INTRODUCTION TO ENTANGLE: PHYSICS AND THE ARTISTIC IMAGINATION

Ariane Koek

> The very nature of materiality is an entanglement. Matter itself is always already open to, or entangled with, the "Other." The intra-actively emergent "parts" of phenomena are co-constituted. Not only subjects but also objects are permeated through and through with their entangled kin; the other is not just in one's skin, but in one's bones, in one's belly, in one's heart, in one's nucleus, in one's past and future.
>
> KAREN BARAD

> Everything we call real is made of things that cannot be regarded as real.
>
> NIELS BOHR

We are all made of star dust. Matter is 95 percent empty. Our feet are older than our heads. The ground beneath our feet is full of holes. We are made of stuff which is older than the earth we inhabit.[1]

Hearing these kinds of statements, the material reality we live in is blasted apart. These everyday observations by particle physicists show how physics can open up new realms of perceiving reality which take us into different dimensions. Our material world takes on a whole different existence, and the things we cannot see (and do not regard as real) create, as Niels Bohr indicates, our reality. The invisible makes the visible, the immaterial, matter, and vice versa. Separation is illusory. Everything is entangled in a state of intra-connection and constant becoming.

From the tiny to the vast, technology is now allowing us to observe matter in the micro to the macro in detail we have never been able to see before: from a supernova exploding in a galaxy about 930 million light years away across the vastness of the universe to the measurement of gravitational waves below the level of the nucleus with astounding accuracy. New material realities are constantly opening up in scales and details which challenge our perceptions. We are in an era of new phenomenologies.

LEFT: *Flathead-First Light*
Julian Charrière
2016

RIGHT: *Configuration 7* (part of installation)
Goshka Macuga
2015-2016

Entangle: Physics and the Artistic Imagination is dedicated to works by contemporary artists working in art and design in the twenty-first century who are inspired by particle physics. This is the science which investigates the fundamental constituents of matter – particles – as well as the invisible structures and the forces of nature which shape and govern our world. Artists are usually credited with allowing us to see the world through a different lens. Physics offers artists an additional lens for looking at the world differently, thus providing them with another compelling source of inspiration for their imaginations and their creative practice.

But physics and the arts share a commonality. Both physics and the arts explore the fundamental questions about how we came into existence and try to make sense of our place in the world. Both set out to discover answers to these questions. However, they express the process and answers in different ways: physics through the abstract language of mathematics, which is then brought down to earth and tested out by scientific methodology, concrete engineering, and experimentation; the arts through the senses and making objects and/or experiences which reflect these discoveries and its process. Artists and particle physicists also share a very particular affinity. Particle physicists are divided into theorists who think in the abstract, beyond the paradigms, and the experimentalists who test these theories. In a sense, an artist is a combination of both: s/he is both a theorist and an experimentalist even though the ways of knowing and expressing knowledge are so different.[2]

What is entangled in the process of both of these different ways of knowing and looking at the world is crucially the imagination – that mysterious process by which we make unexpected links, out-of-the-box connections, and have inexplicable intuitions beyond the known world. This exhibition deliberately takes as its focus artists who for part of their practice use physics as springboards of their imaginations.

This is just one particular focus within what is often referred to as the arts/science field. Since 1967 this field has been expanding with ever-increasing energy: with the founding of Experiments in Art and Technology (E.A.T.) at the Bell Laboratories initiative, headed by the engineer Billy Kluver and the artist Robert Rauschenberg, which spearheaded the co-creation of new work across the disciplines, and the pioneering work of the Hungarian émigré artist György Kepes, who founded the Center for Advanced Visual Studies at the Massachusetts Institute of Technology (MIT), Boston. Today, in the twenty-first century, it is particularly popular with new initiatives being announced every week. This popularity is due to a number of factors: economics – the reduction of funding for the arts and humanities, with science being "relatively" better funded; the rise of public engagement as a priority for science organizations, including reaching beyond their traditional audiences; and, in a world beset with global challenges, the drive to innovate which is understood to happen when disciplines mix.[3] Add to this also the eternal hunger of artists to find new sources of inspiration, as well as a world in which science, not art, is now seen as the ultimate source of wonder, and the key factors for art science's ascendancy are very clear.[4]

However, the term arts/science or even sci art, which is applied to this field, suggests that it is one unified and homogenous movement. It isn't. In reality it is a multiplicity of movements which go in many different directions, and which are defined and driven by many different intentions, seeking different outcomes and having very different and varying aesthetics.[5] For example the arts/science work of Ars Electronica, ZKM, and Music Tech Fest can be defined as being driven by the exploration of the limits and possibilities of technology. That of the Science Gallery Dublin and the Exploratorium in San Francisco is defined by its intention to engage the audience, with its emphasis on public engagement and interaction with the ideas of science aided by artists and designers. Sometimes these movements overlap because the intentions are mixed, sometimes they don't. Sometimes the emphasis is on the scientific side, sometimes it is more on the artistic, or there is a balance in between.

There are artists who use the tools, experiments, and techniques of science to create their artwork, as in the case of Evelina Domnitch and Dmitry Gelfand, who merge physics, chemistry, and computer science, and of the British artist Anna Dumitriu, who works with digital and biological media. The work of the painter Keith Tyson, who features in *Entangle,* deliberately comes from the perspective of science being imaginative fuel for artists who he calls, together with scientists, "knowledge seekers."[6] This approach taken by the exhibition is not new, but it is significant both today and in the past. As the art historian Gavin Parkinson points out in his essay in this catalogue, there is a long tradition of science as fuel for the imagination of artists. For example, the Surrealist manifesto by André Breton was highly influenced by physics; and physics remained an important source for Salvador Dalí until he died.

Because of the multiplicity of movement with its diversity of intentions and outcomes, which are potentially entangled, there's an argument that the term art science or sci art is redundant and meaningless – or at the very least should be treated with caution.[7] What is perhaps far more important is the notion of transdisciplinarity – that intellectual and creative space where different forms of knowledge and expertise meet across, around, and on their boundaries and borders. I founded the Arts at CERN program on this premise. So much so that the focus in the program in its first five years was very much more on the process and the encounters between the artists and the physicists in the laboratory in Geneva, rather than on any output.[8]

The thinking was to get the curation of the process of the interactions between artists and scientists right, and then the creative work will naturally happen without any deadlines whilst the minds and hearts of the artists and physicists collide to spark the imagination. Four of the artists in the exhibition were part of the first years of the Arts at CERN program. Julius von Bismarck, a former student at Olafur Eliasson's famous interdisciplinary school Institut Für Raumexperimente, Berlin, was the first Collide International artist-in-residence, spending two months in total at the laboratory. Physics inspires his daily creative practice to this day. He was followed two years later, in 2014, by the Japanese musician and digital artist Ryoji Ikeda, the third Collide International artist who made two large-scale installations as a result of his CERN encounter. The other two artists, the Dutch fashion designer Iris van Herpen and the Polish artist Goshka Macuga, participated in the Visiting Artists program, with its one day of intense visits and briefings on the latest findings in physics. Both artists continue to visit CERN in order to refresh their knowledge and blast their imaginations into new dimensions.

Space, Time, Light, Gravity, Matter, Entropy – these are a few of the themes which preoccupy the fourteen artists in *Entangle*. And to make this clear at Bildmuseet, a contemporary art gallery which eschews explanatory texts on its walls, there was an accompanying audio-cloud at the heart of the exhibition. This was experienced online, as a podcast, in the exhibition on headsets or mobiles, and in the catalogue. In "diptychs" artists and physicists talk about the same phenomena from their different standpoints. Recorded at different times and in different places, it is only on the page and in the air that they and their reflections on different phenomena "meet" for the first time.

For example, the Turkish physicist Bilge Demirköz, who has helped build the Alpha Magnetic Spectrometer (AMS) detector on the International Space Station, reflects on the phenomenon of space and what it means to her. Her words are alongside those of the architect Sou Fujimoto, who is known for turning architectural concepts of space inside out and who confesses that for him outer space is terrifying because of what he calls its lack of density. For him, trees are the ultimate symbols of space.

In her interview, the fashion designer Iris van Herpen reveals how matter is her inspiration as well as her greatest enemy in the process of creating new materials and forms. Her thoughts are laid alongside those of one of the world's leading experts on antimatter, Dr. Michael Doser, who reveals the duel to the death of matter against antimatter, the innate combative nature of particles that led to the creation of the universe and matter itself.

These juxtapositions reveal the differences as well as connections of seeing the same phenomena through different eyes. It is in the connections, the differences, and the gaps in between that the imagination thrives and creativity grows. We are forced to think and imagine beyond our own parameters, particularly by not knowing and by failure to fully understand. After all, we only learn to walk as a child by falling down and picking ourselves up, time and time again, until we know our own limits and once we have tested gravity, like amateur physicists, to our utmost capability. Knowledge is built on the unknown and failure, with imagination daring to take us beyond our physical and conceptual limits, as Julius von Bismarck's video piece *Escape Shapes* (2016) in the exhibition indicates.

Julius himself says: "What makes it [physics] so inspiring for me is that you can always discover something that you couldn't understand or even imagine before and that you maybe still can't imagine. This boundary of my imagination is where I get a lot of inspiration. Every new weird fact that is funny to imagine or hard to imagine is for me an inspiration to go into a corner of my brain that I haven't used before or that is not existing yet. I have to kind of extend my imagination to understand it. Then, I'm failing in that. I like that failure. That's actually an inspiration for a couple of works I made."

Or as the physicist Albert Einstein famously said in a renowned newspaper interview in 1929: "Knowledge is limited. Imagination embraces the whole world."[9] This

statement is dissected in Philip Ball's essay in the catalogue, in which he shows that the imagination is not just the exclusive domain of artists: it is fundamental to both experimental and theoretical physicists and the actual process of discovery.

The role of the imagination in discovery was also considered when the best-selling physicist Carlo Rovelli, who has written the lead essay for the catalogue, was drawing on one of the blackboards that form part of the Polish artist Goshka Macuga's new commission for Bildmuseet. It is a composite installation comprising blackboards drawn on by nine contemporary physicists, the German artist Joseph Beuys, Albert Einstein, and the founder of biodynamics and educationalist Rudolf Steiner. When Rovelli wrote an equation using the Penrose system for describing his theory of the white hole, the theoretical opposite counterpart to the black hole, he said that just because white holes in the universe haven't been seen yet doesn't mean that they don't exist. "You just have to imagine them." He added that when black holes were first predicted by Einstein in 1916 with his general theory of relativity, people said they did not exist. Fifty-five years later, the first one was observed and now they are commonly accepted as real.

Thus, the notion of science as being purely objective and logical is a myth. Imagination and intuition are entangled in the process of scientific discovery, just as they are in the artistic process. Our perception of science as the ultimate objective truth, which precludes the imagination, dates from the Enlightenment – the so-called Age of Reason, in the seventeenth century. This false separation may be due to a fear of science's origins when it was closely associated with alchemy – which is often characterized as the search for the philosopher's stone – the key to the material world and the transformation of matter, including base metals to gold. Science, in particular chemistry and the natural sciences, became detached from the perceived magic of alchemy by creating scientific methodology, factual proof, and analysis. But the imagination is very closely connected to magic. As Philip Ball points out in his catalogue essay, imagination shares the same etymological root as "magic" – "which, in the age just before the time of Isaac Newton, did not necessarily mean superstitious agency but the 'hidden forces' by which natural magicians comprehended and claimed to manipulate nature."

However, there may be a more complex reason for the separation of the imagination from science. It may relate to power and social control. The Italian philosopher Federico Campagna in his book *Technic and Magic: The Reconstruction of Reality* starts on the premise that reality is always a reconstruction.[10] Reality is never real per se. In fact, this is certainly what science says. We don't ever actually see an object in the real world: we only see the light bouncing off it, which is reflected in our eyes, and then our brains create an impression of the object which we then "see." He charts from the Age of Enlightenment the rise of Techne – logic, form, and order with its language of absolutism – as a way of controlling human beings and thus their behavior. Magic or the imagination poses a threat to Techne's social and political control of the masses because it centers its reconstruction of the world around the notion of the "ineffable," the unnamable and inexplicable which cannot be put into words or ever be pinned down, yet lies at the very heart of existence. This idea is not far away from the writings of the Romantic poets, such as Percy Bysshe Shelley, who wrote about the radical ability of the imagination to challenge all borders and to create revolution. He also went so far as to claim that the imagination is the "great instrument of the moral good."

I would go so far as to also say that this is why today contemporary art is becoming persistently driven to become utilitarian and more useful. Art is increasingly in danger of becoming a direct tool to describe, illustrate, and/or co-create solutions for political and social issues – what I would call "art by design." There is increasing pressure for contemporary art to have a purpose, system, and logic, which bleeds it of its mystery and ineffability – and thus also dissolves its imaginative and experiential powers as well as aesthetics. These powers also can transform lives, change attitudes, ways of looking at and experiencing the world – but they are not directly applied or measurable. Couple this with the rise of science and technology as dominant cultural and economic forces, and there is also the danger that science and technology together may swallow contemporary art whole – and become the more dominant part – to the detriment of art and ultimately of society.

All of these different factors create an urgent need to investigate and revise the way in which we understand the relationship between science and the arts, their histories, and how they intra-relate. One important step in this direction is a new book called *The Experimental Imagination* by the academic Tita Chico.[11] She shows that the arts and sciences in fact borrowed from each other in order to argue their legitimacy as modes of knowledge-making in Britain during the eighteenth-century Enlighten-

ment. Literature used the tropes of science to legitimize its own claims to objectivity, whilst science used metaphors from literature as a way of explaining the imagination of science, giving it status by laying claim to be communicating to the popular realm. As her work shows, it is too simplistic to suggest that the Enlightenment heralded the division between objectivity and rationalism in science, and ego and experience in the humanities. The intra-connectiveness is far more complex than that. And we are only just beginning to unravel this entanglement.

Furthermore, Linda Dalrymple Henderson, the primary academic in the field of physics and art, based at the University of Texas at Austin, sheds new light on the relationship with the arts from the scientific point of view. She points out that ideas about space and time in fiction predated those of Einstein, which led to the general theory of relativity. Works of fiction may have opened up scientists' minds to exploring these possibilities in the first place.[12] This hints at what the eminent biologist Edward O. Wilson calls the extra dimension of the humanities, which science doesn't have: "the infinity of fantasy worlds."[13]

What is increasingly emerging in the fashion for art science or sci art is growing anecdotal evidence of how in fact the arts are influencing the work of the scientists themselves. For example, the theoretical physicist James Wells, who amongst other areas, looks at extra dimensions and new worlds, participated in the Arts at CERN program. He talked about how the experience of working with Julius von Bismarck made him look at his own theoretical work differently and would no doubt affect his findings in the future. The experimentalist and antimatter expert Michael Doser, one of the founding members of the CERN Cultural Board for the Arts program, similarly talked about how working with artists taught him how the artists' enjoyment of detours in making work caused him to look at alternative ways of problem solving his scientific experiments.[14] However, there is no proof that these interactions have led to big discoveries – yet. Much more academic investigation and extensive long-term tracking are required into how the arts have impacted upon science, and scholarship is only at the beginning. But what can be said without doubt, according to the former physicist and CEO/Artistic Director of Arts Catalyst, Nicola Triscott, is that the culture of physics as a whole is benefiting through what the philosopher John Dewey calls the "experiential" possibilities of art and its humanizing effect.

All of these factors point to the histories of arts and science being much more entangled than has been appreciated. There may very well be an "intra-action" between the arts and science – very much as there is in "tangential realism" – the approach created by the physicist turned philosopher Karen Barad. In her influential book *Meeting the Universe Halfway* from 2007, she talks about how everything is entangled – subject and object, inanimate and animate, sentient and non-sentient beings, stressing that

> To be entangled is not simply to be intertwined with another, as in the joining of separate entities, but to lack an independent, self-contained existence. Existence is not an individual affair.[15]

This is not simply inter-connection or inter-action. It is what Barad calls "intra-action," where the existence of one thing affects the existence and composition of another entity, whether sentient or not, across time and space. It's always changing, and always in the process of being. This is the entanglement described in the introductory essay by Carlo Rovelli, which also contains an honest and forthright confession: that we don't know *how* entanglement works the way it does. We just know *what* it does. As physics itself admits, we only know 6 percent of the universe. We have another 94 percent learn more about, which apparently comprises the mysterious Dark Matter and Dark Energy which theoretically make up the rest of the universe.

For the next steps in scientific discovery, just as in art, what we need more of is greater curiosity, and above all our imagination, to drive knowledge and our different ways of knowing forward.[16] And perhaps that indicates what is really at the heart of all our existences: not only the intra-action between the visible and invisible, the material and immaterial, but also, crucially, "the ineffable." This cannot be contained/explained/reduced to a formula however hard we try in our rational and technological age. Like Sarah Sze's piece *Dark Matter,* seemingly made up of random detritus – Q-tips, photographs, postcards, glass tumblers, a reading lamp – what is entangled is that indefinable and illusive space on the borders of consciousness and unconsciousness, where imagination and knowledge meet. In that space, as in Sarah's work, we are in a constant state of entangled be-(com)ing – together (a)part.

[1] Anselm Kiefer, in his speech accepting the Heinrich Heine Prize in December 2014, spoke of the power of his visit to CERN under the Visiting Artists program earlier that year with the curator of his Royal Academy show, Kathleen Soriano. He recalls the scientists telling him that we are older than the earth because we carry with us particles that were present before the creation of our planet. See Anselm Kiefer, "Alexander, du bist ein Teilchenbeschleuniger," *Welt.de*, December 13, 2014, https://www.welt.de/kultur/kunst-und-architektur/article135326592/Alexander-du-bist-ein-Teilchenbeschleuniger.html (all URLs accessed in January 2019).

[2] Of all the sciences, particle physics is arguably the closest to the arts and artists, because it has all of these elements, including its intense philosophical questioning of what we see and what is behind it, as well as the nature of existence.

[3] *The Art Newspaper* online, October 4, 2011.

[4] Observation by the curator Kathleen Soriano: "Your point about the rise of science as a source of wonder made me think about how art was a source of wonder more when it was celebrating religion, or trying to inspire us to be more spiritual or religious. Now that there is no religion (hardly), is that another reason for science walking into that space?"

[5] In a lecture at The Exploratorium, San Francisco, October 2018, I outlined at least eight different forms of art/science collaborations. I listed them as: artists who are driven by technology developed by or for science to create artistic work by exploring the limits and/or the aesthetics of technology; artists who use scientific practices, methods of experimentation and images to create new artworks; artists who work together with scientists to jointly create a new artwork together; artists who are combined with scientists to come up with solutions and products which address societal issues and global problems; artists who are used as the "canary in the coal mine" to be the voice of the people to enable scientists to look at their work from a more humanitarian and potentially ethical perspective; artists used to communicate and illustrate the science of the strand which is as old as the engagement of art and science itself; and the ideas of science as fuel and inspiration for the imagination of artists. In the future, it is not outside the realm of possibility that there may be an eighth strand – artists invited to help scientists to devise experiments in different ways. What defines all of these approaches is the point of departure and intention. The next day after the lecture, two of the attendees came up to me and said that they had listed at least another six.

[6] Ariane Koek, "Keith Tyson: the art of science and discovery," *CERN Courier*, February 24, 2010, https://cerncourier.com/keith-tyson-the-art-of-science-and-discovery/. "If you attempt to marry and equate art with science, then you fail. If you allow what is not similar about art and science, and their different methods and processes to co-exist and thrive, then a real art/science collaboration and aesthetic will emerge."

[7] Ken Arnold, "A Very Public Affair: Art Meets Science," *Interdisciplinary Science Review*, December 2017.

[8] Ariane Koek, "Creative Collisions - Beyond Paradigms," *Journal of the New Media Caucus*, 2013, http://median.newmediacaucus.org/isea2012-machine-wilderness/creative-collisions-beyond-paradigms-2/. Also see Ariane Koek, "In/visible: the inside story of the making of Arts at CERN," *Interdisciplinary Science Review*, December 2017.

[9] "What Life Means to Einstein: An Interview by George Sylvester Viereck," *The Saturday Evening Post*, October 26, 1929, http://www.saturdayeveningpost.com/wp-content/uploads/satevepost/what_life_means_to_einstein.pdf.

[10] Federico Campagna, *Technic and Magic: The Reconstruction of Reality* (London: Bloomsbury, 2018).

[11] Tita Chico, *The Experimental Imagination: Literary Knowledge and Science in the British Enlightenment* (Stanford, CA: Stanford University Press, 2018).

[12] Peter L. Galison, Gerald Holton, and Silvan S. Schweber, eds., *Einstein for the 21st Century: His Legacy in Science, Art, and Modern Culture* (Princeton, NJ: Princeton University Press, 2008), p. xiii.

[13] Edward O. Wilson, *The Origins of Creativity* (London: Penguin, 2018), p. 187. "If science is the bedrock of the humanities, the humanities have further reach. Where scientific observation addresses all phenomena existing in the real world, scientific experimentation addresses all possible real worlds, and scientific theory addresses all conceivable worlds, the humanities encompass all three of these levels and one more, the infinity of all fantasy worlds."

[14] Quotes taken from notes on conversations with the author in 2012-14.

[15] Karen Barad, in her influential book *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* from 2007, published by Duke University Press.

[16] In 2011, the National Science Foundation in the USA, in collaboration with The Exploratorium, San Francisco, held a conference called Art as a Way of Knowing. This landmark conference with over 125 international artists, scientists, and transdisciplinary thinkers posited that the arts are a legitimate way of inquiry, research, and knowing as much as the sciences. See Marina McDougall, Bronwyn Bevan, and Robert Semper, "Art as a Way of Knowing Conference Report," 2012, https://www.exploratorium.edu/files/pdf/cils/Art_as_a_Way_of_Knowing_report.pdf.