That Obscure Object of Desire: Some Notes for a Slow Art-Science

Silvia Casini
University of Aberdeen

Abstract: Although not a book that can be labelled as "art-science", the novel *Atlante Occidentale* (1985), published in English as *Lines of Light*, was conceived by the Italian writer Daniele Del Giudice during a fieldwork visit at the CERN laboratory in Geneva in the early 1980s. The two protagonists, the writer Ira Epstein and the physicist Pietro Brahe, have a common obsession: the drive to experimentation. Both characters seek to create new tools (machines) out of existing material for understanding reality – Pietro a particle collider, Ira the written word. As I argue in the article, *Atlante Occidentale*, a work of fiction, makes a point which should be at the core of any attempt to better understand art-science collaboration: art and science are both ways of world-making.
The article provides readers with a brief overview of the mainstream narratives on and in art-science collaboration and suggests a series of strategies apt for challenging those narratives. First, I argue that experimentation rather than creativity is the glue making any collaboration between art and science possible. Second, I show the importance for both scholars and artists of carrying out laboratory fieldwork and archival research to access science in the making and, hence, to engage in potentially transformative art-science collaborative work. Finally, I call for a radical rethinking of the scale and syntax of art-science projects given that some of the most successful models of such collaborative endeavours are in deep crisis.

Keywords: art-science collaboration; experimentation; fiction; art-science *amateurs*.

Submitted: October 30, 2022 – **Accepted:** November 25, 2022

Corresponding author: Silvia Casini, University of Aberdeen, Dept. of Film and Visual Culture, King's College, Aberdeen, United Kingdom. Email: silvia.casini@abdn.ac.uk

T/S TECNOSCIENZA
Italian Journal of Science & Technology Studies

1. Where Art and Science Collide

> All my life, all my work has been nothing more than connecting people to objects, and objects to experience and feelings, to self-perception, to ideas. Perhaps what I have invented so far is nothing more than a special lens, which allows you to see the background and the figure in their relationship, with equal dignity. As a boy you will have been brought up for math, or science. I had an aptitude for people. (Daniele Del Giudice, *Atlante Occidentale* 1985, 62)

The novel *Atlante Occidentale* was conceived by the Italian writer Daniele Del Giudice during a fieldwork visit at the CERN laboratory in Geneva in the early 1980s. First published in 1985 in Italian and then in English as *Lines of Light* (1988), the book has been re-published by the Italian editor Einaudi and enriched by fieldwork notes jotted down by the author. The fieldwork visit took place in the context of the art and science programme *Arts at CERN* that still hosts a series of artist-in-residence projects in the world's largest and most respected centre for scientific research. The first CERN artist-in-residence was the performer James Lee Byars who spent a few Summers at CERN during the 1970s, a stay documented by a few black and white photographs.[1] It is unknown to many, though, that Daniele Del Giudice spent a period at the nuclear research facility in the early 1980s with the purpose of writing a book. The above passage hints at some of the themes and methods that pertain to both art and science: discovery, originality, relational thinking, self-reflexivity, a Gestalt principle of visual perception, the dualism between the qualitative and the quantitative dimension, which is, according to Newfield (2019), how the old dualism between art and science manifests itself.

"Where Art and Science Collide" is the tagline of the Science Gallery international network whose mission is "to ignite creativity and discovery where science and art collide".[2] In the industrialised, economically stronger part of the world, prestigious research institutions, foundations and universities (such as the Wellcome Trust, CERN, the MIT Media Lab, SymbioticA, Laboratoria Art&Science Space, the Science Gallery Network) have been actively supporting art-science programs and initiatives aimed at engaging the lay public with scientific research and science advocacy. The book by Daniele Del Giudice too is about a literal rather than metaphorical collision. The narrative is organised around a chance encounter between an old writer, Ira Epstein, and a young physicist, Pietro Brahe, both amateur pilots. Two cultural matrices, the humanistic and the scientific, avoid a collision (two small aircraft piloted by the two main characters, Pietro Brahe and Ira Epstein, respectively, almost clash in the opening pages of the book). The failed collision is, nevertheless, the engine that kicks off the narrative. Del Giudice's novel was not meant to be about art-science, yet the violent impact avoided at the last second between the two aircraft, an impact that does not literally occur, opens up the space for a different relationship between the two universes embodied by the protagonists, the world of art (literature included) and that of science. All interactions in the book are anticipated by this first collision, followed by a series of other collisions, such as the one of the underground ring functioning as particle accelerator, and by the imagination of Epstein that creates collisions among words, objects, perception, and action.

Atlante Occidentale is concerned, first and foremost, with language and vision, the two infrastructures that lie beneath art and science. Pietro Brahe monitors streams of protons as they speed around a huge thirty-km ring. His desire is to be able to overcome the limits of his human sensorial apparatus and "see" directly the essence of matter after each experiment, that is the *quid* that the technologies, first, record and then, convey into the form of electronic graphing on the computer screen. In contrast, Ira Epstein has almost given up writing: he cannot write anymore because he "sees" stories – they unfold as pictures in his imagination, unmediated by preconditioning linguistic conventions. Del Giudice's novel attempts to experiment with – if not to combine – a poetic language and the technical precision of a prose devoted to describing an experiment in its unfolding or the breath-taking spectacle of fireworks. As the literature scholar Franco Ricci puts it, through his writing Del Giudice seeks to find a synthesis between the humanistic and the scientific thinking process by asking questions such as:

> What direction will poetic language take when bombarded by scientific specificity? Can such a hybrid language meet the exigencies of the world? (Ricci 1990, 46)

Although not a book that can be labelled as "art-science", *Atlante Occidentale* is an example of a fiction book that should be read by anyone interested in the culture of experimentation across the arts and the sciences. This novel has become a north star during the research, curatorial work and writing I undertook for my own book, *Giving Bodies back to Data*, published in 2021 in the Leonardo art-science series of the MIT Press. The dialogues and encounters between the two protagonists, the young particle physicist Pietro Brahe and the old writer Ira Epstein, showed me how the solid world of magnets, cables, and electronic circuits can suddenly reveal an elusive world of impalpable and invisible phenomena to which artists can give a form.

My present reflections are grounded in extensive work I have conducted both as researcher and as curator of art-science projects. For almost a decade I have been working on the epistemological, aesthetic and historical role played by data-visualisation practices across contemporary biomedicine, neuroscience and the arts (see Casini 2017; 2021a and 2021b). In this article I seek to provide readers, first, with a brief overview of the mainstream narratives on and in art-science collaboration and, second, with a series of strategies apt for challenging those narratives, using a set of tools coming from the science and technology studies (STS) toolbox and from historical epistemology. I argue that experimentation rather than creativity is the glue making any collaboration between art and science possible. Furthermore, I show the importance of carrying out laboratory fieldwork and archival research to access science in the making and, hence, to engage in potentially transformative art-science collaborative work. Finally, I call for another scale and syntax for art-science projects, given that some of the most successful models of such collaborative endeavours are in deep crisis.

In relation to this last point, one should remember how just a few months ago, the closure of Science Gallery Dublin was announced because the "operational model has run its course".[3] At the time of writing, there is an online public petition for saving SymbioticA, the "artistic laboratory dedicated to the research, learning, critique and hands-on engagement with the life sciences".[4] This space is also under threat of imminent closure by the decision of the University of Western Australia to withdraw its financial support. Although the crisis of such venues might be motivated, on the one hand, by the uncertainties of the present world (such as the global pandemic and the socio-economic consequences of the Russian invasion of Ukraine started early 2022) and, on the other, by the failure of run-as-corporation higher education institutions to provide sustained support for such initiatives, the model of art-science collaboration might need a profound rethinking. Another scale and syntax for art-science projects can emerge from the less structured, tentative, slower-paced approaches to setting up collaborative projects.[5] This type of art-science collaboration would benefit science research communities in a way quite different from the well-established public engagement activities and scientific literacy initiatives that are often wrongly labelled as art-science. My contribution is an invitation to artists and scholars to experiment with ways of better articulating the work of imagination, affectivity and craftsmanship in science practice. By doing so, one would help cultivate a community of science "amateurs" and "connoisseurs" (Stengers 2018) which could be nurtured in the guise of what happens already in the circuits of music and the arts.

2. Experimentation Rather than Creativity to Challenge Dominant Art-Science Narratives

In Del Giudice's novel, Ira Epstein and Pietro Brahe could not differ more. Yet, they have a common obsession: experimentation and the drive to describe the world using different instruments. Pietro tries by exploring subatomic particles inside an underground ring dug under the Jura mountains; Ira is an analytic weaver of stories. Both characters are seeking to create new tools (machines) out of existing material for understanding reality – Pietro a particle collider, Ira the written word. *Atlante Occidentale* implicitly makes a point which should be at the core of any attempt to better understand art-science collaboration: art and science are both ways of world-making.

The value of experimentation rather than creativity is often undermined by art-science literature and projects that are still framed by certain dominant narratives. The bourgeoning field of Art, Science, and Technology Studies (ASTS) is preceded by seminal research on art and science carried out by researchers in history of science and art, visual culture, image science and STS (Bredekamp, Dünkel and Schneider 2015; Daston and Galison 2010; Elkins 2008; Grau and Veigl 2011; Jones and Galison 1998; Latour and Weibel 2002). As Rogers and Halpern argue in their "Introduction" to the *Routledge Handbook of ASTS* (2021), it is crucial to examine the dominant narratives underpinning our understanding of art-science.

The first narrative is the two-cultures metaphor which:

> became the standard way of talking about the relationship between art and science, even though what constituted these cultures did not remain static. (Rogers and Halpern 2021, 44)

This narrative originates in the Rede lecture (entitled *The Two Cultures*) given in Cambridge by the British scientist and novelist Charles Percy Snow in 1959 and then turned into the well-known book *The Two Cultures and the Scientific Revolution* (1964). Snow lamented the rift between literature and science education and suggested possible means of developing a mutual understanding. The two-culture divide narrative is characterised by the tendency to consider art and science, respectively, as monolithic ahistorical entities, without considering the variety of practices and traditions present in each of them. This narrative is often followed by a call for the arts and humanities to justify their existence by partnering with the sciences.

The second narrative relies on the myth of the lone genius, an idea present both in the context of science and literature but particularly encouraged in the arts. According to this myth, all power, recognition and agency must be given to an individual, with great talent and intellect, without paying much attention to wider socio-technical infrastructures – as well as surrounding economic, epistemic and political conditions – that enable (or not) invention, discoveries and innovative experiments to take place.

Finally, it is worth mentioning the instrumentalism and parasite metaphor which sees science playing the role of the muse for the arts: this narrative becomes dominant also because too often artists' engagement with science is limited to remediating the final products of the scientific laboratory work such as the images and data-visualisation produced during an experiment or by a certain technological apparatus. An example of such use is artists incorporating brain scans in their work without questioning the status of these image-data. Only a few artists engage with science by using its instruments, the tools, created or used by scientists to produce their outputs. This is a more challenging pathway that requires scientific knowledge, technical skills and infrastructural capacity such as that available in the SymbioticA Laboratory.

To further deepen the understanding of the origin of the art-science rift, one should go to the 1830s, when the term scientist was coined in analogy with the term artist, and the two replaced the early modern "Renaissance Man", whose knowledge was expected to be universal rather than discipline specific (Jones and Galison 1998). The art historian Jean Clair, who curated the exhibition *L'âme au corps: Arts et sciences 1793-1993* (Galeries nationales du Grand Palais, Paris, October 1993-January 1994), laments that the divorce of art and science, which he frames as "spiritual catastrophe", is caused by two circumstances. First, since Romanticism art has given away the monopoly of objectivity to the sciences, keeping for itself only the soft hypertrophy of the ego that characterizes the self-styled genius of the artist. Science, conversely – lost in its graphs and fragmented specialties – has cut itself off from the real world:

> But once the sciences have occupied the various fields of knowledge with their authority, the artist, kicked out from a kingdom he once shared on equal terms and sent back to the empiricism of the craftsman ("stupid as a painter"), the artist cannot help but give himself to soliloquy or prophecy, in search of a status but also of a lost profession. (Clair 2016, 16)[6]

Clair uses the tools offered by art history to demonstrate that this divorce has been only a momentary split. As an example, referring to the drawings of the neurons made by Santiago Ramón y Cajal (1852-1934), regarded as the father of the modern neurosciences, Clair demonstrates how drawing, in particular, has always been in a dialogue with science. With tremendous talent for drawing, Cajal was able to create detailed drawings of the structure of the nervous system observed through the microscope, formulating a theory of the brain as an organ comprising individual nerve cells, the neurons. Rather than simply beautiful visualisations, his drawings provided information (DeFelipe 2010).

Although art-science cross-fertilization is nothing new (Kemp 2005), recent decades have seen an increase in artists challenging the split between the two cultures of science and humanities, creating works that, in some cases, are experiments conducted using the tools, methods, and aesthetics associated with scientific practice.[7] The fact that collaborative projects are increasingly popular softens Clair's pessimism in relation to the possibility of a dialogue between art and science. Nevertheless, his attention to drawing and craftsmanship, that is the belief that art has to do with skill and talent acquired through study and practice, is useful to move away from the Romantic idea of the creative genius. Both the work of Peter Galison (1997) on the traditions of theory, experimentation, and instrument-building within physics and that carried out by Knorr-Cetina (1999) on the epistemic cultures of molecular biology and high energy physics have already highlighted the existence of different communities within science, thus dismantling a monolithic understanding of science practice. Scholarly work in STS and historical epistemology has explored the connections between the cultures of experimentation in science and art, examining the material practice and the experiential dimension of artists and scientists working in the laboratory and the studio (Patterson 2015; Rheinberger 1997; Schatzi and Knorr-Cetina 2000).

It is, therefore, not creativity that art and science have in common, but the goal of experimenting, of making new worlds by reconfiguring bits and pieces of existing ones. In the words of the philosopher Nelson Goodman, who pointed out how there are no privileged or right ways of describing the world:

> The many stuffs – matter, energy, waves, phenomena – that worlds are made of are made along with the worlds. But made from what? Not from nothing, after all, but from other worlds. (Goodman 1975, 61)

Goodman conceptualises art and science as overlapping segments of a continuum rather than rigidly distinguished on the basis of fictionality (art) versus factuality (science). The laboratory culture of experimentation is like the culture of experimentation present in an artist's studio and in art practice in general. Doing science and making art are both forms of skilled craftsmanship which is part of the intellectual endeavour undertaken in the laboratory and in the artist's studio/workshop (Smith 2004; Jones and Galison 1998). Considering experimentation as the common ground between art and science can foster collaborative projects in which the power relationship between the two is more equally balanced.

The work of biologist and historian of science Hans-Jörg Rheinberger offers a conceptual toolkit to tackle the dominant narratives mentioned. His analysis of experimental systems within science can be extended to art practices and to understanding the relationship between the two systems for producing experiments – albeit of different kinds (Schwab 2013). Rheinberger devotes pages to the analysis of experimentation arguing that the foundational gesture of science is to make things visible in the broader context of laboratory experimentation. An experimental system is set up by two drives, one toward analysis, which is about the examination of the constitutive elements of the phenomenon under study (molecules, chemical elements, physical forces, etc.). The other drive is toward synthesis consists of the effort to create new things (Rheinberger 1997). Although hardly admitted by scientists, what is at stake in experiments, Rheinberger argues, is not hypothesis-testing but an emergent, open-ended, and imaginative interplay between what he calls "epistemic things" (the actual object of inquiry which is still unresolved at the laboratory bench) and "technical objects" which are the instruments and techniques used (Rheinberger 1997, 28-29 and 65).

It is this dynamic between epistemic things and technical objects that defines experimentation and makes possible the creation of new worlds. A systematic and multidisciplinary study of this dynamic is the first requirement for framing the relationship between science and art beyond the cliché of creativity as some scholars have convincingly demonstrated in the last few years (Rogers et al. 2021; Borgdorff et al. 2020; Sormani et al. 2019). After all, "experimenting", a term originally closer to the sciences than to the arts, is key for artistic research practice too. Artistic and scientific experiments are different in terms of reproducibility, possibility to generalise results, and controllability (Borgdorff 2013, 115-116). An experiment, regardless of whether it is labelled artistic, scientific or somewhat in-between, always opens up possibilities or, using Rheinberger's own expression, "machines for making the future" (1997, 28), that is, a venue that produces or enables variations, alterations, mismatches, repetitions. The nonalignment between the original intention of the experimenter and the product of artistic or scientific research can be generative of knowledge. An experimental system therefore thrives on uncertainty and surprise.

Among other actions, encouraging experimentation supports and make visible the vast, albeit often unknown, underground world of slow-paced, grassroot and low-budget projects designed and curated by networks of researchers and artists across the globe.[8] These projects draw inspiration from the *Bauhaus Design School* that shaped modernism and levelled any distinction between "artists" and "craftsmen"; they also put to work the possibilities offered by the digital culture and the do-it-with-others spirit, embracing citizen science outside institutional settings. A sustainable, self-reflexive art-science practice is possible by nurturing small-scale bottom-up collaborative projects that give space to actual experimentation rather than just the celebration of creativity and societal impact – typically, the third mission of universities in the Western corporate higher education model.

3. Laboratory Fieldwork and Archival Research as Doors to Fiction, Imagination and Affect within Experimental Culture

In art-science collaboration forms of critique emerge where the outcomes are not obvious from the outset. The collaboration itself is often organised around different and sometimes overlapping logics of interdisciplinarity to use the terminology adopted by Born and Barry (2010): according to the logic of accountability, art-science collaboration can assist scientific research with social accountability by bringing in ethical, political, societal questions. Following the logic of innovation, these collaborations contribute to scientific research thus enabling economic growth. Finally, according to the logic of ontology, art-science collaboration opens new realms of possibility not seen in everyday laboratory practice, sometimes even producing new objects and knowledge through interdisciplinary research. The last one is the most difficult type of interdisciplinary logic to implement and achieve.

The main roles that the artist or the humanities/social sciences scholar can undertake in the context of laboratory art-science collaboration are that of the attached observer, of the embedded humanist/social scientist/artist, or of the active participant. Sometime these roles can overlap. The role of the "attached observer" (Leach 2006) envisages the scholar/artist embedded in the laboratory as an anthropologist doing ethnographic work, taking down notes of how facts are produced in the everyday laboratory life (Latour and Woolgar 1979). It almost never happens to see a scientist being an "attached observer" in an artist's studio. Another role is that of the "embedded-humanist/social scientist/artist" in the laboratory. The embedded scholar/artist observes and (sporadically) intervenes in scientific practice to shape the course of action of a project/experiment and then they study the product of the intervention (Fisher et al. 2015). The last role can be that of an active participant in a research project in which the humanist/social scientist/artist co-design the project methodology together with the scientist. Active participation can help explore hidden agendas and assumptions at work in the laboratory (Calvert and Schyfter 2016). The output of the collaboration is a co-authored hybrid, which does not necessarily mean that the art and science contribution is equally distributed. Art and design practice, namely, have a "speculative, experimental and open-ended character" (Ingold 2013, 8) that can inform not only scientists, but also researchers in STS conducting collaborative work with scientists (Calvert and Schyfter 2016).

Regardless of the role scholars and/or artists undertake within art-science collaboration illustrated in the previous section, scientific practice should be studied by looking at the "situation" which is defined as:

> the dynamic entanglement of conceptual, material, social, and institutional factors involved in developing knowledge and clearly positions research efforts in relation to the publics for whom such knowledge is expected to be of value. (Leonelli 2016, 8)

Scholars and practitioners involved in art-science collaborative work are in the position of making visible the choices that scientists make in the laboratory. The choices made by scientists with respect to data (their collection, interpretation, and display) emerge from intellectual, technical, political and/or economic struggles, all of which entail power imbalances. These choices remain hidden in the final published output.

This invisibility happens because in scientific practice, "facts", included data-visualisation strategies, are constructed, then stabilised and black-boxed. In science studies, Bruno Latour defines black boxing as the way scientific, technical and social work is made invisible by its own success. When a machine runs efficiently, when a matter of fact is settled, one needs focus only on its inputs and outputs and not on its internal complexity. Thus, paradoxically, the more science and technology succeed, the opaquer and more obscure they become (Latour 1999, 304). Latour uses the metaphor of the black box to describe scientific practice: to make science is to construct and close a black box. Laboratory findings and events, for example, are often black-boxed and presented as matter of facts. The black box can be re-opened on several occasions. First, when a controversy arises, the solution provided falls apart and there is the need to re-examine the assumptions made. Second, a black box can be opened by looking at the early stages of the development of a technology, for example before the data visualisation protocol becomes standardised. Third, a black box can be opened by artists who enter experimental systems as if they were spaces of imagination.

To focus on the materiality of science, on the epistemological role played by aesthetics, and on the impact that science and technology have on societal and ethical issues, humanities/social sciences scholars and artists engaged in collaborative work with scientists need to pay attention to science in the making. This is visible in the laboratory (science in the making *now*) and in the archive (science in the making *then*). Laboratory ethnography and archival research can provide access to science in the making. The archive and the laboratory bench are places where historical records of science are kept and where scientists make visible their leaps in imagination, their tinkering with materials. Archives are the places where to find what the biologist Francois Jacob calls "night science, the workshop of the possible where what will become the building material of science is worked out" (Jacob 1998, 158). The material coming from archival research and laboratory fieldwork hint at the struggles of scientists with forms of thinking and making that are kept at the margins of the discipline regardless of the central role they play in science. Often hosting unpublished tentative writing and sketches, the archive becomes the repository of "sociotechnical imaginaries" (Jasanoff 2015, 19) rather than of dead documents and objects waiting to be brought back to life. Together with laboratory fieldwork, archival research can help both scholars and artists to bring to the foreground the importance of craftsmanship, imagination and affectivity that always accompany scientific practice and discovery.

Scientific practice is entangled with affect. Science studies using a feminist and new materialist lens, in particular, have long insisted upon the embodied, visceral character of our cognition (Barad 2007; Haraway 1988; Harding 1991). The affective turn has emerged across different disciplines as a mood of inquiry focusing on emotion and affect to generate and re-configure knowledge (Clough and Halley 2007; Massumi 2002; Wilson 2010). Scholars combining STS with anthropology, cognitive studies and undertaking laboratory fieldwork in different disciplines (from neuroscience to molecular biology and space exploration) have demonstrated how often scientists articulate their science through their bodies. Gestures and imagination contribute to shaping scientific knowledge. Scholars Morana Alač, Natasha Myers and Janet Vertesi all address multimodal embodied practice in the laboratory, basing their works upon extensive laboratory fieldwork in neuroscience, molecular biology and space exploration, respectively. Myers (2015), for example, describes how molecular biologists *feel* their way through data to interpret molecular forms. Vertesi (2014) explores the intimacy that space scientists develop with their instruments through their sensorial apparatus, not only for vision, but also for haptic and remote sensing.

Reflecting on how to access and conceptually frame the role played by affectivity, imagination and fiction within scientific research is important to bring to the foreground experimentation and, thus, challenge all the dominant art-science narratives illustrated in the previous section. The affective register of laboratory labour can emerge both through undertaking laboratory fieldwork and archive-based work. Affectivity is connected to materiality, with reference not just to bodily processes, but also to the material world as a site of affective exchanges between human and non-human agents, including machines and their components. Digging up design sketches, old photographs, lab notes and newspaper clippings that might seem to be marginal at first look (the "cursed" part of scientific research) turns out to be the driving force and narratives behind the development of a certain technology or scientific theory. These "things" are repositories of memory and affective labour. For example, the manual labour involved in the creation of each component of a new technology (from the design and assemblage of hardware to writing the code, to the methods for turning data into images) is not simply a way of taking care of the technological object but much more a way of taking care of the end users of this technology (researchers, prospective patients and further on). Regardless of how collective the labour is, it is always framed around the final publication in which the manual labour mentioned above ends up being significantly neglected. Artists can contribute to digging up the histories of archival objects, of embodied and emotional laboratory work and less institutional narratives related to scientific practice. Foregrounding how affectivity is part of laboratory culture might lead to a scientific practice where matters of concern and care are on equal footing to matters of fact.

Sketches and non-academic writing give access to the dimensions of affectivity, imagination and fiction, often neglected when engaging with the culture of scientific experimentation. Scientists' academic writing that ends up in peer-reviewed papers in prominent journals is polished, authoritative and detached from any context not directly relevant to the data discussed. Modern science is about the production of knowledge: unbiased, factual, objective. A specific writing style corresponds to this new way of being a scientist: the impersonal style of writing, which is enforced in all academic published outputs, has become the conduit of scientific authority. The published papers in which scientists report the results of their investigations are hardly ever literal accounts of the historical processes through which their authors have reached the conclusions they present. Once an investigation or research project has been completed, the path it followed becomes largely irrelevant to the investigator, who is expected to marshal the best arguments and evidence available to support the claims she wishes to make. Sometimes the case to be presented sufficiently resembles the process of discovery, so that the order of presentation recapitulates the order of investigation; but temporal rearrangements, omissions of failed or aborted trails, and other retrospectively inessential steps, are made routinely, with no intention to falsify a record of discovery. Consequently, scholars aiming to reconstruct the historical and socio-cultural routes to landmark discoveries have long sought other forms of documentation to fill the gaps left by the published reports of the completed work.

Scribblings, notes and sketches belong to the experimental system described by Rheinberger and represent a special genre of scientific writing (Holmes et al. 2003). They are literary activities in their own right. They are the ways in which science is carried out in the multi-dimensional space that exists only on paper – a space where any potential experiment and idea can be given shape, where research threads are laid out even if they might not be easily transposed to the laboratory bench. These writings are precious recordings that can illustrate the specific style (aesthetics) of a scientist's own research and way of thinking. Hardly published in academic papers, these scribblings are confined to personal notebooks, footnotes or appendixes. It is even more important, then, so I argue, to give them a presence back, for example through an art-science collaborative project or through an exhibition.[9]

Experiments undertaken on paper are an explorative fictional tool used to create other worlds. Fiction is at the core of scientific practice (Frigg 2010, 248). According to a common-sense understanding of the term "fiction", something is fictional when it does not exist. Often scientists need to momentarily postulate nonexistent entities because they need them to achieve certain goals or predictions. One well-known example is Bohr's postulation of classical electron orbits, later dismissed by Schrödinger's quantum mechanics. Fiction in the sense of "non-existence" can, therefore, be useful to advance an argument. In a second sense, fiction can be understood as a counterfeit activity with the goal of deceiving or misleading. However, it can also be understood as imagination and make-believe. Scientists use models (as fictional entities) to study features of the object or event that the model is expected to represent. Modeling a phenomenon requires several elements working together so that the audience can engage with and explore the phenomenon in a plausible manner. Philosopher of science Roman Frigg uses the example of fictional characters in literature (i.e., Madame Bovary and Sherlock Holmes) to argue that scientific models function in a similar way – we believe in them and discuss them although they only live in our imagination (Frigg 2010, 257).

Make-belief (as if), and "what if" constructions are present at the laboratory bench, but they are disciplined in the final academic publications. In public engagement, the play of make-believe – e.g., "what if" scenario-building – is often reduced to an activity only ancillary to science, performed in view of gaining the interest and support of the public for scientific research. Make-believe and imagination are connected to experimentation rather than to creativity. To give an example, the hand-drawn sketches and scribblings by Thomas Edison ("the Wizard of Menlo Park") were visual manipulations of ideas, short-end descriptions and suggestions for the material arrangement of an experiment.[10] Artists are always allowed to play, fictionalize, tinker with materials as part of their experimental process, which is often visible in the final artwork. The same does not apply to scientists. What if constructions are present at the laboratory bench, but they are disciplined and silenced in the final academic publications. Laboratory fieldwork and archival research can reveal how the space of *what if* and make-believe (*as if*) is one of imagination and experimentation, at the same time. The tentative writing and sketches from the laboratory or personal notebooks of scientists show how sometimes scientists draw imaginary objects – that is, they give physical form to their mental images – and in the process of doing so, they learn to see them better. Scientists' laboratory notebook entries and diagrammatic sketches, often accessible either via laboratory fieldwork or archival research, offer an insight into the scientific method and creative process: the passage from intuitive, at times imaginative, understanding to rigorous formal proof and experimentation.

If the contribution of laboratory fieldwork and archival research to access science in the making can be articulated, far more challenging is making explicit what art can bring to science and STS. One could highlight the enhanced self-reflexivity within the laboratory: thanks to collaborative work, scientists become more aware of the cultural, historical, socio-political context in which their practices and instruments are embedded; new forms of interaction with the public, through exhibitions, performances and workshops can be envisaged thanks to collaboration with artists. Humanities scholars and social scientists might be exposed to materiality, process, to the *work* of art (Jones 2022), to methodologies that do not encompass exclusively the written word. Art can not only make visible but also reconfigure and challenge existing modes of experience and sense perception. Time is ripe, then, for adding art to STS. Scholars should be encouraged to embrace multi-sensorial ways of knowing that are at work in the artist's studio but also in scientific practice, moving beyond what Galison identified with *visual* STS (2014). Tactile learning has a role in scientific modelling, for example, in Linus Pauling's molecular models. Multi-sensory actions are undertaken by the Critical Art Ensemble (CAE), a tactical media collective that combines artistic interventions with performative writing revitalising many STS concepts.

4. Conclusions

To conclude, attention to science (and art) in the making is how social sciences and humanities scholars, artists and scientists can all engage in a fruitful, slow-paced, and mutually challenging dialogues and collaborations. As the historian of science Hans-Jörg Rheinberger has demonstrated, the spaces and practices of experimentation are characterised by uncertainty – where the liveliness of data and experimentation has not yet been stilled by epistemological resolution (Rheinberger 2011, 315). Each experimental system contains narratives in *excess*, both old stories and fragments that might contribute to future stories (Rheinberger 1994, 78). Exploring the affective dimension of science practice and its narratives through laboratory fieldwork and archival research brings out the socio-cultural and political aspects of science in the making. Art-science collaborative work would then become encouraging scientists not only to become aware of the broader history of their practices and tools, but also to reconnect to the imaginative, affective, and craftsmanship dimension of science in the making. When successful, this method can foster the conceptual shift from "matters of fact" to "matters of concern" (Latour 2004) and even to "matters of care" (Puig de la Bellacasa 2017). Matters of fact do not engage with network complexity and power dynamics. Phenomena are observed in a "clinical" way, positioned by the norms created by certain theories and validated throughout certain experimental protocols. Matters of concern reveal the interest and agencies among human and non-human actors. Matters of care, too, engage with the broader, relational contexts that phenomena inhabit as integral parts of the world, but they also actively contribute to make those concerns visible and heard. Thinking with care, namely, is "an active process of intervening in the count of whom and what is ratified as concerned" (Puig de la Bellacasa 2017, 52). This is how worlds can not only be inhabited but also contested and imagined anew.

Notes

[1] https://cds.cern.ch/record/2012228?ln=en (accessed September 2022).

[2] https://www.kcl.ac.uk/news/science-gallery-london-where-art-and-science-collide (accessed October 20, 2022)

[3] Trinity College Provost Linda Doyle on 28th January 2022. See: https://dublin.sciencegallery.com/ (accessed October 21, 2022).

[4] See: https://www.change.org/p/save-symbiotica (accessed October 21, 2022).

[5] An example of such grassroot approaches is discussed in Buiani (2019).

[6] My translation is from the original text in Italian: "Ma una volta che le scienze avranno occupato con autorità i diversi campi del sapere, l'artista, scacciato da un regno che condivideva da pari a pari, rimandato all'empirismo dell'artigiano ('stupido come un pittore'), non potrà far altro che darsi al soliloquio o al vaticinio, alla ricerca di uno status ma anche di un mestiere perduto".

[7] On art-science experiments, see, for example, Webster (2005); Kac (2007); Ginsberg et al. (2014); Sormani et al. (2019).

[8] The journal *Leonardo* is a source of information on both established and more tentative and small-scale projects.

[9] My most recent collaborative project with biomedical physicists and an artist entailed both laboratory fieldwork and archival research. The output consisted of two exhibitions *Immobile Choreography* and *From Where Do We See?* See: http://www.ghat-art.org.uk/immobile-choreography-publication-launch-and-talk/ (accessed November 25, 2019).

[10] See *The Thomas A. Edison Papers Project*, a research centre at Rutgers School of Arts and Sciences, http://edison.rutgers.edu/NamesSearch/SingleDoc.php?DocId=NM003015 (accessed September 15, 2022). On Edison and his visual thinking method, see Wills (2019).

References

Alač, M. (2011) *Handling Digital Brains: A Laboratory Study of Multimodal Semiotic Interaction in the Age of Computers*, Cambridge, MIT Press.

Barad, K. (2007) *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*, Durham, Duke University Press.

Borgdorff, H.A. (2013) *Artistic Practices and Epistemic Things*, in M. Schwab (ed.), *Experimental Systems: Future Knowledge in Artistic Research*, Leuven, Leuven University Press.

Borgdorff, H.A., Peters, P. and Pinch, T. (2020) *Dialogues between Artistic Research and Science and Technology Studies*, Leuven, Leuven University Press.

Born, G. and Barry, A. (2010) *Art-Science: From Public Understanding to Public Experiment*, in "Journal of Cultural Economy", 3(1), pp. 103-119.

Bredekamp, H., Dünkel, V. and Schneider, B. (2015) *The Technical Image: A History of Styles in Scientific Imagery*, Chicago, University of Chicago Press.

Buiani, R. (2019) *Squatting for* SciArt, in "Antennae: The Journal of Nature in Visual Culture", 47, pp. 27-47.

Calvert, J. and Schyfter, P. (2016) *What can science and technology studies learn from art and design? Reflections on "Synthetic Aesthetics"*, in "Social Studies of Science", 47(2), pp. 195-215.

Casini, S. (2017) *Beyond the Neuro-Realism Fallacy: From John R. Mallard's Hand-painted MRI Image of a Mouse to BioArt Scenarios*, in "Nuncius: Journal of the Material and Visual History of Science", 32(2), pp. 440-471.

Casini, S. (2021a) *Giving Bodies back to Data: Image-makers, Bricolage, and Reinvention in Magnetic Resonance Technology*, Cambridge, MIT Press.

Casini, S. (2021b) *What Counts as Data and for Whom?: The Role of the Modest Witness in Art-Science Collaboration*, in H. Rogers, M. Halpern, D. Hannah and K. de Ridder-Vignone (eds.), *The Routledge Handbook of Art, Science and Technology Studies*, New York and London, Routledge.

Clair, J. (2016) *Le farfalle dell'anima*, in "Museologia Scientifica Memorie", 15, pp. 13-18.

Clough, P.T. and Halley, J. (2007) *The Affective Turn: Theorizing the Social*, Durham, Duke University Press.

Daston, L. and Galison, P. (2010) *Objectivity*, New York, Zone Books.

DeFelipe, J. (2010) *Cajal's Butterflies of the Soul: Science and Art*, Oxford, Oxford University Press.

Del Giudice, D. (1985) *Atlante Occidentale*, Turin, Einaudi.

Elkins, J. (2008) *Six Stories at the End of Representation*, Stanford, Stanford University Press.

Fisher, E., O'Rourke, M., Kennedy, E., Evans, R., Gorman, M. and Seager, T. (2015) *Mapping the Integrative Field: Taking Stock of Socio-Technical Collaborations*, in "Journal of Responsible Innovation", 2(1), pp. 39-61.

Frigg, R. (2010) *Fiction and science*, in J. Woods (ed.), *Fictions and Models: New Essays*, Munich, Philosophia Verlag, pp. 247-287.

Galison, P. (1997) *Image & Logic: A Material Culture of Microphysics*, Chicago, Chicago University Press.

Galison, P. (2014) *Visual STS*, in A. Carusi, A.S. Hoel, T. Webmoor and S. Woolgar (eds.), *Visualization in the Age of Computerization*, New York, Routledge, pp. 197-225.

Ginsberg, A.D., Calvert, J., Schyfer, P., Elfick, A. and Endy, D. (2014) *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature*, Cambridge, MIT Press.

Goodman, N. (1975) *Words, Works, Worlds*, in "Erkenntnis", 9(1), pp. 57-73.

Grau, O. and Veigl, T. (2011) *Imagery in the 21st Century*, Cambridge, MIT Press.

Haraway, D. (1988) *Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective*, in "Feminist Studies", 14(3), pp. 575-599.

Harding, S. (1991) *Whose Science? Whose Knowledge? Thinking from Women's Lives,* New York, Cornell University Press.

Holmes, F.L., Renn, J. and Rheinberger, H-J. (2003) *Reworking the Bench: Research Notebooks in the History of Science*, in "Archimedes: New Studies in the History and Philosophy of Science and Technology", 7, pp. 295-308.

Ingold, T. (2013) *Making: Anthropology, Archaeology, Art and Architecture*, London, Routledge.

Jacob, F. (1998) *Of Flies, Mice and Men*, Harvard, Harvard University Press.

Jasanoff, S. (2015) *Future Imperfect: Science, Technology and the Imaginations of Modernity*, in S. Jasanoff and S.H. Kim (eds.), *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*, Chicago, University of Chicago Press.

Jones, C.A. (2022) *Foreword*, in H. Rogers, M. Halpern, D. Hannah and K. de Ridder-Vignone (eds.), *Routledge Handbook of Art, Science, and Technology Studies*, New York and London, Routledge.

Jones, C.A. and Galison, P. (1998) *Picturing Science, Producing Art*, New York and London, Routledge.

Kac, E. (2007) *Signs of Life: Bio Art and Beyond*, Cambridge, MIT Press.

Kemp, M. (2005) *Leonardo*, Oxford, Oxford University Press.

Knorr-Cetina, K. (1999) *Epistemic Cultures: How the Sciences Make Knowledge*, Cambridge, Harvard University Press.

Latour, B. (1999) *Pandora's Hope: Essays on the Reality of Science Studies*, Harvard, Harvard University Press.

Latour, B. (2004) *Why has Critique Run out of Steam? From Matters of Fact to Matters of Concern*, in "Critical Inquiry", 30(2), pp. 225-248.

Latour, B. and Weibel, P. (2002) *Iconoclash, Beyond the Image-Wars in Science, Religion and Art*, Karlsruhe and Cambridge, ZKM and MIT Press, pp. 14-37.

Latour, B. and Woolgar, S. (1979) *Laboratory life: The Construction of Scientific Facts*, Princeton, New Jersey, Princeton University Press.

Leach, J. (2006) *Extending Contexts, Making Possibilities: An Introduction to Evaluating the Projects*, in "Leonardo", 39(5), pp. 447-51.

Leonelli, S. (2016) *Data-Centric Biology: A Philosophical Study*, Chicago, Chicago University Press.

Massumi, B. (2002) *Parables for the virtual: Movement, affect, sensation*, Durham, Duke University Press.

Myers, N. (2015) *Rendering Life Molecular: Models, Modelers and Excitable Matter*, Durham, Duke University Press.

Newfield, C. (2019) *The Trouble with Numerical Culture*, in "MLA Profession". Available at: https://profession.mla.org/the-trouble-with-numerical-culture/ (retrieved October 20, 2022).

Patterson, Z. (2015) *Peripheral Vision: Bell Labs, the S-C 4020, and the Origins of Computer Art*, Cambridge, MIT Press.

Puig de la Bellacasa, M. (2017) *Matters of Care: Speculative Ethics in More Than Human Worlds*, Minneapolis, University of Minnesota Press.

Rheinberger, H-J. (1994) *Experimental Systems: Historiality, Narration and Deconstruction*, in "Science in Context", 7(1), pp. 65-81.

Rheinberger, H-J. (1997) *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube*, Stanford, Stanford University Press.

Rheinberger, H-J. (2011) *Infra-Experimentality: From Traces to Data, from Data to Patterning Facts*, in "History of Science", 49(3), pp. 337-348.

Ricci, F. (1990) *"Atlante Occidentale": Daniele Del Giudice's "New Atlantis"*, in "Mosaic: A Journal for the Interdisciplinary Study of Literature", 23(1), pp. 45-53.

Rogers, H., Halpern, M., Hannah, D. and de Ridder-Vignone, K. (2021) *The Routledge Handbook of Art, Science and Technology Studies*, New York and London, Routledge.

Schatzki, T. and Knorr-Cetina, K. (2000) *The Practice Turn in Contemporary Theory*, New York and London, Routledge.

Schwab, M. (2013) *Experimental Systems: Future Knowledge in Artistic Research*, Leuven, Belgium, Leuven University Press.

Smith, P.H. (2004) *The Body of the Artisan: Art and Experience in the Scientific Revolution*, Chicago, Chicago University Press.

Snow, C.P. (1964) *The Two Cultures and a Second Look: An Expanded Version of the Two Cultures and the Scientific Revolution*, Cambridge, Cambridge University Press.

Sormani, P., Carbone, G. and Gisler, P. (2019) *Practicing Art/Science: Experiments in an Emerging Field*, New York and London, Routledge.

Stengers, I. (2018) *Another Science Is Possible: A Manifesto for Slow Science*, Cambridge, Polity Press.

Vertesi, J. (2014) *Seeing Like a Rover: How Robots, Teams, and Images Craft Knowledge of Mars*, Chicago, University of Chicago Press.

Webster, S. (2005) *Science and Society: Art and Science Collaborations in the United Kingdom*, in "Nature Reviews Immunology", 5, pp. 965-969.

Wills, I. (2019) *Scientific Failure: Etheric Force*, in "Thomas Edison: Success and Innovation through Failure", Studies in History and Philosophy of Science, 52, Cham, Switzerland, Springer, pp. 141-168.

Wilson, E. (2010) *Affect and Artificial Intelligence*, Seattle, University of Washington Press.