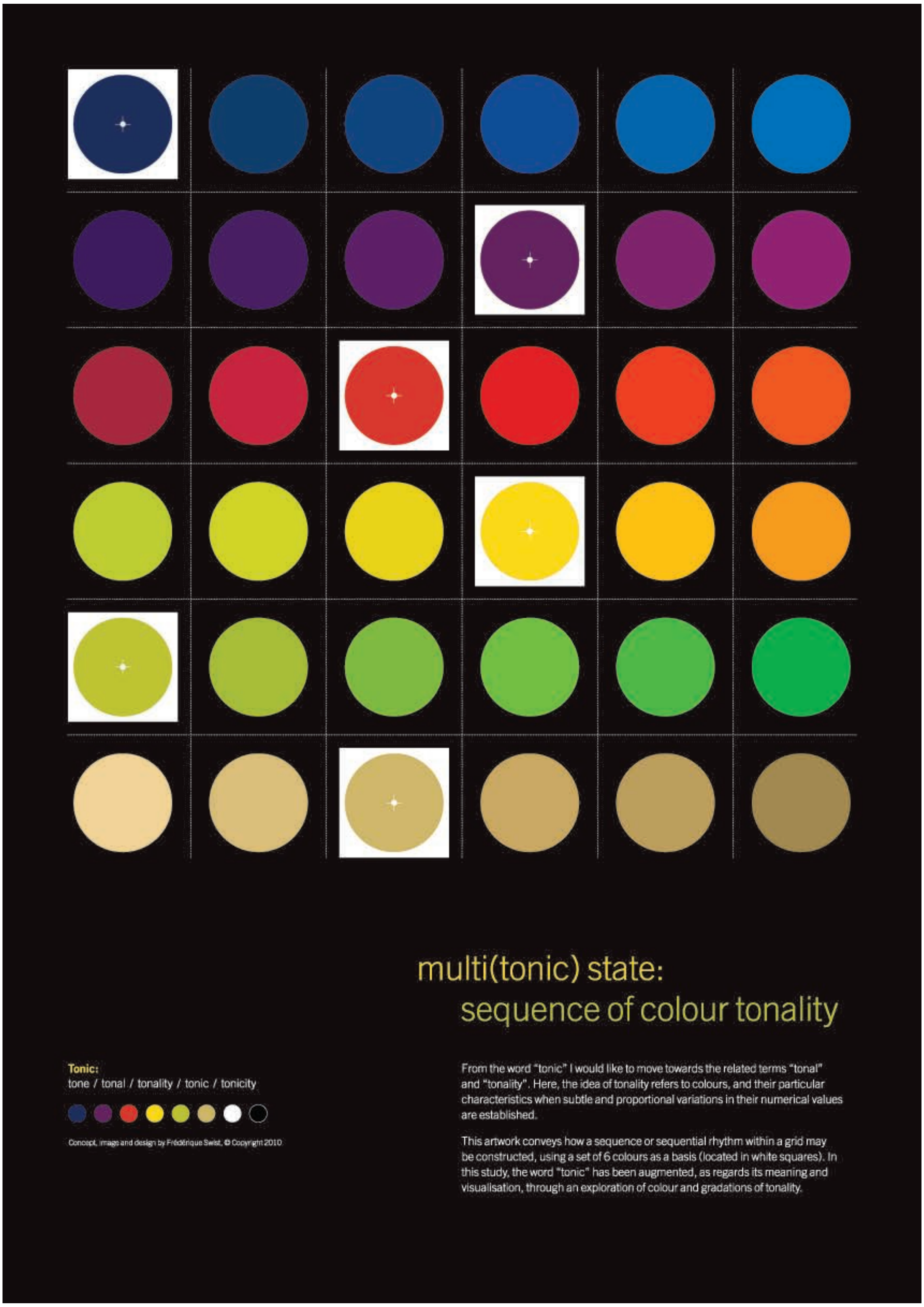


Figure A4.6: *Multi(tonic) State: Sequence of Colour Tonality* (2010), digital print, 594 × 420 mm.

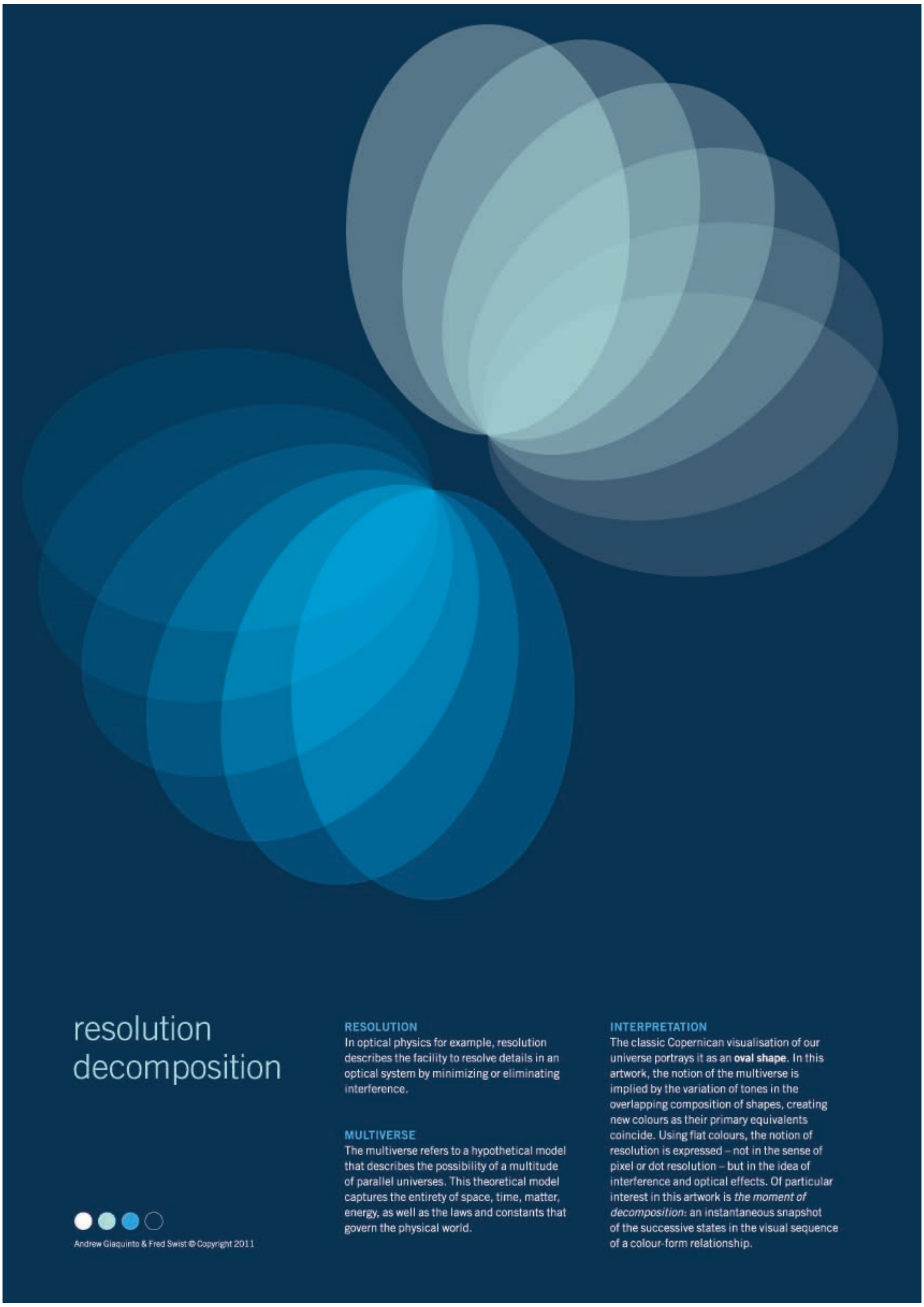


Figure A4.7: *Resolution, Decomposition* co-designed with Andrew Giaquinto (2011), digital print, 594 × 420 mm.

A | 4 | 3 *Novum* magazine

Moosmann, C., 'Science + Imagination' in *Novum* no. 1 (January 2008), pp. 50-51.

In 2008, the German design magazine *Novum* published a two-page profile on my design work for IOP Publishing. The article was presented both in German and English (although Germany-based, the magazine addresses an international audience in the creative industries). Christine Moosmann, Deputy Editor-in-Chief, commissioned the article after she had seen a selection from my portfolio. Instead of conducting an interview, written material was sent to her, along with visual examples. The article was part of a themed issue on information graphics. See pp. 195-196 for the article in its original page layout in the printed magazine, and below an extract from the magazine's mission statement:[1]

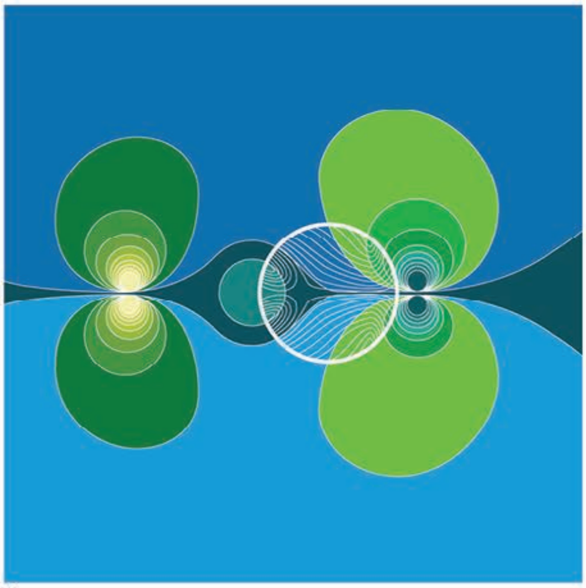
> *Novum – world of graphic design* is a monthly magazine featuring the best in contemporary graphic design, illustration, photo design, the new media, corporate design, advertising and typography. *Novum* also spotlights new talents and the latest trends. It presents a balanced mix of visions for the future and state-of-the-art-design to inspire all creatives in the world of international graphic design and advertising. Each month the *Novum plus* section takes a close look at a different field of design. With themes such as paper, animation film, trade fairs and education, these informative, up-to-date reviews make *Novum* even more collectible. The individual themes are looked at from the point of view of technical experts, clients and designers, making *Novum* an even more collectible and valuable source of reference for all those involved in design.

1 http://www.novumnet.de/en/service-contact/press/fact-sheet.html [Accessed 3 October 2013].

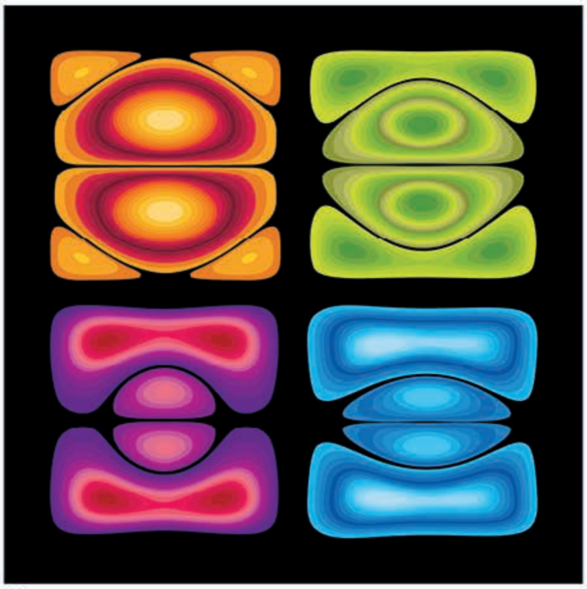
novum plus : orientation

FANTASIEVOLLE WISSENSCHAFT

Albert Einstein meinte: Fantasie ist wichtiger als Wissen, denn Wissen ist begrenzt. Mit ihren an der Physik orientierten Grafiken beweist Frédérique Swist, daß eine von der Wissenschaft inspirierte Kunst in der Tat neue Türen aufstoßen kann.



01



02

05

Zwischen Kunst und Wissenschaft bestand schon immer eine enge Verbindung: Künstler studierten Anatomie, um den Körper zu begreifen, Mathematik, um Perspektiven zu ermitteln, und Naturwissenschaften, um Licht, Raum, Zeit und Bewegung zu ergründen. Die Vertreter der Optical Art haben es Frédérique Swist besonders angetan und auch sie versucht, mit Hilfe der Physik neue Darstellungsformen zu erschließen, die sich zwischen Illustration, Informationsgrafik und Kunst bewegen.

Nach ihrer Ausbildung zog es die junge Französin nach England. Nachdem sie in verschiedenen Agenturen in London gearbeitet hatte, wurde sie schließlich im Jahr 2000 als Grafikerin am Institute of Physics Publishing in Bristol angestellt. Das IOP ist eine gemeinnützige Organisation, die sich der wissenschaftlichen Kommunikation verschrieben hat und Bücher, Magazine, Referenztitel sowie elektronische Medien publiziert. Und vielleicht mußte so viel Kontakt zu wissenschaftlichen Arbeiten, Diagrammen, Tabellen und Physikern irgendwann abfärben. Heute ist Frédérique Swist Senior Designer und experimentiert neben ihrer regulären Tätigkeit mit physikalischen Abbildungen, die sie wissenschaftlichen Arbeiten entnimmt, und überführt diese in künstlerische Darstellungen. »Mein Wissen über Physik ist begrenzt, doch ich sehe dies als Vorzug an«, sagt die Gestalterin. »Ich stehe oft mit Physikern in Verbindung, nutze ihr Wissen und profitiere von ihrem Vermögen, Sachverhalte in der Physik auf eine fesselnde Weise zu erklären.«

Mit ihren Arbeiten versucht Frédérique Swist einen Beitrag zur Kommunikation zu leisten und Wissenschaft aus einer ästhetischen Perspektive zu ergründen. So gibt sie physikalischen Phänomenen, die für Laien unverständlich sind und auch für die meisten Wissenschaftler lediglich in der Theorie oder unter abgeschlossenen Laborbedingungen existieren, ein Gesicht. Mittels Vektorgrafiken erschafft sie beispielsweise Darstellungen von quasikristallinen Oberflächen, laserimplodierten Zielen unter maximaler Kompression, doppelten Heterostrukturen oder Rydberg-Atomen, die in elektrostatischen und magnetischen Feldern mit Helium kollidieren. Mit dem Gestaltern eigenen Gespür für Formen, Farben und Dynamik gelingt es ihr, diese komplexen Vorgänge künstlerisch zu interpretieren und eine Bildsprache zu erschaffen, die wissenschaftliche Phänomene repräsentiert und dennoch eine eigene Faszination entfaltet.

Die »physikalischen« Kunstwerke von Frédérique Swist unterstreichen, daß unsere Welt auch auf molekularer und atomarer Ebene einen unendlichen Formenreichtum bereithält. Infografiken sind sie nur im weitesten Sinn, doch es gelingt ihnen, Gefühl und Intellekt gleichermaßen anzusprechen und uns die Schönheit eines abstrakten Faches vor Augen zu führen. *cm*

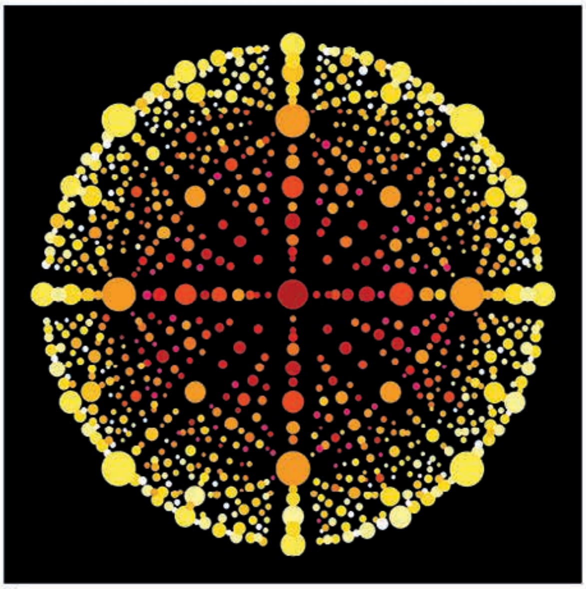
50 novum 01 /08

Figure A4.8: *Novum* magazine no.1 (January 2008), p. 50.

SCIENCE + IMAGINATION

Albert Einstein regarded imagination as more important than knowledge, because knowledge is limited. With her graphics on the subject of physics, Frédérique Swist demonstrates that art inspired by science can indeed open up new doors.

03



04

01 *Interpretation von spannungsgleichen Verläufen eines Paares von Dipolen entlang der Querrichtung / Interpretation of equipotential plots for a pair of dipoles along the transverse direction*
02 *Interpretation von Wirbeln, die unter dem Einfluß eines elektrischen Feldes in einem Microkanal entstehen / Interpretation of vortices froming in a fluid under the influence of an electric field in a microchannel*
03 *Interpretation eines Phasenraums im Niedrigenergiebereich für das Hybrid-Fermi-Ulam-Bouncer-Model / Interpretation of a phase space in the very low energy domain for the Hybrid-Fermi-Ulam-Bouncer model*
04 *Interpretation eines angereicherten Musters an einem Kristall-Feuchtigkeits-Interface / Artistic interpretation of a rich pattern seen at a crystal/humidity interface – a striking phenomenon in the physics of liquid crystals*
05 *Broschürentitel, Flyer und Werbeprospekte / Brochure cover designs, flyers and marketing leaflets*

There always was a close relationship between art and science – artists studied anatomy for a better understanding of the body, mathematics to grasp perspective, and natural sciences to gain insights into the interrelationship of light, space, time and movement. Frédérique Swist is particularly attracted to the exponents of Optical Art, and she is now also venturing, with the help of physics, to open up new forms of representation, at the interface between illustration, information graphics and art.

After finishing college, the young French woman moved to England, where she worked for various agencies in London before starting in 2000 as a graphic designer at the Institute of Physics Publishing in Bristol. The IOP is a not-for-profit organisation dedicated to science communication, publishing books, magazines, reference titles and electronic media. All this contact with scientific work, diagrams, tables and physicists has had a strong influence on Frédérique, now Senior Designer at the publishers. For in addition to her paid employment, she experiments with physics illustrations taken from scientific works, turning them into artistic representations. »My knowledge of the subject of physics is limited, but I use this as an asset in my work,« says the designer. »I often liaise with physicists, use their knowledge to define the meaning of each artwork, and benefit from their expertise in explaining aspects of physics in a more engaging way.«

Frédérique Swist sees her work as a contribution to science communication, and as a way of giving science an aesthetic perspective. She gives a face to physical phenomena which are hard for lay persons to understand, and which for most scientists only exist in the theory or under closed laboratory conditions. Using vector graphics she creates representations of quasicrystal surfaces, laser-imploded targets at maximum compression, double heterostructures, probing Rydberg atoms through collisions with helium in the presence of static electric and magnetic fields. With the designer's feeling for form, colour and dynamics, she succeeds in giving an artistic interpretation to these complex processes and generating an imagery that represents the scientific phenomena while also unfolding its own unique fascination.

The »physical« artworks of Frédérique Swist show that our world has an endless fascination of forms at molecular and atomic level, too. Only in the broadest sense can they be described as infographics, appealing as they do to both feeling and intellect and opening our eyes to the beauty of this abstract subject. *cm*

www.iop.org

01 / 08 **novum** *51*

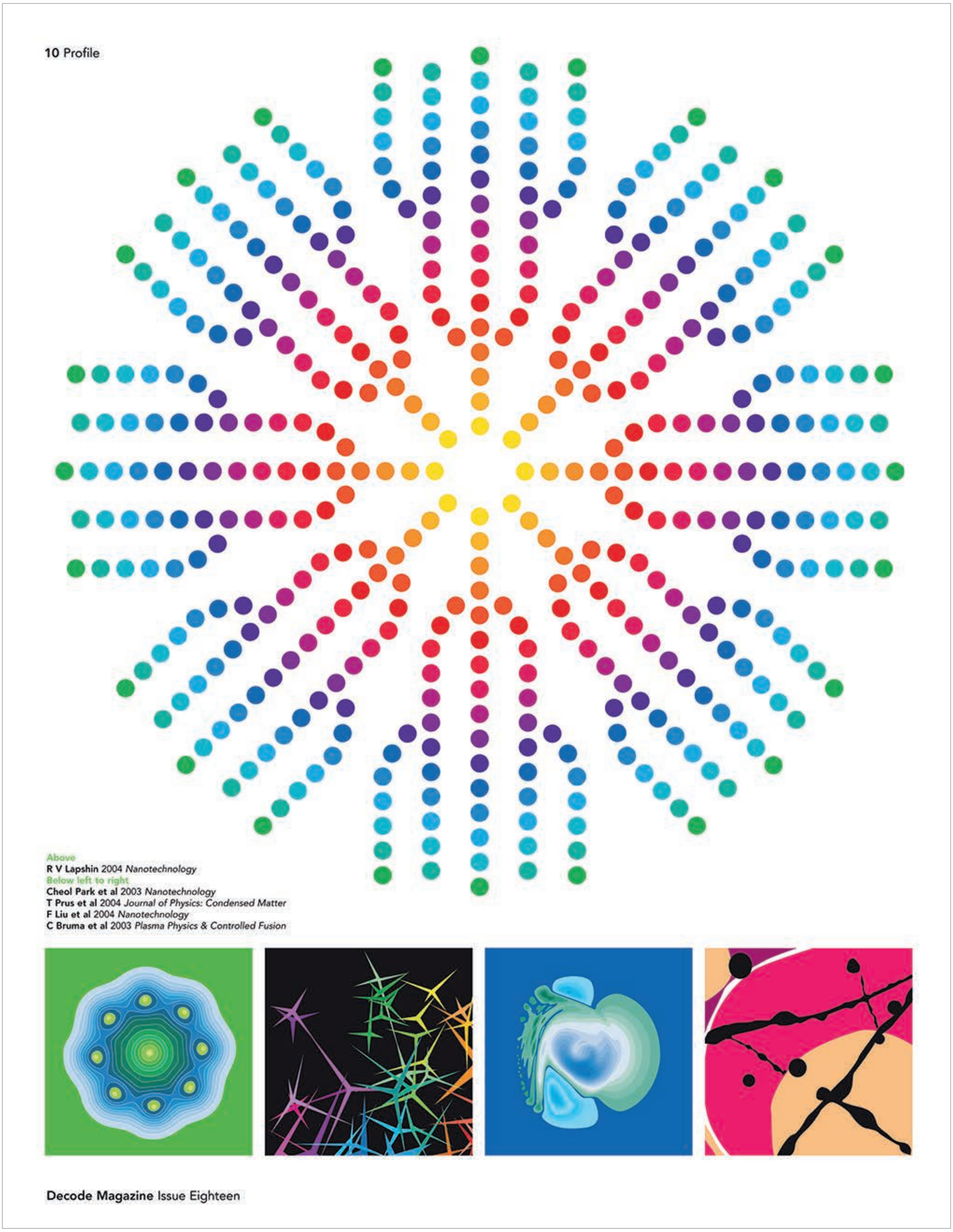
Figure A4.9: *Novum* magazine, p. 51.

A | 4 | 4 *Decode Magazine*

Stackpool, G., 'Profile: Frédérique Swist' in *Decode Magazine* no.18 (April 2005), pp. 10-11.

In 2005, an article was published in *Decode Magazine*, featuring a range of artworks and an interview by Gabrielle Stackpool. *Decode*, founded by Gabriel Solomons, ran between 2003 and 2008, as a platform for the creative and cultural scene in Bristol and Bath, celebrating new talents in writing, poetry, illustration, design and the arts. See pp. 198-199 showing the double-spread article in the magazine's page layout. The magazine no longer exists, but the article is available online, through Intellect Publishing's website.[1]

1 http://www.intellectbooks.co.uk/repository/view-Article,id=307/ [Accessed 3 October 2013].


10 Profile

Above
R V Lapshin 2004 *Nanotechnology*
Below left to right
Cheol Park et al 2003 *Nanotechnology*
T Prus et al 2004 *Journal of Physics: Condensed Matter*
F Liu et al 2004 *Nanotechnology*
C Bruma et al 2003 *Plasma Physics & Controlled Fusion*

Decode Magazine Issue Eighteen

Figure A4.10: *Decode Magazine* no.18 (2005), p. 10.

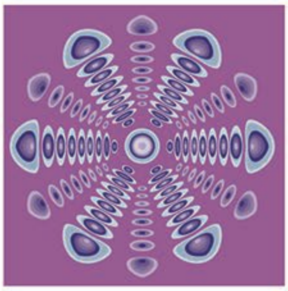
11 Profile

FRÉDÉRIQUE SWIST DESIGNER

WHO'S WHO

THE BRISTOL ARTIST THAT'S HELPING TO RAISE THE PROFILE OF PHYSIC'S THROUGH HER VIBRANT WORK SHARES SOME OF HER SECRETS

WORDS BY GABRIELLE STACKPOOL



Top **Jong-Hwan Yoon and Sang-Joon Lee** 2003 *Measurement Science & Technology*
Above lt/rt **O A Shenderova et al** 2001 *Nanotechnology* / **C Gray et al** 2004 *Reports on Progress in Physics*

At first The Institute of Physics Publishing in Bristol seems like an unlikely place to find one of Bristol's most prolific and interesting designers. But Frédérique Swist, senior designer at the Institute is proof that the relationship between art and science is flourishing and that the two disciplines are inextricably linked. From the Egyptian pyramids through to Georges Seurat who studied the physics of colour as an art student in Paris, and more recently Andy Goldsworthy who manipulates science and nature to make us see things around us that were there all along, it's a relationship that has produced the world's greatest artists and artworks.

Frédérique works in collaboration with her Art Director Andrew Giaquinto with support from her Managing Director Jerry Cowhig, and in the last three years she has been experimenting and developing her work.

The Institute's core business is publishing academic journals for international research centres and universities; however an important objective is to raise the profile of physics within the community and Frédérique's images are helping by illustrating journal covers, posters, publicity material, and by making the messages more accessible to the community. "We want to reach out to people" explains Andrew "like texting for example, everyone uses it, and its changing language, and its all come about by the application of physics."

So, where do the images come from? "I start with a graph, or scientific image or drawing from a journal" Frédérique says as she flicks through a rather scary looking mathematical text book, "and I look for a drawing which is visually attractive and would work outside of the context of the book. Then I digitally manipulate the colour, shape and composition so I arrive at something which is quite a change from the original image." The original image could be a line drawing of a physics experiment or from a photo taken under a neutron microscope; what emerges is a beautiful, striking, compositionally perfect print. As Frédérique says "The subject matter is usually invisible to the naked eye, and through graphic manipulation we allow the eye to travel through a scientific journey, thus appreciating and discovering the subject from a different perspective". "I like to include a reference to the original subject matter so that people can appreciate where it came from," she says. The images have a rather psychedelic quality to them, like looking at a particularly brilliant kaleidoscope. "Yes" laughs Frédérique "they do have that 60's psychedelic feel to them." We both agree that they would make great textile prints, so it's no surprise that she is also involved in fashion illustration and website design.

You can see Fred's work for yourself (by appointment) at the Institute of Physics headquarters in Portland Place, London in the form of seven limited edition prints, one of which was selected for the Print Exhibition 2004 at The Royal West of England Academy in Bristol. ●

You can contact Frédérique at the Institute of Physics Publishing at Temple Back, Bristol, Tel 0117 930 1075, email fred.swist@iop.org for more information

Decode Magazine April 2005

Figure A4.11: *Decode Magazine*, p. 11.